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Reservoir Characterization and Identification of Formation Lithology from Well Log Data of Nahr Umr Formation in Luhais Oil Field, Southern Iraq

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Abstract

The identification of a bed's lithology is fundamental to all reservoir characterization because the physical and chemical properties of the rock that holds hydrocarbons and/or water affect the response of every tool used to measure formation properties. The main purpose of this study is to evaluate reservoir properties and lithological identification of Nahr Umr Formation in Luhais well -12 southern Iraq. The available well logs such as (sonic, density, neutron, gamma ray, SP, and resistivity logs) are digitized using the Didger software. The petrophysical parameters such as porosity, water saturation, hydrocarbon saturation, bulk water volume, etc. were computed and interpreted using Techlog software. The lithology prediction of Nahr Umr Formation was carried out by appling IPSOM technique using density, neutron, and gamma ray logs. Nahr Umr Formation in well Luhais -12 was divided into three zones based on well logs interpretation and petrophysical Analysis: Zone-A, Zone-B, and Zone-C. The formation lithology is mainly composed of sandstone interlaminated with siltstone and shale according to interpretation of density, neutron, and gamma ray logs using IPSOM technique. Interpretation of formation lithology and petrophysical parameters shows that zone-C is characterized by clean sandstone with high porosity and water saturation whereas zone –B consists mainly of alternating shale beds with siltstone and sandstone with high porosity and water saturation less than zone –C and increasing of hydrocarbon saturation but Zone –A consists mainly of siltstone and sandstone layer with some of shale beds that contains hydrocarbon.

Keywords: Nahr Umr Formation, Luhais oil field.

الخواص المكمنية والتعرف على صخارية التكوين من معلومات المجسات البئرية لتكوين نهر عمر في حقل اللحيس النفطي، جنوب العراق

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الخلاصة

ان من اساسيات التقييم المكمني هو التعرف على صخارية الطبقات وذلك لان الصفات الفيزيائية والكيميائية للصخور الحاوية على الهايدروكاربون او الماء تؤثر على استجابة الادوات المستخدمة في قياس صفات التكاوين. الهدف الاساسي من هذه الدراسة هو تقييم الصفات المكمنية ومعرفة الصخارية لتكوين نهر عمر في بئر اللحيس –12 جنوبي العراق. ان المجسات البئرية المتوفرة مثل (الصوتي،الكثافة،النيتروني،اشعة كاما،الجهد الذاتي ومجسات المقاومية) تم تحويلها الى قيم رقمية بأستخدام برنامج Didger. تم حساب وتفسير الصفات البتروفيزيائية مثل المسامية والتشبع المائي والهايدروكاربوني بالاضافة الى حجم الماء وغيرها بأستخدام برنامج Techlog. تم انجاز التنبوء الصخاري لتكوين نهر عمر بتطبيق تقنية IPSOM باستخدام

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مجسات الكثافة والنيترون واشعة كاما. تم تقسيم تكوين نهر عمر في حقل اللحيس النفطي الى ثلاثة انطقة بالاعتماد على تفسير المجسات البئرية والتحليل البتروفيزيائي وهي: نهر عمر– أ، نهر عمر–ب، نهر عمر– ج. ان صخارية التكوين تتألف بصورة رئيسية من الصخور الرملية ومايتداخل معها من الصخور الغرينية والاطيان بالاعتماد على تفسيرات مجسات الكثافة والنيترون واشعة كاما باستخدام تقنية IPSOM. ان تفسير صخارية التكوين والصفات البتروفيزيائية تبين ان نطاق نهر عمر– ج يتميز بصخور الحجر الرملي النقي المتميز بمسامية عالية وتشبع مائي عال بينما نطاق نهر عمر – ب يتالف بصورة رئيسية من تتابع من السجيل مع الصخور الرملية والغرينية بصورة منتظمة ومتبادلة مع تميزها بمسامية عالية ايضا وتشبع مائي اقل من نطاق نهر عمر ج لكن النطاق نهر عمر – أ يتالف بصورة رئيسية من الصخور الغرينية والرملية مع بعض من طبقات السجيل الحاوية على الهايدروكاربون.

