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Reservoir Characterization Using Conventional Logsin the North West Java Basin, Indonesia

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ABSTRACT : Hydrocarbon reservoir characterization studies using well logs have been carried out in the North West Java Basin to evaluate the prospectivity of hydrocarbons in a structure both immediately after exploration discovery and in the development phase and even up to the EOR stage. This characterization is very necessary so that investors get accurate information regarding the presence of hydrocarbons in a field. Various methods for reservoir characterization have been widely applied in reservoirs in the North West Java basin, such as seismic, log, core and other methods. This research focuses on the reservoir characterization method using logs, where the log data used is a set of conventional log data which is usually called the triple combo log. By carrying out the stages of work which are usually called log analysis, it is possible to characterize sandstone reservoirs in the West Java Basin using the example of the Upper Cibulakan formation sandstone reservoir, which is a formation consisting of interbedded lithology between sandstone and shale with a few limestone inserts. The results show variations in porosity, saturation and permeability values. The petrophysical parameters evaluated showed porosity ranging between (5-33%), water saturation (33-89%), hydrocarbon saturation (11-67%) and permeability (0.6-276)

KEYWORDS: Hydrocarbon reservoir, Triple Combo log analysis, upper Cibulakan sandstone

I. INTRODUCTION

Upstream oil and gas activities are capital intensive activities with high risks, but if these activities are successful they will provide very significant income. Thus, appropriate planning, delineation and development of reservoirs is very important to answer the challenge of turnover and return on investment as much as possible. Even though currently technology related to oil and gas industry activities such as seismic, logging technology, sophisticated drilling equipment and many other new technologies are used in the process of obtaining hydrocarbons, knowledge of geology, geophysics and reservoirs and drilling remains a determining factor in the search for hydrocarbons. In the exploration phase where seismic data and field geology are the main data used, the knowledge of a geophysicist and geologist carrying out interpretation work is very crucial in determining the coordinates of the wildcat well drilling point. After hydrocarbons are discovered through exploration wells and the results are declared commercial, the next stage is to prepare what is known as a Plan of Development. In this work of preparing a POD, what is known as reservoir characterization is required Reservoir characterization work is a detail of previous work known as petroleum system analysis where of the 5 parameters in the petroleum system analysis work, the emphasis is on the introduction and detailed analysis relating to reservoirs that have been proven to contain hydrocarbons. Reservoir characterization work is necessary because the nature of the reservoir is very heterogeneous. This heterogeneity includes the geometry of the reservoir, the nature of the constituent lithologies, in sandstone it is also related to the shape and size of the grains, roundness, sorting and other characteristics which ultimately will influence the quality of our reservoir. Reservoir characterization will give us a better understanding of the reservoir we have, especially the reservoir parameters that determine how much hydrocarbon is in our reservoir,

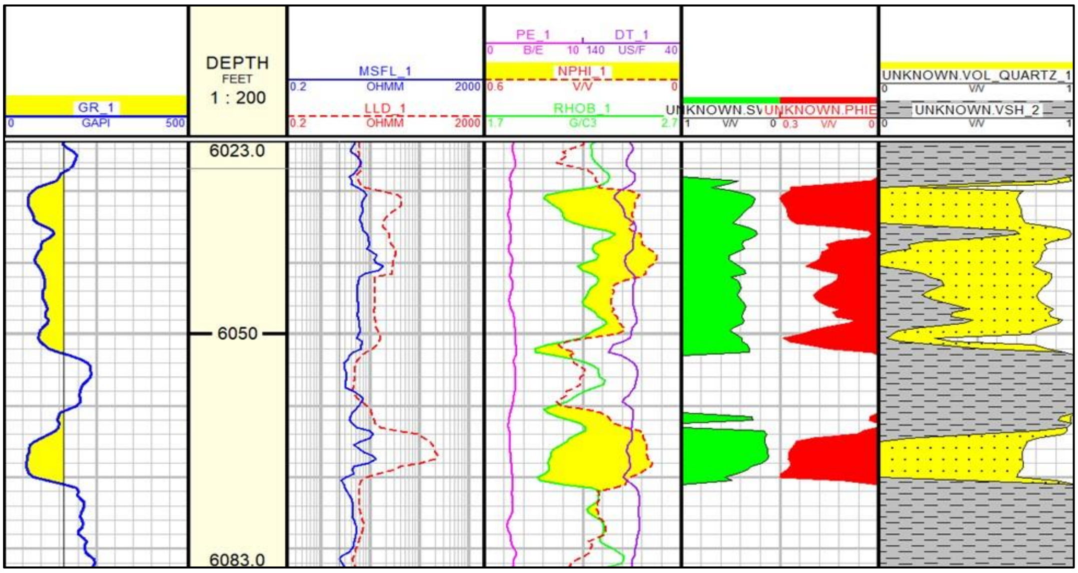
such as the value of density, permeability, water saturation and thickness of the reservoir containing hydrocarbons

