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3-D lithofacies Model of Mishrif Formation in Nasiriyah oil field Southwestern Iraq

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Abstract

Petrophysical data interpretation study has been done for ThiQar – Nasiriya oil field at the southwestern part of Iraq in order to build the 3-D lithofacies model of the Mishrif reservoir which currently is the main unit of bearing the oil in subsurface area covered about (447) km^2. This study is achieved by using CMG, Petrel, Techlog, and other approval software. The study depended on the direct and indirect well logs data analysis supported with coring analysis, and drilling geological reports. The lithofacies of Mishrif Formation units detected form direct logs responses on behavior of SP, Resistivity, and GR logs, and from indirect analysis on behavior of (ØN-ρb) crossplots where the values of the both parameters projected in the limestone zone, some in dolomite and little in sandstone zone. The same case is for most of the wells with little difference in wells NS-12, 13, and 14 that properly have behavior of sandstone. In addition, the result is supported by coring description during the drilling. The results of the analysis integrated and distributed by sequential indicator simulation method as maps and 3D model. The lithofacies model of Mishrif Formation units in this study helped us to estimate the geological environmental deposition facies for each unit which was graduated from back reef in west and NW to the reef in the middle, fore , and slope in SE of the field.

Keywords: Petrophysical Interpretation , 3-D Lithofacies of Nasiriyah oil field.

موديل السحنات الصخرية الثلاثي الابعاد لتكوين مشرف في حقل الناصرية جنوب غرب العراق

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الخلاصة

تم دراسة وتفسير البيانات البتر وفيزيائية لحقل الناصرية الواقع في محافظة ذي قار جنوب غرب العراق لبناء الموديل الليثولوجي الثلاثي الابعاد لتكوين مشرف النفطي الرئيسي بالحقل بمساحة تغطي حوالي 447 كم^2. وقد انجزت هذه الدراسة باستخدام البرامج Petrel، CMG، وغيرها . اعتمدت الدراسة على التحاليل المباشرة وغير المباشرة لبيانات مجسات الآبار مدعومة بنتائج تحليل اللباب الصخري والوصف في التقارير الجيولوجية اثناء حفر الابار. تم تحديد ليثولوجية تكوين مشرف من معرفة استجابة المجسات GRوSP والمقاومة وكذلك من التحليل غير المباشر لقيم المجسات من خلال المرتسم (ØN–ρb) حيث ان اغلب القيم لهذا التحليل وقعت في نطاق الصخور الجيرية وبعض منها في نطاق صخور الدولامايت وقليل منها في نطاق الحجر الرملي مثل الابار ناصرية 12 و13و14. وهذا ماتم توثيقه أيضا من خلال الوصف الصخري للباب الصخري اثناء الحفر. تم ربط النتائج وتمثيلها بشكل خرائط وموديل ثلاثي الابعاد اعتمد بتوزيع الخصائص الليثولوجية على طريقة Simulation Method Sequential Indicator . كما ساهم الموديل بتخمين

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الموديل السحني لتكوين مشرف الذي يكون عبارة عن منصة بحرية تتدرج من بيئة خلف الحيد في اتجاه شمال – غرب إلي بيئة المنحدر في اتجاه جنوب – شرق من الحقل.

Introduction:

The Mesopotamian Basin in Iraq consists of a wide asymmetric syncline and it is one of the most important productive hydrocarbons field in the world. It has variety of structures from simple to complex [1]. The Nasiriyah oil field is one of the most promising oil field in the Mesopotamian basin, which is discovered in 1976. Mishrif Formation is the main carbonates reservoir in Nasiriyah oil field. It is important in the other oil fields in central and southern of Iraq such as, Buzergan, Amara, Halfaya, Majnoon, Rumaila, and West Qurna [2]. Integration of all the geosciences data into the log analysis results is modern and more common use of the title "Petrophysicist" instead of "Log Analyst". Petrophysics is term of study of physical and chemical rock properties and their interactions with fluids, based on well log measurements, laboratory data, and other geosciences data using the fundamental laws of mathematics and physics. Quantitative analysis of well logs provides values for a variety of concerning properties such as porosity, water saturation, fluid type (oil/gas/water) lithology permeability, well-to-well correlation [3]. Nasiriyah oil field lies in ThiQar province at the southwestern part of Iraq close to Nasiriyah city east of the Euphrates river in about (38) km northwest of the Nasiriyah center Figure-1. Gravity survey carried out between (1940-1950) by Basra oil company (BPC) for most southern areas of Iraq included studied area. In addition, magnetic survey carried out between (1973-1974) by the French Company C.G.G. The results of the interpretations of both surveys have been encouraging for the implementation of a detailed seismic survey of the area where they showed that there are folds that have the same direction of the folds of hydrocarbon potential in other areas of the southern Iraq. First exploratory seismic reflection survey for Nasiriyah oil field was carried out between (1973-1976) which is covered (1218) Km^2. According to the results of the survey, NS-1 well has been drilled in 1978. The works of the seismic survey continued until 1995, where reinterpretation of seismic data had been done by Italian Companies (Repsol, Agip, and Eni). Preplanning design for the field still under contraction by Japanese Company (JC), American company (GXT) and Iraqi Oil Exploration Company (INOEC), [4]; [5]. The main purpose of this paper is to determine and evaluate the petrophysics properties of Mishrif Formation in Nasiriyah oil field.

