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Using Computer Processing Interpretation (CPI) Technique to Evaluate Mishrif Formation in Garraf Oil Field, Southern Iraq

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Abstract

The aim of this study is to determine and evaluate the units and subunits of Mishrif Formation in Garraf oil field 85 km north of Nasiriyah city depending mainly on the geophysical well logging data and other amiable geological information. The sets of the geophysical well logs data acquired from GA-4, GA-AIP, GA- B8P, GA-3 and GA-5 wells of Garraf oil field are used to determine the petrophysical and lithological properties for each zone in Mishrif Formation to locate, define and evaluate hydrocarbon production from each zone in the reservoir which is also known as formation evaluation. The digitization was done by using Didger software and the interpretations were made using Interactive Petrophysics Program v 3.5 and Petrel software. It is found that middle and Lower parts of Mishrif Formation include several reservoir units (M 1.2, L 1, L 1.2, L 2, L 2.2, L 2.3 and L 2.4) that have been sealed by two cap layers (M 1 and M 2). M 1.2, L 1 and L 1.2 are considered as high quality reservoir units, because they have high values of porosity and hydrocarbon saturation.

Keywords: Mishrif Formation, Garraf oil field, Petrophysical properties

استخدام تقنية تفسير المعالجة الحاسوبية لتقييم تكوين المشرف في حقل الغراف النفطي، جنوب العراق

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الخلاصة

تهدف هذه الدراسة الى تحديد وتقييم الوحدات الرئيسية والثانوية لتكوين المشرف في حقل الغراف النفطي الذي يقع على بعد 85 كيلومترا شمال مدينة الناصرية وذلك بالاعتماد بشكل رئيسي على بيانات المجسات البئرية الجيوفيزيائية والمعلومات الجيولوجية الأخرى المتوفرة. لقد استخدمت بيانات الجس البئري الجيوفيزيائية المستحصلة من الآبار(GA-5, GA-3, GA-B8P, GA-A1P, GA-4) في حقل الغراف النفطي لأيجاد الخواص البتروفيزيائية والليثولوجية لكل نطاق من انطقة تكوين المشرف لتحديد وتعريف وتقييم الانتاج الهيدروكاربوني لكل نطاق من المستودع والذي يعرف ايضا تقييم التكوين. لقد تم تحويل المجسات الى الصيغة الرقمية باستخدام برنامج (Didger) وتمت عملية التفسير باستخدام برنامج (Interactive petrophysics V3.5 و Petrel software) . لقد وجد بأن الجزئين الوسطي والأسفل من تكوين المشرف يحتوي على عدة وحدات مكمنية وهي (L2.2, L2.3, L2.4 M1.2, L1, L1.2, L2 ,) والتي تم تغطيتها بطبقتين غطائيتين هما (M1 و M2). لقد اعتبرت الطبقات (M 1.2 و L 1 و L 1.2) وحدات مكمنية عالية الجودة لانها تمتلك قيم عالية من المسامية والتشبع الهيدروكاربوني.

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Introduction:

The initial study of Mishrif Formation in Garraf oil field declared that the reservoir comprises 3-essential units, upper, middle and lower.

The Garraf field consists of different reservoir zones and the zones considered for this study is Mishrif Formation. The main oil accumulation zones in the field are the Mishrif and Yamama Formations .The second accumulation zones are found in the Ratawi and Zubair Formations.

This study is conducted to determine and evaluate the units and subunits of Mishrif Formation in Garraf oil field based on geophysical well logs data, cuttings and cores. The study shows the vertical and lateral variations in facies and reservoir properties. Petrophysical properties are the study of rock properties and their interactions with fluids (gases, liquid hydrocarbons and aqueous solutions). Geophysical well logging is the technique of making petrophysical measurements in the subsurface earth formations through the drilled borehole in order to determine both the physical and chemical properties of rocks and the fluid they contain [1]. Due to the enormous amount of data, well logging can provide the technology plays a pivotal role in hydrocarbon exploration and production industry. These techniques can be used in all phases of hydrocarbon exploration and production process. Rapid and sophisticated development in well logging technology has revolutionized the hydrocarbon industry [2]. The aim of this study is the application of the available sets of well logs data acquired from GA-4, GA-A1P, GA-B8P, GA-3 and GA-5 wells of Garraf oil field to determine the petrophysical and lithological properties for each zones in Mishrif Formation to locate, define, and production evaluate hydrocarbon from a given reservoir and it is also known as formation evaluation. The study includes two steps, the pre-interpretation and the interpretation. The pre-interpretation includes the determination of effective porosity (corrected to shale effects), checking the digitization result of available well logs by didger software and all the parameters that are required in the interpretation processes. The interpretations were made using Interactive Petrophysics Program v3.5 and Petrel software.

Study Area

The Garraf Oil Field is located in Dhi Qar Governorate, approximately 265 km. southeast of Baghdad and 85 km. north of Nasiriyah city Figure-1. The Garraf oil field is a northwest-southeast trending anticline with 24 km. length and 5 km. width. Many wells were drilled in Garraf oil field since 1984. Garraf oil field represents forms of a series of anticlinal structures developed on the southern flank of the Zagros Mountain front flexure, the trend of the anticline is parallel to the main Zagros trend [3]. Mishrif reservoir, located between approximately 2270 and 2450 m TVD, is the uppermost oil accumulation in the Garraf structure. The thickness of the Formation in Garraf oil field reachs about 209 m in well GA-4. Mishrif Formation belongs to the upper most Albian- Lower Turonian, supersequence (IV), which corresponds to the tectonostratigraphic megasequence AP8 of Sharland, 2001 [4].

Mishrif Formation represents a heterogeneous formation originally described as organic detrital limestones, capped by limonitic fresh water limestones [5]. The lower contact of the formation is conformable with the underlying unit Rumaila Formation. The upper contact is unconformable with Khasib Formation [6].

Methodology:

This research involves the analysis of petrophysical properties using data from the available open hole geophysical logs such as (Spontaneous Potential, Gamma Ray, Density, Sonic, Neutron and Resistivity logs) of studied wells. The available open hole logs data were digitized in order to be imported into the appropriate software for analysis and interpretation, Didger V.4 software was used for the digitization of logs. One reading per 0.5m depth is selected for recording the input data measurements. The proper corrections (i.e. Shale effect, borehole conditions, depth of invasion, etc.) for Gamma ray , neutron, density and resistivity log , were applied before commencing the open hole well log analysis as based on Schlumberger's well log analysis basic Corrections . **Interactive Petrophysics Program v3.5** was used for well logs analysis and **Petrel software** was used to evaluate the petrophysical properties.

