Journal of Petroleum Research and Studies

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

DOI: http://doi.org/10.52716/jprs.v12i1.593

Evaluation of Carbonate Formation using both Gas While Drilling and Nuclear Magnetic Resonance Log (Case study, An Oilfield Southern Iraq)

Muslim Al-Ali, Hussein Albaaj

Basra Oil Company.

Corresponding Author E-mail: muslumalali@gmail.com

6th Iraq Oil and Gas Conference, 29-30/11/2021

Abstract

Two wells close to each other (Well A and Well B) have been selected from the same oilfield in southern Iraq. Both wells were drilled through the Mishrif Reservoir, however, perforated within different sub-units. It was observed that one of the wells shows obvious flow naturally while the other did not notice any kind of flow.
The type of hydrocarbon interpretation by Gas while drilling method (GWD), the results confirmed that both of these wells were located in oil-bearing reservoir with comparable gas profiles.

However, petrophysical properties of the pore distribution and permeability using Neutron Magnetic Resonance (NMR) data in Techlog identified key differences in rock quality between the wells across the perforated intervals.

Reservoir quality reveal very wide differences in performance in spite of both wells are penetrating the oil bearing layers within Mishrif reservoir.

Keywords: Carbonate Formation, Gas While Drilling (GWD), NMR Log.

1. Introduction

Stratigraphic column is very necessary to indicate the units and show the upper and lower boundary of this important reservoir of the Late Cretaceous (Cenomanian – Turounian) is important carbonate reservoirs in Iraq and the Middle East, it provides the reservoirs for many oilfields like West Qurna, Buzurgan, Amara, Halfay, Majnoon, Rumaila, Zubiar and Qaraf, which contain about 30% of total Iraqi oil reserves [1], [2], [3].

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

The aim of this study is to evaluate carbonate formation by GWD^{TM} method which is using gas while drilling data to estimate type of hydrocarbon in the reservoir and using NMR to evaluate pore size description and permeability which is one of the main evaluation parameters for determining the potential production of a reservoir because it clarify the capability of fluids to flow through rocks.

During Exploration and Development well drilling, gas data measurement (gas shows) is common procedure. Continuous gas monitoring demonstrates the presence of hydrocarbon bearing intervals in general but rarely helps to identify the fluid types (oil, condensate and/or gas, water). In latest days, research on mud gases has proceeded to include isotopic identification of various hydrocarbon components [4]. Furthermore, determining gas origin and maturity can reveal differences in gas charge across adjacent reservoir intervals, allowing reservoir continuity to be analyzed [5]. Gas readings are used with reference to the background level. The gas readings are then graphically shown on either the mud log, or the geologist mud log. This makes an easy assessment evaluation of the recorded relative amounts of gas.

The use of Pixler and/or Geoservices (or equivalent), Wetness, Balance, Character, and Gas Normalization diagrams was likely to be limited until a few years ago [6], [7], [8], [9]. Recent advancements in gas acquisition technologies, as well as the most recent GWD^{TM} method, allow reservoir interpretation to be done in nearly real time for fluid detection and contacts (OWC, GOC, etc.), lithological changes, and efficiency barriers, allowing operations to be managed (e.g., coring, wireline logging and sampling, testing). Traditionally, hydrocarbon abundance analyses in drill mud gas have been used to assist wireline (LWD and MWD) log analyses to define pay zone during drilling.

An advance useful tool to assessment permeability is the Nuclear Magnetic Resonance (NMR) tool. It is measuring the relaxation time of the hydrogen nucleus when excited by an external magnetic field. The relaxation time is directly related to pore size. Large pores have long relaxation times and small pores have short relaxation times. Moreover, porosity, clay-bound water (CBW), bulk volume irreducible (BVI) and bulk volume movable (BVM) can be provided from NMR logs [10].

Open Access
No. 34 part 1, March 2022, pp.105-120
P- ISSN: 2220-5381
E- ISSN: 2710-1096

The NMR measurement of T2 at any given depth in the well is not a single number, like R_t, but a distribution over time of a series of values that gives the analyst a picture of the porosity and the pore-size distribution (Figure: 1) [11].

