



Reservoir Characterization of East Baghdad Oil field, Iraq

Ali KH. Al-Temimi*

Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.

Received: 20 Sep 2018

Revised: 24 Oct 2018

Accepted: 27 Nov 2018

*Address for Correspondence

Ali KH. Al-Temimi

Department of Geology,

College of Science,

University of Baghdad,

Baghdad, Iraq.

Email: asdtmim@yahoo.com



This is an Open Access Journal / article distributed under the terms of the **Creative Commons Attribution License** (CC BY-NC-ND 3.0) which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. All rights reserved.

ABSTRACT

The log interpretations have been carried out using Interactive Petrophysics Program (IP) and show that the Tanuma Formation consists of mainly limestone with inclusion of dolomite and indicated that this formation is divided in to many units in EB 10 (from TA1 to TA 18), the (TA1, 2, 3, 4, 5 and TA16, 17, 18) 8 unit represent the principle oil-bearing unit in East Baghdad oil Field and in EB58 (from TA7, 8, and TA9) 3 unit represents the principle oil-bearing unit in East Baghdad oil Field. and show that the Khasib Formation consists of mainly limestone with inclusion of dolomite and indicated that this formation is divided in to many units in EB 10 (from KB1, 2, 3, 4, 5, and 6) 6 unit represents the principle oil-bearing unit in East Baghdad oil Field. In EB81 this formation is divided in to many units 10, all of them are principle oil-bearing unit in East Baghdad oil Field. The log interpretations of Zubair Formation show that this formation consists of mainly alternation sandstone with shale with lenses of differential compaction of sandstone, indicated that this formation is divided in to twenty units (from ZB1 to ZB20), the (ZB1, 2, 3, 5, 6, 7, 8, 9, and ZB18) units into represent the principle oil-bearing units in EB10 in East Baghdad oil Field. while in EB58 that this formation is divided into fourteen units (from ZB1 to ZB14), the (ZB1, 2, 3, 4, 5, 10, and ZB14) units represent the principle oil-bearing units.

Keywords: Interactive Petrophysics Program, limestone, oil-bearing unit

INTRODUCTION

In present study to assessment hydrocarbons in East Baghdad oil field, three formations have commercial oil that (Tanuma, Khasib and Zubair Formations) as well as characterization and affinities for crude oil we need knowledge characterize the reservoir that fill it. The different characters of reservoir units such as lithology, types of porosity, permeability and types of fluids can be deduced from the study of geologic logs. In the present study the primary





Ali KH. Al-Temimi

and secondary porosity as well as water and oil saturation were determined in addition to subdividing the succession. Addition to microfacies analysis for determined different type of porosity and four boreholes with their gamma ray, neutron, density, sonic and resistivity logs were studied. In the present study use core sample from EB92 and make thin section to compare different units zone with (CPI) as a result from logs. In this part discusses how different log types measure various properties in the boreholes and surrounding formations, what factors affect these measurements, where on a standard log display a particular curve is recorded, and how interpreted information is obtained from the logs using both charts and mathematical formulas. As logging tools and their interpretation methods are developing in accuracy and sophistication, they are playing an expanded role in the geological decision-making process. Today, petrophysical log interpretation is one of the most useful and important tools available to petroleum geologist [1]. Many parameters or different parameters can be recorded such as, formation resistivity, sonic velocity, density and Radioactivity. The recorded data can then be interpreted to determine the lithology and porosity of the penetrated formation and also the type and quantity of fluids (oil, gas or water) within pores. The various logs can be used to define these parameters and to analysis the stratigraphic relationships. The porosity and oil saturation addition to lithology and subdivision of the reservoir units were estimated in the current study. Gamma ray, self-potential, neutron, density, sonic and resistivity logs were studied in East Baghdad oil field for four boreholes :(EB-10, EB-25, EB-58, and EB 81). The parameters of log interpretation are determined directly or inferred indirectly and measured by one of three types of logs:

- 1) Electric
 - Spontaneous Potential
 - Resistivity
- 2) Radioactive
 - Gamma Ray
 - Density
 - Neutron
- 3) Acoustic or sonic logs

The most common log types that are routinely employed for log analyses (lithology, porosity, fluid evaluation) and stratigraphic correlations are summarized in Table 1 [2].

- Basic Principles of used well logs

It is important to understand the fundamental principles of well logs used in this study.

- Electrical Logs

Spontaneous Potential (SP)

The Spontaneous Potential (SP) log was one of the earliest electric log used in the petroleum industry, and has continued to play a significant role in well log interpretation. Primarily the Spontaneous Potential log is used to identify impermeable zones such as shale, and permeable zones such as sand.

However the SP log has other uses perhaps equally important which are: Detect permeable beds, detect boundaries of permeable beds, determine formation water resistivity R_w and determine the volume shale impermeable beds [3]. The SP log records the electric Potential setup between an electrodes in a sonde down up the bore whole and fixed electrode at the earth surface [4]. It can only be used in open holes filled with conductive [11]. The electric charge of the (SP.) is caused by the flow of ions (largely Na and Cl) from concentrated to more dilute solutions. Generally this flow is from salty formation water to fresher drilling mud [4]. The factors that are essential to produce an SP current involve: a conductive fluid in the borehole, a porous and permeable bed surrounded by an impermeable formation and a difference in salinity (or pressure) between the borehole fluid and the formation fluid. The shale volumes can be calculated mathematically from the self-potential log by the following [5] formula:

$$V_{Sh} = 1 - \frac{(SP_{cl} - SP_{Sh})}{SP_{cl} - SP_{Sh}} \dots\dots\dots (1)$$





Ali KH. Al-Temimi

Where:

SP: SP log reading.

SPsh: SP log reading in the shale.

SPcl: SP log reading in the clean rock.

The determination of shale volume from self-potential log is unacceptable in the formations that contain hydrocarbons (oil and gas) because this method gives high values of (Vsh) [1]. The Spontaneous Potential in current study is used to determine water resistivity of formation water, formation contact of the Zubair, Khasib, and Tanuma Formations in East Baghdad oil field.

Resistivity Logs

Resistivity is one of the most useful physical properties measured in the borehole. Formation resistivity measurements, in conjunction with porosity and water resistivity, are used to obtain values of water saturation and consequently, hydrocarbon saturation. They are also used in conjunction with lithology logs to identify hydrocarbon bearing intervals and to estimate the net pay thickness. Resistivity is the degree to which a substance “resists” or impedes the flow of electrical current. It is a physical property of the material, independent of size and shape. In well logging, both resistivity and conductivity are used frequently. One is the reciprocal of the other [4].

Resistivity (ohms m /m) = $1 \times 1000 / \text{conductivity (millimhos/m)}$ (2)

The resistivity unit used in well logging is ohm-meter²/meter, which is usually shortened to ohm-meter. Electrical conductivity is expressed in mhos per meter. In order to avoid decimal fractions, in electrical logging, it is expressed in millimhos per meter. The three main ways of measuring the electrical resistivity of formations penetrated by boreholes are the normal log, lateral and Induction log techniques [4]. The electrical resistivity of a formation varies greatly: solid rock is highly resistivity as is porous rock saturated in fresh water, oil or gas, Shale on the other hand and porous formations saturated with salty or brine has very low resistivity. When run simultaneously SP and resistivity logs enable qualitative interpretation of lithology and nature of pore fluids to be made. There are two types of resistivity logs to be used:-

1. Induction logs used to measure true resistivity from formation (**RT**) or uninvaded zone. This log was used to compute water or oil saturation from the uninvaded zone, (**Sw, Sh**) by Archie formula.
 2. Short normal log was used to measure resistivity from flushed zone (**Rxo**).
- These values of resistivity were used to compute water and oil saturation from flushed zone (**Sxo, Sh**).

Radioactive logs

Gamma Ray log

Gamma ray logs measure natural radioactivity in formation and because of this measurement, they can be used for identifying lithology and for correlating zones. Besides that it provides information for calculating the volume shale in a sandstone or carbonate [3]. Abrupt changes in gamma-ray logs response are commonly related to sharp lithological breaks associated with unconformities and sequence boundaries [6]. Shale-free sandstones and carbonates have low concentrations of radioactive material and give low gamma ray readings. As shale content increases, the gamma ray log response increases because of the concentration of radioactive material in shale. The volume of shale expressed as a decimal fraction or percentage is called V shale [3].

Density log

The formation density log is a porosity log that measures electron density of formation. It can assist the geologist to:





Ali KH. Al-Temimi

1. Identify evaporate minerals.
2. Detect gas bearing zones.
3. Determine hydrocarbon density.
4. Evaluate shaly sand reservoirs and complex lithologies.

Density is measured in grams per cubic centimeter, g/cm³ (or Kg/m³ or Mg/m³), and is indicated by the Greek letter ρ (rho). Two separate density values are used by the density log:

The bulk density is the density of the entire formation (solid and fluid parts) as measured by the logging tool. The matrix density is the density of the solid framework of the rock. It may be thought of as the density of a particular rock type (e.g., limestone) that has no porosity. Porosity is derived from the bulk density of clean liquid-filled formations when the matrix density ρ_{ma} and the density of the saturating fluids of are known [1]:

$$\Phi_{\rho} = (\rho_{ma} - \rho_b) / (\rho_{ma} - \rho_f) \dots\dots (3)$$

Where:

Φ_ρ = Porosity by density log

ρ_b = Formation bulk density (the log reading) .

f = fluid density (Saltwater mud 1.16).

ρ_{ma} = matrix density

Neutron Log

Neutron logs are porosity logs that measure the hydrogen concentration in a formation. In clean formations (i.e., shale-free) where the porosity is filled with water or oil, the neutron log measures liquid filled porosity (Φ_N) [1]. Older neutron logs were scaled in counts, but modern neutron logs are recorded in apparent porosity units with respect to a given mineralogy. Whenever pores are filled with gas rather than oil or water, neutron porosity will be lowered, this occurs because there is less concentration of hydrogen in gas compared to oil or water. Neutron log responses vary depending on:

1. Differences in detector types.
2. Spacing between source and detector
3. Lithology i.e. sandstone, limestone and dolomite [3].

Acoustic or Sonic logs

The sonic tool measures the interval transit time (t) or the time in microseconds for an acoustic wave to travel through 1 feet (or 1 m) of a formation along a path parallel to the borehole. The interval transit time (Δt) is dependent upon both lithology and porosity. In this technique interval transit time are recorded of clicks emitted from one end of the sonde travelling to one or more receivers at the other end. The sound waves generally travel faster through the formation than through the borehole mud [4]. To calculate porosity Wyllie time-average equation can be used [7]:

$$\Phi_s = (\Delta t - \Delta t_{ma}) / (\Delta t_f - \Delta t_{ma}) \dots\dots\dots (4)$$

Where:

Φ_s = sonic-derived porosity.

