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Research Article

EXPLORING AND EXAMINING THE PETROPHYSICAL CHARACTERISTICS AND RESERVOIR MODELING OF NAHR UMR FORMATION AT LUHAIS OIL FIELD, SOUTH OF IRAQ

Fahad Mansour Saqr AlNajm

Department of Geology, College of Science, Basra University, Iraq

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ABSTRACT

This study aimed to exploring and examining the Reservoir Modeling of the Nahr umr Formation at Luhais oil field. Based on the interpretation of the open hole data from wells (Lu-05, Lu-06, Lu-07, Lu-10, Lu-18, and Lu-20) .Which have been calculated Shale Volume, total porosity, Primary and secondary porosity, water and hydrocarbon saturation and Bulk water oil volume. Depends on the calculated of petrophysical properties, Nahr umr Formation can be divided into two members(in the Upper Shale member and in the Lower Sandstone member) according to the main lithology (Shale Volume), The contact between both is marked N/2. Each of these members is further subdivided into units (a, b, c, d, and e Units) in the upper Shale member, and (A1, B1, C1, D1, E1, F1, G1, H1, I1, and J1 Units) in the Lower Sand member. Three-dimensional reservoir model of oil saturation was constructed using the Petrel Software, (2009). Distribution of these petrophysical properties for each reservoir unit within the studied field has been done. The results showed that the best reservoir units are the C1, E1 and G1 reservoir unit. Its worth mentioned here that the heterogeneity of the thicknesses of these units and its individual direction. In addition, observed that the oil saturation increases towards the north of the field at the well (Lu-07) and the center of the field at the well (Lu-18).

INTRODUCTION

The Nahr Umr Formation (late Aptian to early-mid-Albian) has average thickness of 222m in Luhias oil field. It consists predominantly of argillaceous rocks laid down in a shallow, subtidal, shelf environment. The lithology comprises thick beds of variegated shale, red-brown to green or brownish-gray, with thin, inter-bed limestone and occasional thin beds of marl and sandstone in the middle. Near the base, the shale contains phosphatic concretions and pyritic and glauconitic, limestone horizons (Alsharhan and Nairn, 1988; Alsharhan, 1994).

The upper contact with Mauddud formation is gradational and marked by N/1 which is the first appearance of Shale below the Mauddud limestone. The lower contact with Shuaiba formation also is gradational and placed on the top of first limestone below the lowest Shale of Nahr Umr formation. (Bellen *et al*. 1959).

The Nahr Umr Formation is a lateral equivalent of the Burgan Formation in Kuwait (Douban and Medhadi, 1999; Sharland *et al*., 2001). In SW Iran the formation passes into the shales and limestones of the Kazdhumi Formation (Furst, 1970). It also correlates with the Rutbah Sandstone of the Palmyrides(Brew et al.,1999) and the Kurnub Sandstone penetrated in Risha wells of NE Jorda (Sharland *et al*., 2001).

The main goal of the study to determine petrophysical properties of Nahr Umr reservoir units in Luhais oil field and detailed review of the most important petrophysical properties to clarify their changes vertically and laterally within the wells by using programs (Techlog and Petrel).

Studied area

The studied area is located in Southwestern Iraq, lies within the Mesopotamian basin, Zubair Subzone. The structural contour map on the top of Nahr Umr formation indicates that the structure is likely complex of Ameobatic shape. The crest is in the vicinity of Lu-18 well and it appears that it may be divided into two small crests with a gentle small other Crest in the other side (fig. 1).

The study area represented by six oil wells within the Luhias oil field (Lu-05, Lu-06, Lu-07, Lu-10, Lu-18 and Lu-20). Structural contour map indicated that the dimensions of the field are about 20 km long and 7.5 km wide. The axis of structure extend to northwest – southeast direction, and it turned out that dip slope of the north-east flank approximately

Corresponding author:* **Fahad Mansour Saqr AlNajm
Department of Geology, College of Science, Basra University, Iraq

(2°), either southwest flank has reached the degree of inclination of about(1.5°)(fig. 1).

