Scientific Contributions Oil & Gas, Vol. 46. No. 2, August: 53 - 63

SCIENTIFIC CONTRIBUTIONS OIL AND GAS
Testing Center for Oil and Gas
LEMIGAS

Journal Homepage:http://www.journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

The Comparation of Water Saturation Approaches to Reveal a Low Resistivity Reservoir Potential Case in Gumai Formation, South Sumatra Basin

Dhea Adisty Pratami[1], Sarju Winardi[1], Sugeng Sapto Surjono[1], Widi Atmoko[2]

[1]Gadjah Mada University
Kaliurang Street Km 5, Yogyakarta, Indonesia

[2]PT. Sigma Cipta Utama
BSD Techno Park, South Tangerang, Indonesia

Corresponding author: Sarju_winardi@ugm.ac.id

Manuscript received: April 11st, 2023; Revised: July 21st, 2023
Approved: July 24st, 2023; Available online: September 07st, 2023

ABSTRACT - The LRLC reservoir zone has been identified in SN-3 well, at the DAP-1 interval on Gumai Formation. This interval has a low resistivity value from 3-5 ohm.m and the drill stem test (DST) results show oil with gas without water. This study is objected to identify the causes of LRLC reservoir in gumai formation and finding a suitable sw calculation method. Some data such as well logs, reports, cores, and XRD are used to calculate petrophysical parameters such as Vsh, Phie, and Sw, and would be validated by DST data. Water saturation (Sw) calculations from Archie and the CEC method (Waxman Smits, Dual Water, Juhasz) were performed and the results were compared. The results showed that the main cause of the DAP-1 interval LRLC zone was the presence of clay minerals consisting of mixed layers (Illite/smectite). These clay minerals will be associated with high cation exchange capacity (CEC) values, with the value 70 (meq/100g), which can increase conductivity and reduce resistivity values. Based on lumping the more optimistic results of sw calculation from Waxman Smits Sw method (Sw based on CEC method). The DST data on the SN-3 well does not have water test data, so the calculation of the Sw value that is close to the Swirr value is considered the most suitable Sw for the low resistivity reservoir conditions of the Gumai Formation in the study area. The best practice for low resistivity reservoir for suitable petrophysical calculation is necessary to pay attention to the rock lithology conditions, the presence of mineral clay, and determining suitable Sw appropriate to the reservoir conditions.

Keywords: petrophysics, LRLC, CEC, and gumai formation

How to cite this article:

Dhea Adisty Pratami, Sarju Winardi, Sugeng Sapto Surjono, Widi Atmoko, 2023, The Comparation of Water Saturation Approaches to Reveal a Low Resistivity Reservoir Potential Case in Gumai Formation, South Sumatra Basin, Scientific Contributions Oil and Gas, 46 (2) pp., 53-63, DOI. org/10.29017/SCOG.46.2.1563.

INTRODUCTION

Low resistivity low contrast (LRLC) is a case of pay zones that are easily overlooked due to the resistivity log values response reading as a water-bearing. LRLC was not considered previously because remarkable hydrocarbon accumulations are hidden in the reservoir intervals with the low contrast between the hydrocarbon-bearing and the water-bearing (Worthington 2000). This study is located in the Gumai Formation, South Sumatra Basin. The reservoir zone containing oil or gas commonly shows a high resistivity value response from the resistivity log, which is more than 10 ohms (Palacky 1987). In the case of LRLC reservoir intervals containing the hydrocarbons show a low resistivity value (Worthington 1997).

There are several causes of the low resistivity value in response to resistivity log readings such as reservoirs having high water saturation but will produce oil or gas. High water saturation is caused by the presence of conductive minerals such as glauconite, pyrite, hematite, and graphite minerals (Hamada et al. 2000). One of the first indications of low resistivity is conductive minerals in South Sumatra basin (Holis et al. 2016). Other causes of usual occurrences such as the formation of water salinity, clay content, and fine sandstone grain size can bind the water so it is called irreducible water saturation (Boyd et al. 1995) Low resistivity low contrast reservoirs can occur in lithologies other than clean sand, such as shaly sand and carbonate, these lithologies have a high level of heterogeneity when compared to clean sand. The pay zone for the low resistivity low contrast case has a resistivity value ranging from 0.5 to 5 ohms (Boyd et al. 1995). The low pay zone response to resistivity log readings in the LRLC case makes it difficult to distinguish between pay sand and pay shale or there is low contrast between the wet zone and pay zone, so it needs to analyze more possible causes of low resistivity in Gumai Formation from several previous researchers.

Case of low resistivity in the gumai formation

Based on the previous study found cases of low-resistivity reservoirs in the Gumai Formation. Low-resistivity zone is a hydrocarbon-bearing that is often considered a water zone because have a low-resistivity value (Worthington 2000).

Based on the research of (Rohmana et al. 2017) the study found that several factors can affect resistivity value in the Gumai Formation: very fine grain size, clay mineral content, distribution of clay minerals such as laminated and dispersed clay, highly saline water, and presence of microporosity.

(Zaemi et al. 2022) conducted their research there are five causes of low resistivity reservoirs at that research:

- The effect of grain size in rocks (very fine sand to medium sand). Grain size sand with fine grain size can hold more formation water (irreducible water). The effect of grain size can lower the resistivity value.
- The presence of clay minerals in rock such as illite, glauconite, kaolinite, and chlorite can contribute to the low resistivity value.
- The presence of conductive minerals in rocks, such as pyrite and siderite. Conductive minerals in the rock give an effect on the resistivity value.
- The high salinity of formation water (<10.000 ppm) makes low the reading of resistivity value, due to clay-bound water in the reservoir.
- The thickness of rock layers can impact the resistivity value and also the thickness due to the influence of the depositional environment.

