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The analysis of Reservoar Porosity Calculation based on Well Log in Bintuni Basin Area

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Abstracts

The Bintuni Basin is one of several oil and gas producing basin in Eastern Indonesia. This basin has one of the hydrocarbon-producing reservoir in the Kais Formation. The carbonate reservoir in Kais Formation is Middle to Upper Miocene age. The understanding of reservoirs is important for further field development. Petrophysical analysis is a method for understanding reservoirs especially porosity parameter and estimation of hydrocarbon reserve. The data used in study is well data including, mudlog report, well report, Gamma Ray (GR), Sonic, Resistivity (ILD, ILS, MSFL), density (RHOB) and NPHI logs. The aim study is to analyze the reservoir using Gamma Ray log and porosity calculation using Sonic, RHOB and NPHI logs. The study method includes regional geological literature review, marker analysis, Gamma Ray picking, and reservoir porosity calculations. According to Gamma Ray picking analysis, the Kais Formation GR has values of GRsand = 25 API and values of GRshale = 80 API. The Low Gamma Ray below 60 API is interpretated as carbonate reservoir. For porosity validation, the porosity of routine core analysis (RCAL) data is plotted into porosity logs (porosity calculation using Sonic, RHOB and NPHI logs). Based on the porosity calculation using three porosity logs (Sonic, Density, NPHI Logs), the porosity estimated from density log is more match with the porosity of routine core analysis (RCAL) data. According to porosity calculation at WTU Well, the porosity from log density in the Kais Formation has value from 2% - 25%. The porosity in Carbonate has large value as a result of secondary porosity.

Keywords: Bintuni Basin; Carbonate; Kais; Porosity; Reservoir

1. Introduction

Bintuni Basin had become one of the most attractive basins in Indonesia following the significant discovery of Mesozoic Petroleum System [9]. This Basin is part of the number of productive Hydrocarbon-Producing Tertiary basins in Eastern Indonesia. This basin is one of the giant basins in Eastern Region of Indonesia [2]. The basin has a similar stratigraphy to the Salawati Basin, with the exception that pinnacle reefs did not develop to the same degree [7]. This basin is in the southern part of the Bird's Head [12]. The Bintuni Basin itself is bounded to the north by the Kemum Block and the Ayamaru Plateau, to the east by the Thrust-Fold Lengguru line and to the west by the Misool Onin-Kumawa Highlands in ([20] in [2]). This basin is separated from the Salawati Basin by the Ayamaru Plateau and separated from the Berau Basin by the Sekak Hills (Figure 1) [3].

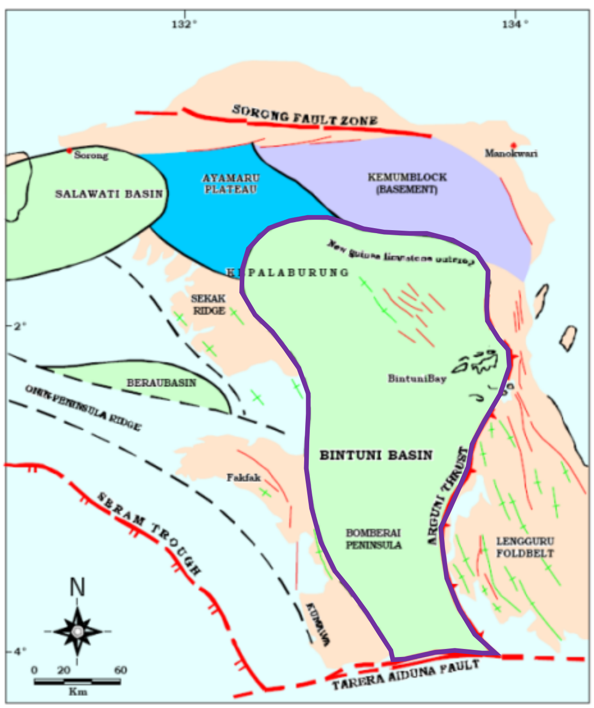

Figure 1. Current Situation Map of Bintuni Basin modified from [18] in [27]. The Bintuni Basin is shown by purple line.

A log is a graph of the depth (can also be time) of a data set that shows the parameters adjusted for inclusion in a well drilling [8]. The well log is a continuous record of the rock properties below the surface. The most reliable indicator of reservoir rock will be from the behavior of the density/neutron logs, with the density moving to the left (lower density) and touching or crossing the neutron curve. In clastic reservoirs in nearly all cases this will correspond to a fall in the gamma ray (GR) log [25].