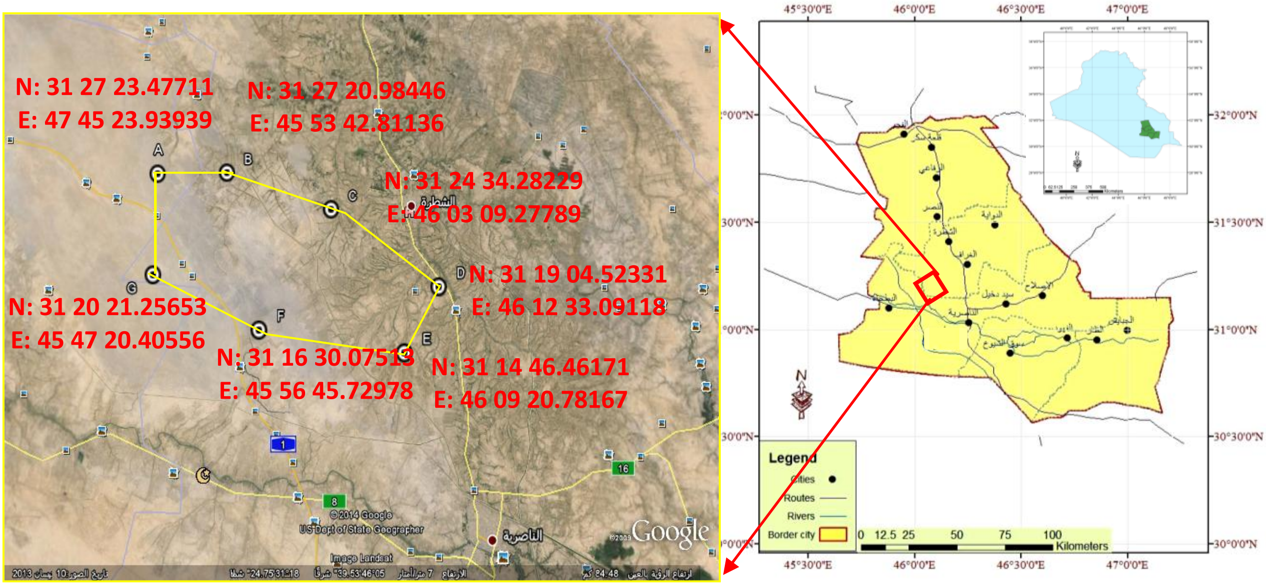

Figure 1- Shows the geographic coordinates of the study area.

Geological Setting

The area characterized by almost a flat area covered by Holocene sediments, which consists mainly flood plain sediments presented in Hammar Formation [6]. In addition, there are moving sand dunes especially in the west and northwestern part of the area.

The platform of Iraqi territory is divided into two basic units, the Stable and Unstable Shelves. Tectonically, Nasiriyah oil field is located in unstable shelf close to Arabia platform in the Mesopotamian zone, which covers most of south and central parts of Iraq. It is characterized by the presence of limited sub-surface anticline and domes in variable directions NS, NW, and SE [7], [8], [9]. The Cretaceous period is the most active period in the Mesozoic and it is the most important depositional environment in Iraq. Depositional environment succession of Mishrif Formation during cretaceous rocks in the lower part of Cenomanian-Early Turonian cycle has wide sediments extending start from open-shelf to fore-reef slope ,then reef flat and finally inner-shelf conditions [10], [11]. The stratigraphic of Mishrif Formation located between Kifl or Khasib and Rumaila Formations gradually. Mishrif Formation composed of heterogeneous porous, detrital, and organic limestone rich in fossils index such as Rudest, large Foraminifera, and Algae. These lithofacies reflected wide extend of various environment sediments start with fresh water sediments in the upper of Mishrif graduated to the deep marine environment at the lower part of the Mishrif [11], [12].

Data Base

Data set that are used in this study are including fourteen digital well logs (LAS files) such as(GR,SP,DT,RHOB,NPHI,ILD), and previous geological drilling reports included the coring description Figure-2 [5].

