Iraqi Bulletin of Geology and Mining *Vol.14, No.2, 2018* *p 61 – 69*

PETROPHYSICAL PROPERTIES AND RESERVOIR DEVELOPMENT OF ALBIAN SUCCESSION IN NASIRIYAH OIL FIELD, SOUTHERN IRAQ

Marwah H. Khudhair[1] and Aiad A. Al-Zaidy[2]

Received: 25/ 10/ 2017, Accepted: 18/ 01/ 2018
Key words: Petrophysical Properties, Reservoir development, Albian succession, Nasiriyah Oil Field, Iraq

ABSTRACT

The carbonate-clastic succession in the studied wells is represented by the Nahr Umr and Mauddud formations deposited during the Albian Sequence. This study includes petrophysical properties and reservoir characterization of this succession in 5 wells within the Nasiriyah oil field. According to values and shape of gamma ray logs and shale values, the studied formations were subdivided into five zones named; A, B, C, D, and E. Three types of rocks were identified in these zones according to their total porosity: **Type I:** High-moderate active porosity rocks; **Type 2:** High-moderate inactive porosity rocks and **Type 3:** Low-non porous rocks. According to the relationship of resistivity-porosity and hydrocarbon saturation two reservoir horizons have been identified in this study within the Nahr Umr Formation. The Mauddud Formation, on the other hand, does not show any hydrocarbon in the studied succession, due to the overwhelming presence of shale strongly affected by diagenetic processes such as cementation and compaction. Horizon 1 appears in the upper sand member of Nahr Umr Formation, encountered in wells No.1, No.2, and No.3. This type of rocks is characterized by high-moderate porosity (effective porosity) with low volume of shale and high deep resistivity. The thickness of this type ranges from 21 m to 48.5 m. Horizon 2 is represented by breaded river lithofacies, occurring in all the studied wells except No.3. It is divided into two sub-horizons in well No.5. This type of rocks is 12.25 – 57 m thick and characterized by high-moderate porosity with low volume of shale and high deep resistivity.

الخواص البتروفيزيائية والتطور المكمني لتتابع الالبيان في حقل الناصرية النفطي، جنوبي العراق

مروة حاتم خضير و أياد علي الزيدي

المستخلص

يتمثل التتابع موضوع الدراسه الحالية بتكويني نهر عمر ومودود المترسبين خلال دورة الألبيان وتضمنت الدراسة البتروغرافية والتحليل السحني والخواص المكمنية لهذا التتابع في خمسة آبار ضمن حقل الناصرية النفطي. قسم التتابع الى خمس أنطقة (A، B، C، D و E) بالاعتماد على شكل وقيمة أشعة گاما وحجم السجيل الموجود وقسمت هذه الأنطقة الى ثلاث أنواع من الصخور بالاعتماد على المسامية الكلية هي: **1)** عالي-متوسط المسامية الفعالة، **2)** عالي الى متوسط

[1]Department of Geology, College of Science, University of Baghdad, Iraq, e-mail: marwageo281@yahoo.com
[2] Department of Geology, College of Science, University of Baghdad, Iraq.

المسامية غير الفعالة، و **3)** قليل الى عديم المسامية. تم تقييم الخواص المكمنية لتكويني نهر عمر والمودود من خلال مناقشة التغيرات في المساميات الثانوية والفعالة والنفاذية بالاعتماد على المقاومية والمسامية. تم حساب الاشباع الهايدروكاربوني وتحديد مستويين مهمين في المقاطع المدروسة ضمن تكوين نهر عمر، بينما لم يظهر تكوين مودود أيشواهد لوجود الهيدروكاربونات ويرجع ذلك ربما الى نسبة السجيل العالية وتأثر التكوين بالعمليات التحويرية وخاصة السمنتة وعملية التراص. يقع المستوى الأول في الجزء الأعلى للوحدة الرملية ضمن الآبار ناصرية-1، ناصرية-2 و ناصرية-3 ويتميز بوجود صخور ذات مسامية فعالة عالية الى متوسطة ونسبة سجيل ضئيلة ومقاومية عميقة عالية ويتراوح سمكه بين 21 – 84.5 متر. يتميز المستوى الثاني بقيم مسامية فعالة عالية وقيم سجيل ضئيلة ومقاومة عميقة عالية ويتراوح سمكه بين 12.25 – 57 مترا ويتمثل بسحنة بيئة النهر الضفائري في جميع الآبار المدروسة عدا البئر ناصرية-3.