The understanding of reservoirs is important for further field development. The calculation of reservoir porosity is needed in calculating the economics of a field Petrophysical analysis is a method for identification and manufacture of reservoir models and estimation of hydrocarbon reserve [15]. The previous study [5] and [27] discussed geology, facies models and porosity based on very limited core data, while this study discusses porosity based on well logs in Kais Formation. One of the hydrocarbon-producing reservoirs in the Bintuni Basin is the Kais Formation. This formation has a miocene age. The Kais Formation has a carbonate lithology is shown blue line box by Figure 2. The Kais Formation limestone was classified into three members; Upper Kais, Middle Kais, and Lower Kais [1]. The purpose of this study is to analyze the reservoir using GR log and porosity calculation based on Sonic, RHOB and NPHI logs..

Based on exploration well report, the Ainim Formation has Permian age. This Formation is a member of the Aifam Group in the Bintuni Basin. This formation comprises of sandstones and shales interbedded, with siltstone, coal seams, and limestone. Sandstone lithology is generally white milk, which at the upper part becomes varicoloured, arkosic, granular medium until smooth, medium-bad sorted. Shales lithology generally colored dark gray to black, mostly greenish, some contain pyrite mineral, mica, carbonaceous, slightly calcareous. Coal lithology generally has thickness of less than one meter and there are at least 15 coal seams. And also thin bed limestones has silty to sandy, light gray color, fine crystalline, chalky, containing shells fragments [5].

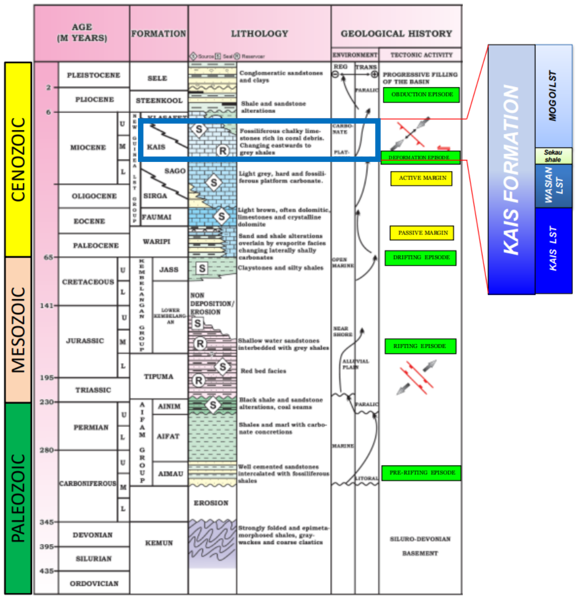

Figure 2. Tectonostratigraphic column of the Bintuni Basin modified from [27]. The Kais Formation is shown by blue line box.

Stratigraphic column of the Bintuni Basin Ainim Formation

Lower Kembelangan/Tipuma Formation

The Lower Kembelangan / Tipuma Formation it mentioned in many reports has Triassic-Jurassic age. Sedimentary character of Jurassic equivalent to Tipuma or the Lower Kembelangan Formation is the possibility of sandstone with reddish grains, and maroon claystone at the bottom of the Jass (Cretaceous) Formation. The Jass Formation is assumed to overlies the Jurassic bed. The Jass Formation is dominated by shale with thin layers of siltstone and sandstone. Shales are generally gray, calcareous, partly graded with marl. Siltstone is gray, sandy until shaly, partially tuffaceous, calcareous. Sandstone has white colour, calcareous, very finegrained, silty. In upper part, the Jass Formation were dominated by marine shales, with thin layers of limestone and sandstone. Shale has gray to dark gray colour, calcareous. Sandstones, with a grain of loose, fine to coarse grains, conglomeratic, and calcareous [5].

Waripi Formation

The Waripi Formation has Paleocene - Eocene age. This sediment unit has thickness about 320 meters. the Waripi Formation is stated as member of New Guinea Limestone Group. This formation is dominated by sandstone, dolomite, anhydrite, shale and thin claystone. Dolomite has cream-colored, micro-crystalline, sucrosic - fine-grained, hard, partly graded with anhydrite. Anhydrite: white to milky, fine-grained, easily crushed, partly shaley, with dolomite and calcite fragments. Shales have greenish gray to dark gray, calcareous. Sandstone has fine grain, well sorted, rounded, containing argillaceous matrix [5].

