Gas While Drilling (GWD) Classification in Shaly-Sand Reservoir; an Effort to Unlock Gumai Play Potential in South Sumatra Basin, Indonesia*

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Abstract

Gumai Formation, which acts as regional seal for Talang Akar Formation, becomes one of the most prolific reservoirs in South Sumatra Basin - Indonesia and the primary exploration target in this area. Marine conditions were eventually established during the continuation of transgression sequence leads an open marine facies deposition in Early Miocene. Marine clastic deposits where calcareous shales, claystone and siltstones interbedded with fine-grained calcareous and glauconitic sandstones are the domination of lithology which targeted as the hydrocarbon reservoir. Until 2016, the primary objective of PetroChina's exploration and production in Betara area is only from Lower Talang Akar Formation. Successful testing in some exploration wells, which flowed gas and condensate from Gumai reservoir, opened the opportunity to explore the new play potential in Betara Complex. An integration and evaluation of Gas While Drilling data initiated with the objective to determine our next Gumai reservoir candidate which capable to increase Jabung Block hydrocarbon discoveries. However, the limitation of conventional wireline logs data in Gumai interval generating a technical challenge in term of geological approach. This paper describes how Gas While Drilling indicator is processed to generate potential and non-potential zone by cut-off and gas behavior analysis. Validation which performed by correlation and comparison with well logs, Drill Stem Test (DST), and Reservoir Performance Monitor (RPM) data succeed to observe Gumai reservoir in Betara Complex. After the data integration has been done, we are able to generate a Betara Complex potential map which could be overlay with reservoir characterization distribution as a part of risk assessment in term of potential zone presence. Mud log utilization and geophysical data information successfully covered the geological challenge in this study.

Introduction

Utilization of Gas While Drilling (GWD) data is standard practice during the exploration and development activity. For the quick look analysis, GWD could easily help us in determining hydrocarbon potential and analyze the fluid characterization in the existing formation. In case to explore new potential in a very limit data condition, PetroChina Indonesia tried to improve the analysis by using GWD method. We analyzed the gas behavior, conduct gas data verification, gas ratio analysis by following methods, and compare those result to some of verify data. We hope the GWD method could be able to perform the reservoir interpretation in near real time for fluid identification and contact as well as existence of lithological change.

Methods

To conduct the interpretation, all the datasets in this study was derived by PetroChina International Companies in Indonesia. The data consisting of drilling parameter, mud log, wireline log, well test, sidewall core and pulsed neutron reservoir monitoring measurement. This study used four onshore wells in Gumai Formation, Jabung Block - South Sumatra Basin (Figure 1) which are NEB Base-1, NEB-55, North Gemah-1 and NEB-5. We have done gas while drilling analysis in Gumai Formation to specifically determine gas behavior in targeted reservoir as well as gas cutoff and gas ratio. We integrated drilling and post drill data to unlock Gumai overlooked play potential (Figure 2).

Reservoirs and Exploration Targets

Gumai Formation is the most prolific reservoir and the primary exploration target in South Sumatra Basin. Marine condition was established during the continuation of transgression sequence led to open marine facies deposition in Early Miocene, which resulted the deposition of marine shales, siltstones and sandstone with rare carbonate deposition over the crests of basement highs. Sandstones thickness and quality increase higher in the Gumai section as marine conditions regressed regionally in the basin (Figure 3).

The sandstone facies in Gumai Formation generally characterized by clear to translucent, white to off white, locally green to dark green, orange to tan, black, dominantly loose quartz, locally friable to moderately hard with calcareous cement, very fine to fine grain, sub angular to sub rounded, locally rounded, trace of pyrite, trace of glauconite, trace of carbon material, trace of fossil fragments, poor to moderately sorted, poor to fair visible porosity. Based on wireline log interpretation, Gumai Formation known to have two different patterns of gamma ray log (fining and coarsening upwards). Those patterns show Gumai controlled by two different geological events, which also has different energy deposition (Figure 4).

Based on observation on North Gemah-1 as an example well, a poor-quality data is observed by the noise when recorded data and also the heavy component goes beyond the Ethane (Figure 5). On the contrary, North Gemah-1 well shows the good value trends are above the limit (Figure 5). GQR on the well indicates the presence of heavy component, so almost all the data deflated to the left site.

Interpreted lithology that derived from ROP and lithology cutting are plotted together next to Wh, Bh, and Ch ratio in order to pick reservoir zone. Three reservoir zones are observed on A-4 well. Res-A starts from 4619’ MD to 4650’ MD (31’), Res-B starts from 4659’ MD to 4692’ MD (33’), and Res-C starts from 4700’ MD to 4735’ MD (31’). On Res-A, B and C Wh is less than Bh that indicates productive gas condensate with has density increased into the lower part. Whereas Ch is more than 0.5 also proved that the reservoir zone is consist of productive gas condensate (Figure 6).

Analysis

Pixler plot trend on Res-A, B and C shows that the value of C1/C2 (red bands) on Pixler Ratio ranging from 10 to 20 which is indication of gas condensate. The trends of C1/C5 was appears start from the beginning of the interest reservoir. This condition interpreted to be high gravity oil that possible contained in layer of reservoir. The width of the green bands on FS ratio indicates tight condition with no significant water association (Figure 7).

The deflection of HM, LM and LH on reserval ratio reveals indicates the hydrocarbon composition on each reservoir zone. The crossover of LM & HM ratio and increasing of total gas on Res-A, B and C implies a gas zone, specially indicate wet gas condition. Goes to the lower part of interest zone, we have not found the existence of Gas-Water Contact (GWC) that will be used to distinguish the fluid distribution (Figure 8).

Neutron reservoir monitoring measurement data results is used to validate the interpretation of reserval ratio and Pixler ratio plot. In neutron reservoir, monitoring measurement data shows the interested reservoir has small gas envelope indication which mean the reservoir have a possibility in containing hydrocarbon but with low mobility condition. Those measurements also matched with the analysis in fluid saturation data that assume the reservoir interval existed in tight layer condition (Figure 9).

Comparison with wireline data, 3 reservoir zones (A, B, C) seems to support each other. Generally, selected pay zone are being equal to zone depth interval. Fluid interpretations are validated by testing result also proved that reservoir flowed 2.75% oil and gas in average. By exploring the other opportunity with gas while drilling analysis we could find the better spot to conduct future testing program (Figure 10).

Once the GWD interpretation has been validated with the supporting data, reservoir fluid can be characterized properly. The vertical fluid compositions become heavier with depth but not continuously. After we have done with gas behavior analysis, we conducted petrophysical interpretation in those three interest zones to know the connection among each other.

On Figure 11 we could see 3 interest reservoir has 0.1 – 0.15 (10-15%) porosity fractional in average amount. If we trying to classified these zones belong to tight reservoir. For the water saturation, the amount ranged in between 40-75% in average (Figure 11). Based on the comparison we assume gas while drilling availability in the reservoir could sharpen the justification on determining the new potential zone, because of the mutual correlation between gas behavior and petrophysical analysis.