Geology of Upper Cibulakan Formation Sandstone : The sandstone reservoirs from the Cibulakan Formation to the Cisubuh Formation are very well developed in the North West Java Basin. More than hundreds or even thousands of wells in the North Jawarat Basin area have been drilled and penetrated the Sandstone Reservoir, to date hundreds of wells are still producing from reservoirs which are currently believed to originate from Sandstone reservoirs, all of which are in the North West Java Basin, 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 well data such as complete log data, especially data Triple Combo which will be very useful in petrophysical analysis in sandstone reservoirs

By studying reservoir characterization through petrophysical analysis of Sandstone reservoirs based on available log responses, it is hoped that we can answer questions about Sandstone reservoir characterization through petrophysical parameters, so that hydrocarbon potential that may have been overlooked in the Upper Cibulakan Formation sandstone 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 sandstone reservoirs

II. METHODOLOGY

Three types of Triple Combo well logs, T-01, T-02, and T-03 as shown in Figures 1 and 2, obtained from drilling from one of the oil and gas companies operating in the North West Java Basin, are the data used for the analysis. log as the method used in reservoir characterization this time. Basically, triple combo logs are standard logs that are usually acquired by oil and gas companies and are usually referred to as conventional logs because triple combo logs are standard logs that have been known for a long time.



However, to obtain the log analysis parameters required for reservoir characterization work is still very sufficient. The work carried out in log analysis will be explained in the next description