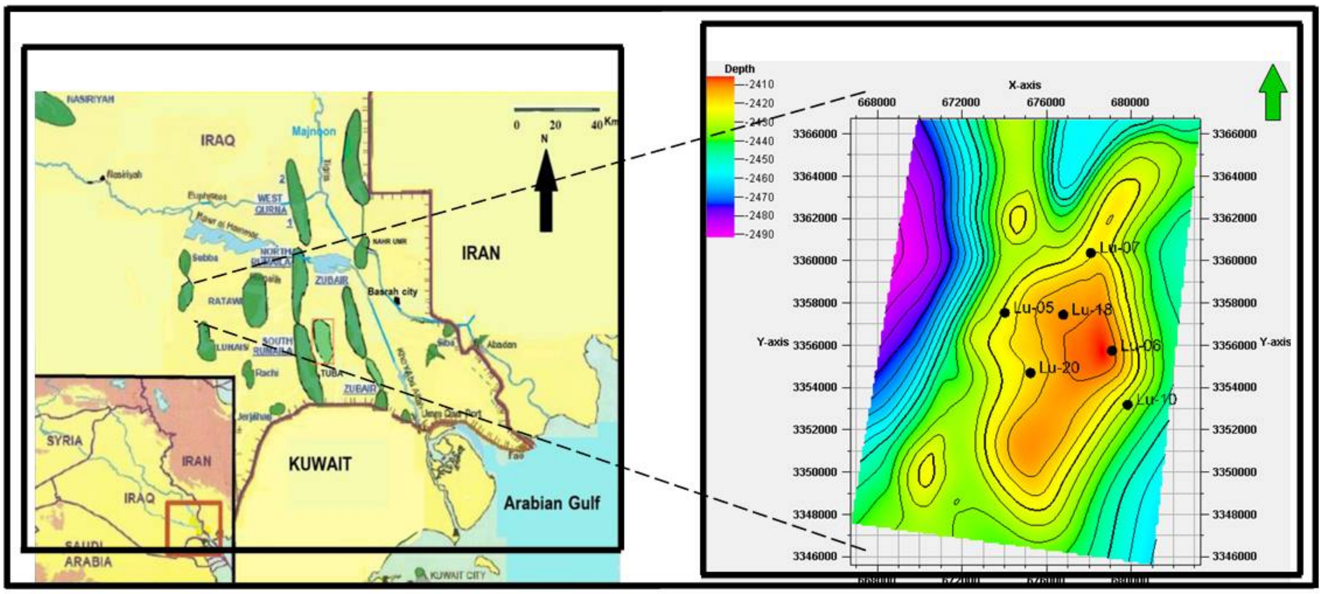

Fig 1 Map of the studied area and structural contour (Top of Nahr Umr Formation)

Research methods

1. Petrophysical characteristics have been calculated through the use of open hole logs, such as (Gamma Ray (GR), Neutron (NPHI), Density (RHOB), Sonic (DT), and Deep Resistivity Log (Rt).
2. Nahr Umr Formation is divided into reservoir and unreservoir units dependent on the results of petrophysical properties (CPI).
3. Reservoir characteristics for reservoir units within the wells of the field were done by use the Techlog and Petrel Software (2009).

Results of the Petrophysical parameters analysis

Calculated of shale volume

Gamma ray log is the best tool using to identify and calculate the volume of shale. Calculated of shale volume in the following equation:

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad \text{…….. (1)}$$

Where:
I_{GR}: Coefficient of gamma rays index.
GR_{Log}: read the gamma rays of the formation.
GR_{min}: minimum gamma rays read opposite clean layers.
GR_{max}: maximum gamma rays read opposite shale layers.
It is then calculating the volume of shale (Vsh) using the following equation:

$$V_{sh} = 0.33[2^{2*I_{GR}} - 1] \quad \text{……………… (2)}$$

Depends on the percentage of the shale volume extracted from previous equation (2) for studied wells were identified free shale zones (clean zone), which is by the volume of shale less than (Vsh <% 10) and zones containing volume shale large from (%70 < V_{sh} ≥ %10) as shally zone (no clean zone) and Shale zone(V_{sh}>%70).

Calculation of porosity

There are several methods of calculation of porosity; it is possible to calculate the primary porosity of the sonic log, as in equation Wyllie *et al*. (1958) which are used in the depths of the shale-free (clean Zone):

$$\emptyset_S = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} \quad \text{…… (3)}$$

Where:
$\emptyset_S$: porosity calculated from sonic log.
Δt_{log}: Full-wave interval of the formation and registration of the log is measured directly (µsec/ ft).
Δt_{ma}: wave interval transit thought matrix (47.5µsec/ft to limestone rocks).
Δt_f: wave interval transit thought pore fluid (185 µsec/ ft to saline water).

But in the depths that exceed Shale volume by about (10%), (Shally zone) are used equation (Dresser Atlas, 1979) to remove the effect of shale and correct, as in the following equation:

$$\emptyset_S = \left[\frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}\right] - \left[\frac{\Delta t_{sh} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}\right] * V_{sh} \quad \text{…….. (4)}$$

Where:
Δt_{sh} : Full-wave interval of the adjacent shale.

It is possible to calculate the porosity of the Density log through the use of density as in equation Wyllie *et al.* (1958):

$$\emptyset_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad \text{………………. (5)}$$

Where:
$\emptyset_D$: Porosity calculated from the density log.
ρ_{ma}: the matrix density (2.71 g / cm ^{3} for limestone).
ρ_b: the density of the total composition.

ρ_f: density of the fluid (1.1 g / cm ^{3} for the saline water). As for the interval containing shale can be used Dresser Atlas, (1979) equation to remove the effect of shale:

$$\phi_D = \left[\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right] - \left[\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right] * V_{sh} \quad \dots (6)$$

Where ρ_{sh} represent total density of the adjacent shale.

While the Neutron log measures the porosity directly to the depths of the shale-free zones, but for the depths of the record containing shale can be used Tiab and Donaldson (1996) equation:

$$\phi_{Nc} = \phi_N - (\phi N_{sh} * V_{sh}) \quad \dots\dots\dots (7)$$

Where:

ϕ_N: porosity derived from neutron log.

ϕ_{Nc}: porosity derived from neutron log corrected the impact of shale.

ϕ_{Nsh}: neutron porosity of the adjacent shale.