Δt_f = interval transit time of the formation fluid (salt water mud = 185 μsec/ft). Δt_{ma} = interval transit time of matrix,

Δt = interval transit time in the formation, we can get the matrix velocity values by using (Table 2) [5].

• **the Direct Applications:**

• **The Stratigraphic Boundaries:**

The recent study depends on many log types to determine the upper and lower boundaries of the studied formations.

• **SP log :** The Sp log is a reading or recording of positive values (right side) in the upper and the lower part of Tanuma Formation (Figure 1). In Khasib Formation the reading record negative values (left side) in the upper boundaries, and positive deflection (right side) in the lower boundaries (Figure 2)





Ali KH. Al-Temimi

- Resistivity log: Rxo and Rt log of Tanuma Formation deflect toward the right (high resistivity) in the upper contact, the decreasing in readings (lowresistivity) occurs in the lower contact (Figure 1). In Khasib Formation the Rxo and Rt log deflect (right side) “decreasing in recording at the upper and lower contact”.
- Porosity log (Neutron, density and sonic): low porosity is observed in the upper and lower contact in Tanuma and Khasib Formations.
- Gamma ray log: gradual deflection (decrease to left) is observed in the upper and lower Tanuma Formation while in Khasib Formations recording increases (right side) at the Upper and lower parts of the formations (Figure 1 and 2).

• **Primary and Secondary Porosity**

Porosity can be defined as the percentage of voids to the total volume of rock. It is measured as a percent and expressed as the symbol (ϕ) Phi.

Porosity (ϕ) = Volume of pores /total volume of rock
 ×100% (7)

The primary porosity is the amount of pore present in the sediment at time of deposition. It is usually a function of the amount of space between rock – forming grains. The sonic porosity represents the primary (intergranular) porosity [3].Secondary porosity (vuggy,moldic , channels and fracture) are the result of geological processes (diagenesis) after the deposition of sediments [8]. It computed by this formula [5].

$SPI = (\Phi_{n.d} - \Phi_s)$ (8)

Where:

SPI = secondary porosity index.

$\Phi_{n.d}$ = neutron-density properties combination.

Φ_s = sonic-derived porosity.

The secondary porosity index (SPI) may be computed as the difference between total porosity as determined from Neutron and/or Density logs, and primary porosity obtained from sonic log.

$SPI = \phi_{total} - \phi_{primary}$ (9)

When sonic properties are compared with neutron and density properties the total porosity can be subdivided between primary recorded by the sonic log, and secondary porosity .The type of porosity in the Zubair, Khasib, and Tanuma Formations in East Baghdad field is mainly a primary porosity and secondary porosity.

The porosity in the Zubair Formation increases in EB-10, EB-21, EB-58, and EB-81. In Khasib, and Tanuma Formations the porosity less than Zubair's porosity in the same wells (Figure 3, 4 and 5).

• **Water and hydrocarbon Saturation**

Fluid saturation is usually obtained from resistivity logs. Different resistivity logs with variable fluid saturation occur at different distances from the borehole wall. A micro resistivity log is used to obtain the resistivity in the flushed zone behind the borehole wall while deep resistivity device (induction or lateral logs) is used to obtain the resistivity in the virgin(uninvaded) zone. Fluid saturation is estimated from resistivity measurement by the Archie equation. This equation relates the resistivity of the formation to the porosity, water saturation and resistivity of the water formation [9]. Archie determined experimentally that the water saturation in the following formula:

$S_w = (F R_w/R_t)^{1/n}$ (10)

S_w = water saturation of un-invaded zone.

F = Formation factor

R_w = resistivity of water ohm-m³/m

R_t = resistivity of the un invaded zone ohm-m³/m n=usually taken as 2

The water saturation could be calculated for the invaded zone in the following formula:

$S_{xo} = (F R_{mf}/R_{xo})^{1/n}$ (11)

S_{xo} = water saturation of the un-invaded zone





Ali KH. Al-Temimi

F= Formation factor

Rmf= resistivity of mud infiltrate ohm-m³/m

Rxo= resistivity of invaded zone ohm-m³/m

n= usually taken as 2

(Rt) is obtained from the deep resistivity log, and **(Rxo)** is obtained from the microspherical resistivity log.

Formation factor is the constant of proportionality of resistivity of clean formation with the resistivity of the brine with which is fully saturated. Archie proposed the formula [10]:

$$F = a/\phi^m \quad \dots\dots\dots (12)$$

Where:

(m) Is the cementation factor, it equal to 2 in carbonate.

(a) Is constant and equal to 1 in compacted the formation.

The **(Rmf)** is known for bottom hole temperature and it should be corrected for formation temperature. The temperature gradient is required in order to calculate formation temperature:

$$G = (BHT - ST)/TD \quad \dots\dots\dots (13)$$

Where:

G is temp gradient, BHT is bottom hole temp.

ST is surface temperature.

TD is total depth.

Now Formation temperature could be calculated:

$$FT = G * Fd + ST \quad \dots\dots\dots (14)$$

Where:

FT is formation temperature.

Fd is formation depth.

The **(Rmf)** could be corrected for the Formation temperature Using the following equation:

$$Rmf_{\text{Formation}} = Rmf_{\text{temp}} * \frac{(BHT + 6077)}{(FT + 6.77)} \quad \dots\dots (4-15)$$

Where:

(Rmf temp) is the resistivity of **(Rmf)** at known temperature, which is the **BHT**. The **(Rw)** could be calculated in more than one way.

The recent study calculates the **Rw** from the SP log. [10].

Rw at

$$75^\circ F = (77 * Rwe + 5) / (146 - 377 * Rwe) \quad \dots\dots\dots (16)$$

Where:

Rwe is the equivalent water resistivity and it could be calculated using:

$$Rwe = Rmfe / (10 - SSP/K) \quad \dots\dots\dots (17)$$

Where:

$$K = 60 + (0.133 * ST) \quad \dots\dots\dots (18)$$

(SSP) is the static SP curve and it could be calculated by knowing the difference between the maximum negative deflection and the opposite positive deflection (shale base line) for thick permeable bed [10].

(Rmfe) is the equivalent resistivity of mud infiltrate, and it's could be calculated by computing the **(Rmf)** at 75°F then:

$$Rmfe = Rmf * 0.85 \quad \dots\dots\dots (19)$$

After calculating **Rw** at 75°F it is converted to the formation temperature using equation (16)

After calculating **Sw**, the saturation of hydrocarbon could be calculated using:

$$Sh = 1 - Sw \quad \dots\dots\dots (20)$$

Where:

(Sh) is the hydrocarbon saturation.

The (figures 4-6, 4-7) show the values of Shin EBS-10, EB-81 in Khasib and Tanuma Formations. Figure 8 show the values of Sh in EB-10 in Zubair Formation.





Ali KH. Al-Temimi

• **Bulk Volume Water**

The product of a formation's water saturation (**Sw**) and its porosity (**Φ**) is the bulk volume of water [3]. On the other hand, the bulk volume of water can be computed in the invaded zone using the following formula [11]:

$$BVW = Sw * \Phi \quad \dots\dots\dots (21)$$

$$BVXo = Sxo * \Phi \quad \dots\dots\dots (22)$$

Where:

BVW= bulk volume water of un-invaded zone.

BVXo= bulk volume water of flushed zone.

Sw= water saturation of un-invaded zone.

Sxo = water saturation in the flushed zone.

Φ = porosity.

Therefore, hydrocarbon production from a zone at irreducible water saturation should be water free [12]. Because the amount of water formation can hold by capillary pressure increases with decreasing grain size, the bulk volume water also increases with decreasing grain size. The bulk volume water values for carbonates should be used only as a very general guide to different types of porosity [1]

Bulk volume of hydrocarbon represents the moveable hydrocarbon saturation (**Shm**) and residual hydrocarbon saturation (**Shr**) (unmovable). The bulk volume of hydrocarbon is calculated from the following equation [1]:

$$Bvo = Sh * \Phi \quad \dots\dots\dots (23)$$

Where:

Bvo =bulk volume of hydrocarbon.

Sh=hydrocarbon saturation.

Φ=porosity.

To calculate residual hydrocarbon saturation (**Shr**) (unmovable) the following equation should be used [1]:

$$Shr = 1-Sxo \quad \dots\dots\dots (24)$$

Where:

Shr = residual hydrocarbon saturation

Sxo = water saturation in the flushed zone

To calculate a moveable hydrocarbon saturation (**Shm**) the following equation should be used [1]:

$$Shm = Sxo-Sw \dots\dots\dots (25)$$

The restricted place between (**BVw**) and (**BVxo**) represents the moveable hydrocarbons but between **Φ** and (**Φ, Sxo**) represents the residual hydrocarbons and between the (**Φ**) and (**Φ,Sw**) represents the bulk hydrocarbons [1] (Figure 9, 10, and 11).

• **Volume of Shale (V shale):**

The volume of shale very importance on water saturation but must be greater 10-15% [13][3].The Gamma ray index IGR is computing by [11].

$$IGR = \frac{GR \log - GR \min}{GR \max - GR \min} \quad \dots\dots\dots (26)$$

I GR = Gamma ray index.

GR log = Gamma ray recorded by log (API).

GR max = Maximum value of Gamma ray.

GR min = Minimum value of Gamma ray.

The Volume of shale (V. Shale) computing by :-[14]

$$Vsh = 0.33 (2 \times (2 \times IGR) - 1) \quad \dots\dots\dots (27)$$

Figures 12, 13, 14 show that the volume of shale, from these figures remark that there is a unit barrier shale rock in all studied wells in the Tanuma and Khasib, and Zubair Formations.



**Ali KH. Al-Temimi****The indirect applications of well logs (from the equations and the Cross plots), the Determination of Lithology using Density vs. Neutron cross plot**

The employment of the cross plot of the different logs is used in determination of various parameters including the lithology and the active zone. The neutron–density cross plot is one of the oldest quantitative interpretation tools, this is considered important and very frequently used which provides satisfactory resolution of porosity, good lithological resolution for quartz, calcite, and dolomite [3]. From figures (15, 16) most points fall on limestone line, only a few points fall on the dolomite line that indicate the lithology of Tanuma and Khasib is limestone and dolomite, and in (EB-10) there is more points in sandstone line.

