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Evaluation of Reservoir Characteristics of Wells X, Y, Z in the Pliocene Interval of the Tarakan Sub-Basin, Tarakan Basin, North Kalimantan

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ABSTRACT. The Tarakan Basin is one of the basins that has been producing hydrocarbons since 1901, with nine active oil fields to this day. The exploration of oil and gas in the Tarakan Basin has been ongoing for a considerable time. It is the oldest exploration in Indonesia, and it continues due to its estimated economically viable reserves based on its geological conditions. Research on evaluating reservoir characteristics in the Tarakan Sub-Basin with a Pliocene age interval aims to determine the subsurface lithology and fluid conditions qualitatively and the quantitative characteristics of the reservoir rocks. This study utilizes quantitative petrophysical analysis using a deterministic method with primary data consisting of wireline log data, as well as secondary data, including core data, mud logs, biostratigraphy data, drill stem test data, and sidewall core data. Based on the analysis results, the petrophysical properties of the target reservoir in the study area include an average shale volume (VSH) of 16.65–29.31 %, average effective porosity (PHIE) of 11.80–27.09 %, which falls into the categories of fair to excellent quality, hydrocarbon saturation ranging from 7.68–43.03 %, an average permeability value (PERM) of 10.03–613.29 mD, falling into the categories of good to very good, and a net pay thickness ranging from 4 feet to 16.7 feet, with a total thickness of 67.4 feet containing oil and gas fluids.

Keywords: Petrophysics · Facies · Tarakan Basin · East Borneo.

1 INTRODUCTION

The Tarakan Basin is one of the three major Tertiary basins in the eastern part of the Kalimantan continental margin, including the Tarakan Basin, Kutai Basin, and Barito Basin (Saputra, 2018). Exploration activities in the Tarakan Basin have been carried out since 1901 when the first oil seep was discovered in the Pamusian area, the southern part of Tarakan Island, by the Dutch oil company Bataavshe Petroleum Maathapij (Salam, 2010).

The exploration of oil and gas in the Tarakan Basin has been ongoing for a considerable period of time and is considered the oldest exploration in Indonesia. Exploration activities in the Tarakan Basin have been continued due to the estimated presence of economically viable oil and gas reserves based on its geological conditions. Significant discoveries of oil and gas fields have been made in Bunyu Island, Tarakan Island, and the East Coast of Kalimantan through offshore exploration. Numerous exploration and development wells have been drilled in these areas. Currently, the Tarakan Basin has several producing areas, specifically nine oil fields (Satyana, 1999).

The regional stratigraphy of the Tarakan

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Basin in the Tertiary and Quaternary periods is divided into several formations, namely the Sujau Formation, Seilor Formation, Mangkabua Formation, Tempilan Formation, Tabalar Formation, Birang or Naintupo Formation, Latih or Meliat Formation, Menumbar Formation, Tabul and Santul Formation, Sujau or Tarakan Formation, Domaring Formation, Bunyu Formation, and Waru Formation (Achmad and Samuel, 1984). The regional stratigraphic conditions are closely related to the Sabah Orogeny events in North Kalimantan (Malaysia) in terms of tectonics (Balaguru & Hall, 2009).

The geological study of the Tarakan Basin regarding the physical properties of rocks with their unique characteristics is fundamental in the exploration of oil and gas. Evaluating the characteristics of a well is necessary to understand the subsurface conditions, especially in reservoirs targeted for production (Harsono, 1997). Research using deterministic petrophysical analysis of rock physical parameters and hydrocarbon fluid types is essential to supplement the limited data from previous studies. Deterministic petrophysical analysis is crucial for petroleum geologists as it helps determine physical rock characteristics such as lithology, resistivity, porosity, and permeability. Through deterministic petrophysical analysis, logging data can be used to identify productive zones, determine the depth and thickness of the zones, and differentiate between oil, gas, or water in a reservoir (Sari *et al.*, 2013).

The research location is in the Tarakan Sub-Basin, Tarakan Basin, North Kalimantan, with the wells under study being Wells X, Y, and Z in the Pliocene interval. These wells are located in the central part of the Tarakan Basin, in the offshore, eastern part of Nunukan and represent the youngest sub-basin filled by the Tarakan Formation and Bunyu Formation, which are Late Miocene to Pleistocene in age (Chaniago, 2011). The research area is an exploration field managed by PT Pertamina Hulu Energi, located offshore, with potential resources to increase oil and gas reserves in the Tarakan Basin (Pertamina Hulu Energi, 2016).

Based on the information provided, studying the reservoir characteristics in the Tarakan Basin, specifically in the research area of Wells X, Y, and Z in the Pliocene interval, is interesting to investigate further based on previous research. This will help understand the subsurface conditions, identify reservoirs with significant potential for high-quality hydrocarbon production, and determine reservoir characteristics using deterministic petrophysical analysis in one of the oldest research wells in Indonesia, which has been significantly influenced by geological structures such as growth faults. These reasons form the background for completing the final project titled "Evaluation of Reservoir Characteristics of Wells X, Y, Z in the Pliocene Interval of the Tarakan Sub-Basin, Tarakan Basin, North Kalimantan." Pliocene rock formations are subject to further analysis because these formations have rarely been studied, so there is still minimal information. So far, the formations that have been studied more often are Miocene and older formations.

2 Geological Setting/Site Characterization

The Tarakan Basin is located on the island of Kalimantan, specifically in the northeastern part of the island. The Tarakan Basin is one of the three major Tertiary basins (Tarakan Basin, Kutai Basin, Barito Basin) on the eastern continental margin of Kalimantan. The dominant characteristic of the Tarakan Basin is the presence of fine to coarse-grained clastic sedimentary rocks with carbonate deposits.

Based on the topography (physiographic conditions), the Tarakan Basin is divided into onshore and offshore areas. In the northern part of the Tarakan Basin, it is bordered by Semporna High, which is located north of the Indonesia-Malaysia border. In the southern part, the Tarakan Basin is bounded by the Mangkalihat Mountains, separating it from the Kutai Basin. In the western part, it is bounded by the presence of the Kuching High. The Sulawesi Sea borders the eastern part, specifically the Makassar Strait (Pertamina BPPKA, 1996) (Figure 1).