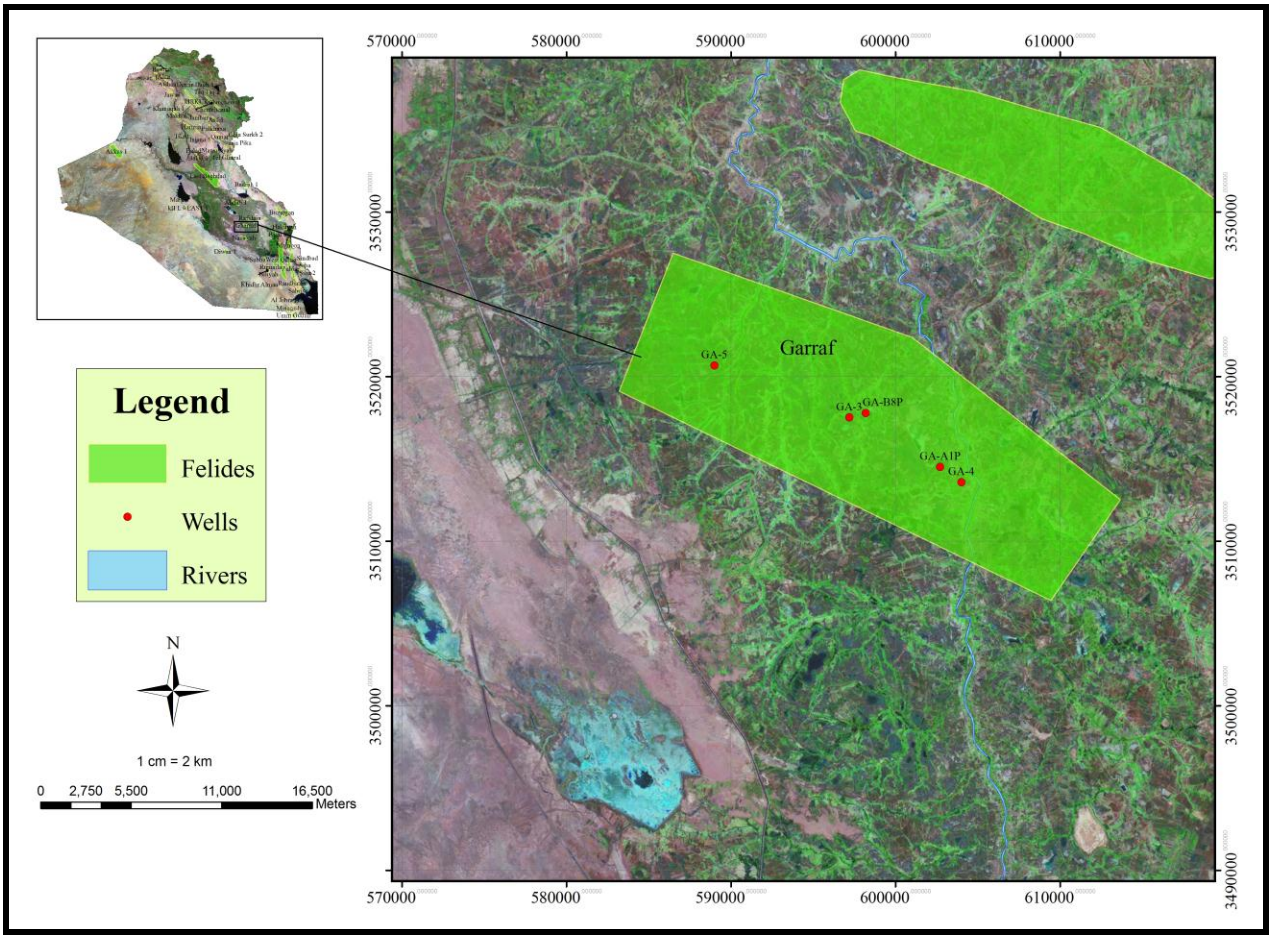

Figure 1- General map of Iraq showing location of the study area

Properties of Reservoir:

For determining reservoir properties of Mishrif 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) [7]

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

Where: GRlog = gamma ray reading of formation; GRmin = minimum gamma ray reading (clean carbonate): GRmax = maximum gamma ray reading (shale). For the purpose of this work, the formula of Dresser Atlas (1979) [8] for older rocks was used to determine the shale volume

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

B- Porosity: Total porosity within Mishrif Formation was determined from combination of Neutron – Density derived porosities. Neutron log measure the direct porosity after correction based on the equation of Tiab & Donaldson (1996) [9]

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

Where ØNcorr. = corrected porosity derived from Neutron log for un 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) [10] 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 derived from Density log for unclean rocks**:** ØDsh = density porosity for shale.

Total porosity (Øt) is then calculated as follows

Øt = (ØN + ØD) / 2 **(6)**

The effective porosity (Øe) is then calculated, using equation of Schlumberger (1998) [11] after total porosity corrected from shale volume

Øe = Øt * (1-Vsh) **(7)**

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

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

Δt is increased due to the presence of hydrocarbon. To correct for hydrocarbon effect, Hilchie (1978) [12] suggested the following empirical equations:

Ø = ØS * 0.7 (gas) **(9)**

Ø = ØS * 0.9 (oil) **(10)**

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

ØScorr = ØS – (Vsh* ØSsh) **(11)**

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 made corrections for shaliness and hydrocarbon effect

SPI = (Øt – Øscorr) **(12)**

C- Water and hydrocarbon saturation:

Water saturation for the uninvaded zone was calculated according to Archie (1942) [13]:

Sw = {(a * Rw) / (Rt * _m)} $^{1/n}$ **(13)**

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)} $^{1/n}$ **(14)**

Where: Rw = Resistivity of water formation that is previously determined from SP log. a = tortuosity factor; m = cementation factor; n = saturation exponent.

Then the hydrocarbon saturation can be calculated by using the following equation:

Sh = 1 – Sw **(15)**

Moveable hydrocarbon saturation was calculated based on Schlumberger (1998) [11] equation

MOS = Sxo - Sw **(16)**

Whereas residual oil saturation was calculated from Schlumberger (1987) [14] as in the following equation;

ROS = 1 - Sxo **(17)**

D- Permeability: Permeability is the ability of fluids to pass through a porous material Selley, 1998 [15].

It is determined from the Electromagnetic Propagation Log (EPT).

