Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 3 Volume 26 March 2020

Chemical, Petroleum and Environmental Engineering

Petrophysical Analysis of an Iraqi Gas Field (Mansuriya Gas Field)

Hasan Saleh Azeez *
Ministry of oil ,midland oil company, Baghdad, Iraq
E-mail :hsnalbaghdade@gmail.com

Dr. Abdul Aali Al-Dabaj
University of technology, petroleum technology department, Baghdad, Iraq
E-mail :resaldabaj@yahoo.com

Dr. Samaher Abdil-Rasool Lazim
University of technology, petroleum technology department, Baghdad, Iraq
E-mail :samaher2013@yahoo.com

ABSTRACT

Mansuriya Gas field is an elongated anticlinal structure aligned from NW to SE, about 25 km long and 5-6 km wide. Jeribe formation is considered the main reservoir where it contains condensate fluid and has a uniform thickness of about 60 m. The reservoir is significantly over-pressured, **(TPOC, 2014)**.

This research is about well logs analysis, which involves the determination of Archie petrophysical parameters, water saturation, porosity, permeability and lithology. The interpretations and cross plots are done using Interactive Petrophysics (IP) V3.5 software.

The rock parameters (a, m and n) values are important in determining the water saturation where (m) can be calculated by plotting the porosity from core and the formation factor from core on logarithmic scale for both and the slope which represent (m) then Pickett plot method is used to determine the other parameters after calculating Rw from water analysis.

The Matrix Identification (MID), M-N and Density-Neutron crossplots indicates that the lithology of Jeribe Formation consists of dolomite, limestone with some anhydrite also gas-trend is clear in the Jeribe Formation.

The main reservoir, Jeribe Formation carbonate, is subdivided into 8 zones namely J1 to J8, based mainly on porosity log (RHOB and NPHI) trend, DT trend and saturation trend.

Jeribe formation was considered to be clean in terms of shale content .The higher gamma ray because of the uranium component which is often associated with dolomitisationl and when it is removed and only comprises the thorium and potassium-40 contributions, showed the gamma response to be low compared to the total gamma ray response that also contains the uranium contribution.While the Jeribe formation is considered to be clean in terms of shale content so the total porosity is equal to the effective porosity.No porosity cut off is found if cutoff permeability 0.01 md is applied while the porosity cut off approximately equal to 0.1 only for unit J6 & J8 if cutoff permeability 0.1 md is applied.

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2020.03.09

Article received:21/7/2019
Article accepted:24/9/2019
Article published:1/3/2020

It can be concluded that no saturation cutoff for the units of Jeribe formation is found after a cross plot between water saturation and log porosity for the reservoir units of Jeribe formation and applied the calculated cut off porosity.
The permeability has been predicted using two methods: FZI and Classical, the two methods yield approximately the same results for all wells.
Keywords: Mansuriya Gas field, Petrophysical properties, reservoirs, crossplot.

((دراسة الخواص البتروفيزيائية لأحد الحقول الغازية العراقية- حقل المنصورية الغازي))

*** حسن صالح عزيز**
وزارة النفط العراقية ,شركة نفط الوسط
العراق ,بغداد

د.عبد العالي الدباج
الجامعة التكنلوجيا , قسم تكنلوجيا النفط
العراق ,بغداد.

. د.سماهر عبد الرسول لازم
الجامعة التكنلوجيا , قسم تكنلوجيا النفط
العراق ,بغداد

الخلاصة

حقل المنصورية الغازي عبارة عن طية ممتدة من الشمال الغربي إلى الشمال الشرقي ، ويبلغ طولها حوالي 25 كم وعرضها 5-6 كم. يعتبر تكوين الجريبي المكمن الرئيسي حيث يحتوي على غاز متكثف ويبلغ سمكه حوالي 60 متر.
يشمل هذا البحث تحليل مجسات الآبار ، والذي يتضمن تحديد معاملات معادلة ارجي البتروفيزيائية ، وتشبع الماء ، المسامية ، النفاذية ، نوع صخارية التركيب وما إلى ذلك. يتم إجراء التفاسير باستخدام برنامج Interactive Petrophysics (IP) V3.5.
تعد قيم معاملات الصخور (a, n, m) مهمة في تحديد تشبع الماء حيث يتم حساب (m) باستخدام رسم لوغارثمي بين معامل تكوين الصخور للباب والمسامية من اللباب للحصول على الميل الذي يمثل (m) ثم باستخدام طريقة مرتسم Pickett plot يتم حساب المعاملات الأخرى بعد حساب مقاومة الماء المكمني Rw من تحليل المياه.
تشير طريقة (MID، M-N و Density-Neutron) إلى أن تركيب الجريبي يتكون من الدولوميت ، الحجر الجيري مع بعض الأنهيدريت ، كما ان تأثير الغاز واضح في هذه المرتسمات.
يقسم تركيب الجريبي الرئيسي إلى 8 وحدات هي J1 إلى J8 ، تعتمد بشكل أساسي على سلوك تسجيلات المسامية وبالإضافة الى كميات التشبع المائي والهيدروكاربوني .
تم أعتبار تركيب الجريبي خالي من الطفل والاطيان حيث ان اشعة كاما العالية بسبب وجود اليورانيوم المتواجد غالباً مع الصخور الدلولمايتية وعند أزالة تاثير اليورانيوم وابقاء تاثير الثوريوم والبوتاسيوم 40 ، كانت اشعة كاما منخفظة بصورة واضحة .
بما ان تركيب الجريبي تم اعتباره خالي من الاطيان والطفل فعندها تكون المسامية الفعالة تساوي المسامية الكلية .
لم يتم ايجاد حد قطع للمسامية في حالة تطبيق حد قطع النفاذية 0.01 مللي دارسي .
وبالتالي يمكن اعتبار عدم وجود حد للقطع بالنسبة للمسامية والتشبع المائي لتركيب الجريبي ضمن حقل المنصورية الغازي .
تم حساب النفاذية بطريقتين (FZI) و(الطريقة الكلاسيكية) و كانت نتائج الطريقتين متقاربة لجميع الآبار.

1. INTRODUCTION

Petrophysics is the study of rock properties and their interactions with fluids (gases, liquid hydrocarbons, and aqueous solutions). The geologic material forming a reservoir for the accumulation of hydrocarbons in the subsurface must contain a three-dimensional network of interconnected pores in order to store the fluids and allow for their movement within the reservoir. Accurate knowledge of these properties required for efficient development, management, and prediction of future performance of the oilfield, **(Schlumberger, 1989)**.

