

## **Structural geology and petrophysics analysis to Injection wells of Mishrif Formation in Shuaiba Dome – Zubair Oil Field**

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### **Abstract:**

Mishrif formation is the one of the most important reservoir in Southern – Iraq and the injection water important to support the reservoir pressure. The current study combined the interpretations of PLT, structural geology and petro-physics to understand the distribution of the injection rate for nine injection wells to the Mishrif Formation in Shuaiba Dome (or culmination) - Zubair Oil Field. PLT analysis calculated injection rate for Mishrif Formation, structural analysis included geometric and genetic analysis, whereas petrophysics analysis used open hole logs interpretation and core data for the injection wells to determine the petro-physics characteristics (especially the distribution of porosity and permeability). The current study concluded that the injection rate, porosity and permeability of Mishrif Formation distributed unequally across it. This variation is almost regular, whereas the Upper Mishrif more than Lower Mishrif, while Middle Mishrif get the least value. The thickness of Lower Mishrif more than Upper Mishrif. This may affected by a folding mechanism due to tectonic activity (reactivated basement faults and Hormuz salt structures).

**Keywords:** Mishrif Formation, Zubair Oil Field, PLT analysis, Petro-physics analysis, Geometric and Genetic analysis, Shuaiba Dome.

## تحليل الجيولوجيا التركيبية والبتروفيزياء لأبار حقن تكوين المشرف – قبة الشعيبية في حقل

### الزبير

#### الخلاصة:

يعتبر تكوين المشرف من أهم المكامن النفطية لحقل الزبير - جنوبي العراق، حيث تستخدم تقنية حقن المياه لدعم الضغط المكمني فيه لغرض زيادة الإنتاج. ربطت الدراسة الحالية بين نتائج تفسير تحليلات الجيولوجيا التركيبية، والبتروفيزياء، ومجسات فحص الإنتاج لفهم توزيع كمية الحقن لـ 9 آبار ضمن قبة (أو ذروة) الشعيبية وعلاقتها بالصورة التركيبية والصفات البتروفيزيائية لتكوين المشرف في قبة الشعيبية في حقل الزبير. تضمن التحليل التركيبي كلا من التحليل الهندسي والتحليل المنشأ، بينما استخدم التحليل البتروفيزيائي مجسات الآبار المفتوحة وبيانات اللباب لتحديد المواصفات البتروفيزيائية (بالأخص توزيع المسامية والنفاذية)، وتم تحديد نسب كمية المياه المحقونة في طبقات تكوين المشرف بواسطة مجسات الإنتاج. استنتجت الدراسة الحالية بأن سماكة طبقة المشرف الأسفل أكبر من سماكة طبقة المشرف الأعلى وربما يعزى ذلك إلى دور ميكانيكة الطي بالثني، والتي ربما جاءت نتيجة لدور القوى التكتونية المسؤولة عن تشكل قبة الشعيبية في حقل الزبير وهي: إعادة تنشيط فوالق القاعده ودور املاح هرمز. وبالتالي فإن توزيع كلاً من المسامية والنفاذية ونسب حقن المياه توزعت بصورة غير متساوية حول تكوين المشرف. وان هذا الاختلاف أو التباين (للمسامية والنفاذية ونسب الحقن) متوزع بصورة منتظمة، بحيث ان المشرف الأعلى يمتلك القيم الأعلى قياساً بالمشرف الأسفل، بينما اقل القيم تكون للمشرف الأوسط.

**الكلمات المفتاحية:** تكوين المشرف، حقل الزبير النفطي، تحليل مجسات الإنتاج، التحليل البتروفيزيائي، التحليل التركيبي، وقبة الشعيبية.

### 1. Introduction

Mishrif Formation is one of the most important reservoirs in Iraq and divided into three main divisions Upper, Middle, and Lower Mishrif [22]. Study area lies within the Mesopotamian basin, Zubair Subzone [12]. Mishrif Formation is a carbonate Formation that deposited in the Middle Cretaceous (Cenomanian-Early Turonian) [2].

Rudist are the most important facies of Mishrif Formation, thus it considered as the most permeable zone [15, and 12].