Results and Discussions:

Figure-2, 3, 4, 5 and 6 represents computer processing interpretation (CPI) for wells (GA-4, GA-A1P, GA-B8P, GA-3 and GA-5) that has been deduced using IP program. The Figure shows the full interpretation process as following:

1. The lithology track: This represents the effective porosity (PHIE), and percentage of Matrix (Dolomite, Silt, Sand, Limestone and Anhydrite).
2. Fluid analysis track: which represents water saturation or indirectly hydrocarbon saturation, after subtracting it from unity.
3. Porosity and permeability track: This track includes corrected permeability, mobility and calculated permeability.
4. Total and effective porosities track: This track also includes the corrected porosity values. These values are used in economic evaluation of the main units of Mishrif Formation in Garraf oil field.

Tables-1, 2, 3, 4 and 5 show the subdivisions of reservoir units with important properties.

The studied Formation depending on the petrophysical properties (porosity and water saturation), is interpreted as follows:

- Cap rocks

Two cap layers (M1 and M2) were identified. The GR, DT log response shows high values in cap rocks, whereas effective porosity (PHIE) values are low due to the dominance of isolated pores. In contrast, water saturation is high. Thus, volume of oil (VOIL) is low.

-Reservoir zone

The reservoir units (M1.2, L1, L1.2, L2, L2.2, L2.3 and L2.4) of Mishrif Formation represent limestone. Therefore, they show low GR log values. In addition, total and effective porosities (PHIT & PHIE) values are high as calculated from porosity logs. The volume of oil (VOIL) is high as a result of low water saturation. Figures-7, 8 and 9 show that the economic units of Mishrif Formation in Garraf oil field represent in units M1.2, L1 and L1.2 are considered as high quality reservoir units due to the high value of PHIE and low water saturation.

M1.2 Reservoir Unit:

The M1.2 unit is dominated by fore slope facies. The unit thickens towards GA-5 and GA-4 wells. Generally, this unit shows good PHIE and water saturation average values that can reach 18% and 43%, respectively. However, the reservoir quality decreases in the area between GA-5 and GA-3 as indicated by the higher water saturation and lower PHIE values Figure-7.

L1 Reservoir Unit:

The L1 reservoir unit represents a back-shoal facies body that pinches out towards GA-3 well. The direction of thinning is associated with decreasing PHIE values and increasing water saturation. The average PHIE is 16%, and water saturation is 39% Figure-8.

L1.2 Reservoir Unit:

The L1.2 unit is characterized by high reservoir properties due to the dominance of thick rudist foreslope and rudist buildup facies units. This unit thins towards GA-3 and GA-4 wells, in addition to back-shoal facies as in GA-3 well Figure-9. In most wells, little changes in PHIE and water saturation have been observed. The average of PHIE is 26%, and water saturation reaches 16%. Therefore, they represent the best reservoir unit in Garraf oil field.