INTRODUCTION

The Nasiriyah oil field is located in the South of Iraq (Al-Naqib, 1967) within the Mesopotamian Zone of Buday and Jassim (1987), (Fig.1) and comprised of a subsurface anticline with NW – SE axis. The carbonate-clastic succession in this study is represented by the Nahr Uamr and Mauddud Formations و deposited during the Albian sequence. The present study includes petrophysical properties and reservoir characterizations of these successions in five wells (No. 1, 2, 3, 4, and 5) within the Nasiriyah oil field.

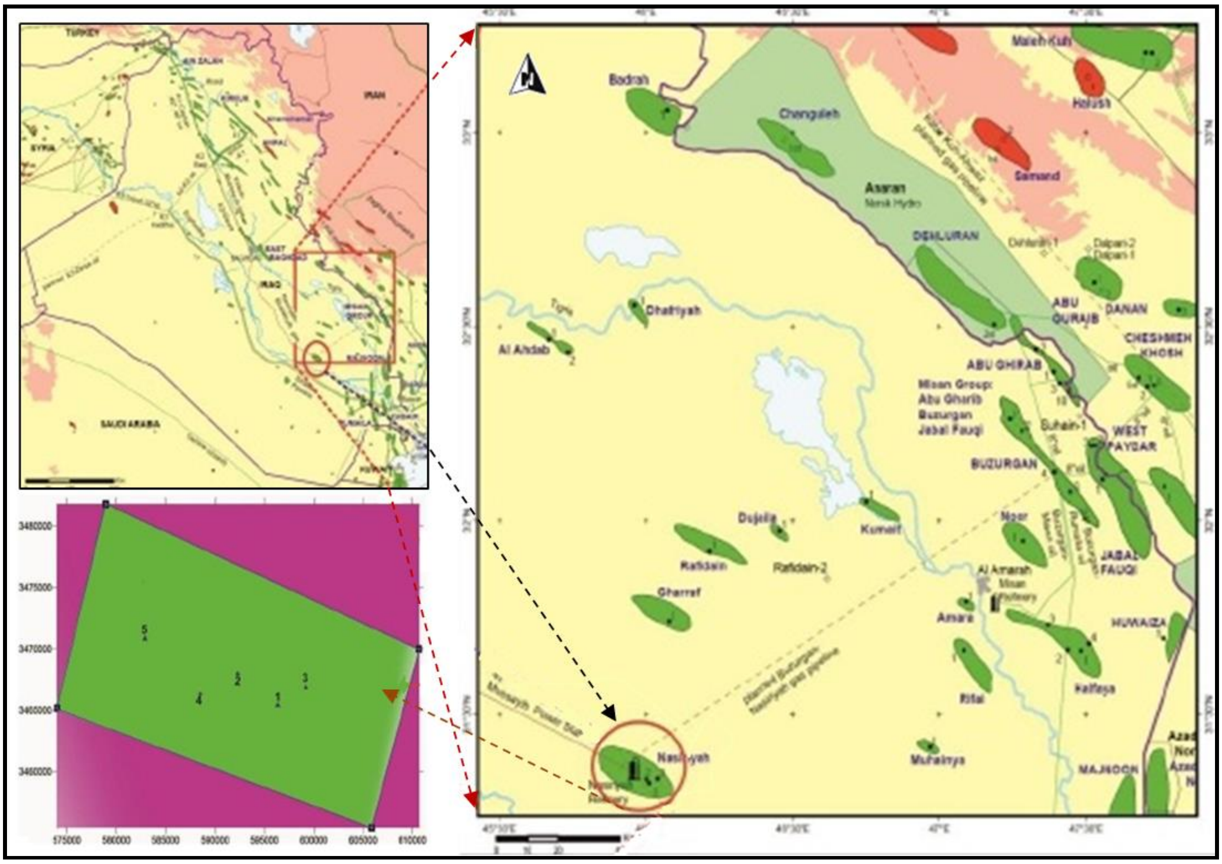

Fig.1: Location of the study area

The clastic-carbonate successions of the Nahr Umr and Mauddud formations are part of the Albian-Early Turonian Sequence of the Wasi'a Group. The Nahr Umr Formation was defined by Glynn Jones in 1948 (in: Bellen *et al*., 1959) in the Nahr Umr structure in south Iraq. The two major depocenters 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 (Bellen *et al*., 1959). The proportion of sand in the formation increases towards the Salman Zone.

