

ANALYSIS OF GAS RATIO DRILLING TO IDENTIFY THE G-80 SANDSTONE RESERVOIR FOR WELL CORRELATION IN THE SEMBERAH FIELD, KUTAI BASIN

*Desianto Payung Battu¹, Adi Tonggiroh² and Meutia Farida³

¹Engineering Faculty, Universitas Hasanuddin, Makassar, Indonesia

*Corresponding Author, Received: 17 Aug. 2025, Revised: 21 Sep. 2025, Accepted: 02 Oct. 2025

ABSTRACT: Data uncertainty caused by drilling activities can affect the accuracy of distinguishing productive from non-productive zones, especially in fluid characterization and reservoir evaluation, which are core objectives of geoscience. Each well in Semberah has an objective to penetrate several layers of target, including both oil and gas reservoirs. Gas ratio analysis is an established method for identifying reservoir characteristics by analyzing formation fluid molecules that rise to the surface with the drilling mud when the drill bit breaks through the formation. The integration of drilling data, well logs, and gas analysis from six wells in Semberah has led to a deeper understanding of reservoir potential during drilling. The analysis focused on G-80 sandstone, one of the reservoirs found throughout the Semberah field. Similar trends were observed in total gas compared to resistivity log values, which ranged from 42 to 700 units, versus resistivity measurements from 6.0 to 18.7 ohms. The C1/Sum C ratio ranged from 0.8 to 0.9, WH value indicated dry gas, BH value more 50 is gas while below 50 is water or undeveloped reservoir. The fluid mobility characteristic of the estimated potential porosity gas ratio indicates an approach to porosity values derived from petrophysical analysis. The results of this study demonstrate that gas ratio analysis can support geoscience research and contribute to a broader understanding of the area.

Keywords: Total Gas, Gas Ratio Drilling, Gas Chromatography, Wetness, Balance, Fluid Mobility Estimated Potential Porosity

1. INTRODUCTION

Semberah Field is an onshore oil and gas field in East Kalimantan, Indonesia. It is part of the Sanga-Sanga block operated by Pertamina, with production starting in the 1970s. The area lies within the Kutai Basin, one of the most important sources of hydrocarbons in East Indonesia. It is a large sedimentary basin with Tertiary-age sediments, ranging from Paleocene to Pliocene. The structural geology includes both deep and shallow marine features, forming potential reservoirs associated with multiple layers resulting from fluvio-tidal deltaic sedimentation deposited in the ancient Mahakam Delta.

The sedimentation process developed the Mahakam delta into a mix between fluvial and tidal influence and generated a variety of reservoir characteristics through the petroleum system [12,19]. Semberah Field has been producing since 1974, production peak in 2000 from multilayer reservoir zone and continues to decline till the current period [1,11,13]. However the activity to maintain and increase production are still ongoing which improve on method and technology. The geologically stratigraphic column is divided into E, F, G, I, and J layers, where these layers still produce with a certain remaining reserve with a fairly low production rate with quite low permeability reservoir in the I to J layers.

During recovery, remaining reserved on the development phase, formation evaluation during drilling now is most important and effective to gather

more information. One of the data points that can be gathered during drilling is the gas ratio, where the complex stratigraphy can be interpreted by combining with lithology from cutting analysis.

One of the key factors for successful appraisal and development of any oil or gas field is gently understanding of the reservoir target characteristics, where that information can be gathered during drilling or after completing the well. Many methods were developed in the past decade, one of which is gas ratio drilling. The fluid molecules contained in the reservoir come out at the same time as the drill bit crushes the formation. The cutting was lifted to the surface along with the circulating drilling mud, where the next activity was to observe and describe the lithology.

Once lithology was crushed by bit, the reservoir fluid is released into the drilling mud. The gas detection technique was improved to determine the hydrocarbon-bearing zone from the separation mud and gas from the formation. Detection was combined by gas trap, analysis, and pump equipment to allow gas sucking through the line for further analysis [7-10]. The ability of mud-gas logs to delineate different hydrocarbon types is a function of drilling and mud parameters as well as the technology used in the extraction and analysis of the mud gases. Light hydrocarbon shows support few interpretation procedures to ensure the hydrocarbon-bearing zone. There are charts created by Pixler 1968) and Hayworth 1984 and they developed their own interpretation method.

