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## The Use of Gamma Ray Log Data to Compute and Study the Deposition of Shale Volume of Mishrif Formation in Middle and Southern Parts of Iraq

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### Abstract

The shale volume is one of the most important properties that can be computed depending on gamma ray log. The shale volume of Mishrif Formation (carbonate formation from middle Cenomanian- early Turonian) was studied for the regional area of the middle and southern parts of Iraq. The gamma ray log data from seventeen wells ( Kf-3,Kf-4, Ad-1,Ad -2,Dh-1, Bu-47, Ns-2, Ns-4, Am-1,Am-2,Hf-2,Hf-115,Mj-3,Mj-15, Su-7,Wq-15 and Lu-7) distributed in the study area were used to compute the shale volume of Mishrif Formation. From the available data of the considered wells, a regional isopach map of Mishrif Formation was obtained. The isopach map indicates that the maximum thickness of Mishrif Formation is located at the eastern part of the study area. The results of the CPI and the shale volume map, which were computed using the Techlog and surfer software, show that the maximum value of shale volume is located at the southern part of the study area (Su-7 well), while the minimum value is at the eastern part (Hf-2well). According to the classification of Kamel and Mabrouk (2003), Mishrif Formation seems to be a Shaly Formation in the study area, except Halfaya oil field at the eastern part of the study area, which seems as a Clear Formation. The top map of the shale marker bed, which appears in most studied wells, shows a regional trend of the formation toward the northeast. According to the variation of the thickness of the shale marker bed, the study area is divided into four zones.

**Keywords:** Mishrif Formation, Techlog 2015, shale volume, gamma ray log, southern Iraq.

استخدام معطيات مجس اشعة كاما لحساب ودراسة حجم السجيل في تكوين المشرف في وسط وجنوبي العراق

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### الخلاصة

يعتبر حجم السجيل واحد من اهم المعاملات التي يمكن الحصول عليها عن طريق معلومات الجس البئر (مجس اشعه كاما) . تم حساب حجم السجيل لتكوين المشرف الكلسي من وسط السينوميينين - بداية التورونين في منطقة اقليمية تشمل وسط وجنوب العراق . استخدمت معطيات مجسات اشعة كاما في سبعة عشر بئر موزعة في منطقة الدراسة لحساب حجم السجيل لتكوين المشرف. المعلومات المتوفرة امكنت من

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حساب خارطة اقليمية لسمك تكوين المشرف والتي اوضحت ان اعلى قيمة لسمك التكوين كانت في الجزء الشرقي. تم الوصول الى نتائج CPI وخارطة حجم السجيل باستخدام برنامج Techlog و برنامج Surfer حيث اظهرت النتائج والخرائط ان اقصى قيمة لحجم السجيل كانت في الجزء الجنوبي عند البئر 7-Su فيما كانت اقل قيمة في الشرق عند البئر 2-Hf. طبقا لتصنيف كامل ومبروك (2003) فان تكوين المشرف يعتبر تكوين سجيلي (Shaly) في معظم مناطق الدراسة عدا حقل حلفايه حيث يعتبر تكوين خالي من الطين (Clear). تم رسم خارطة لأعلى طبقة السجيل الأساسية والتي تظهر في تكوين المشرف في معظم الابار في منطقة الدراسة والتي عكست انحدار تكوين المشرف على المستوى العام نحو الشمال الشرقي. ووفقا لتغير سمك هذه الطبقة امكن تقسيم منطقة الدراسة الى اربع انطقه

## Introduction

The well log method is an important geophysical exploration method, which is used to explore the subsurface parameters depending on spatial physical properties [1]. Shale volume is one of the formation evaluation steps which is calculated from natural gamma ray log. Well log data are also used to calculate and correct other parameters like porosity and water saturation, which affect hydrocarbon saturation. Shale zone could indicate high porosity with low value of permeability (low effective porosity zones). Shale volume is defined as the ratio between clay content volume to the bulk volume of the formation rocks [2]. In this study, we attempt to study the shale volume distribution of Mishrif Formation in the center and south of Iraq. Iraq tectonically is divided into two major tectonic zones. These are the stable and unstable shelves. The stable shelf includes the western part of Iraq. The studied area belongs to the Mesopotamian zone in the unstable shelf, which is equal to the outer platform in Iraq [3, 4]. The Mesopotamian zone is the main basin in Iraq, which includes most of the cretaceous sedimentary formations. The most important cretaceous formation is Mishrif Formation that reserves 80% of oil in the south of Iraq [5]. Mishrif formation is a heterogeneous formation, consisting of organic detrital limestone with beds of algal, rudist, and coral- reef limestone [6, 7, 8]

## Previous studies

Many studies were achieved on oil fields in Mishrif Formation in southern Iraq. Well logs were used to determine petrophysical parameters of the formation and calculate shale volume. These are the first steps followed to evaluate the formation.

