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Petrophysical Properties and Well Log Interpretations of Tertiary Reservoir in Khabaz Oil Field / Northern Iraq.

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ABSTRACT

The aim of this study is interpretation well logs to determine Petrophysical properties of tertiary reservoir in Khabaz oil field using IP software (V.3.5). The study consisted of seven wells which distributed in Khabaz oilfield. Tertiary reservoir composed from mainly several reservoir units. These units are : Jeribe, Unit (A), Unit (A'), Unit (B), Unit (BE), Unit (E),the Unit (B) considers best reservoir unit because it has good Petrophysical properties (low water saturation and high porous media) with high existence of hydrocarbon in this unit. Several well logging tools such as Neutron, Density, and Sonic log were used to identify total porosity, secondary porosity, and effective porosity in tertiary reservoir. For Lithological identification for tertiary reservoir units using (NPHI-RHOB) cross plot composed of dolomitic-limestone and mineralogical identification using (M/N) cross plot consist of calcite and dolomite. Shale content was estimated less than (8%) for all wells in Khabaz field. CPI results were applied for all wells in Khabaz field which be clarified movable oil concentration in specific units are: Unit (B), Unit (A') , small interval of Jeribe formation , and upper part of Unit (EB).

Keyword: Tertiary reservoir, Petrophysical properties, Khabaz field.

تفسيرات الخواص البتروفيزيائية والجس البئري لمكمن الثلاثي في حقل خباز النفطي / شمال العراق

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الخلاصة

الهدف من هذه الدراسة هو تفسير مجسات الابار لتحديد الخواص البتروفيزيائية للمكمن الثلاثي في حقل خباز النفطي بواسطة برنامج (IP) اصدار (3.5). الدراسة تضمنت سبعة ابار موزعه في حقل خباز . المكمن الثلاثي يتكون من عدة وحدات مكمنية اساسية . هذه الوحدات هي : Jeribe,UnitA,UnitA',UnitB, UnitBE ,and UnitE حيث ان (UnitB) تعتبر افضل

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الوحدات مكمنية لانها تتميز بمراصفات بتروفيزيائية جيدة من حيث التشبع المائي المنخفض والمسامية العالية مع وجود كميات ضخمه من الهيدروكاربون في هذه الوحدة .مجسات ابار كثيرة منها (Neutron , Density) التي استخدمت في الدراسة لتحديد المسامية الكلية والثانوية وكذلك الفعالة في مكمن الثلاثي.لتحديد الصخارية المكمن الثلاثي بواسطة استخدام مرتسم (NPHI-RHOB حيث يتكون بشكل اساسي من الحجر الجيري والدولومايت ولتحديد المعادن يتم ذلك براسطة مرتسم (N/M) حيث يتكون من كالسايت والدولومايت . تقدًر حجم الشيل في عموم المكمن الثلاثي اقل من (8%). تبين نتائج (CPI) لكل الابار حقل حباز بأنه نفوط المتحركة تتمركز في وحدات محدده من وحدات المكمن الثلاثي للحقل خبار وهي : (Unit B) , (Unit A') , مناطق محدده من تكوين جيربي و الجزء العلوي ل (Unit EB).

الكلمات الرئيسية: المكمن الثلاثي , الخواص البتروفيزيائية , حقل خباز .

1. INTRODUCTION

Petrophysical interpretation represents one of most essential process to understand reservoir properties in subsurface structures, geological formation, and physical measurement. This process was used to identify Petrophysical properties which related to interpretations and corrections of well log records (**Cannon, 2016**). The well log related to samples which can be obtained in to subsurface. Reservoirs are subdivided in to several units or zones depends on various Petrophysical properties (primary and secondary porosity, lithology, permeability, fluid saturation, mineralogy **(Ellis and Singer, 2008).**

2. MAIN OBJECTIVES

1. Select units in tertiary reservoir which have good porosity (total, primary, secondary, and effective).
2. Mineralogical and lithological identification for units of tertiary reservoir.
3. Introduce percentage of shale content in all units of tertiary reservoir.
4. Identify concentration of movable and residual oil in tertiary reservoir units.
5. Quantify hydrocarbon saturation (oil and gas) in tertiary reservoir units.

3. AREA OF CASE STUDY

Khabaz oil field is represent one of the more importantly north Iraqi oil fields which characterized by multiple pay zones which produces from tertiary (Jeribe reservoir) and cretaceous (upper and lower Qamchuqe reservoirs). Its located North West (NW) of Kirkuk city and (12 km) far away from center of Kirkuk city. It's encircled by three oil fields Bai Hassan from North West and Baba dome exist in Kirkuk field from north east and Jumbour field from South east as shown in **Fig. 1**. Structurally represents a single symmetrical and anticline dome at subsurface consist of about (18 km) length and about (4 km) width **(Qader and Al-Qayim, 2015).**

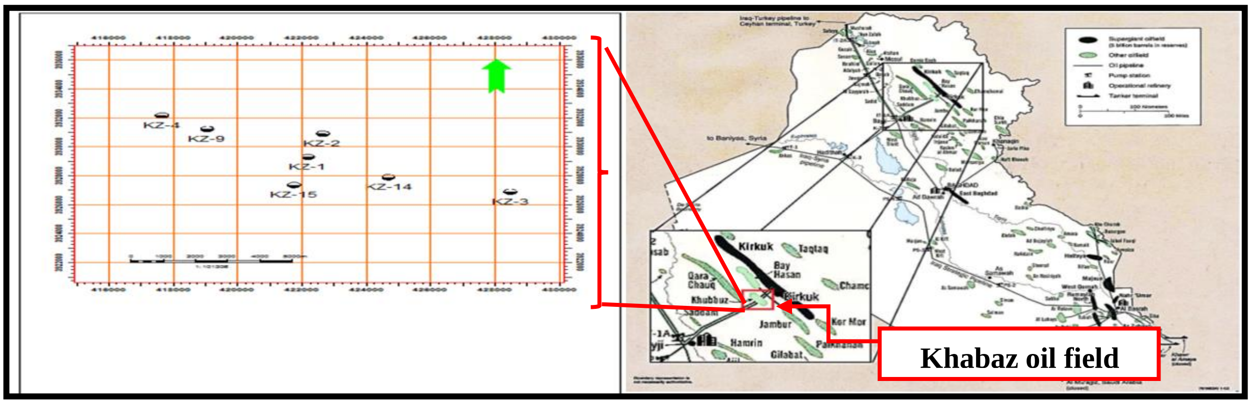

Figure 1. Location map of khabaz oil field.

4. METHODOLOGY

Digder software (V.3.03) used to digitize the scanning copies for wells to provide LAS files for seven wells in Khabaz field (Kz-1, Kz-2, Kz-3, Kz-4, Kz-9, Kz-14, Kz-15).These LAS files for well log are imported to interactive petrophysics software (IP V.3.5), then readings of log are taken as one reading per (0.15m). The log curves are checked to be in depth with each other. All log curves, then depth-matched, the available gamma ray readings taken as a reference guide for depth matching, true corresponding between gamma ray readings and other logging tools was clear at formations tops.. Environmental corrections were made using the current Schlumberger charts which are applied to (IP) software as environmental corrections module, caliper logs, mud properties, and temperature gradient were supplied more accurate for corrections. LAS files were imported to (IP) software which used to determine and correct reservoir properties, resistivity logs, density logs, neutron log, m and n as shown in flow work diagram in **Fig. 2.**