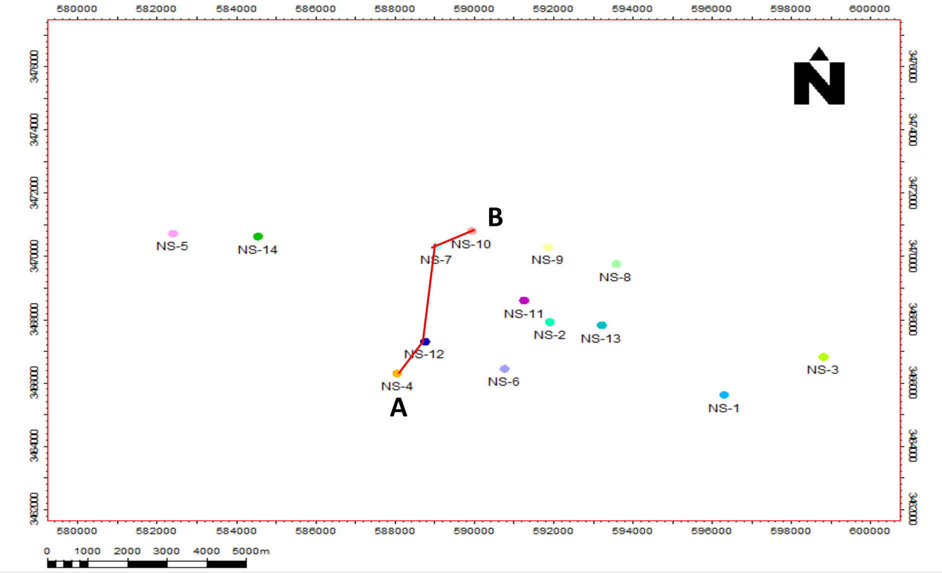

Figure 2- Shows well locations in the studied area.

Methodology

To create the lithofacies model of Mishrif reservoir, the following steps are applied:

1. Selection the best wells (fourteen wells) NS-1 to NS-14 that have almost all the available logs data(GR,SP,DT,RHOB,NPHI,ILD) which can used for the lithological correlation.
2. Editing and calibrating the selected wells logs data.
3. Using previous petrophysical properties calculated from core analysis.
4. Correlation the well section to illustrate the variation in reservoirs thickness.
5. Identification and correlation between the lithofacies of Mishrif Formation units.
6. Distribution the lithofacies information for each unit as map.
7. Constructing the 3-D lithofacies model.

Theoretical Review

Well logging is a method of the measurement of the physical and chemical properties of the penetrated layers by the wellbore. Each device of well log has a special theoretical background of measurement differ from the other. Due to the high cost of the process of data acquired in well logging, manufacturers trying to design devices of various types and principles to give the best results with less time and cost [13]. Many applications of well logging have been documented such as determination and identification of the petrophysical properties of the rock and fluids of the oil and gas reservoirs such as porosity, permeability, water and hydrocarbon saturation, and others. In addition, it was used for Inter-borehole correlation, dip determination, rock strength, In-situ stress orientation, [14], [15], [16].

In the oil industry, well log interpreter called log analysis. Log analysis is a process of using well logs data to evaluate the formation and fluid contents of reservoir rock. The evaluation achieved when the logs data analysis translate to the petrophysical properties. These translation can be direct analysis method or indirect analysis method. Formation lithlogy deification is one of the petrophysical properties can be evaluate by direct method in behavior of the Gamma logs (**GR**) supported with density and neutron logs, In addition, it is possible to identify the lithlogy of the interested reservoir from (**SP**) and resistivity log[15];[3].

Gamma Ray log:

Gamma ray logs measure natural elements radioactivity in the formation which found almost in the clay rocks. (GR) can be used for identify clay content in all layers as equation below [16]:

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

where,

IGR = gamma ray index.

GRlog= gamma ray reading by log(API).

GRmin= minimum gamma (clean sand or carbonate).

GRmax= maximum gamma ray (shale).

Density log:

Density is measured in grams per cubic centimeter g/cm3 and is indicated by the Greek letter ρ (**rho**). Two separate density values are used by the density log: the bulk density (**ρb** or **RHOB**) and the matrix density (**ρma**). 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 (**ρma**) and the density of the saturating fluids (**ρf**) are known [17]:

$$\mathbf{\Phi D = (\rho ma - \rho b) / (\rho ma - \rho f)} \quad (2)$$

Where,

ρma = the density of matrix of the formation.

ρf = the density of formation fluid in the vicinity of borehole (mud filtrate).

ρb = the bulk density of the formation.

Neutron Log

Neutron logs measure the hydrogen concentration present in the formation. It is reflects the amount of the liquid filled in the porosity of the rock, and this will help in the identify the high pours rock which is clay and other [17]. Neutron logs responses depending on [18]:

* Differences in detector types.
* Spacing between source and detector
* Lithology i.e. sandstone, limestone and dolomite.

