



## **The Evaluation of Reservoir Quality of Mishrif Formation in South and North Domes of Buzurgan Oil Field**

Ali Duair Jaafar Al-musawi, Dr. Medhat E. Nasser

Department of Geology, College of Science, Bagdad University, Iraq.

Corresponding Author E-mail: ali72.jafar@gmail.com

### **Abstract:**

Buzurgan field in the most cases regards important Iraqi oilfield, and Mishrif Formation is the main producing reservoir in this field, the necessary of so modern geophysical studies is necessity for description and interpret the petrophysical properties in this field.

Formation evaluation has been carried out for Mishrif Formation of the Buzurgan oilfield depending on logs data. The available logs data were digitized by using Neuralog software. A computer processed interpretation (CPI) was done for each one of the studied wells from south and north domes using Techlog software V2015.3 in which the porosity, water saturation, and shale content were calculated. And they show that MB21 reservoir unit has the highest thickness, which ranges between (69) m in north dome to (83) m in south dome, and the highest porosity, between ( 0.06- 0.16) in the north dome to ( 0.05-0.21) in the south dome. The water saturation of this unit ranges between (25% -60%) in MB21 of north dome. It also appeared that the water saturation in the unit MB21 of south dome has the low value, which is between (16% - 25%).

From correlation, the thickness of reservoir unit MB21 increases towards the south dome, while the thickness of the uppermost barrier of Mishrif Formation increases towards the north dome. The reservoir unit MB21 was divided into 9 layers due to its large thickness and its important petrophysical characterization. The distribution of petro physical properties (porosity and water saturation) has shown that MB 21 has good reservoir properties.

**Keywords:** petro physical properties, Formation evaluation, effective porosity, pay thickness, cutoff.

### الخلاصة:

يعد حقل بزركان النفطي واحد من اهم الحقول العراقية، ويعد تكوين المشرف هو المكنم الرئيسي المنتج في الحقل. ان الغرض الرئيسي من هذا البحث هو دراسة الخواص البتروفيزياوية للحقل وعمل مضاهات بين القبتين الشمالية والجنوبية وملاحظة التغيرات في السمك والتحسين في الصفات البتروفيزياوية. حيث تم اجراء التقييم المكنمي للحقل بالاعتماد على معلومات الجس البئري بعد ان تم التحويل الرقمي لها باستخدام برنامج Neuralog وباستخدام برنامج Schlumberger Techlog تم حساب الخواص البتروفيزياوية التي تشمل (المسامية، التشبع المائي والنفطي، حجم السجيل ) ومن خلال النتائج التي حصلنا عليها تبين ان MB21 هي الوحدة المكنمية الرئيسية المنتجة حيث كانت ذات سمك يتراوح بين 69m في القبة الشمالية و 83m في القبة الجنوبية ونظرا لاهميتها المكنمية تم تقسيمها الى 9 طبقات بالاعتماد على التغيرات في الخواص البتروفيزياوية وكان معدل المسامية الفعالة يتراوح بين ( 0.06 – 0.16 ) في القبة الشمالية و (0.05 – 0.21) في القبة الجنوبية وكان معدل التشبع المائي يزداد في القبة الشمالية حيث يتراوح ما بين (25% - 60%) في الوحدة المكنمية MB21 ويقل في القبة الجنوبية حيث يتراوح ما بين (16% - 25%) . لقد اثبتت النتائج ان الصفات البتروفيزياوية تتحسن في القبة الجنوبية بالمقارنة مع الشمالية وتتحسن الخصائص البتروفيزياوية في قمة القبة Crest وتقل باتجاه جناحي الطية الـ Flank.

### Introduction:

Formation evaluation is the process of analysing and interpreting geophysical data performed as a function of wellbore depth, by describing the processes that determine the viability of a formation to produce hydrocarbons. According to the data availability, formation evaluation can be done using core data, well log and initial production data.

Once formation evaluation is performed on the reservoir, it is crucial to pay attention to the location of the possible reservoir zone in the drilled section determination of fluid type (gas, oil, water) present in the pore space, saturation level, and the mobility of the fluids across the connected pore space of the rock. To better achieve such information, it is important to have a good understanding of porosity (total, primary, effective porosity), water saturation computation, pay thickness and selection of cut-offs [1].