The Mauddud Formation includes the Upper part of the Qamchuqa Formation and is considered the most widespread Lower Cretaceous formation in Iraq. It has variable thickness due to lateral facies change and erosional truncation. At outcrop in NE Iraq, the Qamchuqa Formation comprises organic detrital; detrital and locally argillaceous limestones with variable degrees of dolomitization (Bellen *et al*., 1959). In some areas, fresh- or brackish-water limestone beds were reported (Jassim and Goff, 2006). In Southern Iraq, the Mauddud Formation comprises frequently dolomitized organo detrital limestone.

The present study involves petrophysical properties of the Nahr Umr and Mauddud formations in the Nasiriyah oil field, and the effects of diagenetic development on reservoir properties, with the construction of a reservoir model for these formations.

METHODOLOGY

The present study is based on:

- Digitizing well logs using Didger software.
- Using interactive petrophysical software IP (V3.5) for the environmental correction, lithology, mineral identification and logs interpretation.
- Study of the well logs and relate the log response to facies and diagenetic changes.
- Building petrophysical model and petrophysical properties, throughout well correlation, in the Mauuddud and Nahr Umr formations in the Nasiriyah oil field.

PREVIOUS STUDIES

Ebraheem (2015) studied Reservoir characters within West Qurna oil field for Shuaiba and Nahr Umr formations, according to the values of gamma ray and shale content it was divided into three zones (A, B, C). Zone A is composed of sandstone with little amount of shale, with total porosity ranges between (< %10 – %30) which enabled dividing the zone into two petrophysic units; high-moderate active porosity and high-moderate inactive porosity. Zone B is characterized by three subzone: Box shape, with low gamma and sharp boundaries; Funnel shape, which refers to increasing upward gamma ray value and Bell shape, which refers to relatively decreasing upward gamma ray value. Zone C is represented by an irregular log shape with very low shale content. According to the relationship between resistivity-porosity and the hydrocarbon saturation, two types of reservoires were identified; Type A appeared in the sand part of the Nahr Umr Formation, characterized by high-moderate porosity (effective porosity) with low volume of shale and high deep resistivity. Type B is shown in the upper and lower parts of the Shuaiba Formation and characterized by high-moderate porosity (effective porosity) with high deep resistivity.

Hussein (2015) studied the Nahr Umr and Mauddud formations in Luhais oil field. The evaluation of reservoir characterization was discussed in terms of changes in the secondary and effective porosities and permeability. According to resistivity and porosity, the hydrocarbon saturation was calculated and three zones were determinated in the studied section; Zone A, Zone B and Zone C, these zones were divided into two rock types according to total porosity: High-moderate active porosity rocks (Type I), and Low-non poros rocks (Type II).

RESULTS AND INTERPRETATION

The interpretation of results is made through direct reading of the well logs as well as through established relationships and cross-plots in order to find the important lithological and petrophysical properties.

- **Shale Volume Determination**

Shale is usually more radioactive than sand or carbonate; hence, gamma-ray logs can be used to calculate shale content in porous reservoirs. The volume of shale, expressed as a decimal fraction or percentage, is called V shale. Calculation of the gamma-ray index is the first step needed to determine the volume of shale from a gamma-ray log (Larionov, 1969). According to the values and the shape of the gamma-ray log and the shale content, Nahr Umr and Mauddud formations were divided into five zones, named as A, B, C, D, and E, from the top of the Mauddud Formation to the lower contact of Nahr Umr Formation, as shown in Table (1) and Figure (2).