Evaluation of the Units of Zubair Reservoir

Zubair Formations in East Baghdad oil field consists mainly of porous sandstone. Figures (17) and (18) show the computer interpretation (CPI) of EB-58 and EB-10 that are deduced using Interactive Petro physics (IP) software. These figures show the petrophysical properties and fluids analysis which has been deduced by interpretation of well logs. From figures of (CPI) for East Baghdad wells, Zubair, Formations is divided into twenty (20) units according to the reservoir characteristics (porosity and saturation). The reservoir includes the following units (ZB1, ZB2, ZB3, ZB4, ZB5, ZB6, ZB7, ZB8, ZB9, ZB10, ZB11, ZB12, ZB13, ZB14, ZB15, ZB16, ZB17, ZB18, ZB19, ZB20). Main focus of this study is on the all unit, This reservoir unit represents oil bearing unit in the Zubair Formation and characterized by good oil show due to high porosity and low water saturation. The reservoir unit is characterized by moderate hydrocarbon shows but tends to have good oil shows where the porosity increases and water saturation decreases.

Evaluation of Tanuma and Khasib Reservoir units:

Figures (19, 20, 21, and 22) show the computer processes interpretation (CPI) of EB-10 and EB-81 that are deduced using Interactive Petro physics (IP) software. From figures of (CPI) for East Baghdad wells, Khasib and Tanuma Formations are divided into twenty tow units separated according to the reservoir characteristics (porosity and saturation). The reservoir including the following units: (T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, Kh12, Kh13, Kh14, Kh15, Kh16, Kh17, Kh18, Kh19, Kh20, Kh21, Kh22). The main focus in the studied wells is on the some units since they have good porosity and permeability.

RESULTS AND DISCUSSION

Zubair Formations in East Baghdad oil field consists mainly of porous sandstone. Figures (17) and (18) show the computer interpretation (CPI) of EB-58 and EB-10 that are deduced using Interactive Petro physics (IP) software. These figures show the petrophysical properties and fluids analysis which has been deduced by interpretation of well logs. From figures of (CPI) for East Baghdad wells, Zubair, Formations is divided into twenty (20) units according to the reservoir characteristics (porosity and saturation). The reservoir includes the following units (ZB1, ZB2, ZB3, ZB4, ZB5, ZB6, ZB7, ZB8, ZB9, ZB10, ZB11, ZB12, ZB13, ZB14, ZB15, ZB16, ZB17, ZB18, ZB19, ZB20). Main focus of this study is on the all unit, This reservoir unit represents oil bearing unit in the Zubair Formation and characterized by good oil show due to high porosity and low water saturation. The reservoir unit is characterized by moderate hydrocarbon shows but tends to have good oil shows where the porosity increases and water saturation decreases. Figures (19, 20, 21, and 22) show the computer processes interpretation (CPI) of EB-10 and EB-81 that are deduced using Interactive Petro physics (IP) software. From figures of (CPI) for East Baghdad wells, Khasib and Tanuma Formations are divided into twenty tow units separated according to the reservoir characteristics (porosity and saturation). The reservoir including the following units: (T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, Kh12, Kh13, Kh14, Kh15, Kh16, Kh17, Kh18, Kh19, Kh20, Kh21, Kh22). The main focus in the studied wells is on the some units since they have good porosity and permeability.





Ali KH. Al-Temimi

From figures (15, 16) most points fall on limestone line, only a few points fall on the dolomite line that indicate the lithology of Tanuma and Khasib is limestone and dolomite, and in (EB-10) there is more points in sandstone line.

REFERENCES

- 1- Asquith, G. B. and Krygowski, D., 2004, Basic Well Log Analysis, 2nd Edition: AAPG Methods in Exploration Series 16. Published by The American Association of Petroleum Geologists Tulsa, Oklahoma, 244p.
- 2- Catuneanu, O., 2006. Principles Sequence Stratigraphy, First edition. Elsevier, Amsterdam, 375p.
- 3- Asquith, G. B. and Gibson, C. (1982) Basic well logs analysis for geologists, methods in Exploration series, AAPG, 216P.
- 4- Selley, R. C. (1998) Elements of Petroleum Geology, Academic press, London, UK.,470P.
- 5- Schlumberger, 1970. Well Evaluation Conference, Libya, Services Techniques Schlumberger, France, 2-5, P: 2-6.
- 6- Krassay A. A., 1998. Outcrop and drill core gamma-ray logging integrated with sequence Stratigraphy: examples from Proterozoic sedimentary successions of northern Australia. AGSO J GeolGeophys 17: p. 285-299.
- 7- Wyllie M. R. J., Gregory A. R., and Gardner. G. H. F., 1958. An experimental investigation of the factors affecting elastic wave velocities in porous media: Geophysics, v. 23, p. 459–493.
- 8- Tiab, D., and Donaldson, E.C, 2004. Petrophysics Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties, Second Edition, GPP, 881p.
- 9- Archie G.E., 1942. The Electrical Resistivity Log as an Aid in determining Some Reservoir Characteristics: AIME, Vol.146, p.54.
- 10- Schlumberger, (1979) Log Interpretation Charts, Schlumberger Well Surveying Corporation, U.S.A., 97P.
- 11- Schlumberger, 1984. Log interpretation charts. Schlumberger, 106pp.
- 12- Morris, R.L., and W.P. Biggs, 1967. Using log derived of water saturation and porosity: Soc. Professional well log analysis, 8th Ann. Logging symp. Trans.
- 13- Hilchie D. W., 1978. Applied open hole log interpretation: Golden, Colorado, D. W. Hilchie, Inc., 309 p.
- 14- Dresser, Atlas, 1979. Log interpretation charts: Houston. Dresser industries, Inc., 107P.

Table 1. Types of well logs, properties they measure, and their use for geologic interpretations

Log	Property measured	Units	Geological interpretation
Spontaneous potential	Natural electric potential (relative to drilling mud)	Millivolts	Lithology, correlation, curve shape analysis, porosity
Conventional resistivity	Resistance to electric current flow (1D)	Ohm-metres	Identification of coal, bentonites, fluid types
Micro resistivity	Resistance to electric current flow (3D)	Ohm-metres and degrees	Borehole imaging, virtual core
Gamma ray	Natural radioactivity (e.g., related to K, Th, U)	API units	Lithology (including bentonites, coal), correlation, shape analysis
Sonic	Velocity of compressional sound wave	Microseconds/metre	Identification of porous zones, tightly cemented zones, coal
Neutron	Hydrogen concentration in pores (water, hydrocarbons)	Per cent porosity	Porous zones, cross plots with sonic and density for lithology
Density	Bulk density (electron density) (includes pore fluid in measurement)	Kilograms per cubic metre (g/cm ³)	Lithologies such as evaporites and compact carbonates
Dipmeter	Orientation of dipping surfaces by resistivity changes	Degrees (azimuth and inclination)	Paleoflow (in oriented core), stratigraphic, structural analyses
Caliper	Borehole diameter	Centimetres	Borehole state, reliability of logs





Ali KH. Al-Temimi

Table. 2. Sonic velocities and interval transit times for different matrixes. These constants are used in the sonic porosity formulas above [5].

Lithology/Fluid	Matrix Velocity ft/sec	Δt_{matrix} or Δt_{fluid} (Wyllie) $\mu\text{sec}/\text{ft}[\mu\text{sec}/\text{m}]$	Δt_{matrix} (RHG) $\mu\text{sec}/\text{ft}[\mu\text{sec}/\text{m}]$
Sandstone	18,000 to 19,500	55.5 to 51.0 [182 to 186]	56[184]
Limestone	21,000 to 23,000	47.6[156]	49[161]
Dolomite	23,000 to 26,000	43.5[143]	44[144]
Anhydrite	20,000	50.0[164]	
salt	15,000	66.7[219]	
Casing(iron)	17,500	57.0[187]	
Freshwater mud filtrate	5,280	189[620]	
Saltwater mud filtrate	5,980	185[607]	

Table 3. Top, bottom, Phi, Sw of Zubair, Khasib, and Tanuma Formations

Wells	Formation	Top (m)	Bottom (m)	Mean of (Phi)	Mean of (SW)
EB-10	Zubair	3046.5	3455	0.23	0.28
EB-10	Khasib	2133	2236	0.23	0.32
EB-10	Tanuma	2017	2133	0.21	0.31
EB-21	Zubair	3085	3423	0.25	0.32
EB-21	Khasib	2240	2348	0.27	0.20
EB-21	Tanuma	2123	2240	0.2	0.27
EB-58	Zubair	3045	3450	0.23	0.21
EB-58	Khasib	2146	2239	0.23	0.24
EB-58	Tanuma	2021	2145	0.25	0.22
EB-81	Zubair	3052	3441	0.23	0.18
EB-81	Khasib	2143	2243	0.23	0.21
EB-81	Tanuma	2025	2143	0.22	0.23





Ali KH. Al-Temimi

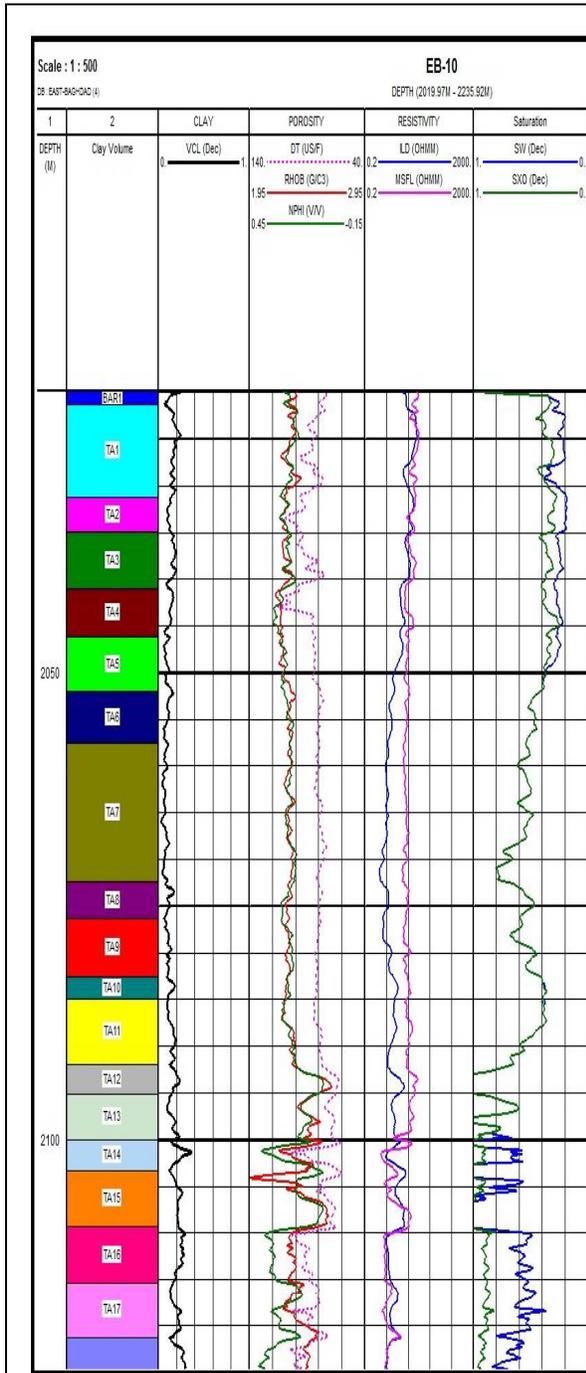


Figure 1. Types of logs that show the strigraphic boundaries of Tanuma in the well EB-10