The Gumai Formation is regionally a seal for the Baturaja Formation, but in the Gumai Formation, there are also intervals as reservoirs (Bishop 2001). According to (Melfi et al. 2017), low-resistivity cases in the Gumai Formation can be identified from well logs indicating the presence of glauconite content which is a conductive mineral. The presence of glauconite content is validated by mud log data which shows that there are traces of glauconite in that interval. So it can be concluded that the possibility of low resistivity is caused by the presence of conductive minerals namely glauconite. Therefore, further, identification is needed which aims to identify the causes of LRLC in the Gumai Formation is considered a good candidate reservoir for exploration and production if it is economical. Exploration and research of low resistivity reservoirs is expected to be a step in adding new hydrocarbon by conducting petrophysical evaluations and revealing suitable Sw calculations to obtain a low resistivity low contrast reservoir prospect zone in the Gumai Formation, South Sumatra Basin.

Geological setting

The research area is located in the South Sumatera Basin specifically in the Central Palembang Sub-Basin, the position of the South Sumatera Basin is in the back-arc basin area. South Sumatera Basin was formed as a pull-apart basin and associated with the NW-SE trending dextral strike-slip fault. The tectonic phases of the South Sumatra basin consist of four phases including Compression (Jurassic-Late Cretaceous), Tensional (Late Cretaceous-Early Tertiary), Miocene tectonic phase resulting in uplift, and the last compression occurs again (Plio-Pleistocene)

(Pulunggono et al. 1992) Research studies on low resistivity reservoirs focus on the Gumai Formation, the Gumai Formation is generally composed of marine shale lithology which is fossiliferous, and limestone lithology with glauconitic mineral content (Bishop 2001). Glauconite is one of the conductive minerals, so the presence of these minerals can cause a decrease in the resistivity value of the log. The Gumai Formation is also divided into two parts, the upper part is composed of sandstone-rich lithology occurring in more regressive conditions and the lower part is composed of mud-rich lithology at maximum transgression conditions.The Gumai Formation was deposited in shallow to deep marine environments (Sarjono & Sardjito 1989). The Gumai Formation is a regional seal for the Baturaja Formation in the South Sumatra Basin, which was caused by the maximum transgression in the Early Miocene which caused the formation to be dominated by open marine glauconite shale, due to the absence of material supplies from the terrestrial (Ginger & Fielding 2005). In some cases, it turns out that the Gumai Formation does not only function as a seal but also contains several reservoir intervals (Bishop 2001). Stratigraphy of South Sumatera Basin if sorted from old to young is composed of basement rock, Lahat Formation, Talang Akar Formation, Baturaja Formation, Gumai Formation, Air Benakat Formation, Muara Enim Formation, and Kasai Formation (Barber et al. 2005) as seen on figure 1. The Gumai Formation was selected based on SN-3 well in this study area that has low resistivity values and DST data containing hydrocarbons indicating oil and validated by petrophysics calculations and finding suitable Sw calculation methods for reservoir conditions.

METHODOLOGY

This study used one well which is SN-3 well located in Sou This study used one well which is SN-3 well located in South Sumatra Basin (Figure.2), the well data consisted of well log data, well reports, core data, petrography analysis (XRD or SEM), and Drill Stem Test (DST) data. Wireline log data is composed of gamma-ray (Gr) log, Sp, Caliper, Resistivity log data (Rt), density log (Rhob), and Neutron log (Nphi). These data are used for initial screening in determining LRLC analysis and petrophysical analysis has been carried out. Well report data is composed of final well report data, drilling operations, and stratigraphic reports. The core data contains the lithology, porosity, permeability, and special core analyses (SCAL). Determining water saturation (Sw) uses Rw and Rw uses the parameters such as a, m, and n. Parameter a is the cementation value in the reservoir, m exponent porosity, n exponent saturation. The parameters a,m, and n are obtained from the special core analysis (SCAL). XRD and SEM data (Petrographic) are used to determine the conductive mineral and CEC (Cation Exchange Capacity). Interval with prospect hydrocarbon will be validated by DST data. These data will be used for physical properties, clay minerals as conductive minerals, and petrophysical analysis.th Sumatra Basin figure 2, the well data consisted of well log data, well reports, core data, petrography analysis (XRD or SEM), and Drill Stem Test (DST) data. Wireline log data is composed of gamma-ray (Gr) log, Sp, Caliper, Resistivity log data (Rt), density log (Rhob), and Neutron log (Nphi).

These data are used for initial screening in determining LRLC analysis and petrophysical analysis has been carried out. Well report data is composed of final well report data, drilling operations, and stratigraphic reports. The core data contains the lithology, porosity, permeability, and special core analyses (SCAL). The SCAL data provide a,m and n values to calculate water saturation (Sw). Limited SCAL data can be covered by Sw which is calculated to distribute the initial water saturation in wells (Faiza et al., 2019). (XRD and SEM data (Petrographic) are used to determine the conductive mineral and CEC (Cation Exchange Capacity). Interval with prospect hydrocarbon will be validated by DST data. These data will be used for physical properties, clay minerals as conductive minerals, and petrophysical analysis. Several Sw calculation methods will be carried out by considering the lithology of the reservoir, formation water, and mineral content. Conventional sw calculations such as Archie's can only determine the water saturation value properly in a clean sand formation reservoir, it does not contain shale.