Table 1: Volume of shale and identified zones properties

Zone name	Thickness range	Volume of shale	Appearance in the wells	Stratigraphic location
A	50 – 120 m	10 – 40 %	All wells except well No.3	Upper part of Mauddud Formation
B	53 – 115 m	40 – 65 %	All wells	Lower part of Mauddud Formation
C	45 – 220 m	20 – 68 %	All wells	Upper part of Nahr Umr Formation except well No.3
D	86 – 112 m	10 – 25 %	Three wells No.2, No.4 and No.5	Lower part of Nahr Umr Formation
E	52 m	10 – 30 %	Well No. 3	Upper part of Nahr Umr Formation in well No.3

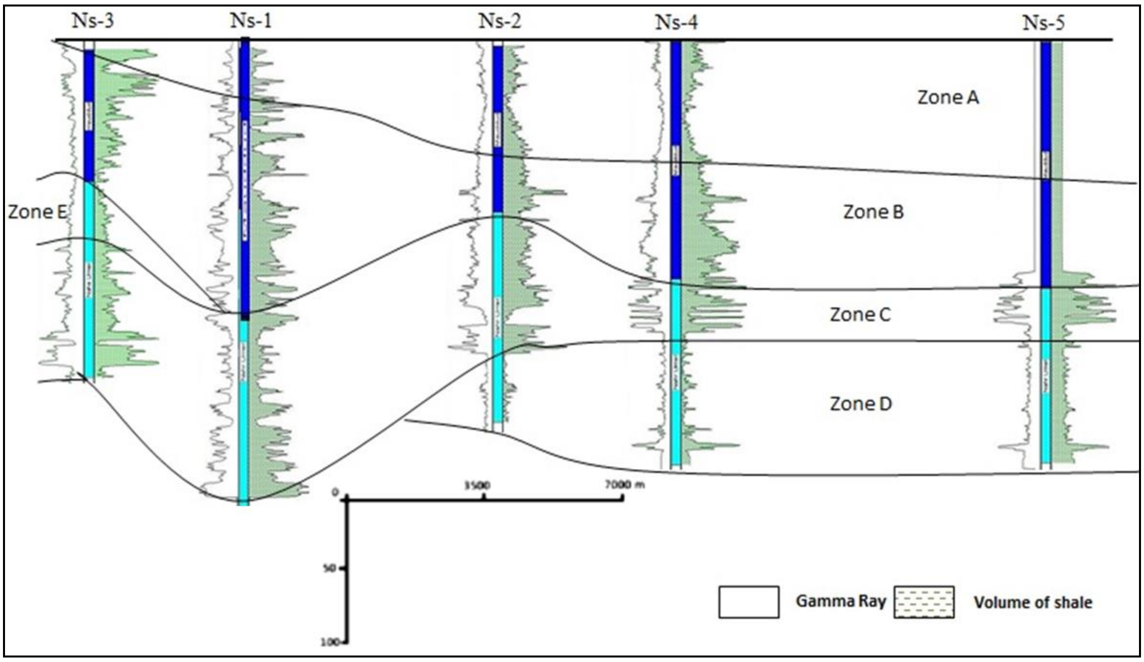

Fig.2: Lateral variation in gamma ray and volume of shale through the studied sections divided into zones

▪ Evaluation of Sequence Porosity

The Nahr Umr and Mauddud sequences were divided in the studied wells according to gamma ray and shale content, into five zones (A, B, C, D and E); therefore we have an interpretation of the logs porosity and porosity evaluation according to these divisions. The porosity logs correlation among the studied wells show an approximate matching with these zones. Wire-log porosity procedures and drawing the porosity-depth relationship for each well were applied rather than logs reading with depth. These relationships include neutron/ density log, total porosity-depth, sonic porosity-depth, effective porosity-depth and the porosity evolution and reservoir characterization (Fig.3).

The porosity logs were studied for the determination of zones with effective porosity, which represents the interconnected void space able to transmit fluids, and to give the porosity evolution and reservoir characterization by the combination of all of these features and their relationships with water or hydrocarbon. Consequently these zones were divided into three types of rocks according to total porosity:

1. High-moderate active porosity rocks (Type I).
2. High-moderate inactive porosity rocks (Type II).
3. Low-non-porous rocks (Type III).