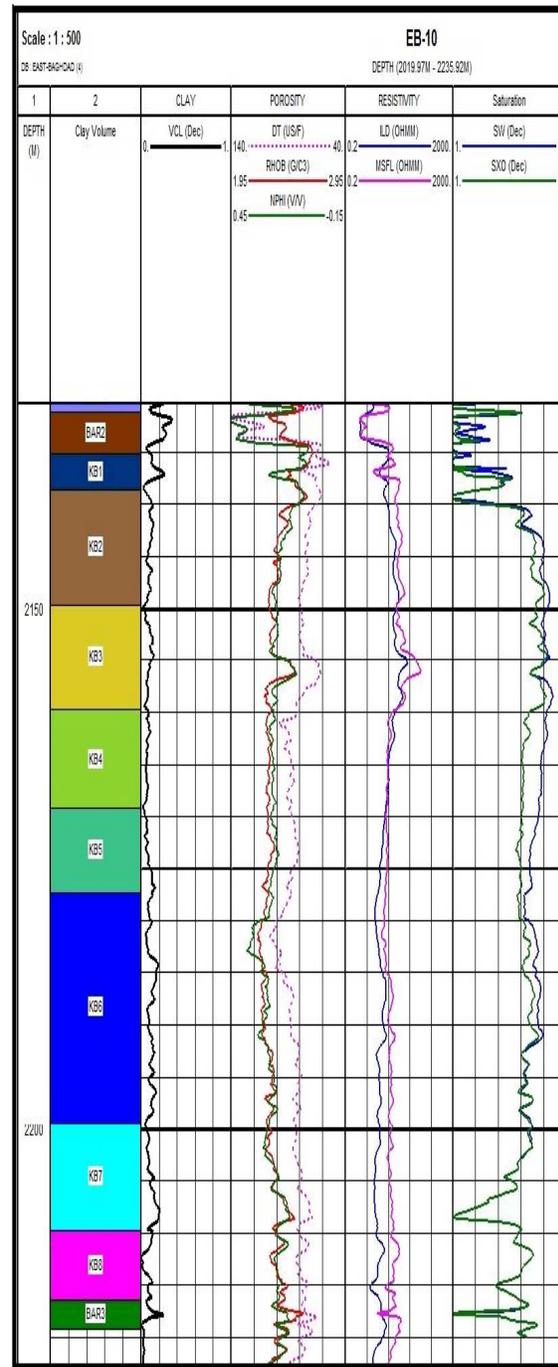


Figure 2. Types of logs that show the strigraphic boundaries of Khasib in the well EB-10





Ali KH. Al-Temimi

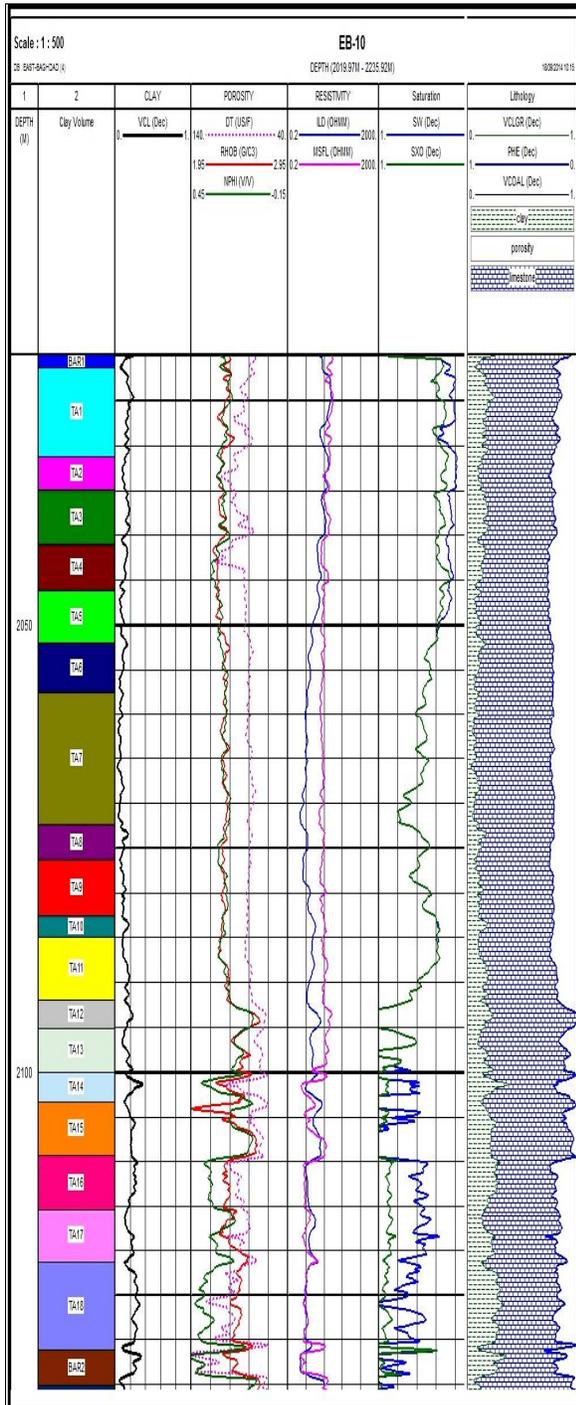


Figure 3. Types of logs that show the porosity of Tanuma Formations in the well EB-10.

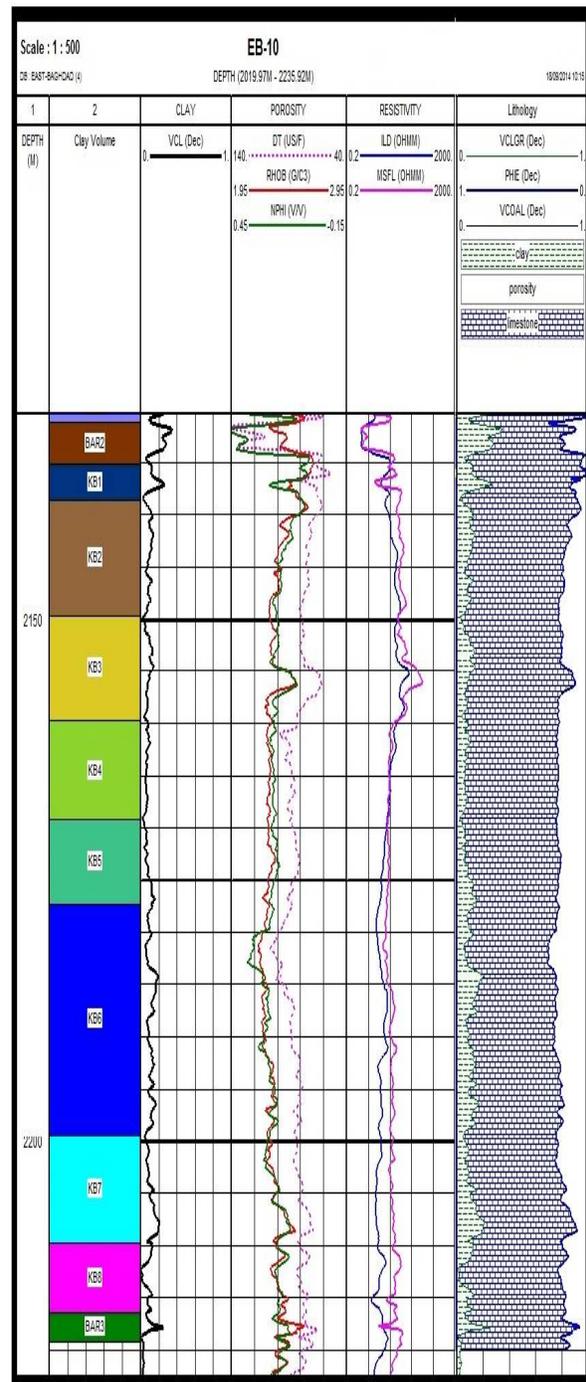


Figure 4. Types of logs that show the porosity of Khasib Formations in the well EB-81.





Ali KH. Al-Temimi

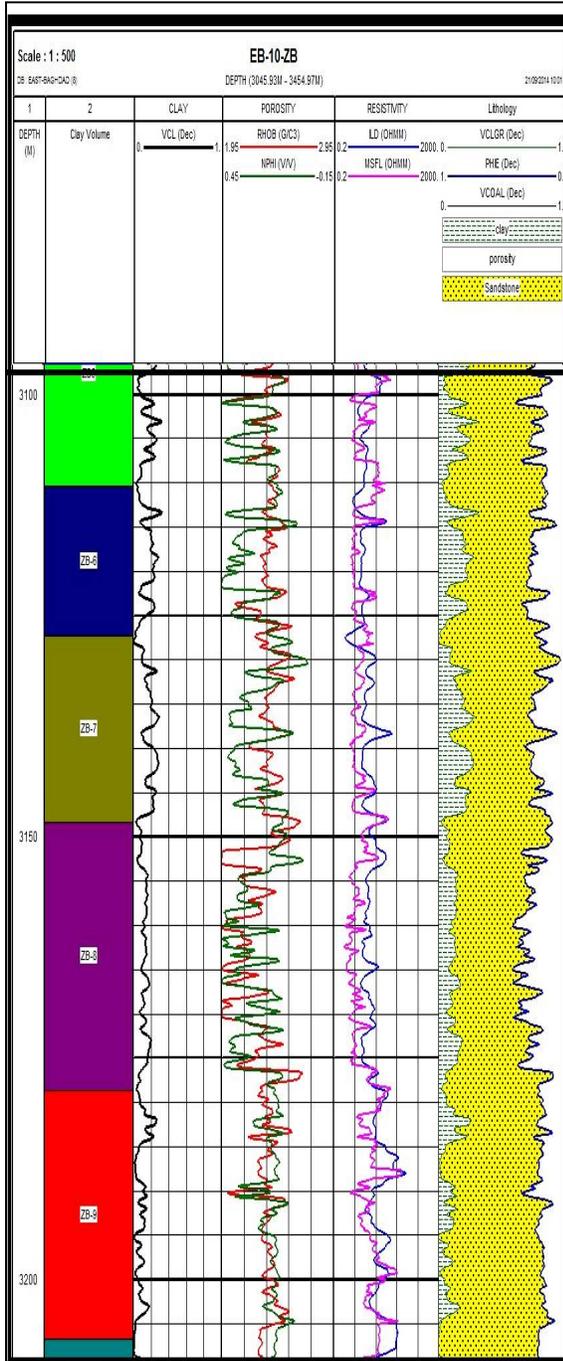


Figure 5. Types of logs that show the porosity of Zubair Formation in the well EB-10.