Regional Stratigraphy

According to Achmad and Samuel (1984), the regional stratigraphy of the Tarakan Basin is divided into sub-basins located in the northern and southern regions, as shown in Figure 1. The stratigraphy of Tarakan basin is

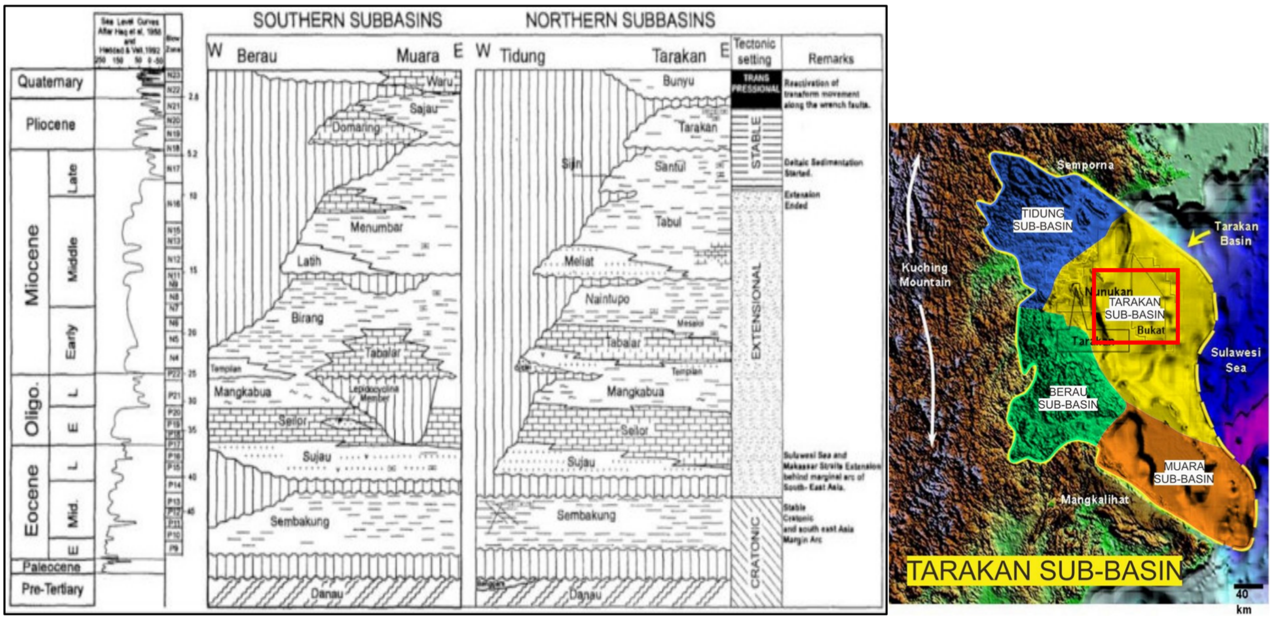

FIGURE 1. Regional Stratigraphy of Tarakan Basin (Achmad dan Samuel, 1984).

arranged in chronological order from the oldest to the youngest, including the Sujau Formation, Seilor Formation, Mangkabua Formation, Tempilan Formation, Tabalar Formation, Birang Formation, Meliat Formation, Menumbar Formation, Tabul Formation, Santul Formation, Tarakan Formation, Domaring Formation, Bunyu Formation, and Waru Formation.

3 METHODOLOGY

Primary data is data that is directly researched by writer in final project research. Primary data analyzed in the form of wireline logs for Wells X, Y, and Z. Data input is carried out in the software, the data input is data in LAS format, then data correction is carried out and validation of completeness of well data. Qualitative analysis was carried out on good data to determine the type of lithology and fluid content present on each well drilled. Analysis used at stage The initial step is a cursory analysis, or a quick look analysis, which can be used to determine lithology, fluids, and reservoir zone. Quantitative analysis is carried out with the aim of obtaining reservoir characteristics consisting of shale volume (Vshale), effective porosity (PhiE), water resistivity (Rw), water saturation (Sw), values permeability, and determining the net pay reservoir zone.

The research uses a deterministic method because the available data is quite comprehensive, including triple combo logs, porosity, density, and laboratory analysis data such as core data. The stages of quantitative analysis include log editing, precalculation, volume of shale, environmental correction, coal determination, porosity calculation, resistivity, water saturation, permeability calculation, determination of cut-off value, and net pay.

Log edit is the initial stage before starting petrophysical analysis, which aims to clean up log data that is still spiky due to environmental disturbances during drilling. Log edit consists of two stages: despike and smooth, both used to refine the log data values. The next stage is Precalculation.

Precalculation is the stage to calculate the geothermal gradient or temperature at well depths. Each well depth has a proportional temperature difference, with deeper wells having higher temperatures. Environmental correction aims to correct noise or reading disturbances on the tools used. This correction is necessary because during data acquisition, each tool can be affected by drilling environment disturbances. Therefore, corrections must be made to ensure the obtained values are more valid. The determination of coal layers is also done using coal cut-off values. The coal cut-off value is obtained based on several influential logs for coal reading, such as the density log, neutron log, sonic log, and resistivity log.

The volume of shale is calculated based on well log data, particularly the gamma-ray log curve. The calculation of clay volume aims to correct the total porosity value of the rock, assuming that the composition filling the rock pores is shale. After calculate volume of shale, the next stage is calculating Porosity, both total and effective. Porosity values are obtained through a combination of density and neutron logs. Porosity can be determined using equations that involve density and neutron logs. The calculation of porosity values must be validated against porosity values from core data within specific intervals to ensure accuracy and validity.

Research Stages

The research is conducted through qualitative analysis, which involves determining the lithology, fluid types, and identifying reservoir zones. This is followed by quantitative analysis, where deterministic petrophysical calculations are performed using the available data to determine the physical parameters of the rock and obtain reservoir characteristic values.

4 Results and Discussion

4.1 Paleontological data

Based on the biostratigraphic data in the Pertamina Hulu Energi Drilling Report (1990) that PT Pertamina Hulu Energi has analyzed, the environmental conditions and age boundaries of the rocks can be determined through the presence of fossils found in each well. The biostratigraphic data obtained is very limited. Therefore, to get more accurate analysis results, validation needs to be done with other data, such as core and sidewall core data.