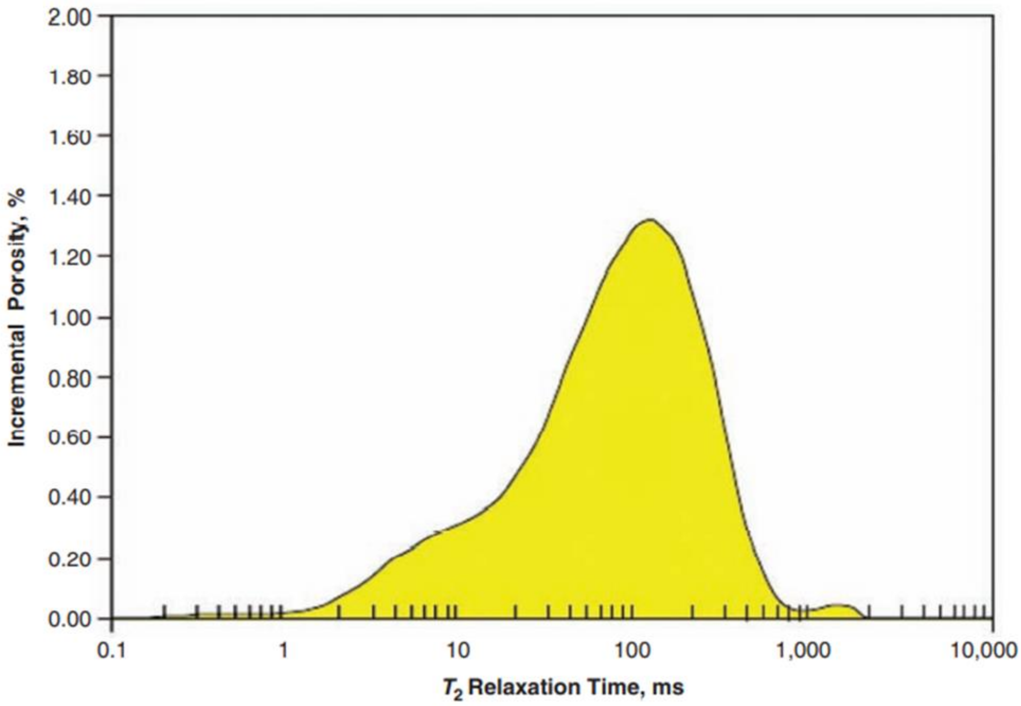

Fig. (1): T2 distribution vs. incremental porosity after [12].

2. Methodology

2.1 Gas While Drilling

The monitoring of gas shows in circulating drilling mud was implemented with two aims in the early days of mud logging measurement. First as a safety device to indicate good behavior for drillers and second as an indication for hydrocarbon bearing zones. Today, gas shows measurement is routinely acquired in the petroleum industry for the same purpose, but it is rarely used to its full potential, due in part to the ongoing bias that the data are not indicative of formation fluids and/or that the analysis of such data is highly affected by varying drilling parameters [13].

The GWD^{TM} methodology is based on measuring the gas concentration in circulating mud and following to quality control processes and criteria to acquire reliable data. This methodology is based on the calculation and analysis of many gas ratios acquired by continuously collecting and analyzing various gas components (C1-C5) from the circulating mud and monitoring them at the rig site by Mud Logging Company [14].

The methodology based on a very rational and regular approach to gas shows in conjunction with drilling and mud logging, and it is integrated with additional techniques such as wireline logs, PVT/thermodynamics, and geochemistry.

In the GWD^{TM} method, the raw gas data are:

- C1, C2, C3, iC4, nC4, iC5 and nC5 expressed in ppm (parts per million).
- TG (Total Gas), expressed in ppm of equivalent methane in air.

The aims of GWD^{TM} analysis to supporting and integrating Formation Evaluation in terms
of:

- Highlighting the main zones of interest.
- Denoting the depth of the sample interval, fluid characterization and differentiation.
- Reduce any uncertainties following conventional logging analysis.

We perform data quality control (QC) before making any interpretations. Some dedicated gas ratios are used to assess the reliability of the gas data. A comparison can be established between the Total Gas Detector and the Gas Chromatograph readings (Theoretical Total Gas) computed by formula 1.

$$\mathbf{SumCcor = C1+2xC2+3xC3+4x\ (iC4+nC4)\ +5x\ (iC5+nC5)} \qquad (1)$$

SumCcor: Theoretical TG in ppm

The next step is to compare this Theoretical Total gas with the Total Gas Detector using
the ratio: TG / SumCcor. In this ratio, TG is the Total Gas Detector and SumCcor is the Theoretical Total Gas computed starting from the measurement of the Gas Chromatograph. The reliability of data ranging in (+/-20%). The values of which are obviously less than 0.8, are unreliable. On the contrary, values greater than 1.2 could be unreliable or due to the presence of heavier components (C6 +) measured by the TG

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

detector but not recorded by the chromatograph. Figures (2 & 3) illustrate the QC data plotted versus depth with an absolute value of C1 for the two wells in our case study.

