



Comparison between Rafidhiya and Shuaiba Domes within the properties of Mishrif Formation in Zubair Field; the implication of structural Geology and petrophysical analyses.

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Abstract:

The current study combined both concepts of structural geology and petrophysical to understand the structural feature of Mishrif Formation and its implication on the petrophysical characterization of the formation in Shuaiba and Rafidhiya Domes (or culminations) in Zubair Field. Shuaiba and Rafidhiya are adjacent domes and these domes belong to the same Field but the domes separated by saddle may related to Basra – Zubair basement fault.

The domes have different petrophysical properties of Mishrif Formation; consequently, influenced in water and oil saturation. Therefore, the study tries to understand the structural and petrophysical position of Mishrif Formation of the domes. The structural analysis included geometric and genetic analysis, whereas petrophysical analysis used open hole logs interpretation to determine the petrophysical characteristics (especially the distribution of porosity, permeability, and water saturation).

It was concluded that may a variation in porosity and permeability of Mishrif Formation for Shuaiba and Rafidhiya domes because each dome was formed by a different folding mechanism effected on the petrophysical properties. The structural geology analysis detects that may be Shuaiba dome formed by bending fold mechanism (vertical force of salt structure), while Rafidhiya dome by buckling fold mechanism (parallel force of collision of

Arabian and Eurasian plate). These mechanisms may directly be affected in permeability distribution, and consequently on oil and water saturation of Mishrif Formation. Thus, Shuaiba Dome has thinning in hinge area and extensional force leads to create fractures and karst phenomena, and as a result, high permeability in upper Mishrif. On the contrary, Rafidhiya Dome has a thickening feature and there is no indication of karst phenomena and low permeability. Therefore, the Mishrif of Shuaiba dome permeable and oil-saturated, while, it flooded with water in Rafidhiya Dome. The disconnection in reservoir pressure confirmed by difference in initial reservoir pressure of Mishrif Formation of Shuaiba Dome and recent reservoir pressure of Mishrif Formation of Rafidhiya Dome.

Keywords: Mishrif Formation, Zubair Oil Field, Petrophysical analysis, Structural analysis, Shuaiba Dome, Rafidhiya Dome.

**مقارنة بين قبتي الرافضية والشعبية من خلال خصائص تكوين المشرف في حقل الزبير النفطي;
بدلالة تحاليل الجيولوجيا التركيبية والبتروفيزياء**

الخلاصة:

جمعت الدراسة الحالية بين تحاليل الجيولوجيا التركيبية والبتروفيزياء لفهم الصورة التركيبية لتكوين المشرف وتأثيرها على المواصفات البتروفيزيائية للتكوين في قبتي (أوذوتي) الشعبية والرافضية في حقل الزبير النفطي. الشعبية والرافضية قبتان متجاورتان وتنتمي هذه القباب إلى نفس الحقل النفطي ولكن بخصائص بتروفيزيائية مختلفة لتكوين المشرف، وبالتالي أثرت على خصائص التشعب النفطي والمائي. تحاول الدراسة الحالية فهم الصورة التركيبية والبتروفيزيائية لتكوين المشرف للقبتين.

تضمن التحليل التركيبي كلاً من التحليل الهندسي والمنشأ، في حين استخدم تحليل البتروفيزياء تفسير مجسات الآبار المفتوحة وذلك لتحديد خصائص البتروفيزيائية (خاصة توزيع المسامية والنفاذية والتشعب المائي والنفطي). وخلصت الدراسة الحالية إلى أنه الأختلاف في المسامية والنفاذية لتكوين المشرف بالنسبة لقبتي الشعبية والرافضية ربما لأنه كل قبة تشكلت بميكانيكية طي مختلفة وأثرت بذلك على الخصائص البتروفيزيائية لتكوين المشرف. أشارت قياسات الضغط المكمني بأنه الضغط المكمني لتكوين المشرف للقبتين. أكدت نتائج التحليل الجيولوجيا التركيبية بأنه ربما تشكلت قبة الشعبية بميكانيكية طي الثني (القوة الرأسية للتراكيب الملحية)، في حين أن قبة الرافضية تشكلت بفعل ميكانيكية الانحناء (القوة الموازية لتصادم الصفيحتين العربية والإيرانية).