Self potential log (SP)

The Spontaneous Potential 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 (Rw) and determine the volume shale impermeable beds [18]. The electric charge of the SP is caused by the flow of ions (largely Na and Cl) from concentrated to more dilute solutions.

Three factors are necessary to produce an SP current:

1. The conductive fluid in the borehole.
2. The porous and permeable bed surrounded by an impermeable formation.
3. The difference in the salinity (or pressure) between the borehole fluid and the formation fluid.

The shale volume can be also calculated mathematically from the self potential log by the following formula [19]:

Vsh= 1- (SP - SPsh) / (SPcl - SPsh) (3)

Where:

SP: SP log reading.

SPsh: SP log reading in the shale.

SPcl: SP log reading in the clean rock.

Resistivity logs

The resistivity of a formation is a key parameter in determining hydrocarbon saturation. Electricity can pass through a formation only because of the conductive water it contains.. Moreover, perfectly dry rocks are seldom found. Therefore, subsurface formations have finite, measurable resistivities because of the water in their pores or absorbed in their interstitial clay.

The measured resistivity of a formation depends on

- Resistivity of the formation water
- Amount of water present.
- Pore structure geometry.

The electrical resistivity of substance is its ability to impede the flow of electrical current through the substance. The unit used in logging is ohm meter2/meter, usually written as ohm-m. Electrical conductivity is the reciprocal of resistivity and expressed in milliohms per meter (mm.hom/m) [20].

R = 10000/C. (4)

Where:

R= resistivity.

C = conductivity.

In order to determine the saturations of hydrocarbons within the formations, first saturations of water should be calculated. The tools used for resistivity logging are classified within depth of investigation as follows:

- Deep resistivity tools for uninvaded zones.
- Shallow resistivity tools for transition zones.
- Micro resistivity tools for flushed zones.

The most common resistivity tools in use can be classified as;

- Dual Laterolog Tool.
- Dual Induction Tool.
- Micro Spherically Focused Log.
- Microlog.

The resistivity of a formation with its matrix and fluid (water and hydrocarbon) and in the pores is true resistivity (Rt) of the formation. A porous and a permeable formation has always water, even it contains hydrocarbon [21].

Lithofacies Interpretation:

The lithological interpretation in the current study depended on the direct and indirect well logs data analysis supported by coring analysis, and drilling geological reports as explained below follows:

1- Direct well logs data analysis:

It is possible some time to identity the lithology of the formation from direct log responding on behavior of resistivity, SP, and GR logs as shown in Figure-3 for well NS-4, which clarify the lithlogy of Mishrif Formation. The results were supported and correlated with the drilling geological report Figure-4.

