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Facies Analysis and Reservoir Characterization Using Petrophysical Methods in the Interest Zone in the 'FAN' Field, Kutai Basin, East Kalimantan

Isfan Fajar Fathur Rahman[1], Wahju Krisna Hidajat[1], Reddy Setyawan*[1], Yunita Meilany[2], and Dhimas Aditya Nugraha[2]

[1]*Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia*
[2]*Pertamina Hulu Sanga-Sanga, Kutai Kertanegara, Indonesia*

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ABSTRACT. One of Indonesia's most prospective oil and gas-producing basins is Kutai Basin, located in East Borneo. In Kutai Basin, there is a natural resource potential in the form of relatively abundant gas due to the richness of the source rock aspect of the Kutai Basin, which is dominated by coal. Besides coal, in the Kutai Basin, claystone with rich organic matter (organic shale) also has an important role as a prospective source rock. The research focuses on reservoir rocks at the research site because of the hydrocarbons accumulated in the reservoir rocks. By focusing research on reservoir rocks, it can describe the modeling and calculation results of petrophysical parameters using several analytical methods. The research aims to identify the type and content of subsurface lithology and fluids, calculate petrophysical parameters, and make the facies distribution map at the research site in the potential and prospective zone to produce hydrocarbons called the zones of interest. The primary data used in this research is well-log data from 10 wells, namely Fan-01 to Fan-10. The secondary data used in this research is mud log data. Based on the analysis data, the VSh value of the 10 wells ranged between 0.27–0.52. The porosity values are in the range of 0.21 to 0.17. The permeability value at the research site is in the range of 161 md to 18 md. The research location is included in the transitional depositional environment, particularly the delta with distributary channels and mouth bars facies. Some lithology, such as sandstone, claystone, coal, limestone, and organic claystone, can also be identified, and there are fluids with gas and water types.

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

1 INTRODUCTION

Judging from its geological history, Indonesia comprises a group of islands with abundant natural resources (SDA) potential, one of which is oil and gas. This is due to several geological factors ranging from abundant natural basins and the high quantity of hydrocarbon-producing microorganisms in the past to Indonesia's tectonic structure and composition, which was formed as a system of these natural resources. One example of a prospective oil and gas-producing basin in Indonesia is the Kutai Basin or commonly known as the Kutai Basin, which is located in East Kalimantan Province (Figure 1). According to Yuniardi (2012), in the Kutai Basin, there is a natural resource potential in the form of gas which is quite abundant. This is because the source rock or source rock in the Kutai Basin is dominated by coal. In addition to

*Corresponding author: R. SETYAWAN, Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia. Jl. Prof. H. Soedarto, S.H., Tembalang, Kec. Tembalang, Kota Semarang, Jawa Tengah 50275. E-mail: reddy@live.undip.ac.id

coal, in the Kutai Basin, there is also claystone rich in organic material (organic shale) which also has an important role as a source rock or prospective source rock (Nauval, 2019). This is supported by other studies that refer to aspects of the depositional environment. According to Kurnianto (2014), at the Miocene interval, the reservoir in the Kutai Basin was formed in a depositional environment dominated by a fluvial environment to a delta front which is included in the Balikpapan formation unit with quartz sandstone lithology as the unit. Main reservoir in this depositional environment, it is possible to deposit sediments such as sand material to maceral, which can act as a component of the petroleum system to produce products such as sandstone which acts as a reservoir rock to coal or organic shale, which acts as a source rock (Renaldo, 2016). The results of these sedimentary products accumulate in reservoirs with a relatively shallow depth at current conditions so that it is easy to carry out further research with the aim of exploration and exploitation. Based on previous research, natural resource maturity zones, generally natural gas, accumulate in reservoir rocks at 1100 to 2000 meters below the surface (Ahmad, 2019).

Based on the research that has been carried out at PT. Pertamina Hulu Sanga-Sanga, in the Kutai Basin, a study has been carried out using the good logging method from several drilling wells in the 'FAN' field, which is focused on reservoir rock from each drilling well. This is because the hydrocarbon reservoir rock accumulates. By focusing research on reservoir rocks, it will be able to describe the modeling and calculation results of petrophysical parameters more specifically and in detail. The results of the well-logging method will produce a collection of information in the form of log data. The log data will be further processed using petrophysical analysis methods both qualitatively and quantitatively in such a way that facies maps and reservoir characterizations are produced, which are helpful as analytical parameters related to the results of calculations, modeling, and determination of a prospective area of research sites focused on the system of the reservoir rock. These results can support data in development or optimization activities, be it exploration or further exploitation at the research site.

2 GEOLOGICAL SETTING/SITE CHARACTERIZATION

The Kutai Basin to the north is bordered by the Mangkalihat High and the Sangkulirang Fault; in the south by the Adang Fault; in the west by the Kuching Heights; and in the east by the Makassar Strait. Delta Mahakam is a product of sediment from the fluvial system/Mahakam River, which has a formation that tends to be finger-like and resembles a fan (PHSS, 2021). The Mahakam Delta is one of Indonesia's largest Deltas, which has been proven to produce hydrocarbons. The alternation of regression and transgression phases dominates the stratigraphy of the Kutai Basin.