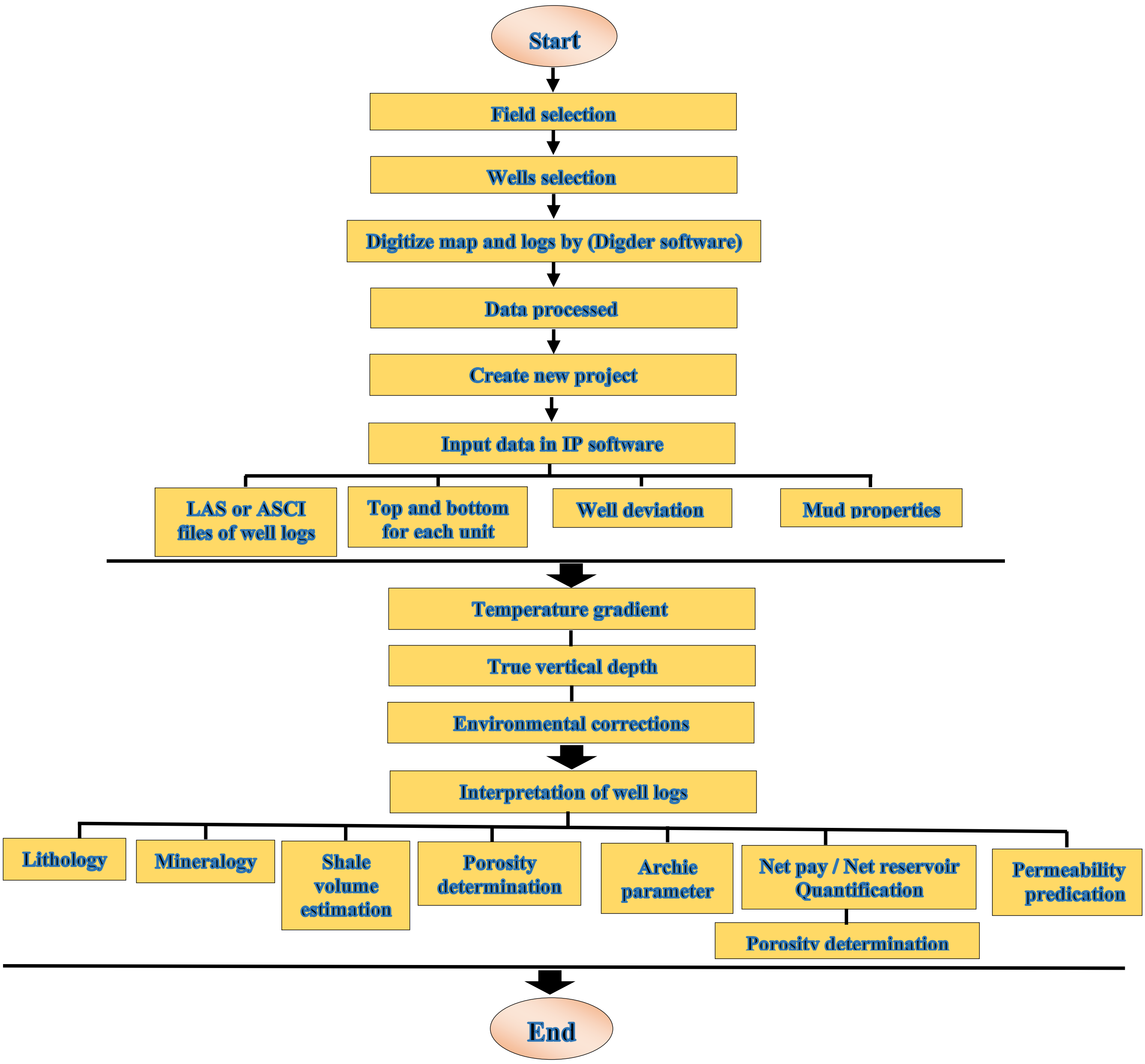

Figure 2. Petrophysical interpretation work flow diagram.

5. BOREHOLE ENVIROMENT

Through drilling operations, normally can be noted pressure of mud column larger than pore pressure in the formation, in order to prevent Blowout into the borehole. The differential pressure between mud filtrate and mud column in the permeable zone and some sediments in the mud which deposited on borehole formed mud cake. Mud cake has very low permeability about (4-10 md). The rate of mud filtrate invasion, whenever move away from borehole shown in **Fig. 3**. Flushed zone represents a zone which have most of hydrocarbon and water are invaded also called invaded zone (**Schlumberger, 1989).**

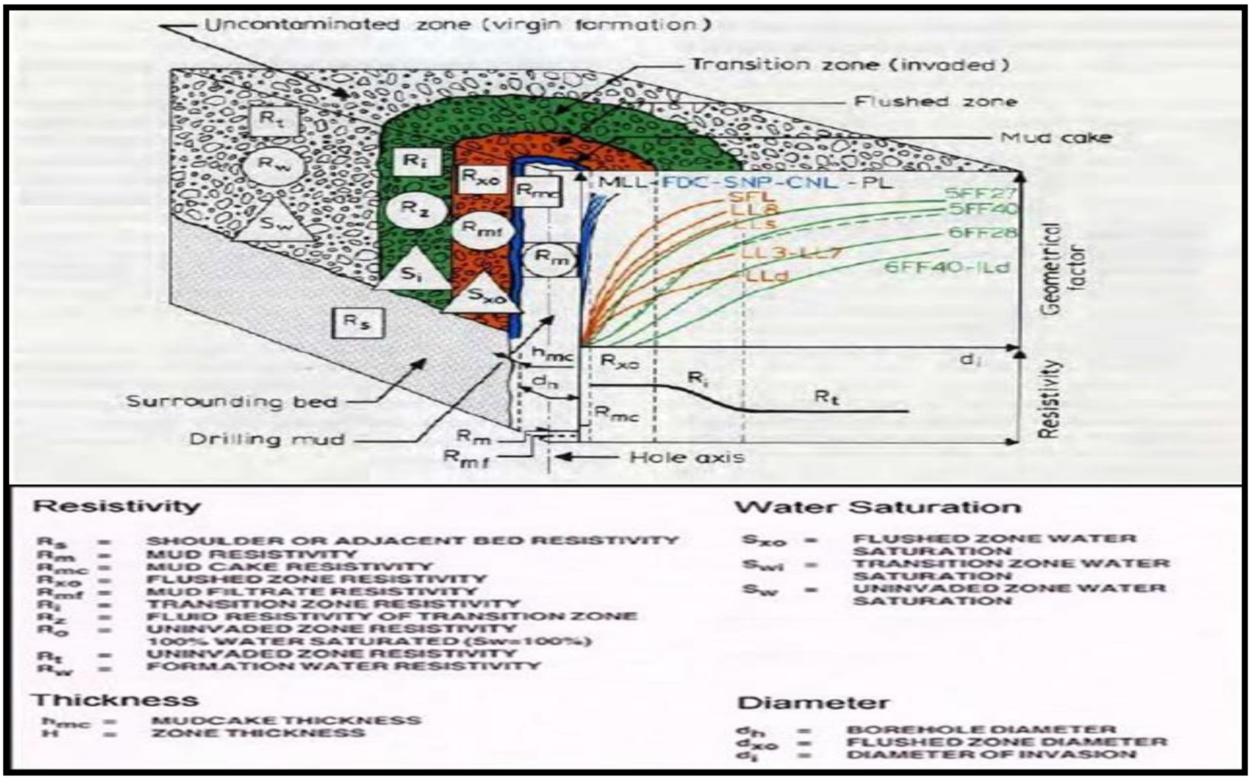

Figure 3. Borehole environmental and symbols of resistivity, thickness, water saturation, and diameter of borehole.

6. ENVIROMENTAL CORRECTION OF WELL LOGS

The borehole environmental can be made by measurement of well logging. A lot of well log records should be modified to stander condition of well log operations because of there are big difference between condition of log tool and condition of bore hole (**Bowen, 2003).** Basically, there was characterized several log measurement leads to various corrections such as.

1. Resistivity logs corrections for borehole effect, invasion of wellbore effects, and bed thickness effects.

2. Density logs corrects for only borehole size.

3. Neutron logs require correction for formation, temperature, borehole diameter, mud salinity, and formation pressure.

6.1 Resistivity Log Corrections

Apparent resistivity is measured by resistivity log. It's consider a resistivity of homogeneous medium. Apparent resistivity consider true resistivity if measurement condition be known. Before this step must be correction various kinds of resistivity log such as, LLS to LLSC, DLL to DLLC, MSFL to MSFLC and so on which illustrated in **Fig. 4.** These corrections were done by IP software **(Imad, 2012).**