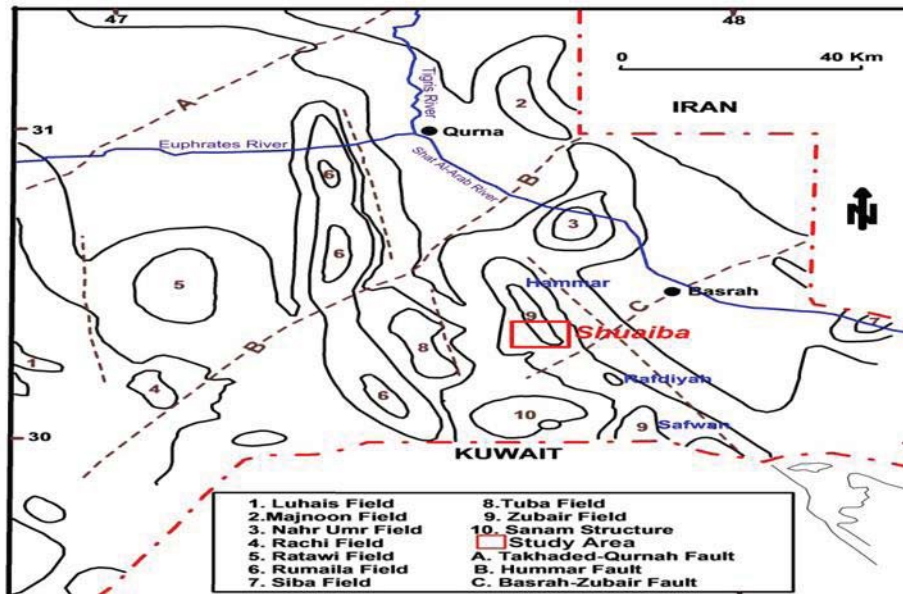
Generally, the rudist facies deposited in the crestal areas of actively syn-sedimentary anticline structure southern Iraq and these facies affected by dissolution process [12] and [5]. The thinning, erosion and conglomerates of Misrif crest due to regional uplift during the late Cenomanian to Turonian period [6] and [9]. PLT analysis employed the highest injection rate to evaluate the distribution of water for perforated layers, structural

analysis included geometrical and genetic analyses. Geometrical analysis interested with the geometric elements of Mishrif Formation. While, the genetic analysis employed the results of geometric analysis and the geophysics interpretations to determine the forming causes, type and the origin of Mishrif structure. Petrophysics analysis used open hole logs interpretation and core data for injection wells in the current study area to determine the petrophysics characteristics of Mishrif Formation [especially the distribution of porosity and permeability].

All previous analyses connected together in trying to understand the geological situation and its effect on the injection performance of Mishrif Formation within Shuaiba Dome.

## **2. Geologic Setting:**

Mishrif Formation is overlain unconformably with Khasib Formation and underlie conformably with Rumaila Formation. It is equivalent to Saravk Formation in Iran. According to the tectonic division of [8], Zubair Oil Field lies in Mesopotamian Zone within an Unstable Shelf of Arabian Platform. While [17] and [18], the field lies in sagged basin within the Mesopotamian zone of the qusiplat form Foreland belt of the Arabian plate. Zubair Oil Field is located in the Zubair Subzone of the Mesopotamian Zone, whereas; the structures of this Subzone controlled by the basement structures and Infracam brain salt [12]. [4] stated that Zubair Oil Field belongs to the Unstable Shelf, and the factors of instability are basement faults, salt structures, and Alpine Orogenic Movements. These factors worked together to produce subsurface anticline structures southern Iraq. Zubair Subzone bounded by basement faults, which are Takhadid-Qurna Transversal fault from the north and Al Batin fault from the south [12] (**Figure 1**). The negative gravity anomaly of the primary Zubair Subzone structures confirmed the presence of deep-seated Infracam brain salt rocks [12, 13, 14 and 15].



**Fig. (1) Tectonic model for oil fields in southern of Iraq [16]**

### **3. Materials and Methods:**

#### **3-1. PLT analysis:**

Interpretation made by Emeruade software v2. 6 for the wells ZB-035, 43, 93, 117, 120, 214, 220, 221, and 265 to determine the injection rate Mishrif Formation. The current study used the biggest injection rate in the PLT surveys for each injection well. The PLT used with wire-line (GR, CCL, Gradiomano meter, Full-bore Spinner, Pressure and Temperature). There were six passes down and up at different cable speeds (10, 20 and 30 m/min) across the perforated interval.