The alternation of this phase lasted from the Miocene to the present, which we can see as the sedimentation of the modern Mahakam Delta. The process that occurred in the delta during the Miocene age was not much different from the process that occurs today. The Kutai Basin generally comprises tertiary sediment, which shows the results of transgression cycles and sea level regression (PHSS, 2021).

Stratigraphy in the working area of PT. Pertamina Hulu Sanga Sanga is included in the Balikpapan Formation Group, which consists of quartz sandstone with fine to medium grain sizes interspersed with claystone, siltstone, shale, limestone, to coal. In general, these rocks are of middle Miocene age, formed in the distributional channel and delta-front depositional facies to the mouth bar of the Paleo-Delta Mahakam system (PHSS, 2021). In more detail, the research was conducted in the 'G' zone in the 'FAN' Field, Kutai Basin, East Kalimantan. The zone division carried out by PHSS is based on the stratigraphic sequence, which limits one sequence to another. The 'G' zone is a zone that was deposited in the middle Miocene age in the delta front depositional facies (Figure 2).

3 METHODOLOGY

This research was conducted using several analytical methods based on primary and secondary data from the PT Pertamina Hulu Sanga Sanga agency with objects consisting of 10 drilling wells starting from the FAN-01

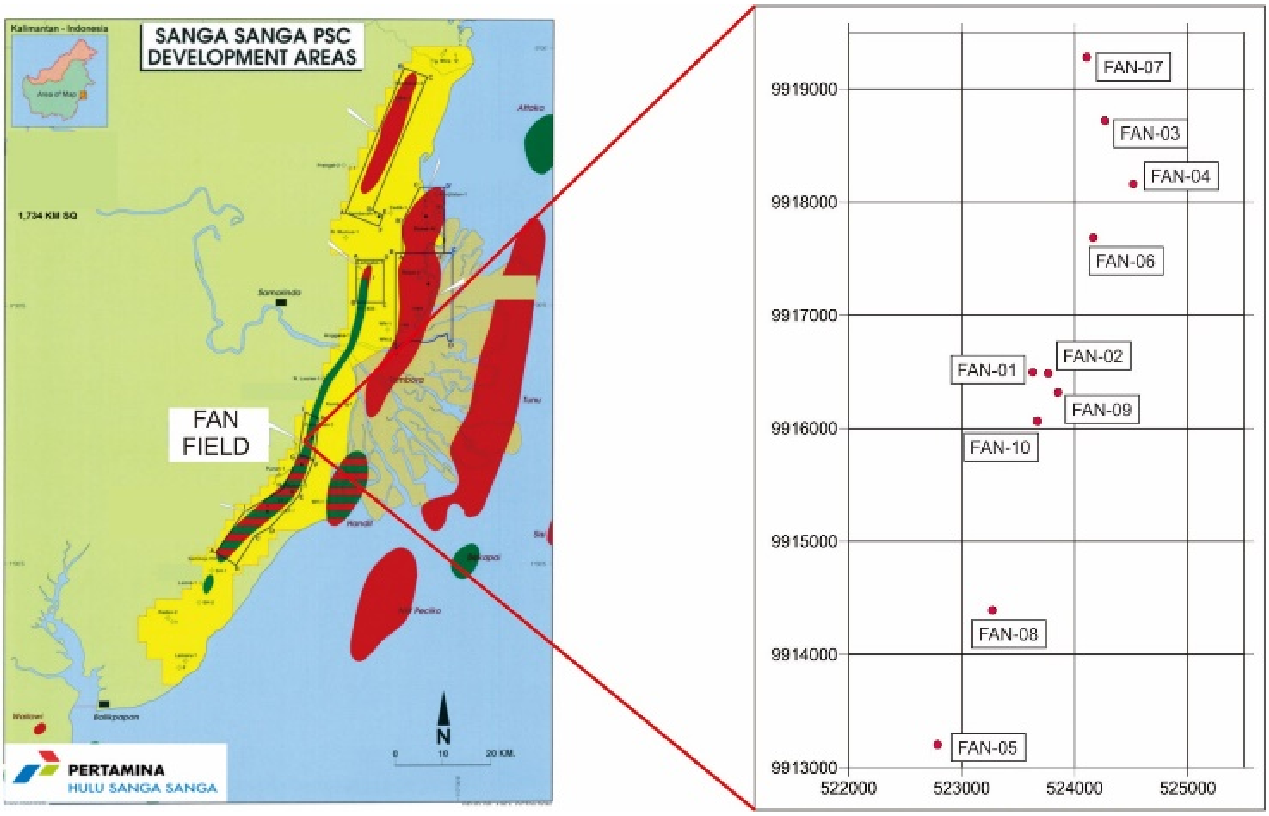

FIGURE 1. Research site map.