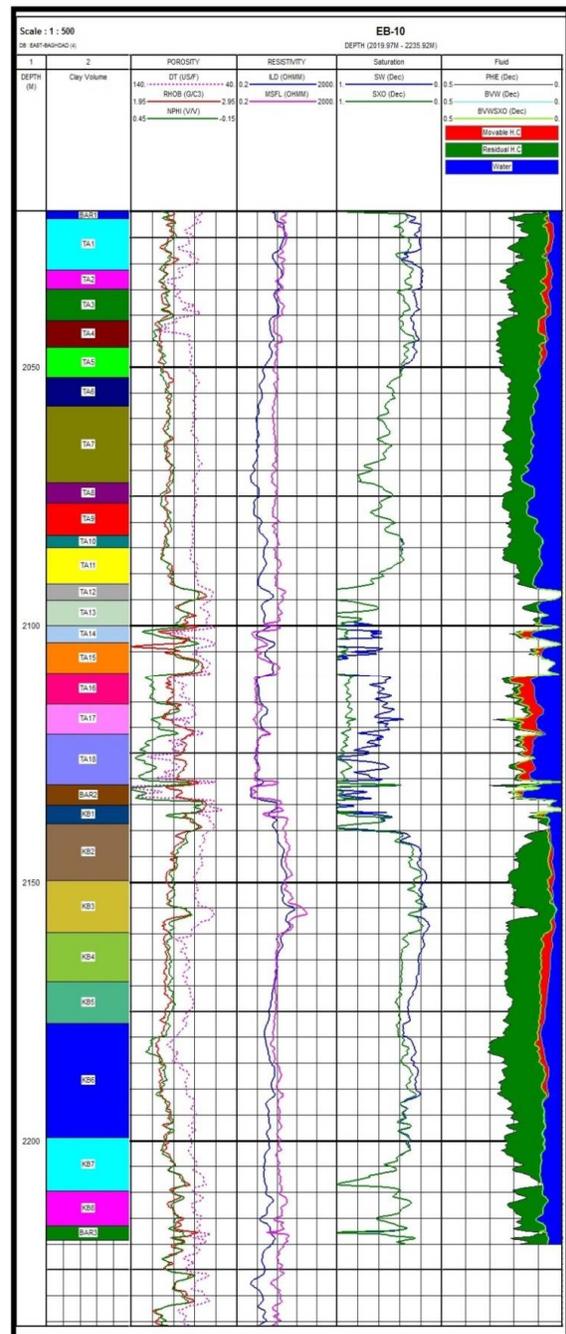
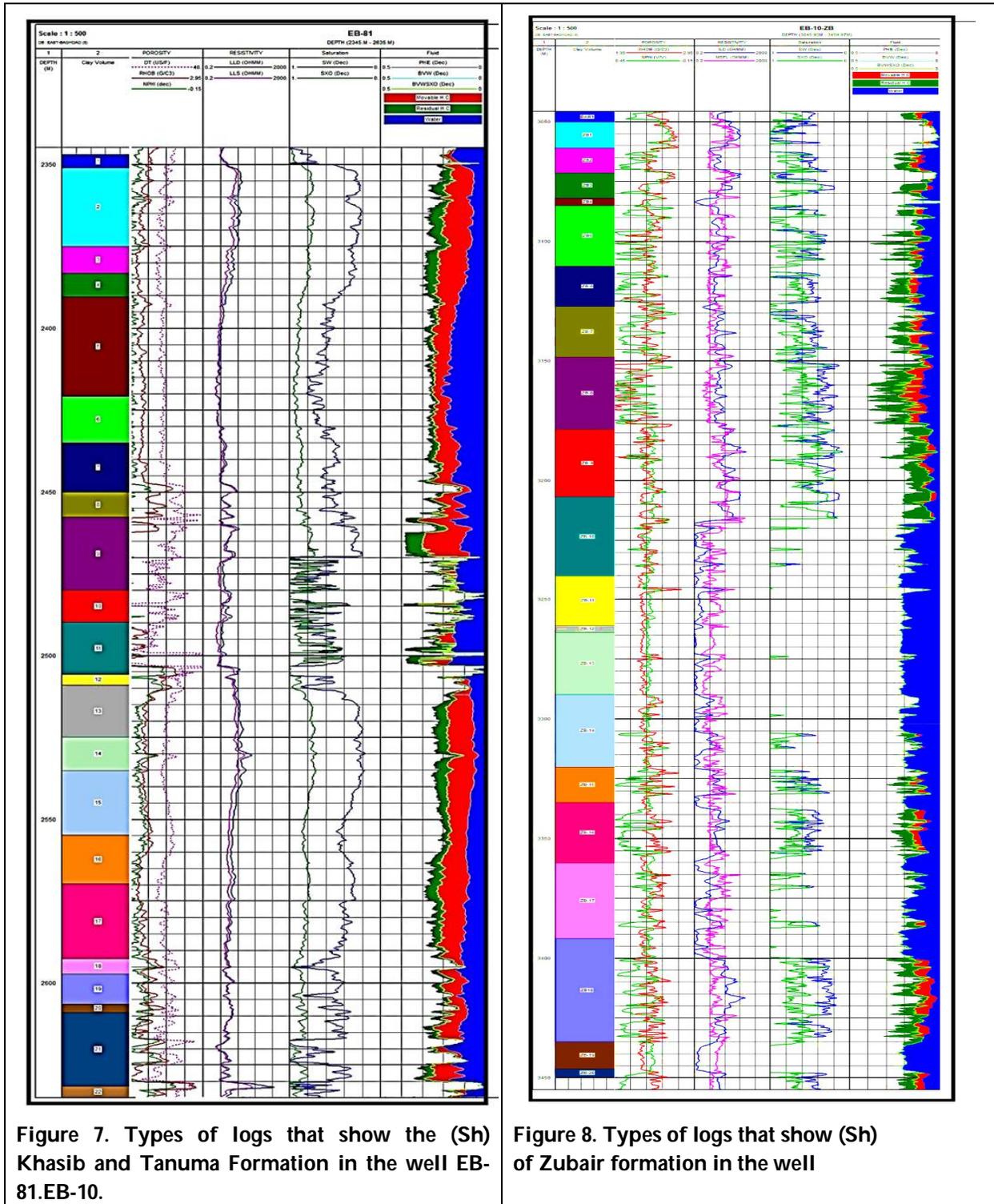


Figure 6. Types of logs that show the (Sh) Khasib and Tanuma Formation in the well EB-81.





Ali KH. Al-Temimi





Ali KH. Al-Temimi

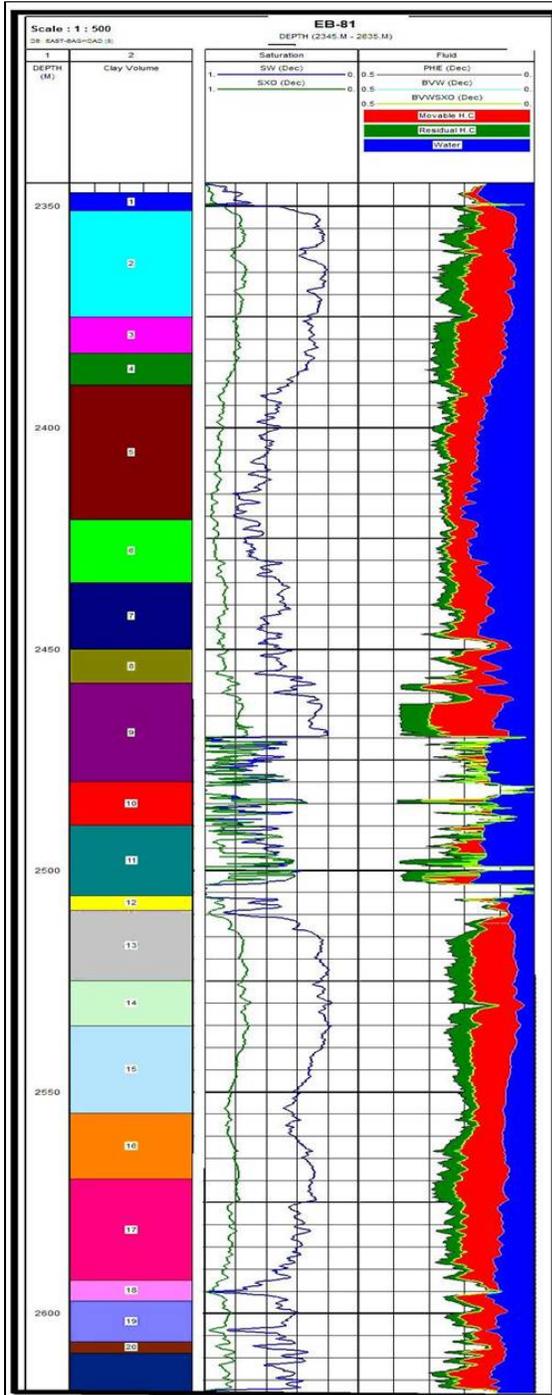


Figure 9. Types of logs that show the (Sw) in Khasib and Tanuma formations in the well EB-10.in the well EB-81.