Introduction:

Understanding reservoir lithology is the foundation from which all other petrophysical calculations are made. To make accurate petrophysical calculations of porosity, and water saturation the various lithologies of the reservoir interval must be identified and their implications understood. The Nahr Umr Formation is one of the siliciclastic deposits of the Cretaceous sequence of Iraq. The two major depocentres in central and South Iraq correspond to areas which received clastics from the Rutba Uplift and the Arabian Shield. In its type area in southern Iraq, the Nahr Umr Formation comprises black shale bedded with medium to fine grained sandstones with lignite, amber, and pyrite [1]. The proportion of sand in the formation increases towards the Salman Zone. The main purpose of this study is to make use of all the available sets of well logs data acquired from LU-12 well of Luhais oil field to determine the petrophysical and lithological properties for each reservoir units in Nahr Umr Formation. The study includes two steps: firstly, the interpretation of well logs to determine reservoir characterization and to delineate zones of Nahr Umr Formation, secondly, lithology predication of formation by IPSOM technique using density, neutron, and gamma ray logs.

Study Area:

Luhais oil Field is located in the Southern part of Iraq, within the Mesopotamian basin at the stable shelf .The studied area is located in the southern desert, about 90 km south-west of Basra city, which lies about 50 km southwest of the Northern Rumaila oil field Figure-1. The Luhais oil field has been discovered in 1961 and the first production began in 1970. The length of the field area is about 20 km, while the width is ranging between (5) kilometers in the north part of the field and (10) km in the South part. [2, 3].

Geological Setting:

Nahr Umr Formation which overlies unconformable AL-Shua`aiba Formation (Aptian), the upper contact surface is conformable and graditional with the Mauddud Formation [4]. The formation is thickest in Southern Iraq and Kuwait (around 400 m), south of Baghdad (160 m), and in Northwest Iraq (where the Rim Siltstone occurs). While in the studied well it was 232m. In its type section in South Iraq at the Nahr Umr Oil field (NU-2) (North of Basrah province), Nahr Umr Formation comprises black shale interbedded with medium to fine grained sandstones with lignite, amber, and pyrite [1]. The proportion of sand in the formation increases towards the Salman Zone.

Methodology:

The study involved analysis of petrophysical properties using data acquired from the available open hole logs of LU-12 well such as (spontaneous potential, gamma ray, density, sonic, neutron, and resistivity logs). The Didger Software was used for the digitization of the logs. One reading per 0.125 m depth is selected for recording the input data measurements, which is used in this study. Environment corrections and interpretations of well logs were carried out and plotted using Techlog software to evaluate petrophysical properties of Nahr Umr Formation. Techlog software was used to evaluate reservoir lithology using IPSOM technique from density, neutron, and gamma ray logs.