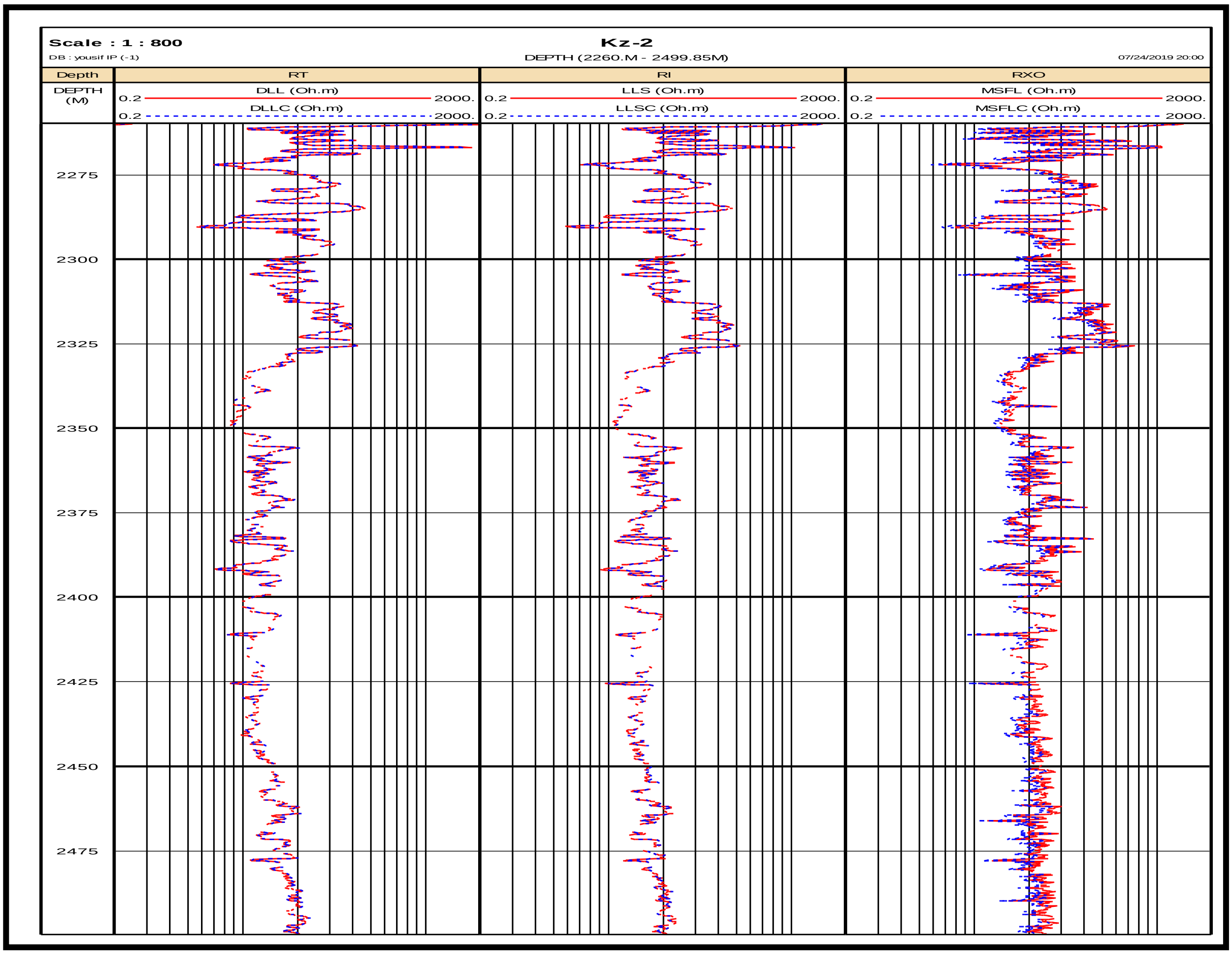

Figure 4. Resistivity log corrections for well (Kz-2).

6.2 Density and Neutron Logs Corrections

Density and neutron must be corrected in order to obtain more accurate for calculations porosity determination shown in **Fig. 5.** Corrections have been applied by using the following equations For density porosity log applying the following equations **(Schlumberger, 1997)**:-

$$\emptyset D\ correc. = \emptyset d - (V_{sh} \times \emptyset_{Dsh}) \quad (1)$$

For neutron porosity log applying the following equations **(Debrandes, 1985)**:-

$$\emptyset N\ correc. = \emptyset n - (V_{sh} \times \emptyset_{Nsh}) \quad (2)$$

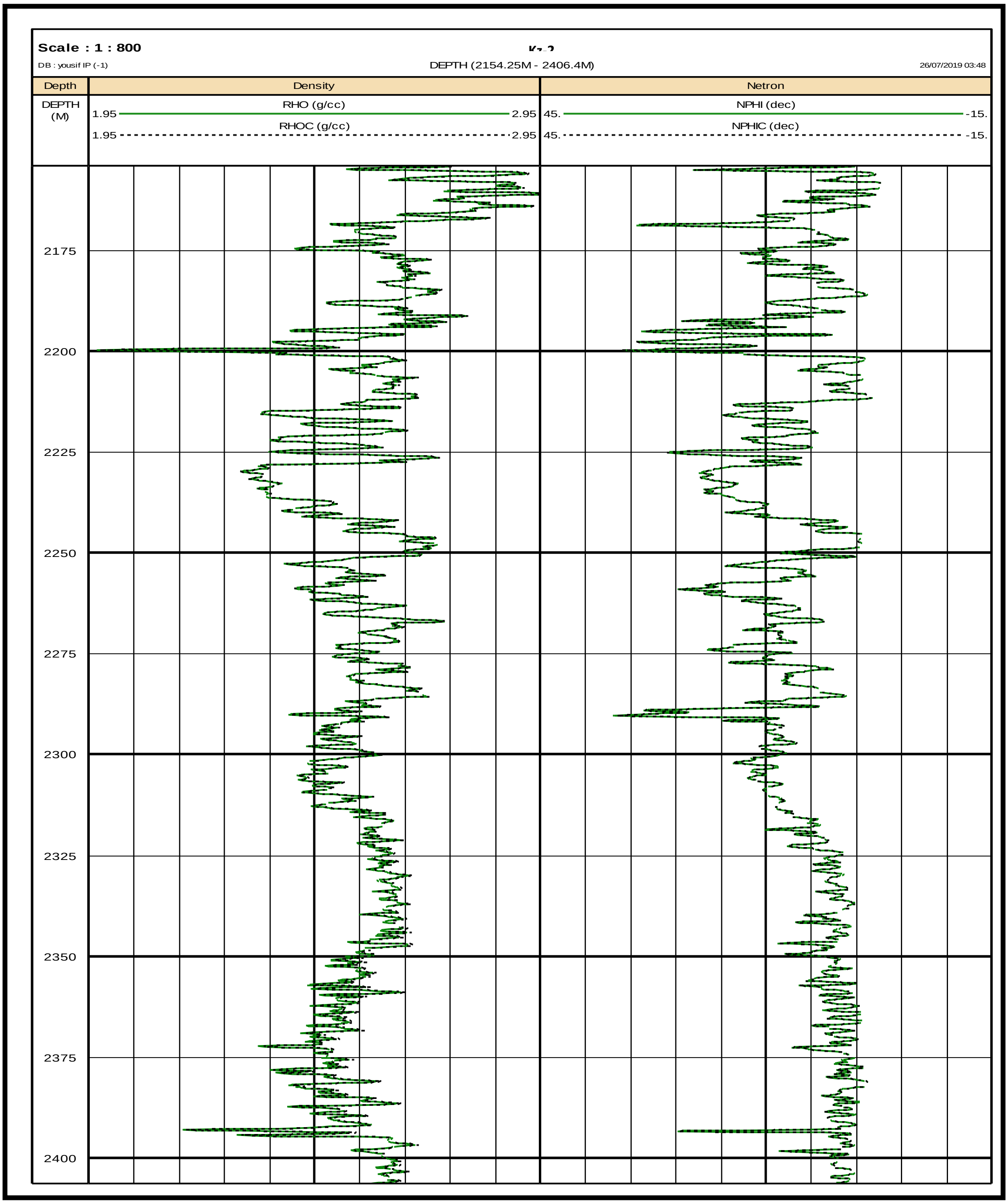

Figure 5. Neutron and density logs corrections for well (Kz-2).