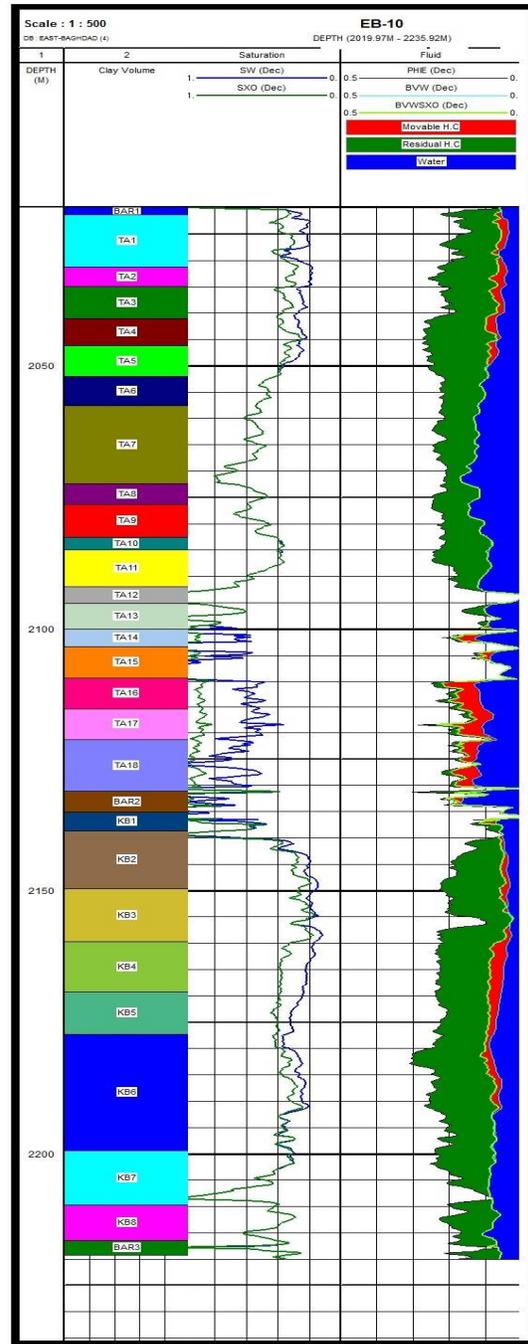


Figure 10. Types of logs that show the (Sw) in Khasib and Tanuma formations





Ali KH. Al-Temimi

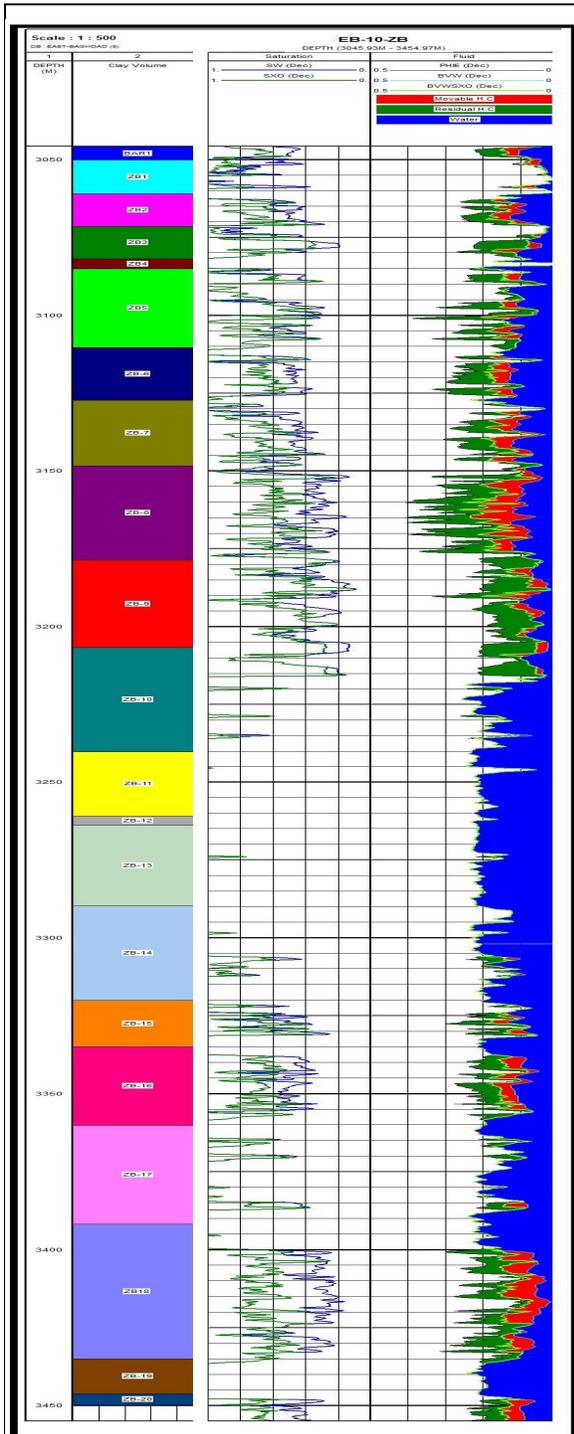


Figure 11. Types of logs that show the Sw KhasibKhasib and Tanuma Formations in the well EB-10.

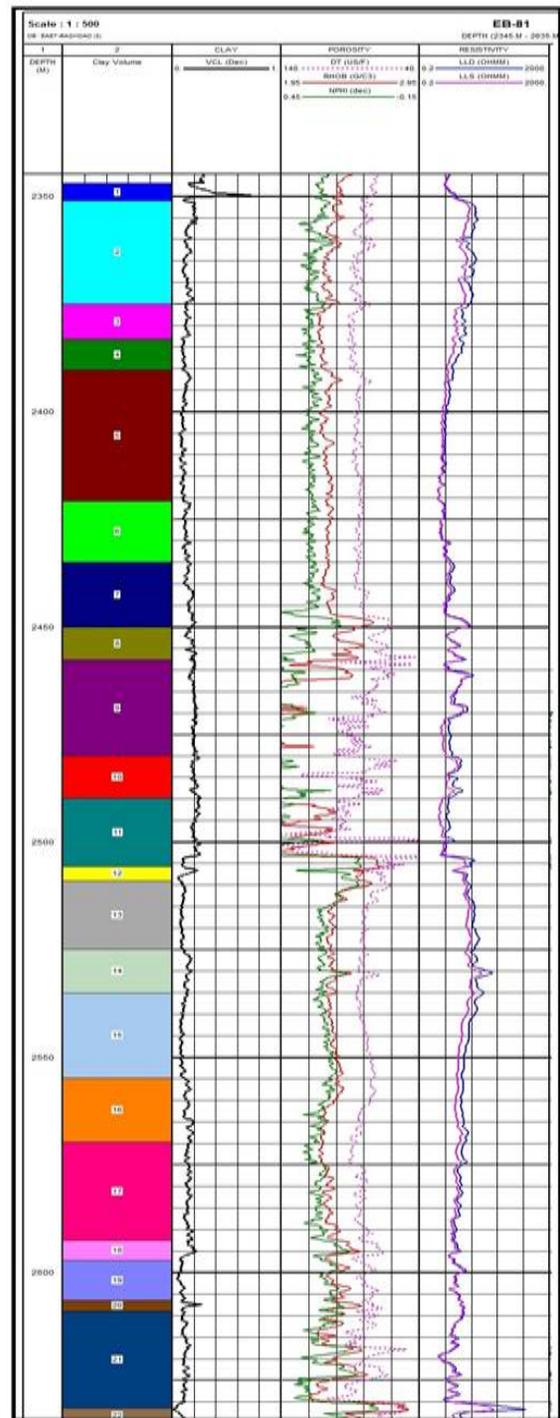


Figure 12. The shale volume of and Tanuma Formations in EB-81.





Ali KH. Al-Temimi

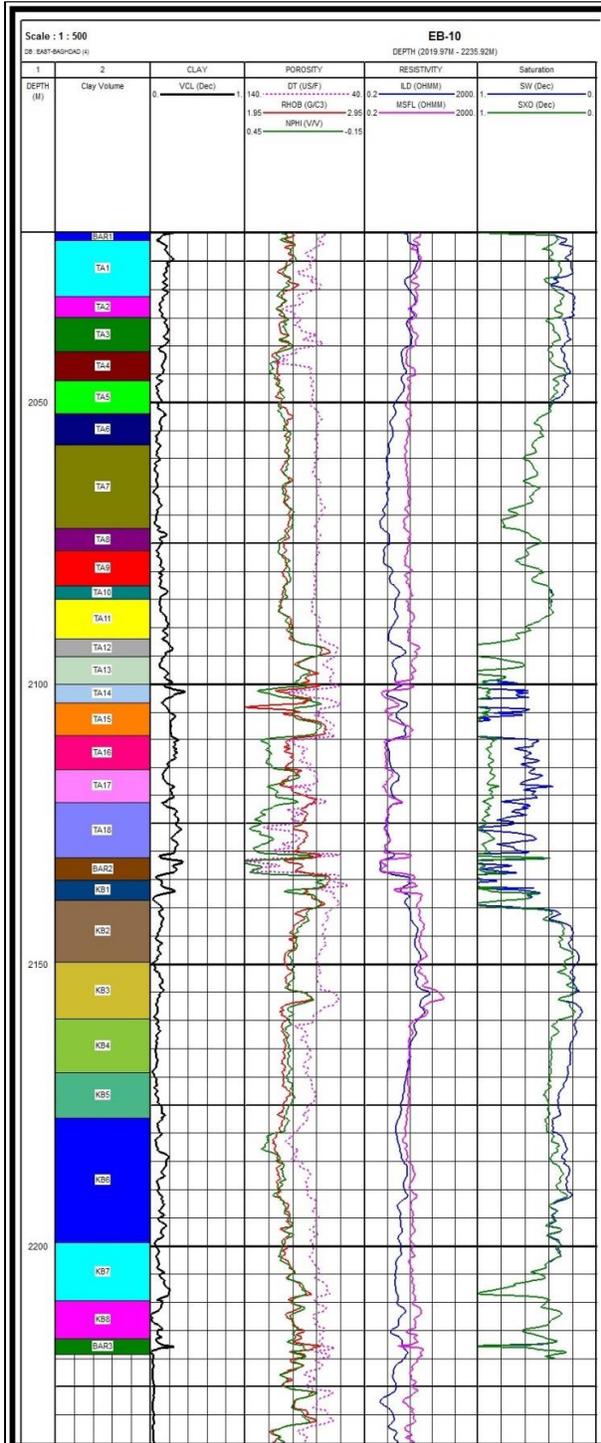


Figure 13. The shale volume of Khasib and Tanuma Formations in EB-10. Formations in EB-10