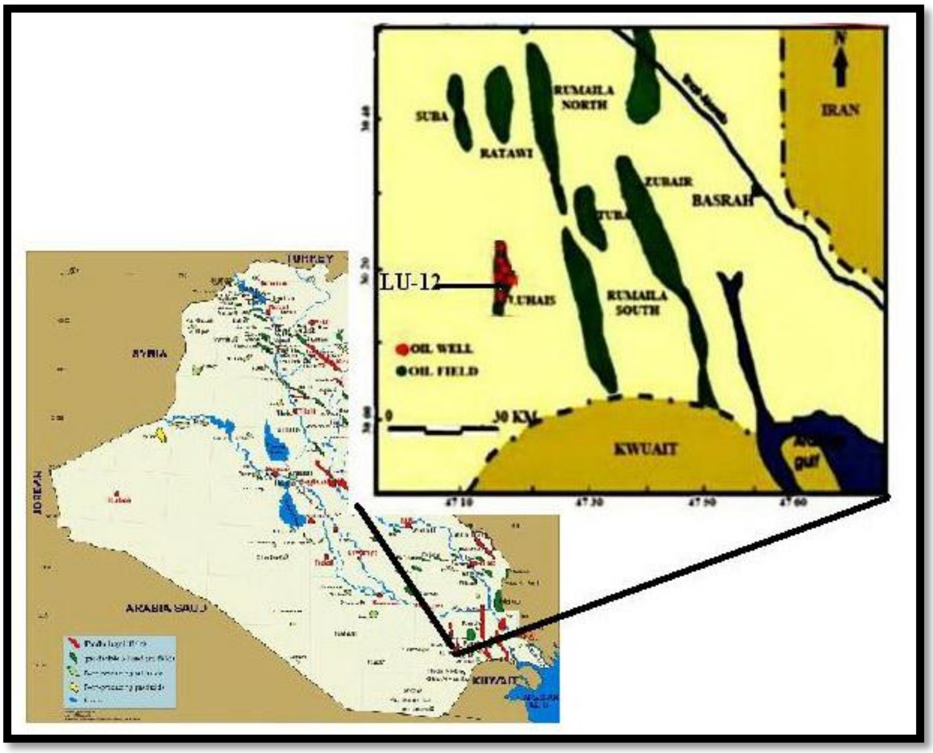

Figure 1- Location map of the study area after Hassan (2011)[5].

Petrophysical Parameters:

For determining reservoir characterization of Nahr Umr Formation, petrophysical parameters must be obtained and evaluated. These parameters include:

A- Volume of shale (Vsh): To derive Vsh from gamma ray (GR Log), it is imperative that the gamma ray index (IGR), determined by using equation of Schlumberger (1974) [6]

$$IGR = (GRlog - GRmin) / (GRmax - GRmin) \quad (1)$$

Where: GRlog = gamma ray reading of formation; GRmin = minimum gamma ray reading (clean sand or carbonate): GRmax = maximum gamma ray reading (shale). For the purpose of this work, the formula of Dresser Atlas (1979) [7] for older rocks was used to determine the shale volume

$$Vsh = 0.33 * [2 (2*IGR) - 1] \quad (2)$$

B- Porosity: Total porosity within Nahr Umr Formation was determined from combination of Neutron – Density derived porosities. Neutron log measure the direct porosity after corrected based on the equation of Tiab & Donaldson (1996) [8]

$$ØNcorr = ØN - (Vsh * ØNsh) \quad (3)$$

Where ØNcorr. = corrected porosity is derived from Neutron log for no clean rocks**:** ØNsh = Neutron porosity for shale. Density porosity is derived from the bulk density of clean liquid filled formations when the matrix density (ρma) and the density of the saturating fluids (ρf) are known, using Wyllie *et al.*, (1958) [9] equation

$$ØD = (\rho ma - \rho b) / (\rho ma - \rho f) \quad (4)$$

Where ρma = density of matrix (2.71 gm/cm3 for limestone, 2.87 gm / cm3 for dolomite, 2.61 gm / cm3 for sandstone), ρf = density of fluid (1 gm/ cm3 for fresh water, 1.1 gm/ cm3 for saline water).

In intervals, whose shale volume is more than 10%, we used equation (5) to remove shale effect from porosity calculation

$$ØDcorr = ØD - (Vsh * ØDsh) \quad (5)$$

Where ØDcorr. = corrected porosity is derived from Density log for unclean rocks**:** ØDsh = density porosity for shale.

Total porosity (Øt) is then calculated as follows

$$Øt = (ØN + ØD) / 2 \quad (6)$$

The effective porosity (Øe) is then calculated, using equation of Schlumberger (1998) [10] after total porosity corrected from shale volume

$$Øe = Øt * (1-Vsh) \quad (7)$$

Sonic log (Δt) based on Wyllie time- average equation (8) was used to determine primary porosity

ØS = (Δtlog - Δtma) / (Δtfl - Δtma) (8)

Then, in order to correct sonic porosity from shale effect within formation, the following equation is used:

ØScorr = ØS – (Vsh* ØSsh) (9)

Where ØS = sonic derived porosity: Δtlog = interval tansit time in the formation; Δtma = interval transit time in the matrix; Δtfl = interval transit time in the fluid in the formation; ØSsh = apparent porosity of the shale; ØScorr = corrected sonic porosity.