The reservoir evaluation is performed by means of

gas ratios, where the first step is to ensure that the signal is not affected by drilling operation circumstances and reflects the presence of a hydrocarbon-bearing zone [4]

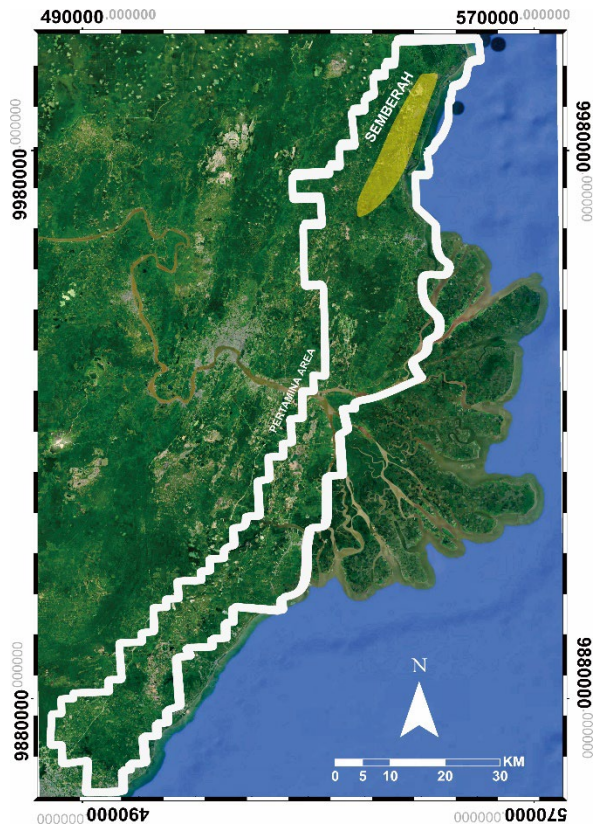


Fig.1 Semberah Field Map

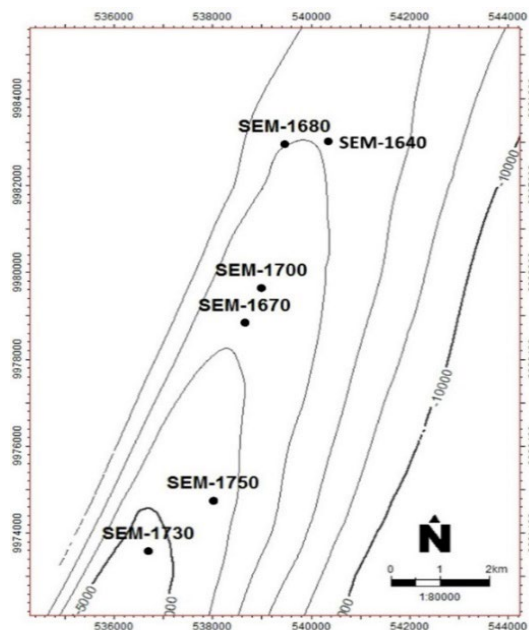


Fig. 2 Structural Map G-80 SST

Continuous gas monitoring sometimes enables us to indicate, in general terms, the presence of hydrocarbon-bearing intervals but rarely to define the

fluid types (oil, condensate, and/or gas, water) [2,3,5]

However, gas data at present is largely underutilised because some opinions if it is not fully representative of the formation fluids [6]. Many reasons against this technology, a poorly established correlation between reservoir fluid and shows at the surface. Other hand, the influence on recorded data, such as formation pressure, mud weight, and temperature is supports this uncertainty.

2. RESEARCH SIGNIFICANCE

This study introduces a novel integration of drilling gas ratio analysis with well logs and drilling data to improve reservoir evaluation in the Semberah field. Unlike conventional approaches that treat drilling gas data in isolation, this research demonstrates how combining gas chromatography outputs with resistivity and petrophysical analyses can reduce uncertainty in distinguishing productive from non-productive zones. The originality lies in applying this integrated method specifically to the G-80 sandstone, providing new insights into fluid mobility and porosity during drilling. This approach establishes a unique framework for real-time reservoir characterization and decision-making in complex hydrocarbon systems.