Calculate the total porosity (effective) and secondary porosity

Table 1 Units of Nahr Umr fm. In study Wells

Well: Lu-05
RTKB: 62.9m
Coordinate X : 674015 Y: 3357533

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2424.1	5		
	B	2429.1	12.5		
Shale	C	2441.6	14	60	
	D	2455.6	12.5		
	E	2468.1	16		
	N2/A	2484.1	2		
	B1	2486.1	5.5		
	C1	2491.6	11.5		128
	D1	2503.1	10.5		
Sand	E1	2513.6	17.5	168	
	F1	2531.1	3.5		
	G1	2534.6	5		
	H1	2539.6	4		
	I1	2543.6	104		
	J1	2647.6	4.5		
Shuaibba Fm.		2652.1			

Well: Lu-06
RTKB: 73.1m
Coordinate X: 679081.9 Y: 3355735.8

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2407.9	4.75		
	b	2412.65	16.5		
Shale	c	2429.15	18.75	68.25	
	d	2447.9	11.5		
	e	2459.4	16.75		
	N2/A	2476.15	4		
	B1	2480.15	9		
	C1	2489.15	13.75		247
	D1	2502.9	2.25		
Sand	E1	2505.15	18	178.75	
	F1	2523.15	2.25		
	G1	2525.4	3.5		
	H1	2528.9	5		
	I1	2533.9	118		
	J1	2651.9	3		
Shuaibba Fm.		2654.9			

Well: Lu-07
RTKB: 69.8m
Coordinate X: 678086 Y: 3360362

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2420.7	6.5		
	b	2427.2	12.5	65.75	
Shale	c	2439.7	17.25		
	d	2456.95	11.25		
	e	2468.2	18.25		
	N2/A	2486.45	1.25		
	B1	2487.7	10.75		232.75
	C1	2498.45	2.25		
	D1	2500.7	8.25		
Sand	E1	2508.95	4.25	167	
	F1	2513.2	1.25		
	G1	2514.45	2.75		
	H1	2517.2	4.75		
	I1	2521.95	128.25		
	J1	2650.2	3.25		
Shuaibba Fm.		2653.45			

Well: Lu-10
RTKB: 74.8m
Coordinate X : 679829.7 Y: 3353187

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2430.7	4.75		
	b	2435.45	16		
Shale	c	2451.45	22	68	
	d	2473.45	6.25		
	e	2479.7	19		
	N2/A	2498.7	4.25		
	B1	2502.95	10.75		
	C1	2513.7	12.25		249
	D1	2525.95	10.5		
Sand	E1	2536.45	1.25	181	
	F1	2537.7	2.75		
	G1	2540.45	2.25		
	H1	2542.7	1.75		
	I1	2544.45	132.5		
	J1	2676.95	2.75		
Shuaibba Fm.		2679.7			

Well: Lu-18
RTKB: 64.93m
Coordinate X : 676783.5 Y : 3357439

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2411.57	3.75		
	b	2415.32	16.25	65.25	
Shale	c	2431.57	18.25		
	d	2449.82	10.75		
	e	2460.57	16.25		
	N2/A	2476.82	3.25		
	B1	2480.07	7.75		
	C1	2487.82	10.75		237.25
	D1	2498.57	3.75		
Sand	E1	2502.32	4.75	172	
	F1	2507.07	1.75		
	G1	2508.82	21.25		
	H1	2530.07	5.25		
	I1	2535.32	110.75		
	J1	2646.07	2.75		
Shuaibba Fm.		2648.82			

Well: Lu-20
RTKB: 71.2m
Coordinate X: 675229.8 Y: 3354689

Member	Unit	Top(SL)	Thickness(m)		
	N1/a	2418.8	5.25		
	b	2424.05	14		
Shale	c	2438.05	16.5	61.75	
	d	2454.55	20		
	e	2474.55	6		
	N2/A	2480.55	7.25		
	B1	2487.8	5.75		
	C1	2493.55	5.75		239
	D1	2499.3	7.25		
Sand	E1	2506.55	8.25	177.25	
	F1	2514.8	2.75		
	G1	2517.55	13.75		
	H1	2531.3	2.75		
	I1	2534.05	120.5		
	J1	2654.55	3.25		
Shuaibba Fm.					

Total porosity or the so-called influential porosity (effective porosity) is calculated through the use of Schlumberger, (1997) equation:

$$\emptyset_{N.D} = \frac{\emptyset_N + \emptyset_D}{2} \quad \text{.................... (8)}$$

Where $\emptyset_{N.D}$: effective porosity calculated from neutron and density logs.

$$SPI = \emptyset_{N.D} - \emptyset_s \quad \text{... (9)}$$

Where, SPI: Coefficient of secondary porosity index.

Calculation of Formation Factor (F)

The experiments showed that the formation factor (F) can be associated with porosity through equation Archie, (1944) equation:

$$F = \frac{a}{\emptyset^m} \quad \text{................. (10)}$$

Where:
m: cementation factor.
a: tortuosity factor(1).

Water and Hydrocarbon saturation

Water saturation(S_w) is the ratio between the size of voids filled with water to a total volume of rock voids and measured as a percentage; either hydrocarbon saturation is what remains of the size of the voids in the rock, and, as in the following equation.

$$S_w + S_h = 1 \quad \text{... ... ... (11)}$$

Both are calculated from water saturation in the uninvaded zone (S_w) Archie, (1944) equations (11 and 12):

$$S_w = [(F * R_w)/R_t]^{1/n} \quad \text{.............. (12)}$$

Where:
R_w: Formation water resistivity (0.02Ω. m).

Calculate the total Bulk water oil volume

Can calculate the total volume of water(BVw) and Oil (BVh) in uninvaded zone through the following equations:

$$BV_W = S_W * \emptyset_{N.D} \quad \text{.............. (13)}$$

$$BV_h = S_h * \emptyset_{N.D} \quad \text{.............. (14)}$$

Interpretation of well log curves (CPI)

The completion of the analysis of petrophysical properties of the reservoir using open well logsas previously mentioned, the wells of the study area to Nahr Umr Formation facilitates the process of dividing the formation to the number of units of reservoir and non-reservoir units depending on such characteristics Table(1) and figures (2 to 4).