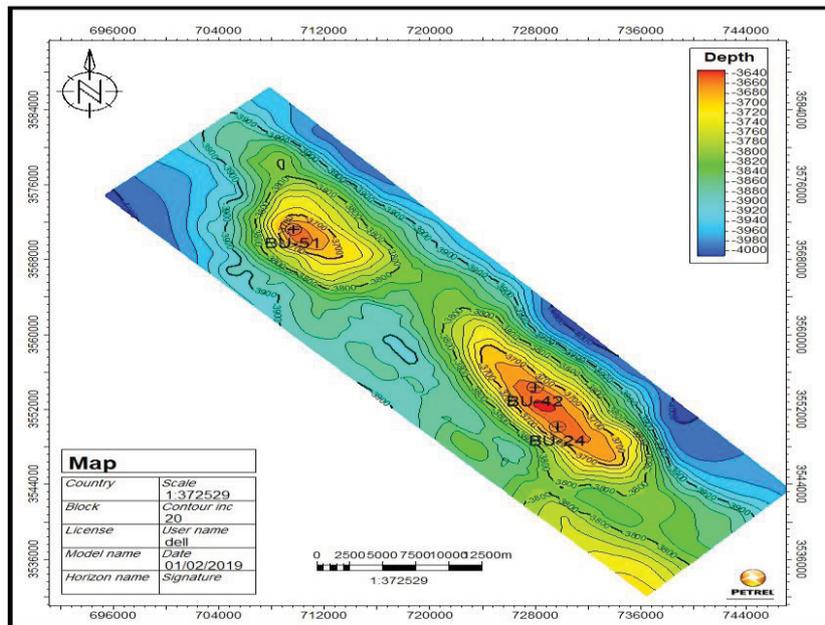
### Formation Evaluation and Log Analysis:

Formation evaluation can be generally defined as the practice of determining both the physical and chemical properties of rocks and the fluids they contain. The objective of formation evaluation is to locate, define, and produce from a given reservoir by drilling as few wells as possible. To this end, oil companies utilize a variety of formation evaluation methods [2].

Wireline logs are one of the many different sources of data used in formation evaluation. However, due to accurate depth determination and near proximity of receiver to formation, wireline logs occupy an important position in formation evaluation. Logging is a very small, but very important, piece of the larger puzzle. The decision to plug or complete a well is often based upon the logs response and hence a proper and accurate acquisition and analysis of these data is a must [2].

### Area of study:

Buzurgan oil field is located in South –Eastern part of Iraq close to Iran boundary, 40 Km North East from Amara. The Mishrif Formation represents an important reservoir in southern Iraq.



**Fig. (1) Shows the selected wells in south & north domes of Buzurgan oilfield (adapted on Top depth structure)**

### Petrophysical Properties:

Petrophysics is the study of the chemical and physical characteristics that define the habit and presence of rocks and liquids. Logging helps to describe physical characteristics of rocks for example, porosity, lithology, permeability and pore geometry. Logging data are utilized to detect pay zone to fix thickness and depth of intervals, to distinct amongst gas, oil or water in reservoir and to estimate oil reserve [3].

Petrophysical properties that are discussed in this text include:

- Shale volume
- Porosity
- Water saturation
- Permeability

### Clay Volume:

Because clay is typically further radioactive than carbonate, GR tool will be suitable candidate to calculate amount of clay in permeable reservoir. The shale volume is expressed as a decimal fraction or percentage is named  $V_{shale}$ . The measurement of the Gr index is the principal stage required for define the shale volume by GR log [3].

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

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

Where:

$I_{GR}$  : is the gamma ray index,

$GR_{log}$  : is the gamma ray log reading in zone of interest, API units,

$GR_{min}$ : is the minimum gamma ray reading in clean zone, API units, and

$GR_{max}$ : is the maximum gamma ray reading in shale zone, API units.

### Porosity:

Porosity is the ratio of spaces to the total volume of rock. Porosity is signified as a percentage by the Greek letter phi,  $\phi$  [3]. Porosity logs Neutron, Density, and Sonic are

mainly related to porosity, and they also influenced by lithology, formation matrix, kind of porosity and degree of shaliness and kind of liquid existing in the pores [4].

The neutron –density logs provide the best combination to identify gas zones and determining their porosity. The combination also provides porosity in complex lithology and volume of shale for shaly formation evaluation.

Porosity logs include sonic logs, density logs, and neutron logs. The sonic log records matrix porosity, whereas the nuclear logs (density or neutron) determine the total porosity [5].

For reservoir characterization it is important to distinguish between:

1. Total porosity (the fraction of bulk volume occupied by the total pore space or the space not occupied by solid components).
2. Effective porosity (the fraction of bulk volume occupied by interconnected pore space allowing fluid flow).

Porosity should be calculated from the density log using the equation [6]:

$$\varphi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \text{-----} (3)$$

Where,

$\varphi_D$  : is the density-derived porosity, fraction.

$\rho_{ma}$ : is the matrix density, [whose value is 2.71 gm/cc for limestone and 2.87 gm/cc for dolomite].

$\rho_b$  : is the formation bulk density, gm/cc.