3. MATERIAL AND METHODS

3.1 Well Data

Six wells were analyzed on Semberah Field; these wells were drilled in 2022-2023 and currently produce oil and gas from multiple layers of hydrocarbon. Many reservoirs reservoir already been proven to produce at the Semberah field, one of them is the G-80 sandstone. Each of the reservoir layers has a unique stratigraphy characteristic, where it is sometimes found as a channel in the other well, deployed as a bar deposit.

This layer develops almost wholly at the Semberah field with direction along the major anticlinorium NE-SW (Fig. 2). Generally, the location of the well is slightly on the crest of structural map sandstone G-80. All wells used have complete data, both wireline log gamma ray (GR), resistivity (Res), density (RHOB), neutrons (Neu), as well as gas ratio chromatography C1-C5 data. A geological cross-section was made to easily identify for G-80 sandstone characteristics in each of the well developments.

Table 1. Availability Well data

Well	GRay	Res	Den	Neu	C1-C5
SEM 164	✓	✓	✓	✓	✓
SEM 167	✓	✓	✓	✓	✓
SEM 168	✓	✓	✓	✓	✓
SEM 170	✓	✓	✓	✓	✓
SEM 173	✓	✓	✓	✓	✓
SEM 175	✓	✓	✓	✓	✓

3.2 Gas Ratio Drilling

Extraction drilling mud to delineate the type of hydrocarbon and safety drilling are function of the primary gas drilling ratio analysis. Gas ratio analysis is a well-recognized technique for fluid characterization and reservoir evaluation. Presence of hydrocarbon was firstly detected by methane concentration, acid test, hot water test, and intensity color of stain, fluorescence, and residual cut from mudlogging technology [18,20].

Gas ratio drilling is a comparison between 2 or more types of alkane gas formed from GWD (Gas While Drilling) extraction. Comparison between light and types of alkane gas formed from GWD extraction. Observation with specific analysis of gas trend allows for gaining an interpretation of hydrocarbon-bearing zones to non-potential hydrocarbon zones [14-16]. The configuration of ratio GWD is used to characterize the type of fluid hydrocarbon in situ during drilling operations. Improvement of aspect data interpretation will be guided by the local geological and petroleum model.

$$\text{Wetness (WH)} = 100 * (C2 + C3 + C4s + C5s) / (C1 + C2 + C3 + C4s + C5s) \quad (1)$$

$$\text{Balance (BH)} = (C1 + C2) / (C3 + C4s + C5s) \quad (2)$$

The most commonly used gas ratios versus depth during drilling are WH and BH. They can help to identify formation fluid changes; therefore, fluid contact as gas-oil contact (GOC) or oil-water contact (OWC) can be estimated. This ratio measures the proportion. Meanwhile, BH can be combined with WH to improve the reliability of fluid interpretation. The presence of a dense hydrocarbon fluid can be confirmed, and this should aid in the distinction of a very wet gas from a very high gravity oil.

$$\text{Fluid Mobility Estimated Potential Porosity (FMPPx)} = ((C1 + C2) / (C4s + C5s)) / 1000 \quad (3)$$

FMPP gas ratio analysis during drilling is really useful for early identification of formation fluid, which sometimes replaces wireline operation, where gas ratio analysis could replace petrophysics analysis with high accuracy applied on multiple reservoir layers [17], such Mahakam Delta.

$$C1/\text{SumC} = C1 / (C1 + C2 + C3 + nC4 + iC4 + nC5 + iC5) \quad (4)$$

The C1 value represents the lightest and simplest alkane component. Changes in the C1 value can indicate lithological changes, while SumC represents the total of the chromatographic values that the existing gas system can detect.

3.3 Porosity Petrophysics

The calculation of porosity for siliciclastic rocks is generally the same as the calculation of porosity in lithology, namely, comparing the pore volume value to the rock volume. Porosity factor describes the total volume of pores and, as a rule, is defined by methods of gamma-gamma density logging, neutron logging, and acoustic logging, and it is called porosity methods.

$$\begin{aligned} \Phi_t &= \Phi_e + V_{Cl} \times \Phi_{t \text{ WetClay}} \\ \Phi_e &= \text{Porosity Effective (V/V)} \\ V_{Cl} &= \text{Volume Clay (V/V)} \\ \Phi_{t \text{ WetClay}} &= \text{Porosity Total Wet Clay (V/V)} \\ \Phi_t &= \text{Porosity Total Wet Clay (V/V)} \end{aligned}$$

3.4 Well Log Data

Uncertainty in reservoir characterization within deltaic environments is addressed by integrating multiple sources of logging data. In the Semberah field, wells were typically drilled in two or three sections, depending on subsurface geological hazards, with the middle and final sections generally representing the production zones. Formation evaluation relied mainly on wireline logging, which provided datasets such as gamma ray, resistivity, density, neutron, and sonic logs. These data were essential for constructing stratigraphic correlations, particularly for the G-80 sandstone reservoir.