Secondary porosity index (SPI) was computed by the difference between total porosity and the primary porosity (that is determined from sonic log) after corrections are made for shaliness

SPI = (Øt – Øscorr) (10)

C- Water and hydrocarbon saturation:

Water saturation for the uninvaded zone was calculated according to Archie (1942) [11]:

$Sw = \{(a * Rw) / (Rt * \_m)\}^{1/n}$ (11)

Water saturation in the invaded zone (Sxo) can be simply calculated from the same equation above by replacing Rw with Rmf (mud filtrate resistivity available from well log headers) and Rt with Rxo (measured resistivity of the invaded zone):

$Sxo = \{(a * Rmf) / (Rxo * \_m)\}^{1/n}$ (12)

Where: Rw = Resistivity of water formation that is previously determined from SP log. a = tortuosity factor; m = cementation factor; n = saturation exponent. Archie's coefficients (a, m, and n), which are more sensitive to pore type, should be determined for different types of carbonate and clastic rocks. Archie (1942) [11] provided a path from qualitative log interpretation to quantitative log analysis through an equation that required parameters which were not available from logs, and which, in the time before calculators and computers, required some effort to solve. Aware of ability of people to recognize pattern, Pickett, (1966) [12] developed a graphical solution to Archie's equation which allowed the quick determination of water saturation by observation of the data, and without the need for numerical calculations. In this study Pickett's plot method has been used in the determination of Archie's parameters from well log using Interactive Petrophysics software (V.3.5). It is a graphical solution to Archie equation that involves plotting true or deep resistivity (Rt) against porosity (φ) on logarithmic scale Figure-2.

Than can be calculating the hydrocarbon saturation, by using the following equation:

Sh = 1 – Sw (13)

Moveable hydrocarbon saturation was calculated based on Schlumberger (1998) [10] equation:

MOS = Sxo - Sw (14)

Whereas residual oil saturation was calculated from Schlumberger (1987) [13] as follows equation:

ROS = 1 - Sxo (15)

Evaluation of Formation Lithology:

Lithology prediction of formation was carried out using IPSOM technique in Techlog software from density, neutron, and gamma ray logs. The Ipsom modules (The intelligent classifier to sharpen Facies modelling) provides automatic classification solutions with both supervised and unsupervised methods. These methods are based on the neural network technology (The Kohonen algorithm). Ipsom is designed for use in:

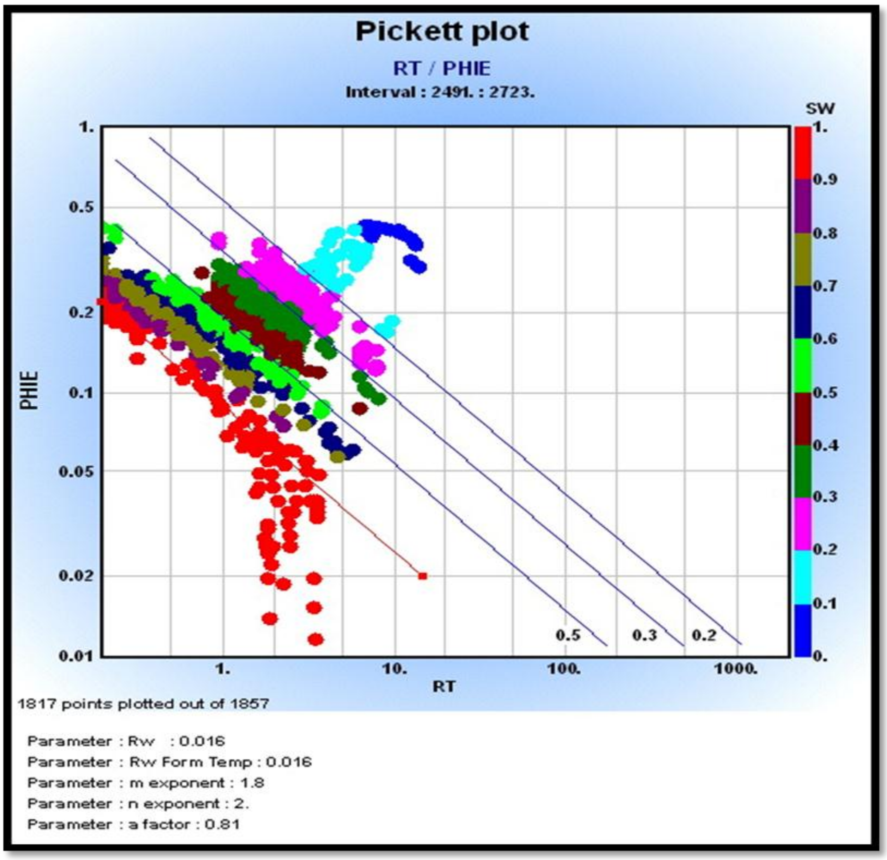

Figure 2- Pickett plot for Nahr Umr Formation in well LU-12.