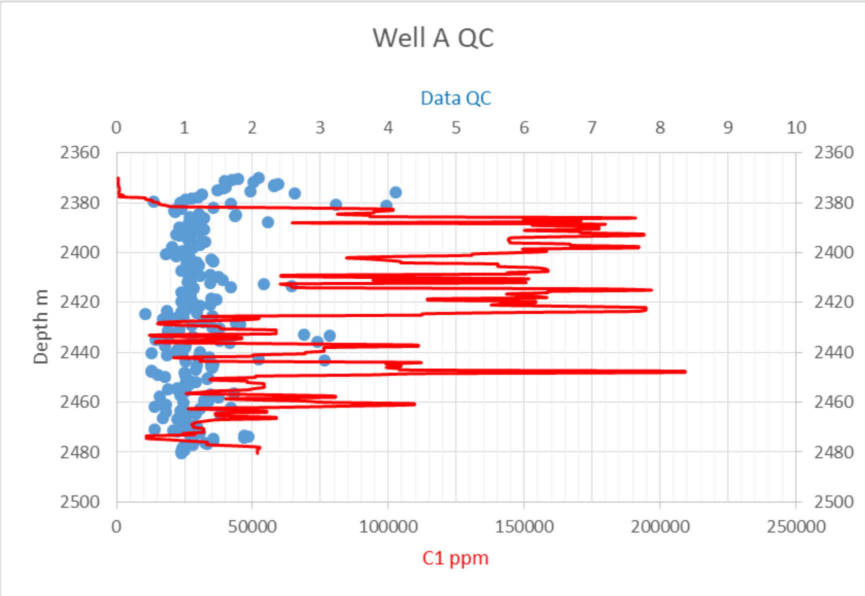

Fig. (2): The QC of gas data in Well A

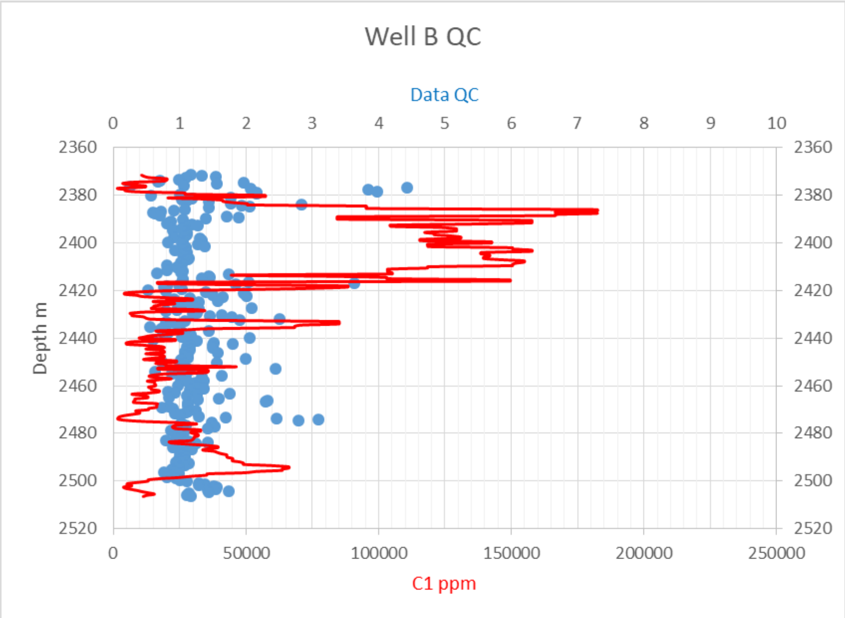

Fig. (3): QC of gas data in Well B

The other data has been used in this case study wireline log, which is consist conventional wireline log and NMR log, so before a formation is logged with an NMR tool, the protons in the formation fluids are randomly oriented. When the tool passes

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

through the formation, the tool generates magnetic fields that activate those protons. First, the tool's permanent magnetic field aligns, or polarizes, the spin axes of the protons in a particular direction. Then the tool's oscillating field is applied to tip these protons away from their new equilibrium position. When the oscillating field is subsequently removed, the protons begin tipping back, or relaxing, toward the original direction in which the static magnetic field aligned them.21 Specified pulse sequences are used to generate a series of so-called spin echoes, which are measured by the NMR logging tool and are displayed on logs as spin-echo trains. These spin-echo trains constitute the raw NMR data [12].

2.2 NMR Processing Workflow:

Petrophysical processing is done in Techlog software using a deterministic method. Workflow followed is summarized below:

2.2.1 Flagging of bad data: This is done using the caliper log and DRHO.

Figure (4) shows a compact composite of the caliper log from two different tools. Wherever the caliper was reading less than 8.5 in, there is a bad hole flag where the bulk density and microresistivity become unreliable.

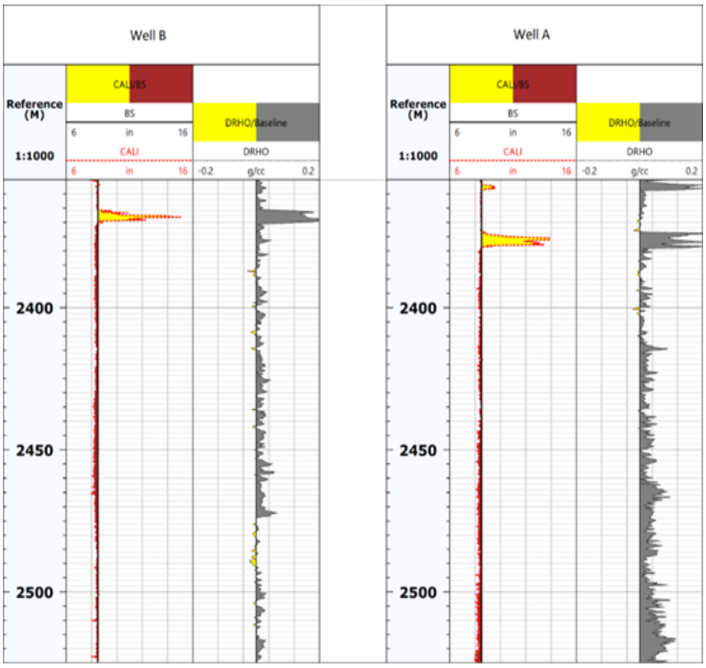

Fig. (4): Log Quality Control and Editing using caliper log and correction density

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

2.2.2 Calculated total porosity using conventional open hole data.

Porosity as an essential reservoir property can be calculated indirectly from Gamma-Gamma-Density log, Neutron log, and Acoustic -/Sonic log, in this case study density and neutron has been used, Figure (5).