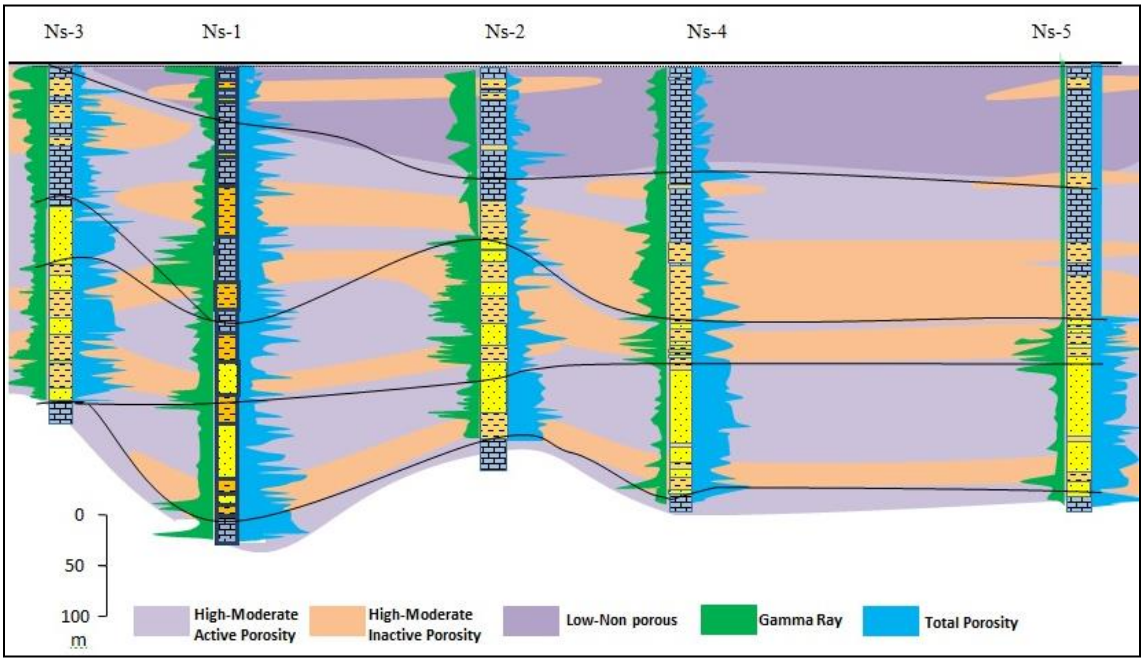

Fig.3: Porosity classification and correlation in the studied wells

– **Zone A:** It contains two types of rocks according to total porosity; high-moderate inactive porosity rocks (Type II) and low-non-porous rocks (Type III). Type (II) appeared in three wells (No.1, No.2 and No.5); represented by shale-rich rocks with poor permeability (inactive porosity). Type (III) is represented by the non-porous rocks which appeared in all wells except well No.3 (Fig.3). This type distinguishes the upper part of the Mauddud Formation (Zone A).

– **Zone B:** It is found in two horizons: the upper one is characterized by high-moderate active porosity (Type I) while the lower one characterized by high-moderate inactive porosity

(Type II) caused by the presence of a high volume of shale (Fig.3). This horizon represents the lower part of Mauddud Formation within the mud-dominated member.

– **Zone C:** It is represented by the shale-dominated member of the Nahr Umr Formation, with high-moderate inactive porosity rocks (Type II). This zone appeared in all wells (Fig.3). There is a limited presence of high-moderate active porosity rocks (Type I) within the sand-dominated lithofacies, which appears in wells No.3 and No.1.

– **Zone D:** It represents the lower part of Nahr Umr Formation within the sand-dominated member, with high-moderate active porosity (Type I), which appears in all wells (Fig.3). There is a limited presence of high-moderate inactive porosity rocks (Type II) within the shale-dominated lithofacies, found in all wells except well No.3.

– **Zone E:** This zone appears in well No.3 only, represented by sand-dominated lithofacies of the upper part of Nahr Umr Formation with high-moderate active porosity rocks (Type I).