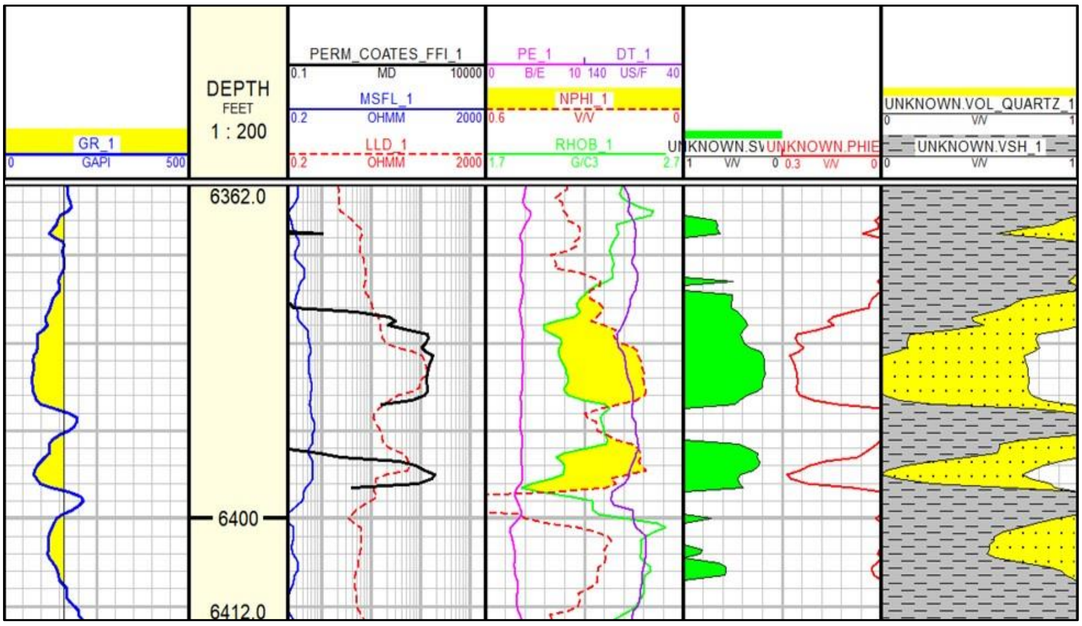


Figure 2: Triple Combo Well T-02

Interpretation of Reservoir Rocks : Log analysis work begins with the interpretation of the rocks that make up the reservoir. There are several ways to carry out interpretation, however, it is usually done using a single log (GR), multiple (Neutron-Density) or using three logs at once (Neutron-Density-PEF). An example of interpretation of the lithology that makes up the reservoir, in this case sandstone produced from double logs, can be seen in Figure 3

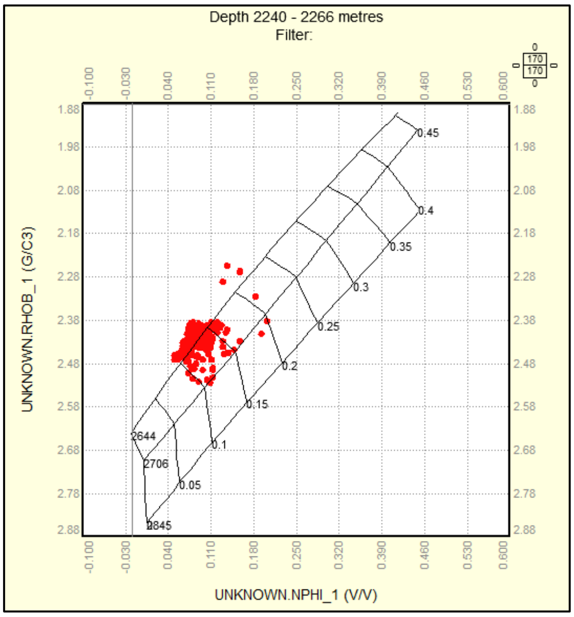


Figure 3: Determination of Lithology Using Neutro-Density Crossplot

Interpretation of limited lithology in sandstone and shale can also be done quickly using GR logs, which is a limited single log method that can show lithology in the form of sand and shale. There are many methods for calculating clay volume but the one that is widely used is the method using log GR. Clay volume is calculated based on the equation:

$$\textbf{\% Shale} = (\boldsymbol{Gr\ Log - Grmin})/(\boldsymbol{Gr\ max - Grmin})\ \textbf{x100} \quad (1)$$

Note
% Shale = Percentage of shale
GRlog = Gr value in log
GRmax = Maximum Gr value
GRmin = Minimum Gr value
The equation can also be written as

$$\mathbf{Ɛsand = 1 - Ɛshale} \qquad (2)$$

The lithology assumption is determined from Ɛ > 0.5

Pay and Non-Pay Zones : Neutron Density Logs are usually used to identify and characterize various fluid contents in formations, namely hydrocarbons are identified from the presence or absence of separation (cross over) between the two logs. Resistivity logs are usually used to identify fluids in the reservoir, although in carbonate rock reservoirs the use of Resistivity Logs must be more careful because high readings could be due to the lithology of the carbonate rock and not due to fluid readings. In sandstone reservoirs, high resistivity log readings are usually an indicator of the presence of hydrocarbon fluids, whereas low resistivity log readings are usually an indicator of formation water fluids

Porosity Estimation : There are several methods commonly used to calculate the porosity of logs. Neutron Log, Density and Sonic Log as well as a combination of these three logs are the methods commonly used, in this research the porosity calculation uses a combination method using Neutron Log and Density Log. The measurement of gamma-gamma logs or in the industry known as density logs is based on a gamma source (usually Co60) which is placed on a rod that is slid along the well skid. These gamma rays interact with electrons in the surrounding material and are then reflected back to be received by the detector. The intensity of the reflected light depends on the density of the surrounding medium or rock and the filling fluid within it (bulk density). The deflection or intensity received by the detector is directly recorded as bulk density which is directly proportional to porosity, Glover, 2021. The Triple Combo Well T-01 log has a reservoir bearing hydrocarbon thickness of 20, gas zone identification can be seen from the Neutron and Density log separations as well as resistivity value readings, while the formation water zone can be seen at the bottom of the upper sandstone reservoir gas zone with low resistivity readings. low and the Neutron-Density separation is narrower when compared to reservoir separation with gas content