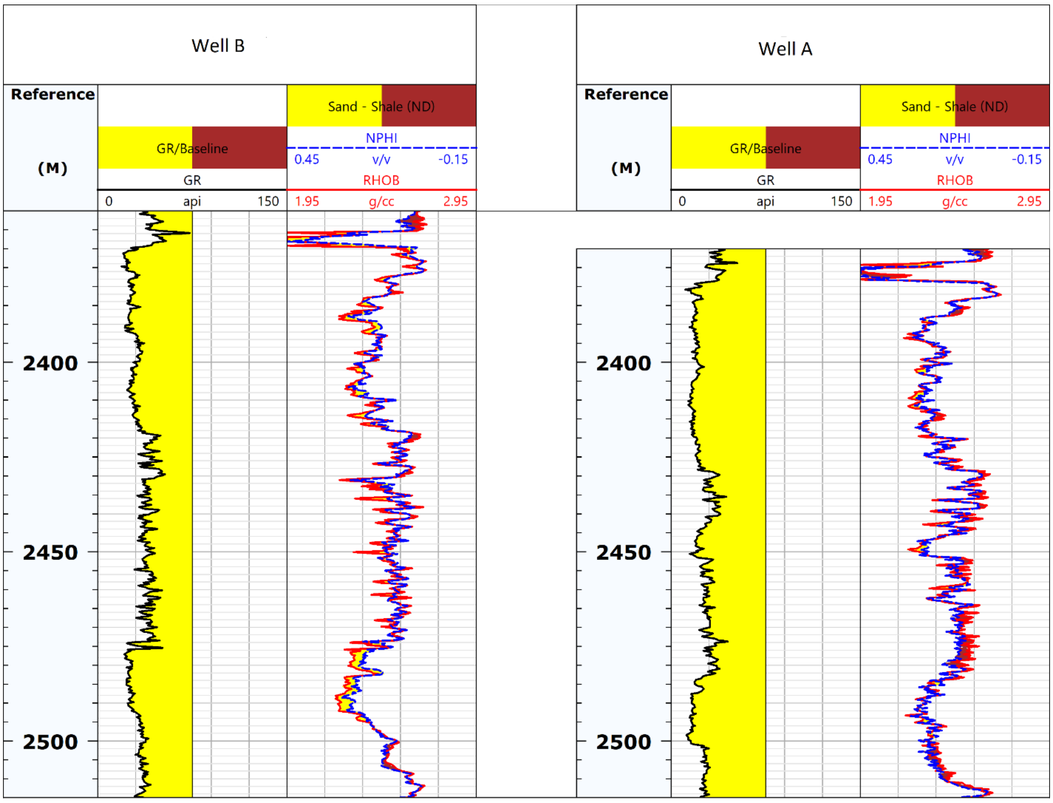

Fig. (5): Log Quality Porosity using Density and Neutron logs

2.2.3 Calculated the total porosity from NMR.

Conventional wireline logging tools are excessively influenced by the rock matrix itself. However, the analyst's chief deal with the storage space (the porosity) and the contents of the pores (the fluid saturations and the types of hydrocarbon). Because, in most status, the rock matrix takes more than two-thirds of the volume sensed by the logging tools, the conventional forms of log analysis leave many questions unresolved. The analyst does not constantly know the accurate grain density of the matrix or the resistivity of the water(s) in the pore space. Because there was no tool in conventional open hole logging that directly exposed porosity or oil, it was fair to say that the loggers measured everything they could, subtracted it from the universe,

Open Access
No. 34 part 1, March 2022, pp.105-120
P- ISSN: 2220-5381
E- ISSN: 2710-1096

and what was left had to be oil. With the advent of modern NMR, a step has obviously been taken in the right direction [11]. Figure (6) shows correspondence the total porosity which determined from both NMR tool and conventional open hole log curve.