6.3 Gamma Ray Log Correction

The GR is used to identify shale beds when SP log reading curved. As well as used to evaluation and quantify radioactive minerals **(Schlumberger, 2013).** IP software used to environmental corrections for gamma ray log for (Kz-2) shown in **Fig. 6.**

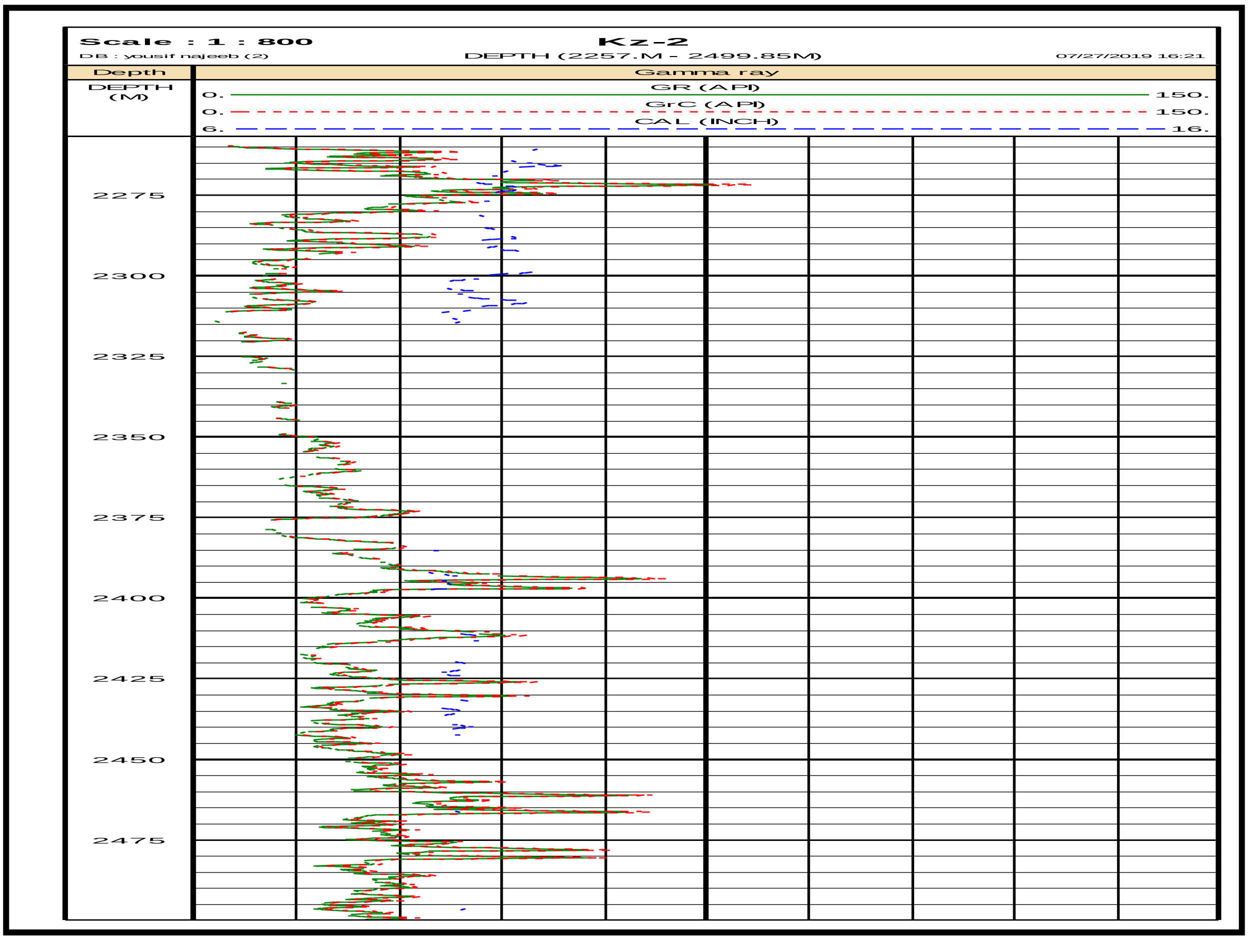

Figure 6. Gamma ray log correction for (Kz-2).

7. PETROPHYSICAL PROPERTIES

7.1 Shale Volume Estimation

Shales are not permeable zone but usually porous and have hydrocarbon. The existence of shale in the reservoir effects on value of porosity and water saturation which are derived from well log. Well logging tools such as (Neutron and sonic) logs will record too high, while Resistivity logs records too low when shale exists in formation. If density of shale will read equal or greater than reservoir index matrix leads to density log records too high (**Aljawad and Tariq, 2019)**. To get more accurate of shale volume calculations must be make corrections for Gamma Ray log shown in **Fig. 7.**

Tertiary rocks can be classified as young rocks depending on geologic period of rocks .So best model to consider for young rocks is Larionvo equation **(Schlumberger, 1997)**. The first step to estimate (Vsh) by using gamma ray log as follow:

$$IGR = \frac{Grlog - Grmin}{Grmax - Grmin} \quad (3)$$

Then for tertiary reservoir young rock method was used (Vsh) as formula **(Asquith and Gibson, 1982)**:

$Vsh = 0.083\ (2^{(3.7*IGR)} - 1)$ (4)

In **Fig. 7.** Clarify the results of shale content estimation for well (Kz-2). Jeribe formation showed volume of shale exceed (18 %) but consider the lower part of all drilling interval. Where shale volume in tertiary reservoir average is less than (8%) in all wells which explained in **Fig. 8.**

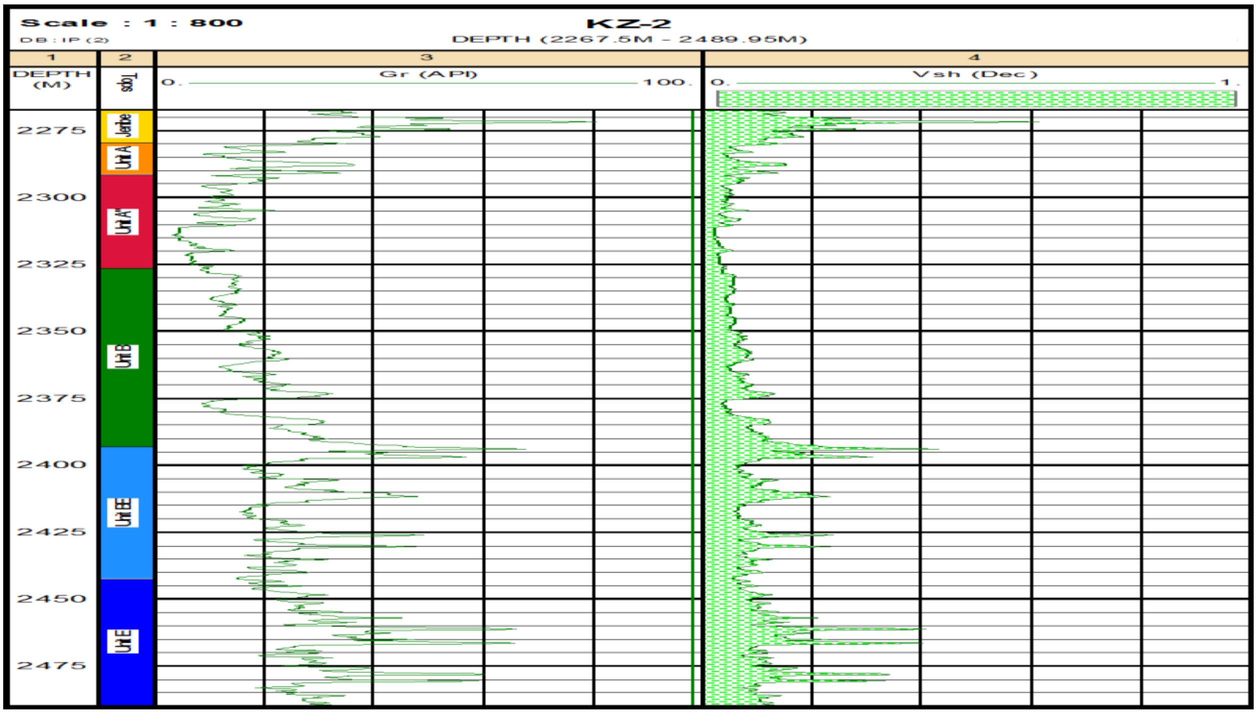

Figure 7. Calculation of Vsh in (Kz-2) well.