1.1 The Area under study

The Mansuriya Gas Field is located in block 45 in Diyala governorate about 45 km north east of Ba'quba. It is also located about 100 km north east of Baghdad **Fig.1.** 2D seismic data was acquired between 1977 and 1982. 2D Seismic lines were re-processed in 2002 and again in 2006.
It is an elongated anticlinal structure about 25 km long and 5-6 km wide. The hydrocarbon accumulation (gas condensate) is located in the Jeribe formation and has a uniform thickness about 60 m **(TPOC, 2014)**.

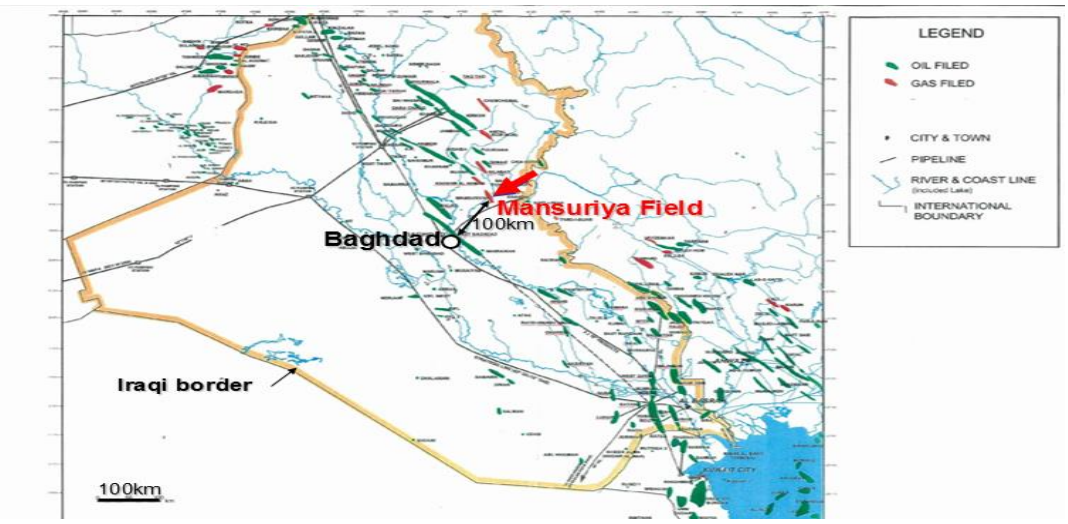

Figure 1. Mansuriya Gas Field Location Map**, TPOC, 2014**.

2. METHODOLOGY:

The available logs data were given as LAS file format for all the wells .The environmental corrections to the log readings were done before starting the interpretation.
The corrections and interpretation of well logs were achieved by using Interactive Petophysics software (IP) version (3.5). It was found that there is no big difference between the corrected logs and the raw log readings because the logs were run in a good borehole with a good mud system.
Accordingly, the input data used where considered the corrected logs to be used evaluate Jeribe formation in Mansuriya Gas Field. The interpretation also includes the determination of porosity, saturation and all the required parameters such as (m and n).
Mansuriya Gas Field has four drilled wells and all of them penetrate the Jeribe formation. Logs and core data were available from all four wells.

3. THE ENVIRONMENT CORRECTION OF WELL LOGS

The environmental corrections are carried out to minimize the effect of the bad hole conditions, **(Asquith , et al.,1982**). IP software was used for the environmental corrections.

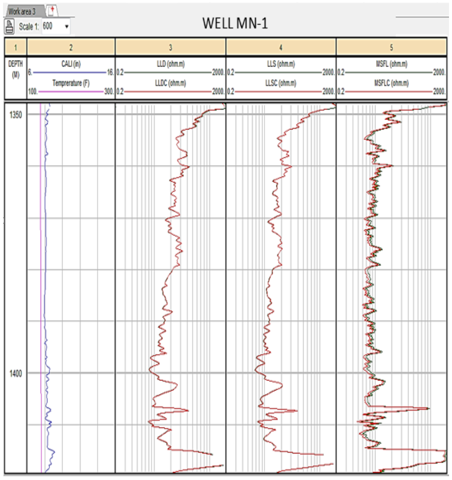

Figure 2. The environment corrections for resistivity tools for well MN-1.

4. RESISTIVITY LOGS

Deep resistivity is a basic measurement of reservoirs fluid saturation and is a function of porosity, **(Schlumberger, 1989).**

5. POROSITY LOGS

5.1 Density log

One of the porosity logs that measure the bulk density for the required depth then equation (1) is used to calculate the porosity as follow, **(Pirson, 1993).**

$$\emptyset_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \tag{1}$$

Where,

Φ_D: porosity from density log (fraction).

ρ_{ma}: the density of the matrix, [whose value is 2.85 (gm/cc) according to core analysis] **(TPOC,2014**).

ρ_b: the bulk density of the formation, (gm/cc) and,

ρ_f: the density of fluid.

5.2 Neutron logs

It is used to determine the porosity directly while its value relative to the amount of hydrogen in the formation which is either from the hydrocarbons or from water in the pores of the formation, **Pirson,1993.**

5.3 Sonic log

One of the porosity logs that measure the capacity of the formation to transmit compressional sound wave for the required depth. Equation (2) is used to calculate the porosity from sonic log value as follow, **(Pirson, 1993):**

$$\emptyset_s = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} \tag{2}$$

Where,

Φs: porosity from sonic log (fraction).

Δt_{ma}: the matrix interval transit time [whose value is 43.5 (μsec/ft) according to core analysis] **(TPOC, 2014)**,
Δt_{log}: interval transit time in the formation, μsec/ft; and
Δt_f: interval transit time in the fluid within the formation [For fresh water mud = 189 (μsec/ft); for salt-water mud = 185(μsec/ft).

5.4 Gamma ray log

Gamma ray log is used to detect the radioactive elements such as uranium thorium and potassium, **(Pirson, 1993).**

5.5 Shale Volume Determination

The behavior of GR log in carbonate rocks as compared to the spectrally corrected gamma ray, GRC curves, where the uranium component (often associated with dolomitisationl) is removed and therefore only comprises the thorium and potassium-40 contributions, showed the gamma response to be low compared to the total gamma ray response that also contains the uranium contribution. For this reason the Jeribe was taken to be petrophisicaly "clean" in terms of shale content, **(Crain, 2015)**.
Also, the SP log in well MN-1 indicates that there is no shale or very small amount in the Jeribe formation as shown in **Fig. 3.**

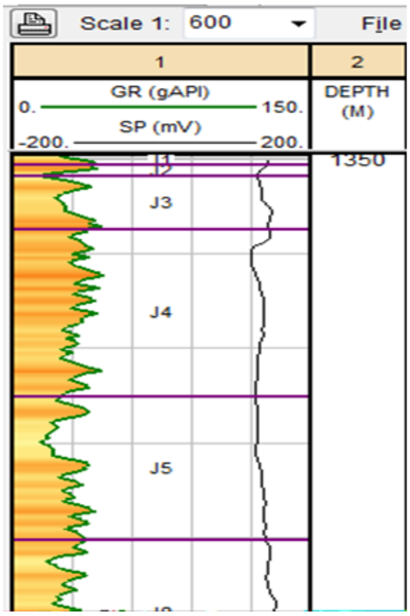

Figure 3. SP log and GR log responses in well MN-1.