Examining the Reservoir

Require a reservoir study to identify and distinguish the petrophysical properties and their relationship lithological facies. This relationship very important in determined the locations of hydrocarbon fluid storage, movement and production (Luciae *et. al*., 2007). Reservoir model basis on petrophysical characteristics such as porosity can be diagnosis and division of the reservoir units. The rate of reservoir oil production indicated on the type of porous system, dimensions of the reservoir units, reservoir pressure and the thickness of these reservoir units' producers. Nahr Umr Formation classify into several reservoir units separated by Shale Units.

Preparation of Reservoir Modeling

Use Petrel Software (2009) for preparation of three-dimensional (I, J, K) reservoir model. As the(J) is parallel to the longitudinal axis of the field, while the axis(I) is perpendicular to the longitudinal axis of the field(J), whereas, (K) represents the vertical axis for the current study values such as thickness, porosity, hydrocarbon saturation , etc.. It was prepared maps of shale volume, porosity and oil saturation per reservoir unit by the following procedures.

Distribution tomography (UP Scale)

Using various mathematic methods in the distribution of reservoir properties .The purpose was to obtain a single value for each property suitable petrophysical properties in a single cell (one cell) per reservoir unit note that the dimensions of the cell is (500 * 500) meter.

Distribution of petrophysical properties

Petrel Software (2009) was used for constructed three dimensional reservoir model through of calculates the saturation of oil. Shale volume, Porosity data and water saturation are the basic inputs in this model that the distributionof the saturation of oil within the reservoir units in Luhais oil field, as shown in the table(2 and 3), figures (5 to 7).

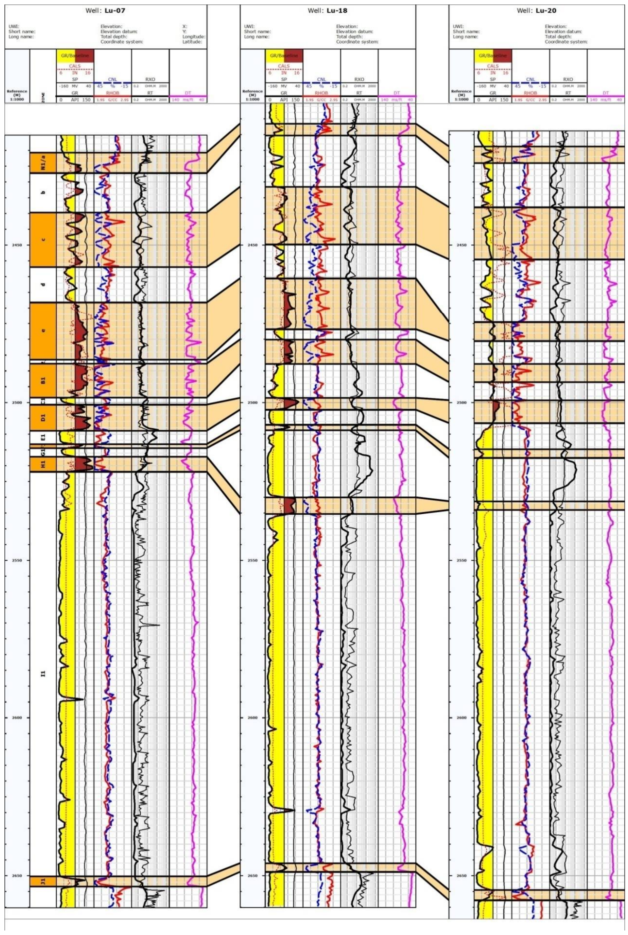

Fig 2 N-S correlation Profile of Nahr Umr Formation in (Lu-7, Lu-18, and Lu-20)

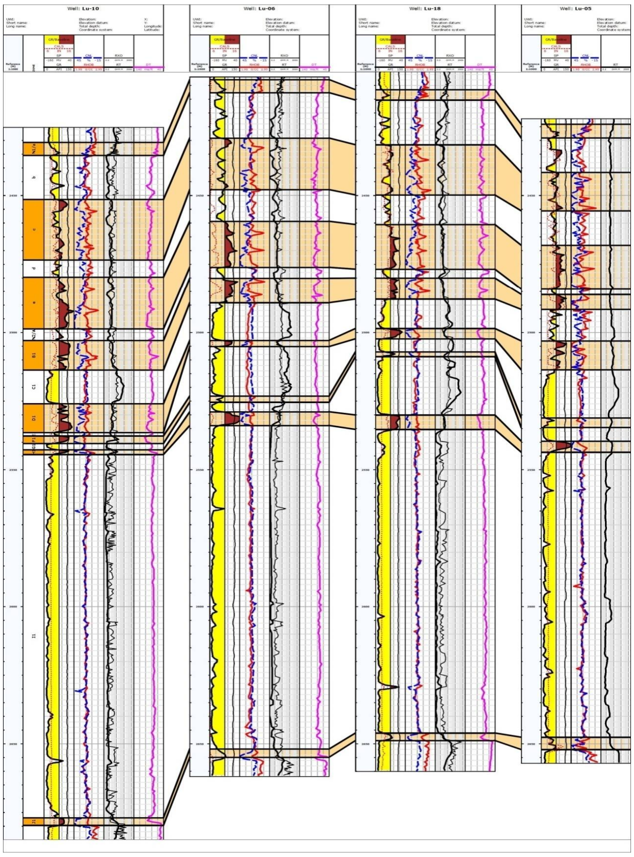

Fig 3 W-E correlation Profile of Nahr Umr Formation in (Lu-10,Lu-06 Lu-18, and Lu-05)