In Well X, Interval 4327–7041 feet, there is a small presence of benthic microfauna such as Operculina, Pseudorotalia, Cribrostonoides, and Trochammina, indicating a shallow environment with some samples having undergone reworking. In the core data, there is also a presence of a larger foraminifera, Schlumbergerella. The age determination of this interval is done using the biostratigraphic data of the fossil Scolocyamus magnus, indicating an Early Pliocene age, and Stenochlaenidites papuanus, which can indicate a Late Pliocene age, with

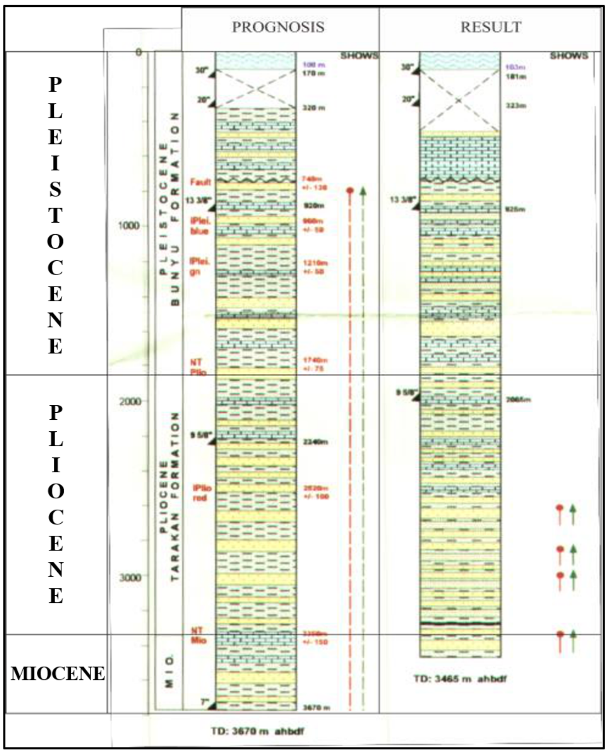

FIGURE 2. Well Y prognosis.

a living environment that belongs to the continental, supralittoral, and transitional parts as shown in Table 1.

Well Y is a well that lacks supporting data such as core data, sidewall core, and biostratigraphic data, so the age boundaries and depths are determined based on formation data and the provided summary by the company. According to the Pertamina Hulu Energi Drilling Report (1997), the Pliocene age interval is found at 5054–10989 feet, as shown in Figure 2.

In Well Z, within the interval of 9171–11577 feet, biostratigraphic data and a drill stem test are available. The lithology present in this interval consists of alternating layers of limestone, shale, and sandstone. This depth is dominated by benthic foraminifera, with relatively few occurrences of planktonic foraminifera. The age determination is based on the stratigraphic position and the last appearance datum of the foraminifera Globoquadrina baroemoenensis, which yields an age range of N18 to N20. As for the depositional environment, it is inferred from the presence of diverse and abundant benthic foraminifera at depths of 10780–11577, such as Cellanthus craticulas, Eponides praccinctus, Amphistegina quoyi, Operculina ammonoides,

TABLE 1. Biostratigraphy summary of Well X.

Age	Depth (ft)	Biozone	Depositional Environment
Early Pliocene or Younger	1066 – 2582	Undetected	Continental, supralitoral – transition to inner litoral
Late Pliocene	2582 – 4327	*Podocarpus Imbricatus* and Stenochaenidites	Continental, supralitoral – transition to inner litoral
Early Pliocene	4327 – 6512	*Scolocymus Magnus*	Supralitoral – inner litoral
Early Pliocene to Late Miocene	6512 – 7041	NN15 – NN11	Supralitoral – inner litoral
Late Miocene	7041 – 7752	NN11 – NN10	Outer litoral – inner sublitoral
Late Miocene to Middle Miocene	7752 – 8956	NN9 – NN8	Outer litoral – inner sublitoral

and to a lesser extent, Cibicides refulgens, Anomalinella rostrata, and Rectobolivina limbata. Based on these benthic foraminifera, it is estimated that the environment represents a shallow inner sublittoral environment with evidence of some poorly fossilized samples. The biostratigraphy summary of Well Z can be seen in Table 2.

4.2 Petrographic data

Petrographic data is only available for Wells X and Z within the Pliocene age interval, with several thin-section rock samples taken at specific depths, as shown in Figure 3. The thin-section samples were described with the assistance of data obtained from PT Pertamina Hulu Energi's drilling report. A balanced comparison was made between the drilling report data and analysis due to the incomplete data obtained from the drilling report.

Details of the rock samples, as shown in Figure 3, indicate that Well X samples X1 and X2 consist of sandstone with a classification based on composition known as subarkose (Pettijohn, 1975). Well Z sample, namely Z3, exhibits the characteristics shown in Figure 3 and consists of limestone. This rock has a matrix composition less than 50 %, classified as over 1/3 mud matrix, hence it is termed as biomicrite (Folk, 1959). Furthermore, based on the absence of original rock components, the composition of mud, the predominance of grain-supported fragments (>10 %), the rock is described as packstone (Dunham, 1962). Lastly, the presence of organic material fragments that were not present during rock formation, with a significant abundance of fragments (>25 %) larger than 2 mm, leads to the description of rudstone (Embry & Klovan, 1971).

Similarly, Well Z sample Z4, with characteristics shown in Figure 3, consists of limestone. It also has a matrix composition of over 50 %, classified as over 2/3 mud matrix, thus termed as biomicrite (Folk, 1959). Based on the absence of original rock components, the composition of mud, the predominance of mud-supported fragments (>10%), the rock is described as wackestone (Dunham, 1962). Additionally, the presence of organic material fragments that were not present during rock formation, with a significant abundance of fragments (>20%) larger than 2 mm, leads to the description of rudstone (Embry & Klovan, 1971).

4.3 Log data validation

The validation of log data with mud log and core data aims to achieve consistency in depth values between wireline log data and core data, as well as to obtain more precise and accurate lithology interpretations. This data validation was performed for Wells X and Z, the main reference wells as the core analysis was conducted by PT Pertamina Hulu Energi (2016).

Conversion is done to the depth with a direct correction from gamma ray (GR) calibration with core rock data that produces a value in the form of a corrected interval. The corrected interval value is used in determining data validation with wireline logs, in the process of determining lithology with mud log data, and the core rock data interval becomes the main reference in determining lithology on the wireline log, while the thickness obtained (recov-

TABLE 2. Biostratigraphy summary of Well Z.