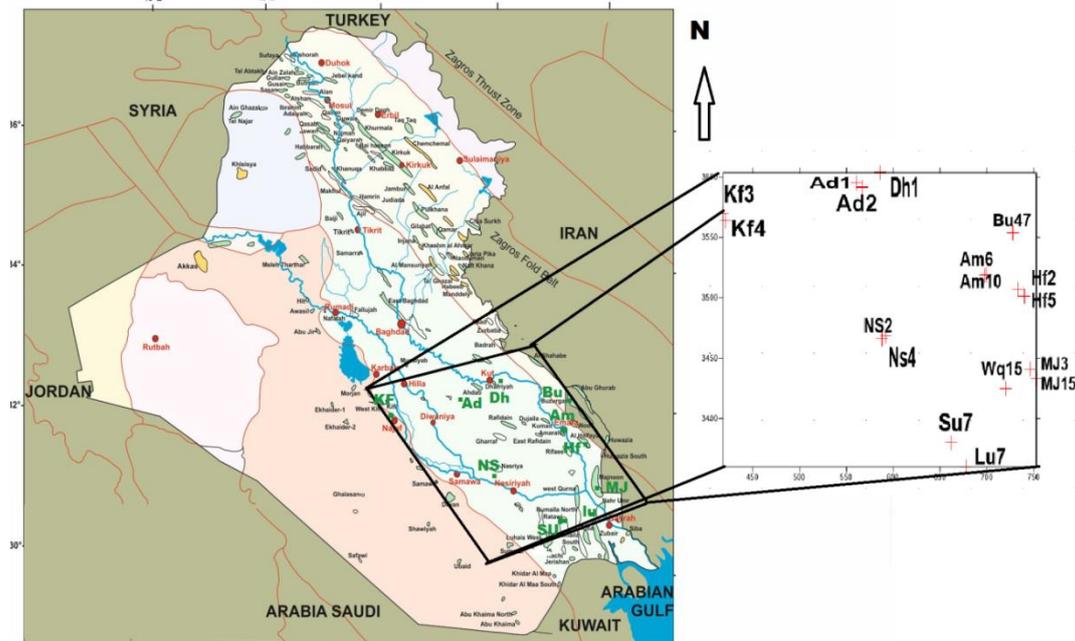
Hlelai and Khorshid (2015) studied Mishrif Formation in Nasiriya oil field depending on well log data analysis supported with coring analysis. The results of the analysis were integrated and distributed by the sequential indicator simulation method as a map and a 3D model using CMG, Petrel, and Techlog software [9]. Al-Yasi and Jaed (2016) studied Mishrif Formation in Garraf oil field. They evaluated the petrophysical properties from well log data using the Computer Processing Interpretation (CPI) technique. The results showed the presence of several units, according to petrophysical properties that were determined from well log sets [10].

Abbas and Mahdi (2019) studied Mishrif Formation reservoir units in Majnoon oil field. They used the well log data (gamma ray, porosity, and resistivity), along with core and cutting samples, to obtain the lithologic facies units. They divided the Mishrif Formation into six units, where the best resource unit was the D unit (with high porosity and permeability and low water saturation) [11]. AL-Baldawi and Nasser (2019) studied the petrophysical characteristics of Mishrif Formation in Ahdab oil field. They divided the formation into 5 units according to reservoir properties. They found that the best one is MI-4 unit (high porosity with low water saturation and low shale content) [12]. Mohammed and Mahdi (2019) studied Mishrif Formation in selected wells of Tuba oil field depending on well log data. They divided the Mishrif Formation into five units. The MB1 and MB2 units were characterized by highly effective porosity [13]. Al-Banna et al (2020) studied Mishrif

Formation in a comparison study between Kumait and Dujaila oil fields using the seismic inversion method and petrophysical properties analysis. They concluded that the lithology and porosity are the main factors affecting the acoustic impedance values [14].

### Study area

The study area includes many wells which are located in the Mesopotamian zone. Figure 1 shows the wells from ten oil fields in the middle and south of Iraq. These wells are Kf3, Kf4, Ad1, Ad2, Dh1, Bu47, Ns2, Ns4, Am1, Am2, Hf2, Hf115, Mj3, Mj15, Su7, Wq15 and Lu7.



**Figure 1-** The oil fields' map of Iraq modified, after [15], and the considered wells locations.

### Methodology

Data in Las file format were digitized by using the Digger 5 Golden software and then corrected. The boundaries (tops and bottoms) of Mishrif Formation of all considered wells are tabulated in table 1 and the data were taken from final geologic reports. Shale volume was calculated from the petrophysical window in the top of the tab window, using gamma ray log. The gamma ray measurements depended on the natural radiation of rock minerals, especially the clay minerals, which contain more radioactive elements. The shale volume was calculated from gamma ray log, as follows:

The gamma ray index IGR was [16]

$$IGR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

where IGR is gamma ray index, GR<sub>min</sub> is the minimum gamma ray reading for clean sand or carbonate, and GR<sub>max</sub> is the maximum gamma ray reading for shale.