Faumai Formation

According to exploration well report, the Faumai Formation has Eocene age. This formation in the Bintuni Basin is mentioned as member of the New Guinea Limestone Group. This Formation has thickness about 589 meters. The unit is dominated by dolomitic limestone at the bottom part, limestone and dolomite in the upper part with thin layer shale. Dolomitic limestone has gray light, partially light brown, crystalline, stylolites, pyrite. Limestone has white color - tan, micro-crystalline, chalky, containing fossils and calcite fragments, pyrite. Dolomite is white - cream, medium – coarse crystalline, stylolites, pyrite, showing medium visual porosity. Dolomite at upper part of this unit has thin shale gray to dark gray colors with a trace sandstones loose grain [5].

Sirga Formation

The Sirga Formation is mentioned as member of New Guinea Limestones Group. This formation overlies the Faumai Formation. Based on exploration well report, this unit has thickness about 10-12 meters. This formation composed by sandstone, dolomite and limestone. Sandstone has loose grains in various colors, containing carbonate granules, fine - very fine grain size, well rounded, fair sorted.

Dolomite and limestone contain calcite grains [5].

Sago Formations

The Sago Formation has thickness about 250 meters. This Formation is still as member of the New Guinea Limestones Group. This formation has Early Miocene age. This unit overlies the Sirga Formation. This formation is Comprised by limestone, dolomite and dolomitic limestone. Limestone: white - grey, partly brown, crystalline-crypto cristalline, stylolites, chalky. Limestone, grey, microcrystalline, chalky, containing of fossils and calcite fragments, pyrite. Dolomite has microcrystalline, cream-colored, sucrosic - fine-grained, brittle, calcite fragments, some containing shells fragments. Dolomitic limestone creamy - white, crystalline very fine – micro-crystalline, gradually becoming chalky limestone, and tight type [5].

Kais Formation

Based on exploration well report, the Kais Formation has Middle Miocene-Upper Miocene age. This formation also reported as member of the New Guinea Limestones Group. This units are deposited which overlies the Sago Formation. Kais Porous is the lower part of the Kais Formation which composed by dolomite with a thickness approximately 122 meters, then overlaid by Sekau Members with a thickness of approximately 90 meters which is composed of limestone and claystone. The Kais Group were divided into three members such as, Kais Porous at lower part, Wasian Limestone at middle part and Mogoi Limestone at upper part. The Mogoi Limestone member has thickness approximately 70 meters, the Wasian Limestone member has thickness approximately 40-45 meters, and the Kais Porous member has thickness approximately 75-80 meters.

Kais Porous member is composed by mudstone - wackestone, light gray to cream colored, hard, partly chalky, stylolitic, with large forams, algae, coral, and other fossil fragments. Porosity of Kais porous is generally vugy, partly dolomitic. The Wasian Limestone Member is composed by mudstone – wackestone facies, light gray to gray-brown colored, hard - very hard, containing fossilized algae, corals, shells, large foram fossil fragments and others [5].

Steenkool Formation

The Steenkool Formation has Pliocene age. This sedimentary unit was deposited above the Kais Group. This sediment has thickness of approximately 420 meters, consisting of claystone, lignite, with a thin layer of dolomite and sandstone [21]. Thin Miocene- Pliocene coals are present in Bintuni basin of West Papua, the latter in the appropriately named 'Steenkool Formation' [26].

Petroleum System in Bintuni Basin Source Rock

The Late Triassic source rock in West Papua has good potential. The Late Triassic source rock is equivalent to the Tipuma Formation. The Lithology is coal with humic organic content type. It has good quality and has the potential to produce oil and gas. While the Early Jurassic source rock in West Papua also has the same good potential [14]. The source rocks may be clustered into three zones: coaly terrestrial shales from Ainim Formation, coaly marine shales of the Lower Kembelangan and marine calcareous claystones of the Waripi Formation [6].

According to [4] in [22], the oil comes from the Aifat Formation shale which is Permian age. The gas reserves found in the Jura layer are very likely to come from the source rock of the Ainim Formation which is of Permian age [22]. Based on [26], Permian and Jura source rocks were interpreted to be buried to depths below 16,000 feet and may have been in the gas window zone.

Reservoar Rock

The Tipuma Formation is proven to have a very good sandstone reservoir potential. Meanwhile the Permian reservoir of the Ainim Formation is also significantly mentioned as a secondary reservoir target. The Formation are Early Jurassic – Middle Jurassic [6].