Wireline logging was performed exclusively in production zones to identify reservoir properties and guide completion strategies. A key challenge was depth alignment: gas ratio data referenced drill pipe depth, while wireline logs corresponded to cable depth, creating minor discrepancies. Although small, these differences required careful correlation to maintain a reliable interpretation.

Compared to offshore operations, onshore drilling offers greater flexibility in selecting well locations, allowing more precise targeting of multiple reservoir zones. Nevertheless, minor depth variations between drill pipe and wireline data remain inevitable. The log composite (Fig. 3) illustrates differences between gas ratio data and lithology interpreted from wireline logs, ranging from 0.4 to 11.2 ft (Table 2), emphasizing the importance of correlation techniques.

The primary goal of correlation is to establish consistent trends across datasets, particularly log responses. Depth adjustments are especially critical in intervals with repeated thin layers, such as coal beds shown in Fig. 3. Standardizing depth references enhances precision in reservoir interpretation, improving understanding of stratigraphy and reservoir distribution. By integrating wireline, gas, and lithology data, uncertainties can be minimized, enabling informed decisions regarding well placement, completion design, and production strategies in complex deltaic reservoirs.

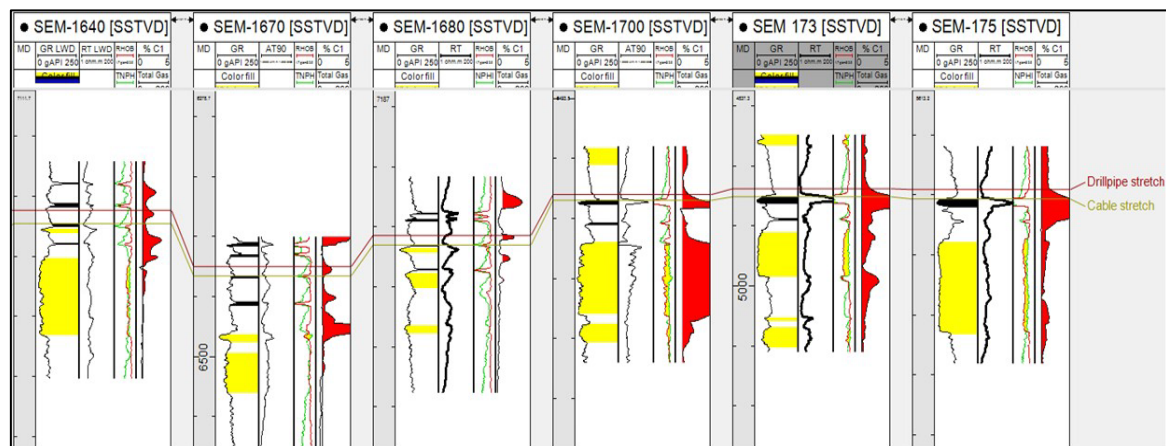


Fig. 3 Depth Shifting due to differentiate *cable stretch* from Wireline compare with *drill pipe stretch* from Gas Log Ratio. Well trajectory created this differentiation during drilling on deviated well to maximized hydrocarbon achieved in one well.

Table 2. Depth-normalized accommodate differentiate cable with pipe stretch

Well Name	Actual Depth (ft)	Shifted Depth (ft)	Differentiate (ft)
SEM 164	7196.6	7190.8	5.8
	7215.0	7208.1	6.8
	7237.3	7226.1	11.2
SEM 167	6400.5	6406.8	6.4
	6427.8	6433.3	5.6
	6450.9	6455.8	4.9
SEM 168	7291.6	7293.2	1.6
	7317.2	7316.8	0.4
	7335.8	7336.6	0.8
SEM 170	6587.4	6586.3	1.0
SEM 173	4929.1	4927.2	1.9
SEM 175	5710.0	5707.1	2.9

4. RESULTS AND DISCUSSION

All parameters presented in the composite log should have a trend that can be used as a determinant to identify changes in stratigraphic markers. Wireline log parameters such as gamma ray, resistivity, density, and neutron will be juxtaposed with gas ratio parameters such as total gas, wetness, balance, fluid mobility, potential porosity, and of course, will be supported by lithology information derived from cutting data information. The gas ratio, both the trend and the value approach, is compared with the log readings and the interpretation results of the log to determine whether there is a relationship between the two, thus providing information that wireline data confirmed can be replaced with the gas ratio to identify the presence of gas Sandstone G-80.