Then, shale volume was calculated from the following equation:

$$V_{sh} = 0.33(2^{(2 \times IGR)} - 1.0)$$

After determining the shale volume, contour maps of shale volume distribution were plotted using the Surfer software.

### Results and discussion

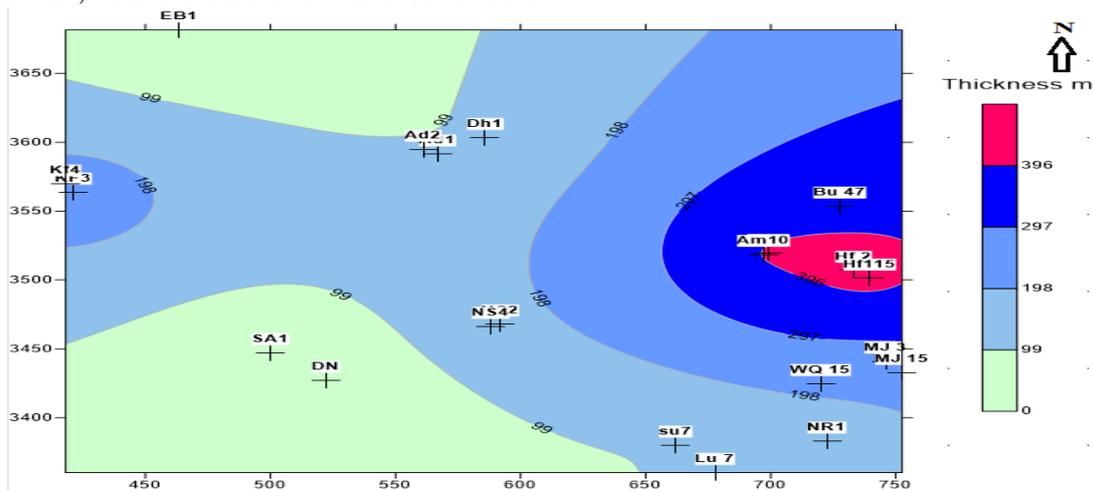
#### 1. Isopach map

Mishrif is one of the formations of the Cretaceous period sequence found in most of the wells drilled in the study area; it varies in thickness and depth from one field to another. Information on the thickness and depth of Mishrif Formation was collected from 17 wells distributed in the middle and south Iraq from more than 11 oil fields, as shown in the Table 1.

**Table 1-** The thickness values of Mishrif formation in the wells used to plot the isopach map of Mishrif formation (data estimated from final geologic reports of Final Geological Report and Final Drilling Report).

Nu.	Well name	top (m)	Bottom (m)	Thickness (m)
1	WQ-15	2243	2465	222
2	HF-2	2825	3244	419
3	HF-5	2900	3325	425
4	NS-2	1921	2089.5	169
5	NS-4	1927.5	2104.5	177
6	AM-6	2864.5	3271	407
7	AM-10	2874	3272	398
8	MJ-3	2555	2810	255
9	MJ15	2544	2792	248
10	SU-7	2050	2155	105
11	Kf3	1520	1760	240
12	Kf4	1471.5	1711	240
13	Dh1	3200	3300	100
14	Ad1	2706	2800	94
15	Ad2	2714	2822	108
16	Lu7	2080.8	2209	128
17	Bu47	3672	4036	364

Mishrif Formation thickness is presented as a 2D image in Figure 2. The results of the thickness distribution in the region demonstrated that the thickness is increases towards the Far East at the wells of Halfaya, Amara, and Bazerkan, and gradually decreases towards the north and south, then further decreased to reach the lowest thickness of the formation (10-14m) at the wells in the southwest of the region, near Diwan and Samawa. Lower thickness values are recorded towards the northwest of the formation, until it disappears in the East of Baghdad well, while it reappears when the thickness increases to 266 meters in a limited area to the west, near Karbala at oil field of Al-Kifl .



**Figure 2-** The isopach map of Mishrif Formation in the study area.

2. *Shale volume CPI*

The shale volume was calculated from the gamma ray logs, using the Techlog program, depending on the information from 17 wells distributed in the study area, as shown in table (2). The curves that demonstrate the change in the shale volume with depth were drawn to illustrate the change in the amount of clay (Figures 3, 4, 5, and 6). These curves show that the percentage of shale volume change in the area is rather small, ranging from 9.1% in the wells of Hf- 2 and Hf-115 to 26.2 % in the well of Su-7.