- Geological interpretation of well log data and facies prediction.
- Optimal derivation of petrophysical parameters such as hydraulic units.

Nahr Umr Formation in Luhais field consists mainly of sandstone interbedded with siltstone and shale [14], So in this study,three classes of lithology types (sandstone, siltstone, and shale) were used as lithology indexation input in Ipsom module.

IPSOM report: Ipsom

1) Workflow parameters

Table 1-Inputs properties of Ipsom module

Inputs properties							
	Variable	**Transformation**	**Min**	**Max**	**Unit**	**Color**	**Activate**
1	Bulk Density	Linear	1.908	2.7239	g/cm3		yes
2	Gamma Ray	Linear	11.4152	112	gAPI		yes
3	Neutron Porosity	Linear	0.118	0.4528	v/v		yes

Table 2- Indexation properties of Ipsom module

Indexation properties						
	Supervised	**Supervised methods**	**supervised methods**	**HC method**	**Weighting Fact**	**Class number**
1	**NO**	**quantitative classification**	**Hierarchical Clustering (HC)**	**Ward**	**1.2**	**3**

2) Main plots

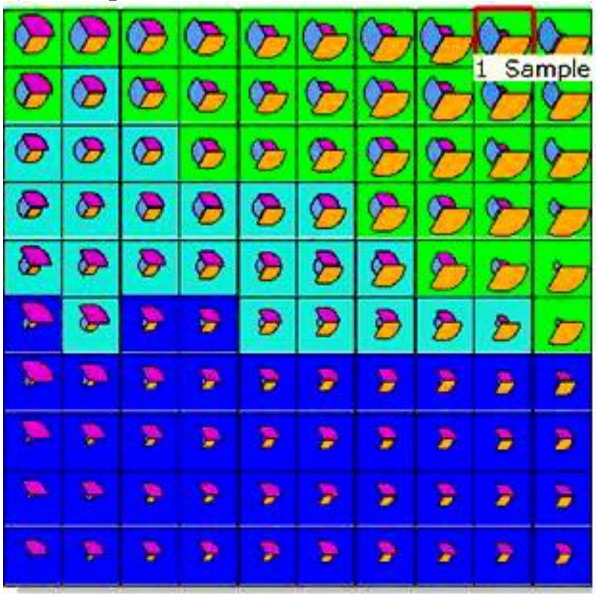

Figure 3- Self-organizing map (Dimension 10*10) of Ipsom module.

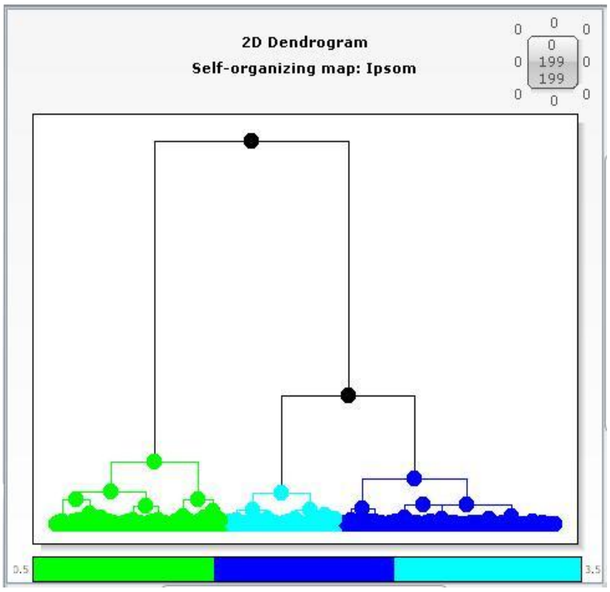

Figure 4- Hierarchical Clustering (HC) of Ipsom module.