4.1 Correlation Resistivity with Total Gas

The resistivity and total gas values compared above show similarities in trend, which is also strongly supported by the existence of cuttings that support the interpretation of the presence of G-80 sandstone. The range of resistivity values obtained from several wells analyzed was 6.0 - 18.7 ohms with total gas values ranging between 42-700 units (Fig. 4).

Before entering G-80 sandstone, changes in the lithology of shale and coal intercalation show the same trend between variations in resistivity values and total gas in wells SEM 164, 167, 168. SEM-170 shows trends in resistivity and total gas values, which make it very easy to recognize the presence of G80A Sandstone. This contrast value comes from the lithological thickness, which is quite large and is typical of clear sandstone. The green line directional shows the trend of increasing reading total gas, and resistivity has the same shape. Total gas shape is very sharp on Coal lithology, while on Sandstone is still controlled by porosity and formation pressure. The number of green lines reflecting the presence of different lithologies in this case, coal and sandstone, compared to the peak resistivity, provides more detailed information about the presence of G-80 sandstone. The consistency of the Total Gas form is strongly supported by the changes shown in the cutting and model of the log itself, although there are still differences in value due to differences in drilling parameters used during drilling in each well, such as Mud Weight, Rate of Penetration, and Flow Rate. Parameters originating from the formation also greatly influence the total gas value, namely the formation pressure of each G-80 Sandstone in each well analyzed, where the higher the formation pressure value, the greater the total gas value obtained. The highest G-80 sandstone pressure value was obtained in well SEM-170, with a pressure of 8.03 ppg, and the lowest value

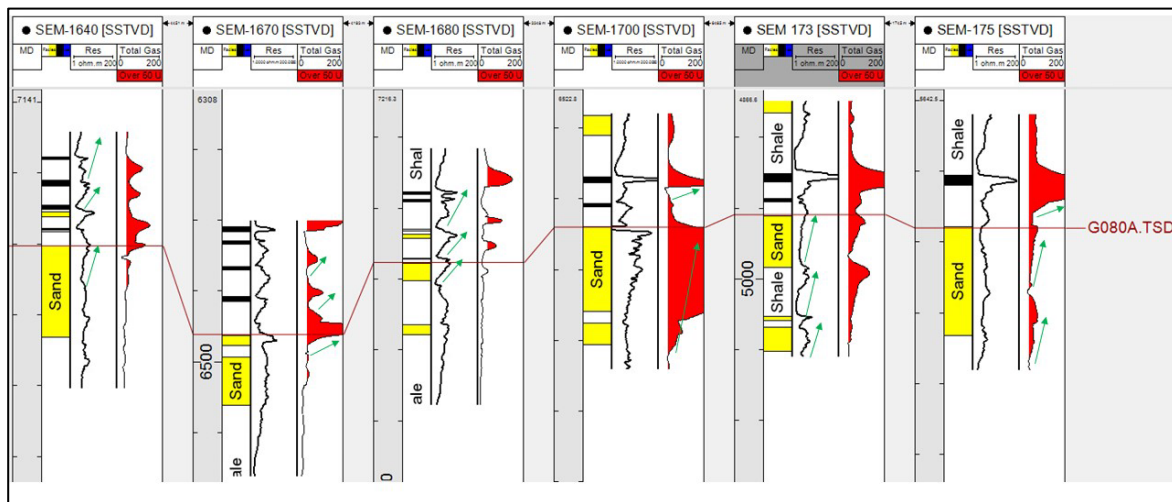


Fig.4. Log correlation showed a relation between Total Gas and Resistivity trend. A similar trend was observed; however, the value depends on many parameters, such as drilling and formation.