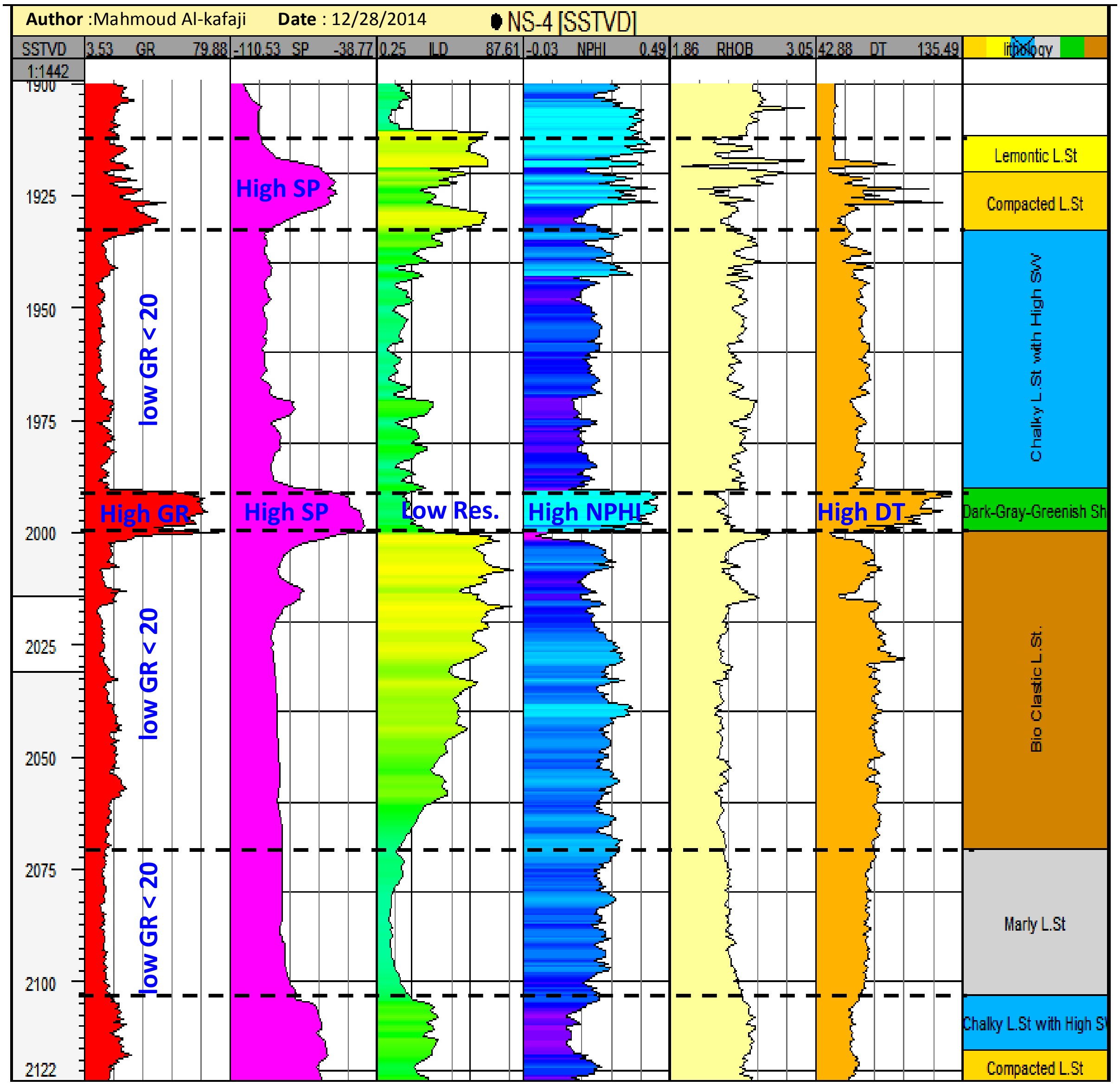

Figure 3- Shows the direct analysis of the lithology in well NS-4.