- **Water and Hydrocarbon Saturation**

Fluid saturation are usually obtained from resistivity logs. Different resistivity logs; with variable fluid saturation occur at different distances from the borehole wall. Fluid saturation are estimated from resistivity measurement by the Archi equation. This equation relates the resistivity of the information to the porosity, water saturation and resistivity of the water formation (Archie, 1942).

According to the relationship of resistivity-porosity and hydrocarbon saturation, two horizon of reservoir (Hydrocarbon apperance) were identified within the Nahr Umr Formatin, while Mauddud Formation doesn't show any apperance of hydrocarbone in the studied succession because of the high presence of shale within the formtion and strongly affected by diagensses processes such as cementation and compaction:

– **Horizon 1 (within zones C and E):** This horizon appears in the upper sand member of the Nahr Umr Formation and found in wells No.1, No.2, and No.3 (Fig.4). This type of rocks is characterized by high- moderate porosity (effective porosity) with low volume of shale and high deep resistivity (Rt). The thickness of this rock type ranges from 21 m to 48.5 m. The other part of this horizon (shale-dominated member) is characterized by high porosity value with high volume of shale and low permeability (Fig.4).

– **Horizon 2 (within zone D):** This Horizon is represented by braided river lithofacies found in all wells ecxapt well No.3, and is separated into two subhorizon in well No.5. This type of rocks is characterized by high-moderate porosity (effective porosity) with low volume of shale and high deep resistivity (Rt). The thickness of this rock type ranges from 12.25 m to 57 m (Fig.4).

- **Bulk Volume Analysis**

Figure (5) represents a Computer Processed Interpretation (C.P.I) for well No.1 and depicts the followings:

- Porosity analysis track, which is divided into effective porosity (e), water-filled porosity in the invaded zone (Bvwsxo), and water-filled porosity in the uninvaded zone (Bvw). The area between (Bvwsxo) and (Bvw) represents the movable hydrocarbon, but the area between (φe) and (Bvw) represents the total hydrocarbon.
- Bulk volume analysis is divided into effective porosity (φe), percentage of shale (Vsh) and percentage of non-shale matrix (Vmatrix).