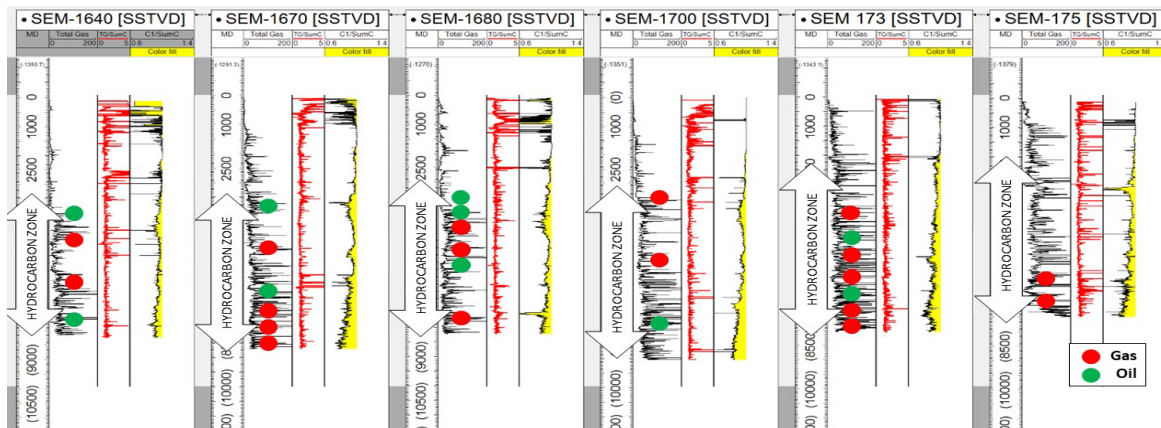


Fig.5 Distinguish between non-Hydrocarbon at Surface with Hydrocarbon zone Gas and Oil circle marking. Decreasing C1/Sum C on yellow filled colour on log gas ratio drilling

was in well SEM-164 with a pressure of 7.35 ppg.

4.2 Hydrocarbon Zone Identification Based on C1/SumC

From the ratio value shown from bottom to top, it is found that there is a decrease in the ratio value C1/SumC up to the hydrocarbon potential limit, as shown in Figure 5 above. In the shallow section drilling area, there are fluctuating values of this ratio. Depending on the type of lithology used in this interval, it is very much dominated by the existence of layers thin layer of coal likely influences the value of this ratio. Gas dryness C1/Sum is a fair indicator of the wetness of the gas and discontinuities in the fluid phase. Thus, it can be used to identify the top of a reservoir section quite confidently.

The interpretative values of gas dryness are if it is >0.95 , dry gas is indicated; if it is between 0.85 to 0.95, condensate or light oil is indicated; if it is between 0.6 to 0.85, possible productive oil is indicated; and if it is less than 0.6, then residual oil is indicated.

There is a phase of change in the ratio value, consistently decreasing from 1, and the log is filled with yellow shading; it is validated by the presence of a hydrocarbon zone based on wireline results, both in reservoirs developed as oil and gas. The lower the value, the smaller it becomes, indicating that the fluid contained should be oil, but the wireline results show a mix between oil and gas reservoir. G-80 Sandstone value on six wells data has a range 0.86-0.95, which indicates hydrocarbon it as confirmed from wireline analysis, developed as a gas and oil reservoir. The

lithology found still contains coal, which can influence the composition of the C1 content.

4.3 Density Neutron with Wetness, Balance, Fluid Mobility, Potential Porosity, Gas Ratio

The WH values from six wells in Semberah ranged from 0.04 to 0.14, yielding very dry gas, indicating a predominance of C1 methane. BH values above 50 indicate a gas reservoir in the sandstone, while values below 50 indicate a water reservoir.

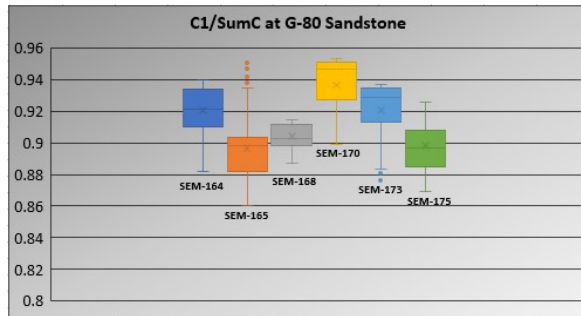


Fig.6 C1/SumC at G-80 Sandstone for 6 well in Semberah

Table 3. Wetness and Balance Interpretation

Well	Wetness	Balance	Interpretation
SEM 164	0.07-0.11	15.4 – 39.81	Water
SEM 167	0.04-0.14	14.03 – 58.64	Gas
SEM 168	0.08-0.11	13.5 – 21.5	Not developed
SEM 170	0.04-0.10	24.1 – 66.37	Gas
SEM 173	0.06-0.12	20.36 – 43.62	Water
SEM 175	0.07-0.13	16 – 37	Water