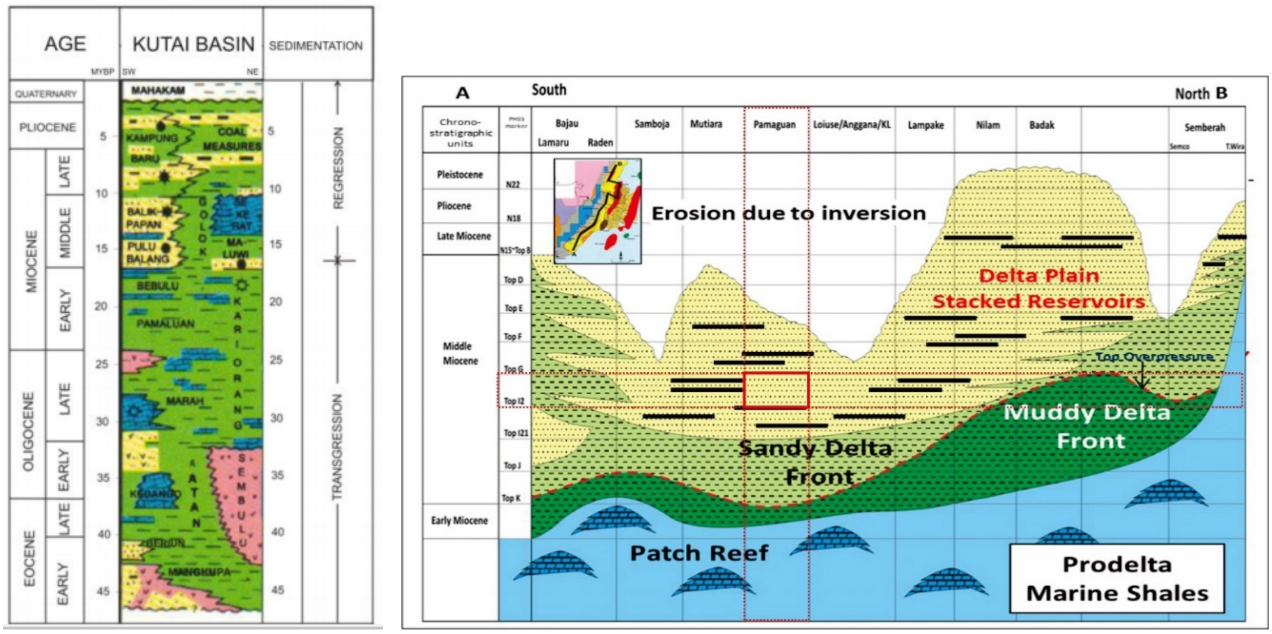

FIGURE 2. Stratigraphic column of Kutai Basin Regional Stratigrafi (left), and the marker zone correlation showing "G" marker (right).

well to the FAN-10 well. Primary data in this study consisted of well-log data, and secondary data in this study consisted of the mud log, pressure, and satellite imagery data (Table 1. The analytical research methods include qualitative and quantitative petrophysical analysis, electrofacies and parasequence analysis, facies and depositional environment analysis, and stratigraphic correlation analysis. This analysis method will produce a map of the distribution of facies and reservoir characterization, which is the main goal of this final project research.

4 RESULTS AND DISCUSSION

Based on the data obtained from the agencies related to the Final Project, an analysis of the petrophysical, electrofacies and parasequence aspects, and facies and depositional environments was carried out to produce a facies map and reservoir characterization at the research location represented by objects in the form of 10 drilling wells starting from the FAN-01 well. Up to the FAN-10 well. The following is a description of the results and further discussion of each analysis.

4.1 Qualitative petrophysics

The qualitative petrophysical analysis identified each drilling well's lithological and fluid aspects based on well log data. The identification of lithology and fluids is based on the response of several logs, such as gamma ray, density, neutron, and resistivity, which can represent a type of lithology or fluid.

Based on the research results, the FAN-01, FAN-05, FAN-06, FAN-09, and FAN-10 (Figure 3) wells can be identified with several lithology types, such as sandstone, claystone, and coal. Several types of lithology can be identified in the FAN-03 and FAN-08 wells, such as sandstone, claystone, coal, and organic claystone. Several types of lithology can be identified in the FAN-04 and FAN-07 wells, such as sandstone, claystone, coal, organic claystone, and limestone. In the FAN-02 well, several types of lithology can be identified, such as sandstone, claystone, and organic claystone.

Judging from the aspect of fluid identification, the FAN-03, FAN-04, and FAN-07 wells can be identified the presence of fluid with the type of gas in the reservoir in each well, which is represented by the thickest sandstone layer. In wells FAN-01, FAN-02, FAN-05, FAN-06, FAN-08, FAN-09, and FAN-10, the presence of fluid with the type of water in the reservoir in each well can be identified, which is represented by the thickest sandstone layer.

4.2 Quantitative petrophysics

Quantitative petrophysical analysis refers to the results of calculating the petrophysical parameters of all drilling wells. In this study, the quantitative analysis focused on the reservoir of each drilling well, and there are 4 calculation parameters, namely shale volume, porosity, permeability, and water saturation (Table 2). Volume shale is calculated based on the gamma-ray log parameters from each drilling well. Overall, the calculation of the volume of shale shows the volume ratio of the fine fraction to the coarse fraction in a drilling well.

The calculation of water saturation is carried out based on the SWIRR parameter of each drilling well. Overall, the water saturation calculation shows the ratio of the water-filled porosity to the overall porosity.