**Table 2-**The results of shale volume and formation type of studied wells, classified according to [17].

No.	Well symbol	Shale volume %	Formation classification according to [17]
1	Kf3	22.5	Shaly formation
2	Kf4	21	Shaly formation
3	Ad1	22.2	Shaly formation
4	Ad2	19	Shaly formation

5	Bu47	20	Shaly formation
6	Ns2	18	Shaly formation
7	Ns4	16.1	Shaly formation
8	Am6	25.5	Shaly formation
9	Am10	22	Shaly formation
10	Hf2	9.1	Clean formation
11	Hf115	9.5	Clean formation
12	Mj3	23.5	Shaly formation
13	Mj15	25.4	Shaly formation
14	Su7	26.2	Shaly formation
15	Wq15	15.7	Shaly formation
16	Lu7	20	Shaly formation
17	Dh1	20.6	Shaly formation

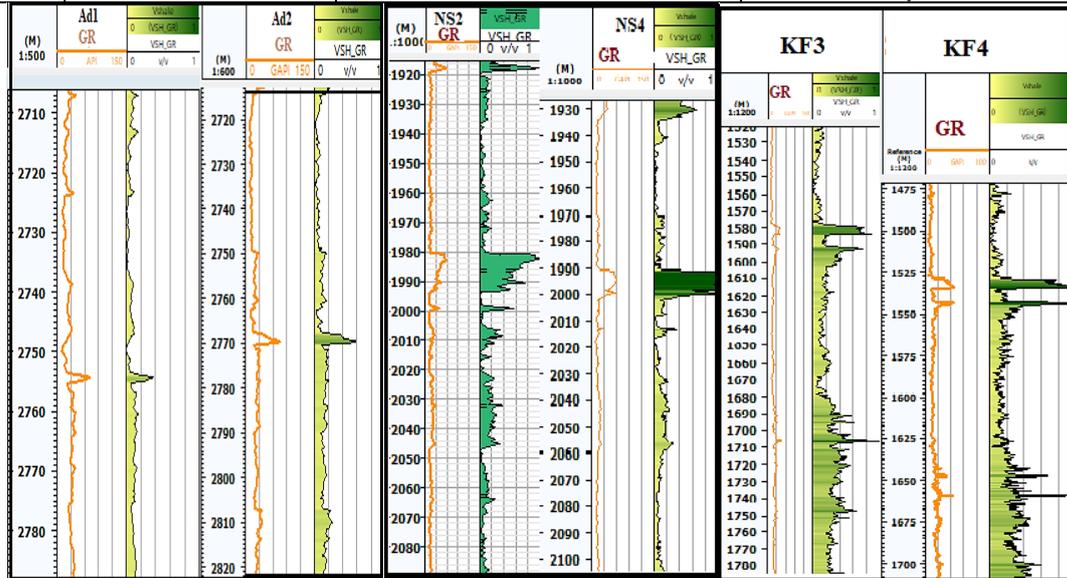


Figure 3- The CPI for calculating the shale volume of Ad-1, Ad-2, Ns-2, Ns-4, Kf-3 and Kf-4 wells.

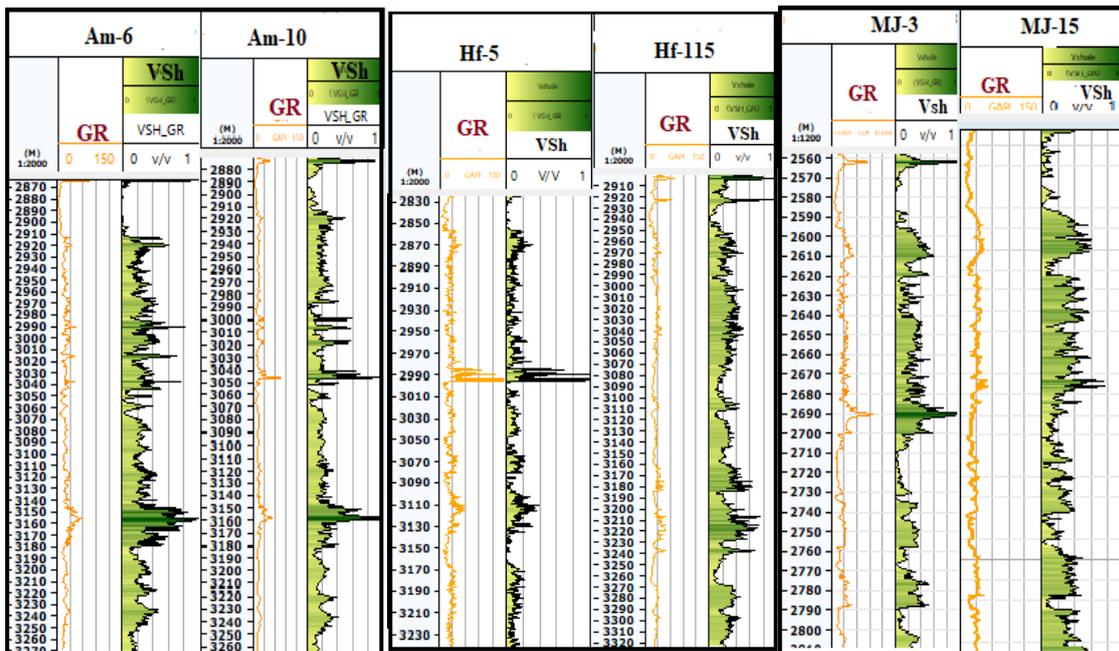


Figure 4- The CPI for calculating the shale volume of Am-6, Am-10, Mj-3, Mj-15, Hf-2 and Hf-5 wells.