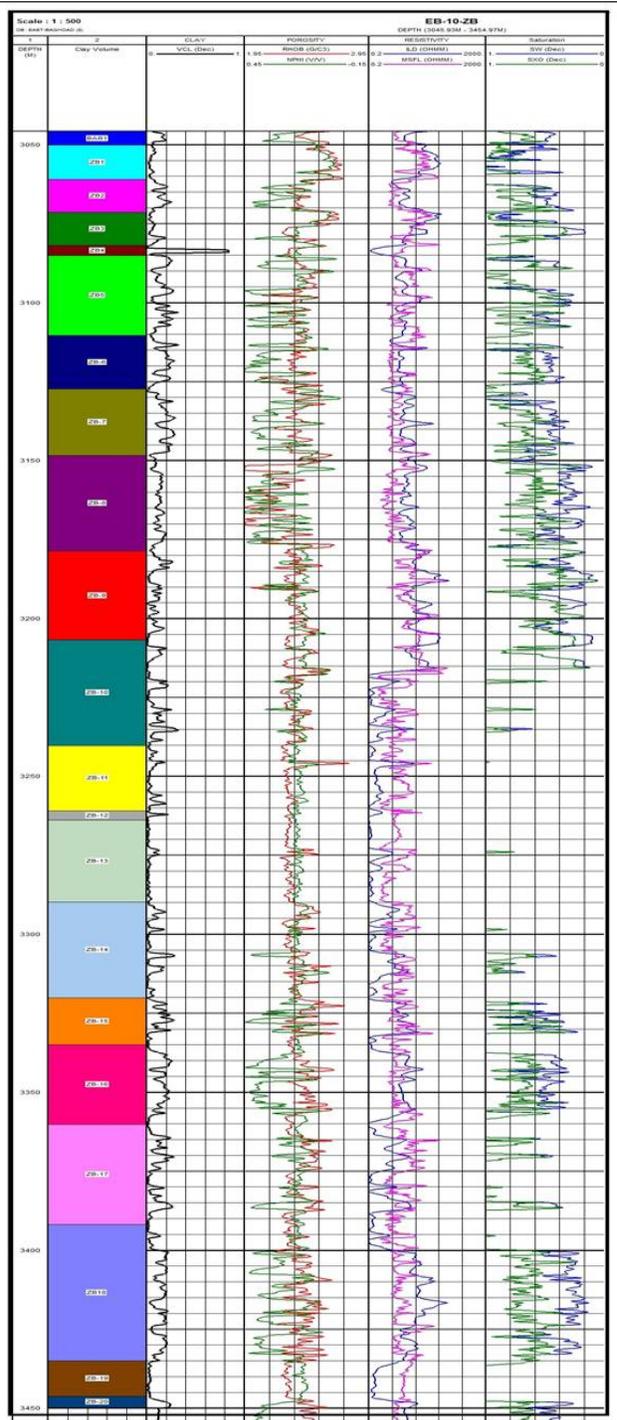


Figure 14. The shale volume of Zubair Formations in EB-10.





Ali KH. Al-Temimi

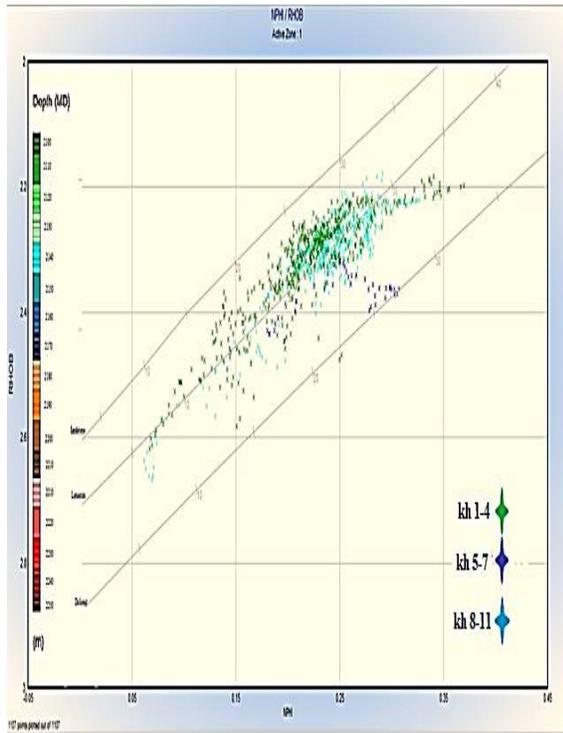


Figure 15. Density vs. Neutron cross plot for Khasib Formations in EB-10.