#### **3-2. Structural Geology analysis:**

The current study used a geological model (static model) of the Zubair Oil Field to construct depth via Petrel v2013. 2 software with scale 1:60000. Steronet 9 software used for stereographic projection to determine the structural geological attitude [interlimb angle, hinge line, and axial surface]. The dip and strike [clockwise] calculated from the depth contour map and thickness variation from isopach contour map of Mishrif Formation. The coordinate system of the Zubair geologic model is Nahrawn 1967 system [to convert from Nahrawan 1967 to WGS84:  $Dx = -253.0050$   $Dy = -157.9160$   $Dz = +416.898$ ].

### **3-3. Petrophysics analysis:**

The current study used the software Geolog v7 to interpret a full set open hole logs [Gamma Ray, Caliper, Density, Porosity, Sonic, Resistivity [Shallow, Medium, and Deep], Photoelectrons, Density corrections, and pressure points data (if available) for the wells ZB-43, 93, 117, 120, 214, 220, 221, and 265 (Zb-35 ignored due to insufficient open hole logs for Mishrif Formation). The core data obtained from ZB-43 core data analysis.

### **4. PLT analysis:**

The PLT log is the one of the most important tool to evaluate the productivity and infectivity of specific zones [19]. The current study used the PLT data for nine selected injection wells to determine the injection rate of each perforated layers of Mishrif Formation. There are six passes down and up at different cable speeds [10, 20 and 30 m/min] across the perforated intervals of Mishrif Formation to determine the injection profiles [QZI and QZT].

## **5. Structural Analysis:**

### **5-1. Geometric Analysis:**

Zubair Oil Field includes four Domes [culminations], these are Hammar, Shuaiba, Rafdiyah, and Safwan[22]. The northern part of Shuaiba Dome separated from the Hammar Dome by shallow saddle and the southern part separated by another saddle from Rafdiya Dome, the region may affected by Hammar basement fault (**Figure 1**). There are many classifications of the folds; each one uses certain geometric parameters of the fold. The current study used contour map of Mishrif Formation (**Figure 2**) and Stereographic Projection results (**Table 1**). According to the essential parameters of the fold, Mishrif Formation in Shuaiba dome classified depending on [a] Fold facing, [b] Fold orientation [dip of axial surface, plunge of hinge line, and symmetry of fold], [c] Fold shape in profile plane [interlimb angle and variation in thickness], and [d] Fold dimensions, Table (2).

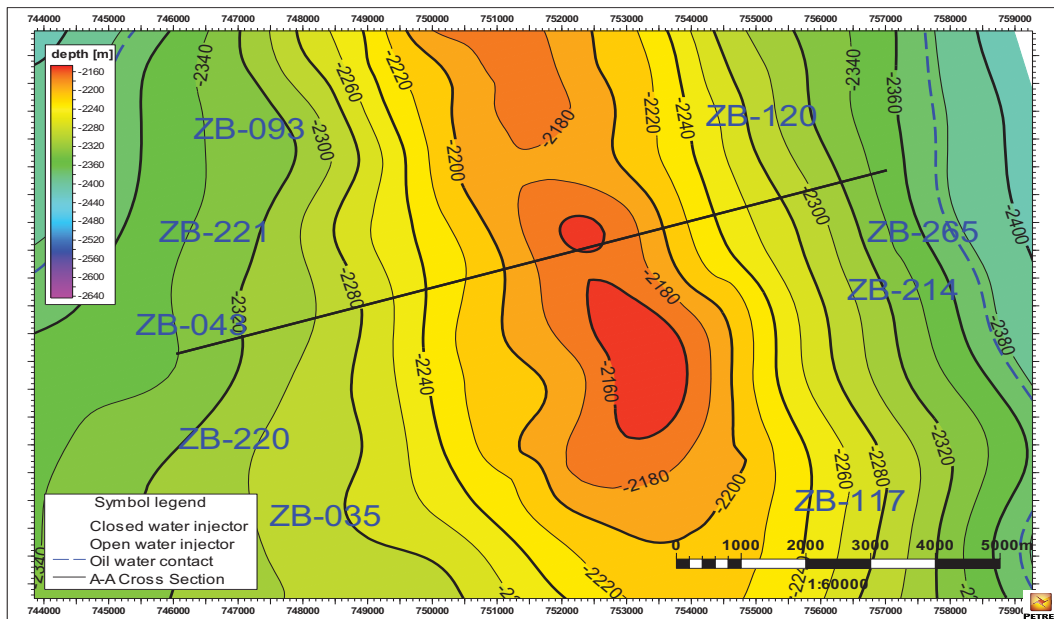
**Table (1) Stereographic Projection results**