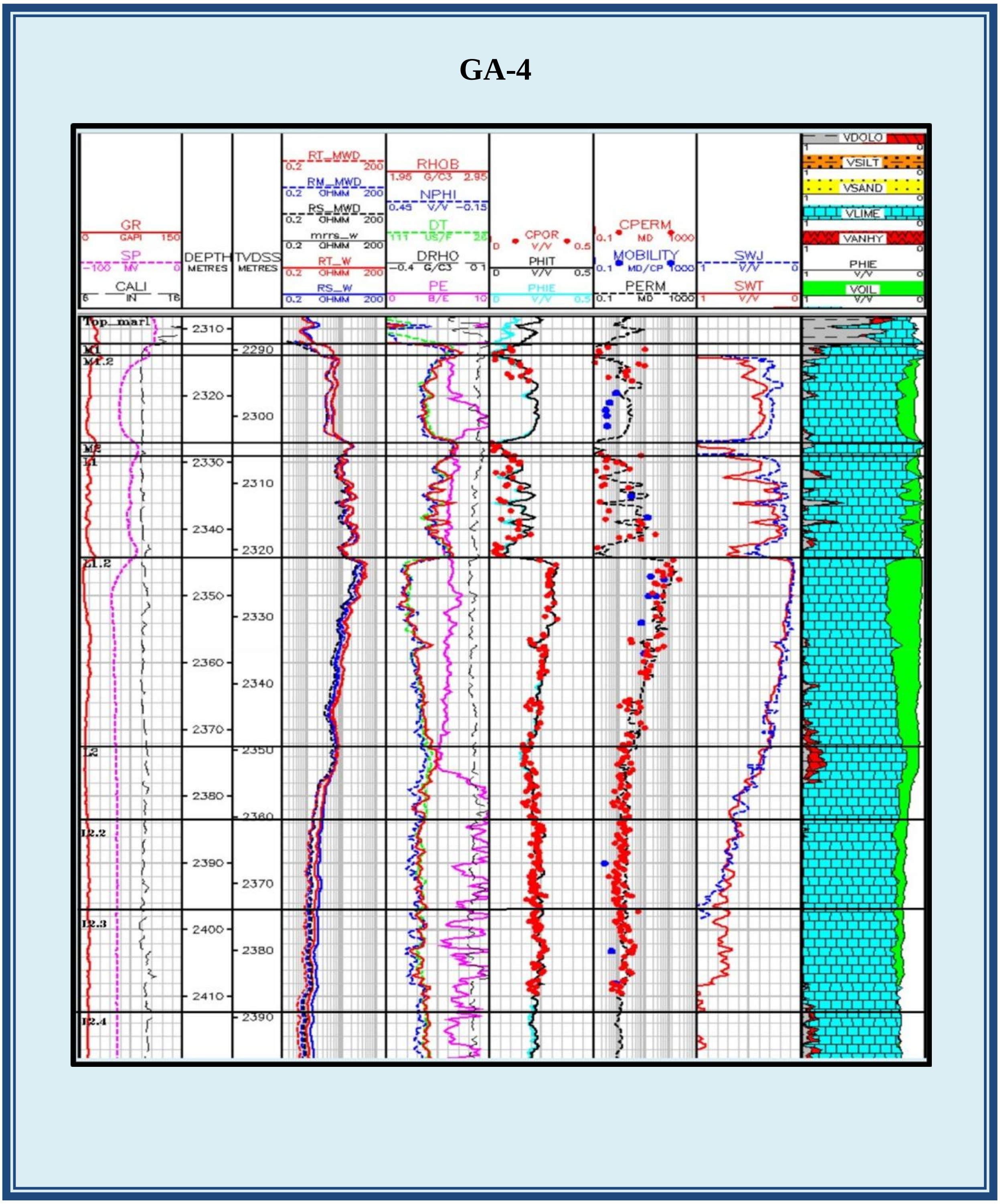

Figure 2- Computer Processing Interpretation (CPI) of well GA-4

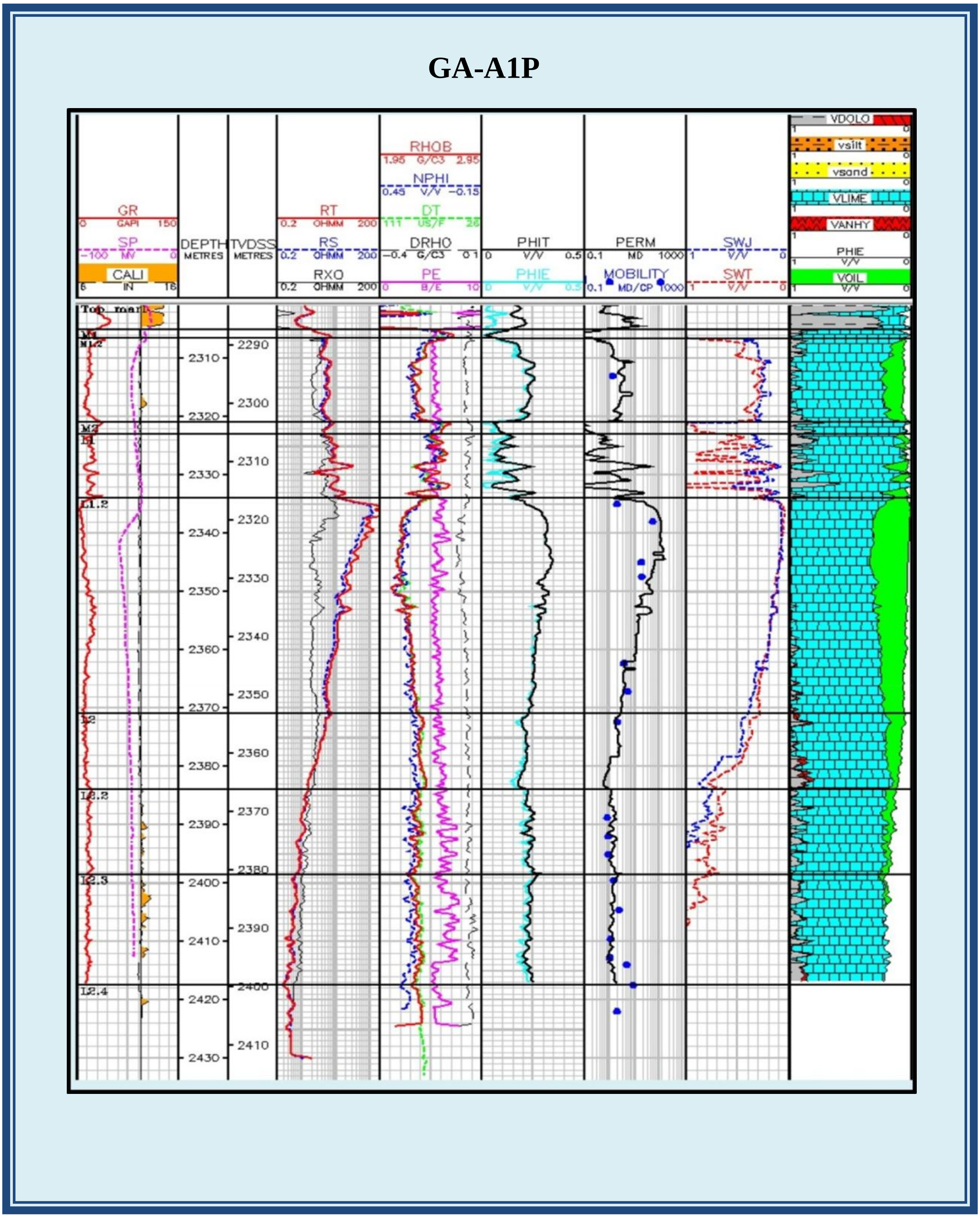

Figure 3- Computer Processing Interpretation (CPI) of well GA-A1P

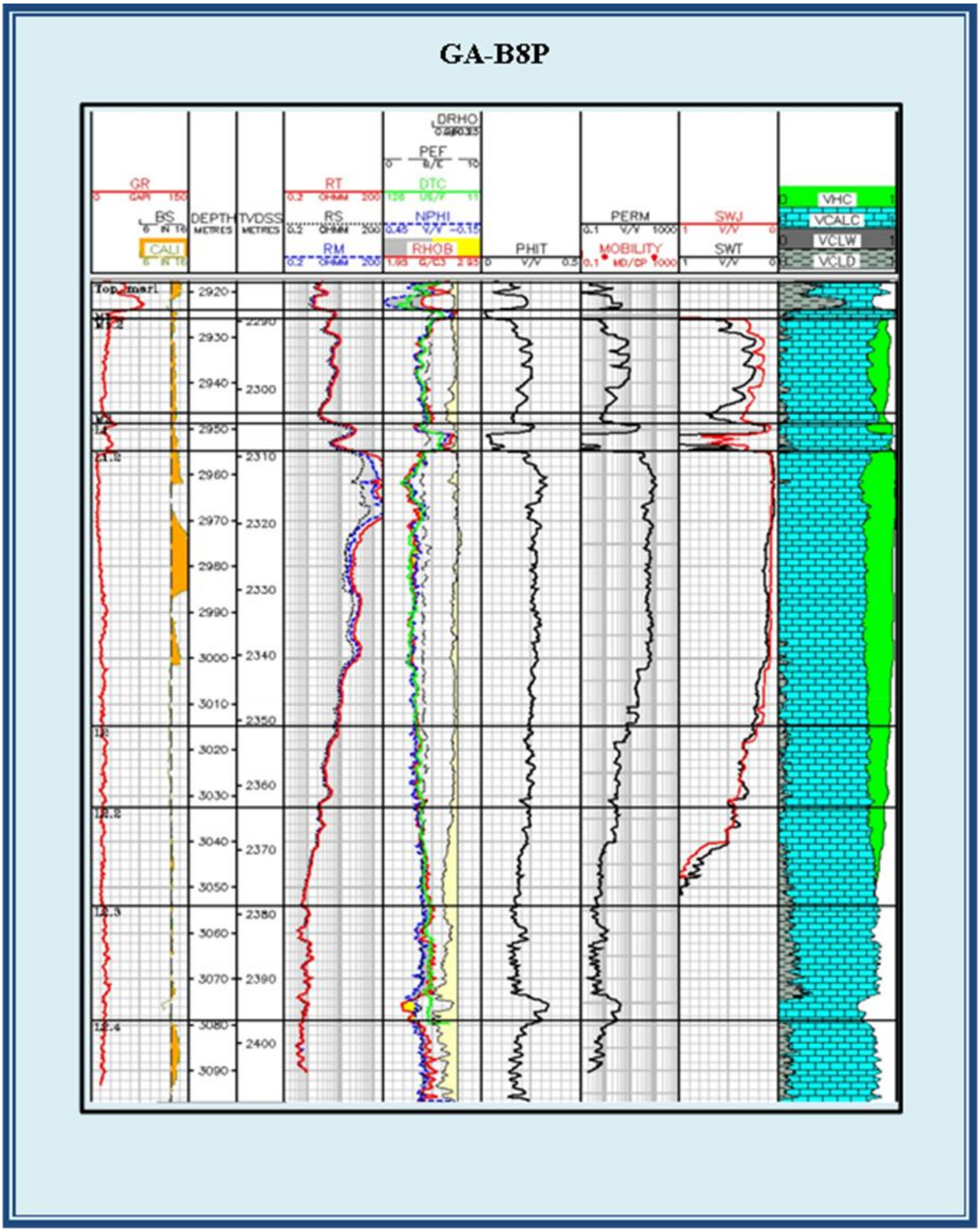

Figure 4- Computer Processing Interpretation (CPI) of well GA-B8P

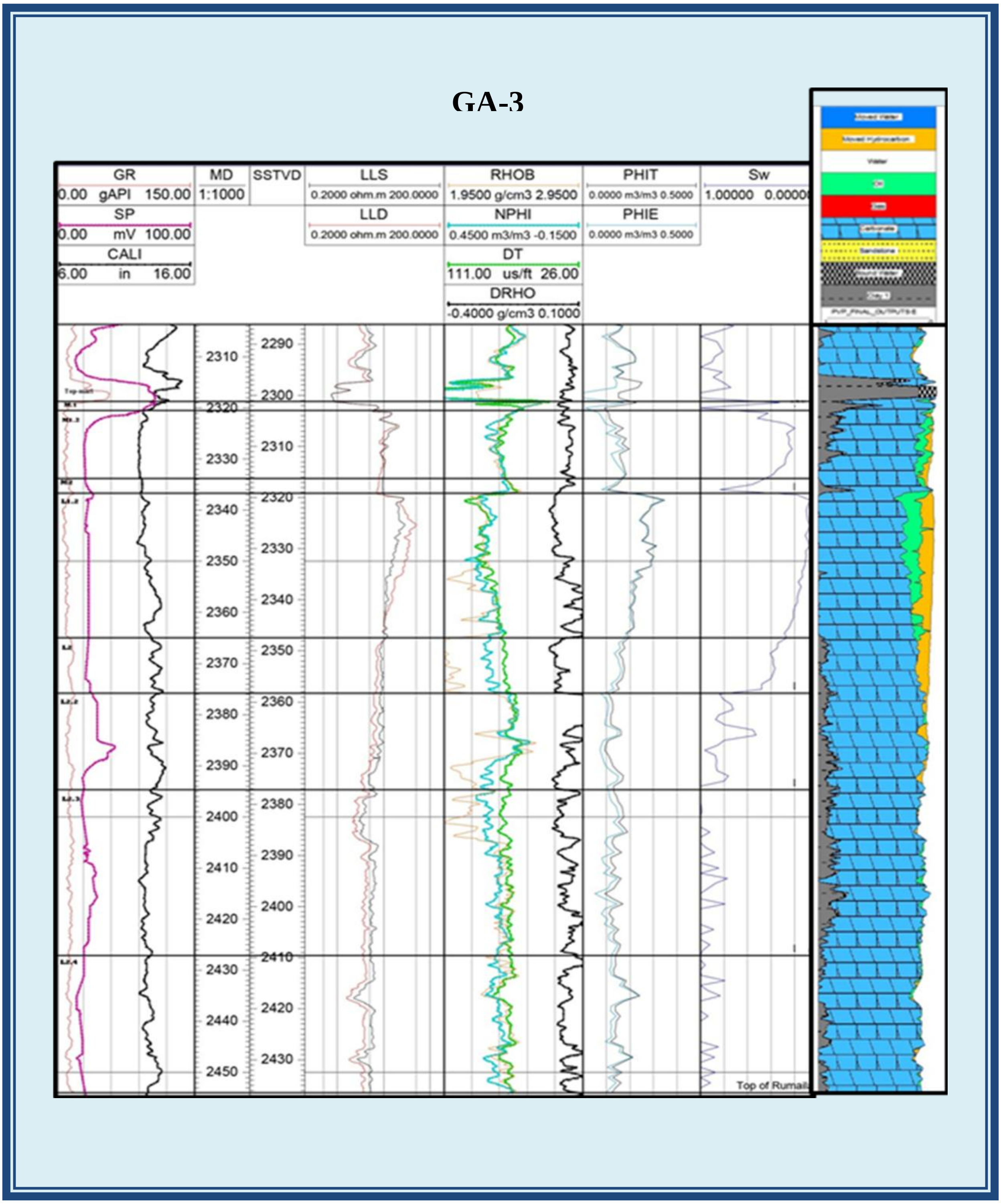

Figure 5- Computer Processing Interpretation (CPI) of well GA-3

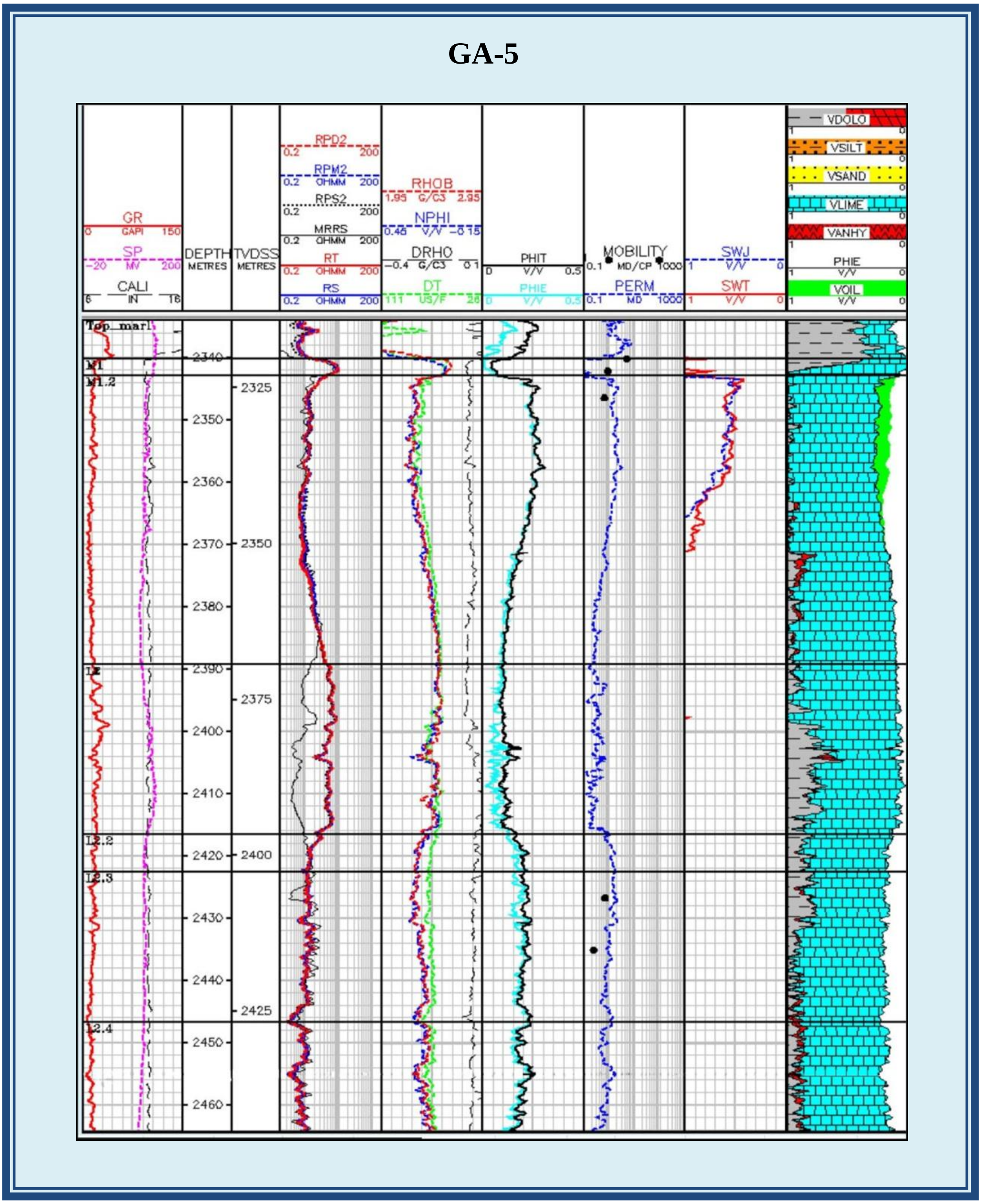

Figure 6- Computer Processing Interpretation (CPI) of well GA-5

Table 1- Interpretation of important properties of Mishrif Reservoir in well GA-4

GA-4		RTKB (m)	21.20			Gross interval thickness	Net Reservoir thickness	N/G Ratio	Ave. porosity Phit% b.v.	Ave. water Saturation Sw% p.v.	Ave. Total Hydrocarbon Saturation Sh% p.v.	Fluid Type
Reservoir	RESERVOIR SUB UNIT	DEPTH										
		Top Markers		Bottom Markers								
		M. MDDF	M. TVDSS	M. MDDF	M. TVDSS							
Mishrif	M1	2312.2	2289.09	2313.2	2290.08	1	Tight					
	M1.2	2313.2	2290.08	2327	2303.89	13.8	13.8	1	19.7	43.5	56.5	oil
	M2	2327	2303.89	2329	2305.89	2	Tight					
	L1	2329	2305.89	2344.91	2321.8	15.91	11.81	0.7	16.1	28.6	71.4	oil