The gamma ray responses from Well MN-2 are presented in **Fig. 4**, where the total gamma ray GR is the red curve and the spectrally corrected CGR is the green curve.

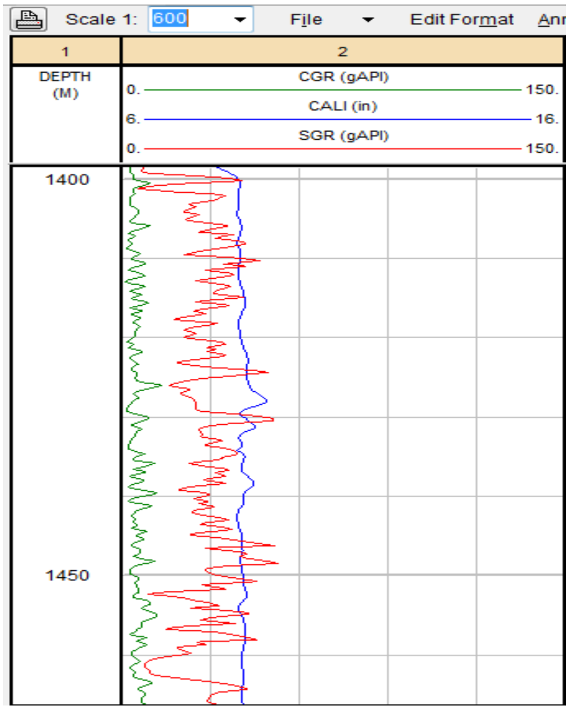

Figure 4.CGR and SGR for the well MN-2**.**

6. **The Matrix Identification (MID) Plot**.MID is used to predict the matrix of the formation depending on the apparent density of matrix and the apparent transit time in rock matrix as follows:

$$\boldsymbol{\rho maa} = \frac{\boldsymbol{\rho b - \Phi ta\rho f}}{\mathbf{1 - \Phi ta}} \qquad (3)$$

$$\Delta tmaa = \frac{\Delta t - \Delta tf\Phi ta}{1 - \Phi ta} \qquad (4)$$

Where,

ρmaa : apparent density of matrix (gm/cc),

Δtmaa : apparent transit time in rock matrix (μsec/ft), and,

Φta : apparent total porosity (fraction) , **(Schlumberger,1989).**

The matrix was determined by the matrix identifiers (MID) crossplot (ρmaa and Δtmaa) for the Jeribe formation as shown in **Fig. 5** for well MN-1.

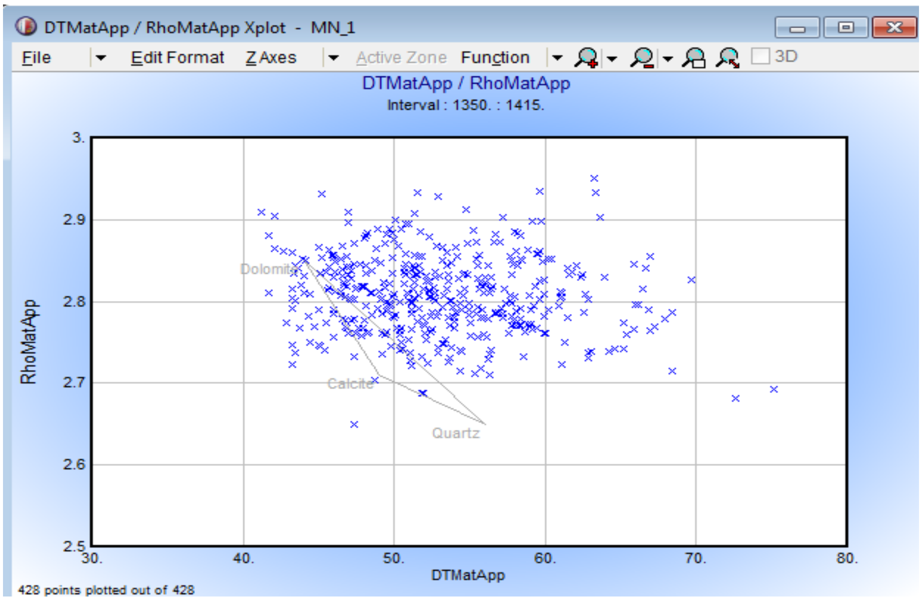

Figure 5.MID plot for the Jeribe formation in MN-1.

While the most of data were plotted around dolomite region and calculated mineral composition show high content of dolomite mineral with some calcite, it is concluded that the Jeribe formation consist of dolomite mineral with some calcite also gas-trend is clear in the Jeribe formation. These crossplots show that the matrix is mainly dolomite and some limestone.

7. M-N CROSS PLOT FOR MINERAL IDENTIFICATION.

The demonstration procedure of this type of cross plots for mineral identification was presented by Schlumberger.

It is a two-dimensional display of all three porosity log responses in complex reservoir rocks, **(Schlumberger, 1989).**

An (M-N) cross plot can be used for lithology determination, gas detection, clay minerals classification, etc. Each mineral has unique set of (M, N) values. However,

$$M = \frac{\Delta tf - \Delta t}{\rho b - \rho f} * 0.01 \qquad (5)$$

$$N = \frac{\Phi Nf - \Phi N}{\rho b - \rho f} \qquad (6)$$

Where, Φ Nf = 1.0.

The M-N crossplots for the Jeribe formation, in **Fig. 6,** for well MN -1, shows that the lithology of Jeribe formation consists of dolomite, limestone with some anhydrite .