$\rho_f$  : is the fluid density [For fresh water mud = 1 gm/cc, for salt water Mud = 1.1 gm/cc].

$$\varphi_s = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} \text{-----} (4)$$

Where,

$\varphi_s$  : is sonic-derived porosity, fraction,

$\Delta t_{ma}$ : is the interval transit time in the matrix [whose value is 47.6  $\mu$ sec/ft for Limestone and 43.5  $\mu$ sec/ft for dolomite)],

$\Delta t_{log}$ : is the interval transit time in the formation,  $\mu$ sec/ft; and

$\Delta t_f$ : is the interval transit time in the fluid within the formation [For fresh water mud = 189  $\mu$ sec/ft; for salt-water mud = 185  $\mu$ sec/ft].

It is necessary to distinguish between the types of porosity.

### **Total porosity:**

Total porosity is defined as the ratio of the volume of all the pores to the bulk volume of a material, regardless of whether or not all of the pores are interconnected [7]:

$$\varphi_t = (\varphi_N + \varphi_D) / 2 \quad \text{----- (5)}$$

### **Effective porosity:**

Effective porosity is the ratio of the volume of interconnected pore to the total volume of reservoir rock [7]

$$\varphi_{eff} = \varphi_t * (1 - V_{sh}) \quad \text{----- (6)}$$

### **Secondary porosity:**

Secondary porosity is porosity formed within a reservoir after deposition. In Mishrif reservoir, secondary porosity is too little or negligible, vuggy or fracture secondary porosity can be calculated by secondary porosity index (SPI) [7].

$$SPI = \varphi_t - \varphi_{sonic} \quad \text{----- (7)}$$

The secondary porosity is the result of geological processes (diagenesis) after the deposition of sediments [8]. It includes vugular spaces in carbonate rocks created by the chemical process of leaching, or fracture spaces formed in fractured reservoirs [9].

The intervals of higher secondary porosity mean existence the effect of diagenesis processes on the porosity of Mishrif formation such as dolomatization and dissolution.

On other hand, has been distinguished an irregular alternation of two type of vuggy porosity by borehole images, it is the separate and touching vuggy porosity. This porosity is either opened or filled partially or completely by calcite cement. The interconnected only through the Inter particle pore network refer to the Separate vugs, though touching vuggy porosity shape an interconnected pore framework [10].

### **Fluids in the pore space: Saturation and bulk volume fluid:**

Porosity represents the ratio between pore volumes related to the bulk rock volume. Saturation represents the ratio between volume of pores which occupied by a fluid related

to the total pore volume. Thus, saturation  $S_i$  describes the volume fraction of a fluid  $i$  in a porous rock:

$$S_i = \frac{\text{volume of fluid } i}{\text{volume of pores}} \text{-----} (8)$$

Saturation is given as a dimensionless fraction or as a percentage. Saturation theoretically has the lower bound at zero (or 0%) and the upper bound at one (or 100%). A reservoir hosting the fluids water, oil, and gas is characterized by three saturation terms; their sum must be 1 [11]:

$$S_{\text{water}} + S_{\text{oil}} + S_{\text{gas}} = 1 \text{-----} (9)$$

Fluid saturation can be determined:

- a. From cores, plugs, or samples (direct determination by fluid extraction, or capillary pressure measurements).
- b. Indirectly from logs (resistivity, dielectric, or neutron measurements).

In addition to the parameter “saturation”, the parameter “bulk volume of the fluid” is used. Bulk volume of a fluid  $i$  relates the volume of that fluid to the rock bulk volume. The bulk volume of, for example, water is therefore given by: [11]

$$BVW = \frac{\text{volume of water}}{\text{rock of volume}} = \phi \cdot S_w \text{-----} (10)$$

The bulk volume of a fluid theoretically has the lower bound zero and the upper bound given by total porosity.

In a (water wet) porous rock, the water, depending on its interaction with minerals and bonding type, is present as [11].

1. Free movable water in the pore space (bulk volume movable *BVM*).
2. Capillary bound water, connected with the grain surface (bulk volume immovable *BVI*).
3. Clay-bound water (*CBW*) with its strong clay-water effects.

**Water Saturation:**

Measuring pore volume in a rock that is engaged by formation water, it is signified as decimal portion or as percentage and has the symbol (Sw). Water saturation  $S_w$  of a reservoirs uninvaded interval is calculated through the Archie’s equation [3].

$$S_w = \left( \frac{F * R_w}{R_t} \right)^{1/n} \text{-----} (11)$$

$F$  is usually obtained from the measured porosity of the formation through relationship:

$$F = \frac{\alpha}{\phi^m} \text{-----} (12)$$

Where:

$R_w$  is the formation water resistivity.

$R_t$  is the true formation resistivity.

$F$  is the formation resistivity factor.

$n$ . is the saturation exponent,  $m$ : is the cementation factor,  $\alpha$ : is a constant.