Indonesian Sw method is calculated based on the characteristics of fresh water in a formation, and also seen based on the high content of shale which is often found in oil reservoirs. Furthermore, non-conventional Sw was calculated, namely Waxman Smith, Juhasz, and Dual Water which calculated the CEC mineral content. A special parameter for low resistivity cases in the research area is to calculate Sw based on the CEC method with the availability of CEC values from XRD. If it is proven to produce Sw which is optimistic and validated by DST and

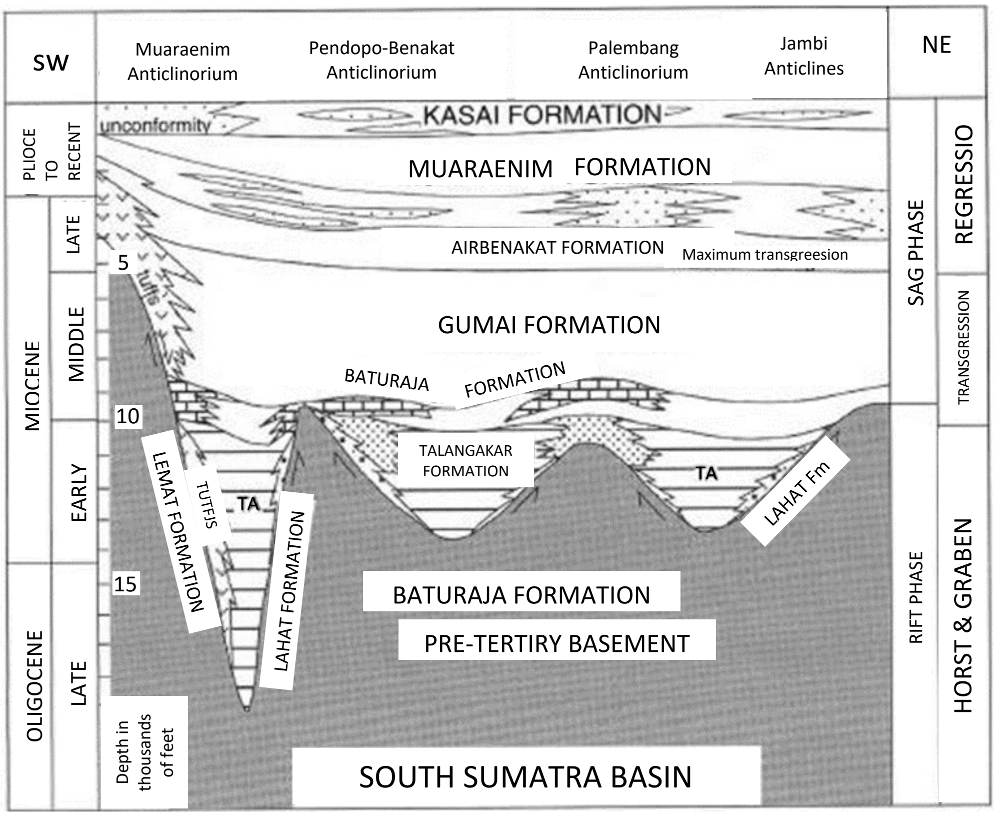


Figure 1
Stratigraphy of South Sumatera Basin and research studies on low resistivity reservoirs focus on the Gumai Formation (Barber et al. 2005)

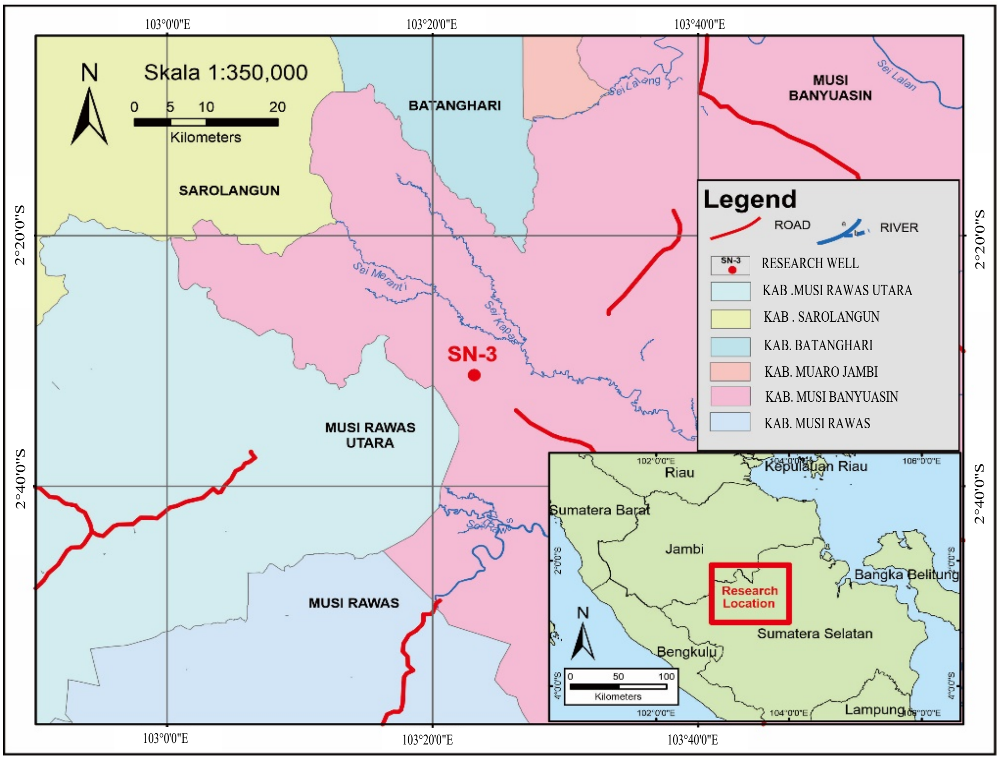


Figure 2
Map of the research area of Musi Banyuasin Regency, South Sumatra Basin, (Badan Informasi Geospatial 2019)

 | DOI.org/10.29017/SCOG.46.2.1563

Swiir data from core data, then Sw is suitable for low resistivity reservoir cases that match the reservoir conditions.