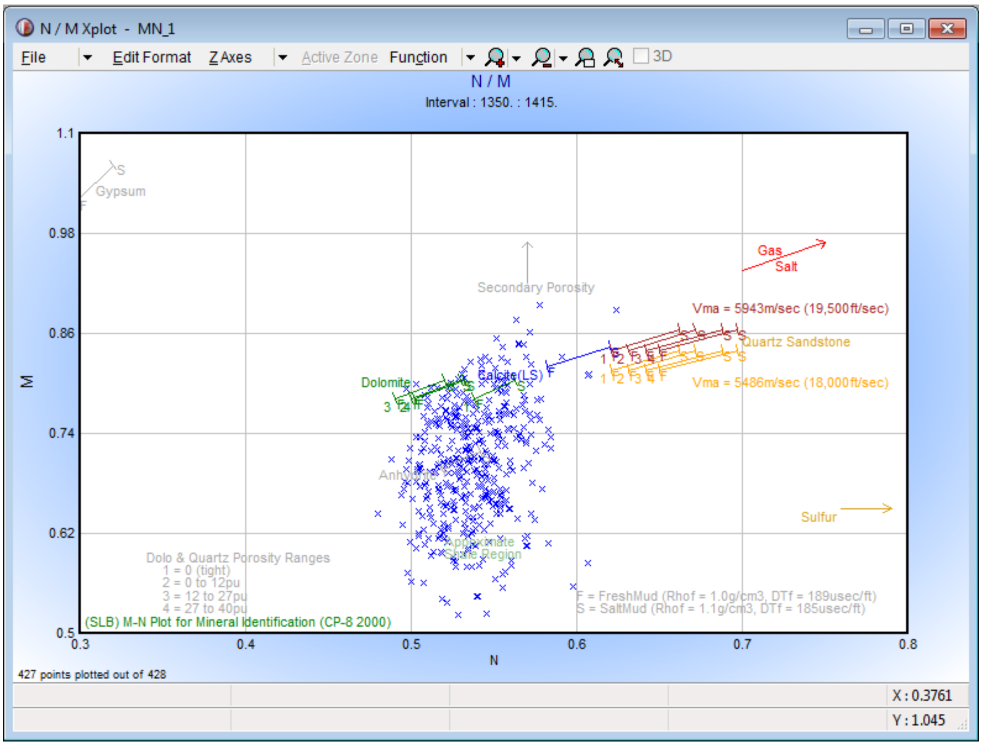

Figure 6. M-N cross plot for the Jeribe formation in MN-1.

8. DENSITY - NEUTRON CROSS PLOT FOR LITHOLOGY:

It is used to determine the lithology of a formation and also the total porosity, **(Asquith, et al.), 1982,** as in **Fig. 7** for well MN-1.

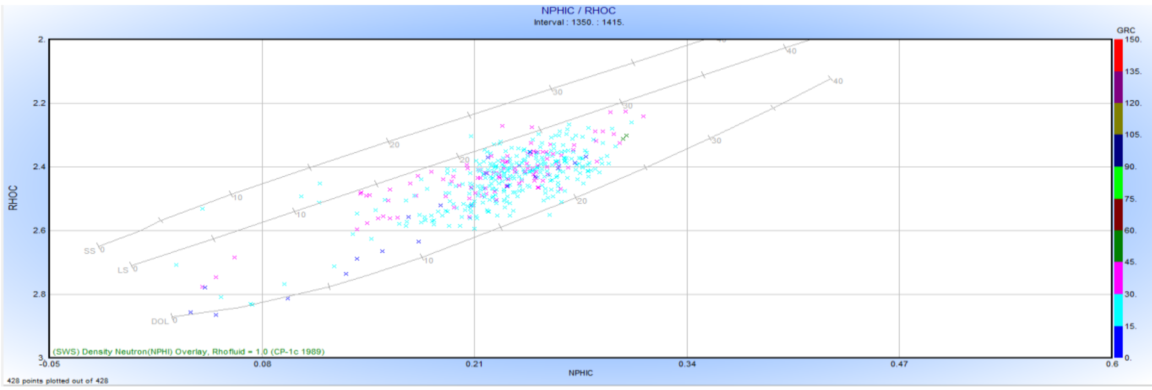

Figure 7. Density-Neutron cross plot for the Jeribe formation in MN-1.

Jeribe lithology is interpreted as mainly dolomite from the above models, limestone or dolomitic limestone is reported as dominant lithology from cuttings and core description.

9. Determination of Porosity

There are three types of porosity:

9.1Total porosity:

It is the ration of the all pores within the rock and the bulk volume using the following equation, **(Asquith, et al., 1982)**:

$$\Phi t = \frac{\Phi N + \Phi D}{2} \quad (7)$$

9.2 Effective porosity:

It represents all the pores within the rock without the pores occupied with clay, **(Schlumberger, 1989).**

$$\Phi e = \Phi t - (1 - Vsh) \quad (8)$$

Where:

Φe = is the effective porosity.

While the the Jeribe formation is considered to be clean so the total porosity is equal to the effective porosity.

9.2 Secondary porosity

It is the porosity formed after the deposition process such as the porosity of fractures. SPI is the secondary porosity index and can be calculated as follows, **(Asquith, et al., 1982).**

$$SPI = \Phi e - \Phi s \quad (9)$$

Fig. 8 shows the effective porosity and secondary porosity index for well MN-1 for the Jeribe formation.

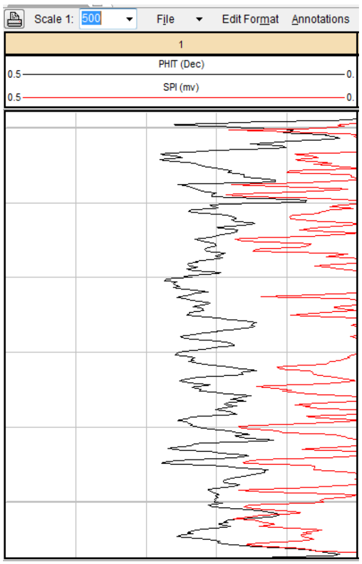

Figure 8. Total and secondary porosity index for well MN-1.

10. CALIBRATION TO CORE.

Core analyses were available from all wells and the core porosity data were compared to the log derived values. Although the comparison showed some scatter, log and core data were in broad agreement, **(Servet, 1998).**

Core porosity with log porosity is plotted for each well and then the porosity from log is corrected according to the equation derived from the plot, **(Schlumberger, 1989)**. **Fig. 9** shows the plot of core porosity and porosity derived from log for all wells. The resulted porosity has a name of (Phi_ND_corrected).