The porosity calculation in this study was carried out based on the density log and neutron log parameters from each drilling well. The calculated porosity type is the effective porosity. Overall, the calculation of the effective porosity shows the percentage of interconnected voids that can store fluid. Porosity calculation is done digitally using Geolog software with the determined method using the Bateman-Konen configuration approach. Permeability calculations are carried out based on the porosity parameters of each drilling well. The permeability calculation shows the value of a rock's capability to flow a fluid. Permeability calculations are also carried out using Geolog software. The calculation uses a determinate analysis method with a Wyllie-Rose configuration approach. The Wyllie-Rose configuration is in accordance with the data used in this study because the configuration uses SWIRR data as a reference in calculations. Those calculations could not be validated because we lacked conventional core data.

TABLE 1. Well Inventory in the research area.

No	Well Name	Logs					Mudlog	Pressure
		GR	Cali	Res	Neu	Den		
1	FAN-01	✓	✓	✓	✓	✓	✓	
2	FAN-02	✓	✓	✓	✓	✓	✓	
3	FAN-03	✓	✓	✓	✓	✓	✓	
4	FAN-04	✓	✓	✓	✓	✓	✓	
5	FAN-05	✓	✓	✓	✓	✓	✓	
6	FAN-06	✓	✓	✓	✓	✓	✓	✓
7	FAN-07	✓	✓	✓	✓	✓	✓	
8	FAN-08	✓	✓	✓	✓	✓	✓	
9	FAN-09	✓	✓	✓	✓	✓	✓	✓
10	FAN-10	✓	✓	✓	✓	✓	✓	✓

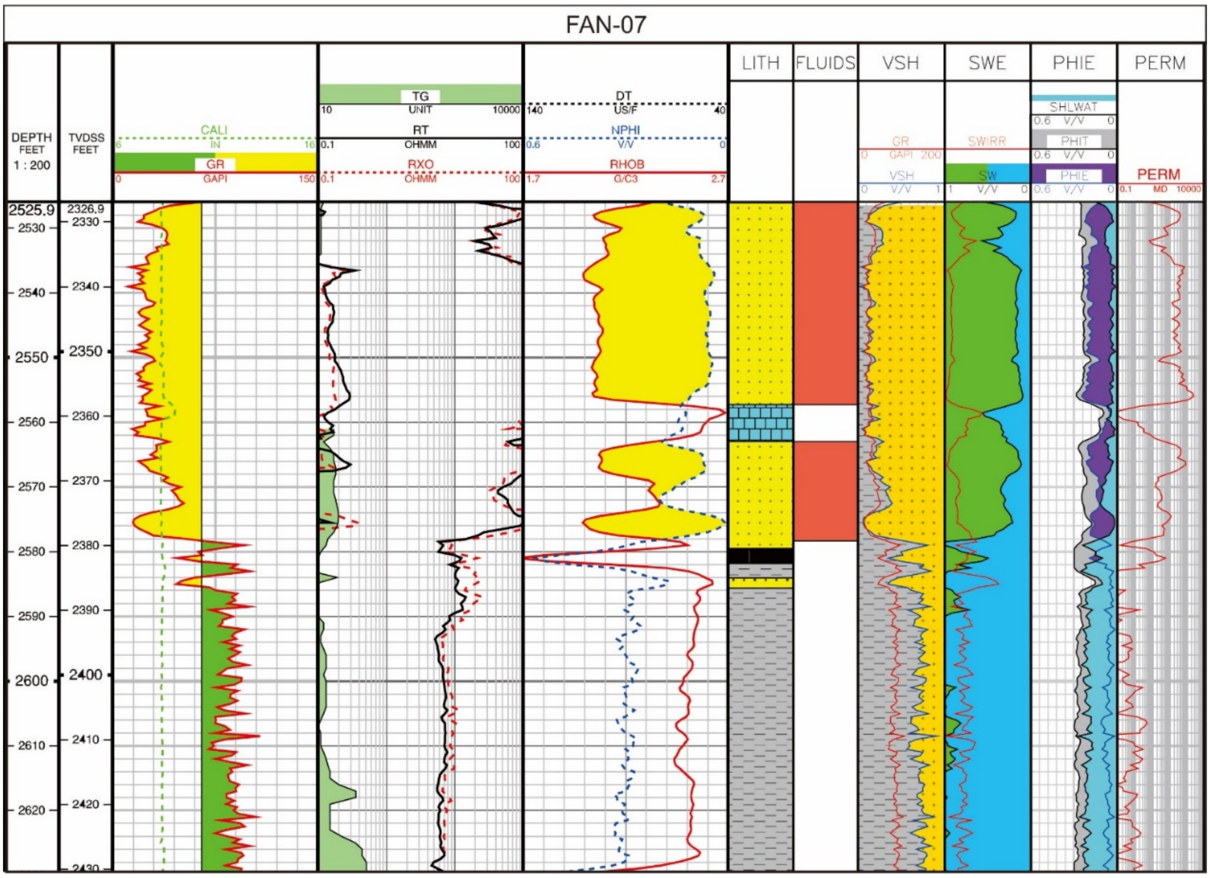

FIGURE 3. Lithology and fluid determinations from FAN-07.

TABLE 2. Tabulation data from all quantitative calculations, such as fish, phie, and Sw.