	L1.2	2344.91	2321.8	2372.5	2349.38	27.59	27.59	1	26.3	18.7	81.3	oil
	L2	2372.5	2349.38	2383.43	2360.31	10.93	10.93	1	21.8	49	26.0	oil
	L2.2	2383.43	2360.31	2396.86	2373.74	13.43	13.43	1	22.5	72.4	26.0	oil
	L2.3	2396.86	2373.74	2420.14	2397.02	23.28	23.28	1	23.2	90	26.0	water
	L2.4	2420.14	2397.02	2455	2431.88	34.9	34.9	1	20.2	100.0	0.0	water

Table 2- Interpretation of important properties of Mishrif Reservoir in well GA-A1P

GA-A1P		RTKB (m)	17.69			Gross interval thickness	Net Reservoir thickness	N/G Ratio	Ave. porosity Phit% b.v.	Ave. water Saturation Sw% p.v.	Ave. Total Hydrocarbon Saturation Sh% p.v.	Fluid Type
Reservoir	RESERVOIR SUB UNIT	DEPTH										
		Top Markers		Bottom Markers								
		M. MDDF	M. TVDSS	M. MDDF	M. TVDSS							
Mishrif	M1	2305	2287.31	2306.2	2288.51	1.2	Tight					
	M1.2	2306.2	2288.51	2321	2303.30	14.8	14	0.9	21.3	35.4	64.6	oil
	M2	2321	2303.30	2323	2305.29	2	Tight					
	L1	2323	2305.29	2333.71	2316.02	10.1	6.6	0.6	16.2	33.4	66.6	oil
	L1.2	2333.71	2316.02	2371	2353.24	37.29	37.29	1.0	28.2	15.4	84.6	oil
	L2	2371	2353.24	2384	2366.22	13	13	1.0	20.7	48.0	52.0	oil
	L2.2	2384	2366.22	2392.56	2374.87	8.56	8.56	1.0	23.2	73.4	26.6	oil