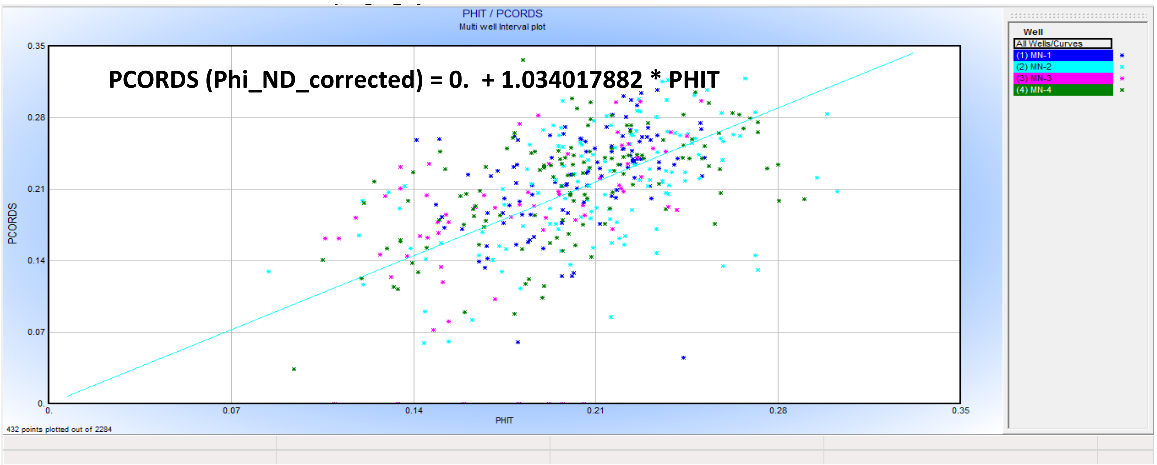

Figure 9. plot of core porosity and porosity derived from log for all wells.

11. DETERMINATION OF FORMATION WATER RESISTIVITY RW

A water sample from the Jeribe formation was obtained in Well Mn-4. The well was tested and found to be water bearing. A salinity of 91,000 ppm was determined from chemical analysis, which is equivalent to 0.048 Ohm.m at 131 °F using Shlumberger chart (Gen 6), **(Schlumberger, 2007)**.

12. DETERMINATION OF ARCHIE PARAMETERS USING PICKETT'S METHOD

Pickett plot method is used to calculate (m) and (a) from well logs by the following equation:

$$Log\ Rt = -m\ log\ \Phi + log\ a\ Rw \qquad (10)$$

By plotting Rt vs. Φe on log-log scale, m is the slope of the line (which represents the points with Sw =100%) and aRw is the intersection point with y-axis at Φe=1. With known Rw from other sources (a) can be easily found. **Fig. 11** shows the picket plot for well MN-4 which shows the values of the tortousity factor (a), saturation exponent (n) and the cementation factor (m) which is obtained by the above technique, Asquith**, (et al., 1982).**

In order to determine the cementation factor (m), **Fig. 10** log-log plot between the core formation factor and core porosity to get the slope which represent (m) for well MN-4, **(TPOC, 2014).**

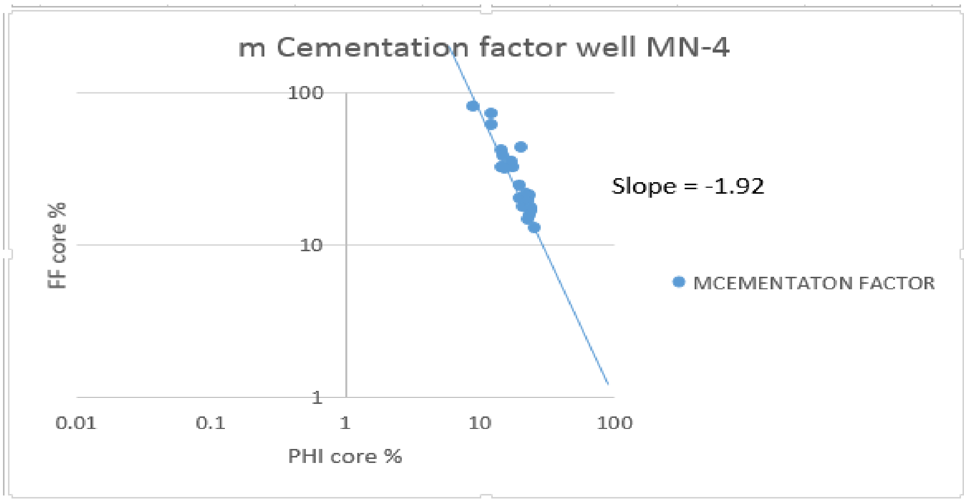

Figure 10.log-log plot of core FF vs PHI core.

The (m) for all wells is ranging from (1.85) to (2.1).

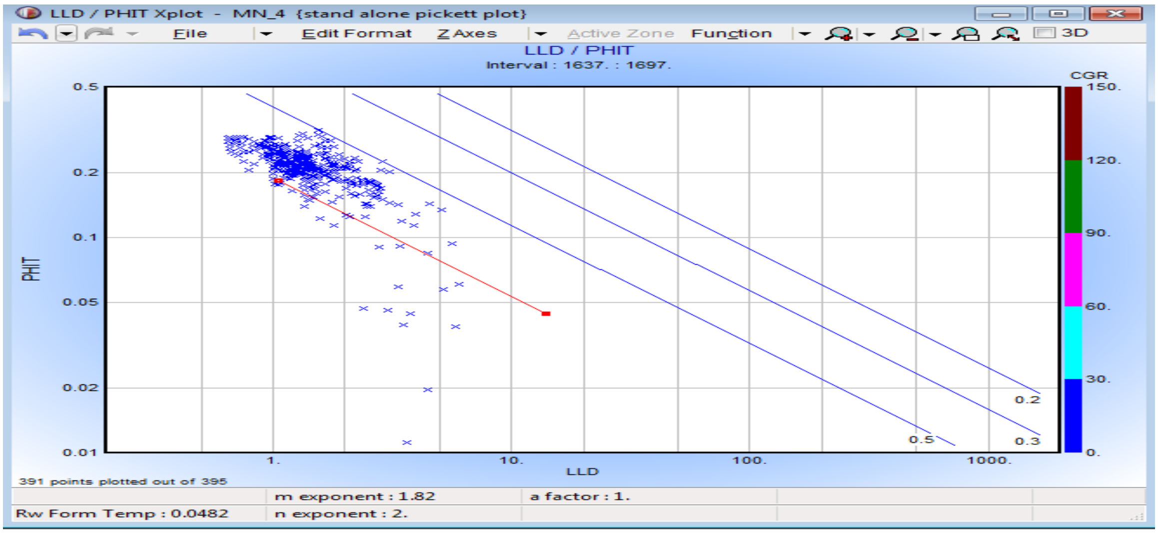

Figure 11. Pickett plot for the Jeribe formation, well MN-4.

There is a good agreement between Rw from pickett plot and from water analysis and Rw is considered to be (0.048 ohm.m) at formation temperature (138 F).

13. FLUID AND FORMATION ANALYSIS

This step considered the final and the most important step in the static formation evaluation to get more accurate water and hydrocarbon saturations for each level.