Seal

Based on [13], the cap rock in the Bintuni Basin is sedimentary claystone and shale from the Late Jurassic to Upper Eocene from the Lower Kembelangan Formation, which traps sandstones for the Upper and Lower Kembelangan Formation. Late Miocene and recent Steenkool claystones are also a trap for oil accumulation in the New Guinea group of limestones.

The Jass Formation in the Bintuni Basin which mainly consists of marine shale and carbonate shale with various thin layers of sandstone also has potential as a seal. These Cretaceous marine shales also act as effective seals for Jurassic reservoirs or older reservoir beds.

Traps and Migration

Hydrocarbon traps in the Bintuni Basin are are mostly structural traps, namely anticlines is estimated late Miocene-early Pliocene age [16]. This allowed secondary migration from the Jurassic reservoir and accumulation in the Paleocene-Miocene interval. Hydrocarbon migration is believed to have passed through the northwestern region of the Bintuni Basin along the anticlinal axis of more than fifty kilometers [13].

2. Experiments Procedure

This study used well data, including mud log, well report, Gamma Ray log, Sonic log, ILD log, ILS log, MSFL log, RHOB log and NPHI log. The mudlog table and well report consists of drilling parameters, proportion of drilling powder, lithology interpretation, well marker and lithology description obtained during drilling. Gamma Ray log, Sonic log, ILD log, ILS log, MSFL log, RHOB log and NPHI log are well log data. The methodology includes regional geological literature review, marker analysis, environmental correction, Gamma ray picking, and reservoir porosity calculations. Porosity calculation using Sonic, RHOB and NPHI logs. The reservoir porosity is validated using well porosity data from routine core analysis (RCAL). The Work flow of reservoir porosity calculation is shown in Figure 3.

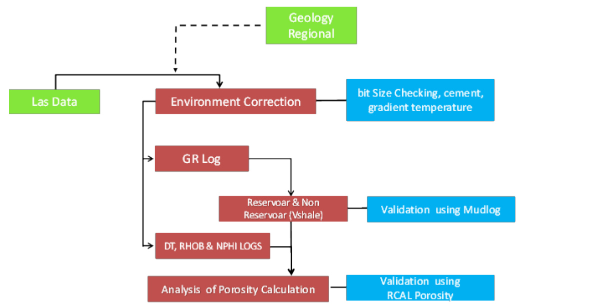

Figure 3. Work flow of reservoir porosity calculation

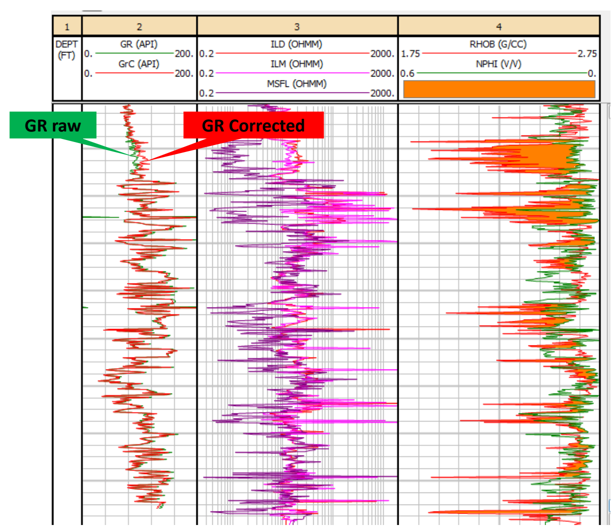

Figure 4. Gamma ray correction from Interactive Petrophysics Software

LAS data obtained from companies processed using Interactive Petrophysics software (IP 3.6). The data precondition had been done before gamma ray picking. Validating las data have been carried out by checking mudlog and well reports. The environmental correction is done to get the real gamma ray log value. Raw Gamma Ray is shown by green line and Corrected Gamma Ray is shown by red line (Figure 4). The gamma ray correction used bit size, cement and temperature gradient data. The next step is analyzing the marker from the well for gamma ray picking. The purpose of gamma ray picking is to get reservoir and non- reservoir rock layers. The calculating porosity is run after obtaining the reservoir layer.