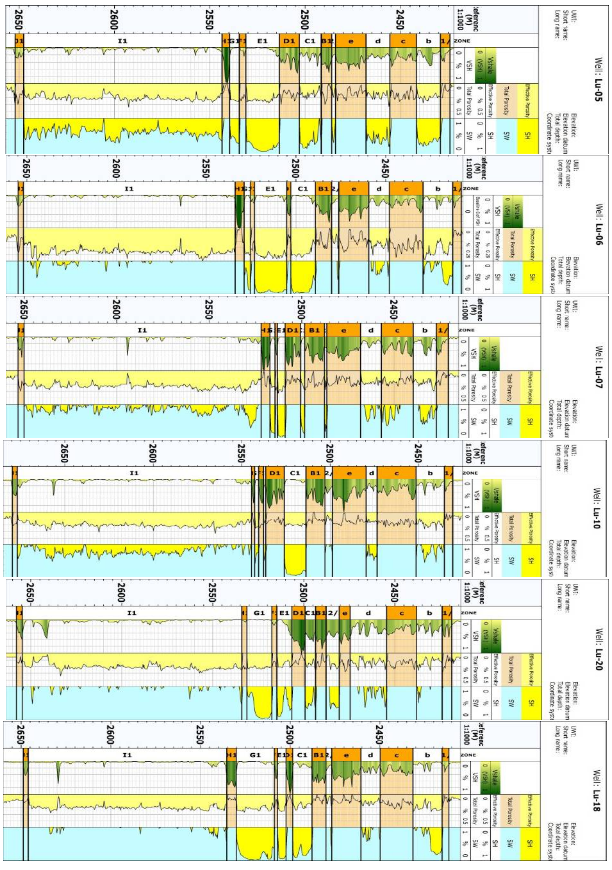

Fig 4 well logs interpretation (CPI) of Nahr Umr Formation at study wells

RESULTS AND DISCUSSIONS

Interpretation of the results of the reservoir model

First Reservoir Unit (b):This unit thickness ranges between 12.5 meters at the well(Lu-05) which locate at west of the field, and thickness(16.5) meters at the well(Lu-06) locates on the center of the field, and the average(14.5 meters) for all wells of the field.This unit is characterized by porosity ranging between(0.14-0.20) in most parts of the field, such as porosity increases towards the wells located in the west of the field, especially at the well(Lu-05). Its oil saturation ranges between (0.23-067), which increases towards the west of the field, well(Lu-05).

Second Reservoir Unit(d): This unit thickness ranges between(6.25) meters at the well (Lu-10) which locates at the east flank of the field and reached thickness about (20 meters) at the well (Lu-20) which locates at south of the field, whereas , reached average (12 meters) for all wells of the field. This unit is characterized by porosity ranging between (0.13-0.18). Noted that the increase of porosity around west of the field. This unit has oil saturation range (0.14-0.59), it's increased toward the wells located in the west of the field as in the wells (Lu-05).

Third Reservoir Unit (A1): This unit thickness ranges between (2) meters at the well (Lu-05) which locates at west of the field. Thickness reached (7.25) meters at the well (Lu-20) which locates at the south of the field, whereas, reached thickness about (3.5 meters) for all wells of the field. This unit is characterized by porous medium (0.11-0.21), which increases to the center and north of the field at the wells (Lu-6, Lu-10), while its oil saturation ranges between (0.11-0.69), with increasing saturation at the northern side of the field as in the well(Lu-07).

Fourth Reservoir Unit (C1): This unit is very important reservoir unit which thickness ranges between (2.25) meters at the well (Lu-07) in the north of the field, and thickness (13.75) meters at the well (Lu-06) in the north of the field. Average thickness reached about (9.5) meters for all wells of the field. This unit is characterized by good porosity ranging from (0.17-0.22), is also characterized by an very good oil saturation of between (0.21-0.87), with increasing porosity and saturation oil toward the wells located in the center and east of the field as well (Lu-10).

Fifth Reservoir Unit (E1): Alsothis unit is very important reservoir unit which thickness ranges between (1.25) meters at the well (Lu-10) in the east of the field, and thickness (18) meters at the well (Lu-06) in the center of the field. Average thickness reached (9) meters for all wells of the field. This unit is characterized by good porosity ranging between (0.15-0.28), with increasing porosity toward the wells located in the north of the field as well (Lu-07). Also is characterized by an oil saturation ranges between (0.24-0.93), where increasing oil saturations at north of the field as well(Lu-07).

Sixth Reservoir Unit (RU-6): Ranges thickness of this unit between (2.75) meters at the well (Lu-07) which locates at north of the field. Reached thickness (21.25) meters at the well (Lu-18) which locates at the center of the field. Average thickness (8) meters of all wells in the field. Also, it has characterized excellent porosity ranging (0.22 - 0.24).