For  $S_{xo}$ , the water saturation in the flushed zone, a similar expression exists [12]:

$$S_{xo} = \left( \frac{F * R_{mf}}{R_{xo}} \right)^{1/n} \text{-----} (13)$$

Where:

$S_{xo}$ : is saturation in the flushed zone, fraction.

$R_{mf}$  is the mud filtrate resistivity.

$R_{xo}$  is the flushed zone resistivity.

$n$  is the saturation exponent.

The residual oil saturation and movable hydrocarbon are calculated from the following equations [13]:

$$S_{or} = [\phi * (1 - S_{xo})] \text{-----} (14)$$

$$S_{hr} = [\phi * (S_{xo} - S_w)] \text{-----} (15)$$

Where,

$S_{or}$ : The residual oil saturation, fraction; and,  $S_{hr}$ : Movable hydrocarbon saturation, fraction.

The  $S_w$  and  $S_{xo}$  can be used to calculate the amount of moveable hydrocarbon [12]:

$$\text{Moveable hydrocarbon} = \phi_{sxo} - \phi_{sw} \text{-----} (16)$$

Water Saturation of the Flushed zone ( $S_{xo}$ ) can be utilized as pointer to hydrocarbon movability, when the estimated value of  $S_{xo}$  is much more than  $S_w$ , at that point Hydrocarbons in the flushed zone maybe have progressed or flushed out of the zone closest the borehole by the attacking drilling liquids [3].

Mishirif Formation in Buzurgan oil field is carbonate rock and regards as clean formation with clear shale zone at the top of Mishirif Formation. Archie’s model is perfect in interpretation of water saturation where applied 55% as the default value of water saturation cut off in Buzurgan field and 60% in Halfaya field in net pay thickness calculation.

**Hydrocarbon Saturation:**

The hydrocarbon saturation is the quantity of pore volume in a stone which engaged by oil, typically detected by the difference amongst unity and water saturation, though the residual hydrocarbon saturation is the difference amongst unity and water saturation in flushed interval [14]:

$$S_h = 1 - S_w \text{-----} (17)$$

$$S_{hr} = 1 - S_{xo}, \text{-----} (18)$$

Where:

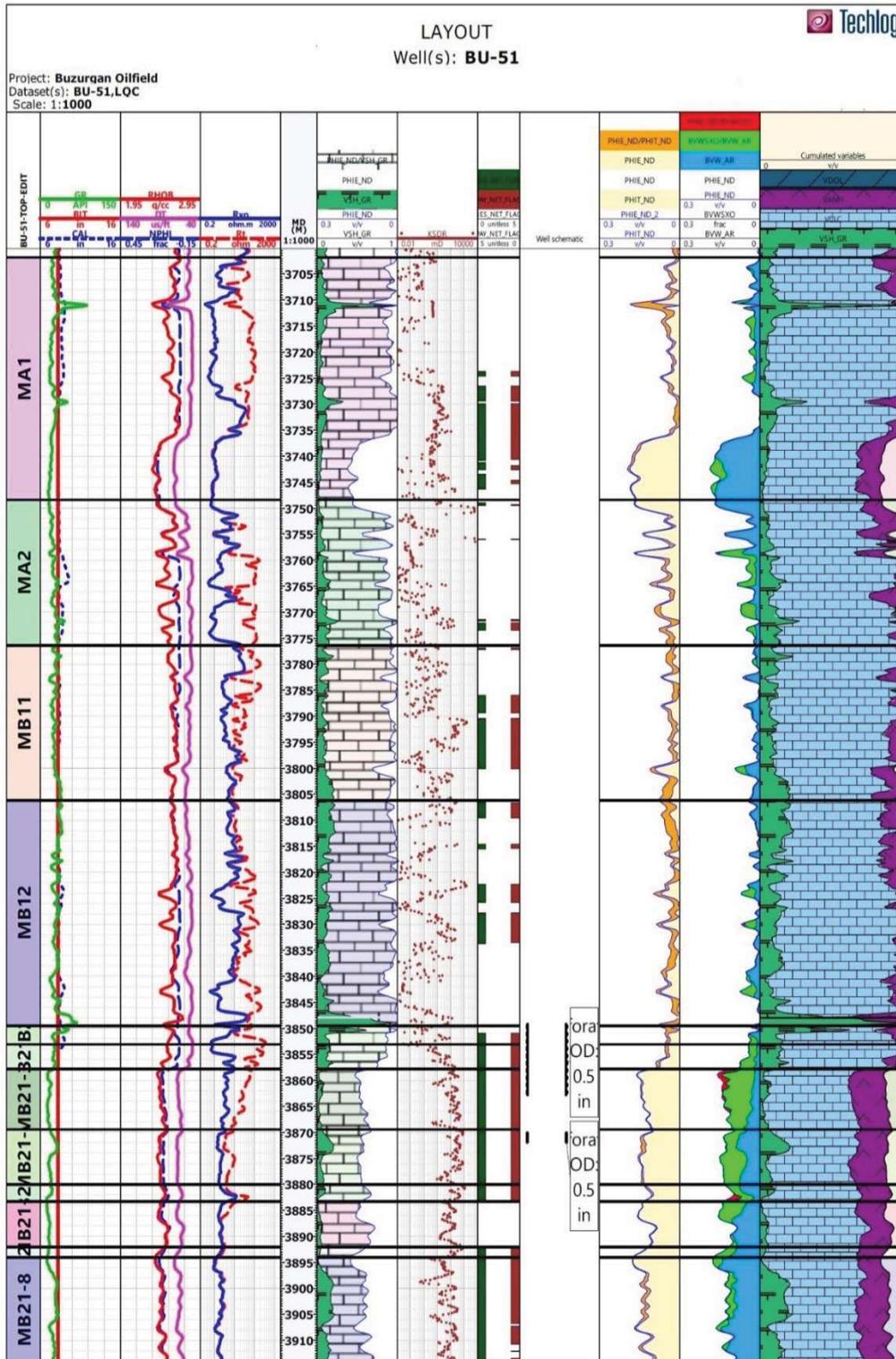
$S_h$ : Hydrocarbon saturation

$S_{hr}$ : Residual hydrocarbon saturation

The  $S_w$  and  $S_{xo}$  can be used to calculate the amount of moveable hydrocarbon equation [12]:

$$\text{Movable Hydrocarbon Saturation } (S_{mo}) = S_{XO} - S_w \text{-----} (19)$$

Hydrocarbon saturation, residual and movable hydrocarbon saturation for all studied wells are estimated and listed in figures from (2 - 6).