RESULT AND DISCUSSION

Identification of LRLC reservoir on Gumai Formation has been conducted on SN-3 well, several analyses have been done to get the prospect zone of LRLC reservoir, as follows:

Causes of low resistivity value in this study

Grain Analyses

Based on the SWC data, the SN-3 well gumai formation interval shows that the reservoir rock lithology is dominated by sandstone with shale lamination. The sandstone has a very fine grain size (Figure 3). Fine-grained sandstones have a high amount of irreducible water or commonly called irreducible water saturation. The amount of water that cannot be reduced in such high quantities will reduce the resistivity value. The fine grain size causes a low resistivity value in the reservoir because water conductivity and fine grain size replace pore space in sandstones (Dwiyono & Winardi 2014). The fine grain size of sand is often measured as water by resistivity tools, even though the reservoir contains hydrocarbons (Audinno et al. 2016). Based on the results of interval petrographic analysis which shows the sandstone has a fine grain size with classification sublitharenite compared to the grain size of litharenite classification sandstones have a lower resistivity value (Audinno et al. 2016). In this study, the petrographic analysis also showed low resistivity values at intervals with sandstone lithology with very fine sizes included in the sublitharenite classification.

Based on these results, the low resistivity reservoir may be caused by a very fine grain size but does not significantly reduce the resistivity value because the exact amount is not known.

Well :SN-3
SWC Depth/No. :1245.Om

Lithology : Sandstone
Classification : Feldspathic litharenite

FRAMEWORK GRAINS			72.8%
Quartz			50.4%
Feldspar			5.6%
	K-feldspar	*5.6%*	
	Plagiocase	*Tr*	
Rock Fragments			11.6%
	Chert	*3.2%*	
	Shale/claystone	*7.2%*	
	Volcanic	*1.2%*	
	Schist	*Tr*	
Mica			Tr
Chlorite			0.4%
Bioclasts			2.4%
Glauconite			0.4%
Altered grains		0.8%	
Organic material			0.8%
Orpaques			0.4%
Zircon			Tr

CEMENTS/REPLACEMENTS	9.6%
Calcite	2.6%
Kaolinite	2.4%
Pyrite	0.4%
Quartz overgrowths	2.4%
Siderite	1.6%

MATRIX	10.0%
Dispersed clay	2.8%
Laminar clay	4.0%
Pseudomatrix	3.2%

VISIBLE POROSITY	7.6%
Intergranular	6.4%
Secondary (dissolution)	1.2%
Intraparticle	Tr

TEXTURAL PARAMETERS

Grain Size (mm)		
Minimum	Mode	Maaximum
0.02 silt	0.08 v. fine	0.24 u.fine

Sorting	: Good
Roundness	: Subangular-subrounded
Grain contacts	: Point>planar
Texture	: Laminated

SUMMARY:

Very fine-grained well sorted sublitharenite containing thin shale laminae and widespread

Figure 3
The Summary of the SWC data sheet showed Sandstone with a very fine grain size in this study
(PT. Corelab Indonesia)

well sorted sublitharenite containing thin shale laminae and widespread

Clay Minerals Analyses

Clay minerals are identified by well data integrated with petrographic and XRD data. This analysis indicates the presence of conductive minerals and clay minerals in the DST interval which contain hydrocarbons. Based on the petrographic and XRD data, the analysis shows conductive minerals such as pyrite, glauconite, and siderite (Figure 3). It is possible that the conductive minerals are one of the causes of low resistivity values, Pyrite is one of the common heavy minerals with a higher conductivity in marine sedimentary rocks (Hamada et al. 2000). These conductive minerals have high conductivity, causing a decrease in resistivity values. Based on the results of the XRD analysis, the amount of conductive minerals is less than 2%, so it does not significantly affect the resistivity value (Prayitno et al. 2001). XRD analysis results showed the presence of Illite (7.24%), kaolinite (7.88%), chlorite (1.76%), and Mixed layers (Illite/Smectite) (8.34%). The dominant clay minerals based on XRD analysis are mixed layers (Illite/Smectite) with a CEC value of 0.70 or 70 (Meq/100gr), these values are obtained from a simulation of calculating the Sw value to get an optimistic Sw that closet to Swiir. XRD data is one of the validation methods for the identification of clay minerals (Tribuana et al. 2015). A high CEC value of 70 (MEQ/100gr) can significantly reduce the resistivity value in the reservoir because clay minerals and CEC generally contain water and bind water (clay-bound water) causing an increase in conductivity which affects the reading of the resistivity value to be low.

Based on the grain analyses of the rocks, conductive minerals, and clay minerals in the Gumai Formation interval. It can be concluded that the dominant presence of clay minerals, namely mixed layers (Illite/smectite) associated with a high CEC value of 70 Meq/100gr) is the cause of the low resistivity reservoir in this study despite the presence of hydrocarbons.