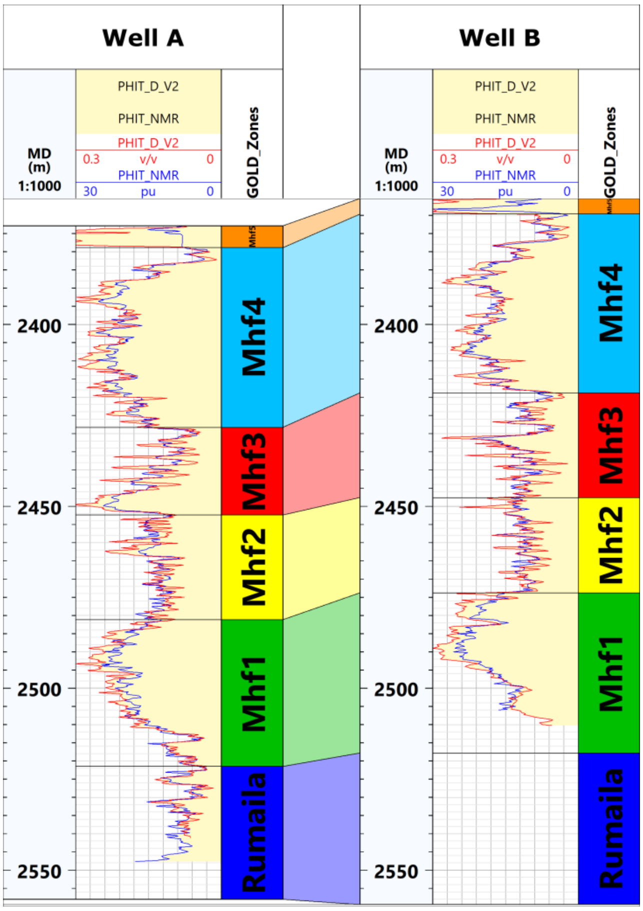

Fig. (6): Illustrate Total Porosity from NMR VS Open Hole

2.2.4 Combined conventional open hole log data with NMR.

Figure 7 shows combined conventional open hole log data for both wells (A and B) which are GR, caliper (CAL) with bit size (BS) logs in the same track, resistivity logs which are micro spherical log (MSFL, lateral log shallow (LLS) and deep lateral log (DLL), porosity logs which are represented by neutron log (NPHI), density log (ROHB), photo electric log (PE) with correction density (DRHO) in the same track, total porosity calculated from density and neutron, water saturation calculated by Archie equation, formation pressure log with advance log which is represented by NMR log.

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

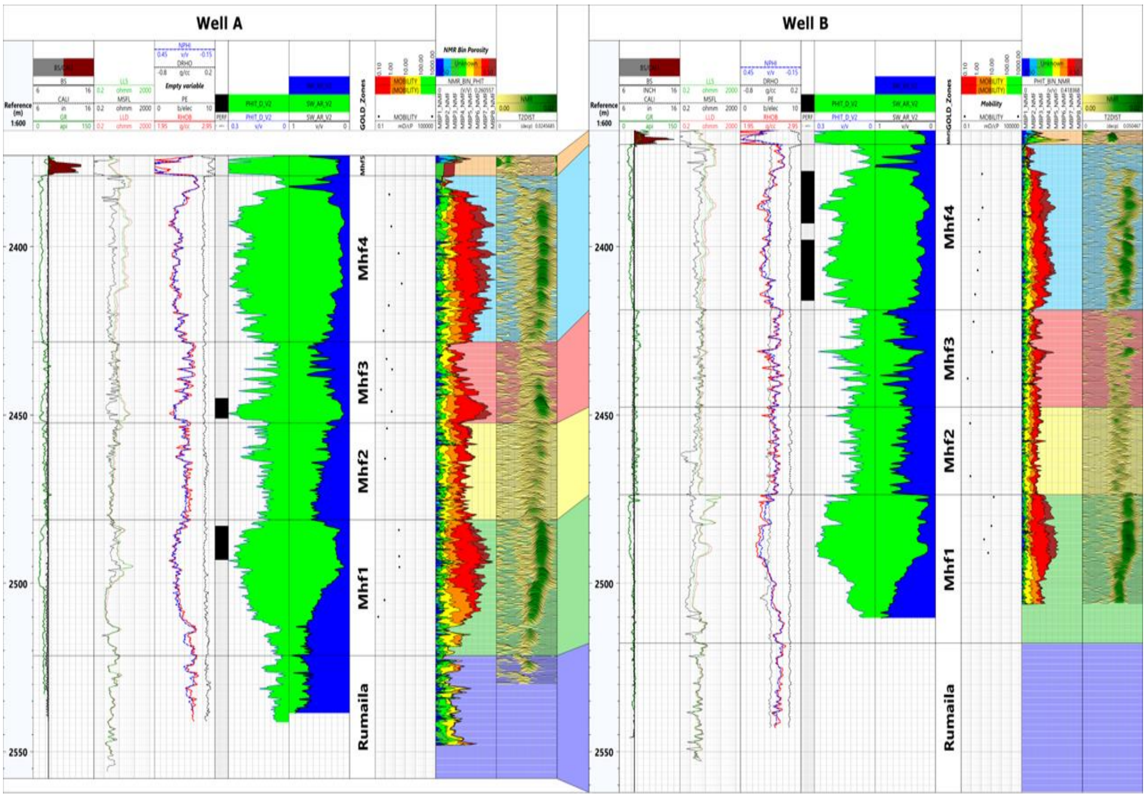

Fig. (7): Combined conventional open hole log data with NMR

3. Mud Gas Data Interpretation

After tested the reliability of data in both wells, some of ratios in GWD™ method used for interpretation, the most important ratio is percentage of Methane ratio that plotted versus depth with an absolute Methane value, Figures (8) and (9). By the curve of C1 in both wells we can observe the upper part of reservoir represent higher values in Methane than the bottom of reservoir but the percentage of Methane in the same range for entire reservoir and that indicate there is no evolution in hydrocarbon, so the reservoir fills in unique fluid.