Left Limb	Right Limb	Interlimb Angle	Hinge Line	Axial Plane
2.2°/162°	1.7° / 342°	176.1°	0.2°/342°	89.7°/162°

**Table (2) Results of Geometric Analysis for Mishrif Formation.**

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	Supratenuous fold
Symmetry of the fold		Asymmetrical fold

The current study also noticed that the thickness of Upper Mishrif is less than Lower Mishrif in all injection wells of Shuaiba Dome and the thickness of left limb is greater than right limb. The reason and indications of thickness variation will clarify in genetic analysis because it is so important to understand the structural picture of Mishrif Formation and its reservoir implication.

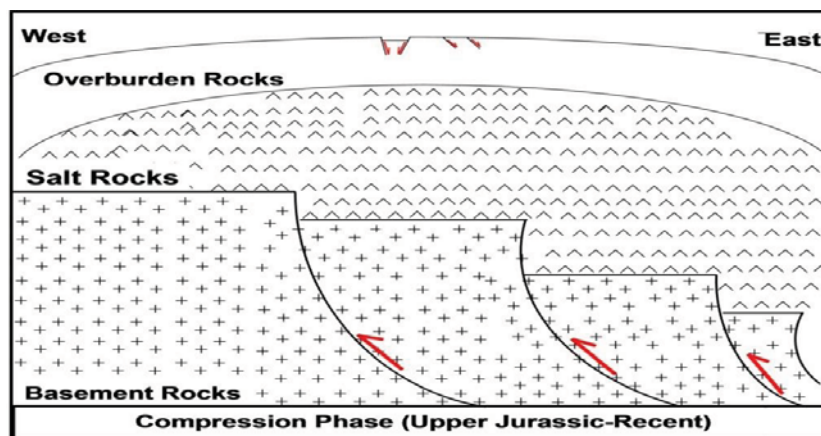


**Fig. (2) Contour map of Mishrif Formation in Zubair Oil Field, Southern Iraq.**

### 5-2. Genetic Analysis:

Three combined main forces have been worked together to produce subsurface anticline structures in southern Iraq included Zubair Oil Field, these are tectonic Movements, reactivated basement faults, and Hormuz salt structures [4], [17], [12], [14] and [13] as shown in tectonic model (**Figure 3**). Geophysical surveys of southern Iraq indicated that the association of negative gravity could be as a result of deep-seated salt beds of Infra-Cambrian salt beds, while, the positive gravity referred to basement uplift [13] [14], [12], [15], and [16] referred to negative anomaly associated with north Zubair Field [Hammar and Shuaiba culminations], may related to Infra-Cambrian salt structures (Hormuz salt).

Arching and thinning of the layers originated by extensional tectonic are common features associated with salt structure and this leads to normal faults over the tops of the anticlines [20]. These faults are may be radial or parallel [7].

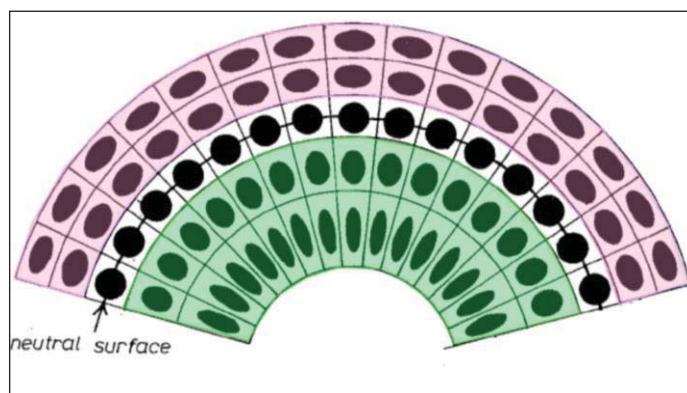


**Fig. (3) Tectonic model for oil fields in southern of Iraq [16].**

The results of geometric analysis confirmed that Mishrif Formation influenced by tectonic activities. The fold axis of Mishrif Formation tends to NW-SE. This direction may attributed to counterclockwise rotation of the Arabian plate and this direction compatible with surrounding fold axes fields of southern Iraq, such as Nahr Umr Filed [16]. Thickness variation between the crest and the limb of Mishrif Formation may attribute to bending fold mechanism due to the effect vertical force of Hormuz salt structures. The difference in the dip values of Mishrif Formation limbs could be attribute to the collision between the Arabian plate and Iranian plate.