Table 2 distribution of porosity in the units of study wells

Well	Lu-05				Lu-06				Lu-07				Lu-10				Lu-18				Lu-20			
variable	PHIE				PHIE				PHIE				PHIE				PHIE				PHIE			
Zone	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)
b	0.28	0.14	0.20	12.5	0.28	0.9	0.19	16.5	0.31	0.11	0.18	12.5	0.29	0.07	0.18	16	0.26	0.06	0.20	16.25	0.26	0.05	0.14	14
d	0.33	0.10	0.18	12.5	0.24	0.06	0.14	11.5	0.23	0.08	0.17	11.25	0.17	0.11	0.15	6.25	0.18	0.05	0.13	10.75	0.27	0.07	0.14	20
A1	0.20	0.11	0.16	2	0.18	0.05	0.11	4	0.28	0.15	0.21	1.25	0.20	0.03	0.11	4.25	0.18	0.05	0.12	3.25	0.25	0.05	0.18	7.25
C1	0.24	0.09	0.17	11.5	0.26	0.10	0.21	13.75	0.28	0.17	0.22	2.25	0.22	0.17	0.20	12.25	0.24	0.11	0.17	10.75	0.27	0.08	0.17	5.75
E1	0.28	0.14	0.23	17.5	0.27	0.14	0.24	18	0.33	0.22	0.28	4.25	0.17	0.13	0.15	1.25	0.26	0.24	0.23	4.75	0.22	0.10	0.18	8.25
G1	0.26	0.23	0.24	5	0.24	0.18	0.22	3.5	0.25	0.18	0.23	2.75	0.25	0.22	0.23	2.25	0.27	0.12	0.22	21.25	0.25	0.19	0.22	13.75
I1	0.34	0.07	0.21	104	0.29	0.09	0.21	118	0.33	0.06	0.23	128.25	0.33	0.08	0.20	132.5	0.28	0.06	0.20	110.75	0.34	0.07	0.21	120.5

Table 3 Distribution of Oil Saturation In The Units of Study Wells

Well	Lu-05				Lu-06				Lu-07				Lu-10				Lu-18				Lu-20			
variable	S_{hc}				S_{hc}				S_{hc}				S_{hc}				S_{hc}				S_{hc}			
Zone	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)	Max	Min	Average	Thick.(m)
b	0.79	0.52	0.67	12.5	0.28	0.09	0.19	16.5	0.58	0.11	0.37	12.5	0.55	0.07	0.27	16	0.83	0.10	0.56	16.25	0.50	0.09	0.23	14
d	0.80	0.24	0.59	12.5	0.24	0.06	0.14	11.5	0.63	0.08	0.34	11.25	0.50	0.14	0.33	6.25	0.50	0.10	0.30	10.75	0.64	0.11	0.29	20
A1	0.69	0.42	0.57	2	0.18	0.05	0.11	4	0.79	0.58	0.69	1.25	0.31	0.07	0.18	4.25	0.58	0.43	0.50	3.25	0.68	0.30	0.58	7.25
C1	0.85	0.28	0.69	11.5	0.26	0.10	0.21	13.75	0.88	0.57	0.75	2.25	0.94	0.56	0.87	12.25	0.92	0.51	0.76	10.75	0.68	0.14	0.55	5.75
E1	0.93	0.63	0.82	17.5	0.27	0.14	0.24	18	0.96	0.90	0.93	4.25	0.50	0.21	0.32	1.25	0.94	0.81	0.91	4.75	0.91	0.1	0.62	8.25
G1	071	0.50	0.61	5	0.24	0.19	0.22	3.5	0.85	0.73	0.81	2.75	0.58	0.19	0.29	2.25	0.98	0.37	0.86	21.25	0.96	0.15	0.72	13.75
I1	0.70	0.14	0.42	104	0.29	0.09	0.21	118	0.69	0.06	0.19	128.25	0.57	0.07	0.24	132.5	0.43	0.07	0.17	110.75	0.55	0.07	0.19	120.5