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

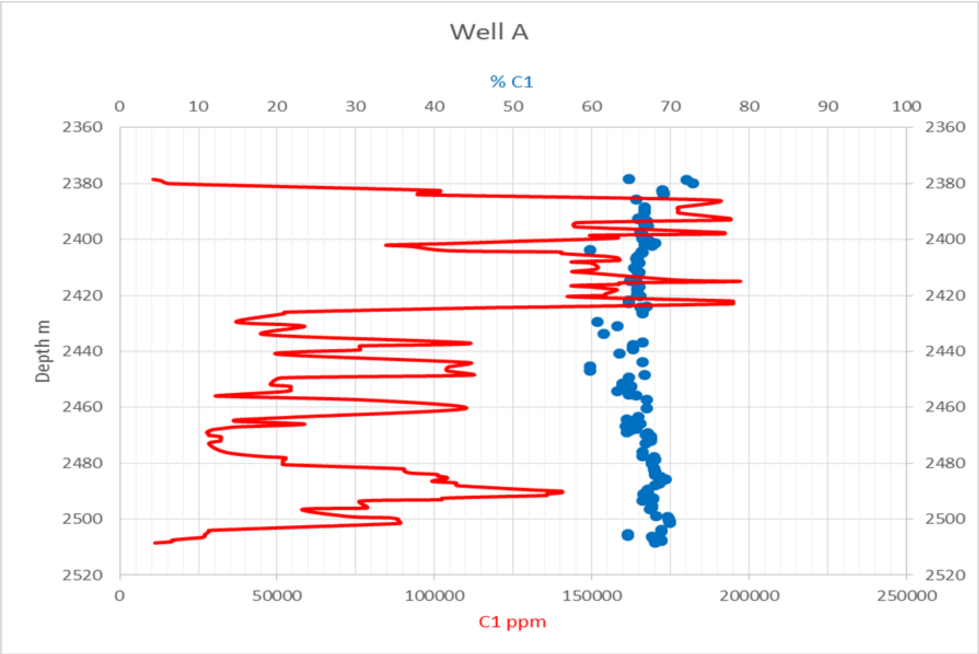

Fig. (8): C1 and %C1 vs Depth for Well A

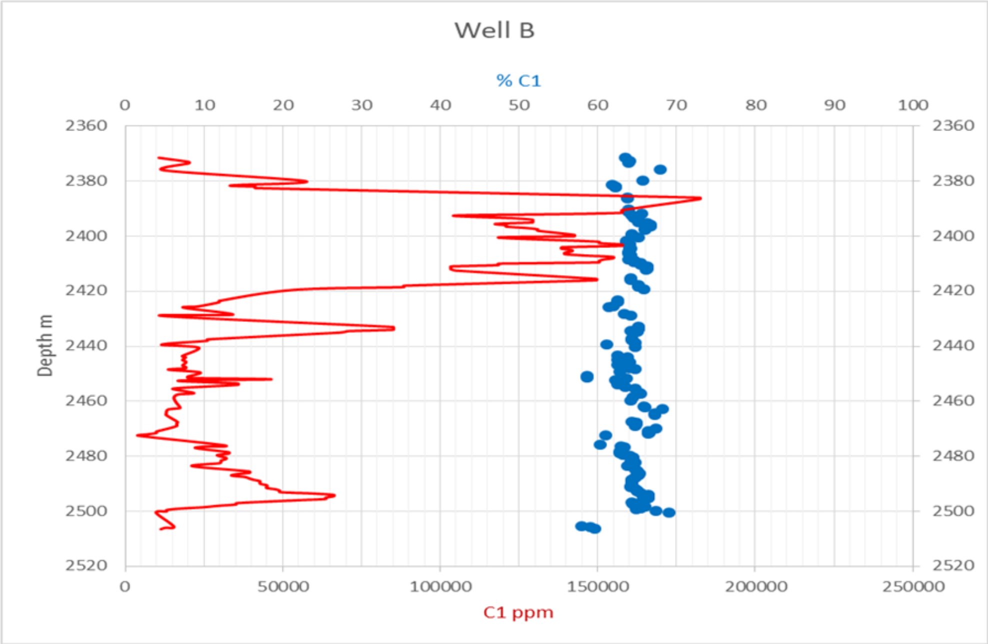

Fig. (9): C1 and %C1 vs Depth for Well B

Other ratio used in this project is C1/C2 ratio that illustrates in Figures (10) and (11), both of wells behave in same way and the range of the Methane/Ethane ratio between

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

3-4 along the reservoir that confirmed the interpretations comes from light gas ratio (%C1) of the hydrocarbon contained in reservoir is unique type of fluid.