The difference of thickness between Upper and Lower Mishrif Formation layers may relate to the kinematic model of folding that called bending folding mechanism (**Figure 4**). While, the variation in porosity and permeability neutral foldinm mechanism creates a fold with extensional force, stretched, thinned, and open fractured in the outer arc. While compressional, shortened, thickened, and closed fracture in the inner arc. As well, the neutral surface stays with no strain change in the middle layer [7], [23], and [10].





**Fig. (4) Suggested mechanism of Mishrif layers explain the differences among the layers, modified from [21]**

According to results of geometric analysis, it is assumed that the Upper Mishrif represents the outer arc of Mishrif fold and this explains its high permeability and thinning. Where the less permeability and thickening of Lower Mishrif, so it represents the inner arc of Mishrif Formation fold. While, the Middle Mishrif may represent the neutral surface, and therefore its permeability less than Upper and Lower Mishrif. Thus, this may clarify higher injection rate of Upper Mishrif and low injection rate of Lower Mishrif, while very low injection rate for Middle Mishrif (**Tabel 3**). As for ZB-221, the injection rate of Lower Mishrif is higher than Upper Mishrif and this may be explained by that ZB-221 lies close to the one of the main fault in Zubair Oil Field. This main fault showed by the results of 3D seismic interpretations, but it doesn't reach to the Upper Mishrif, maybe get to a part of Mishrif Formation, included Lower Mishrif and make changes in its permeability. Mishrif Formation equivalents to the Upper part of Sarvak Formation in Iran and this Formation deposited in same tectonostratigraphic conditions [11]. [9] Mentioned that the Upper part of Sarvak Formation (Sar-3) affected by the tectonic activities that then influenced in its reservoir characters.

Consequently, The current study is suggested a scenario for Mishrif Formation deposition. At Cenomanian-Early Turonian the tectonic activity is prevailed result of obduction between Arabian and Iranian plates, which led to reactivated the basement faults and induced salt structure below Shuaiba Dome and made uplift [Early Cretaceous

uplift], then arching, fracturing, and thinning features with erosion surface represented by the unconformity of Mishrif - Khasib Formation. Upper Mishrif is the most part undergoes to extension force, fracturing and it is exposed to the surface. Meteoric water may utilize the fractures as pathways to leach and this may induce the dissolution process for the rudist carbonate under the water table zone (Karst Zone), and this may cause most of the drilling mud losses. As well as, the porosity and permeability of Upper Mishrif Formation are higher than Middle and Lower Mishrif. Middle Mishrif may represent the neutral surface zone and it is not influenced by extension force, for that reason it has not bad and not connected porosity. While, Lower Mishrif may be subjected to compression force and may close fractures, then it has a permeability but its frequency and distribution are not similar to Upper Mishrif. The full set of open hole logs and available core data are used to determine the porosity and permeability of Mishrif Formation. The calculation of Mishrif Formation permeability refers to high values in the Upper Mishrif, while the low value of permeability is concentrated in the Middle Mishrif. In addition, the caliper log is usually referred to as a bad hole in the first meters of Upper Mishrif (see Appendix).

The core pictures and petrography analysis of Zb-043 show the presence of fractures (veins) in Upper Mishrif at a depth of 2354 m, and this verifies the extension force in Upper Mishrif.

## **6. Petrophysics analysis:**

The full set of open hole logs and available core data are used to determine the porosity and permeability of Mishrif Formation. The calculation of Mishrif Formation permeability refers to high values in the Upper Mishrif, while the low value of permeability is concentrated in the Middle Mishrif. In addition, the caliper log is usually referred to as a bad hole in the first meters of Upper Mishrif.

The core pictures and petrography analysis of Zb-043 shows the presence of fractures (veins) in Upper Mishrif at a depth of 2354 m (**Figure 5**), and this verifies the extension force in Upper Mishrif.