Besides trying to compare the gas behavior analysis with petrophysical interpretation, we also distinguished the fluid type based on well-to-well interpretation. The upper and lower part of reservoir has a wet gas composition that somehow associated with high GOR oil (Figure 8). The reservoir bed is in tight condition that makes the porosity and mobility could not work perfectly.

Gas while drilling distribution map that includes NEB-55, NEB BASE-1, and NGEM-1 wells give the overview analysis about fluid distribution in Betara Complex area. The distribution came from northeast to southwest direction. Wherein, getting near to the southwest part the gas reading value become smaller (40-80 units) because of the sediment depletion (Figure 12).

Conclusions

Our study concludes:

1. Gas data quality control and the integrated of gas multiple ratio plot could give sharpen justification in preliminary interpretation. GWD analysis capable to distinguish fluid characterization and reduce uncertainty in determining potential zone.
2. GWD analysis could produce fluid contacts, assisting formation test (to know mobility and permeability), picking pay zone, and differentiate between productive and nonproductive hydrocarbon.
3. In case of petrophysical calculation, GWD analysis could be a cut off value in determining a possible reservoir zone, but going forward it could not ensure either good or poor reservoir characteristic.
4. For the further studies is necessary to improve GWD interpretation with sensitivity analysis to create better approachment.

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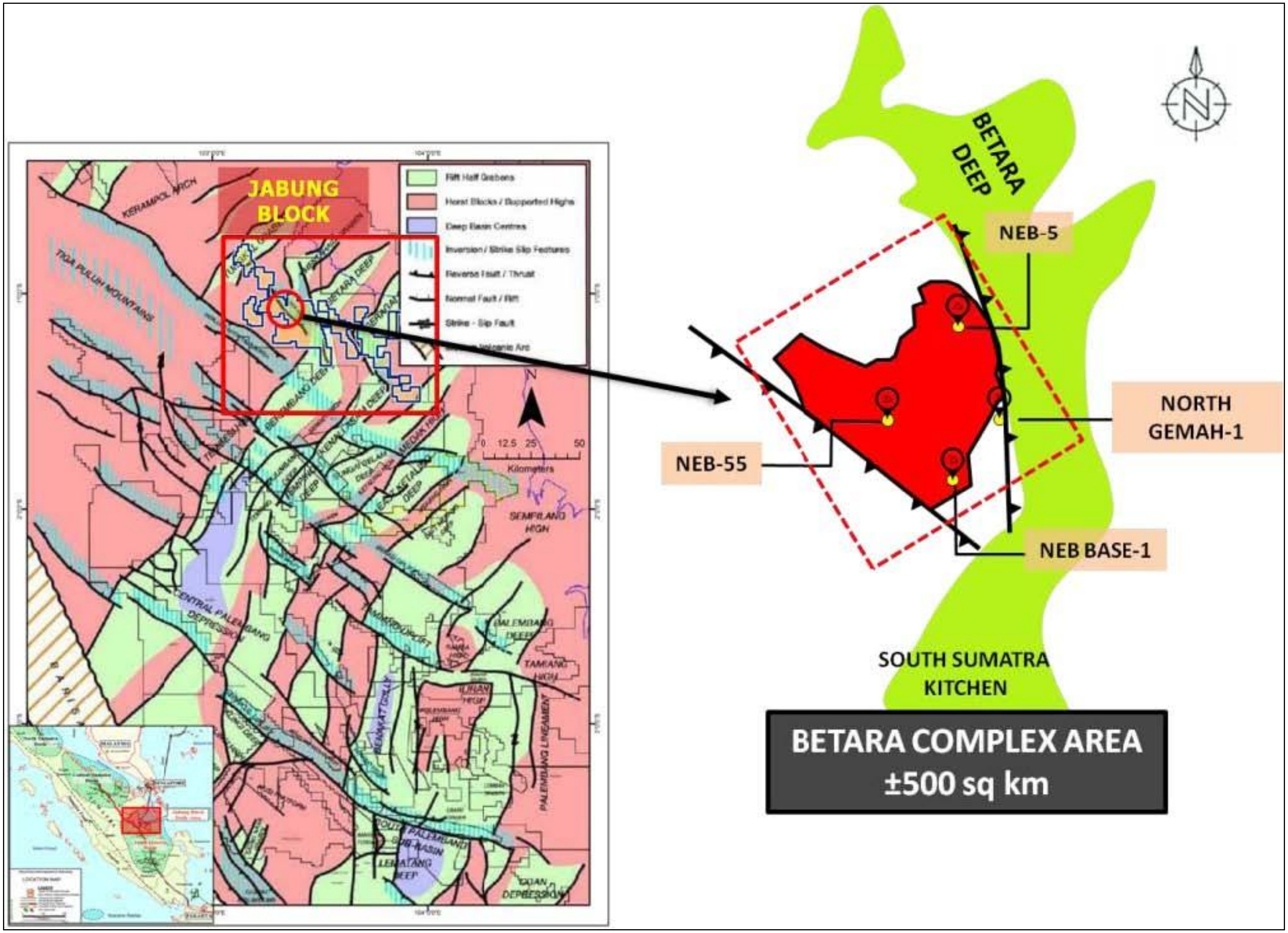


Figure 1. Betara Complex location in the Jabung Block, South Sumatra Basin (Modified after PetroChina's Internal Report – Unpublished).