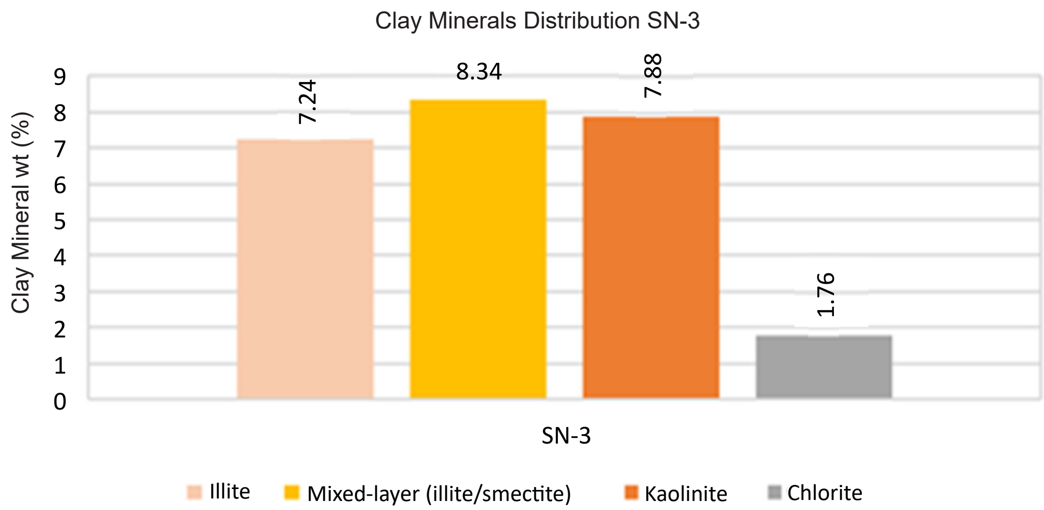


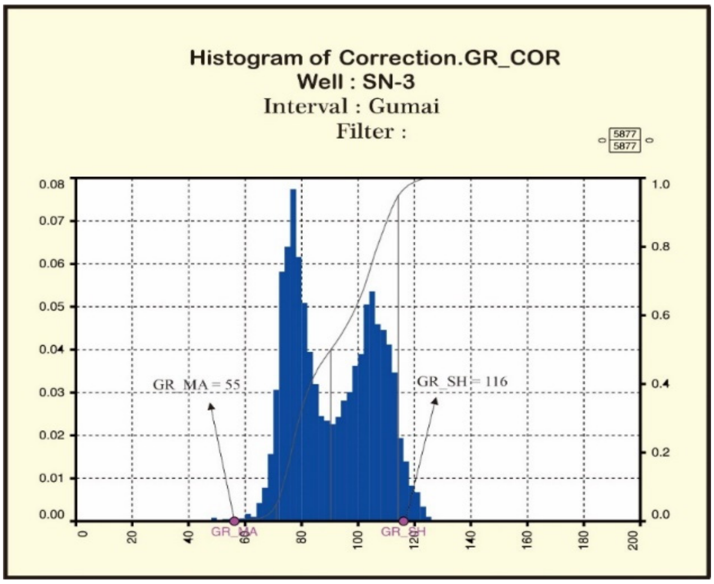
Figure 4
Clay mineral distribution of SN-3 well, where the presence of mixed-layer (Illite/Smectite) is dominantly in this study

Petrophysics evaluation

The Petrophysical evaluation analyses consist of data for log analysis, supporting data used in log analysis are triple combo logs data such as log gamma ray (Gr), resistivity log (RT), density log (RHOB), and neutron log (NPHI) used for petrophysics calculation. Other data such as SCAL (Special core analysis), petrography, and XRD data are used for validating petrophysical calculation. Petrophysical analysis was conducted using Geolog 7 software, including of calculate volume shale (Vshale), porosity, and Sw (water saturation). The result of the average Volume shale (Vsh) (44%) is shown in (Figure 5). Porosity estimation is calculated based on density and density-neutron log. For porosity calculation, the values of shale density and neutron shale are the results of the density log and neutron log cross-plot on the Gumai Formation in the research area (Figure 6a). The density-neutron log visually produces the most appropriate porosity calculation with the core porosity value and has an

 | DOI.org/10.29017/SCOG.46.2.1563

average porosity (14%) (Figure 6b). Determining Rw value for Sw uses the Pickett plot method, with the parameters a: 1, m: 1,8, and n 1,8 with the value of Rw is 0.18 ohm-m and Sw analysis is conducted by calculating Sw based on several methods for comparison such as conventional Sw (Archie) for clean sand and Sw calculation based on lithology and CEC content in the Gumai interval reservoir, so sw calculation is carried out using the CEC methods (Waxman Smits, Juhasz, and Dual Water). So the results of the Sw calculation obtained based on Sw Archie (93%), Sw Indonesia (62%), and Sw based on the CEC group method are obtained from Sw Waxman Smits (38%), Sw Dual Water (93%), and Sw Juhasz (81%) (Figure 7). Based on several Sw calculation methods that have been conducted, it can be concluded that the Archie method produces Sw which is too pessimistic because it does not consider the shale content in its calculations. While the Waxman Smits CEC method has the most suitable Sw value according to the reservoir conditions namely the shaly sand reservoir associated with a high CEC value for the LRLC case, it produces an optimistic value when compared to other Sw calculations. The optimistic calculation of Sw for the LRLC zone in this research area is Waxman Smits 38% because it closely matches Swirr 30%. The results of the petrophysical analysis show that a potential zone is obtained, namely DAP-1 in the SN-3 well with a low resistivity value in the Gumai formation in the study area, that calculation has been validated with core data and DST data.



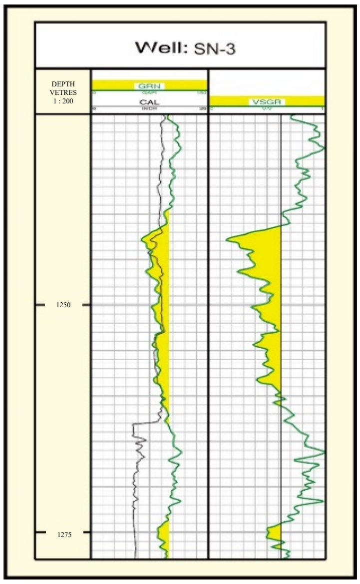


Figure 5
(A) Histogram of Gamma-ray (Gr) log correction showed Gr_MA as sandstone and Gr_SH as shale
(B) Shale volume (Vsh) calculation results from Gamma-ray logs of SN-3 well in interval Gumai Formation

Solution for LRLC in Gumai formation

Petrophysical Evaluation and relationship with LRLC reservoir.