Age	Depth (ft)	Biozone	Depositional Environment
Early Pliocene	2788 – 9169	NN15 – NN12	Transitional, Inner Litoral to Marine Inner Sublitoral
Early Pliocene to Late Miocene	9169 – 11578	NN12 – NN11	Transitional, Inner Litoral to Marine Inner Sublitoral
Late Miocene	11578 – 12204	NN11 – NN9	Marine, Inner Sublitoral (11578–11646ft), Continental, Supralitoral – Transitional Outer Litoral (11646–12204)

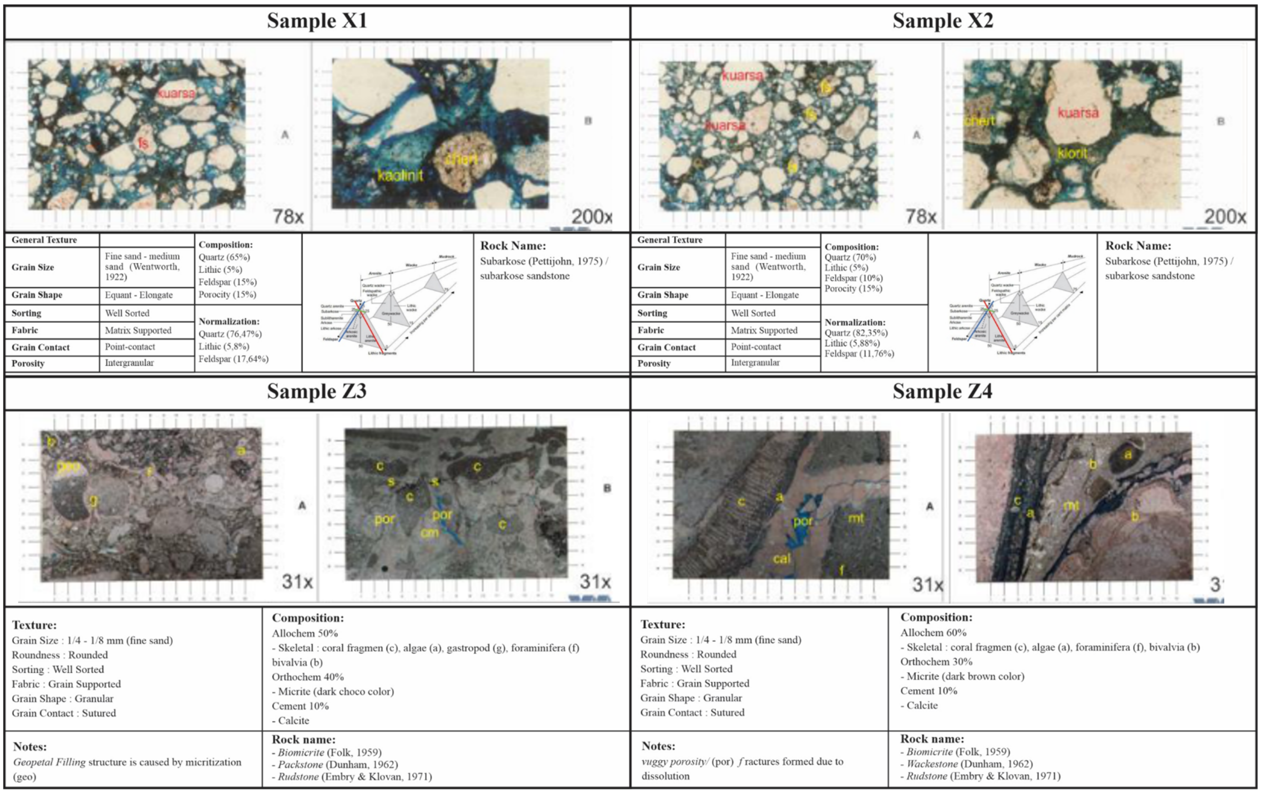

FIGURE 3. Petrographic sample description of Well X (X1 and X2) and Z (Z3 and Z4).

ered thickness) is the thickness of the rock layer used as core rock data (See Figures 4–6.

4.4 Qualitative analysis

The qualitative analysis conducted on Wells X, Y, and Z in this study aims to assist in interpreting the lithology types beneath the surface, fluid types, and reservoir zones in each well before quantitative analysis. The qualitative analysis uses zonation based on distinctive curve deflection shapes to differentiate rock types. The analysis results are supported by supplementary data from drilling wells, such as core data, cutting data, and petrographic description data. The identified lithology types, through log interpretation and petrographic description, include limestone, sandstone, shale, and a minor amount of coal (Figure 7). Lithology determination can also be validated from core and mudlog data. The identified fluid types, in descending order of dominance, include water, gas, and oil. The fluids found in the crossover zone can be distinguished based on the width of the crossover size formed between the neutron log and the density log. Relatively, water fluids have a narrower crossover width compared to oil fluids, and oil fluids have a narrower crossover width compared to gas, which tends to have a wider or wider crossover. Another identification is by analyzing the resistiv-

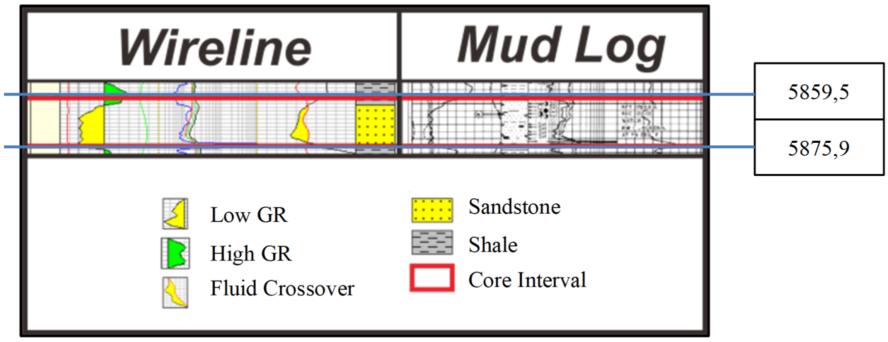

FIGURE 4. Validation of wireline log data with X1 core and mud log.