3) Statistics

Table 3- Statistics of groups

Groups						
Name	**shale**		**sandstone**		**siltstone**	
Colour						
Number of samples	34		43		23	
Variables	**Mean**	Standard deviation	**Mean**	Standard deviation	**Mean**	Standard deviation
Bulk Density	**2.2280**	0.0213	**2.3357**	0.0047	**2.3533**	0.0045
Gamma Ray	**69.5549**	225.5603	**22.6041**	58.5892	**49.5218**	95.8770
Neutron Porosity	**0.3984**	0.0022	**0.2234**	0.0010	**0.2859**	0.0019

Results and Discussions:

The computer processing interpretation (CPI) and petrophysical properties of Nahr Umr Formation were presented in Figure-5. Delineation of Nahr Umr lithology by IPSOM technique was illustrated in Figure-6. These figures show that Nahr Umr Formation was divided into three zones: Nahr Umr-A, Nahr Umr-B,and Nahr Umr-C. Each one of these zones is characterized by different petrophysical and lithological properties which were summarized below:

1. Zone-A: The upper part of this zone consists mainly of siltstone and some sandstone layer in the top of formation whereas lower part consists mainly of shale beds alternating with thin beds of siltstone and base layer of sandstone that separate this zone with zone-B. The petrophysical properties of this zone was showed in Table-4 which illustrated the minimum, maximum, and average values of reservoir properties with the top and bottom of zone and net thickness.
2. Zone-B: It is a shale-dominated unit, alternating with thin bedded of siltstone and sandstone. The shele bed of this zone is thicker than zone-A with a rich organic matter according to interpretation of well logs which are indicated by high hydrocarbon saturation. Table-5 shows the minimum, maximum, and average values of petrophysical properties with the top and bottom of zone and net thickness.
3. Zone-C: It consists mainly of clean sandstone layer, as indicated from well log interpretations using IPSOM technique. Thin beds of siltstone in some intervals are intercalated with the main sandstone beds and shale bed in the bottom of this zone which represents lower contact of the Nahr Umr Formation with the underlying Shuaiba Formation which represents unconformable surface. Table-6 illustrates the petrophysical properties with the top and bottom of zone and net thickness.

Table 4- Petrophysical parameters of zone –A

parameters	Top	Bottom	Thickness	Min	Max	Mean
VSH	2491	2524.5	33.5	0.046	0.467	0.182
PHIT	2491	2524.5	33.5	0.081	0.342	0.214
PHIE	2491	2524.5	33.5	0.028	0.292	0.187
SW	2491	2524.5	33.5	0.228	1	0.602
SXO	2491	2524.5	33.5	0.547	1	0.861
BVW	2491	2524.5	33.5	0.028	0.237	0.11
BVWSXO	2491	2524.5	33.5	0.028	0.237	0.16

Table 5- Petrophysical parameters of zone –B

parameters	Top	Bottom	Thickness	Min	Max	Mean
VSH	2524.5	2609.5	85.	0.013	1	0.365
PHIT	2524.5	2609.5	85.	0.084	0.429	0.245
PHIE	2524.5	2609.5	85.	0	0.42	0.191
SW	2524.5	2609.5	85.	0.077	1	0.499
SXO	2524.5	2609.5	85.	0.209	1	0.819
BVW	2524.5	2609.5	85.	0	0.254	0.08
BVWSXO	2524.5	2609.5	85.	0	0.254	0.147

Table 6- Petrophysical parameters of zone –C

parameters	Top	Bottom	Thickness	Min	Max	Mean
VSH	2609.5	2723	113.5	0	0.473	0.048
PHIT	2609.5	2723	113.5	0.117	0.424	0.23
PHIE	2609.5	2723	113.5	0.061	0.416	0.223
SW	2609.5	2723	113.5	0.118	1	0.779
SXO	2609.5	2723	113.5	0.271	1	0.93
BVW	2609.5	2723	113.5	0.031	0.24	0.172
BVWSXO	2609.5	2723	113.5	0.061	0.37	0.207

Conclusions:

1. The available logs data such as gamma ray, electric (spontaneous potential, laterolog deep and shallow), formation density, sonic, and neutron log) are digitized using the Didger Software. The interpretations of well logs have been carried out using Techlog.
2. Archie's parameters have been calculated using Pickett plots by Interactive Petrophysics Software and show that the values of a= 0.81 for sandstone matrix, m= 1.8 for Nahr Umr Formation, and n=2 at Rw= 0.016 that have been calculated previously.
3. The computer processing interpretation (CPI) of well Luhais-12 has been deduced using Techlog softwar in which the porosity, water saturation, and shale content were calculated. The computer processing interpretation shows that the Nahr Umr Formation can be divided into three zones: A, B, and C which are characterized by different petrophysical properties.
4. The computer processing interpretation (CPI) shows that Nahr Umr –C unit has the highest thickness which has about (113.5m), and the highest porosity about 0.223 and highest water saturation about 0.779.
5. The lithology predication of Nahr Umr Formation was carried out by appling IPSOM technique using density, neutron, and gamma ray logs.
6. The formation lithology is mainly composed of sandstone interlaminated with siltstone and shale according to interpretation of density, neutron, and gamma ray logs using IPSOM technique.