Based on the results of the petrophysical analysis such as volume shale (44%), porosity (14%), and water saturation (38%) use the Waxman Smits method with results of lumping show that the reservoir's low resistivity prospect intervals in the SN-3 well are located in the DAP-1 zone with a depth of 1243-1259 m (Figure 8). The zone intervals of DAP-1 have DST and are proven to produce oil with an oil rate of 82 BOPD and a gas rate of 0.42 MMSCFD, and also have resistivity values ranging from 3-5 ohms (Table 1). The DAP-1 zone is included in the low resistivity reservoir category because the resistivity values are in the range of the LRLC reservoir.

Causes of LRLC cases

Based on the two causes of the low resistivity reservoir, the main factor causing the significant decrease in resistivity value is the presence of Illite/Sectite clay minerals (Mixed layers) (8.34%) which have a high CEC value of (70 meq/100gr). Clay minerals generally bind water, because the water contained has a high conductivity and lowers the resistivity value.

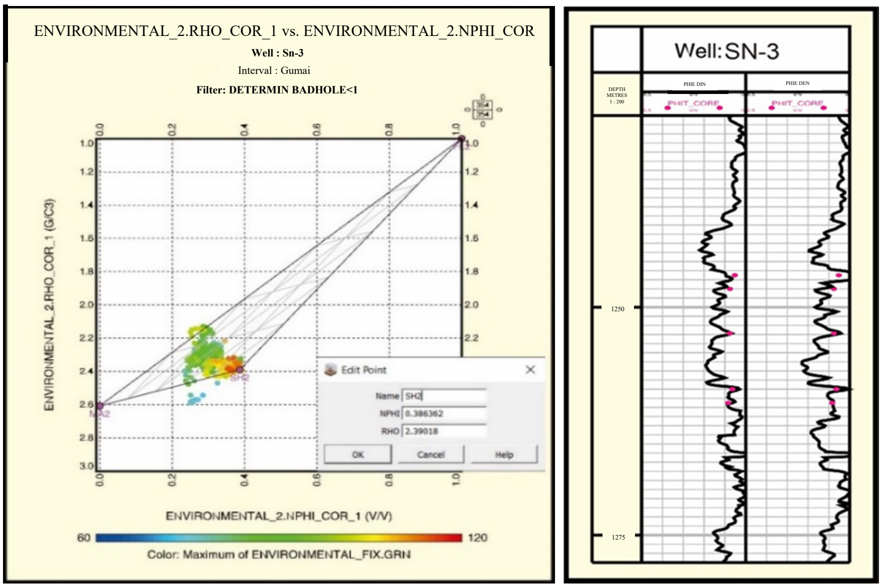


Figure 6
(A) Cross-plot data between density-neutron log and returns the value of shale density and neutron shale
(B) comparison of porosity calculation between density log (right) methods and neutron porosity density log (left)

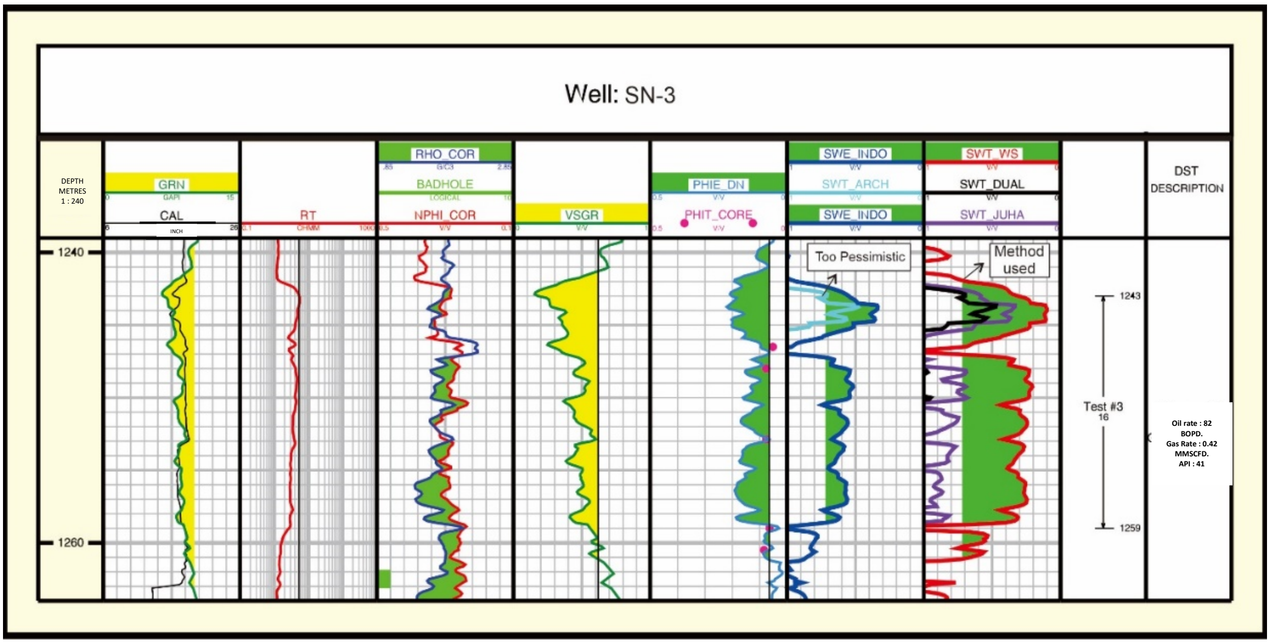


Figure 7
Comparison of several calculation methods of water saturation (SW), while the waxman smists method has the most suitable sw in this study

Proof over LRLC in Gumai based on various Sw, Swiir, and DST data.