The Fluid Mobility Potential Porosity value shows a pattern similar to the character of the Phic value resulting from the petrophysics calculation. Even after comparing the values, there are still big differences between each well analyzed. Since permeability is controlled by pore size and pore throat geometry and porosity, among other factors, the amount of gas

liberated from the formation could have a direct relationship with pore geometry. Wells SEM-170, SEM-173, and SEM-175 are slightly high on permeability, as indicated by significant gas release.

5. CONCLUSION

In general, studies on the presence of reservoirs in the Kutai Basin have primarily relied on log data approaches, focusing on characterizing, mapping the

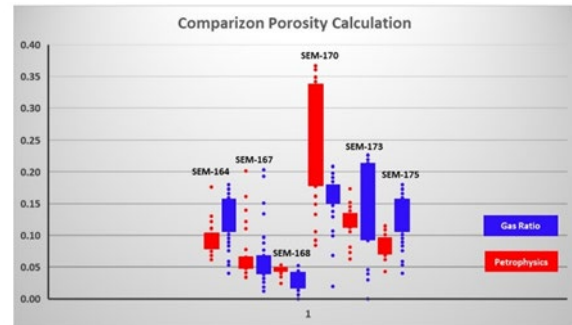


Fig.8 Comparison Porosity Calculation between Gas Ratio and Petrophysics method

distribution, and conducting modeling analyses. Unlike previous studies, this research specifically aims to identify the presence of the G-80 sandstone using gas ratio drilling, which is expected to provide a broader contribution to future research in the Kutai Basin. A few things that can be found in this research include:

1. The peak of each total gas value supported by cuttings data can replace the resistivity log. The trend of the total gas value is similar to the resistivity log, although the values differ due to several factors, both from the drilling and the formation itself.
2. A general overview of the presence of a reservoir zone that will also add information for early detection is by knowing the C1/Sum C value, which varies from 0.86-0.95. For areas that predominantly have coal intercalations, it will be slightly disturbed because the C1 value will be slightly greater than the C1 value of the sandstone reservoir.

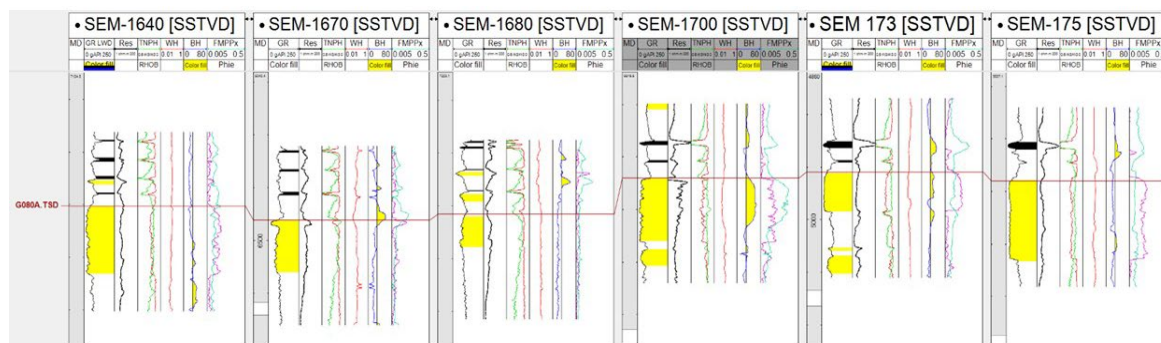


Fig. 7 Log showing trend of Gas Ratio WH, BH, FMPPx compare with GR, Res, Dens and Neu

3. Petrophysics calculations for porosity values based on siliciclastic rocks compared to FMPPx can also provide information on porous rocks with other impermeable lithologies. These values are also strongly supported by the BH, and values more than 50 are strongly developed as a gas reservoir, while values below 50 are either developed as a water-bearing or an undeveloped reservoir.

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