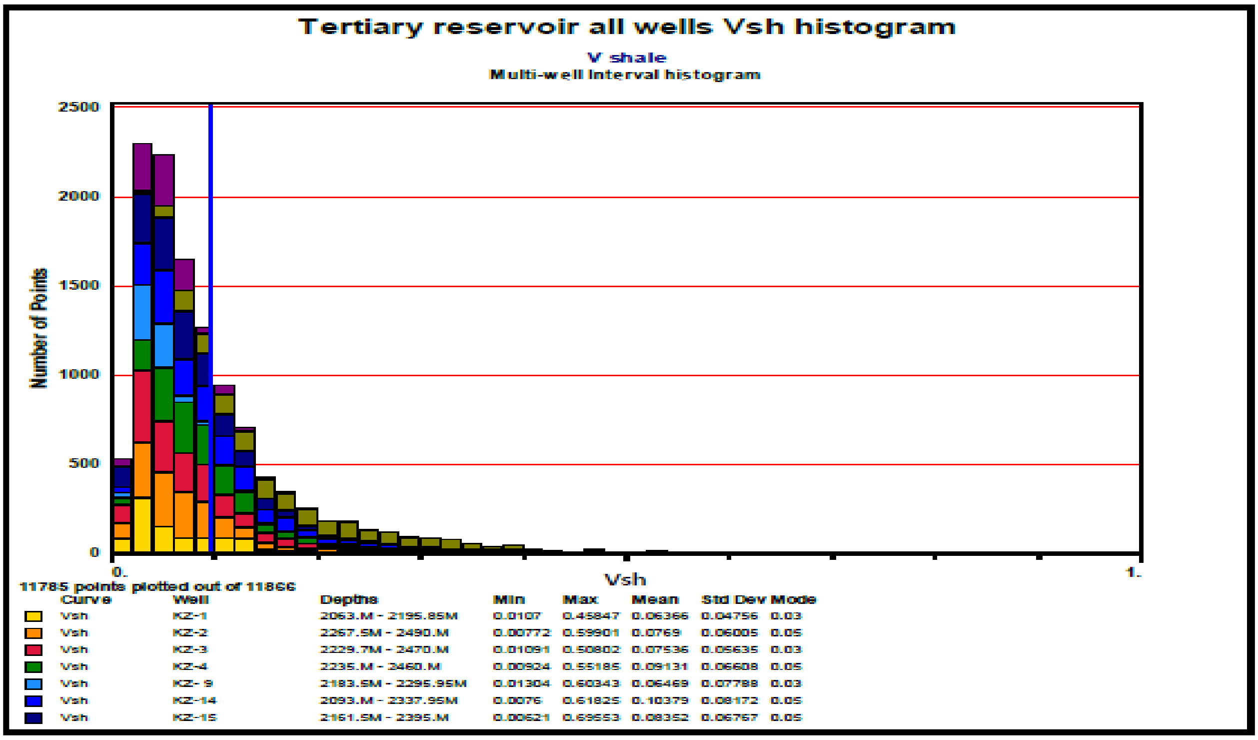

Figure 8. Shale volume histograms for all selected wells in tertiary reservoir.

7.2 Porosity Determination

The total porosity in Jeribe formation can be calculated by integration of Neutron – Density logs readings (**Bowen, 2003**).

7.2.1 Total Porosity

Generally total porosity can be introduced as a ratio pore space of rocks to bulk volume **(Ezeke, 2010).**

$$\Phi t = \frac{\varphi_N + \varphi_D}{2} \quad (5)$$

7.2.2 Effective Porosity

Effective porosity consider total porosity smaller than fraction of pore spaces which are fill by clay and shale. In clean formation, total porosity is similar to effective porosity shown in **Fig. 9.**

$$\emptyset_e = \emptyset_t \times (1 - V_{sh}) \ (6)$$

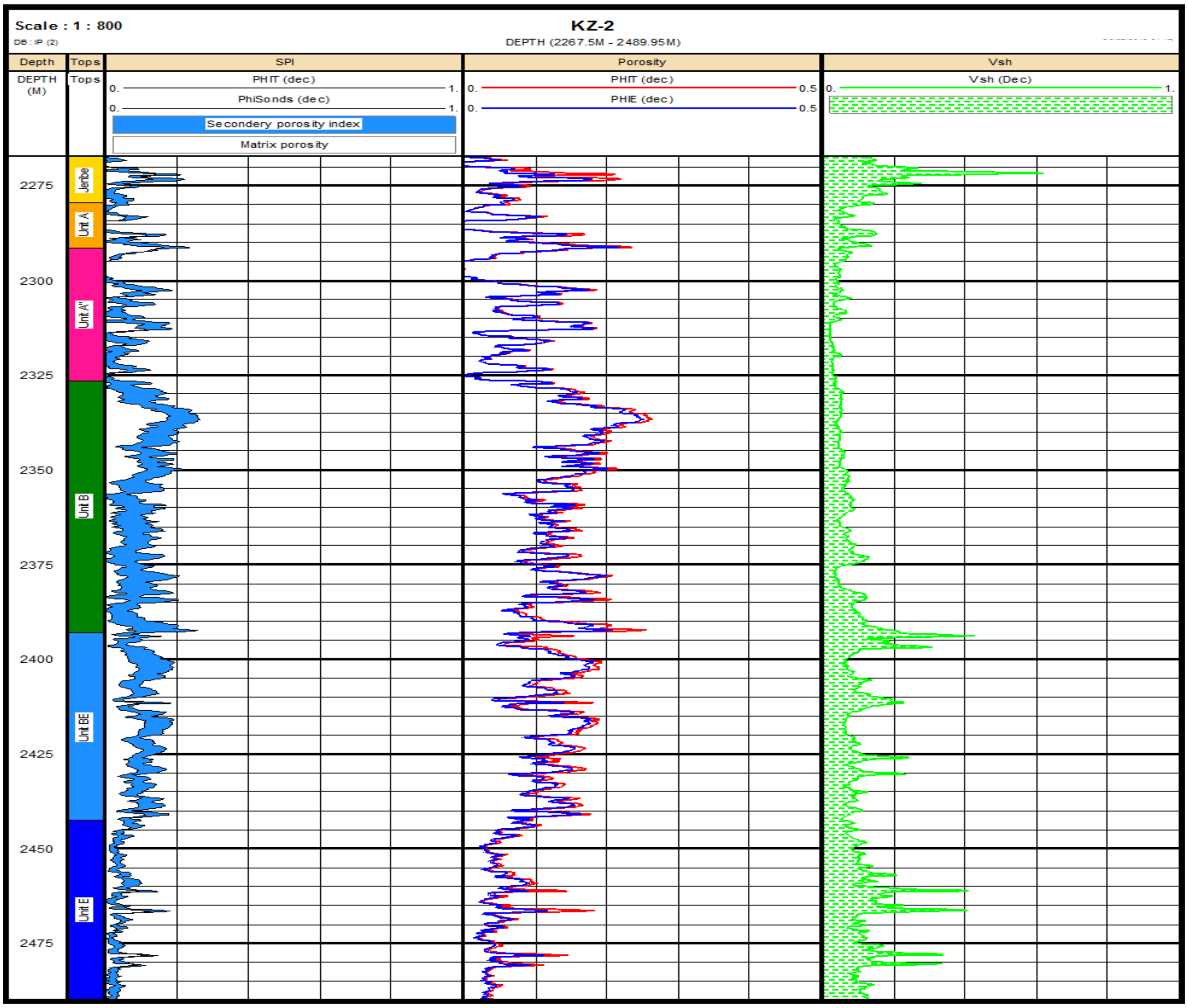

Figure 9. Types of porosity in (Kz-2) well.

7.2.3 Secondary Porosity

Secondary porosity formed after deposition operation in reservoir. Secondary porosity can be determined by secondary porosity index (SPI) **(Ezeke, 2010).**

$SPI = \Phi t - \emptyset_s$ (7)

7.3 DETERMINATION OF LITHOLOGY AND MINERLOGY

It's necessary to determine lithology of formation to describe sediments, solid, rocks, matrix and reservoir characterization, and that have been done by using two cross plot.

7.3.1 The Neutron-Density Cross Plot for Lithology Identifications

This cross plot is much important in well log analysis to determine porosity and lithology of formation by cross plot neutron porosity verses bulk density (ΦN Vs. ρb), for producing fresh water base mud, clean matrix rocks and for full structured liquid. This cross plot explained many lithology such as, sandstone, limestone, dolomite and good lithological resolution for calcite, quartz, and anhydrite are easily selected **(Schlumberger, 2008).**
Neutron-density cross plot for selected wells in khabaz field are clarify that most of points fell between limestone and dolomite lithology curve that illustrated in **Fig. 10** for well (kz-2).