Based on several Sw calculation methods that have been conducted, it can be concluded that the Archie method produces Sw which is too pessimistic because it does not consider the shale content in its calculations. While the Waxman Smits CEC method has the most suitable Sw value according to the reservoir conditions for the LRLC case, it produces an optimistic value when compared to other Sw calculations. That interval shows low gamma ray values, has a cross-over between Rhob and Nphi log, and has a low resistivity value range of 3-5 ohms. The optimistic calculation of Sw for the LRLC zone in this research area is Waxman Smits 38% because it closely matches Swirr 30%. The available DST data at the SN-3 well did not have water test results, so the Sw results which were close to the Swiir value were considered to be the most suitable Sw for the low resistivity reservoir conditions of the Gumai Formation in the study area.

The Best Practice For petrophysical evaluation in Gumai Formation

For the LRLC case, in order to obtain petrophysical calculation results that are suitable for the reservoir conditions for the LRLC case, it is necessary to pay attention to the rock lithology conditions, such as clean sand, shale sand, or carbonate. Is there any content of clay minerals and conductive minerals in the reservoir, then to determine Sw there are several methods of calculating Sw that can be used, the calculation of Sw must pay attention to the lithology and mineral clay content of the reservoir so that Sw is obtained according to reservoir conditions, and these calculations should be validated with core data, petrographic analysis, and DST data.

Other Alternatives for overcoming LRLC in Gumai Formation

According to Rohmana et al., (2017), another solution for LRLC in Gumai Formation is to supervise formation water salinity. In that research, the characteristics of formation water in Gumai Fm are highly saline water. The high salinity of the formation water causes the reservoir to have a low resistivity value due to the high conductivity of the formation water. Therefore it is important to know the classification of formation water in the study for obtaining a petrophysical calculation that is appropriate to the reservoir conditions.

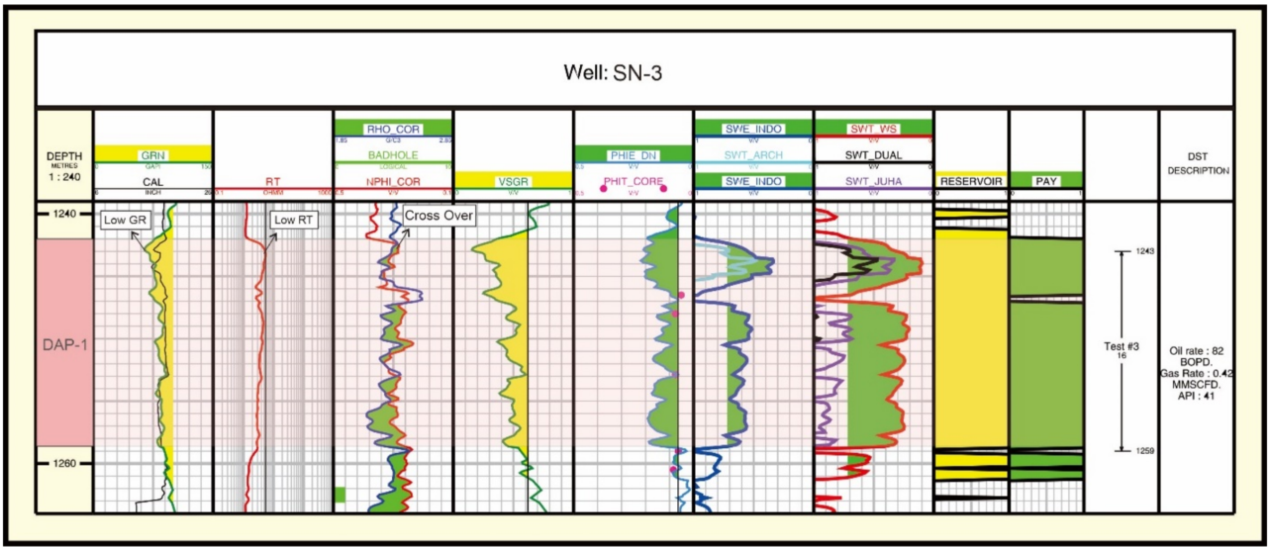


Figure 8
Low resistivity low contrast (LRLC) reservoir prospect zone is at interval DAP-1 on the Gumai formation in this research study

Table 1
Summary of lumping reservoir of SN-3 well on Gumai formation at the research study

Well	Zone	Depth (m)	Rt Value (ohm-m)	DST	Rw (ohm-m)	Avg Vsh	Avg PHIE	Av Sw					Net Pay (m)	Prospect	Formation
								Conventional		CEC Group					
								Archie	Indonesia	Waxman Smits	Juhasz	Dual water			
SN-3	DAP-1	1243-1259	3.8-5	Oil and Gas	0.18	44%	14%	93%	62%	38%	81%	93%	14.5	Prospect LRLC	Gumai

CONCLUSION

The main causing the significantly decreased resistivity value in the Gumai Formation is the dominant clay mineral content in the reservoir, namely Mixed layers (Illite/Smectite) (8.34%). Where Illite/Smectite has a high CEC value (70 Meq/100gr) and clay-bound water in clay mineral has a high conductivity. Reservoir with high conductivity so that it can reduce resistivity value. The DAP-1 zone, SN-3 well in Gumai interval (1243-1259 m) shows low gamma ray values, has a cross-over between RHOB and NPHI log, and has a low resistivity value range 3-5 ohm-m and based on petrophysical calculation in that interval have shale volume (Vsh) (44%), porosity (14%), and Sw Waxman Smits (38%) is closet to Swirr (30%). In this well, DST has been carried out at these intervals with the test results proven to produce oil with an oil rate of 82 BOPD and a gas rate of 0.42 MMSCFD without water. The DST data on the SN-3 well does not have water test results, therefore Sw results that are close to the Swiir value are considered the most suitable for the low resistivity reservoir conditions of the Gumai Formation in the study area.