أثرت هذه الميكانيكيات بشكل مباشر على الخصائص البتروفيزيائية لتكوين المشرف واهمها توزيع المسامية والنفاذية، وبالتالي على تشبع النفط والماء. كنتيجة لهذه الميكانيكيات تميز تكوين المشرف بظاهرة التتحف في منطقة الهامة ضمن قبة الشعبية وايضاً تعرضها الى قوى استطالة أدت الى تكون كسور وبالتالي تشكل ظاهرة الكارست مما كون نفاذية عالية في طبقة المشرف الأعلى. على العكس من ذلك، تتميز قبة الرافضية بظاهرة التثخن (زيادة السماكة) ولا يوجد مؤشر على ظاهرة كارست وبالتالي انخفاض النفاذية. أن تكوين المشرف في قبة الشعبية ذو نفاذية عالية ومشبع بالنفط، بينما تغمر المياه التكوين في قبة الرافضية. اشار الأختلاف بين الضغط الأبتدائي لمكمن المشرف لقبة الشعبية والضغط المقاس في وقت حديث لأبار تكوين المشرف في قبة الرافضية الى انه هناك عدم اتصال بين مكمن المشرف لقبة الشعبية والرافضية.

مفتاح الكلمات: تكوين مشرف، حقل الزبير، تحليل البتروفيزياء، تحليل الجيولوجيا التركيبية، قبة الشعبية، قبة الرافضية.

1. Introduction:

The study area lies within the Mesopotamian basin, Zubair Subzone [9]. Mishrif Formation is a carbonate Formation that deposited in the Middle Cretaceous (Cenomanian-Early Turonian) [3]. It is divided into three main divisions Upper Mishrif, Middle, and Lower Mishrif [16] Rudist facies are the most important facies of Mishrif Formation, thus it's considered as the most permeable zone [1], [2], [6], and [9]. Generally, the rudist facies deposited in the crestal areas of actively syn-sedimentary anticline structure southern Iraq and these facies affected by the dissolution process [6] and [9]. There are no previous studies focused on the influence of the structural geology role of the Mishrif Formation in the study area on its petrophysical properties except only one study referred to the presence of oil just in Shuaiba and Hammar Domes, while Rafidhiya Dome classified as water aquifer.

This study supposed a southern boundary from Shuaiba dome categorized with the termination of good reservoir condition [14]. Thus, the current study tries to achieve a structural geology analysis included geometrical and genetic analyses. Geometrical analysis interested in the geometric elements of Mishrif Formation. While, genetic analysis employed the results of geometric analysis and the geophysics interpretations to determine the forming causes, type, and the origin of Mishrif structure. Therefore, the utilized the contour maps, geophysical studies, and wells data. Petrophysical analysis used open hole logs

interpretations for selected wells in the current study area to determine the petrophysical characteristics of Mishrif Formation (especially the distribution of porosity and water saturation). All previous analyses connected to understand the structural geology picture to find its role in the petrophysical (especially oil/water-saturated) of Mishrif Formation within Rafidhiya and Shuaiba Domes.

2. Geologic Setting:

Mishrif Formation is overlain unconformably with Khasib Formation and underlie conformably with Rumaila Formation (Figure 1). According to the tectonic divisions of [15] and [16], the field lies in the sagged basin within the Mesopotamian zone of the quiplatform Foreland belt of the Arabian plate. Zubair Field is located in the Zubair Subzone of the Mesopotamian Zone, whereas the structures of this Subzone controlled by the tectonic movements, basement structures, and Infracambrian salt [9]. [5] stated that Zubair Field belongs to the Unstable Shelf, and the factors of instability are basement faults, salt structures, and Alpine Orogenic Movements. These factors causes together to produce subsurface anticline structures in southern Iraq. Zubair Subzone bounded by basement faults, which are Takhadid-Qurna Transversal fault from the north and Al-Batin fault from the south [9] (Figure 2). The negative gravity anomaly of the primary Zubair Subzone structures confirmed the presence of deep-seated Infracambrian salt rocks [9], [10], [11], [15], and[16].