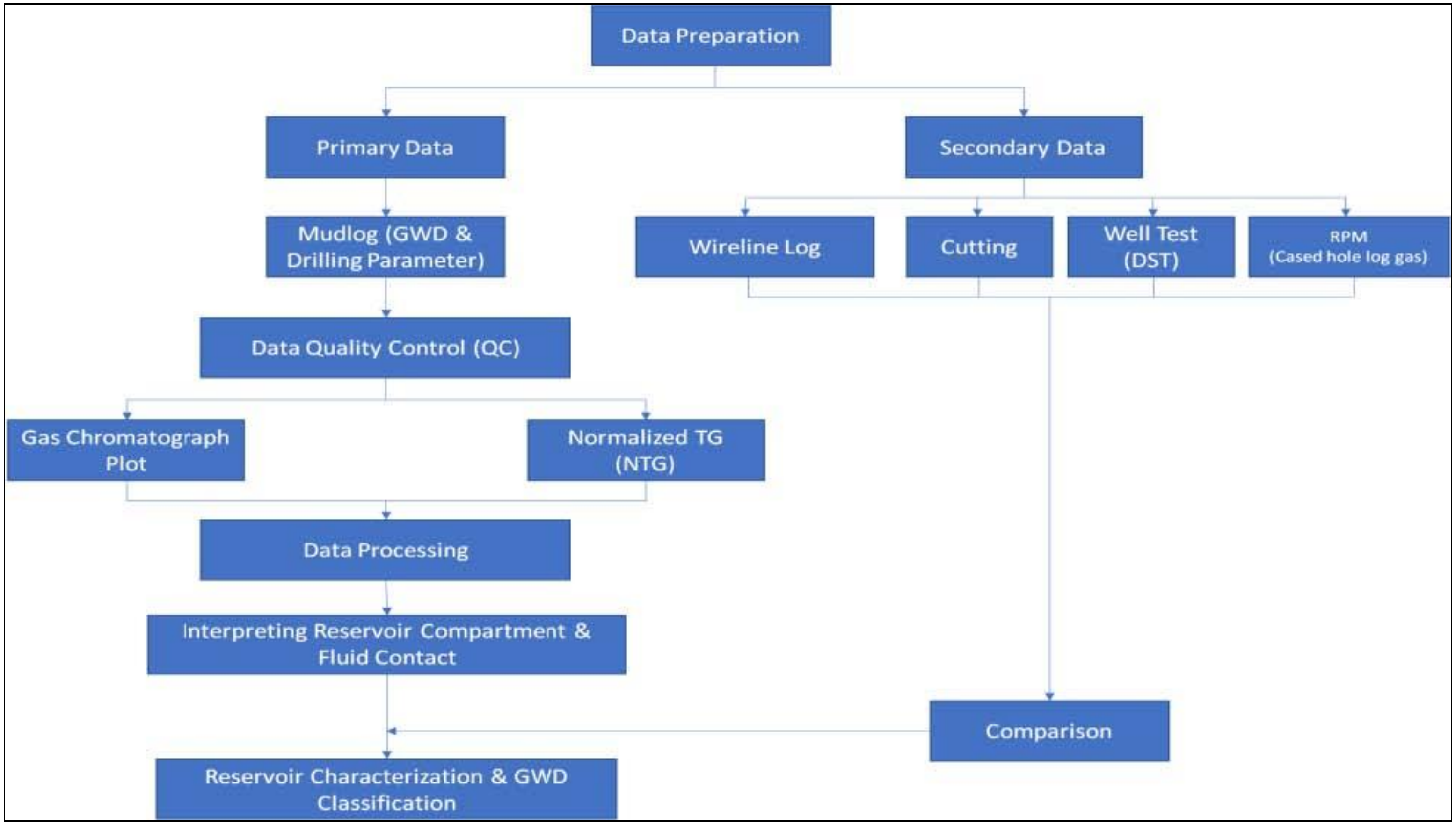


Figure 2. Research Workflow.

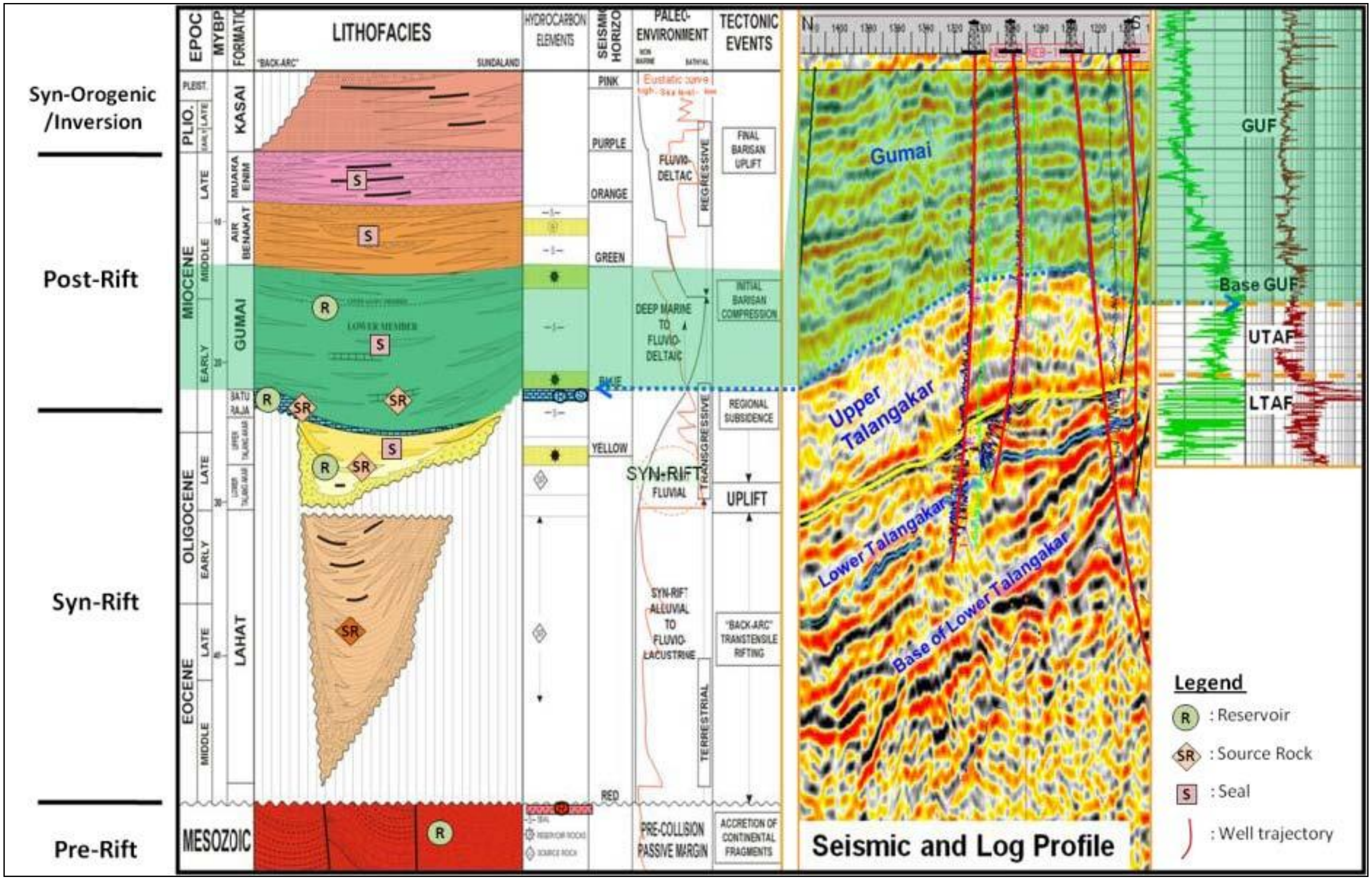


Figure 3. Generalized stratigraphy summary of the Jabung block, South Sumatra basin and its correlation to seismic and well log profiles (Suta, 2003).