3. Result and Discussion

3.1 Kais Limestone Characteristic

Based on Figure 5, the Kais Formation is divided into 4 sub-divisions using Resistivity log from well data, namely Mogoi Limestone, Sekau (shale), Wasian Limestone and Kais Limestone (Porous Kais). According to [27], the Mogoi Limestone consists of mudstone, wackestone, and packstone facies. These facies in Mogoi limestone have poor to moderate porosity, with fracture type porosity, microporosity, and moldic. The Wasian limestone consists of wackestone and packstone facies, which have poor to good porosity, with moldic, and fracture porosity type (dominant). The cementation and replacement process are very intens in these limestones that reduce of the porosity quality. The diagenetic in Mogoi and Wasian limestones is dominated by burial/compaction and dolomitization in fracture line. The Kais limestones (Kais Porous) consist of wackestone and dolostone facies. These Kais porous facies have fair to good porosity, with porosity type intercrystalline (dolomitization), dissolution (dominated), and fracture type. The Diagenetic of Kais limestones (Kais Porous) is dominated by dolomitization, dedolomitization, and vadose diagenetic (dissolution). Based on the RCAL data mentioned the Kais Formation has a porosity ranging between 0-35%.

3.2 Quantitative Analysis of Shale Content (Vsh)

Gamma ray log are usually used to distinguish reservoir and non-reservoir. Radioactive elements tend to be concentrated in clay and shale [23]. Shale is a term commonly used in petrophysics to identify fine-grained rocks, namely very fine sandstone, siltstone and claystone. The volume of shale in the reservoir represents the quality of a reservoir. A small shale volume value indicates a cleaner reservoir, making it easier for the fluid to move to fill the pores [21].

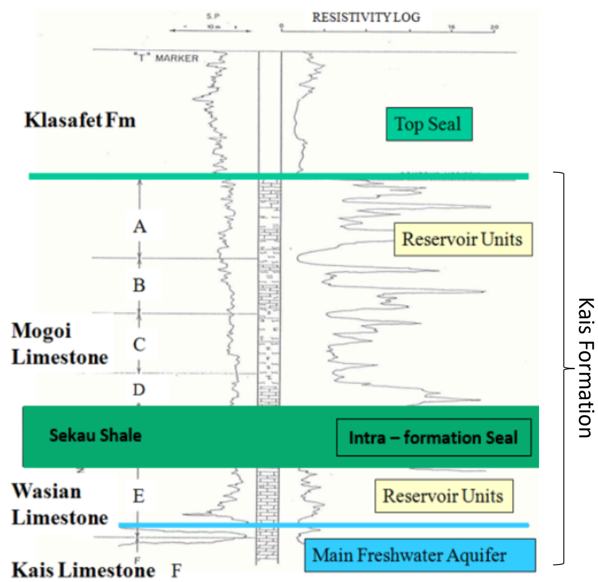

Figure 5. The Kais Formation is divided into 4 sub-divisions using Resistivity and SP logs from well report[13].

Calculation of shale volume in this study used log Gamma Ray. The formula for calculating the volume of shale used in this method is as follows [8]:

$$V_{sh} = \frac{(GR_{read} - GR_{clean})}{(GR_{shale} - GR_{clean})} \quad (1)$$

where :

Vsh : shale volume (fraction)

GRread : GR reading (API)

GRclean: GR reading on clean sand (API)

GRshale: GR reading on shale (API)

The equation (1) above shows a linear relationship between shale volume with Gamma Ray log. The value of shale volume in the Kais Formation target reservoir is based on calculations using formula (1). The Kais Formation GR has values of GRsand = 25 API and values GRshale = 80 API. The carbonate reservoir is interpretated below 60 API. GR values Picking Detailed in Kais Formation is shown in Figure 6.

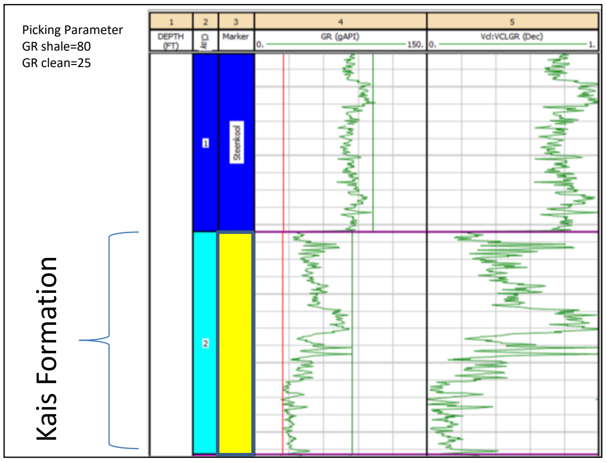

Figure 6. Gamma Ray picking in Kais Formation

3.3 Porosity Calculation

Porosity is the ratio of voids in the rock to the volume of the rock. Thus, porosity is a representation of a rock ability to store fluids. Porosity consists two types: total porosity (PHIT) and effective porosity (PHIE). The total porosity is ratio of the pores in the rock to the total rock volume [13]. The effective porosity is ratio of the pore volume relative to one another to the total volume. The PHIE value will be used for determine potential reservoir zones [17].