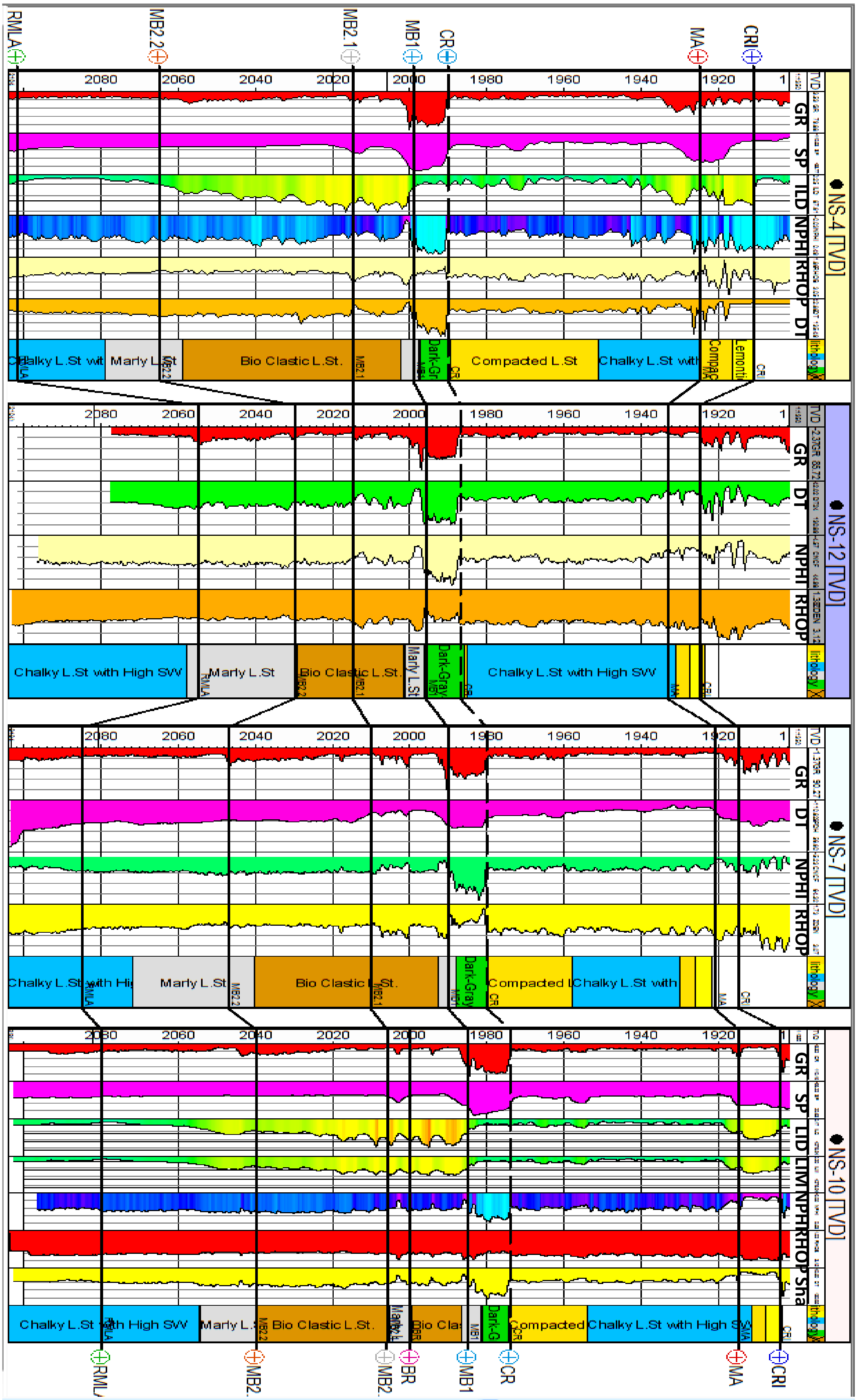

Figure 4- Shows the lithological correlation through various logs types NS-4, NS-12, NS-7, and NS-10 in Nasiriyah oil field.

2- Indirect well logs data analysis:

Indirect analysis of the logs data can be done by in creating the relation from (ØN-ρb) crossplots. This plot was created by Schlumberger company as standard plots, It can be used to identify the type of the prevalent lithology and porosity of the interested formations depending on the porosity and density logs responses by plotting (**ØN**) and (**ρb**) from logs data. The values of parameters for NS-9, 12, 13, and 14 shown in Figure-5 showed that the most points of the relation between (ØN-ρb) were projected in the limestone zone and some in dolomite and few in sandstone area and the same case is obtained for almost the wells with small difference in wells NS-12, 13, and 14 that probably have behavior of sandstone. This issued also from coring description during the drilling report.