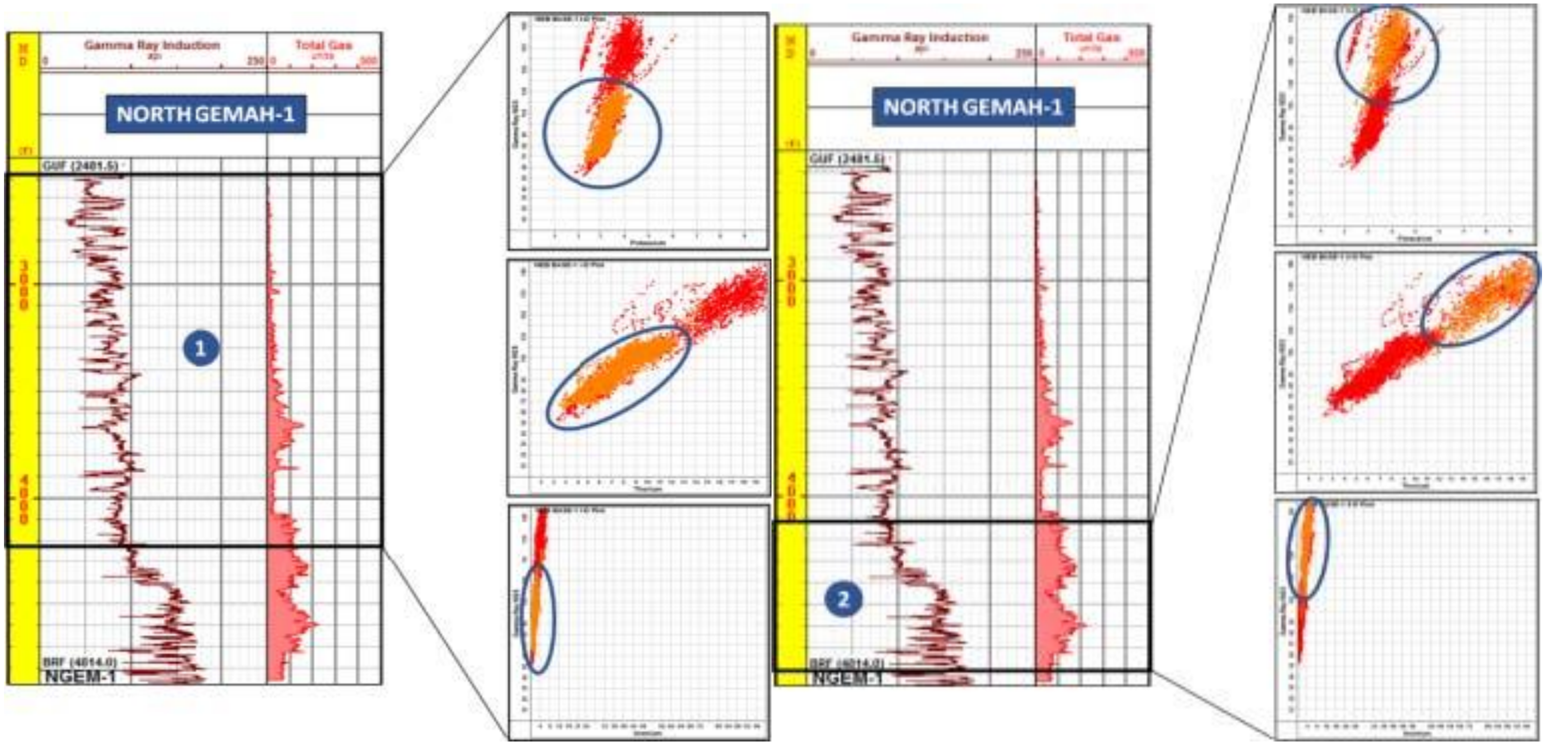


Figure 4. Gamma ray (GR) and radioactive composition in GUF. Two different GR pattern shows GUF controlled by two different geological events with different energy deposition.