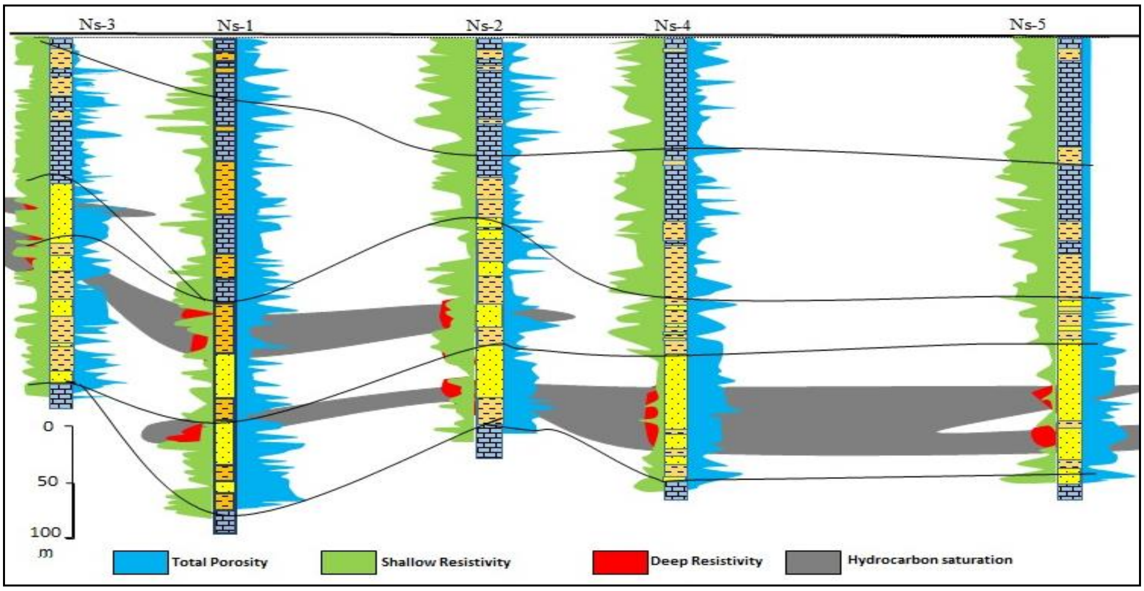

Fig.4: Hydrocarbon saturation in the studied wells

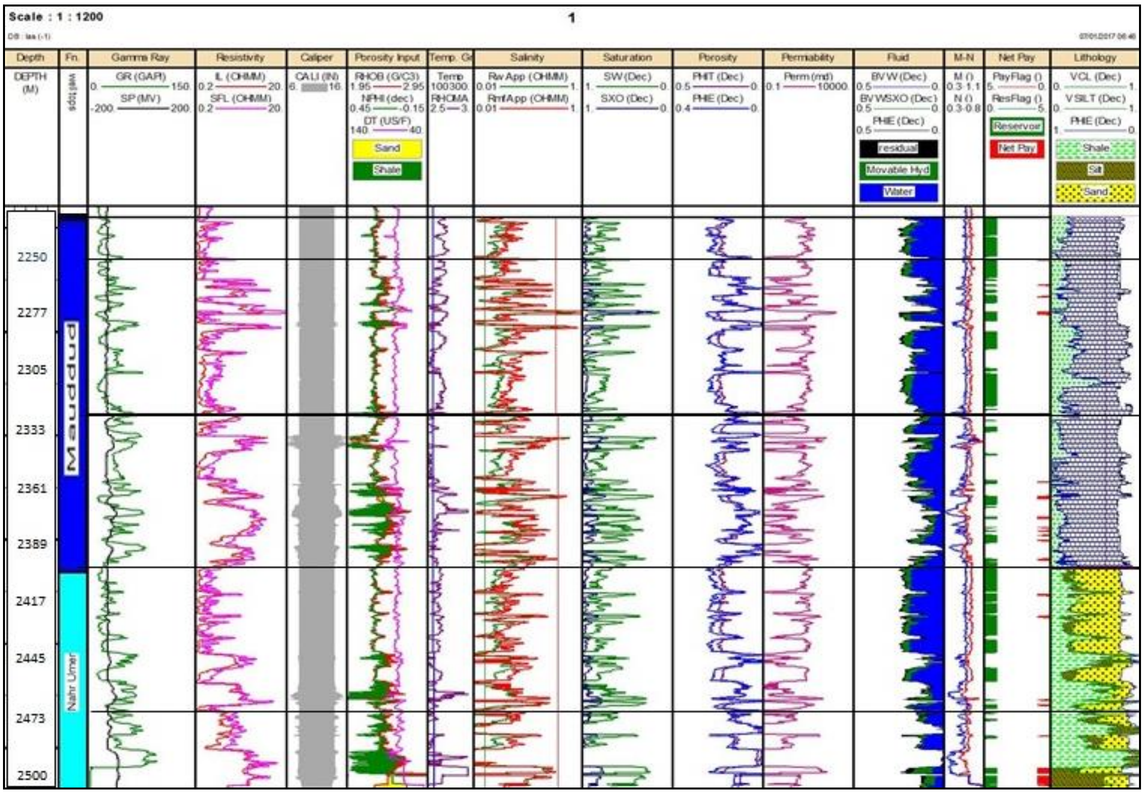

Fig.5: Fluid and formation analysis of well No.1, showing
Net pay and Gross pay

DISCUSSION

The sequences of the Nahr Umr and Mauddud formations in the Nasiriyah oil field can be divided, according to gamma ray and shale value, into five zones (A, B, C, D and E); therefore enabling an interpretation of the porosity logs and porosity evaluation accordingly. The porosity logs correlation among the studied wells shows an approximate matching with these zones. Total porosity, effective porosity and secondary porosity, calculated from neutron, density and sonic logs, show that primary porosity is dominant and secondary porosity is too little or ignored.

Archie's parameters were determined, using pickett's plot, and the range values of a, m and n are found to be (1), (1.61 – 1.65) and (1.76) respectively. Cross-plot of lithology (N-D) and Mineral (M-N) cross-plots indicated that the main lithology of Mauddud Formation in the studied wells is limestone, represented by calcite with some dolomite and shale. On the other hand, the main lithology of the Nahr Umr Formation is sandstone, represented by quartz arenite, greywacke with some shale and appears to have too little or negligible secondary porosity.