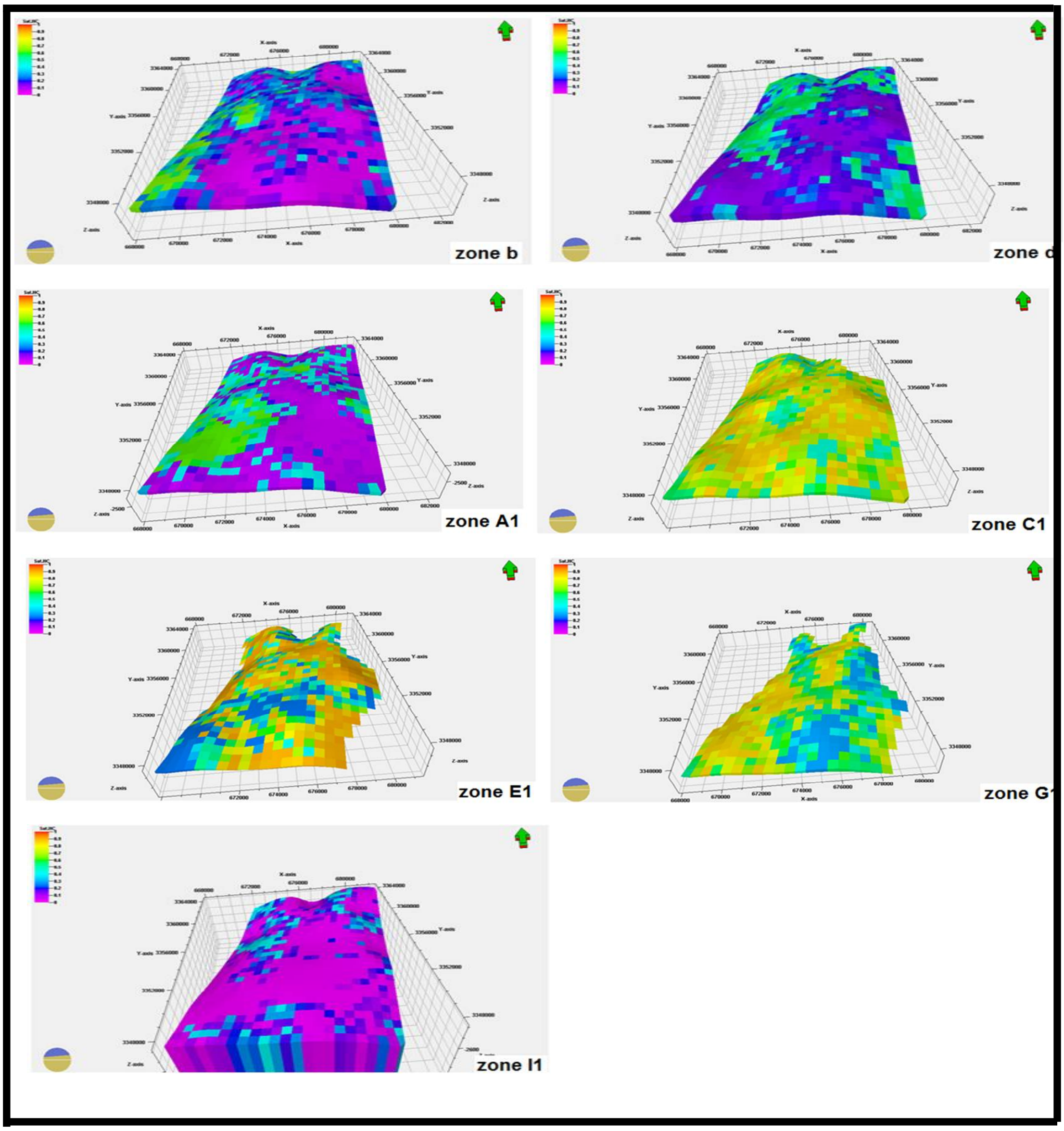

Fig 5 shows the distribution of porosity at Luhias oil field

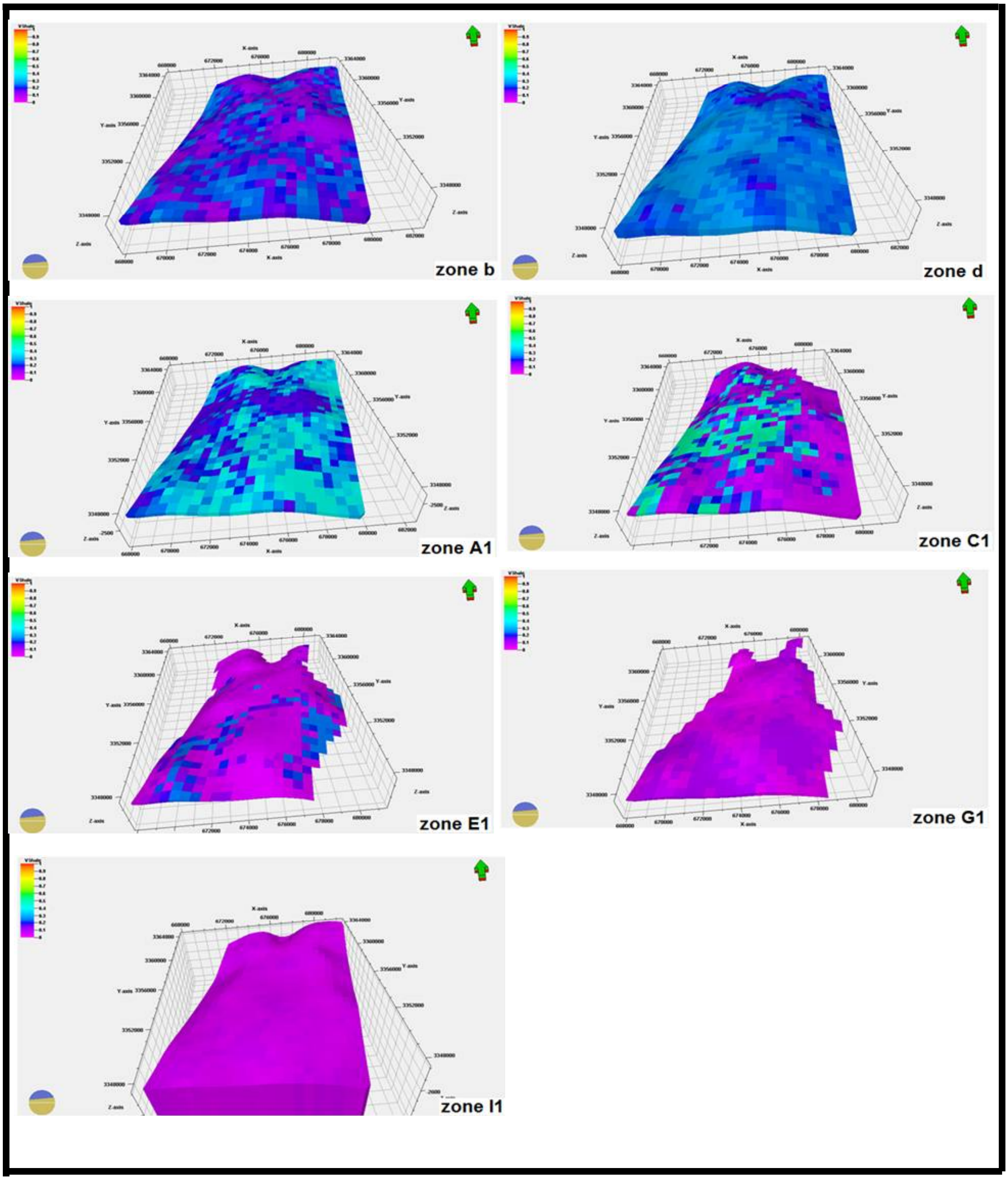

Fig 6 distribution of shale volume at Luhais oil field

Note, the porosity increases towards the west of field at the well (Lu-05), while the oil saturation ranges between (0.22-0.86), with increasing oil saturation toward the wells which locates in the center of the field as well (Lu-18).