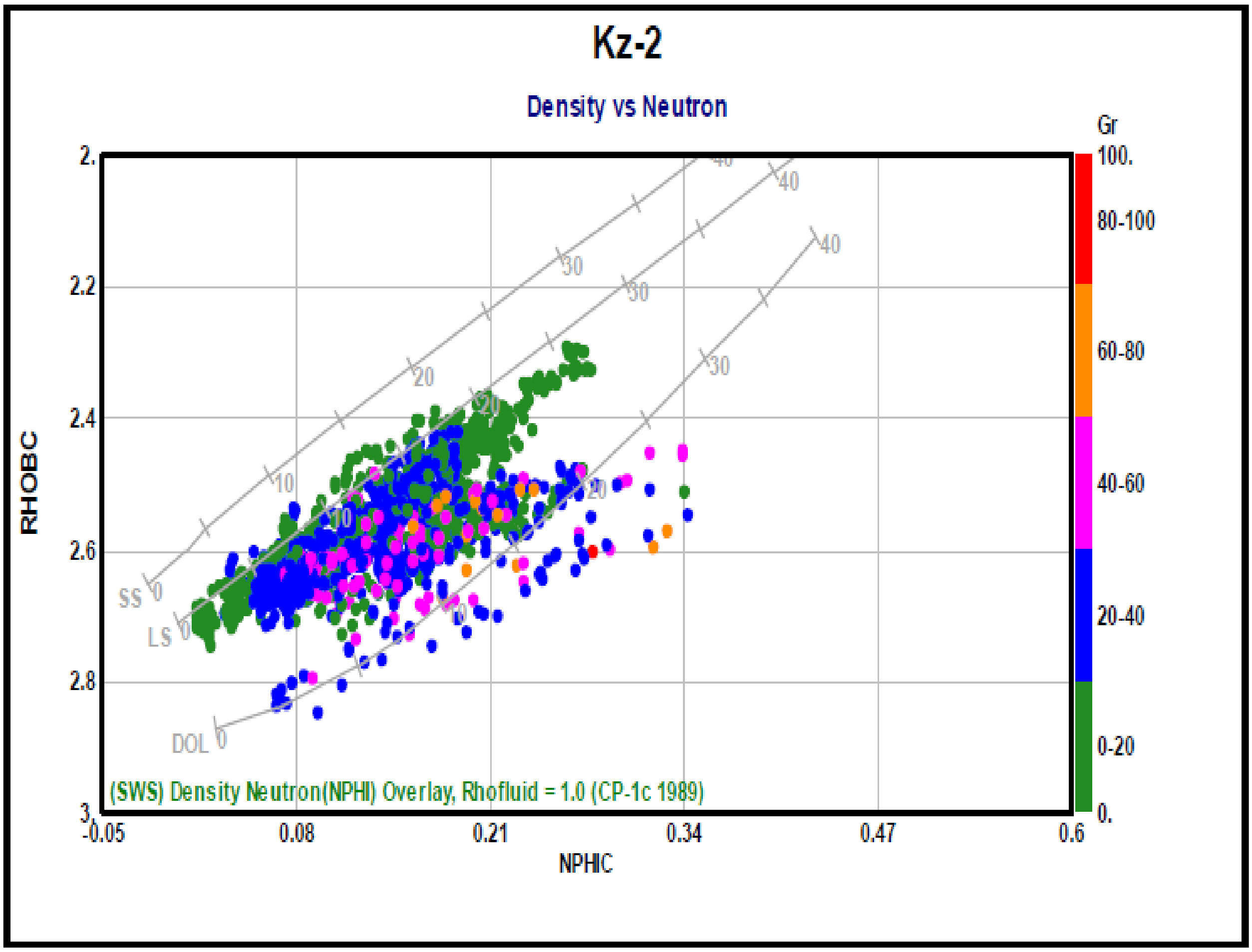

Figure 10. Density Neutron cross plot for (Kz-2).

7.3.2 The M-N Cross Plot for Mineral Identifications

The M-N cross plot generally can be used to facilities lithology interpretation and identify more complex minerals **(Ross, 2015)**. These plots integrated of three mainly porosity logs in order to describe a particular minerals quantities by plotting M and N values in the chart. The M and N values are slopes of individual minerals, calcite, dolomite, sandstone, Gypsum, sulfur, gas and secondary porosity area on the sonic-density and density-neutron cross plot charts in **Fig. 11.** M and N are introduced by following equations.

$$M = \frac{\Delta tfl - \Delta tlog}{\rho b - \rho fl} \times 0.01 \quad (8)$$

$$N = \frac{\Phi Nfl - \Phi N}{\rho b - \rho fl} \quad (9)$$

The M-N cross plot for tertiary reservoir shows that points focused between lines calcite and dolomite with observed tendency approach to secondary porosity area that illustrated in **Fig. 11** for well (kz-2).

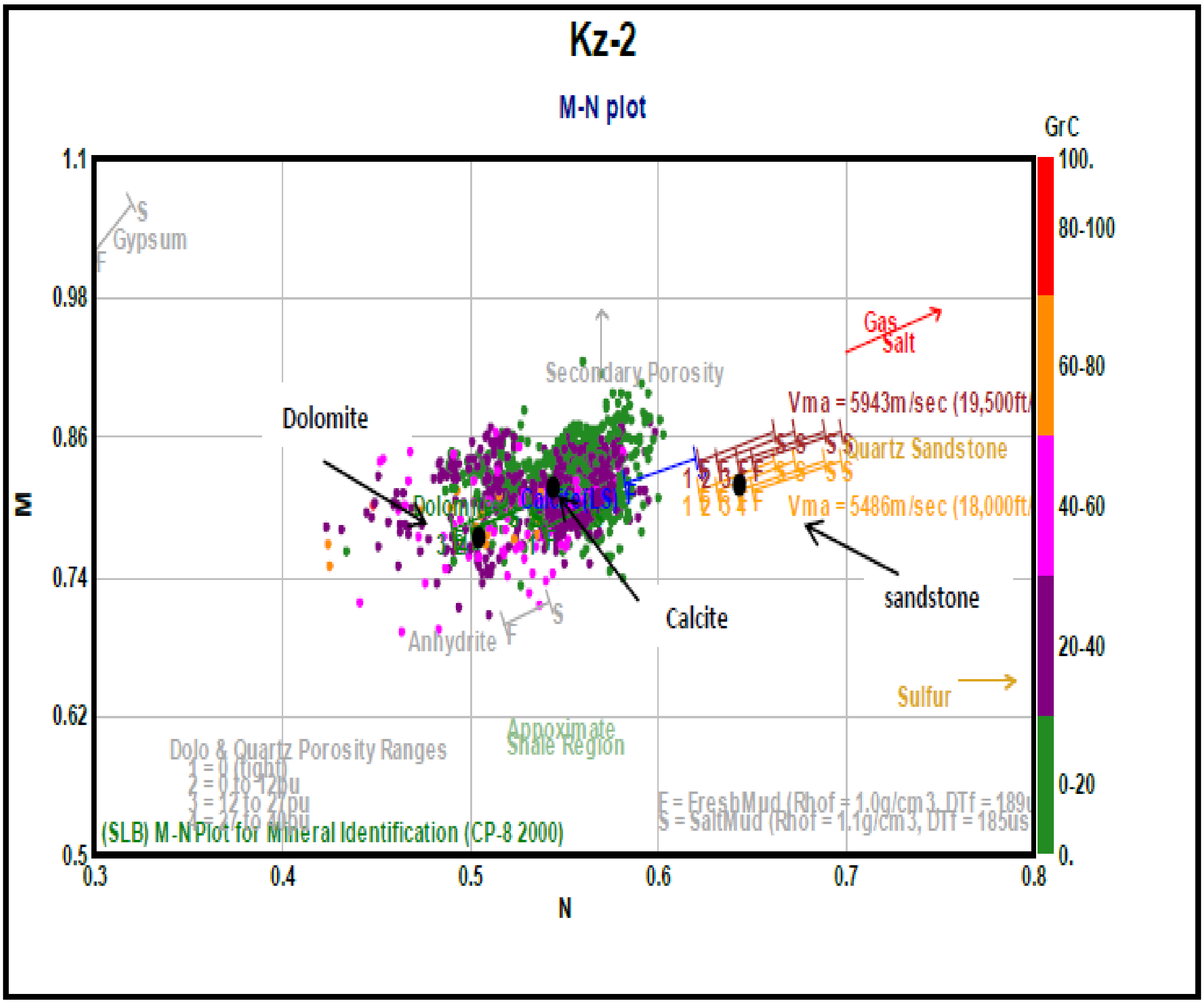

Figure 11. The M-N cross plot in (Kz-2) well.