Density logs can be used to calculate porosity, the density porosity measurement equation is:

$$\rho b = (1 - \varphi)\, \rho ma + \varphi\, \rho f \qquad (3)$$

Equation 3 can be rewritten as:

$$\varphi = (\rho ma - \rho b)/(\rho ma - \rho f) \qquad (4)$$

Note

Φ = Porosity

ρma = sandstone density

ρb = log density value

ρf = fluid density value

Formation Resistivity Factor (F)

Formation Factor (F) is also called formation resistivity factor, calculated using the Archies Formula,

$$F = a/\Phi^{m} \qquad (5)$$

Note

a = tortuosity

m = cementation factor (2 ≤ m ≥1.3)

Φ = porosity

Estimated Permeability Calculation (K) : Empirical estimates of permeability calculations have been introduced by many experts involved in the petrophysical discipline, which basically seeks to find the relationship between rock porosity and its permeability, the clay content of the reservoir and irreducible water saturation. In this research, the empirical equation of the Coates Free Fluid Index is used with the equation:

$$\text{Perm Coates FFI} = (\text{Const Coates} * \text{Phie}^{**2} * (1 - \text{Swirr}) / \text{Swirr})^{**2} \qquad (6)$$

Note

Const Coates is defaulted to 70 Phie and Swirr are in V/V.

This equation is the basis of Chart K4 in the Schlumberger Chart Book, Opt Perm indicates which method was used: Coates FFI

Swirr is obtained from the average Swirr value assumed to be 0.3

Water Resistivity (Rw) : In most empirical equations, the calculation of water saturation requires water resistivity (Rw), namely the resistivity of formation water in the reservoir. The estimated water resistivity value at temperature is obtained from a plot between total or effective porosity which in this case is obtained from the Neutron-Density log by reading the resistivity log in the water reservoir zone using the Picket Plot method or can be written as

$$Rw = Ro/F \qquad (7)$$

Water Saturation, (Sw) : Because the reservoir in the research area is a reservoir containing clay or shale (not clean sand), the water saturation value is calculated using the water saturation equation which accommodates the presence of clay/shale content, which in this case is used by the Indonesian equation

$$Sw = \left\{ (\sqrt{1} / Rt) / (Vsh^{(1-0,5Vsh} / \sqrt{Rsh}) + \frac{\sqrt{\O e^{m}}}{aRw} \right\} \qquad (8)$$

Note
Rt = Actual formation fluid resistivity
Vsh = Shale Volume
Rsh = Shale Resistivity
Øe = Effective Porosity
m = Cementation exponent
a = Tortuosity
Rw = Resistivity of Formation Water

Hydrocarbon Saturation (Sh)
The part of the reservoir whose shaft is filled with hydrocarbon saturation is called Hydrocarbon Saturation (Shr). Hydrocarbon saturation can be calculated by subtracting the total pore volume in a formation from water saturation which can be written as:

$$\mathbf{Sh = 1- Sw \text{ or } Shr = 100 - Sw \text{ in } \%} \quad (9)$$

Note
Sh = Hydrocarbon Saturation

Gross, Net and Net Pay Reservoir Thickness : Reservoirs with clay/shale content have different gross thicknesses and net thicknesses. Gross thickness is the thickness measured from the top of the reservoir to the bottom of a particular reservoir penetrated by drilling, usually determined using Gamma Ray logs, while the net thickness of the reservoir is determined by determining the cut off of Vclay/Vshale, cut off of porosity and cut off of water saturation