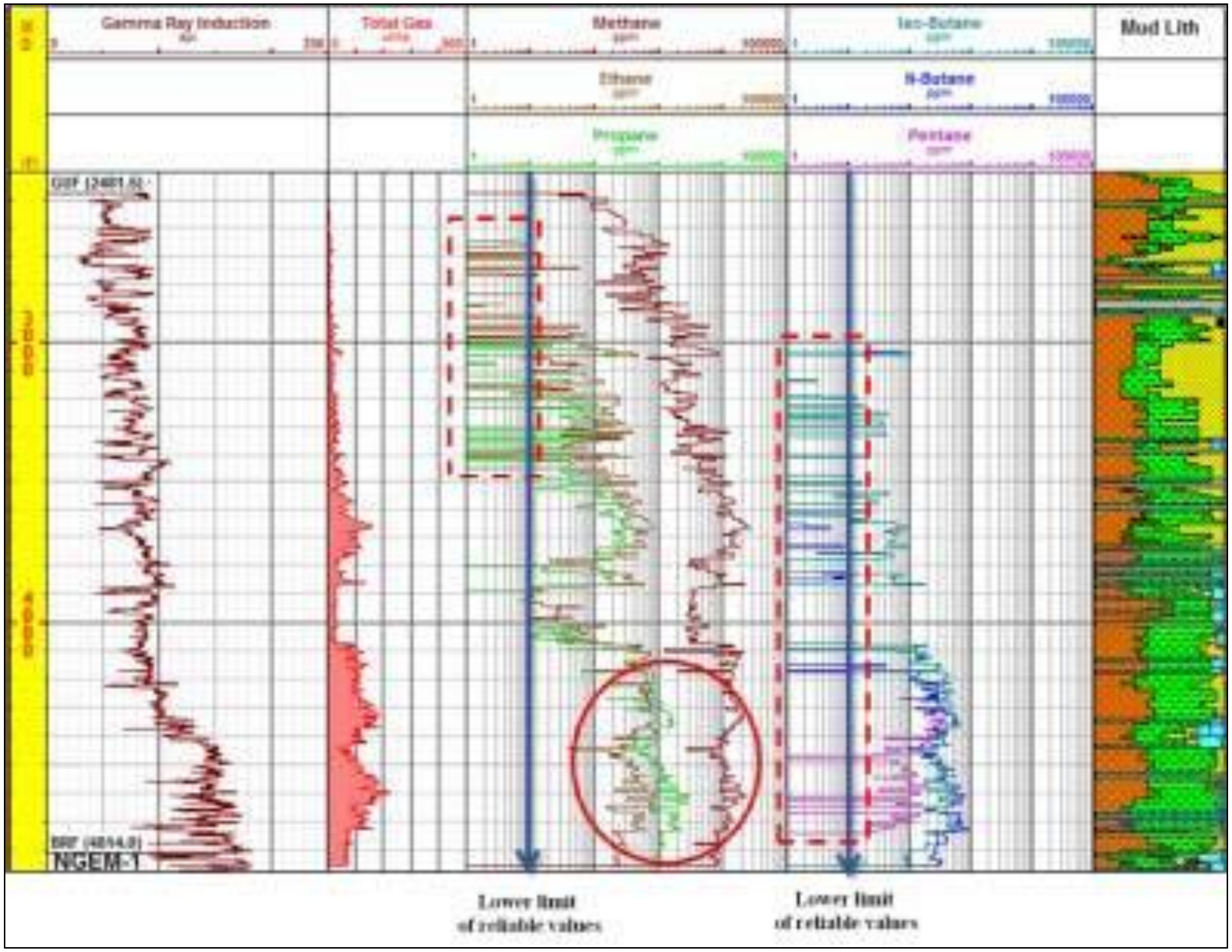
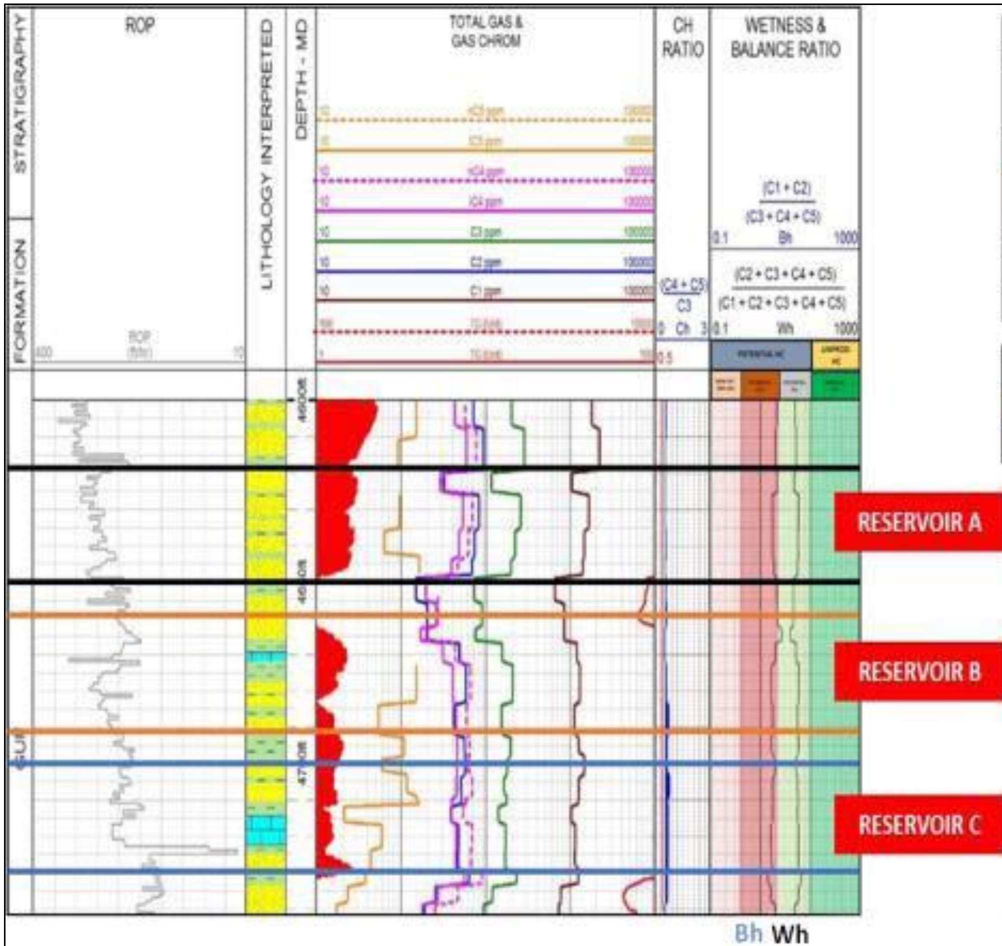


Figure 5. Gas chromatograph trend in North Gemah-1 well, Gumai Formation. Cut-off was applied in 10 ppm as minimal value. A poor quality of gas chromatography in this well indicated by the noise when recorded data (red dotted box) and the heavy component goes beyond the Ethane (red circle).



Wetness Ratio	Balance Ratio	Likely Hydrocarbon Type
$W_h < 0.5$	$B_h > 100.0$	light dry gas, unlikely to be productive
$0.5 < W_h < 17.5$	$W_h < B_h < 100.0$	productive gas
$0.5 < W_h < 17.5$	$B_h < W_h$	productive gas condensate **or** high gravity, high GOR oil
$17.5 < W_h < 40$	$B_h < W_h$	productive oil
$17.5 < W_h < 40$	$B_h << W_h$	nonproductive residual oil

Wetness	Balance	Character	Hydrocarbon
$0.5 < W_h < 17.5$	$B_h < W_h$	$C_h > 0.5$	gas condensate
$0.5 < W_h < 17.5$	$B_h < W_h$	$C_h < 0.5$	high GOR oil

Haworth, et al. (1985)

Hydrocarbon Type:

Productive Gas Condensate

Figure 6. Wetness (Wh), Balance (Bh) and Character (Ch) plot to present a fluid density changes and use to pick the reservoir zone. On the reservoir above, Wh is less than Bh indicating productive gas whereas Ch value more than 0.5.