The changing in mud gas response between the upper part of reservoir and the rest of formation linked to lithological properties not to type of fluid.

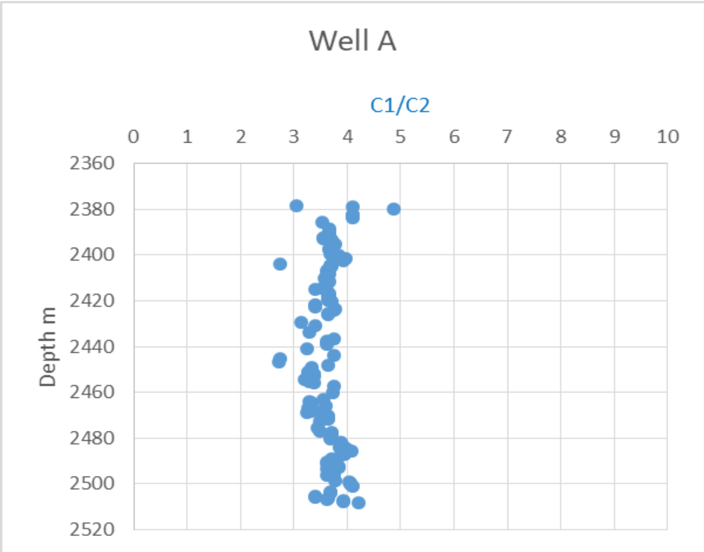

Fig. (10): C1 /C2 vs Depth for Well A

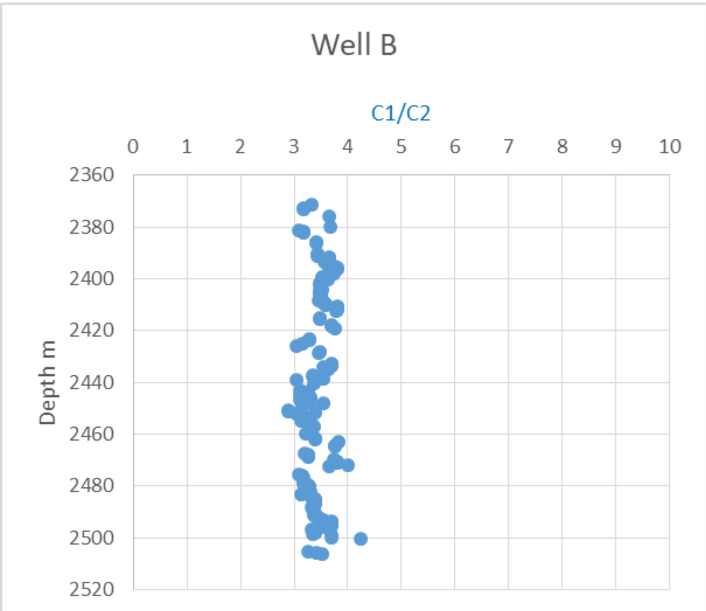

Fig. (11): C1 /C2 vs Depth for Well B

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

4. Wireline Log Data Interpretation

As per open hole wireline log data (Conventional and advance (NMR)) correlation (Figure 7), there is similarity petrophysical properties over Mishrif formation in this case study. Open hole interpretation result in MHF4 shows water saturation (SW) and porosity are very similar as well as the pore size distribution from NMR log present similarity, however well A shows a bit more larger pore size as per NMR result, meanwhile total porosity is similar in both wells in MHF4, as a result petrophysics properties in MHF4 is better than Well B as per NMR result (pore size distribution). MHF2 open hole log data (basic and advance) shows improving petrophysics properties in Well A compare with Well B. MHF1 in both wells are similar, but OWC in Well A is very clear (sharp OWC) as per core and log data has good vertical and horizontal, in other words MHF1 has good communicative, so we need to consider that in the completion strategy.

Current wells situation Well A is perforated in MHF1 and MHF3, while Well B is perforated in MHF4, Well A is flowing but Well B is ceased flowing.

5. Conclusion

- GWD^{TM} analysis shows the changing in mud gas response between the upper part of reservoir and the rest of formation linked to lithological properties not to type of fluid. The problem of well B that not produced from the upper part of reservoir not related for the existing of hydrocarbon or the type of fluid, this result confirmed by the other data (petrophysics analysis) used in this study.
- Petrophysical analysis data (Conventional and NMR) shows in figure 7, there is a variation in rock quality through Mishrif Formation as below:
- Well A:
    - MHF4 unit is differentiate as per density and neutron log average porosity is 22-25%, water saturation is 10% and pore size description as per NMR bin 8 that is presented big pore size, so expected high permeability
    - MHF3 unit has different properties, so the upper part is low porosity about 10%, high SW about 50% and regarding to NMR bin the small

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

pore size is dominated which is less than bin 8, so it seems to microporous layer, but the lower part of this unit has improving properties where porosity more than 25%, water saturation less than 10% and according to NMR bin 8 that is present which is good indicator to permeability due to it has big size pore (bin8).