Seventh Reservoir Unit (I1): This unit thickness ranges between (104) meters at the well (Lu-05) to the west of the field, and thickness (132.5) meters at the well (Lu-18) in the center of the field. Average thickness reached (119) meters for all wells of the field. This unit is characterized by a rate of porosity (0.20-0.23) in most of the wells of the field.

Is also characterized by an oil saturation ranges (0.17-0.42), with increasing oil saturation toward the wells located in the west of the field as well (Lu-05).

CONCLUSION

It is clear from the foregoing that the best wells in the oil saturations within the Luhais field is the well (Lu-07) which locates at north of the field and the well (Lu-18) in the center of the field.

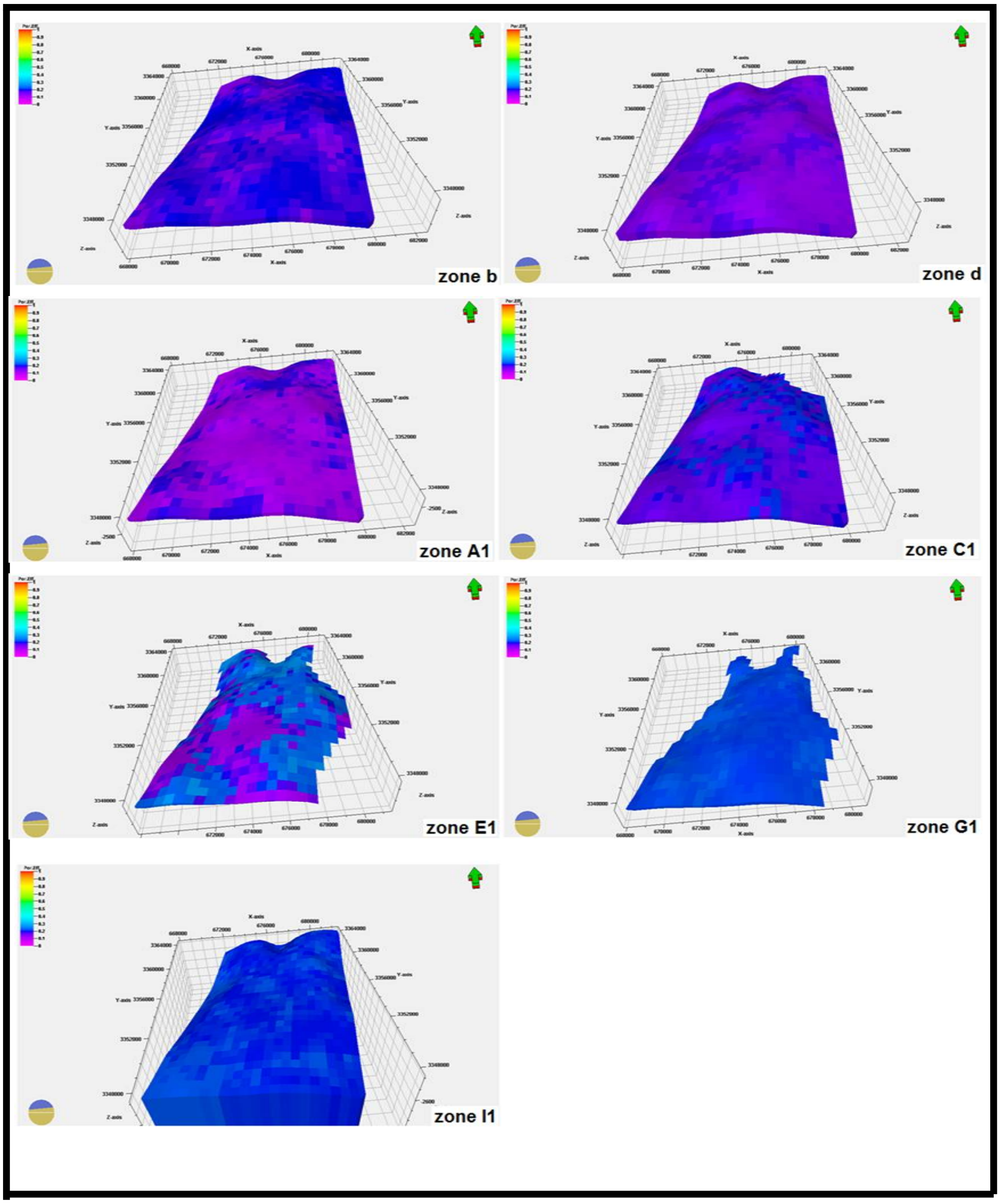

Fig 7 shows the distribution of oil saturation at Luhias oil field

While the best units in terms of oil saturation of reservoir unit is the C1, E1 and G1 respectively, taking into account the thickness variation of these units between wells of the field.

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