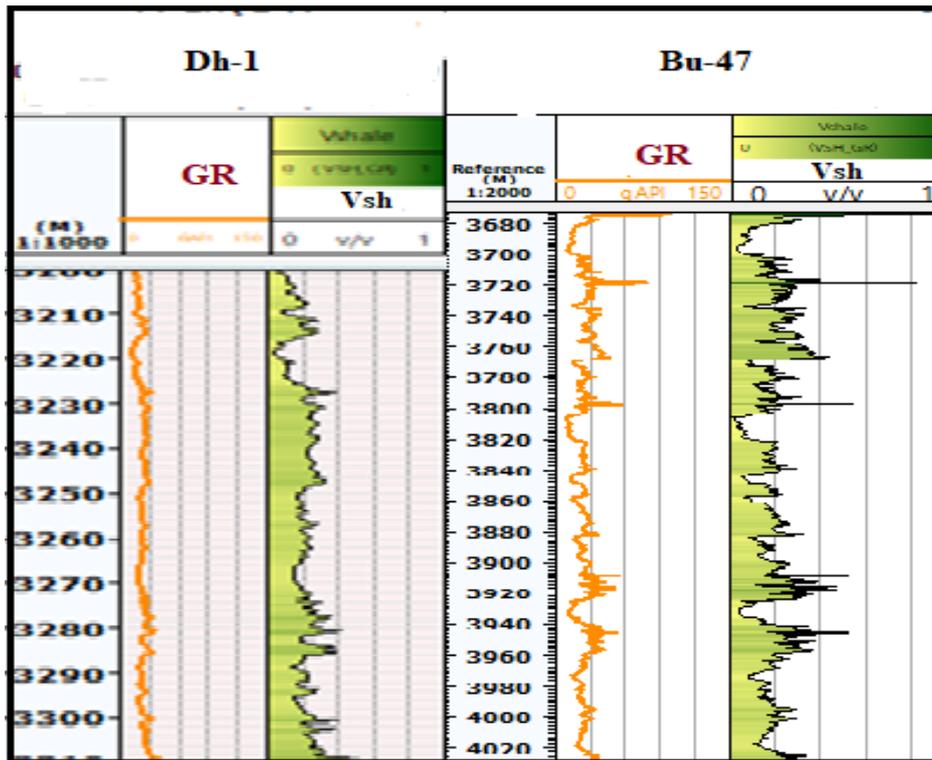


Figure 5 - The CPI for calculating the shale volume of Bu-47 and Dh-1 wells.