13.1 Water Saturation.

Archie equation is used to calculate water saturation. This is an appropriate calculation for a conductive 91,000 ppm equivalent sodium chloride brine, shale free rock and total porosity. In the case of Well MN-1, laterologs were used and the deep laterolog response is used as Rt. Wells Mn-2, -3 & - 4 were drilled using an oil based mud (OBM) over the Jeribe Formation, and here the deep induction response is taken as Rt, **(Asquith, et al., 1982)**.

$$FRF = \frac{a}{PHI^m} \quad (11)$$

$$Sw = [(FRF * Rw) / Rt]1/n \quad (12)$$

Where:

FRF = Formation Resistivity Factor

a = Archie a =1

Φ= fractional porosity

m = cementation exponent (1.85 -2.1)

n = saturation exponent (2)

Rt = True Resistivity Ohmm taken from Deep Resistivity

Rw = Formation Water Resistivity Ohm-m

Figures 15-16 show the final CPI of all Jeribe wells.

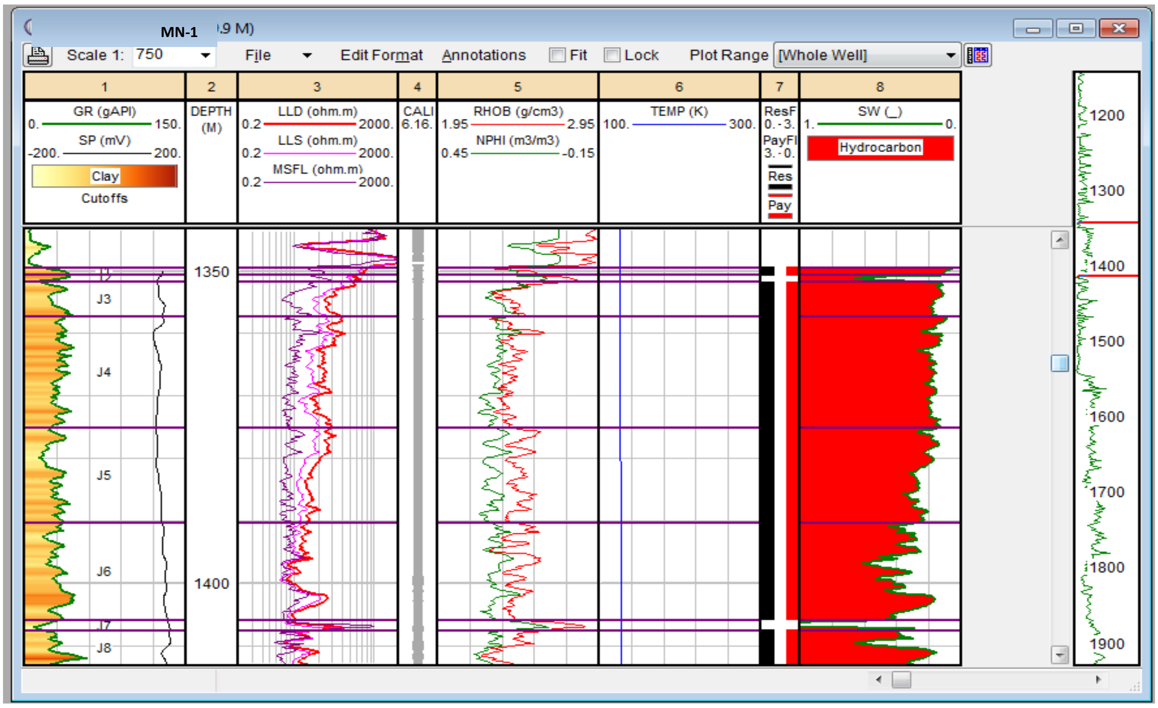

Figure 12.C.P.I. analyses of well MN-1.

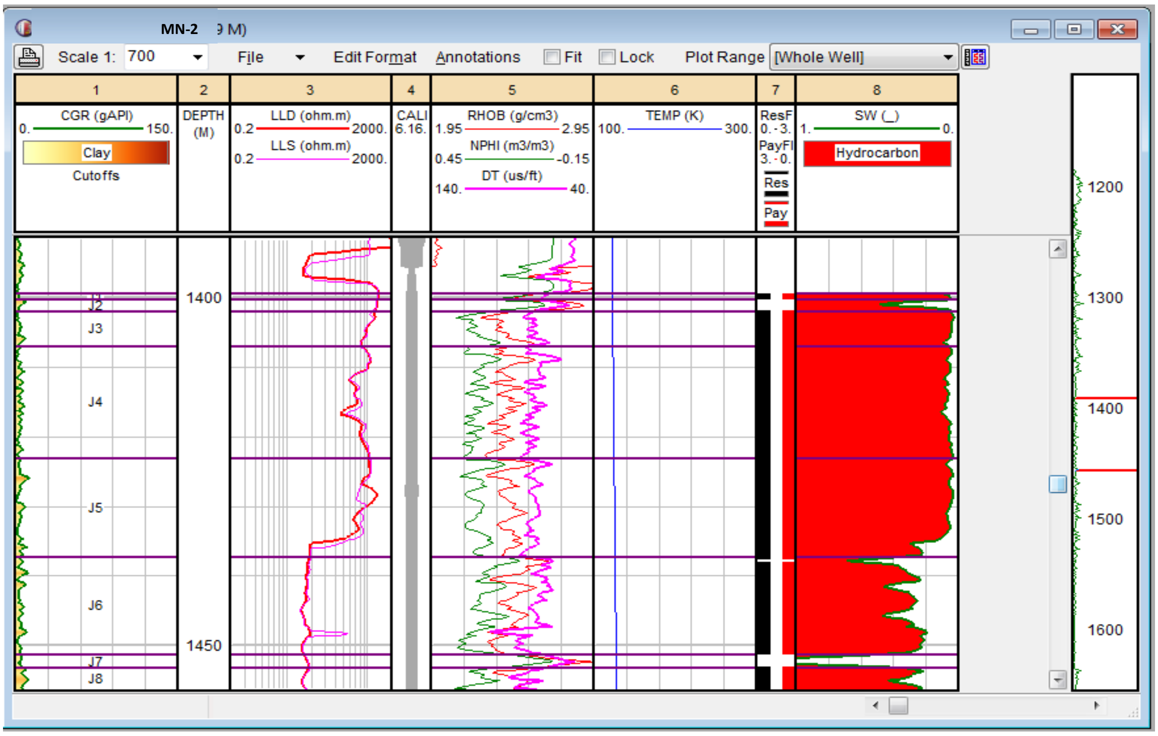

Figure 13.C.P.I. analyses of well MN-2.