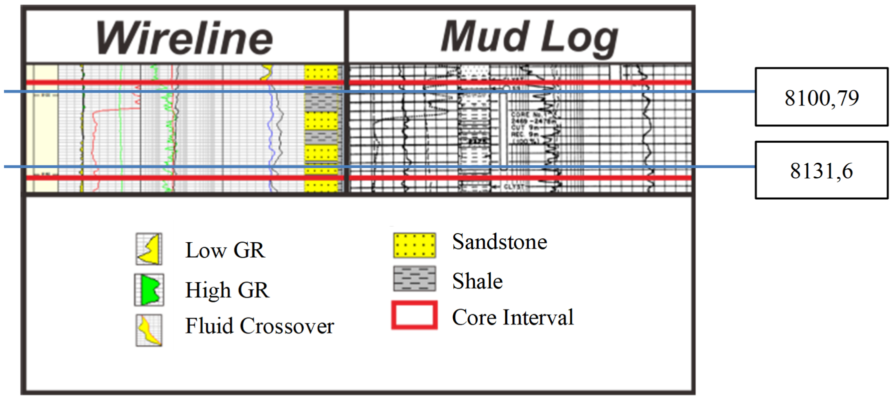

FIGURE 5. Validation of wireline log data with Z1 core and mud log.

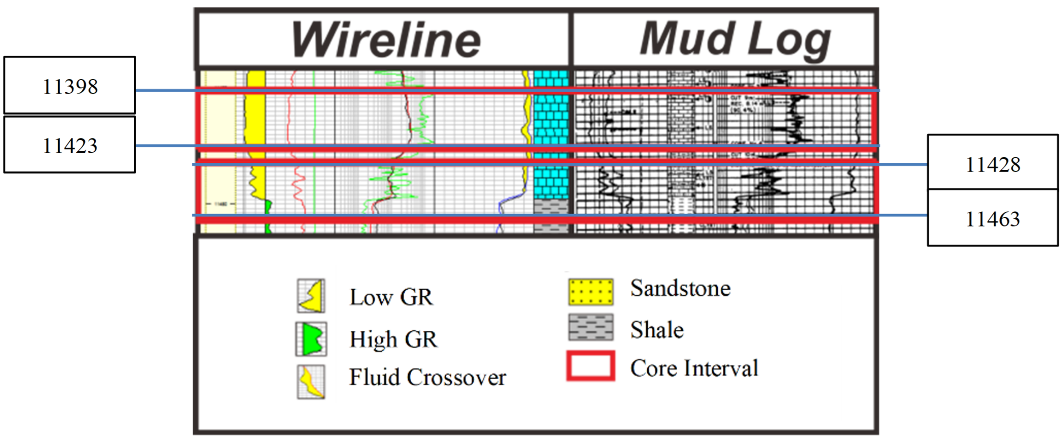

FIGURE 6. Validation of wireline log data with Z3 and Z5 core and mud log.

ity log, which can represent different resistivity values for each type of fluid (Figure 7).

4.5 Quantitative analysis

Quantitative analysis begins with the use of a deterministic method. Deterministic method is a petrophysical calculation method that utilizes equations based on logging tool responses.

Shale volume is the result of calculations based on well log data, namely the gamma ray log curve. In well logs, the shale and sand baselines are used to calculate shale volume and determine the shale content in a zone. Shale baseline is A line drawn on a gamma-ray log through the characteristic of thick shales. It's also the average reading of the spontaneous potential (SP) log opposite shale layers in a well. The Sand baseline is a line drawn on a gamma-ray log on the lowest gamma ray. To find out the minimum, maximum, and average values of a wireline log, you can use a histogram (Figure 8).

The vshale calculation results show that Reservoir SS-1 in well X has the lowest value with a value of 16.65 %. Reservoir SS-4 in well Z has the highest average vshale in well Z, with a value of 29.31 %. Effective porosity values differ for each well. In well X, the Pliocene interval has an average porosity of 19.44 % with a maximum value of 33.22 %. In well Y, the Pliocene interval has an average porosity of 3.19 % with a maximum value of 26.58 %. In well Z, the Pliocene interval has an average porosity of 12.88 % with a maximum value of 27.01 %. Several rock layers interpreted as reservoirs in the target zone have an effective porosity range of 11.8 % to 27.09 %, categorized as good to very good (Koesoemadinata, 1978).

Water resistivity is highlighted in reservoir areas assumed to contain water. The average resistivity value is calculated based on the highlighted areas. After obtaining the average value, the next step is to determine the Rw (resistivity of water) using the picket plot method, which places a line representing 100% water condition to demarcate areas containing water and non-water. Other supporting parameters representing lithological aspects include the lithology coefficient (a) of 0.81 for sandstone and 1 for limestone, the cementation factor (m) of 2.15, and the saturation exponent (n). The resulting resistivity values are Rw = 0.137062 for well X, Rw = 0.11826 for well Y, and Rw = 0.10268 for well Z.

The previously obtained resistivity water (Rw) data is used to determine the saturation water (Sw) value using the apparent water resistivity (Rwa) formula. The average water saturation values are 95 % for well X, 98 % for well Y, and 91 % for well Z. Permeability calculations are performed using Geolog 7 software with a deterministic analysis method using the Wyllie-Rose and Coates Dumanoir equations. Different equations are used to compare the results and determine the most optimistic calculation method for estimating reservoir values. The most optimistic result is obtained using the Wyllie-Rose equation with irreducible saturation water data as the reference. The calculated permeability values range from 10.03 mD to 613.29 mD, categorized as good to very good (Koesoemadinata, 1978).

The cut off and net pay values are determined based on the use of certain parameter value limits to produce net gross, net effective, and net pay. The net gross value is generated from sandstone, which is limited by the shale volume value and acts as a reservoir in the well. The net effective value is generated from a reservoir with a good effective porosity value limited by the reservoir's shale volume and effective porosity. The net pay value is obtained from a reservoir that is limited by the shale volume value (VSH), effective porosity (PHIE), and water saturation (SW), the final result is a reservoir with a rock layer with good quality, has good porosity, and can produce hydrocarbons.

The data used as a reference is the target reservoir data because it has supporting data, namely DST data to determine the reservoir that can produce hydrocarbons. In the initial stage, namely determining the cut off value using a cross plot with a comparison of the shale volume value (VSH) and effective porosity (PHIE), as well as the water saturation value (SWE) and effective porosity (PHIE). The cut-off values obtained for the three wells are as follows: for well X, VSH = 0.292, PHIE = 0.248, SWE = 0.819; for well Y, VSH = 0.254, PHIE = 0.107, SWE = 0.970; and for well Z, VSH = 0.319, PHIE = 0.141, SWE = 0.712.