	L2.3	2392.56	2374.87	2407.44	2389.75	14.88	14.88	1.0	23.8	91.5	8.5	water
	L2.4	2407.44	2389.75	2417.5	2399.67	10.1	10	1.0	22.4	100.0	0.0	water

Table 3- Interpretation of important properties of Mishrif Reservoir in well GA-B8P

GA-B8P		RTKB (m)	19.13			Gross interval thickness	Net Reservoir thickness	N/G Ratio	Ave. porosity Phit% b.v.	Ave. water Saturation Sw% p.v.	Ave. Total Hydrocarbon Saturation Sh% p.v.	Fluid Type
Reservoir	RESERVOIR SUB UNIT	DEPTH										
		Top Markers		Bottom Markers								
		M. MDDF	M. TVDSS	M. MDDF	M. TVDSS							
Mishrif	M1	2924.05	2288.32	2925.82	2289.51	1.8	Tight					
	M1.2	2925.82	2289.51	2946.45	2303.44	20.6	20.4	1.0	19.8	35.2	64.8	Oil
	M2	2946.45	2303.44	2948.77	2305.03	2.3	Tight					
	L1	2948.77	2305.03	2954.77	2309.13	6.0	2.1	0.3	22.0	15.5	84.5	Oil
	L1.2	2954.77	2309.13	3014.49	2350.62	59.7	59.6	1.0	24.2	11.7	88.3	Oil
	L2	3014.49	2350.62	3032.03	2363.03	17.5	17.5	1.0	22.6	33.9	66.1	Oil
	L2.2	3032.03	2363.03	3055	2379.34	23.0	23.0	1.0	19.8	69.2	30.8	Oil
	L2.3	3055	2379.34	3078.94	2396.33	23.9	23.9	1.0	19.6	100.0	0.0	water
	L2.4	3078.94	2396.33	3089.96	2406.20	11.0	11.0	1.0	19.6	100.0	0.0	water