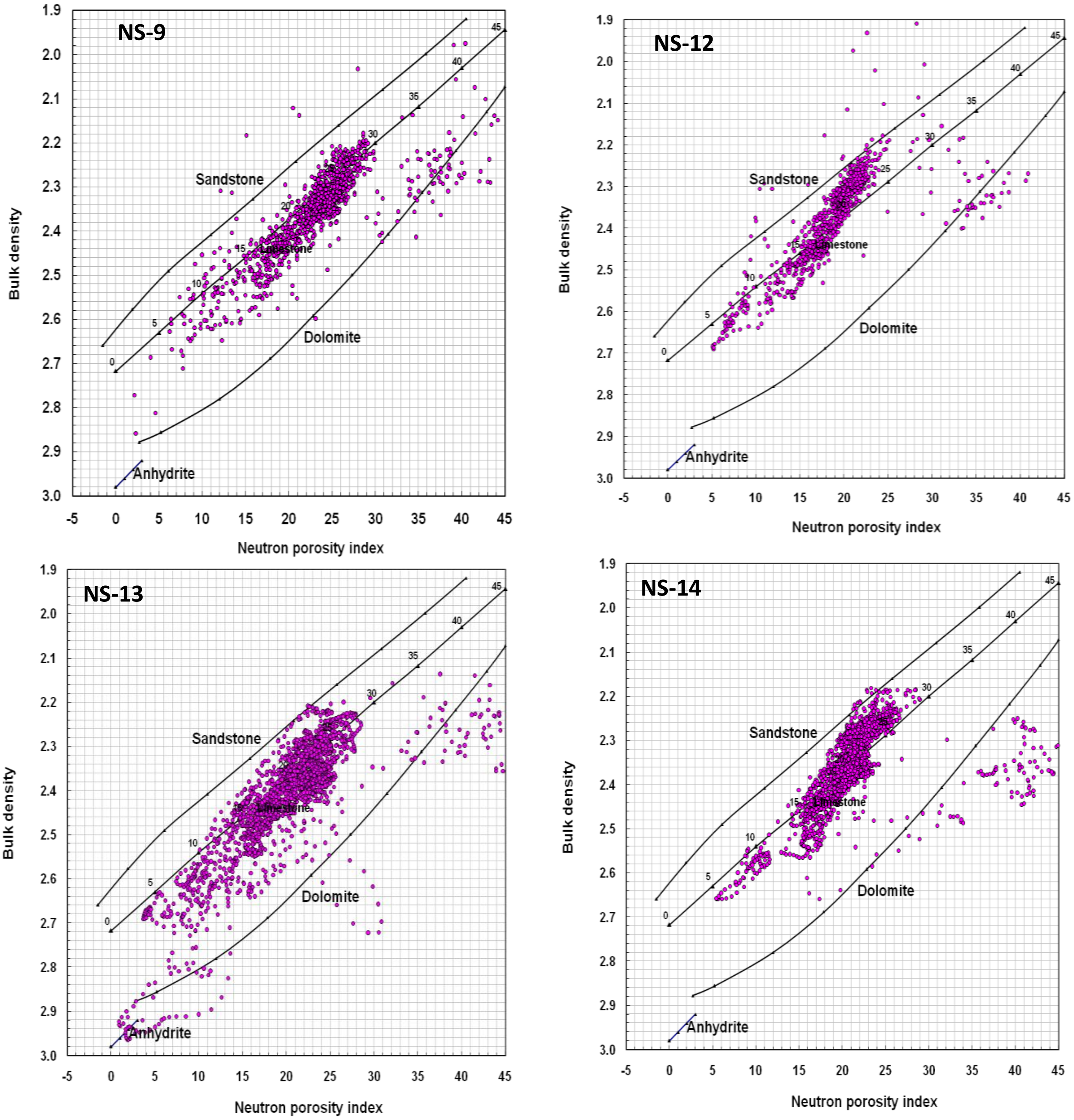

Figure 5- Shows the corssplots of (ØN-ρb) for wells NS-9, 12, 13, and 14 .

3-Coring data analysis:

The multi visits to the laboratory coring analysis in Basra contributed in the collection and documentation of results of the coring descriptions **.**Mishrif Formation lithology consist of the following units:

*** CRI unit :** This unit consists of Buff, beige compacted limestone of thickness ranges between (2-14) m and it has yellow limonite.

*** MA unit:** This unit consist of chalky, marly limestone with high water saturation of thickness ranges between (52-63) m. It has a good porosity (15).

*** CRII unit:** This unit consist of black-gray-greenish shale rock of thickness ranges between (10-12) m. It separates between (MA) and (MB) as horizontal layer in all the wells. It is a good seal rock, which prevent the hydrocarbons movement from bottom (MB) to top (MA).

*** MB unit:** This unit can be divide into (MB1), and (MB2) units. Total thickness is about (65) m. It is considered the main reservoir of the Mishrif Formation in Nasiriyah oil field.

A) MB1 unit: This unit consists of porous, detrital, and organic (Bio clastic) limestone rich in fossils index such as Rudest, large Foraminifera, and Algae of thickness ranging between (11-23) m in different wells. It is the primary productive unit of Mishrif reservoir.

B) Barrier Rock unit: It is a non-continuous horizontal rock barrier separating the unit (MB1) and unit (MB2). It consists of marly limestone of thickness ranging between (1.5-7) m. Its thickness increases in SE direction such in well NS-1 and decreased in NW direction such as in well NS-5 and in other wells.

C) MB 2: It is the lower part of Mishrif Formation, and it is considered as secondary productive unit of Mishrif reservoir. This unit subdivided into parts. (MB 2.1) represents the upper part, which consists of organic porous limestone (Clastic limestone) and marly limestone. It has a high hydrocarbon saturation and productive unit. Its thickness ranging between (35-55) m. (MB 2.2) represents the lower part (Transition zone) of Mishrif reservoir. It consists of chalky limestone rock with a high water saturation ratio and thickness ranging between (32-38) m.

The lithofacies subsurface model of Mishrif reservoir at studied area presented in 2-D and 3-D models and shown in Figure-6. It helps to estimate the environmental deposit facies of the subsurface area which graduated from back reef in NW to the reef slope in SE of the field.

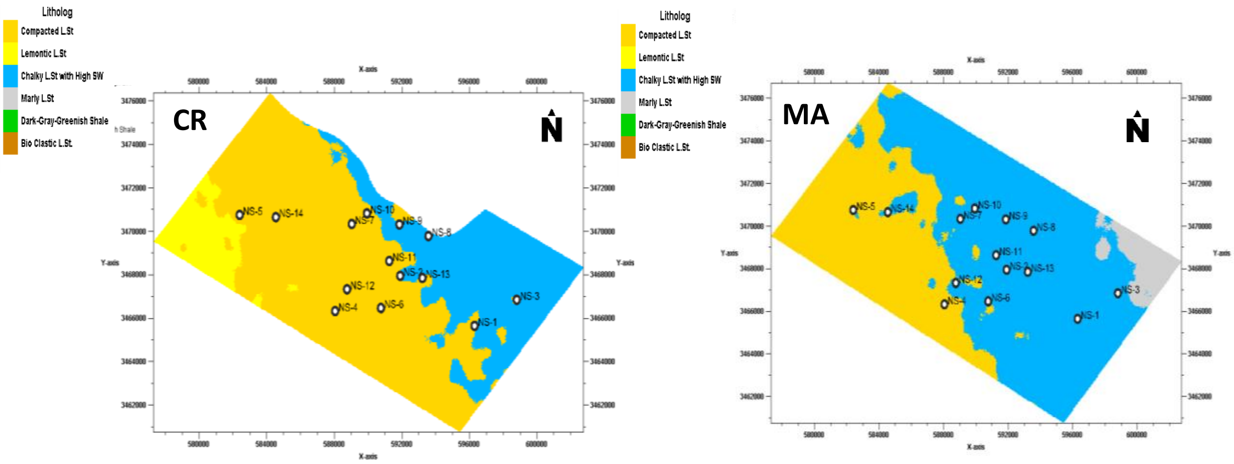

Figure 6- The lithlofacies maps for Mishrif Formation units, and 3D model.