4.3 Electrofacies and parasiquences

Electrofacies and parasequence analysis in this study focused on the reservoir in each drilling well, represented by the thickest sandstone layer. In wells FAN-01, FAN-02, FAN-03, FAN-04, FAN-06, FAN-07, FAN-09, and FAN-10, the results of electrofacies analysis showed a very dominant cylindrical pattern (Figure 4). Judging from the parasequence analysis, each well shows the dominance of a rough upward pattern as a whole or is generally referred to as a progradational or progradational pattern. Based on the results of this analysis, an interpretation can be made of several geological events that can result in the formation of a rough upward pattern, such as regression or shifting of coastline away from the mainland due to global sea level decline or tectonic uplift which both result in a decrease in sediment accommodation space with the assumption of a constant or increasing rate of deposition.

In wells FAN-05 and FAN-08, the results of the parasequence analysis are the same as the previous paragraph, namely the upward roughening or progression pattern. What distinguishes the FAN-05 and FAN-08 wells from other wells is the electrofacies analysis which shows a pattern with the type of funnel.

4.4 Facies and depositional environment

To identify the facies and depositional environment, an analysis of the integrity of the data is carried out, which consists of several analysis results obtained previously (Figures 3 and 4) data as supporting data that can characterize a particular facies and depositional environment. The integrated data analysis and supporting data indicate that the research location was formed in a transitional depositional environment, precisely in the delta.

The Specific characteristics of the deltaic depositional environment include the occurrence of depletion of terrestrial sedimentary material, such as the results of the stratigraphic correlation (Figure 5) of the research location, which can be seen in the appendix and composed of alternations showing the results of special shallow marine deposits such as limestone, sandstone, and claystone to the results of special land-transition deposits such as coal, which were found at the study site. Based on the results of the electrofacies analysis, it can be concluded that at the research site, there are wells that represent the facies distribution channel in the well which shows the results of cylindrical and mouth bar patterns in the well, which shows a funnel pattern.

4.5 Facies map

Based on the analysis of facies and depositional environment, facies delineation can be carried out, represented as a facies map of the research location. The results of making a facies map can be seen in Figure 6. Based on this view, it can be analyzed that the direction of sedimentation represents the mainland and comes from the Northwest or North West towards the Southeast or South East, representing the coast.

4.6 Correlation of facies map to petrophysical parameter

A facies map correlation was carried out on several petrophysical parameters, such as reservoir thickness, porosity, and permeability, to determine the area and prospective wells at the study site. The results of the distribution map of the rough thickness or gross thickness of the reservoir rock can represent the geometry of the reservoir rock at the research location. From the rough thickness distribution map of the reservoir rock, there is a decrease in thickness towards the coast. The gross thickness distribution map can be seen in Figure 7.

The results of the isoporosity distribution map at the research location show that the closer to the coast, the porosity value decreases. This is interpreted because of the thinning of the reservoir rock layer. The depletion of the reservoir rock layer can occur due to the reduced supply of sediment, and the more material deposited closer to the coast, the smoother it will impact the resulting porosity. The image of the isoporosity distribution map can be seen in Figure 8.

The isopermeability distribution map at the research site also shows something similar to the isoporosity map. The closer to the coast, the more the permeability decreases. This can be interpreted as a relationship between porosity directly proportional to permeability. The image of the distribution of the isopermeability map can be seen in Figure 9. Overall, the prospective