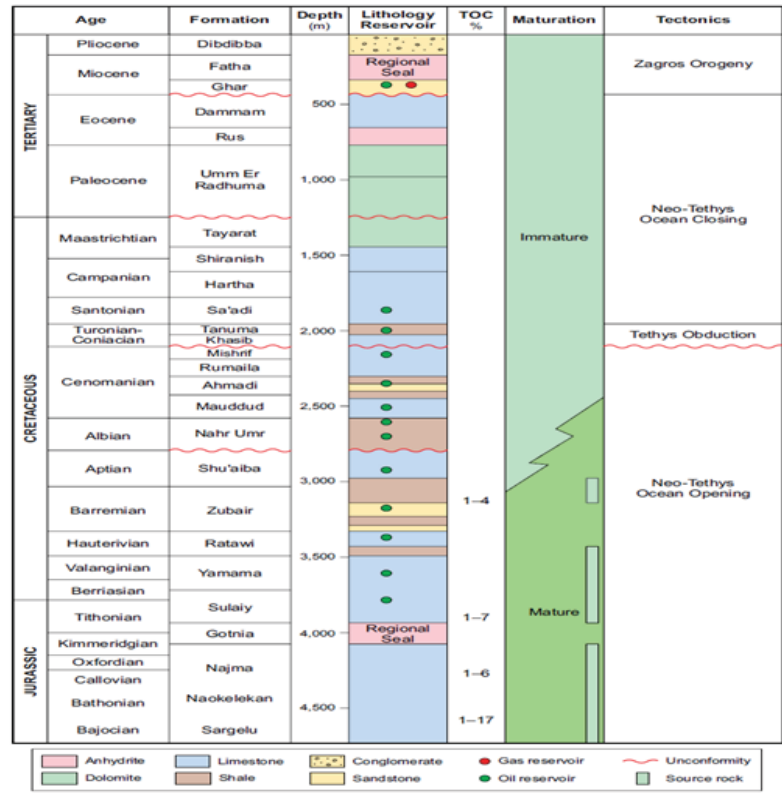


Fig. (4) Stratigraphic section of southern Iraq formations and the major tectonic phases relevant to Jurassic – Tertiary [1].

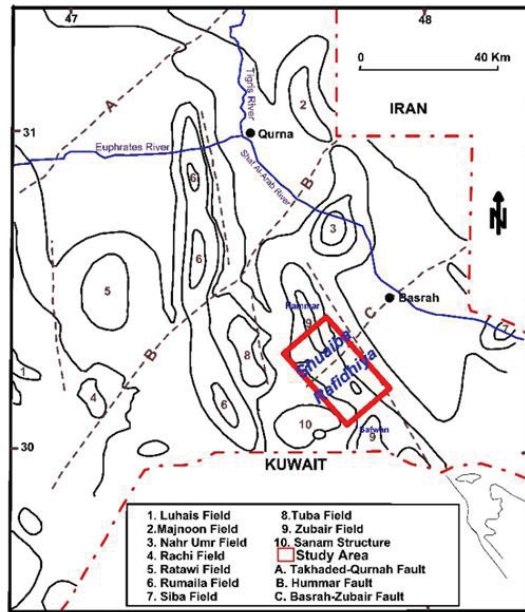


Fig. (2) The location of Zubair Field to the surrounding major structures at the depth [4000m], southern Iraq with some of the basement faults in Mesopotamian zone, modified from [4].

3. Materials and Methods:

3-1. Structural Feature: for geometric analysis, the current study used an updated geological model (static model) of the Zubair Field to construct depth and thickness contour maps via Petrel v2016 software with scale 1:125000. Stereonet 9 software used for stereographic projection to determine the structural geological attitude (interlimb angle, hinge line or fold axis, and axial surface). The dip and strike [counter clockwise] calculated from the depth contour map and thickness variation from thickness (isopach) contour map for Mishrif Formation of Shuaiba and Rafhidiya Domes. The genetic analysis used the geophysical interpretations and the results of geometric analysis.