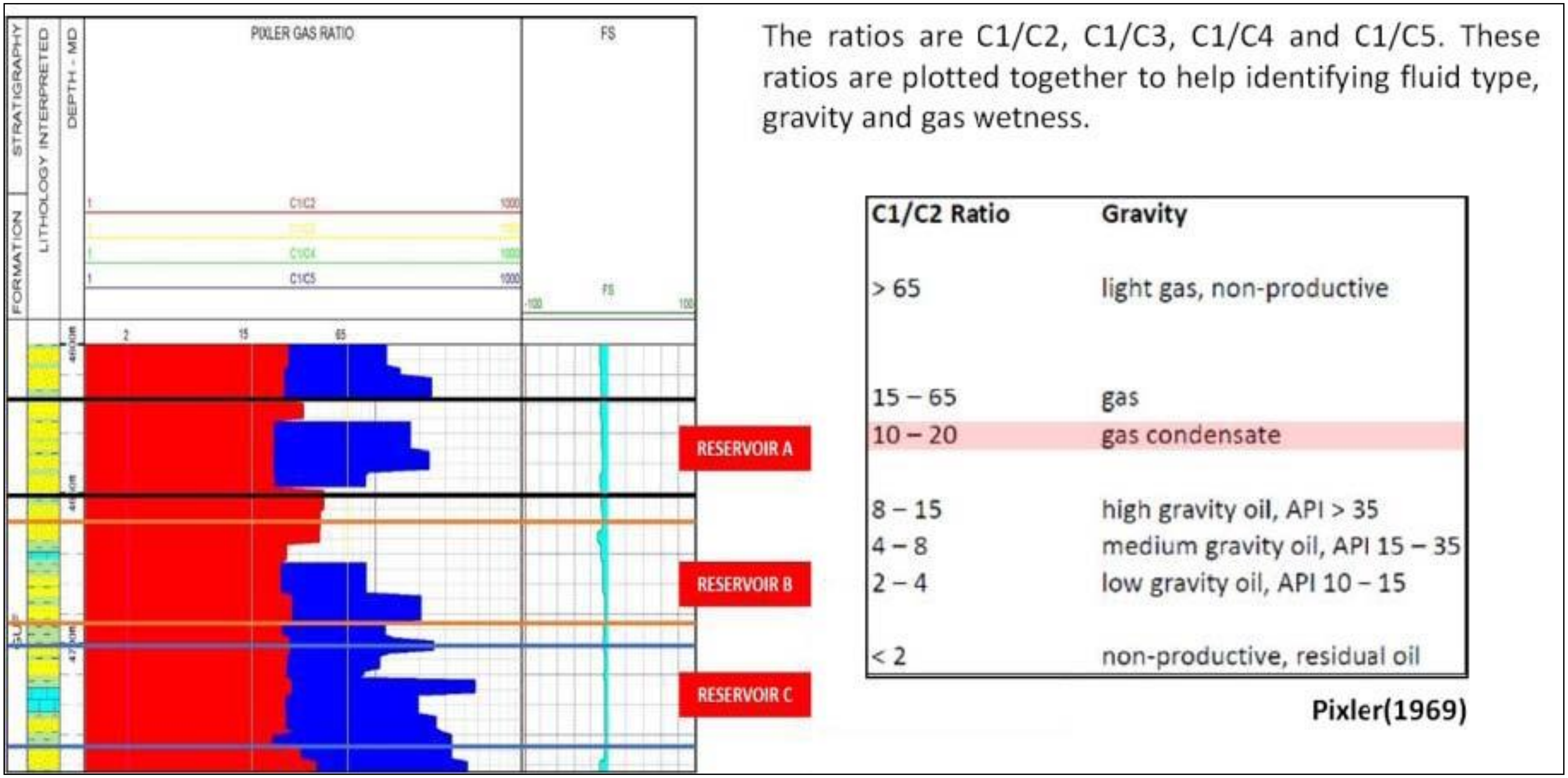


Figure 7. Pixler ratio plot and fluid saturation, value of C1/C2 ratio (red bands) ranging from 15 to 25 showing indication of gas condensate. The wide separation of the dark green bends of FS ratio on the reservoir indicates tight formation (red narrow).

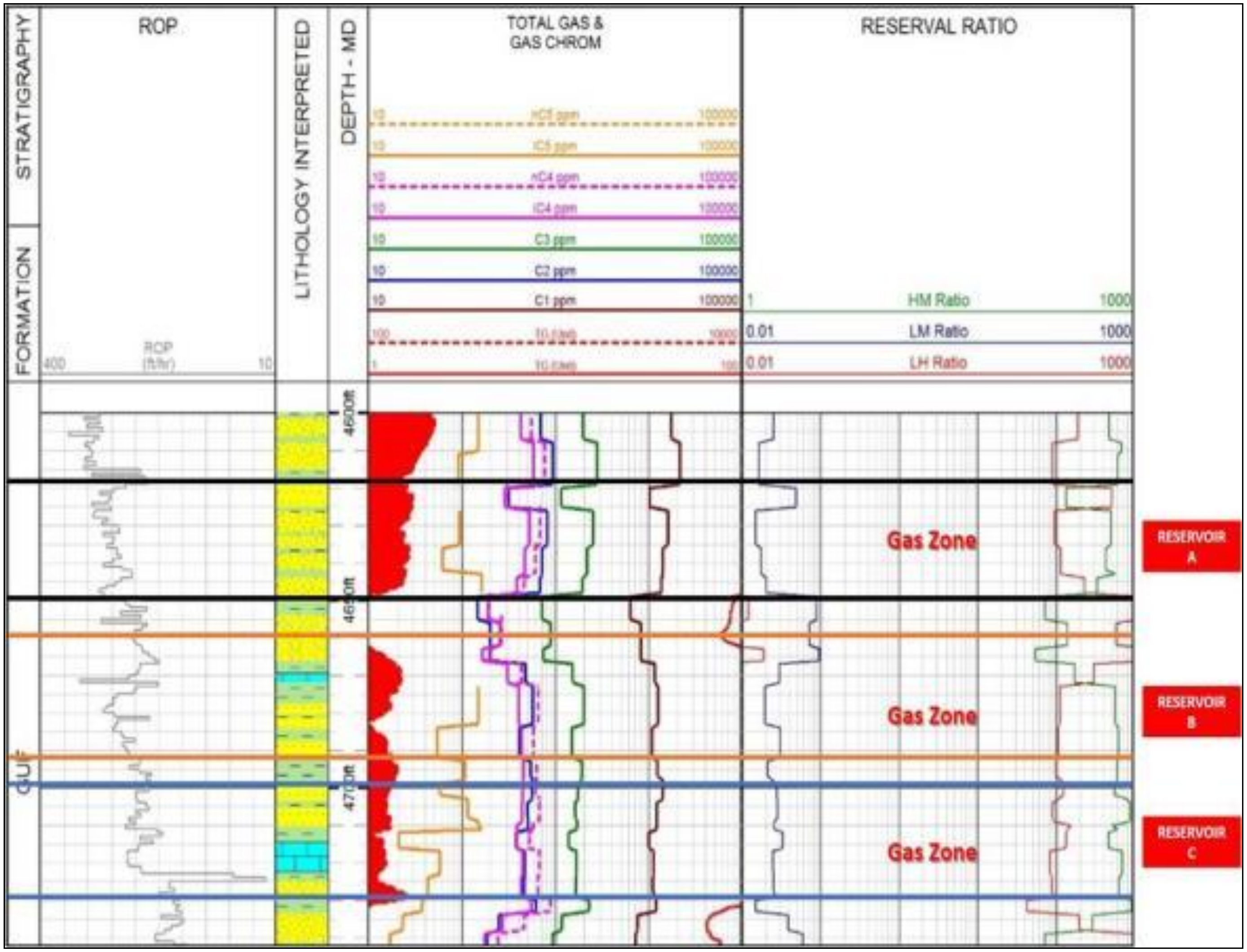


Figure 8. Reserval ratio plot with TG shows hydrocarbon contact in the formation. HM, LM and LH ratio reflecting hydrocarbon composition in each reservoir zone. Three reservoir zones in study area defined as wet gas zone based on the interpretation above.