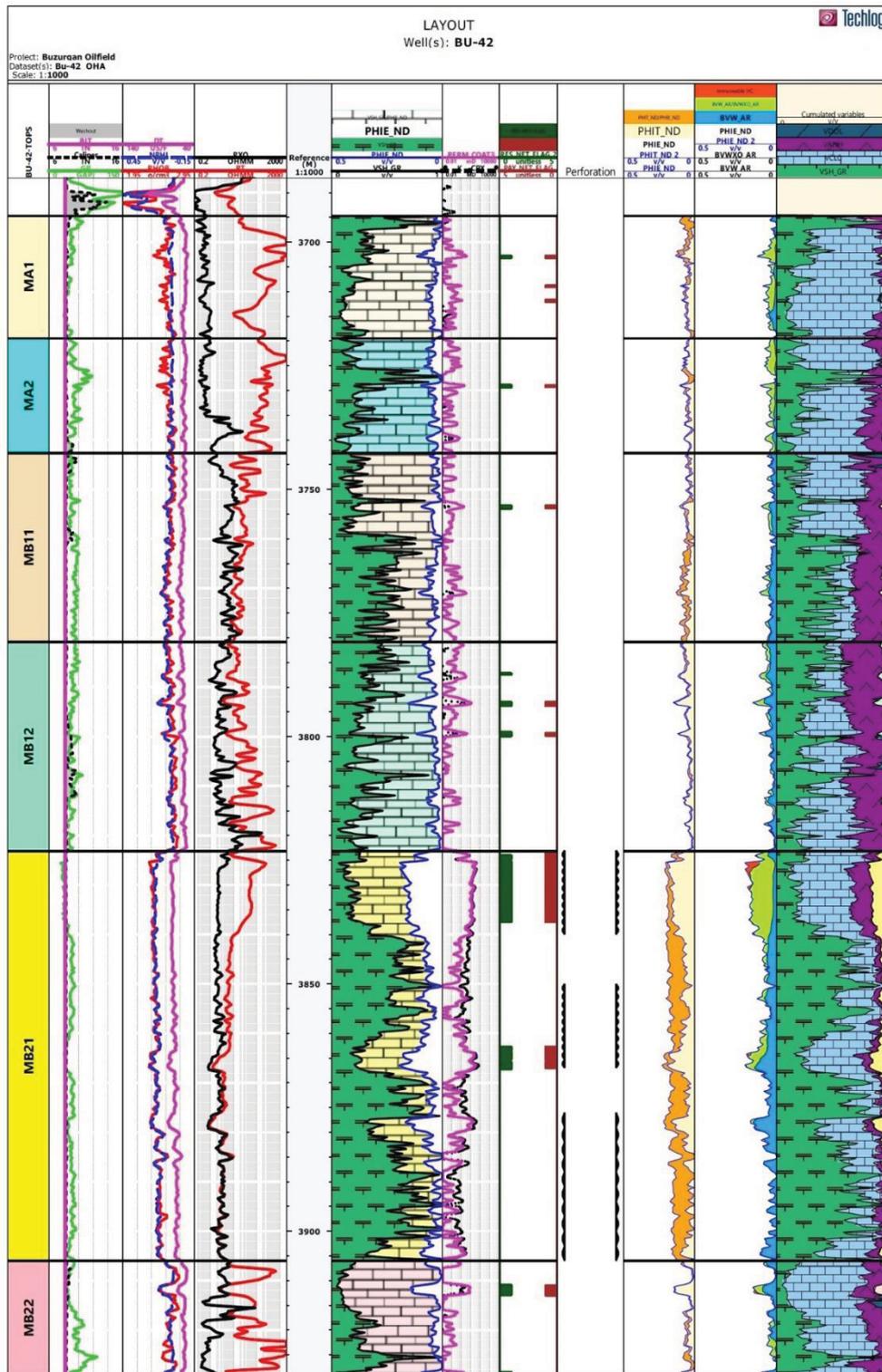


**Fig. (2) Petrophysical interpretation of well BU-51 at the interval between 3700m-3910m.**



**Table (1) shows the average of main petrophysical properties of Bu-51.**

Zones	Top	Bottom	Gross	Net	Net to Gross	BVW	Shale Volume	Porosity	Water Saturation
MA1	3701.8	3748.4	46.6	11.9	0.255	1.742	0.044	0.162	0.902
MA2	3748.4	3776.4	28	5.1	0.182	0.571	0.039	0.138	0.813
MB11	3776.4	3806.2	29.8	29.8	1	0.611	0.113	0.024	0.857
MB12	3806.2	3849.5	43.3	41.1	0.949	0.641	0.133	0.021	0.726
MB21	3849.5	3853.1	3.6	2.2	0.611	0.044	0.134	0.04	0.508
MB21-2	3853.1	3857.83	4.73	4.73	1	0.071	0.143	0.055	0.275
MB21-3	3857.83	3869.46	11.63	11.63	1	0.381	0.043	0.131	0.25
MB21-4	3869.46	3880.03	10.57	10.57	1	0.713	0.103	0.133	0.507
MB21-5	3880.03	3883.27	3.24	3.24	1	0.174	0.066	0.112	0.477
MB21-6	3883.27	3892.04	8.77	8.77	1	0.736	0.039	0.121	0.695
MB21-7	3892.04	3894.02	1.98	1.98	1	0.191	0.035	0.142	0.68
MB21-8	3894.02	3917.6	23.58	23.28	0.987	2.617	0.141	0.129	0.869
MB22	3917.6	3950.4	32.8	30.6	0.933	1.66	0.185	0.065	0.83
MC11	3950.4	3984.5	34.1	26	0.762	0.96	0.106	0.078	0.473
MC12	3984.5	4006.5	22	11.4	0.518	0.331	0.109	0.102	0.284
MC2	4006.5	4027.5	21	4.1	0.195	0.207	0.146	0.063	0.804