3-2. Interpretation of Petrophysical properties: the current study applicates the software Geolog v8 to interpret a full set open hole logs (Gamma Ray, Caliper, Density, Porosity, Sonic, Resistivity [Shallow, Medium, and Deep], for 4 wells from Shuaiba Dome (ZB-245, 279, 302, and 320) and 7 wells from Rafidhiya Dome (ZB-046, 061, 065, 072, 077, 233, and 240). The NMR (Nuclear magnetic resonance) and calculated permeability from petrophysical modeling settled in Geolog software (if available). The porosity and merged permeability (logs, core, and PLT) of Zubair Field upscaled in the static model to construct permeability, porosity, and water saturation maps. The lithology Model included Limestone, Shale, Oil, and Water. Shale volume of shale calculated from GR or SP if Gamma-ray doesn't available over Mishrif reservoir and arithmetic mean has been used to Calculated the volume of shale. The porosity calculated from the Sonic, Den/Neut Model. The Archie's Parameters: ($a=1$, $m= (2.0183*PHIE) +1.7154$ $n= 1.8-2$) and Geolog software formation water salinity 200kppm was used in Mishrif formation). No environmental correction applied to all data because already applied by service companies at the well site as per detail in job notes. Micro Resistivity (MSFL) log has effected from borehole washout where it presents. The pressure points obtained from ZB-233 and ZB-240.

4. Structural Interpretations:

4-1. Geometric Analysis:

Zubair Field includes four Domes (culminations), these are Hammar, Shuaiba, Rafidhiya, and Safwan [13]. The southern part of Shuaiba Dome separated by another saddle from Rafidhiya Dome may it related to Zubair - Basra Basement fault (Figure 2). There are many classifications of the folds and each one uses certain geometric parameters of the fold. The current study used the contour map of Mishrif Formation (Figure 3) and Stereographic Projection results (Table 1). According to the essential parameters of the fold, Mishrif Formation in Rafidhiya and Shuaiba Domes classified depending on (a) Fold facing, (b) Fold orientation (a dip of axial surface, plunge of the hinge line, and symmetry of fold), and (c) Fold shape in profile plane (interlimb angle [7] and variation in thickness [17]). The dips of Mishrif Formation of Shuaiba Dome are equal, while the western limb is slightly steeper than the eastern limb of Rafidhiya Dome (Tables 2 and 3).

Table (1) Sterographic Projection results

Dome	Left Limb	Right Limb	Interlimb Angle	Hinge Line	Axial Plane
Shuaiba	2.5°/162°	2.5°/342°	175°	1°/342°	90°/162°
Rafidhiya	3°/160	2°/340	175°	4°/340°	89.5°/162°

Table (2) Results of Geometric Analysis for Mishrif Formation of Shuaiba Dome

Structural Parameters		classification
Fold Facing		anticline structure
Fold Orientation	the dip of the axial surface	upright fold
	the plunge of the hinge line [fold axis]	non-plunged fold
	symmetry of fold	Asymmetrical fold
Fold shape in profile plane	Interlimb Angle	gentle fold
	Variation in thickness	Supratenous fold

Table (3) Results of Geometric Analysis for Mishrif Formation of Rafidhiya Dome

Structural Parameters		classification
Fold Facing		anticline structure
Fold Orientation	dip of axial surface	upright fold
	plunge of the hinge line [fold axis]	non-plunged fold
	symmetry of fold	Asymmetrical fold
Fold shape in profile plane	Interlimb Angle	gentle fold
	Variation in thickness	T-fold