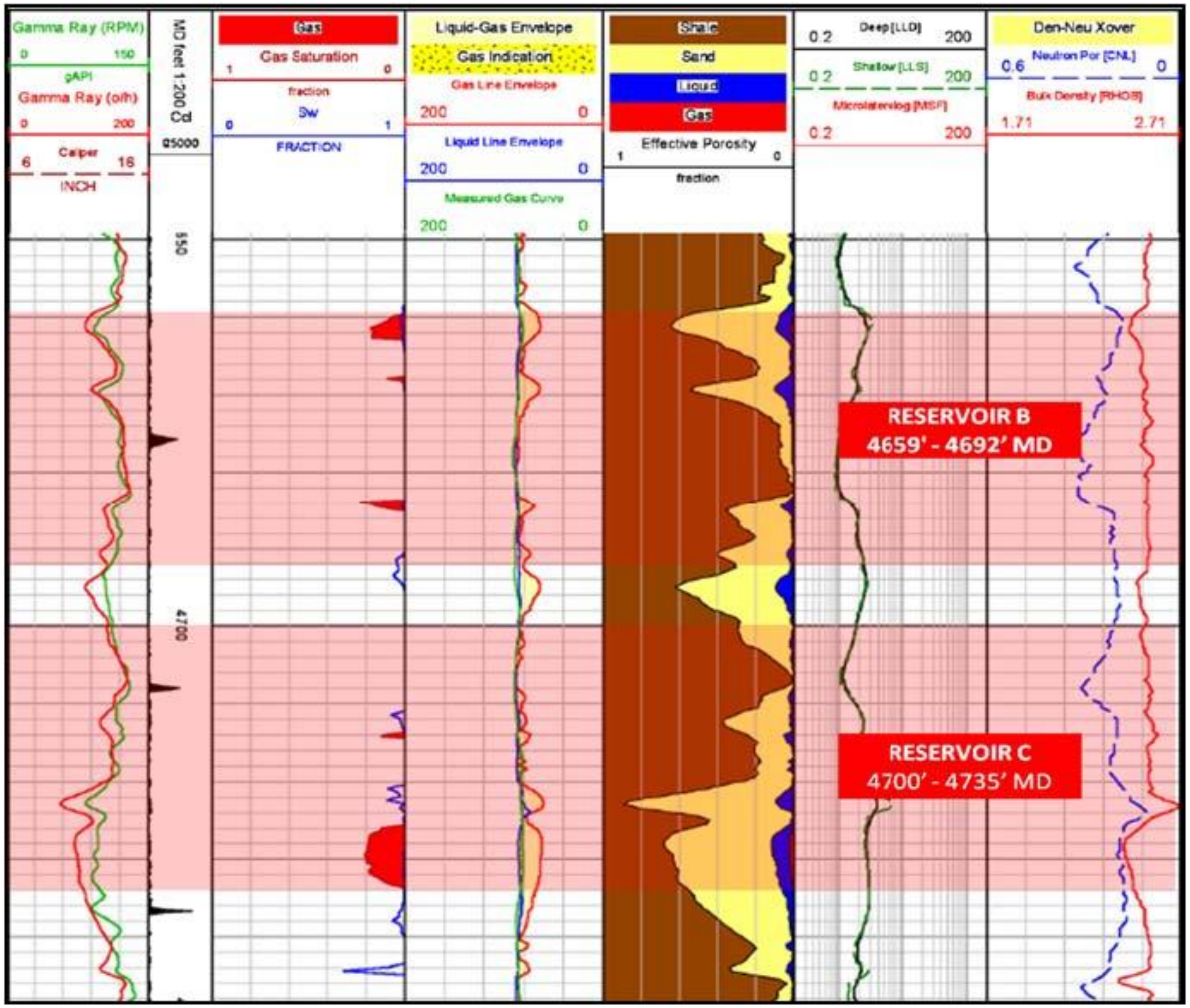


Figure 9. Comparison between pulsed neutron reservoir monitoring measurement data.

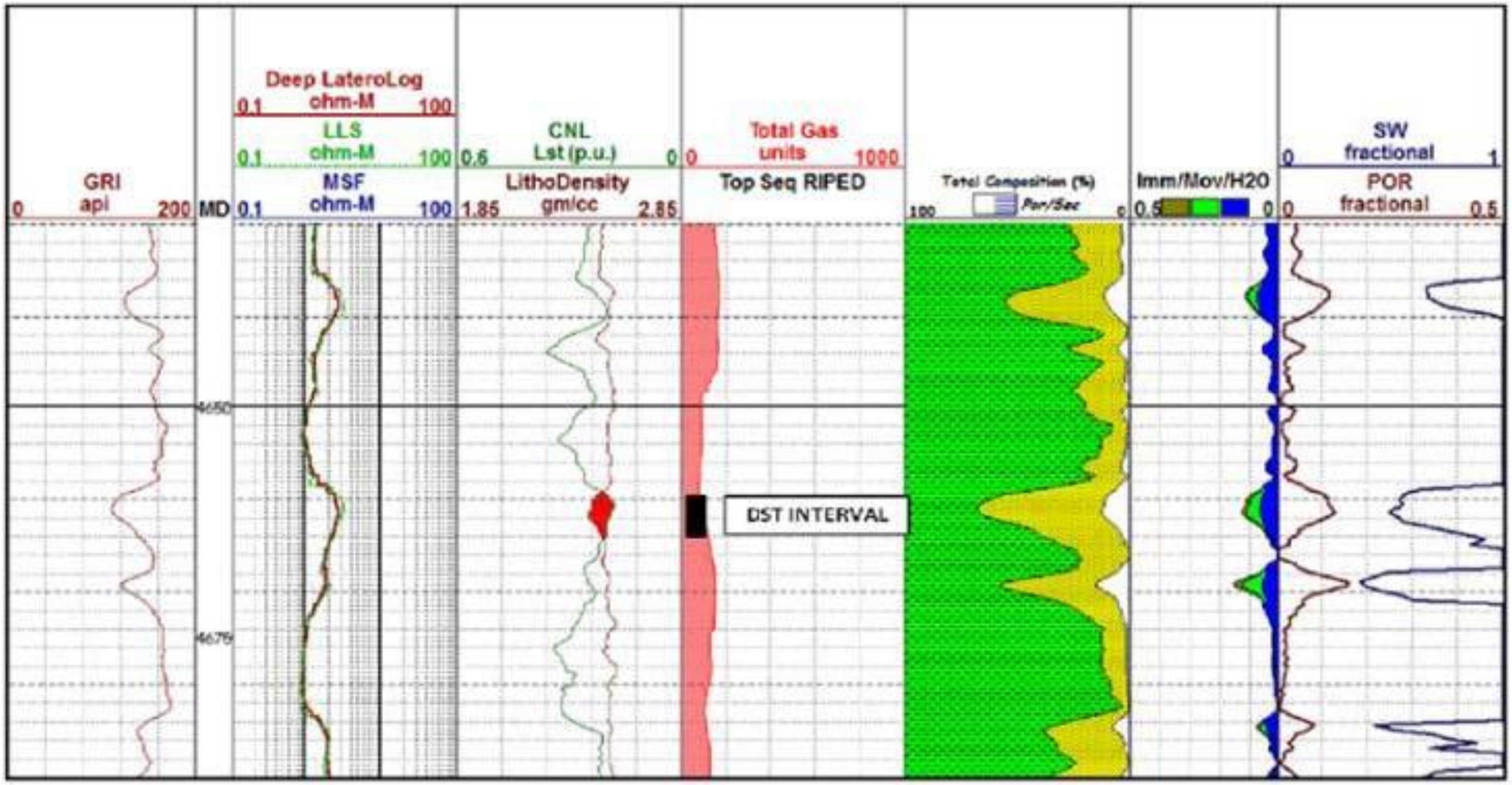


Figure 10. DST result in 4659-4666' MD interval that show the result of hydrocarbon fluid in interested reservoir. Testing was confirmed the analysis by the result of 2.75% oil & gas presence with small porosity value: 10-15% in average.