Table 4- Interpretation of important properties of Mishrif Reservoir in well GA-3

GA-3		RTKB (m)	19.13			Gross interval thickness	Net Reservoir thickness	N/G Ratio	Ave. porosity Phit% b.v.	Ave. water Saturation Sw% p.v.	Ave. Total Hydrocarbon Saturation Sh% p.v.	Fluid Type
Reservoir	RESERVOIR SUB UNIT	DEPTH										
		Top Markers		Bottom Markers								
		M. MDDF	M. TVDSS	M. MDDF	M. TVDSS							
Mishrif	M1	2318.73	2301.19	2320.45	2302.91	1.72	Tight					
	M1.2	2320.45	2302.91	2333.82	2316.28	13.37	13.30	1.0	15.4	36	64	Oil
	M2	2333.82	2316.28	2336.71	2319.17	2.89	Tight					
	L1.2	2336.71	2319.17	2364.93	2347.39	28.22	28.22	1.0	25	15	85	Oil
	L2	2364.93	2347.39	2375.78	2358.24	10.85	10.80	1.0	16.3	42	58	Oil
	L2.2	2375.78	2358.24	2394.65	2377.11	18.87	18.80	1.0	12.8	80	20	Oil
	L2.3	2394.65	2377.11	2427.15	2409.61	32.50	32.50	1.0	14.2	100	0	water
	L2.4	2427.15	2409.61	2454	2436.46	26.85	26.85	1.0	15.5	100	0	water

Table 5- Interpretation of important properties of Mishrif Reservoir in well GA-5

GA-5		RTKB (m)	19.15			Gross interval thickness	Net Reservoir thickness	N/G Ratio	Ave. porosity Phit% b.v.	Ave. water Saturation Sw% p.v.	Ave. Total Hydrocarbon Saturation Sh% p.v.	Fluid Type
Reservoir	RESERVOIR SUB UNIT	DEPTH										
		Top Markers		Bottom Markers								
		M. MDDF	M. TVDSS	M. MDDF	M. TVDSS							
Mishrif	M1	2340.21	2320.34	2342.86	2322.99	2.7	Tight					
	M1.2	2342.86	2322.99	2371.12	2351.23	28.3	28	1.0	24.4	66.2	33.8	Oil
		2371.12	2351.23	2389.29	2369.40	18.2	14.3	0.8	14.0	100.0	0.0	water
	L1	Pinch Out										
	L2	2389.29	2369.40	2416.57	2396.66	27.3	10.5	0.4	12.7	100.0	0.0	water
	L2.2	2416.57	2396.66	2422.53	2402.61	6.0	6.0	1.0	19.2	100.0	0.0	water
	L2.3	2422.53	2402.61	2446.69	2402.61	24.2	24.1	1.0	20.8	100.0	0.0	water
	L2.4	2446.69	2426.76	2464.41	2444.46	17.7	17.7	1.0	19.5	100.0	0.0	water

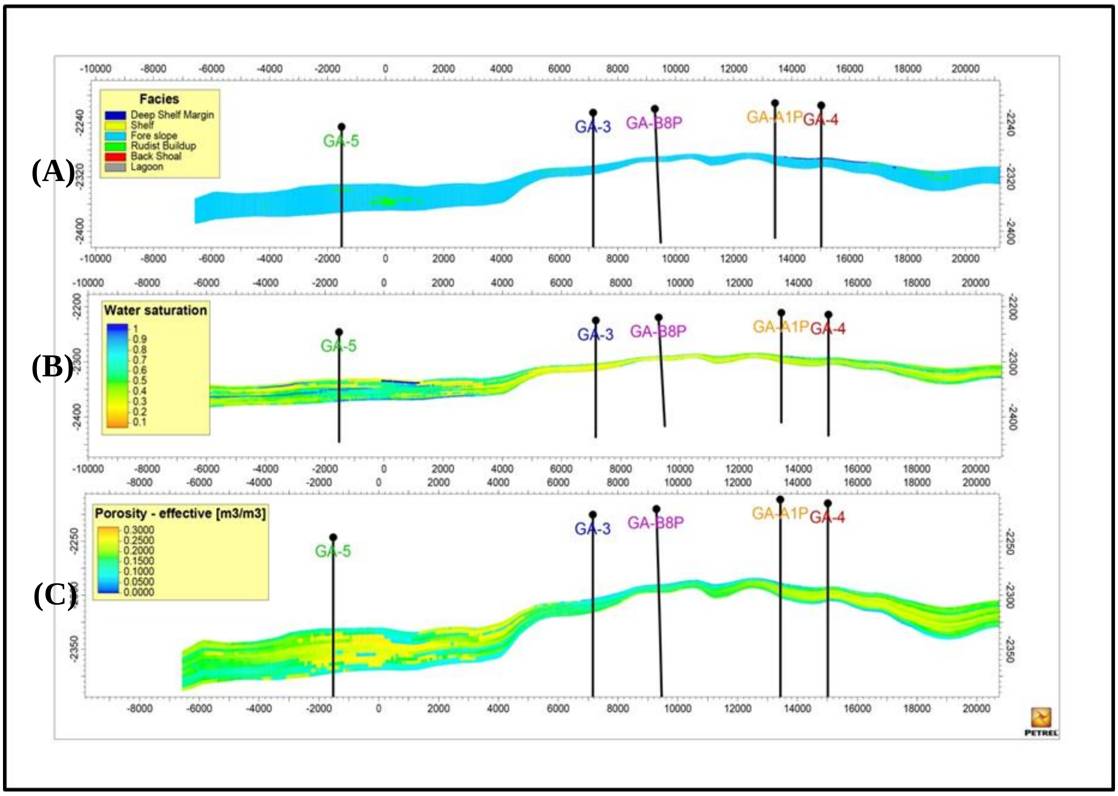

Figure 7- Section of M1.2 reservoir unit in Garraf oil field. (A) Section with facies. (B) Section with water saturation. (C) Section with effective porosity.