Regarding the thickness variation, the thickness map (Figure 3) of Mishrif Formation of Shuaiba Dome shown that the thickness of the hinge area is less than the limb area and petrophysical analysis confirmed that Upper Mishrif is less than Lower Mishrif for Shuaiba Dome. On the contrast, Rafidhiya Dome the thickness of the hinge area is thicker than the limb area and the Upper Mishrif is thicker than Lower Mishrif. The thickness of Mishrif Formation in Rafidhiya Dome is slightly thicker than Mishrif Formation in Shuaiba Dome. The reason and indications of the thickness variation will clarify in the genetic analysis because it is so important to understand the structural picture of Mishrif Formation and its reservoir implication. The fold axis of Mishrif Formation of Shuaiba Dome trend to NW-SE (18°) and for Rafidhiya Dome also is NW-SE (20°). The depth of Mishrif Formation in Shuaiba Dome is shallower than Rafidhiya Dome with $\approx 80\text{m}$ (measured from Shuaiba crest to Rafidhiya crest). This difference may be related to dip displacement Basra-Zubair basement fault and this can be confirmed by a seismic section to declare the whole changes.

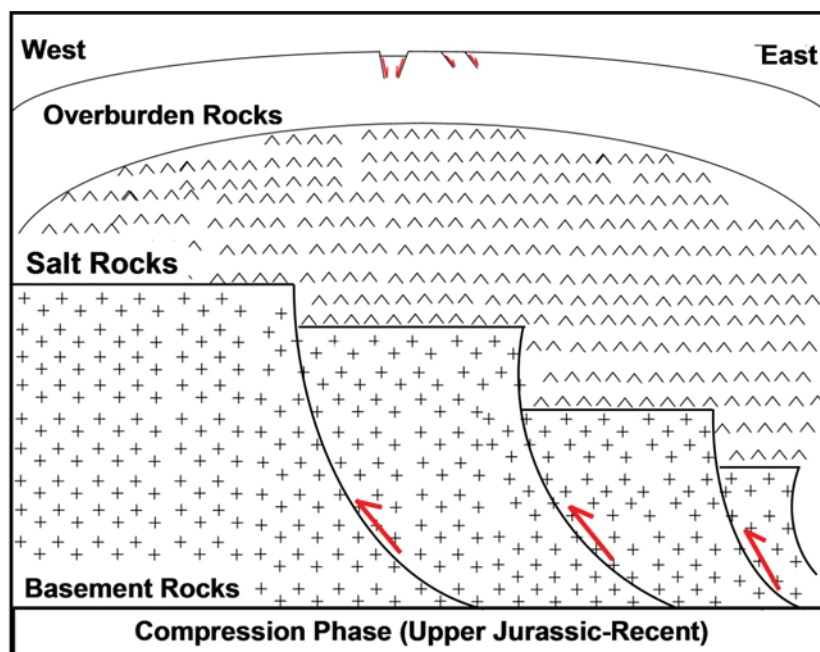


Fig. (3) Tectonic model of oil fields southern Iraq [13].

4-2. Genetic Analysis:

Three main combined forces worked together to produce subsurface anticline structures in southern Iraq included Zubair Field, these are tectonic Movements, reactivated basement faults, and Hormuz salt structures [4], [5], [9], [10], [11], [15] and [16] as shown in tectonic model (Figure 3). Geophysical surveys of southern Iraq indicated the association of negative gravity could be a result of deep-seated salt beds of Infra-Cambrian salt beds, while, the positive gravity referred to basement uplift [9] [15], and [16]. [12] referred to negative residual gravity associated with north Zubair Field and may it is related to Infra-Cambrian salt structures (Hormuz salt). While positive residual gravity associated with the southern part of Zubair Field and it may because of basement uplift. Thus, Shuaiba Dome (northern Zubair Filed) may be made by the effect of salt structures, while Rafidhiya Dome by tectonic movements. The variation in tectonism between the Domes may be related to the effect of Basra-Zubair basement fault between Shuaiba Dome and Rafidhiya Dome, which may lead to separation between the domes and make each one belonging to a block, thus each dome formed by the different folding mechanism.