7.4 Determination of Archie's parameter (a,n, and m)

Application of Pickett's plot is consider a method that's give a graphical solution to Archie's equation to predict water saturation and predict Archie parameter (a,m and n) by plotting resistivity verses porosity (on logarithmic scales), data arrangement as a straight line which can be used in log interpretation by the following equation.

$$Log\ (Rt) = -mLog(\emptyset) + Log(aRw) - nLog(Sw) \quad (10)$$

For water saturated zone (Sw = 100%), so the equation becomes

$$(11) Log\ (Rt) = -mLog(\emptyset) + Log(aRw)$$

After plotting (logRt) vs. (log∅e) **,** (m) is represent the slop of line and (aRw) is intercept point on y-axis at ($\emptyset e = 1$). So (a) can be easily found if known value of (Rw). The (n) saturation exponent can be determined depends on irreducible water saturation (Swi) levels by using the following equation.

$$(12) Log(Rt) = Log(Swi^{n}.Rtirr) + (n-m)Log(\emptyset)$$

Above equation (n-m) is represent slope of line and (m) can found it from Pickett's plot (previous step).So the saturation exponent (n) can be easily determined **(Schlumberger and Houston, 1989). Table 1.** Contains values of Archie's parameter (a, m, and n) for tertiary reservoir by using Pickett's plot. **Fig. 12** is plot of true formation resistivity (Rt) verses effective porosity by (IP V3.5) for well (Kz-2).

Table 1. Archie's parameters values calculated by Pickett's plot.

Well no.	a	m	n
Kz-1	1.04	1.55	2.08
Kz-2	1.07	1.43	1.99
Kz-3	1.06	1.46	1.97
Kz-4	1.04	1.47	2.1
Kz-9	1.02	1.56	2.04
Kz-14	1.05	1.48	2.05
Kz-15	1.04	1.52	2.06

7.5 Fluid saturation

Fluid saturation and porosity are represent most essential reservoir properties to obtained more accurate estimate of oil in reservoir. Because of heterogeneity of reservoir is continues related to these properties verses depth of formation, to get best estimation. Several well log analysis includes resistivity, acoustic are used to get of these properties **(Schlumberger.1972).**

Water saturation of reservoir's un-invaded zone in tertiary reservoir for khabaz field are calculated from Archie's equation expressed as.

$$Sw = \left[\frac{aRw}{\emptyset^m \times Rt}\right]^{\left(\frac{1}{n}\right)} \quad (13)$$

Water saturation in flashed zone is (Sxo) are expressed as:-

$$Sxo = \left[\frac{aRmf}{\emptyset^m \times Rxo}\right]^{\left(\frac{1}{n}\right)} \quad (14)$$

Shallow resistivity tools is used to determined water saturation (Sxo) and deep reading resistivity tools used to computed water saturation (sw).The residual oil saturation and movable oil saturation can be determined by using the following equation .

$$Sor = [\emptyset \times (1 - Sxo)] \quad (15)$$

$$Shr = [\emptyset \times (Sxo - Sw)] \quad (16)$$

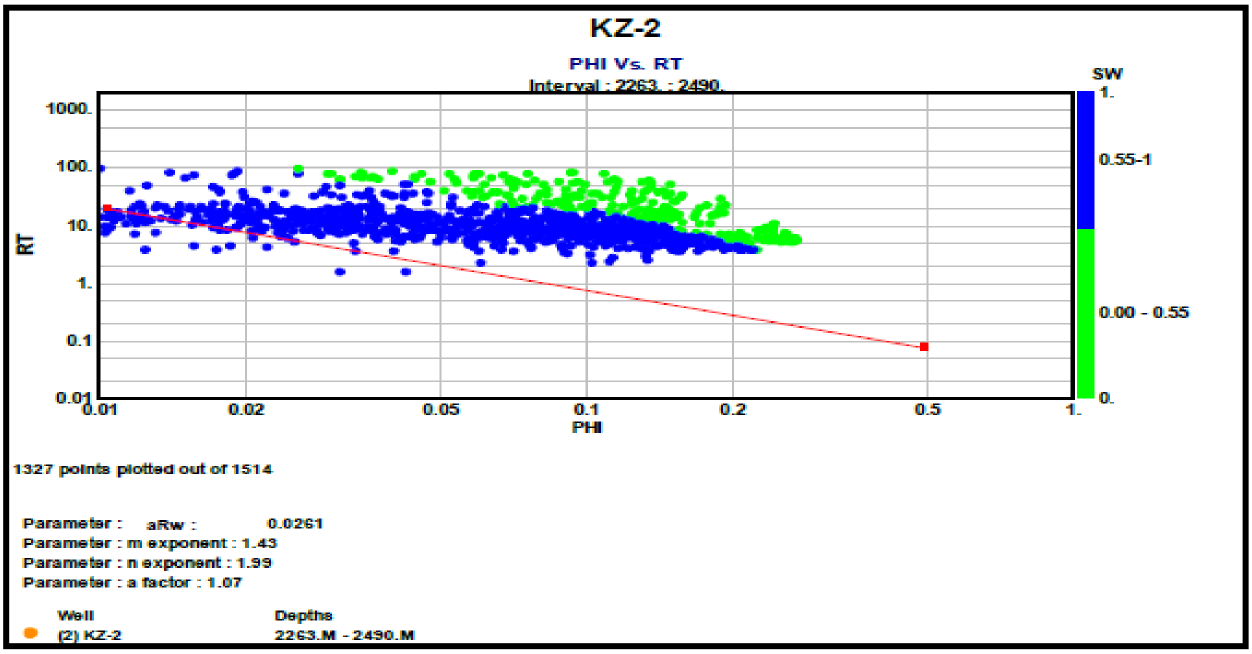

Figure 12. Values of Archie's parameter by Pickett's plot for well (Kz-2).

7.6 Bulk Volume Analyses and CPI

The bulk volume of hydrocarbon (BVHC) is represent volume of hydrocarbon which is existed in pore space and rock reservoir, and the bulk volume of water (BVW) is referred to unit volume of pore space filled by water **(Tonietto, et al.,2014).**

$$BVHC = (1 - Sw) \times \emptyset \quad (17)$$

$$\mathrm{BVW} = \mathrm{Sw} \times \emptyset \quad (18)$$

The area between water saturation in flashed zone (Sxo) and water saturation in un-invaded zone (Sw) represents bulk volume of movable hydrocarbons.

$$\mathrm{BVMO} = (\mathrm{Sxo} - \mathrm{Sw}) \times \emptyset \quad (19)$$

CPI (computer processed interpretation) represent results which have been recorded from log interpretations that includes porosity analysis tracks contains effective porosity (Øe) water filled in the invaded zone (Øe . Sxo) and in un-invaded zone (Øe . Sw) shown in **Fig. 13.** Also, bulk volume analysis includes percentage of shale volume (Vsh) and non-shale volume (V matrix) **(Cosentino, 2001).**