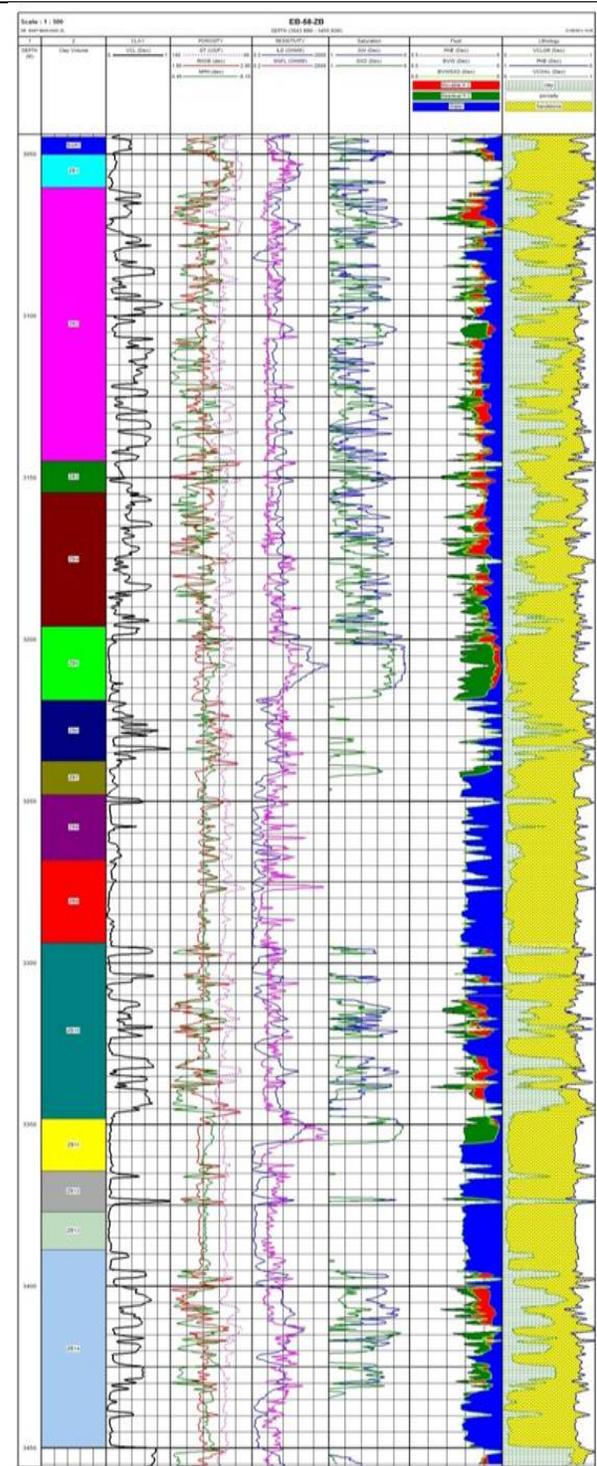


Figure 16. Zubair Formation units in EB-58





Ali KH. Al-Temimi

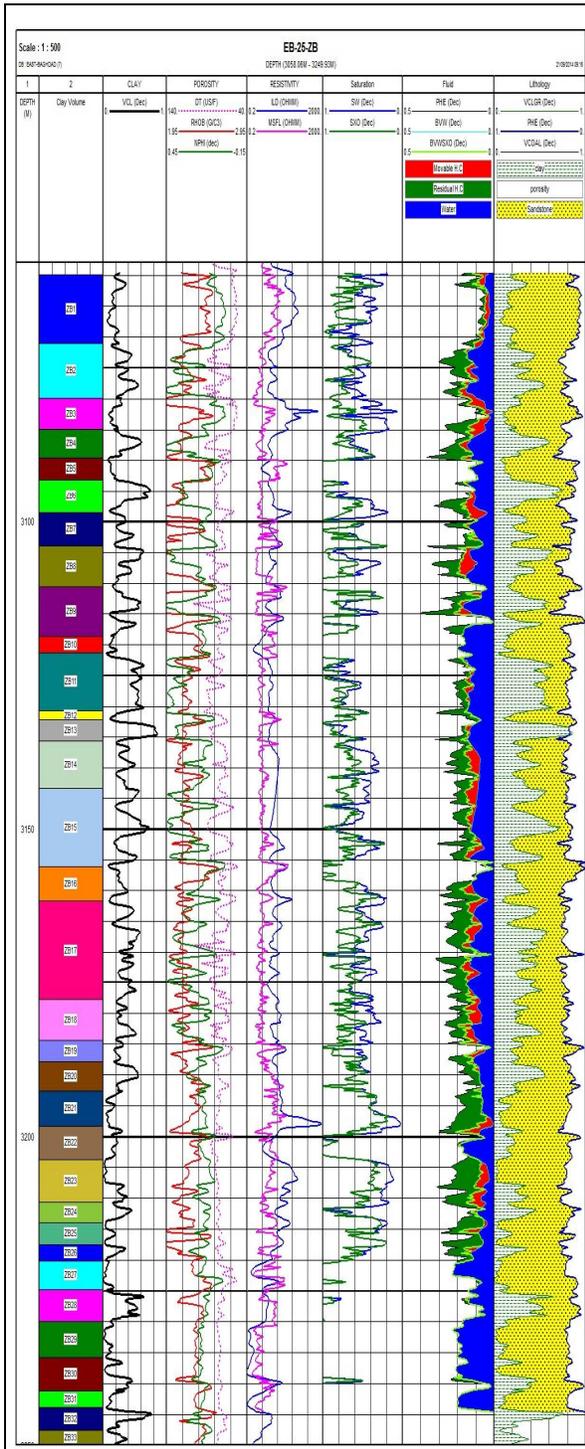


Figure 17. CPI OF Zubair Formation in EB-10

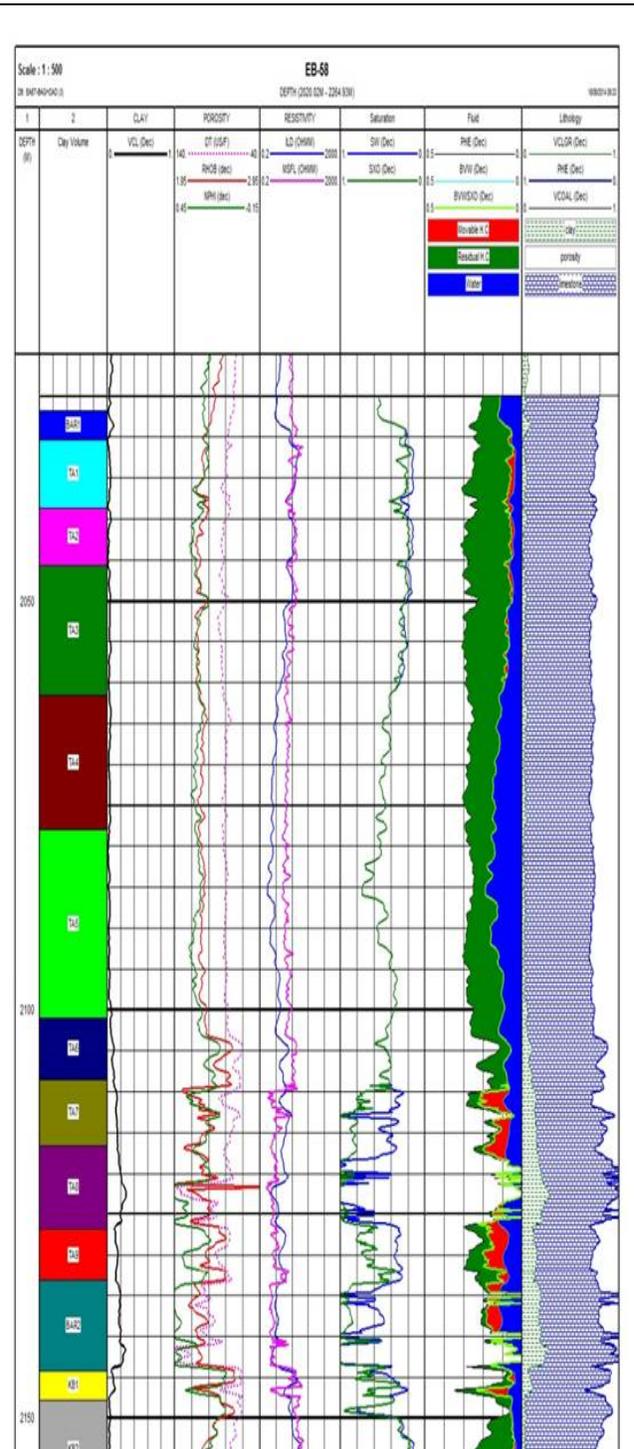


Figure 18. CPI OF Tanuma Formation in EB-58.





Ali KH. Al-Temimi

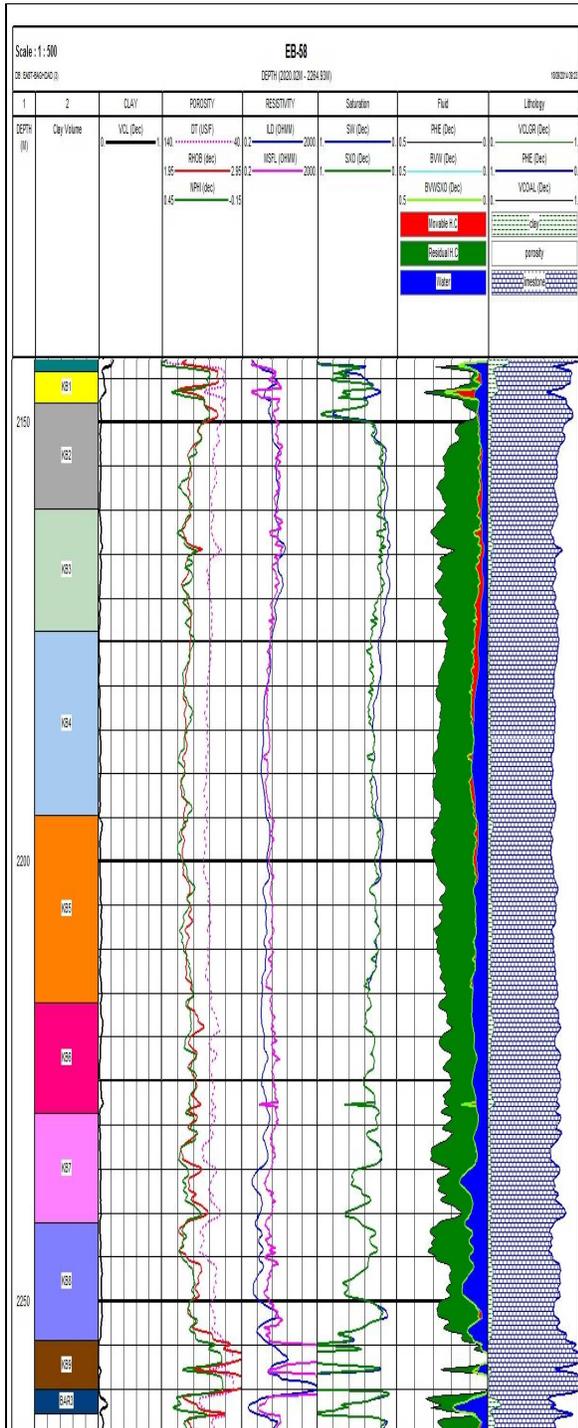


Figure 19. CPI OF Khasib Formation in EB-58.

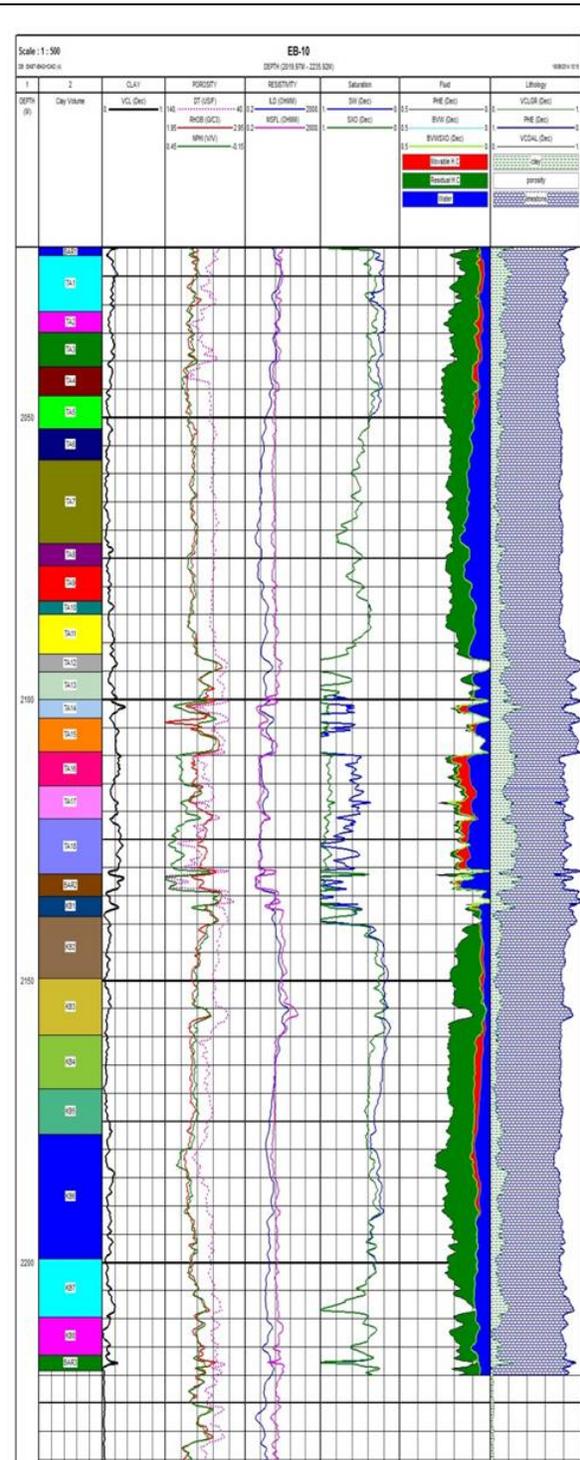


Figure 20. CPI OF Tanuma and Khasib Formation in EB-10.





Ali KH. Al-Temimi

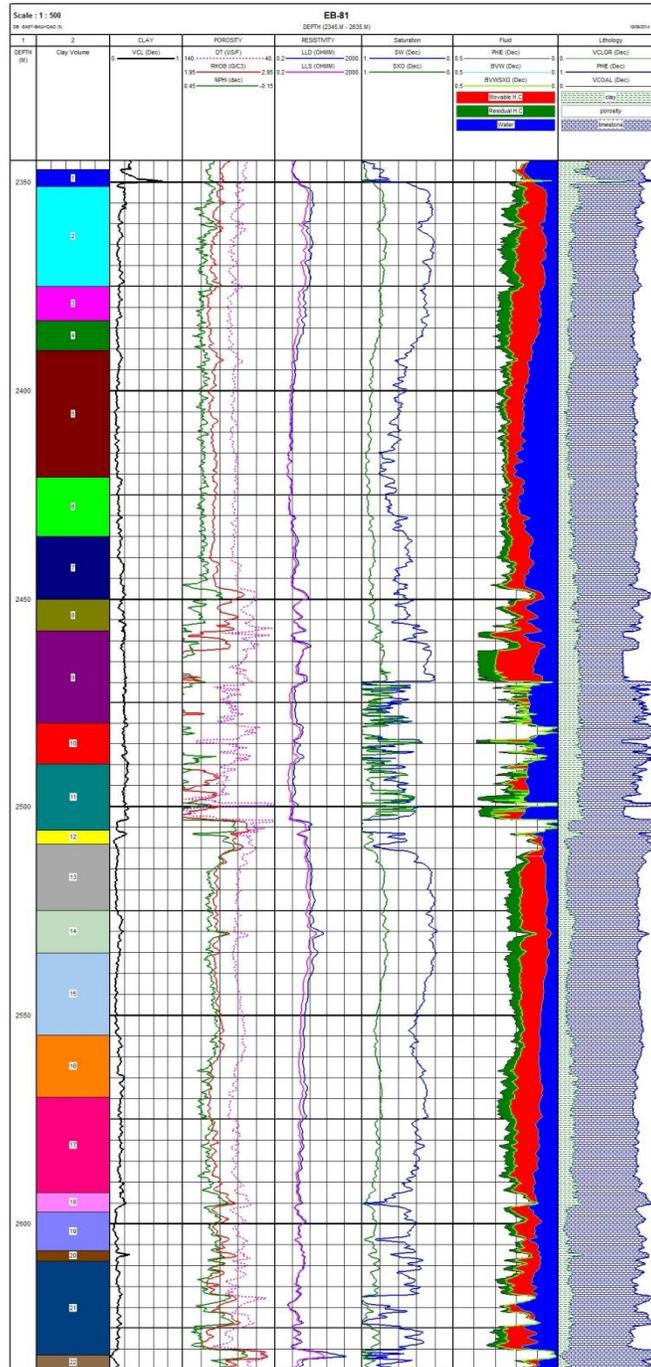


Figure 21. CPI OF Tanuma and Khasib Formations in EB-81.