5. Petrophysical properties:

Petrophysical properties of Mishrif Formation generally divided into Upper Mishrif, Middle Mishrif, and Lower Mishrif based on lithology and porosity distribution [13]. The Upper Mishrif of Shuaiba Dome is the main oil pay zone, while it was saturated with water in Rafidhiya Dome. The porosity and permeability of Upper Mishrif Formation in Shuaiba Dome are higher than Rafidhiya Dome (Figure 4). While the porosity of Lower Mishrif in Rafidhiya Dome is higher than Shuaiba dome. Middle Mishrif Porosity is almost the same in Mishrif Formation in both Shuaiba and Rafidhiya Domes, as shown in (Table 4) of the average Phi calculation from analysis of open holes data. The initial pressure of Mishrif Formation of Shuaiba Dome is 3850psi [18] and for ZB-245 is 3262psi (measured in 2013), while the average reservoir pressure from two wells in Rafidhiya Dome, ZB-233 and ZB-240 were 3910psi (in 2012) and 3840psi (in 2013) respectively. This differential pressure between the domes confirmed that the domes are separated in terms of reservoir pressure connection.

Table (4) Results of Porosity calculation for Mishrif Formation of Shuaiba and Rafidhiya Domes

Dome	Well	Upper ϕ	Middle ϕ	Lower ϕ
Shuaiba	ZB-279	0.18	0.16	0.16
	ZB-245	0.12	0.14	0.15
	ZB-320	0.16	0.17	0.16
	ZB-302	0.16	0.16	0.16
Rafidhiya	ZB-046	0.08	0.11	0.16
	ZB-061	0.12	0.13	0.17
	ZB-065	0.12	0.17	0.17
	ZB-072	0.12	0.14	0.14
	ZB-077	0.14	0.18	0.2
	ZB-233	0.15	0.12	0.18
	ZB-240	0.14	0.2	0.16

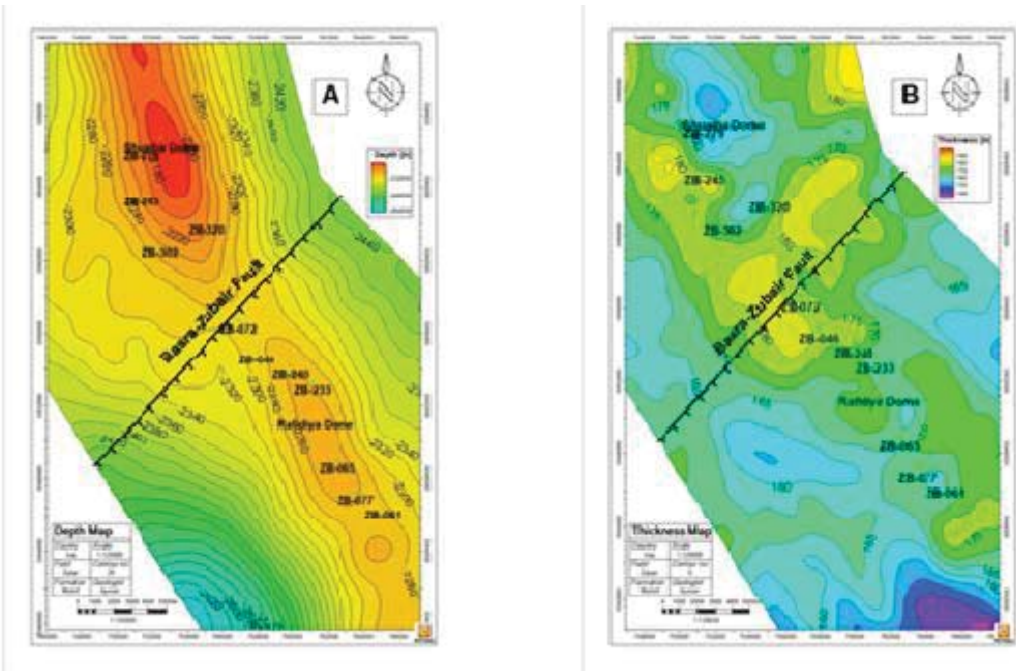


Fig. (4) (A) Depth contour map (B) thickness contour map of Mishrif Formation, Shuaiba and Rafidhiya Domes in Zubair oilfield, southern Iraq.