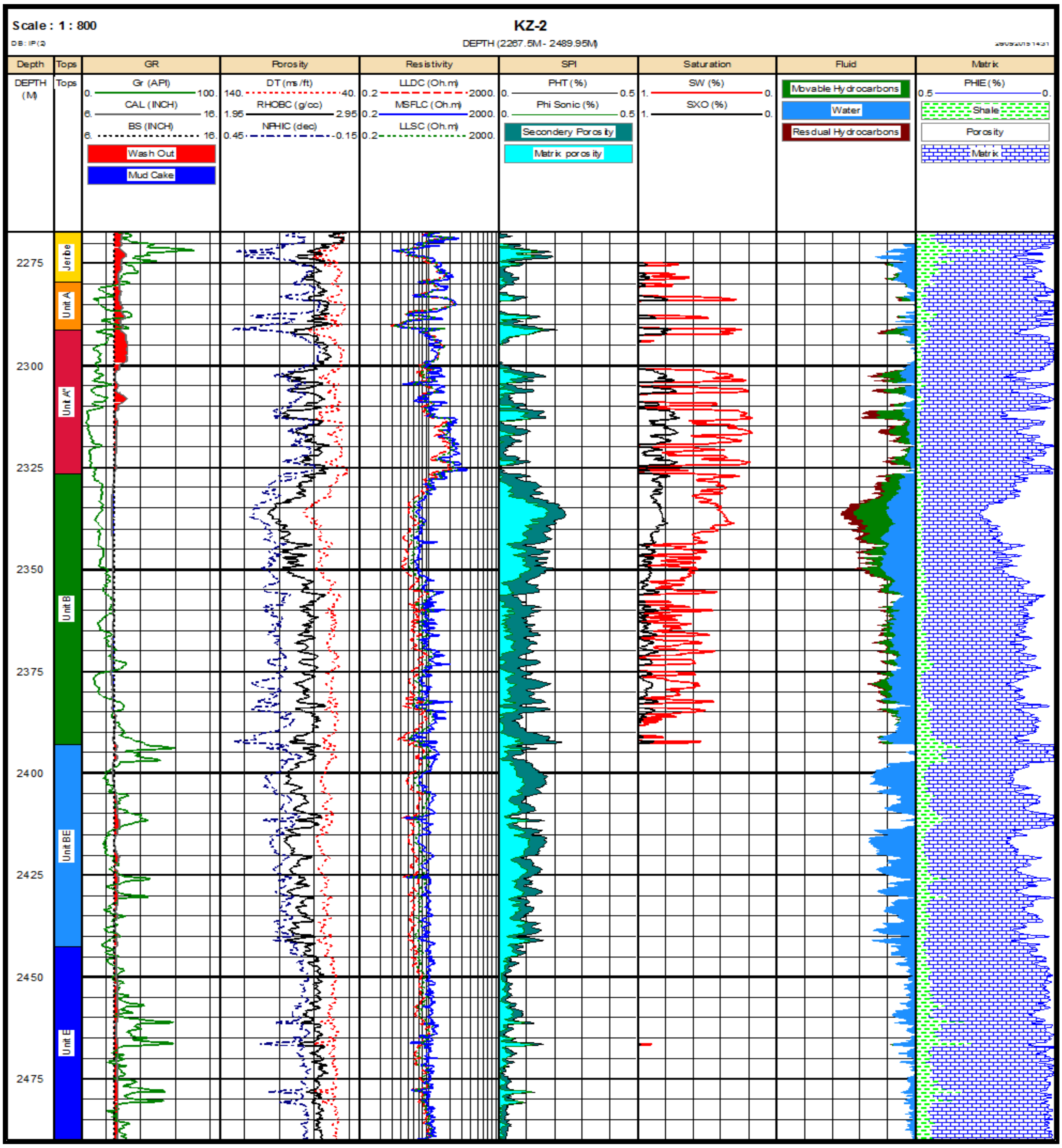

Figure 13. CPI in (Kz-2) well.

7.7 Net to Gross reservoir calculation

Net pay is important parameter in reservoir calculation because it's used to identify geological section which penetrated formation and identify interval of reservoir which have amount of hydrocarbon is a function of production interval. Net pay is quantified value which can be used in Cutoff evaluation are performed to log interpretation data shown in **Fig. 14.** Cutoff is represent specific value used to remove non-reservoir interval **(Baker, 2017).**

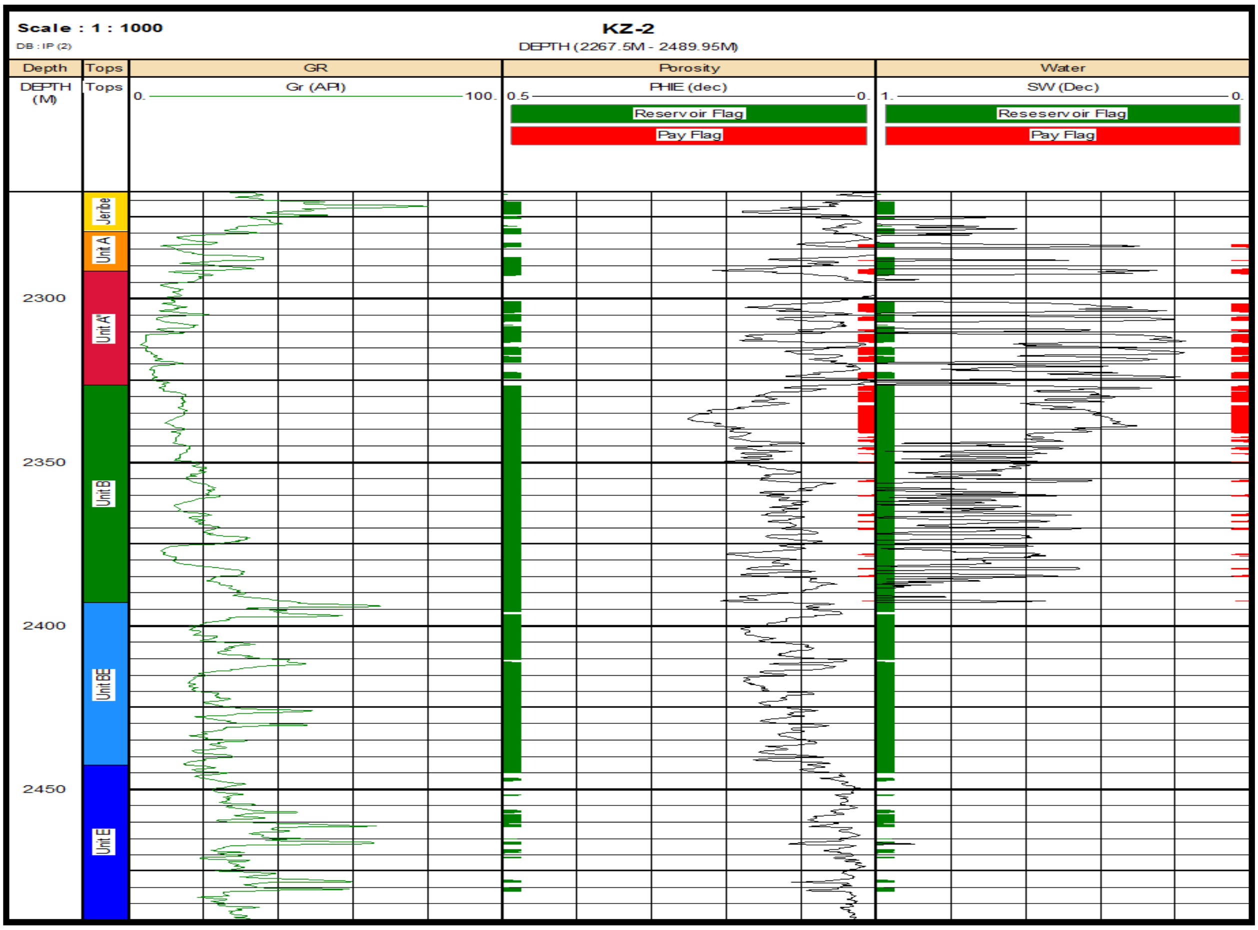

Figure 14. Net to Gross in (Kz-2) well.

8. CONCLUSIONS

1- Secondary porosity index was highest value in unit (B) which represents an essential unit with storage capacity and transmissibility includes tertiary reservoir, total porosity still greatest without any variation as compared with effective porosity kept lowest due to effect shale of volume.
2- Volume of shale estimate less than (18 %) in Jeribe formation includes tertiary reservoir.
3- From Neutron-density cross plot illustrates tertiary reservoir composed mixture of dolomitic-limestone, and From M-N cross plot explain the mineralogy of tertiary reservoir consist of calcite and dolomite.
4- CPI results gives highest percentage of movable hydrocarbon are focused on (unit B) of tertiary reservoir and (unit A') and small interval of Jeribe formation and top part of (unit EB).
5- Hydrocarbon saturation composed of oil and gas, where production in khabaz field includes oil and gas. Hydrocarbon saturation ranging from poor to moderate as a compared with water saturation.

NOMENCLATURE

a, n, and m= Archie's Parameters, dimensionless .
PHINC= Corrected Neutron porosity.
RHOBC= Corrected bulk density. gm/cc
Vsh= Shale volume, fraction.
Sxo= Water saturation in the invaded zone.
Rtirr= True formation resistivity at irreducible zones, Ω.m.
Rmf= Resistivity of mud filtrate, Ω.m.
Δtfl= interval transit time in the fluid.
Δtma=interval transit time in the matrix.

GREEK SYMBOLS

Øe= effective porosity
$\emptyset_{Nsh}$= Neutron porosity in the shale formation.
ρfl=fluid density.

ABBREVIATION

GRI= Gamma ray index.
SPI= Secondary porosity index.
BVHC= Bulk volume of hydrocarbon in un-invaded zone, fraction.
BVW= Water bulk volume.
LLD= Latero log deep.
LLS= Latero log shallow.
MSFL= Micro spherical focused log

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