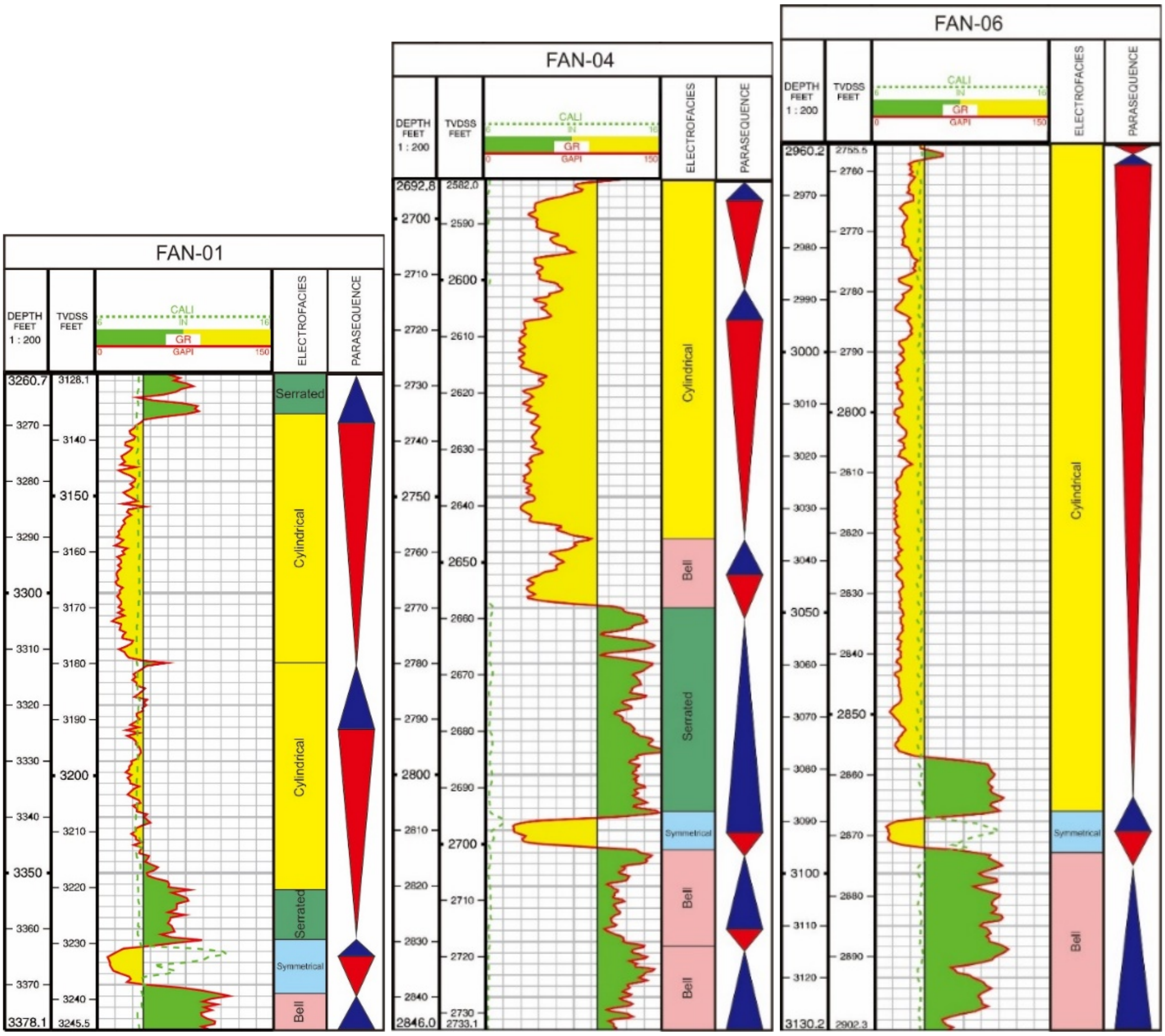

FIGURE 4. Electrofacies and parasequence result of FAN-01, FAN-04, and FAN-06.

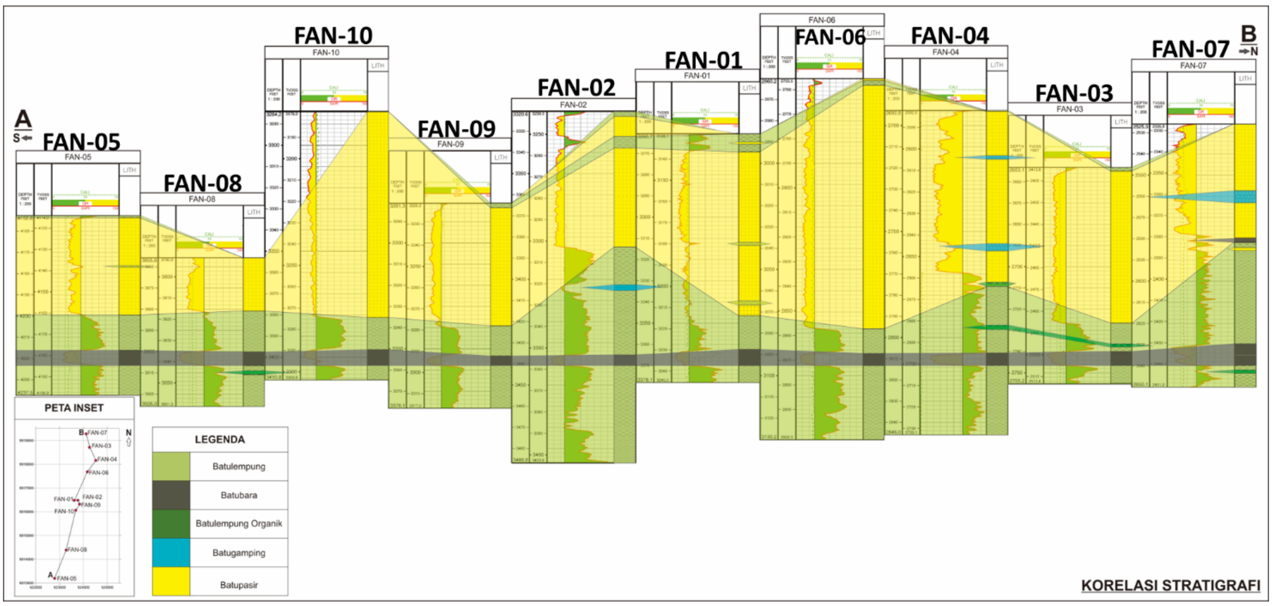

FIGURE 5. Stratigraphic Correlation Results.