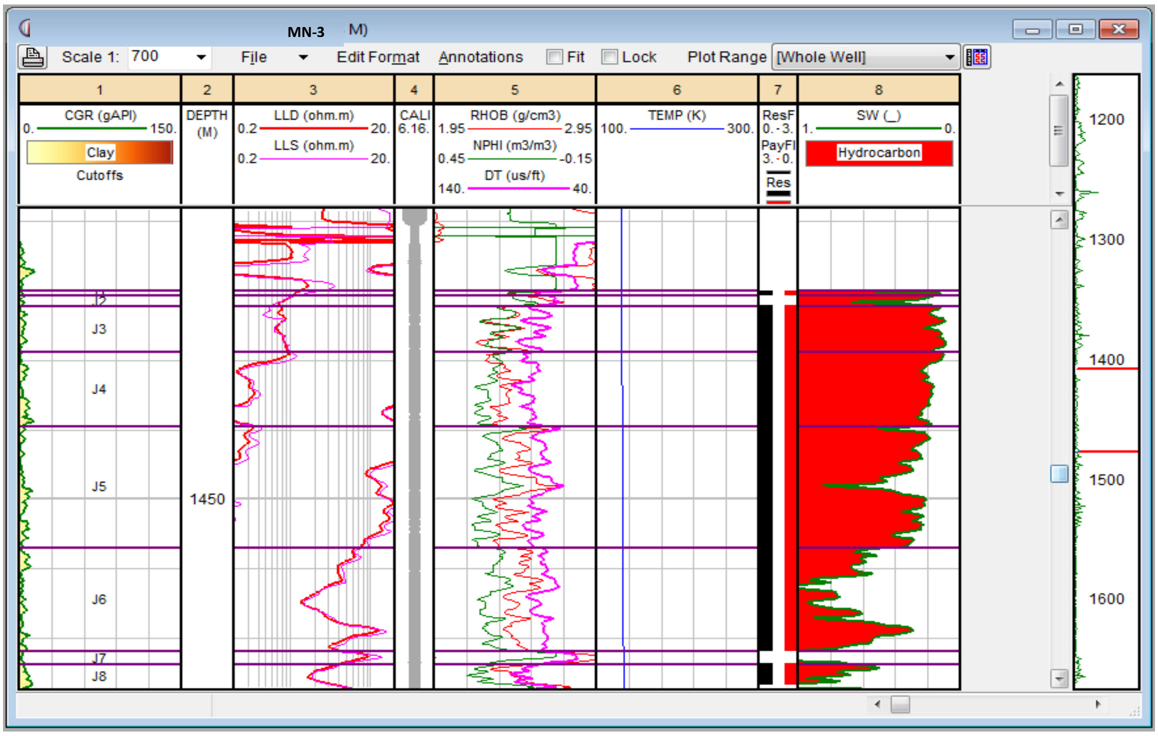

Figure 14.C.P.I. analyses of well MN-3.

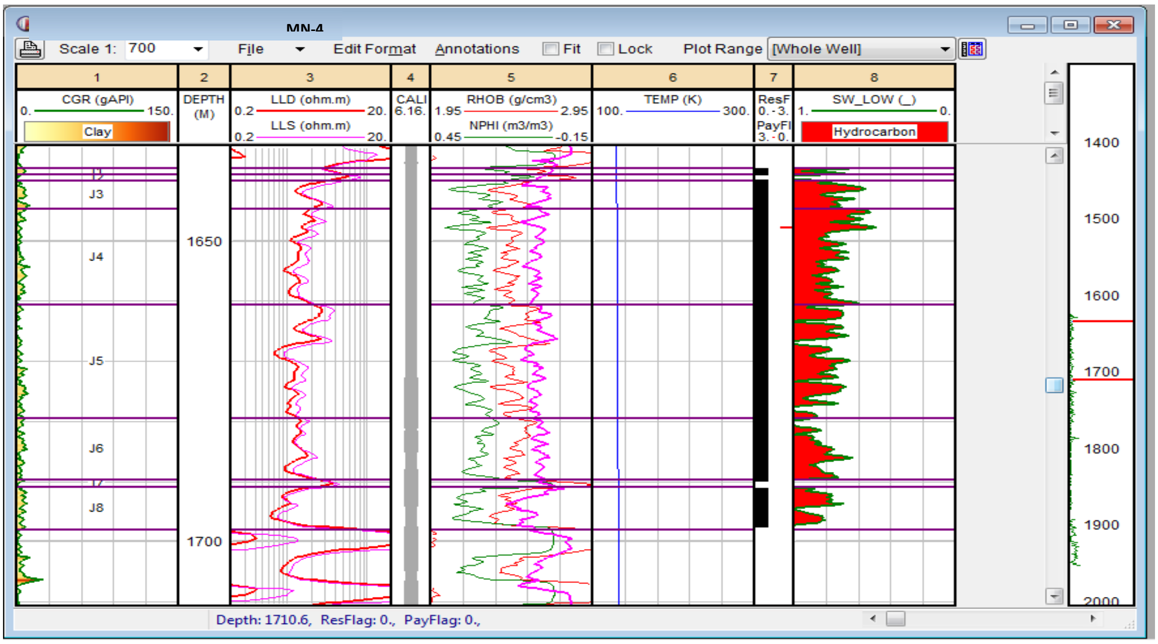

Figure 15.C.P.I. analyses of well MN-4.

14. RESERVOIR ZONATION

The main reservoir, Jeribe Formation carbonate, is subdivided into 8 zones named J1 to J8, based on mainly porosity log (RHOB and NPHI) trend, DT trend and saturation trend, **(Aljawad, 2019).**

15. CUTOFF CALCULATIONS

The cutoff value is applied to specific reservoir parameter (porosity, permeability and water saturation) in order to split the formation into pay and non-pay sections, **(Asquith, et al., 1982).** From the available core data and well logs data for all the four wells, cutoffs for the formation units have been determined as follow:

15.1 Porosity cutoff, (Asquith, et al., 1982).

The available core data analyses have been used to determine the cutoff of core porosity, a plot of permeability (log scale) versus porosity (linear scale) with the intersection of straight line at permeability value of (0.01,0.1 md) with the best fit line.

No porosity cut off is found if cutoff permeability 0.01 md is applied while the porosity cut off approximately equal to 0.1 only for unit J6 & J8 if cutoff permeability 0.1 md is applied .

15.2 Water saturation cutoff, (Asquith, et al., 1982).

To identify water saturation cutoff values, cross plot between water saturation and log porosity for the reservoir units of Jeribe formation has been made, taking log porosity cutoff value and intersecting it with the drawn curve to find water saturation cutoff. **Fig. 16** shows the water saturation cut off for J6 unit.