**Fig. (5) The core picture of ZB-043 shows the presence of fracture (veins) in Upper Mishrif at depth 2354 m.**

**Table (3) Injection rate, tops, thickness, and perforation intervals of Mishrif Formation.**

Well	Type	Layer	Injection B/D	Injection %	Top [m]	Thick [m]
ZB-035	Dump Flooding	Upper Mish.	-1384.94	60.59	2299.81	58
		Middle Mish.	-803.96	35.18	2357.65	50
		Lower Mish.	-96.54	4.23	2407.8	74
ZB-043	Dump Flooding	Upper Mish.	-2000	59.52	2348.4	53
		Middle Mish.	-230	6.85	2401.76	61
		Lower Mish.	-1130	33.63	2463.43	60
ZB-093	Water Injection	Upper Mish.	-1518.35	90.98	2332.87	54
		Middle Mish.	0	0	2387.22	52
		Lower Mish.	-385	9.02	2438.5	74
ZB-117	Water Injection	Upper Mish.	-5392.93	88.08	2288.27	64
		Middle Mish.	-136.64	2.23	2352.22	52
		Lower Mish.	-593.12	9.69	2403.43	66
ZB-120	Dump Flooding	Upper Mish.	-26300	97.22	2316.91	52
		Middle Mish.	-750	2.77	2369	60
		Lower Mish.	X	X	2429.63	61
ZB-214	Water Injection	Upper Mish.	-2189.7	44.89	2371.67	57
		Middle Mish.	0	0	2428.58	55
		Lower Mish.	-2451.16	55.11	2483	63
ZB-220	Dump Flooding	Upper Mish.	-1538.48	48.27	2331.89	57
		Middle Mish.	-18.52	0.58	2389.29	50
		Lower Mish.	-1630	51.14	2439.17	72
ZB-221	Dump Flooding	Upper Mish.	-75.98	2.76	2352.62	64
		Middle Mish.	-610.24	22.13	2416.88	52
		Lower Mish.	-2071.59	75.11	2465	73
ZB-265	Water Injection	Upper Mish.	-5015.63	87.73	2387.38	58
		Middle Mish.	-565.94	8.46	2444.84	60
		Lower Mish.	-250.44	3.81	2505.24	61

## **7. Conclusions:**

### **a) PLT analysis Results:**

PLT (Production Log Tool) analysis of Mishrif Formation injection wells revealed that the injection rate is unequal around the Formation. Whereas, Upper and Lower Mishrif Formation received the maximum amount of injection water rate, and the Middle Mishrif Formation received the minimum amount. The distribution of injection rate of Mishrif Formation is uneven, whereas Upper Mishrif is 64%, Lower Mishrif 27%, and Middle Mishrif 9%.

### **b) Structural Geology Analysis Results:**

Mishrif Formation in Shuaiba dome is an anticline, upright, non-plunge, asymmetrical [dip of the western limb greater than eastern limb, while the length of western limb is longer than eastern limb], and gentle fold. The thickness of Lower Mishrif is greater than Upper Mishrif and the thickness of the crest of Mishrif Formation is thinner than its limbs. This may be attributed to bending force due to salt structure effect. The tectonic activity created Mishrif Formation structure, these are tectonic movements, which reactivated basement faults and this induced Hormuz salt. In addition to bouncy force due difference in density between salt and overburden rocks. The fold axis of Mishrif Formation tends to NW-SE and this direction may attributed to counterclockwise rotation of the Arabian plate and this direction compatible with surrounding fold axes fields of southern Iraq

### **c) Petrophysics Analysis Results:**

The permeability and porosity of Upper Mishrif are higher than Middle and Lower Mishrif, and Lower Mishrif is higher than Middle. The distribution of thickness and permeability of Upper Mishrif, Middle Mishrif, and Lower Mishrif related to uplift tectonic force [Neutral Force Folding]. Whereas, Upper Mishrif subjected to extensional force, Lower Mishrif compression force, while Middle Mishrif may represent a Neutral Surface. Thus the distribution of injection rate is uneven. 3] The caliper log confirms wash out in Upper Mishrif especially in the first 10 meters and this may attribute to the

presence of open fracture and leached area in Mishrif. Mishrif Formation may subjected to Early Cretaceous uplift. The uplift exposes the Upper Mishrif, then it eroded and meteoric water leached and induced the dissolution process. Therefore the permeability of Upper Mishrif is higher than the other part of Mishrif. Thus, this reason may create the drilling mud loss zones (Karast Zone). The core analysis (Porosity and permeability cross plot and petrography study) and core picture confirm the presence of open fractures (veins) in Upper Mishrif.

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