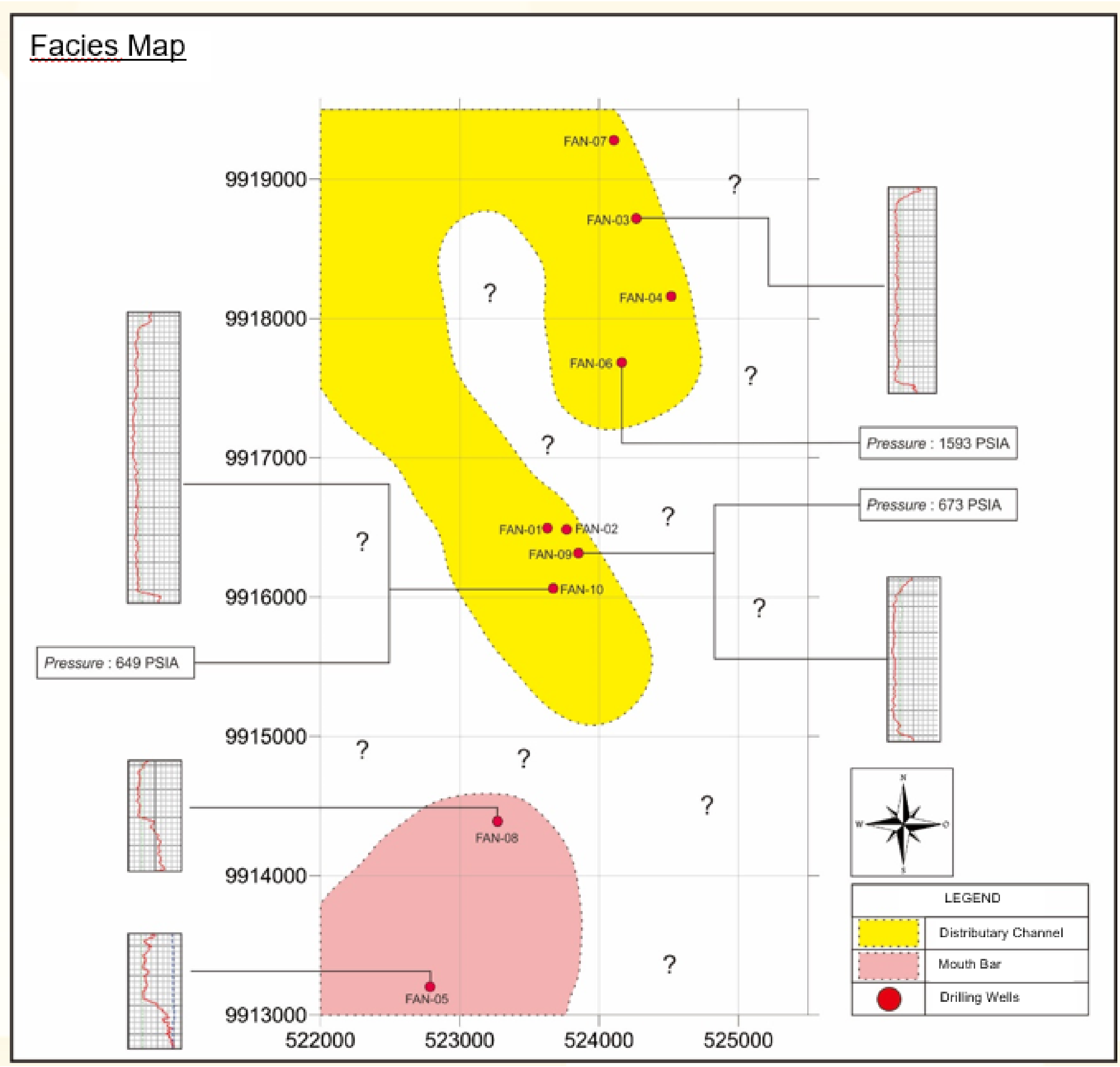

FIGURE 6. Facies Map based on the GR log(shown in the image).

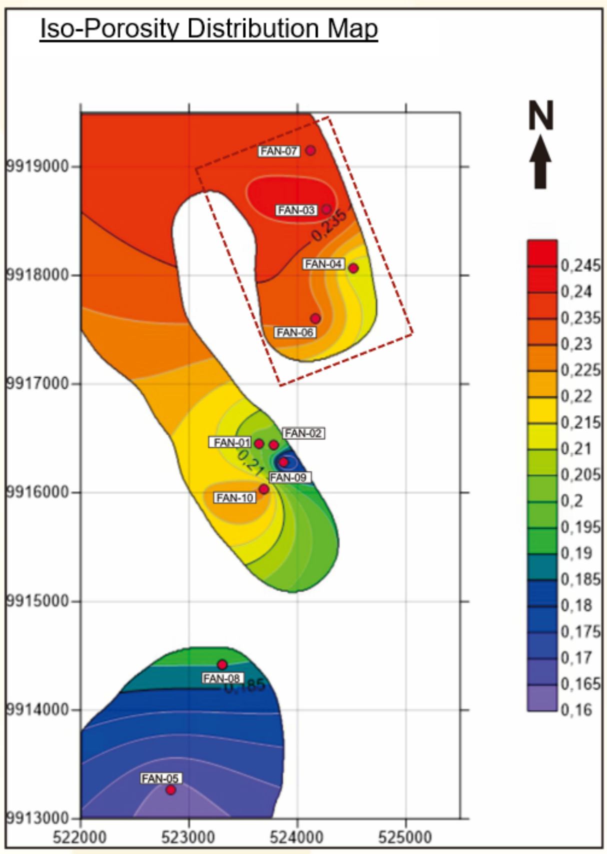

FIGURE 7. Map of reservoir thickness distribution.