The best practice for reservoir LRLC in Gumai Formation for suitable petrophysical calculation are necessary to pay attention to the rock lithology conditions, the presence of mineral clay, classification of formation water, and determining suitable Sw for appropriate to the reservoir conditions.

ACKNOWLEDGEMENT

The authors would like to thank the management data of the sedimentology laboratory Geological Engineering Department, Gadjah Mada University, and PT. Sigma Cipta Utama for the available data and publication permission.

GLOSSARY OF TERMS

Symbol	Defenition	Unit
BOPD	Barrel Of Oil Per Day	
CEC	Cation Exchange Capacity	
MMSCFD	Million Standard CubicFeet per Day	
Rw	Resistivity Water	Ohm-m
a	Cementation Factor	
m	Cementation exponent	
n	Saturation exponent	

REFERENCES

Audinno, R.T., Pratama, I.P., Halim, A., and Kusuma, D.P. (2016) Integrated Analysis of The-Low Resistivity Hydrocarbon Reservoir in the "S" Field, in Proceedings Indonesian Petroleum Association (IPA), **40th AnnualConvention & Exhibition, p.**

Badan Informasi Geospasial (2019) *Peta RBI: Peta Rupa Bumi Indonesia.* https://tanahair.indonesia.go.id/portalweb/download/perwilayah.

Barber, A.J., Crow, M. J. and Milsom, J.S. (2005) Sumatra: Geology, Resources and Tectonic Evolution, *Geology Society Memoir*, London, No. 31.

Bishop, M.G. (2001) *South Sumatra Basin Province, Indonesia: The Lahat/Talangakar- Cenozoic Total Petroleum System*, USGS, Wyoming Colorado, 90-50-S, p. 1-19.

Boyd, A., Darling, H., Tabanou, J., Davis, B., Lyon, B., Flaum, C., Klien, J., Sneider, R.M., Sibbit, A., Singer, J. (1995) The Lowdown on Low- Resistivity Pay, in *Oil field Review,* Schlumberger, p. 4-18.

Dwiyono, I.F., and Winardi, S. (2014) Kompilasi Metode Water Saturation Dalam Evaluasi Formasi, In *Proceeding Seminar Nasional Kebumian* Ke-7, p. 420-437.

Faiza, I. W., Irawan, D., Rakha, M., F, M, A. (2019) Integrated Initial Water Saturation Modelling, in *Scientific Contributions Oil and Gas (SCOG)* Vol.42, p. 95-107.

Ginger, D., and Fielding, K. (2005) The Petroleum System and Future Potential of The South Sumatra Basin, *in Proceedings. Indonesian Petroleum Association (IPA) 30th Annual Convention & Exhibition*, p -.

Hamada, G.M., Al-Awad, M.N.J. (2000) Petrophysical Evaluation of Low Resistivity Sandstone Reservoir, in *Journal of Canadian Petroleum Technology* Vol.9, p. 7- 14.

Holis, Z., Prayogi, A., Puurwaman, I., Damayanti, S., Nugroho, D., Kamaludin, M.K. (2016) The Petrophysic Role of Low Resistivity Pay Zone of Talang Akar Formation, South Sumatra Basin, Indonesia, in SPE Asia Pacific Oil and Gas Conference & Exhibition All Dayas, Perth, Australia, SPE-18244, p. 2-20.

Melfi, F., **Setyowiyoto, J., and Wintolo, D.** (2017), *Evaluasi Petrofisika* Low- Resistivity *Pada Potensi Reservoar Hidrokarbon Formasi Gumai Cekungan Sumatra Selatan*, in Proceeding Seminar Nasional Kebumian Ke-10, p 590-599.

Palacky, G. (1987) Resistivity Characteristics of Geological Targets, in Nabighian, Electromagnetic Methods in *Applied Geophysics- Theory, Society of Exploration Geophysicists*, Tulsa, p. 53-129.

Pulunggono, A., Haryo, A.S., Kosuma, C.G. (1992) Pre-Tertiary and Tertiary Fault System as a Framework of the South Sumatera Basin: A Study of Sar-Maps, in *Proceedings. Indonesian Petroleum Association, 21th Annual Convention & Exhibition*, p.

Rohmana, R.C., Setyowiyoto, J., Husein, S., Indra, Y., and Ramadhan, A. (2017) Evaluasi dan Perbandingan Reservoar Low-Resistivity Formasi Cibulakan Atas, Cekungan Jawa Barat Dengan Formasi Gumai, Sub-Cekungan Jambi, in Proceedings Seminar Nasional Kebumian Ke-10, Indonesia, p. 573-589.

Sarjono, S., dan Sardjito. (1989) Hydrocarbon Source Rock Identification In The South Palembang Sub-Basin, in *Proceedings. Indonesian Petroleum Association, 18th Annual & Exhibition*, p. 427–467.

Tribuana, I. Y., Yogi, A., Prabowo., Wibowo, A, S., Sudija P., Durahman, Y. (2015) Optimization Of Measurement Speed For Spectral Gamma Ray and Clay Mineral Identification, in *Scientific Contributions Oil and Gas (SCOG)* Vol.38, p. 181-191.

Worthingthon, P.F. (1997) Recognition and Development of Low-Resistivity Pay. *SPE Asia Pacific Oil and Gas Conference and Exhibition*. SPE-38035-MS.

Worthington, P.F. (2000) Recognition and Evaluation of Low-Resistivity Pay, *Petroleum Geoscience*, Vol. 6, p. 77–92.

Zaemi, F.F., Rohmana, C.R., and Atmoko, W. (2022) Uncovering The Potential of Low Resistivity Reservoirs Through Integrated Analysis : A Case Study from The Talang Akar Formation in The South Sumatra Basin, in *Scientific Contributions Oil and Gas (SCOG)* Vol.45, p. 169-181.