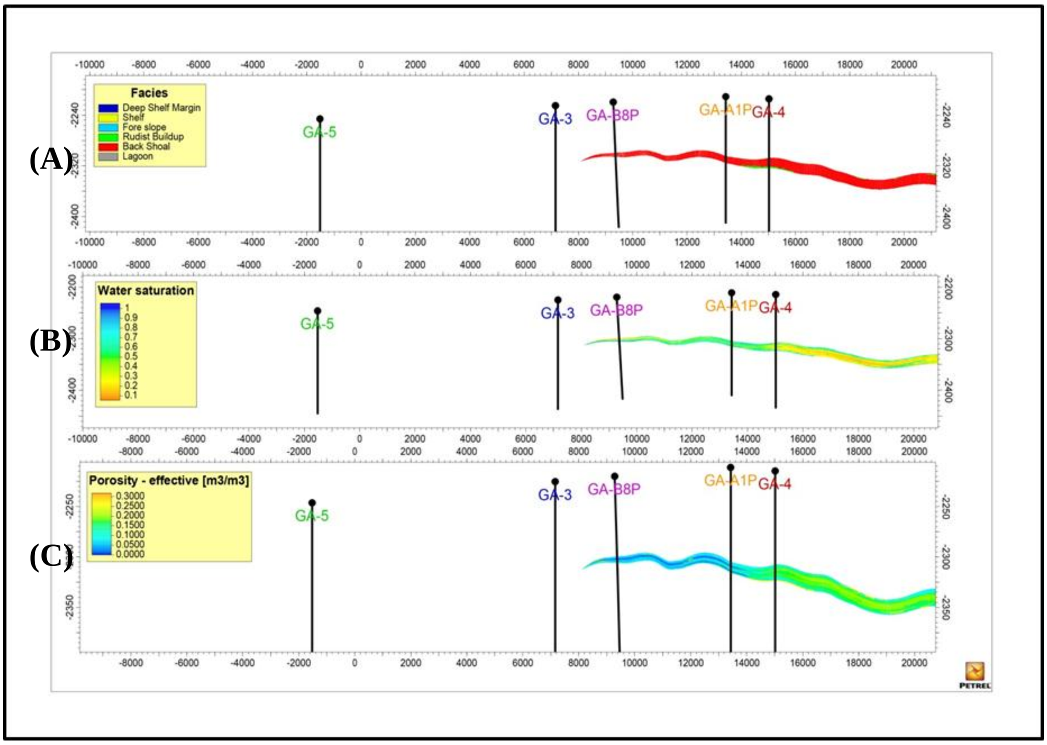

Figure 8- Section of L1 reservoir unit in Garraf oil field. (A) Section with facies (B) Section with water saturation (C) Section with effective porosity

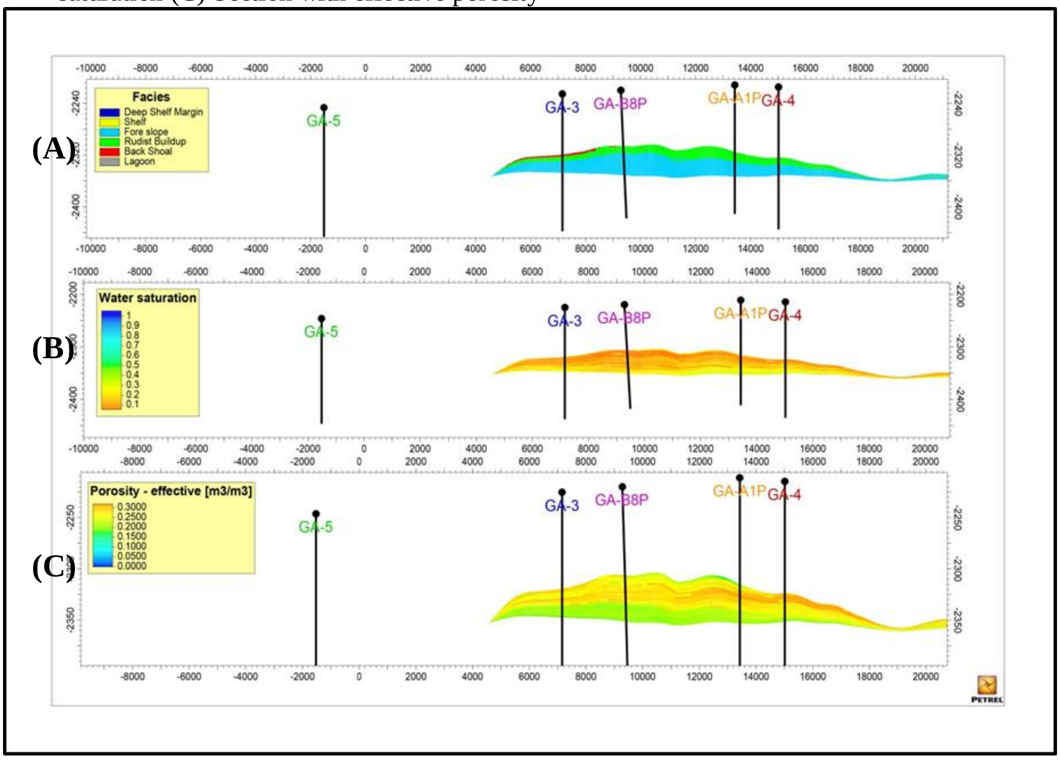

Figure 9- Intersection of L1.2 reservoir unit in Garraf oil field. (A) Section with facies (B) Section with water saturation (C) Section with effective porosity

Conclusions:

According to the CPI results deduced from geophysical well logs Figure-2, 3, 4, 5 and 6, Mishrif Formation in Garraf oil field has been divided into three parts, upper, middle & lower. The upper & middle parts are divided by marl units. The upper part extends from top Mishrif to M1 unit. However, there are oil shows within this part it is not considered within reservoir zone, because it is not producible. Middle & lower parts are reservoir units. They extend from M1 to top of Rumaila Formation. The Mishrif Formation (middle & lower) parts contain several reservoir units (M1.2, L1, L1.2, L2, L2.2, L2.3 and L2.4) that have been sealed by two cap layers (M1 and M2). The evaluation of middle and lower parts of Mishrif Formation depends on values of hydrocarbon saturations, porosity and permeability of these parts as deduced from computer processing interpretation (CPI) logs. M1.2, L1 and L1.2 are considered as high quality reservoir units because they have high values of porosity and hydrocarbon saturation.

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