According to values and shape of the gamma-ray log and shale content, the studied sections of the Nahr Umr and Mauddud formations can be divided into five zones named A, B, C, D and E. Zones A and B are found within the Mauddud Formation and the other three zones within the Nahr Umr Formation. These zones can be divided into three rock types according to total porosity: high-moderate active porosity rocks (Type I), high-moderate inactive porosity rocks (Type II), low-non porous rocks (Type III).

Zone A includes rocks of Type (II) and Type (III); the former is found in three wells (No.1, No.2 and No.5) and is represented by the shale-rich rocks, characterized by poor permeability (inactive porosity) and the latter is represented by the non-porous rocks found at the upper part of the Mauddud Formation in all wells except well No.3. Zone B includes two horizons, the upper one is characterized by high-moderate active porosity (Type I) while the lower one is characterized by high-moderate inactive porosity rocks (Type II) caused by the presence of a high volume of shale. This horizon represents the lower part of the Mauddud Formation within the mud-dominated member. Zone C is represented by the shale-dominated member of Nahr Umr Formation, with high moderate inactive porosity rocks (Type II), which appeared in all wells. There is a limited presence of the high moderate active porosity rocks of Type (I) within the sand-dominated lithofacies which appears in wells No.3 and No.1. Zone D represents the lower part of the Nahr Umr Formation within the sand-dominated member, with high moderate active porosity rocks (Type I), appearing in all wells. There is a limited presence of the high moderate inactive porosity rocks (Type II) within the shale-dominated lithofacies present in all wells except well No.3. Zone E appears in well No.3 only represented by sand-dominated lithofacies of the upper part of Nahr Umr Formation with high moderate active porosity rocks (Type I).

CONCLUSIONS

According to the relationship of resistivity-porosity and hydrocarbon saturation, two horizons of reservoir (Hydrocarbon appearance) were identified within the Nahr Umr Formation in the studied wells of the Nasiriyah oil field. On the other hand, the Mauddud Formation does not show any appearance of hydrocarbon in the studied succession because of the high presence of shale within the formation and the strong diagenetic modifications caused by processes such as cementation and compaction.

Horizon 1 (within zones C and E) appears in the upper sand member of the Nahr Umr Formation in wells No.1, No.2, and No.3. This type of rocks is characterized by high-moderate porosity (effective porosity) with low volume of shale and high deep resistivity (Rt). The thickness of this type ranges from 21 m to 48.5 m. The other part of this horizon (shale-dominated member) is characterized by high porosity value with high volume of shale and low permeability. Horizon 2 (within zone D) is represented by braided river lithofacies in all wells except well No.3; separated into two subhorizons in well No.5. This type of rocks is characterized by high-moderate porosity (effective porosity) with low volume of shale and high deep resistivity (Rt). The thickness of this type ranges from 12.25 m to 57 m in the studied wells.

REFERENCES

Al-Naqib, K.M., 1967. Geology of Arabian Peninsula, South western Iraq. US. Geol. Survey Prof. Paper, 560-G, 5pp.

Archie, G.E., 1942. The electrical resistivity log as an aid in determining some reservoir characteristics. Trans AIME, Vol.146, p. 54 – 62.

Bellen, R.C., Van Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris, 333pp.

Buday, T. and Jassim, S.Z., 1987. The Regional Geology of Iraq. Vol.2, Tectonism, Magmatism and Metamorphism, In: M.J. Abbas and I.I. Kassab (Eds.). GEOSURV, Baghdad, 352pp.

Ebraheem, Z.A., 2015. Development of Petrophysical properties and Reservoir Evaluation of Shuaiba and Nahr Umr Formations in West Qurna oil field, Southern Iraq. Unpublished M.Sc. Thesis. University of Baghdad, 98pp.

Hussein, N.J., 2015. Facies Architecture and Reservoir Characterization of Nahr Umr and Mauddud Formations, Luhais Oil Field, South Iraq. Unpublished M.Sc. Thesis. University of Baghdad, 102pp.

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 341pp.

Larionov, V.V., 1969. Borehole Radiometry: Moscow, U.S.S.R., Nedra.