**Fig. (4) Petrophysical interpretation of well BU-42 at the interval between 3700m-3925m.**

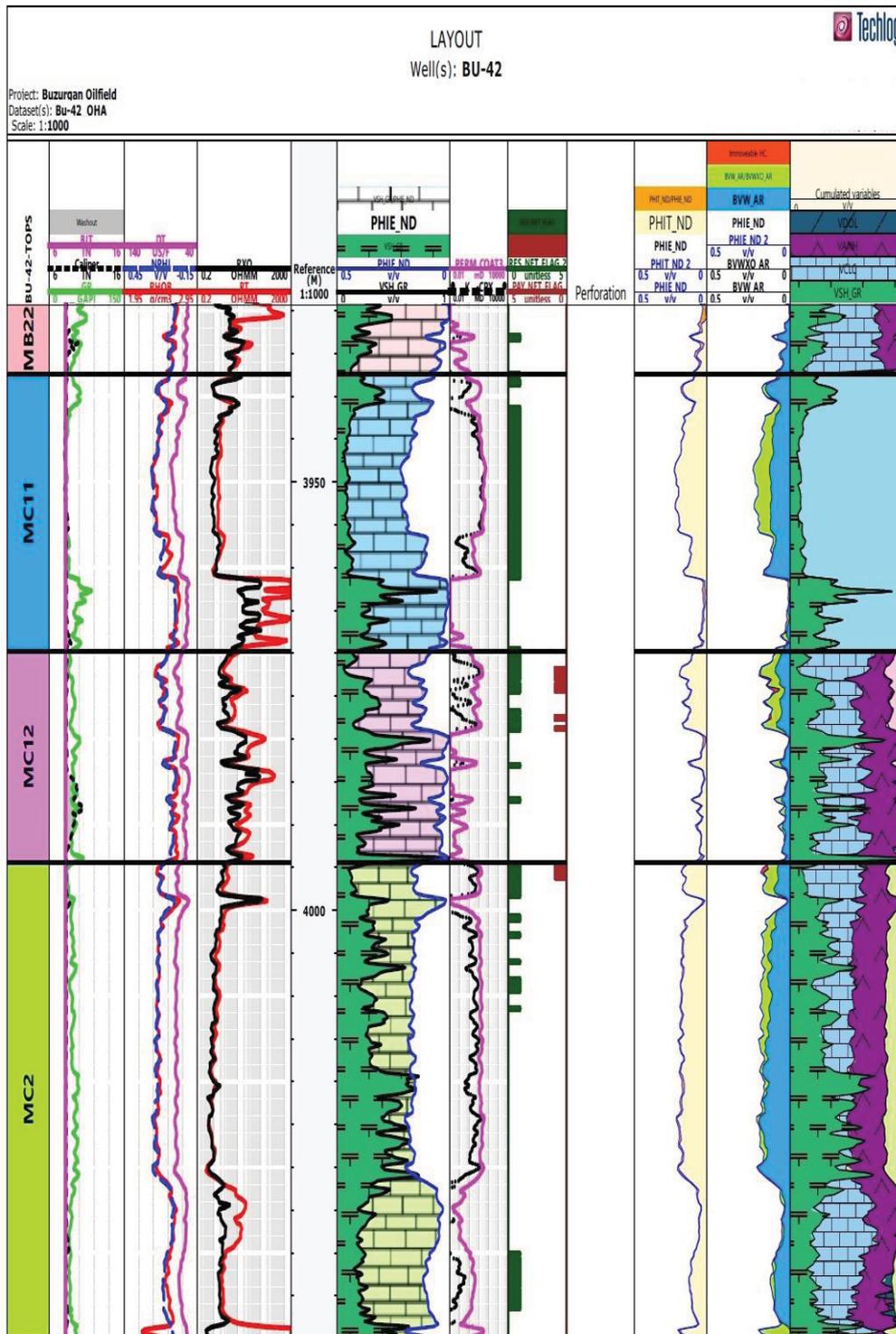
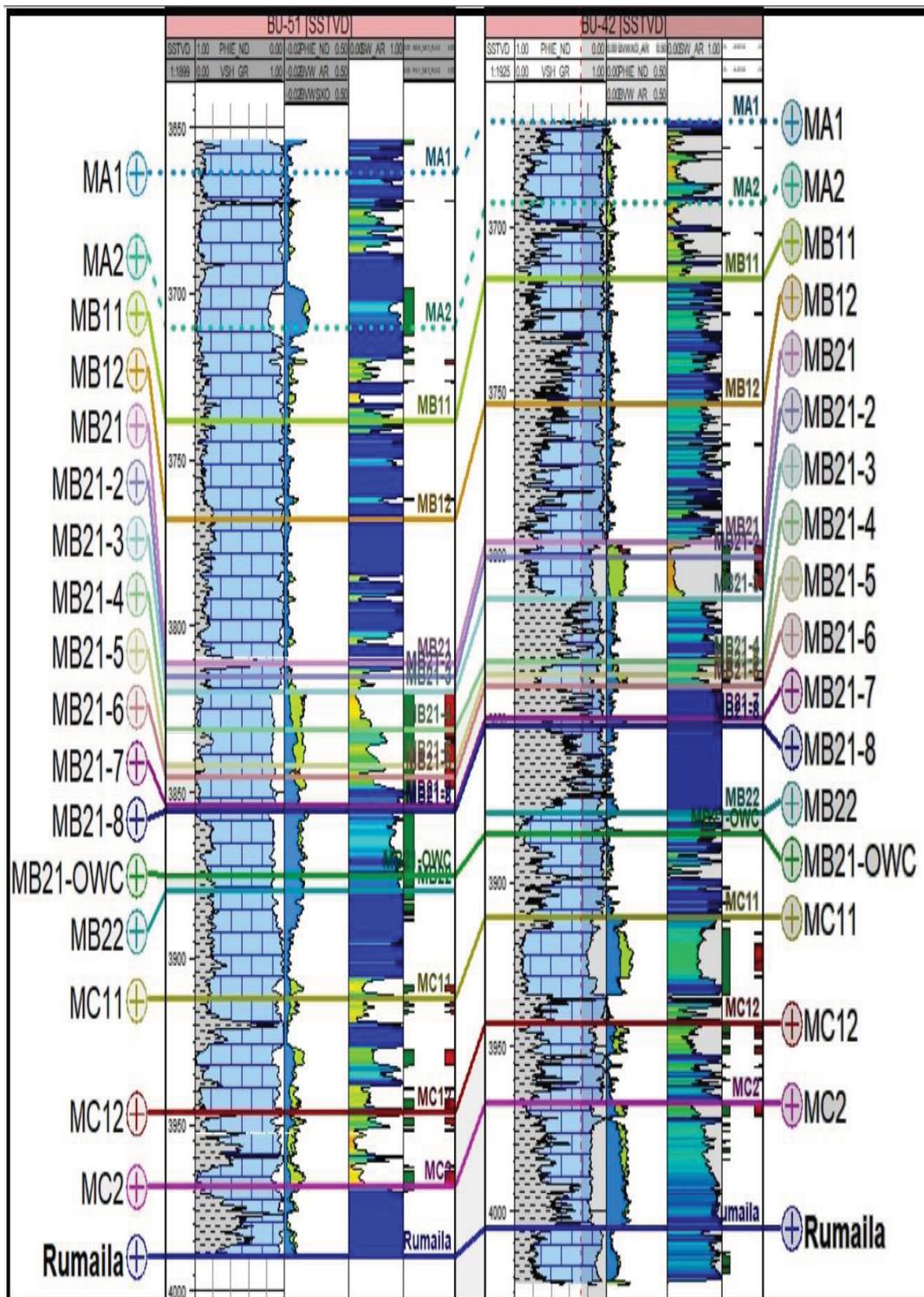