- MHF2 unit which is characterize by low porosity about 13%, high SW about 50% and regarding to NMR bin they are less than 8 pore size which is indicator to microporous.
- MHF1 unit divided into two part according to petrophysical properties, the upper part which is characterize by high porosity about 25%, low SW 10-15% and good permeability indicator according to NMR bin which is dominated by big pore size (bin 8) and the OWC shows close to perforation layer.

- Well B:
    - MHF4 unit as per density and neutron log shows the porosity is high about 20-25%, water saturation is low about 10-15% and regarding to NMR bins which is indicator to pore size description the comparison between this unit and same unit in the well A, the pore size description seems in the well A (which is not perforated) better than Well B (which is perforated this layer but not flowing).
    - MHF3 unit it seems bad quality whence porosity, SW and por size description and it is as one layer but compared with same unit in well A it is divided into two part which is the lower part better rock properties than the lower part same unit in Well B.
    - MHF2 unit it seems bad quality in both wells, same as properties in Well A.
    - MHF1 unit it seems as two part, the lower part lower quality than upper part which is shows high porosity about 25%, l0% SW and regarding to NMR bins the big pore size is dominated which is indicator to good permeability but didn’t perforate.

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

Nomenclature

BS: Bit size

CAL: Caliper log

DLL: Dual lateral log.

GR: Gamma Ray log.

GWD^{TM}: Gas while drilling Tread Mark method.

Kv: vertical permeability

LWD: Logging while Drilling

MSFL: micro resistivity log

NMR: Neutron Magnetic Resonance

NPHI: Neutron Poros

OWC: oil water contact

PE: Photo Electric log

QC: quality control

TG: total gas

SumCcor: theoretical total gas

SW: water saturation

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

References

[1] Aqrawi, A. A. M., Thehni, G. A., Sherwani, G. H., & Kareem, B. M. A. Mid-Cretaceous rudist-bearing carbonates of the Mishrif Formation: An important reservoir sequence in the Mesopotamian Basin, Journal of Petroleum Geology, 21(1), 57-82, Iraq, 1998.

[2] Al-Ahmed, A.A., Organic Geochemistry, Palynofacies and Hydrocarbon Potential of Sargelu Formation (Middle Jurassic) Northern Iraq. (Unpublished), Ph.D. Thesis. University of Baghdad, 2007.

[3] Al-Khafaji, A J., Hakimi M.H., Al-Ahmed A.A., Organic geochemistry characterization of crude oils from Mishrif reservoir rocks in the southern Mesopotamian Basin, South Iraq: Implication for source input and paleoenvironmental conditions, Egyptian Journal of Histology 27(1):117-130, 2018.

[4] Ellis, L., Brown, A., Schoell, M. & Uchytil, S. Mudgas Isotope Logging (MGIL) assists in Oil and Gas Drilling Operations. Oil and Gas Journal, v.101, no.21, pp.32-41, 2003.

[5] Beeunas, M. A., Baskin, D. K., & Schoell, M. Application of gas geochemistry for reservoir continuity assessment and identification of fault seal breakdown. South Marsh Island, 61, 6-10, 1999.

[6] Pixler, B.O. Formation Evaluation by Analysis of Hydrocarbon Ratios, 43rd Annual Meeting SPE, Houston, n.2254, 1968

[7] Haworth, J. H., Sellens, M. & Whittaker A. Interpretation of Hydrocarbon Shows Using Light (C1-C5) Hydrocarbon Gases from Mud Log Data, AAPG Bull.V.69, No.8, p.1305-1310, 1985.

[8] Whittaker, A. & Sellens, G. Advances in Mud Logging Analysis uses alkane ratios from chromatography, Oil & Gas Journal, pp 42- 49, 1987.

[9] Wright, A.C. Estimation of Gas/Oil Ratios and Detection of Unusual Formation Fluids from Mud Logging Gas Data., SPWLA 37th Annual Logging Symposium, 1996.

Open Access
No. 34 part 1, March 2022, pp.105-120

P- ISSN: 2220-5381
E- ISSN: 2710-1096

[10] Trevizan, W., Coutinho, B., Netto, P., Rios, E., Ramos, P., Salazar, J., & Bressan, M. Magnetic resonance (NMR) approach for permeability estimation in carbonate rocks. OnePetro, Brasil, 2015.

[11] Richard M. Bateman, Open hole Log Analysis and Formation Evaluation, Society of Petroleum Engineers, 667p, 2012.

[12] Coates, G. R., Xiao, L., Prammer, M. G. NMR logging: principles and applications, Haliburton Energy Services, 234p, Houston, 1999.

[13] Kandel, D., Quagliaroli, R., Segalini, G. & Barraud, B. Improved integrated reservoir interpretation using the gas while drilling (GWD) data. In SPE European Petroleum Conference. Society of Petroleum Engineers, 2000.

[14] Mitchell, A., Barraud, B., Beda, G., Segalini, G., & Quagliaroli, R. Gas While Drilling (GWD); A Real Time Geologic and Reservoir Interpretation Tool, SPWLA, 40th Annual Logging Symposium, 1999.