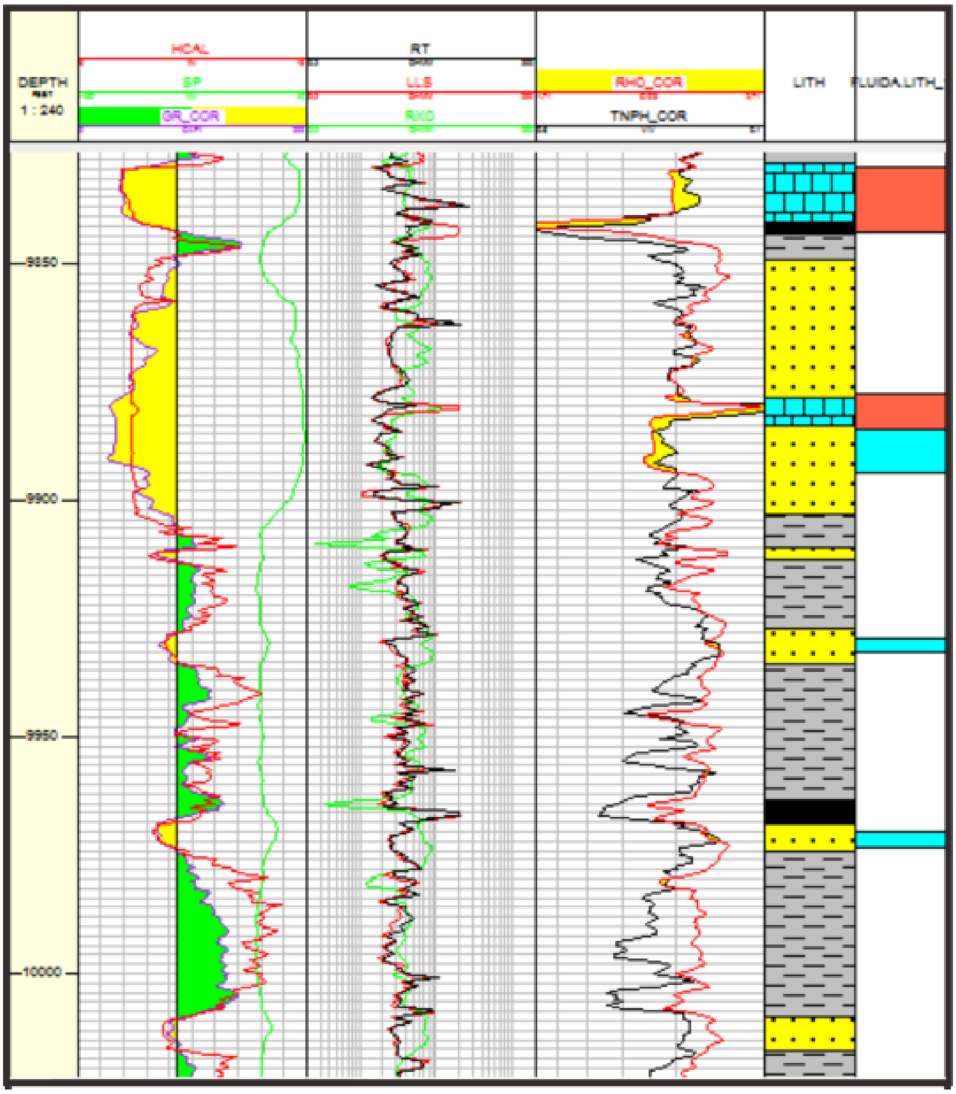

FIGURE 7. Lithology and fluid determination and fluid contact at Well Y at Pliocene interval.

4.6 Reservoir characteristics

Based on the performed petrophysical analysis, several depth intervals of reservoir rocks with hydrocarbon content were identified using supporting data such as hydrocarbon shows, drill stem test (DST), gamma-ray log characteristics, resistivity log, density-neutron log, and described lithology. In the three wells studied, six reservoirs were identified as the research targets, consisting of five sandstone layers and one limestone layer.

Averages of the volume of shale (VSH) calculated for the target reservoir intervals range from 16.65 % to 29.31 %, as shown in Figure 9, falling within the shaly sand category (Pertamina, 2016). The mean values of the volume of shale (VSH) for all target reservoirs can be seen in Table 3.

The effective porosity values (PHIE) obtained in the research reservoirs are quite diverse, ranging from 11.80 % to 27.09 %, which falls into fair to excellent quality categories according to Koesoemadinata's classification (1978). The average values of the effective porosity for the target reservoirs can be seen in Table 3. The water saturation values (SWE) calculation in each research well was performed using the Simandoux equation, which was validated against water saturation values from core and sidewall core data. The average water saturation values in the target reservoirs of the research area range from 56.97 % to 92.32 %, as shown in Table 3.

Permeability calculations in the research area were performed using the Wyllie-Rose method, specifically the East equation (Crain, 1999), as

Table 3. Data tabulation for VSH, PHIE, SWE, and K.

Well Name	Reservoir	VSH	PHIE				SWE				PERM			
		Mean	Minimum	Maximum	Mean	Mode	Minimum	Maximum	Mean	Mode	Min	Max	Mean	Mode
Well X	SS-1	16.65	14.95	28.50	25.41	26.75	76.33	92.19	81.60	78.5	6.66	78.30	49.66	59.56
	SS-2	18.53	16.80	31.04	27.09	29.75	75.23	94.89	82.59	75.5	10.62	103.87	66.88	74.89
	LS-1	22.01	0.00	30.39	4.75	25.25	33.14	10.00	76.94	51.5	0.00	138.53	33.90	66.83
Well Y	SS-3	25.09	0.00	23.75	11.80	13.25	27.28	100.00	92.32	96.5	0.00	247.72	10.03	1.67
Well Z	SS-4	29.30	7.78	22.01	18.77	20.75	57.76	91.99	69.32	71.5	58.48	934.03	566.05	841.39
	SS-5	17.52	15.3	23.06	20.15	20.25	44.14	70.26	56.97	56.5	180.52	1599.96	613.29	530.88