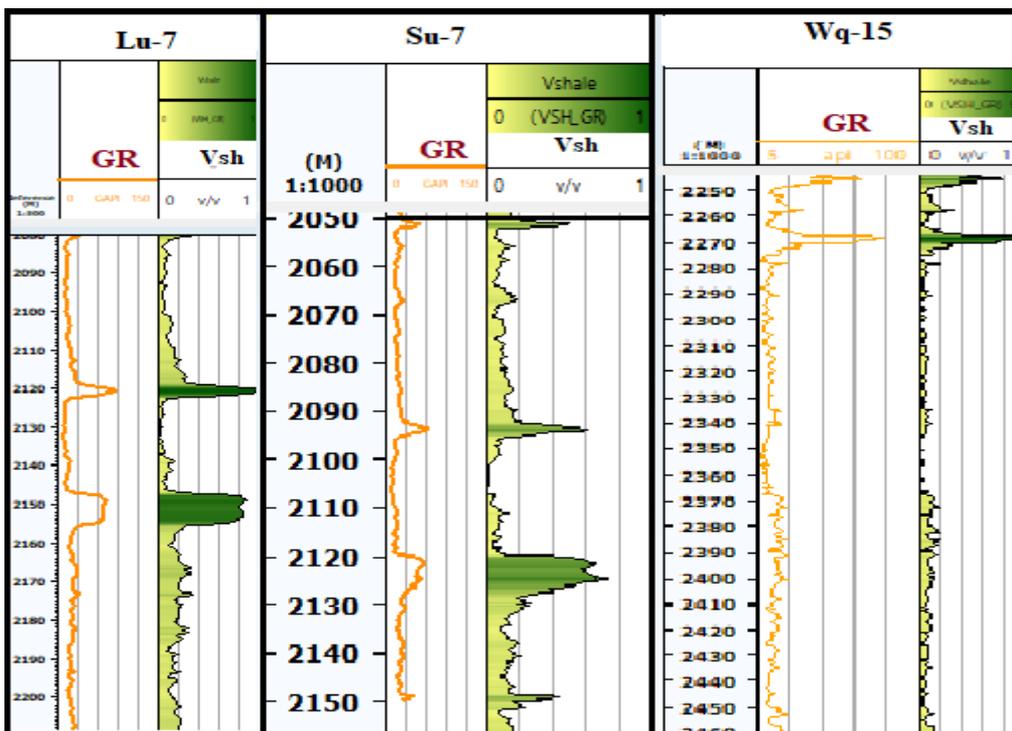
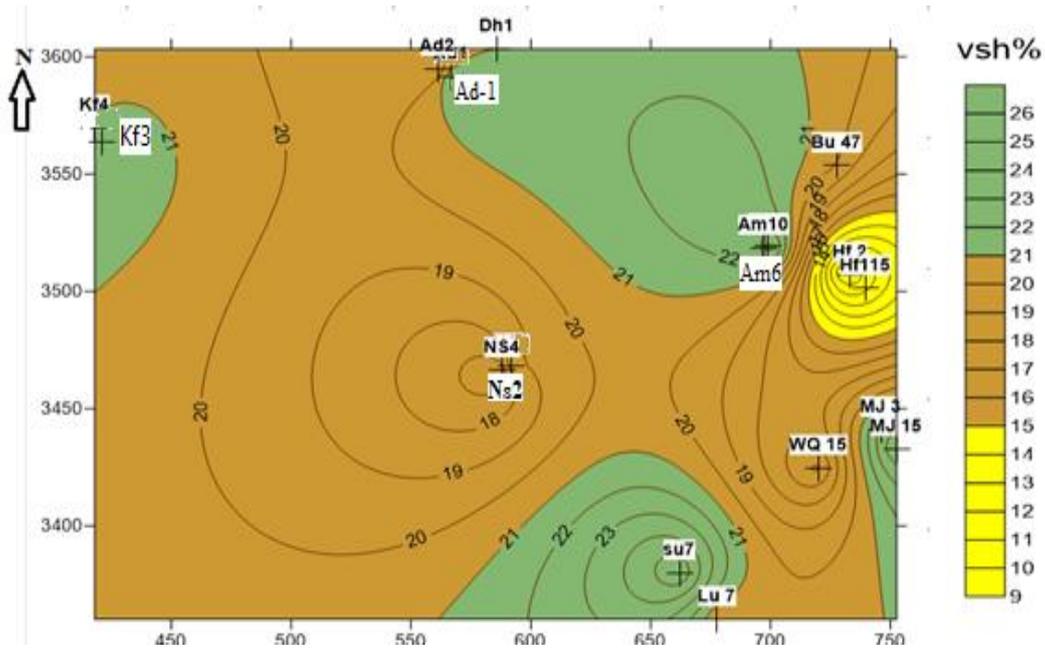


Figure 6- The CPI for calculating the shale volume of Wq-15, Lu-7, and Su-7 wells.

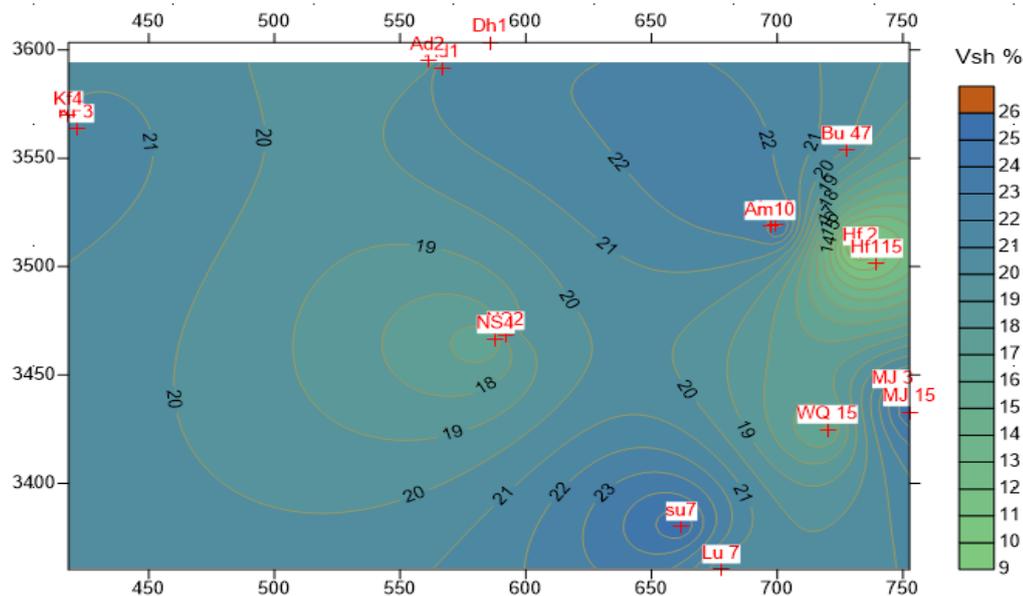
3. Shale volume distribution maps

The shale volume distribution was represented in a 2D map (Figure 7). This map shows an increase in the shale volume values towards the southeast in Su-7 and Mj-15 wells, while it decreases in the other parts of the study area, with minimum values at Hf-2 and Hf-115 wells.