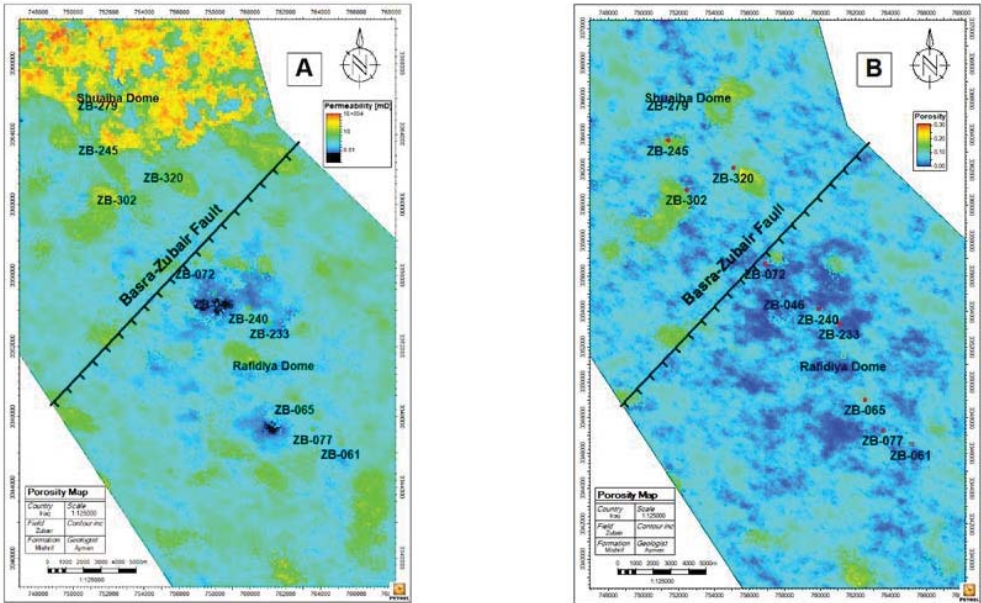


Fig. (5) (A) Permeability map (B) Porosity map of Upper Mishrif Formation, Shuaiba and Rafidhiya Domes in Zubair OilField, Southern Iraq.

6. Results and Discussion:

According to the combination of the results of structural geology (geometric and genetic) and petrophysical analyses, the study suggests a scenario for Mishrif Formation in Shuaiba and Rafidhiya Domes. As for Shuaiba Dome, the salt structure induced by reactivated basement faults and differential density between the salt and overburden rocks to create the structural picture of Mishrif Formation and this confirmed by negative residual. As result, Shuaiba Dome formed by a bending fold mechanism, which is recognized by thinning, extensional outer arc and may fracturing features with erosion surface represented by the unconformity of Mishrif - Khasib Formation and the dissolution processes create karst phenomena (high permeability zones) [13], and this may be the cause of Mishrif Formation of Shuaiba Dome saturated with oil because it included the best reservoir condition to accumulate the oil. Mishrif Formation in Rafidhiya Dome has a thickening feature may be due to buckling fold mechanism, because of a collision between Arabian and Eurasian plate, and may this the reason of association of positive residual with Rafidhiya Dome. Buckling force supposes to create extensional in an outer arc, in addition to shortening of layers, but shortening for parallel layers, which is occurs before folding may lead to a decrease or terminate the extensional of the outer part of a fold [8]. Therefore, there is low permeability in Upper Mishrif, in contrast with Mishrif Formation of Shuaiba Dome as explained above.