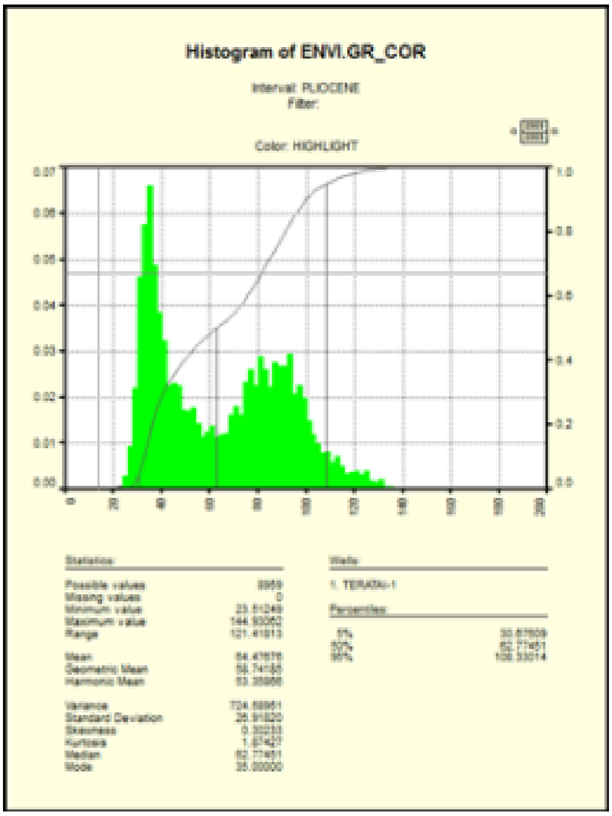

Figure 8. Histogram to determine GR Shale and the GR Matrix.

not all target reservoirs have supporting data such as core data, and the East equation is more suitable for application in research wells. The calculated permeability values can be seen in Table 3, with average values ranging from 10.03 mD to 613.29 mD, falling into the categories of good to very good (Koesoemadinata, 1978).

Next, the net pay was determined with a total thickness of 67.4 feet, consisting of 2 oil reservoirs and 4 gas reservoirs with thickness variations of 4 feet to 16.7 feet. The details of the net pay values in the reservoirs can be seen in Table 4.

5 Conclusion

Based on the research findings, it can be concluded that the boundaries of the Pliocene rock layers are determined based on biostratigraphic data, supported by other data such as core and sidewall core data. The characteristic fossils found in the Pliocene age include palynoflora (*Stenochlaenidites papuanus* and *Podocarpus im-*

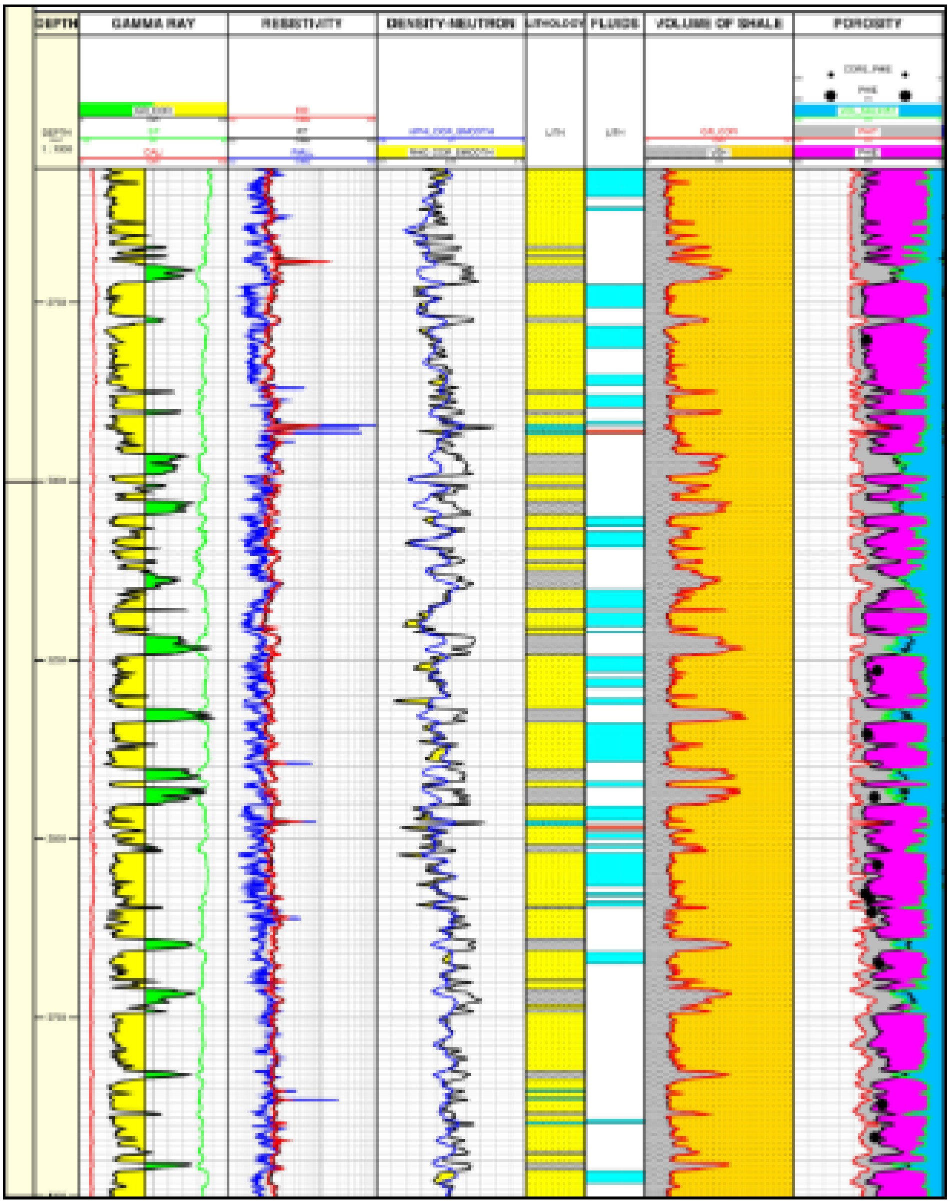

FIGURE 9. Log layout of VShale (track 7) and porosity (track 8) results. The black dots are porosity value from core data. Lithology determination can be seen at track 5 and the fluid type at track 6.

TABLE 4. Net Pay values in the target reservoirs.