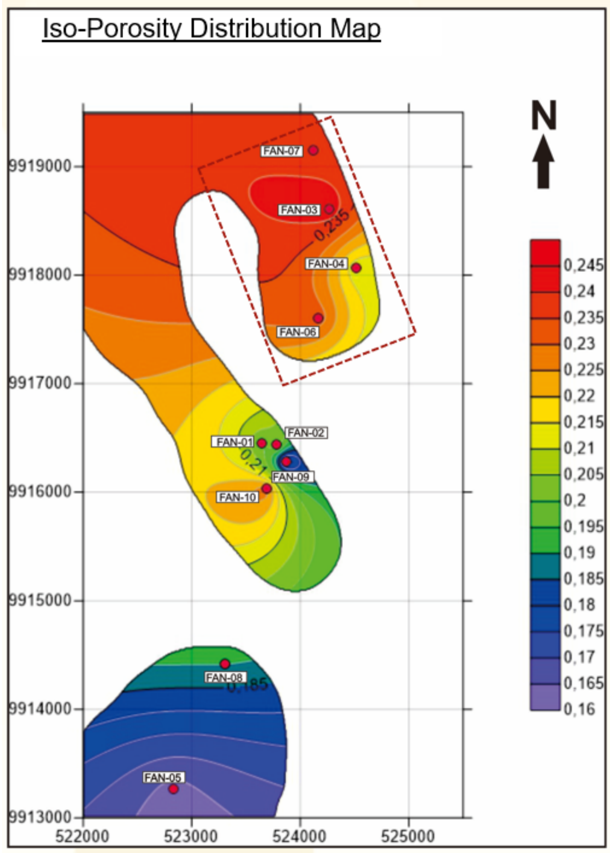

FIGURE 8. Map of iso-porosity distribution.

wells that have the potential to produce hydrocarbons are wells FAN-03, FAN-04, and FAN-07, which are included in the northernmost distribution channel facies delineation.

4.7 Reservoir characterization

Reservoir characterization is a method of grouping or classifying each drilling well based on the calculated data and petrophysical analysis. This classification is useful for representing the level of prospectivity of the reservoir rock for each well. Based on the research results, the classification of reservoir characterization is divided into 2 characteristics of the facies and their depositional environment, namely the distribution channel and the mouth bar.

In the distribution channel facies, the average porosity calculation result is 0.21, which is classified as very good (Koesmoedinata, 1978), and the average permeability calculation is 161 md, classified as very good (Koesmoedinata, 1978). In the mouth-bar facies, the average porosity calculation result is 0.17, which is classified as good (Koesmoedinata, 1978), and the average

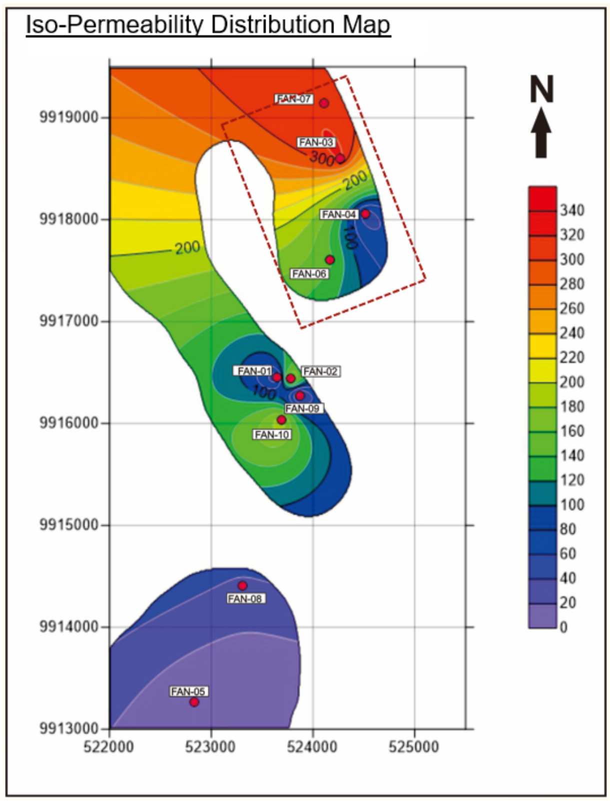

FIGURE 9. Map of the distribution of iso-permeability thickness.

permeability calculation is 18.9 md, classified as good or good (Koesmoedinata, 1978).

Based on the results of petrophysical calculations, it can be stated that reservoir rocks that act as reservoirs of fluids and hydrocarbons at the research site are divided into 2 types based on their facies. The distribution channel facies has a very good perspectivity, while the mouth bar has a good prospective. In general, the characteristics of the reservoir rock at the research site have good prospectivity and the ability to store hydrocarbons or fluids.

5 CONCLUSION

Based on the research that has been done, the conclusions obtained from the results of the discussion are:

a. The results of the identification and determination of lithology at the research site found lithology with the type of sandstone or sandstone, claystone or shale, organic claystone or organic shale, limestone or limestone, and coal or coal.
b. The results of the identification and determination of fluids at the research site found fluid content in the form of gas and water.
c. The results of the calculation of the average porosity value at the study site are in the range of 0.21 to 0.17, which is classified as very good to good, and the calculation results of the average permeability value at the study site are in the range of 161 md to 18 md which is classified as very good to good.
d. The analysis results of the map of the distribution of facies at the study site are included in the transitional depositional environment, precisely in the distribution channel and mouth bar facies.
e. Reservoir characterization at the research site in the distribution channel facies has a very good prospectivity, and the mouth bar facies has a good prospect.

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