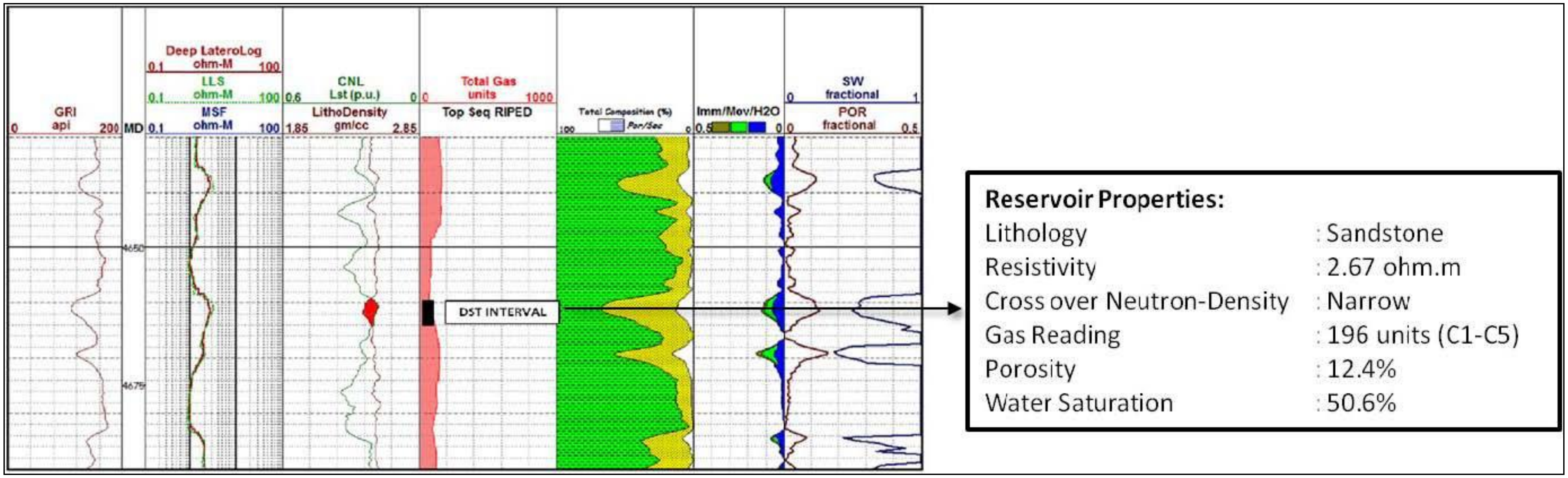


Figure 11. Reservoir characterization analysis to identify the reservoir properties in studied area.

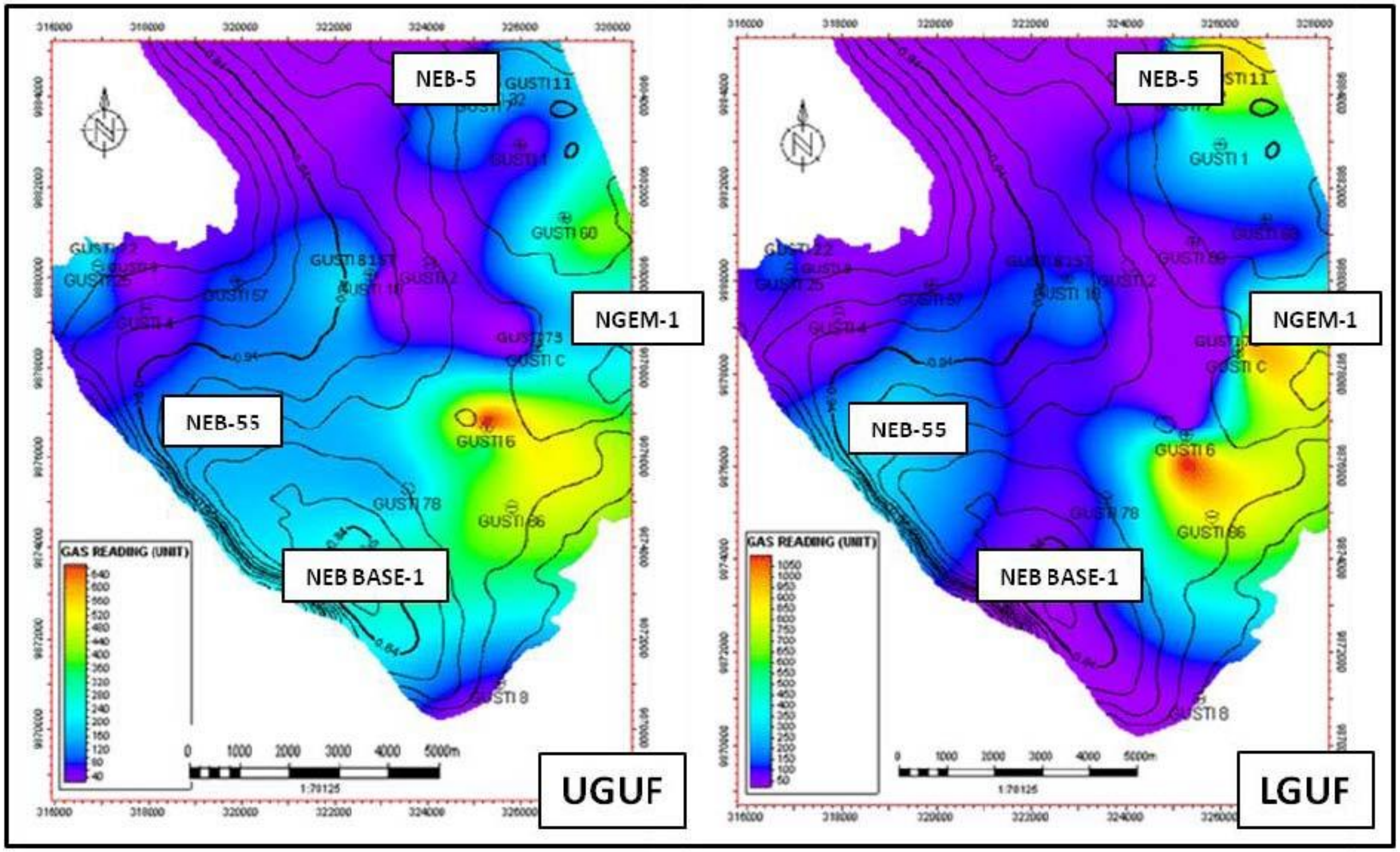


Figure 12. Gas While Drilling distribution map in Betara Complex area.