The first step in determining the clean reservoir thickness is by subtracting the gross thickness from the thickness of the part affected by the cut off of Vclay:

$$\boldsymbol{h} = \mathbf{H\text{-}hShale\ (cut\ off)} \quad (10)$$

Note
H = Overall reservoir thickness
h = Net reservoir thickness
hShale = Shale thickness

then proceed by reducing the thickness of the clean shale reservoir to the porosity cutoff thickness

$$\mathbf{hn = h\text{-}hpor\ (cutoff)} \quad (11)$$

Note
hn = Net reservoir thickness
h = Clean shale reservoir thickness
hpor = Thickness subject to porosity cutoff

finally by reducing the net reservoir thickness by the water saturation cutoff thickness:

$$\mathbf{hnp = hn - hSw\ (cutoff)} \quad (12)$$

Note
hnp = Net reservoir thickness
*h*n = Net reservoir thickness
hSw = Thickness subject to water saturation cutoff

III. RESULTS AND DISCUSSION

Detailed characterization of hydrocarbon reservoirs is usually required in making geological models by analyzing the logs available above and the results are in the table below:

Table 1: Summary of Petrophysical Parameter Calculations from Well T-01

Reservoir	Top	Bottom	Gross	Nett	Net/Gross	Ø	Sw	Shr	K
X1	6027,2	6034	6,8	6	0,88235294	0,13	0,54	0,46	56,46
X2	6035	6053	18	15	0,83333333	0,16	0,4	0,6	35,42

Table 2: Summary of Petrophysical Parameter Calculations from Well T-02

Reservoir	Top	Bottom	Gross	Nett	Net/Gross	Ø	Sw	Shr	K
X3	6059,7	6063,4	3,7	1,5	0,40540541	0,09	0,65	0,35	60,78
X4	6063,4	6071,9	8,5	8	0,94117647	0,2	0,33	0,67	132

Table 3: Summary of Petrophysical Parameter Calculations from Well T-03

Reservoir	Top	Bottom	Gross	Nett	Net/Gross	Ø	Sw	Shr	K
X5	6370	6388,5	18,5	14	0,75675676	0,13	0,53	0,47	144
X6	6390	6398	8	5,5	0,6875	0,1	0,57	0,43	100
X7	6398	6408	10	3	0,3	0,05	0,89	0,11	0,1

Table 4: Summary of log analysis of all wells

Reservoir	Formation Factor FF	Porosity Ø	Permeability K
X1 Well T-01	9	33	276
X2 Well T-01	10	32,5	261
X1 Well T-01	11	31	208
X2 Well T-01	12,5	28	203
X3 Well T-02	13	27	191
X4 Well T-02	16	26	148
X4 Well T-02	16,4	25	129
X5 Well T-03	16,5	24,2	58
X6 Well T-03	15,7	24	4
X7 Well T-03	19	23	0,6

Table 1 is the result of analysis of the T-01 well log which is described as containing eight reservoirs, but only two were identified as hydrocarbon reservoirs with porosity values ranging from 0.13 to 0.16, Sw 0.40 to 0.54 and Sh 0. 46 to 0.60, this also shows that there is no significant difference in porosity but there is a change in Sw which decreases with increasing depth, while Sh increases with increasing depth. This sandstone reservoir contains hydrocarbon oil. Table 2 is the result of analysis of the T-02 well log which is described as containing four reservoirs, but only two were identified as hydrocarbon reservoirs with porosities in the range of 0.09 to 0.20, Sw 0.33 to 0.65 and Sh 0.67 up to 0.35, this indicates a significant change in both porosity and Sw, while Sh increases with increasing depth. This reservoir contains gas and oil with the highest Sh (67%). Table 3 is the result of the T-03 well log analysis which is described as containing five reservoirs, only three of which were identified as containing hydrocarbons with porosity values in the range of 5 to 13%, Sw varying from 53 to 89% and Sh 47 to 11%, this shows that Sw increases with increasing depth, while Sh decreases with increasing depth. The reservoir contains oil, gas and water

IV. CONCLUSION

Reservoir characterization with detailed estimation of petrophysical parameters revealed that the quality of the reservoir was greatly influenced by the presence of sandstone which hadvarying porosity and permeability values. The results of this research show that reservoir quality increases along with increasing porosity and permeability values. The average water saturation in this sandstone reservoir ranges from 33 – 89 percent, hydrocarbon saturation ranges from (11 – 67) percent. From the comparison seen between Table 1 and Table 3 we cansee that the highest hydrocarbon saturation is in well T-02

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