**Figure 7-** The shale volume distribution of Mishrif Formation in the study area

The shale volume of Mishrif Formation was classified into three types according to their values [17]. These classes are: Clean formation if  $Vsh < 10\%$ , Shaly formation if  $10\% < Vsh < 33\%$ , and Shale formation if  $Vsh > 33\%$ . The final results are concluded in table 3.

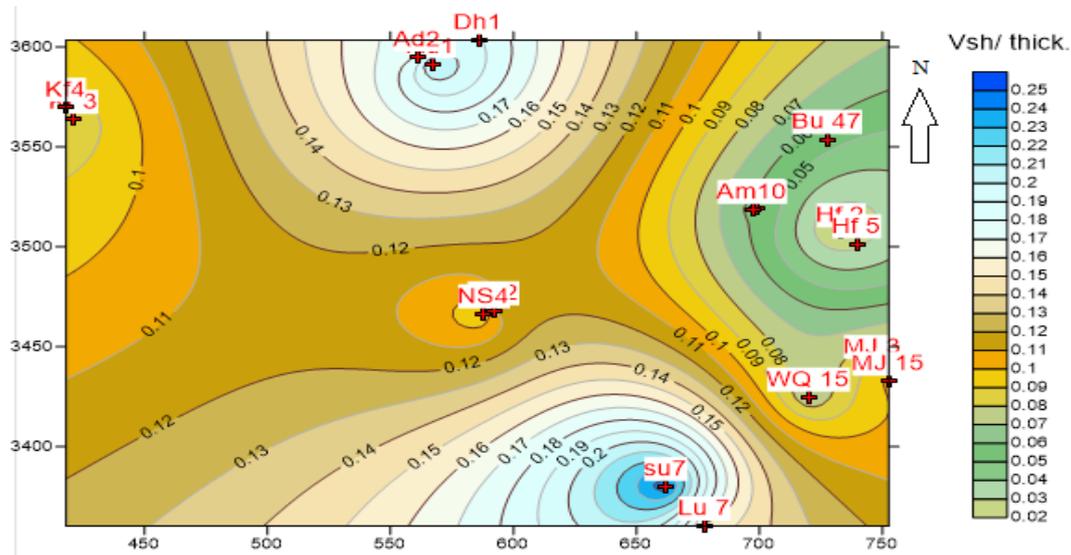


**Figure 8-** The shale volume classification of the study area according to [17]. According to this classification, the Mishrif Formation seems to be located within one class, which is the Shaly formation, except Halfaya Oil Field, which is classified as a clean Formation.

The results of the classification of Mishrif Formation according to the shale volume are shown in table -2-. The results are also presented as a map in Figure 8. This map indicates that Mishrif Formation in most areas is shaly formation, except at Hf-2 and Hf-115 wells where it is classified as a clear formation.

4. *Shale volume to formation thickness ratio*

The Vsh /thickness ratio was calculated and presented as a map in Figure 9. The map shows relatively low ratios at Hf-2 and Hf-115, corresponding with the increase of the thickness of the formation. High ratio values appeared in the northern and southern parts of the study area.



**Figure 9-** A map showing the Vsh/ thickness ratio values of Mishrif Formation in the study area.

#### 5. The shale marker bed

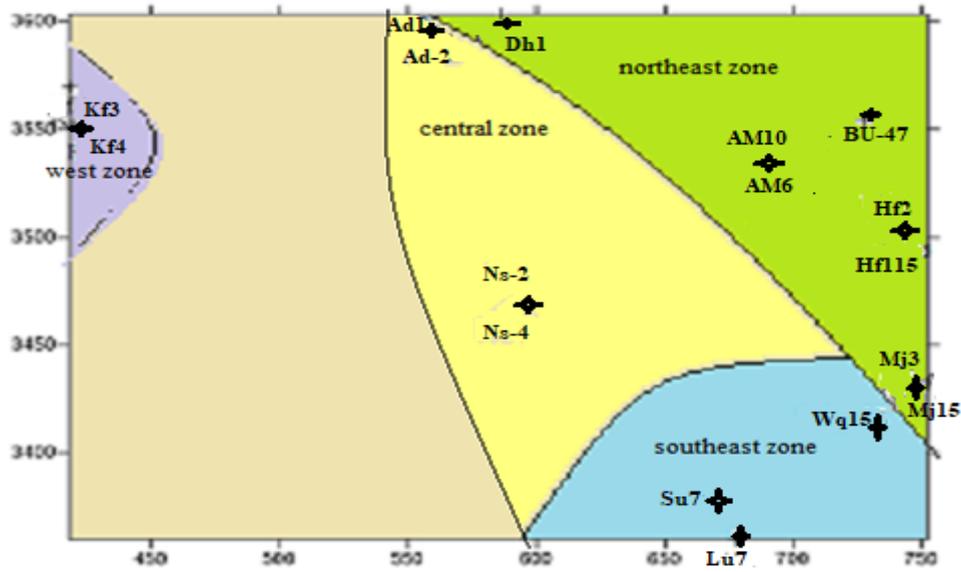
The presence of a shale marker bed was observed from the CPI curves of the study area. This shale bed appears as two parallel beds in some fields, or as one bed or with no bed in other fields. According to the thickness of the shale bed, the study area was divided into the following four zones:

A. The west zone, which includes the wells of Kifl oil field. It shows thick shale bed of 25 meters in wells Kifl 3 and 4.