The structural picture of Mishrif Formation affected on petrophysical properties as shown in its interpretations of Mishrif Formation. The calculations of Mishrif Formation permeability refer to high values in the Upper Mishrif of Shuaiba Dome, on contract with, Rafidhiya Dome (Figure 5). The main oil production comes from Shuaiba Dome (Upper Mishrif) because it has good oil saturation, while Rafidhiya Dome flooded with water (Figure 6) except rare oil presence in small intervals. The saddle between the domes considered a barrier between the domes [14]. The saddle may be related to Zubair-Basra basement fault and this may be forms a separation, which confirmed by the difference in reservoir pressure between Mishrif Formation of Shuaiba and Rafidhiya Domes.

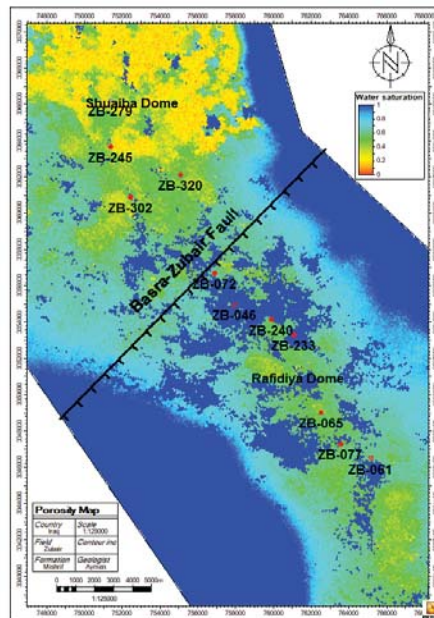


Fig. (6) Water saturation map of Upper Mishrif Formation, Shuaiba and Rafidhiya Domes in Zubair Field, Southern Iraq.

7. Conclusions:

Mishrif Formation in Shuaiba and Rafidhiya Domes are an anticline, upright, non-plunge, gentle fold, and asymmetrical (the dip of the western limb greater than eastern limb, while the length of the western limb is longer than the eastern limb). Regarding thickness variation, Shuaiba Dome classifies as Supratenuous Fold, while Rafidhiya Dome as T-Fold. The thickness of Upper Mishrif Formation and Lower Mishrif Formation of Shuaiba Dome is thinner than Upper and Lower Mishrif Formation of Rafidhiya Dome. While Middle Mishrif Formation of Shuaiba Dome is thicker than Rafidhiya Dome. The thickness of the crestal area of Mishrif Formation is thinner than its limbs for Shuaiba Dome and this may be attributed to bending fold mechanism due to salt structure below it as referred by negative residual. This mechanism generates extensional outer arc (Upper Mishrif) and may be associated with fractures then influenced by meteoric water, which is dissolved the carbonate and make karst phenomena (high permeable zone). While, Rafidhiya Dome formed by a buckling fold mechanism, therefore, the crest area thicker than the area of the limb. it's maybe influenced by shortening for parallels layers before folding and this reduces

the extensional of its outer arc. Thus, there are no karst phenomena in Rafidhiya Dome. The fold axis of Mishrif Formation for both domes tends to NW-SE and this direction may be attributed to counterclockwise rotation of the Arabian plate and this direction compatible with surrounding fold axes fields of southern Iraq. The dips of Mishrif Formation of Shuaiba Dome are equal, while the western limb is slightly steeper than the eastern limb of Rafidhiya Dome. The petrophysical calculations by using available open hole data of Mishrif Formation of study area confirm the variation in porosity, permeability, and oil-water saturation in the comparison between Shuaiba and Rafidhiya Domes. In respect of porosity, Lower Mishrif Formation has the highest porosity and Middle Mishrif is higher than Upper Mishrif for both domes. However, the permeability of Upper Mishrif of Shuaiba Dome is higher than Upper Mishrif of Rafidhiya Dome and may this related to karst phenomena in Shuaiba Dome. The Mishrif Formation of Shuaiba Dome has good economic accumulative of oil, especially in Upper Mishrif and this so clear in open hole logs. While Mishrif Formation of Raidhiya Dome saturated with water (except in rare intervals). The difference in initial reservoir pressure of Mishrif Formation of Shuaiba Dome and recent reservoir pressure of Mishrif Formation of Rafidhiya Dome confirmed the disconnection in reservoir pressure.

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