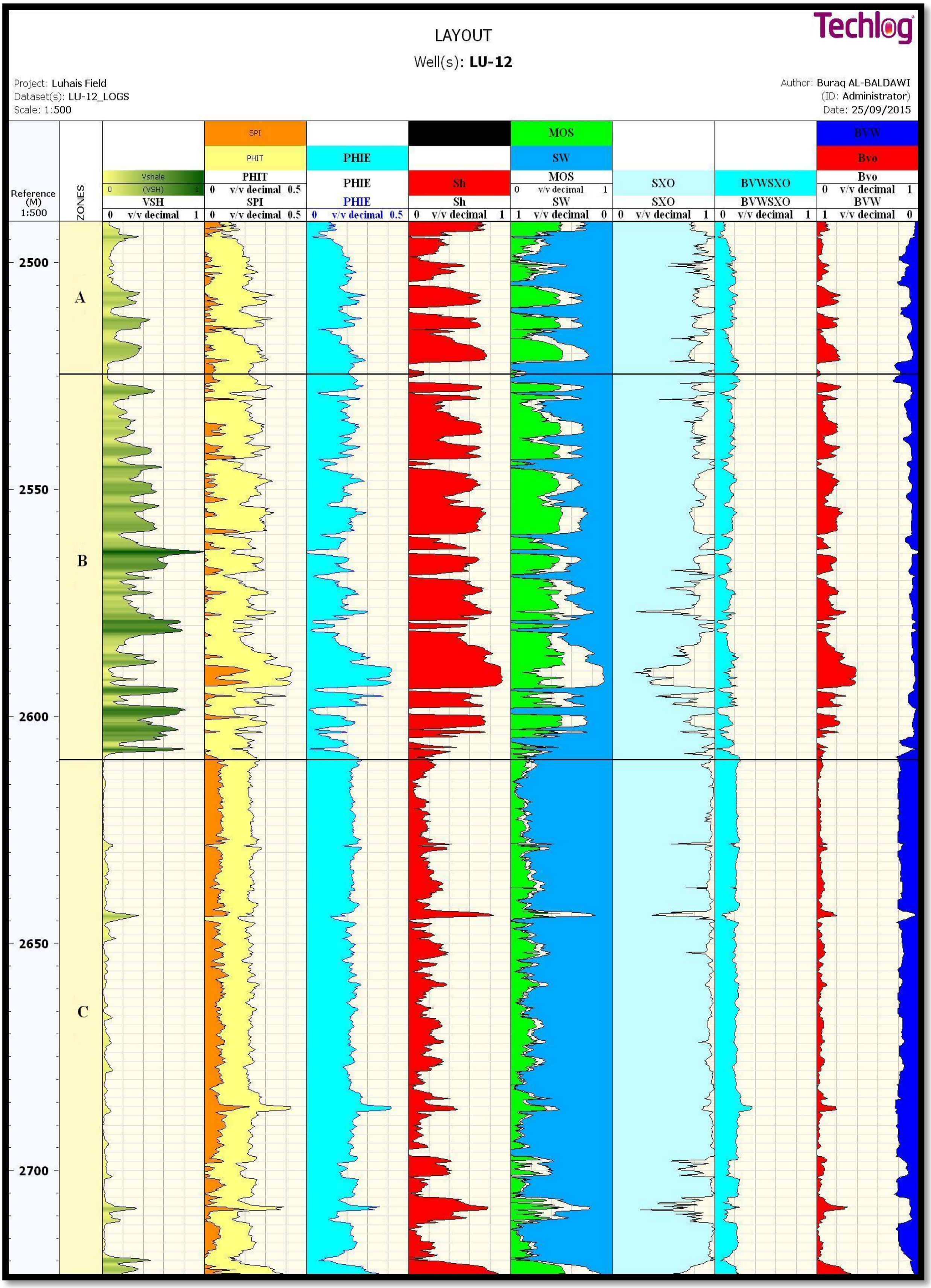

Figure 5- The computer processes interpretation (CPI) of Nahr Umr Formation in well Luhais-12.