B. The central zone, which includes the wells of Nasiriya and Ahdab oil field. The shale layer appears as a single layer. The thickness of this shale bed in Ahdab is about 5 meters, while its thickness in Nasiriya is 12 meters.

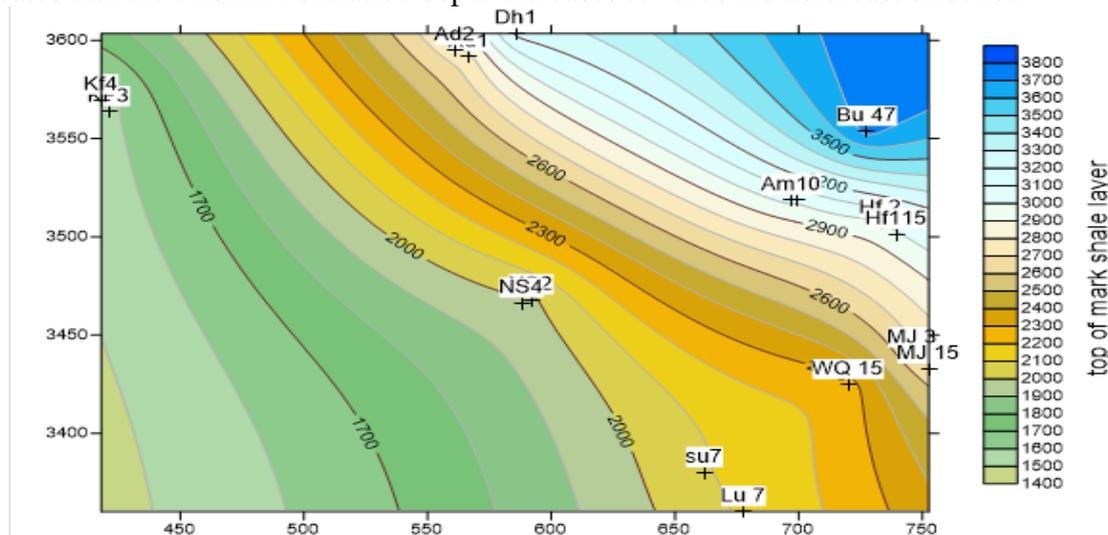
C. The northeast zone, which includes the wells of Dhifriya, Amara, Halfaya, Bazerkan, and Majnoon, which are adjacent to each other. It is observed that there is no prominent appearance of this shale layer in the mentioned oil fields, with a relative increase in shale volume, accompanied with high thickness in this zone.

D. The southeast zone, which includes the wells of Wq, Su, and (Lu the blue zone), shows a convergent shape for the emergence of two parallel ranges of the shale layer and the thickness of the bed ranges around ten meters and is separated by twenty meters with a difference in the depth of the indicated area according to the well and the depth of formation in it, these zones shown in Figure 10.



**Figure 10-** The Mishrif Formation zones in the study area according to the variation within the nature of the shale marker bed

The top layer of the shale marker in Mishrif formation is presented in Figure 11. This map indicates that the Mishrif Formation depth increases towards the northeast direction.



**Figure 11-** The top of shale marker bed in Mishrif formation at the study area.

**Conclusions**

This study discusses the Mishrif Formation in central and southern Iraq. According to the results, several conclusions were obtained.

The Mishrif Formation thickness increases towards the east and reaches its maximum value at Halfaya oil field. It becomes gradually thinner towards the middle, north, and south until it reaches its lowest value in the wells of Samawa and Diwan oil fields at the west, reaching thickness values of 14 and 10 meters, respectively. The formation appears again with relatively high thickness near Karbala in the field of Kifl. The position of Mishrif Formation is affected by transverse faults causing differential subsidence with erosion and onlap. The calculated shale volume ranges between 16 to 26 in all studied wells except Hf Wells, which have values that range from 9 to 9.5. The lowest value of the shale volume was recorded in Hf oil field, corresponding with high thickness of Mishrif Formation compared with other oil fields.

The ratio of Vsh / formation thickness showed an inverse relationship with the thickness of the formation. In the area where Mishrif Formation thickness decreases in the southwest and north of the study area, shale volume is increased. This is due to the fact that the position of the formation changes in the deposition basin and is affected by transverse faults. These impacts cause differential subsidence with erosion and onlap. The occurrence of the shale in the formation is focused in the spatial depths; when the formation thickness is decreased, shale volume is increased relatively.

The structure map of the top of the shale marker bed indicates that the Mishrif Formation is dipping gradually from the southwest toward the northeast.

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