The formula for calculating porosity uses density log [11]:

$$\Phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}} \quad (2)$$

where:

Φ_D : Porosity from density log (v/v)

ρ_{ma} : Matrix Density (kg/m^3)

ρ_b : Bulk density read in density log (kg/m^3)

ρ_{fl} : Fluid density (kg/m^3)

The porosity calculation used several logs, including Neutron log (NPHI), Density log (RHOB), Sonic log, Neutron-density logs, and Neutron-Sonic logs. For porosity validation, the porosity of RCAL data is plotted into porosity logs. Based on the result of the five porosity logs, porosity estimated from density log is more match with the porosity of RCAL data. The porosity of the log density is relatively close to the RCAL porosity value (red dot) shown in Figure 7 using interactive petrophysics software (IP 3.6).

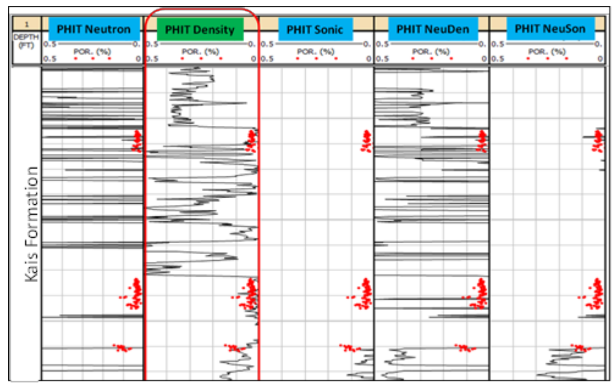

Figure 7. Validation of porosity calculation with porosity RCAL data against five porosity logs in the Kais Formation. The porosity from density log is relatively match with porosity RCAL (The RCAL porosity is shown by red dot).

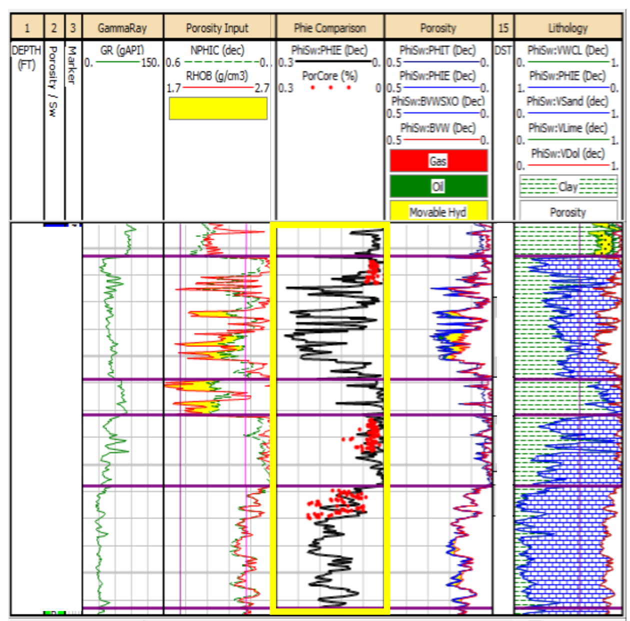

Figure 8. The results of the porosity analysis using the density method (yellow box line) and which have been validated by RCAL porosity data at WTU Well. The RCAL porosity is shown by red dot.

Porosity analysis using the density method has been calculated at WTU Well (Figure 8) using interactive petrophysics software. This calculation has been validated by porosity data from RCAL. Based on porosity calculation at WTU Well, porosity value in the Kais Formation is range from 0.2% - 25% which is still in the porosity range of RCAL data. The existence of a large porosity value in carbonate due to secondary porosity.

4. Conclusion

Based on Gamma Ray picking, the Kais Formation GR has values of GRsand = 24 API and values GRshale = 79 API. The carbonate reservoir is interpretated as low Gamma ray which is below 40 API.

Based on porosity calculation using several logs, the Porosity estimated from density log is match with the porosity of RCAL . The porosity value in the Kais Formation ranges from 2% - 25%.

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