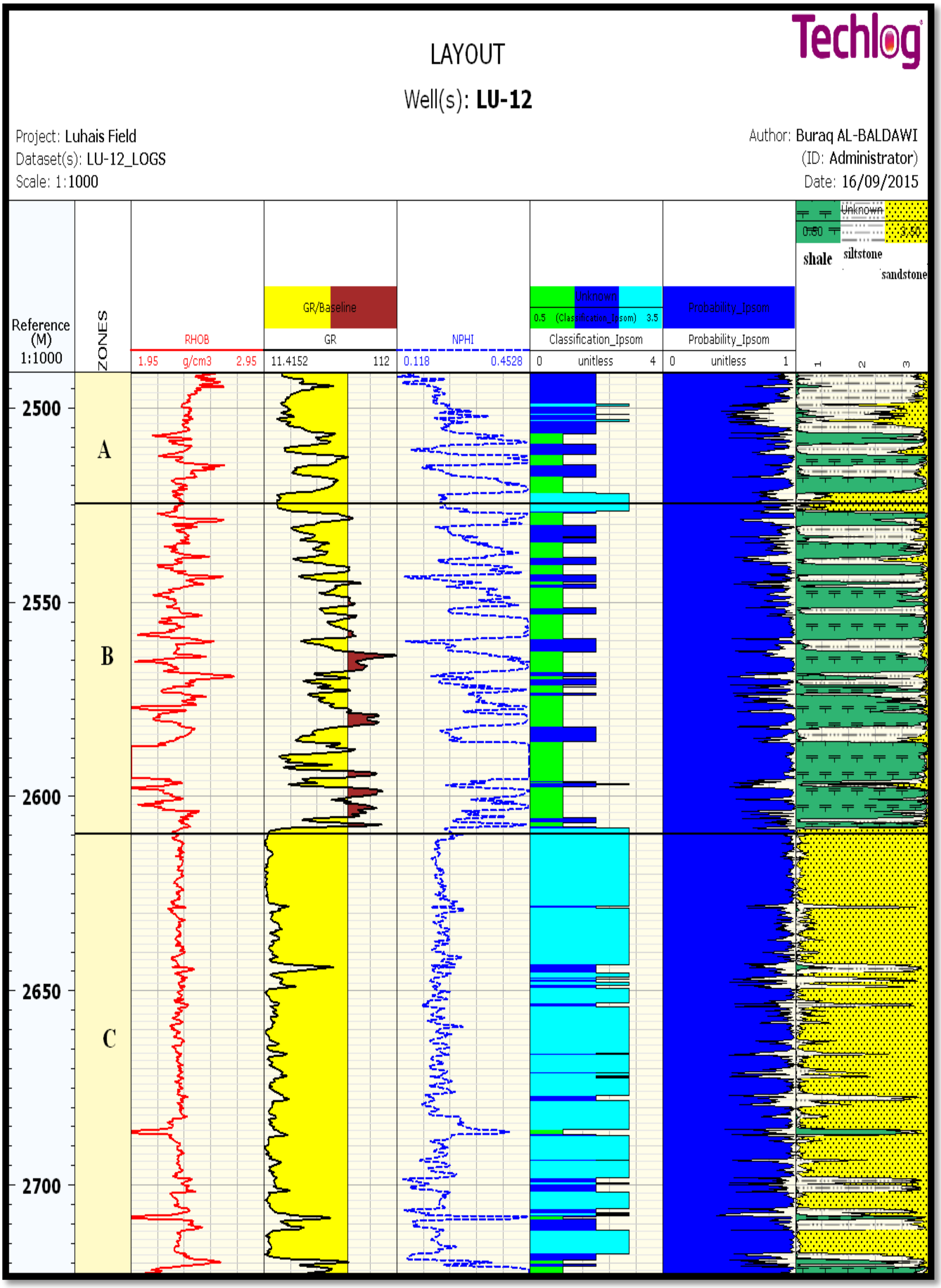

Figure 6- Delineation of Nahr Umr lithology by IPSOM technique.

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