Well Name	Net Pay			
	Net Pay (ft)	Fluids	Top	Bottom
Well X	10.5	Oil	5286	5304
	9.6	Oil	5854	5876
	14.6	Gas	6957	7041
Well Y	12	Gas	10608	10643
Well Z	16.7	Gas	8052	8084
	4	Gas	8498	8512

bricatus) and foraminifera (*Globoquadrina sp* and *Pulleniatina primalis*).

The identified layers through lithological determination in the research wells within the Pliocene interval include limestone, sandstone, shale, and coal. Petrographic data from Well X indicate the presence of subarkose sandstone, while Well Z shows sublitharenite sandstone and limestone (biomicrite, packstone-wackestone, rudstone).

The reservoir characteristics in Wells X, Y, and Z within the Pliocene interval are as follows:

(a) The sandstone layer in reference Well X

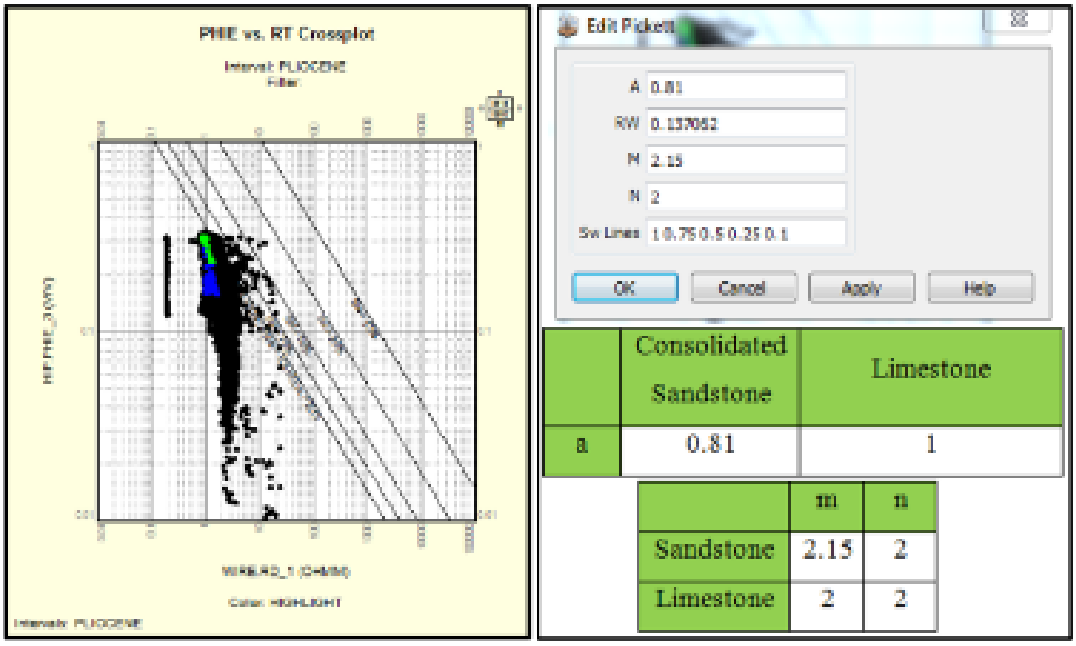

FIGURE 10. Picket plot from Pliocene interval to determine the waterzone to determine the Rw.

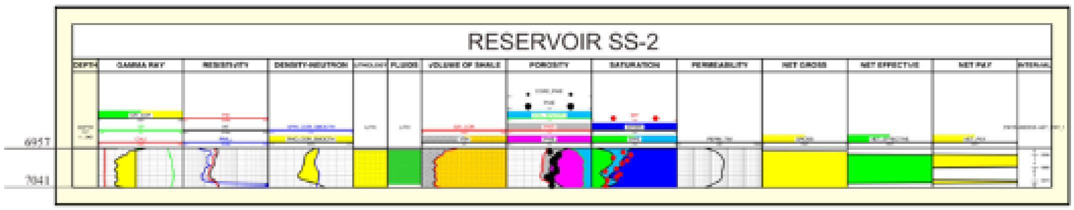

FIGURE 11. Validation of water saturation calculation results based on core data.

with reservoir SS-1 has an average shale volume of 16.65 %, effective porosity (PHIE) of 25.41 %, classified as excellent quality (Koesoemadinata, 1978), hydrocarbon saturation of 18.4 %, and a net pay thickness of 10.5 feet containing oil.

(b) The sandstone layer in reference Well X with reservoir SS-2 has an average shale volume of 18.53 %, effective porosity (PHIE) of 27.09 %, classified as excellent quality (Koesoemadinata, 1978), hydrocarbon saturation of 17.41 %, and a net pay thickness of 9.6 feet containing oil.

(c) The limestone layer in reference Well X with reservoir LS-1 has an average shale volume of 21.01 %, effective porosity (PHIE) of 14.75 % classified as fair quality (Koesoemadinata, 1978), hydrocarbon saturation of 23.06 %, and a net pay thickness of 14.6 feet containing gas.

(d) The sandstone layer in reference Well Y with reservoir SS-3 has an average shale volume of 25.09 %, effective porosity (PHIE) of 11.80 % classified as fair quality (Koesoemadinata, 1978), hydrocarbon saturation of 7.68 %, and a net pay thickness of 12 feet containing gas.

(e) The sandstone layer in reference Well Z with reservoir SS-4 has an average shale volume of 29.31 %, effective porosity (PHIE) of 18.77 % classified as good quality (Koesoemadinata, 1978), hydrocarbon saturation of 30.68%, and a net pay thickness of 16.7 feet containing gas.

(f) The sandstone layer in reference Well Z with reservoir SS-4 has an average shale volume of 17.52 %, effective porosity (PHIE) of 20.15 %, classified as very good quality (Koesoemadinata, 1978), hydrocarbon saturation of 43.03 %, and a net pay thickness of 4 feet containing gas.

(g) Based on the results of research on wells X, Y, and Z with Pliocene age intervals, it is recommended to choose sandstone and limestone reservoir layers because they tend to have good hydrocarbon quality.

(h) Based on the petrophysical analysis that has been carried out on wells X, Y, and Z with a Pliocene age interval, it is best to determine the reservoir target with rock layers in the form of sandstone and limestone that have a porosity value above 11.80 % and a hydrocarbon saturation value above 7.68 % with drill stem test (DST) data that is proven to produce oil and gas.

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