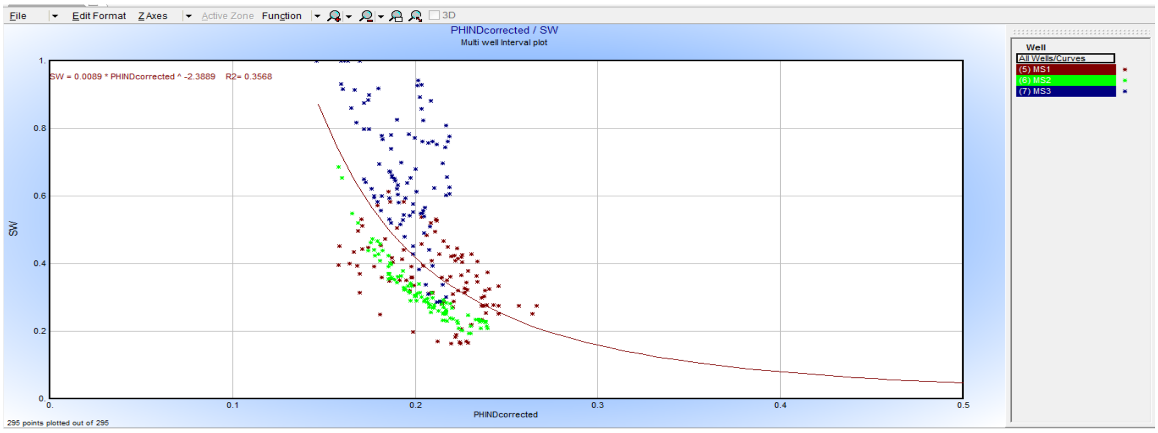

Figure 16. Water saturation cutoff for J6 unit, all wells.

It can be seen that there is no saturation cut off for the units of Jeribe formation.

16. NET TO GROSS

Net to gross defined as the thickness of productive reservoir rocks (net) within the total reservoir (gross) thickness, **(Baker, et al., 2007).**

For Jeribe formation net to gross has been determined by using porosity and water saturation cutoffs, **Table 1** shows the net to gross values for formation units with log calculations summary of well MN-1.

Table 1. Net to gross values with summary calculations for well MN-1.

Zone Name	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw
J1	1349.5	1350.7	1.2	1.2	1	0.152	0.085
J2	1350.7	1352.1	1.4	0	0	---	---
J3	1352.1	1357.4	5.3	5.3	1	0.192	0.148
J4	1357.4	1375.2	17.8	17.8	1	0.211	0.169
J5	1375.2	1390.3	15.1	15.1	1	0.197	0.236
J6	1390.3	1405.9	15.6	15.6	1	0.195	0.354
J7	1405.9	1407.6	1.7	0	0	---	---
J8	1407.6	1415	7.4	7.22	0.976	0.221	0.31
TOTAL	1349.5	1415	65.5	62.27	0.951	0.202	0.245
All Zones	1349.5	1415	65.5	62.22	0.95	0.202	0.245

CONCLUSION :

- The Matrix Identification (MID), M-N and Density-Neutron crossplots indicates that the lithology of Jeribe formation consists of dolomite, limestone with some anhydrite also gas-trend is clear in the Jeribe formation.
- The main reservoir, Jeribe Formation carbonate, is subdivided into 8 zones namely J1 to J8, based on mainly porosity log (RHOB and NPHI) trend, DT trend and saturation trend.
- The Jeribe formation was considered to be clean in terms of shale content .The higher gamma ray because of the uranium component which is often associated with dolomitisationl and when it is removed and only comprises the thorium and potassium-40 contributions, showed the gamma response to be low compared to the total gamma ray response that also contains the uranium contribution.
  - While the Jeribe formation is considered to be clean in terms of shale content so the total porosity is equal to the effective porosity.
  - No porosity cut off is found if cutoff permeability 0.01 md is applied while the porosity cut off approximately equal to 0.1 only for unit J6 & J8 if cutoff permeability 0.1 md is applied .
  - It can be concluded that no saturation cutoff for the units of Jeribe formation is found after a cross plot between water saturation and log porosity for the reservoir units of Jeribe formation and applied the calculated cut off porosity.
  - The permeability is predicted using two methods the FZI and the Classical .The two methods yields approximately the same results for all wells.

REFERENCES_

- Aljawad, M. And Tariq,B.(2019) ‘Estimation Of Cutoff Values By Using Regression Lines Method In Mishrif Reservoir / Missan Oil Fields ‘ , Journal Of Engineering ,[online] 25(2) , pp. 82-95. Available at :<http://joe.uobaghdad.edu.iq>

- Asquith, G., and Gibson, C. “Basic Well Log Analysis for Geologists”, Methods in Exploration Series, AAPG, 1982.

- Baker, H. And Awad ,A. (2017) "Reservoir Characterizations and Reservoir Performance Of Mishrif Formation In Amara Oil Field ". Journal of Engineering, 23(12) pp.33-50. Available at :<http://joe.uobaghdad.edu.iq>

- E.R (Ross) Crain,Petrophysical Handbook,January 2015 . Available at : <WWW.spec2000.net/07-grlog >

- Pirson, S.J.," Handbook of Well Log Analysis", Englewood Cliffs, N.J., Prentice-Hall, Inc., 1993.

- Schlumberger "open Hole Log Interpretation principles and Applications". Handbook, 1989.

- Schlumberger well services, "Log Interpretation Charts", handbook, 2009.
- Servet Unalmiser, SPE, and James J. Funk, SPE, "Engineering Core Analysis" Saudi Aramco, 1998.

- The Integrated Technical Study for the Mansuriya Field or “Mfs” is one of Areas of The Assistance, which has been conducting on “Joint Study Agreement” dated on the 26th of April 2006 by and between MoO and Mitsubishi and Inpex. (unpublished)

- Turkish Petroleum Overseas Company (TPOC) Reservoir Modelling And Simulation Study Of The Mansuriya Gas Field May 2014. (unpublished)

NOMENCLATURE

So, Sw,Sg	Oil, water and gas saturation [fraction]
Φs	porosity from sonic log (fraction)
Δtma	the matrix interval transit time
Δtlog	interval transit time in the formation, µsec/ft
Δtf	interval transit time in the fluid within the formation
ρmaa	apparent density of matrix (gm/cc)
Δtmaa	apparent transit time in rock matrix (µsec/ft)
Φta	apparent total porosity (fraction)
SPI	the secondary porosity index
Rw	Formation water resistivity
Rt	True resistivity
a	the tortuosity factor
n	the saturation exponent
m	the cementation factor
FRF	Formation Resistivity Factor

Greek Symbols	
Ø	Porosity [fraction]
$Ø_e$	effective porosity, fraction

Abbreviations	
CPI	Computer Processed Interpretation
IP	interactive petrophysics
PHI	Porosity [dimensionless]
STO	stock-tank oil
N/G	Net to gross