Fig. (5) Petro physical interpretation of well BU-42 at the interval between 3925m-4050m.

**Table (2) shows the average of main petrophysical properties of Bu-42.**

Zones	Top(m)	Bottom(m)	Gross	Net	Net to Gross	BVW	Av_Shale	Av_Porosity	Av_Water Saturation
MA1	3694.7	3719.5	24.8	0.5	0.02	0.004	0.172	0.102	0.085
MA2	3719.5	3742.7	23.2	0.1	0.004	0.001	0.202	0.09	0.069
MB11	3742.7	3780.9	38.2	0.3	0.008	0.014	0.192	0.094	0.501
MB12	3780.9	3823.2	42.3	0.6	0.014	0.037	0.211	0.136	0.449
MB21	3823.2	3827.72	4.52	3.22	0.712	0.072	0.158	0.174	0.129
MB21-2	3827.72	3840.7	12.98	12.68	0.977	0.366	0.22	0.175	0.165
MB21-3	3840.7	3859.87	19.17	0.87	0.045	0.096	0.476	0.168	0.655
MB21-4	3859.87	3863.64	3.77	3.47	0.92	0.298	0.333	0.143	0.6
MB21-5	3863.64	3867.31	3.67	3.67	1	0.447	0.232	0.2	0.608
MB21-6	3867.31	3876.69	9.38	0.89	0.095	0.119	0.367	0.169	0.79
MB21-8	3879.44	3906	26.56	0.1	0.004	0.013	0.393	0.151	0.834
MB22	3906	3937.4	31.4	0.4	0.013	0.026	0.08	0.126	0.513
MC11	3937.4	3969.8	32.4	1.2	0.037	0.122	0.088	0.187	0.543
MC12	3969.8	3994.4	24.6	4.7	0.191	0.303	0.169	0.14	0.46
MC2	3994.4	4050	55.6	2.8	0.05	0.204	0.133	0.149	0.49



**Fig. (6) Correlation between well BU-42 located in south Dome and well Bu-51 located in north Dome.**

### Results and Discussions:

Comparison between Computer process interpretations (C.P.I) of wells Bu-51 & Bu-42 shows that:

1. Mishrif Formation in the Buzurgan oil field has been divided into many layers based on the differences in petro physical properties. Porosity plays a vital role in these divisions.
2. The distribution of petrophysical properties (porosity and water saturation) has shown that MB 21 has good reservoir properties.
3. The lithology track: represents the effective porosity (PHIE), percentage of shale (Vshale), and percentage of Matrix (Limestone).
4. Fluid analysis track: represents the effective porosity (PHIE), water filled porosity in the invaded zone (BVWXo), and water filled porosity in the un-invaded zone (BVW).
5. The zone between (PHIE) and (BVWXo) represents the residual hydrocarbons. The zone between (BVWXo) and (BVW) represents the movable hydrocarbons. The zone between (PHIE) and (BVW) represents the total hydrocarbons.
6. The main units of Mishrif Formation in Buzurgan oilfield are; MA1, MA2, MB1, MB2, MC1 and MC2. The main units of Mishrif Formation in the study area have been divided into additional sub-units in some of the studied wells based on petrophysical properties especially porosity, these are; MB21, MB21-2, MB21-3 and MB21-4, MB21-5, MB21-6, MB21-7 and MB21-8 in Bu-51 & Bu-42.
7. The Oil Water contact was estimated to be at the depth of 3913m in Bu-51 and at depth of 3912m in Bu-42.
8. Porosity logs indicated that the primary porosity is dominated while the secondary has almost non-effect. Hydrocarbon saturation estimation shows a considerable available accumulation of oil. The dominant litho-facies of the formation is found to be a calcite faces with small amount of dolomite.

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