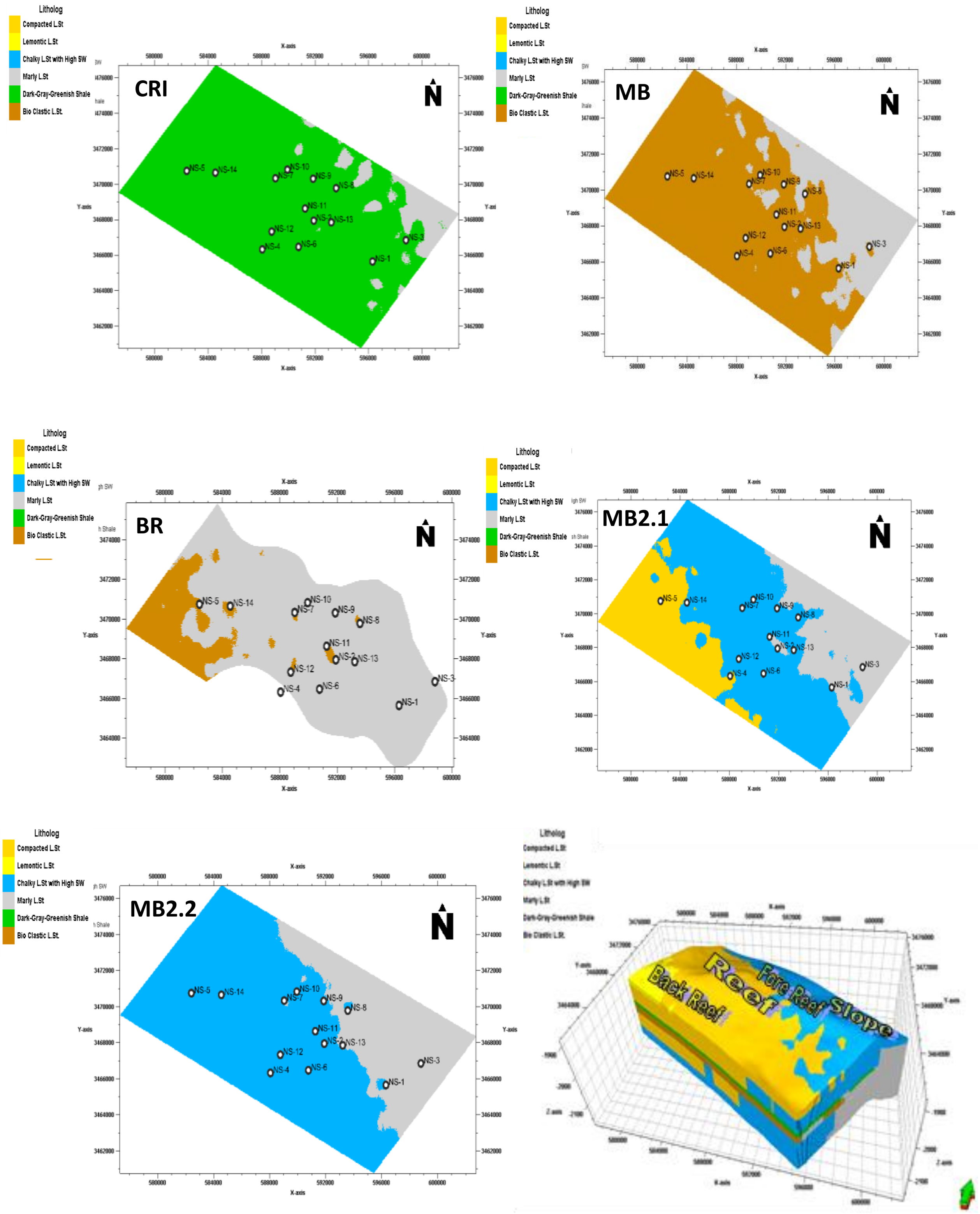

Figure 6- The lithlofacies maps for Mishrif Formation units, and 3D model.

Conclusions

1. 2-D and 3-D lithofacies models created for Mishrif Formation units in Nasiriyah oil field depended on direct and indirect well logs analysis supported with coring data. It illustrated the vertical and horizontal lithofacies distribution of the Mishrif Formation.
2. The lithofacies model of Mishrif Formation units in this study helped us to estimate the geological environmental deposition facies for each unit which was graduated from back reef in west and NW to the reef in the middle, fore , and slope in SE of the field.

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