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Microfacies Analysis of the Mishrif and Kifil Formations of Amara Oil field/South of Iraq

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ABSTRACT

The lithologic and petrographic studies of the Mishrif and Kifil formations in Amara oil field in wells AM11,AM9, AM5 was revealed that the Mishrif formation consists of limestone and dolomitic limestone. While the Kifil formation is consist of the anhydrite and mud-dominated limestone.

The skeletal grains of Mishrif formation includes variety of benthos foraminifera, bivalves (Rudist) ,corals , stromatolite, algae, ostracods, gastropods, echinoderms. Non-skeletal grains are rare and authigenic minerals of pyrite and iron oxide are present. The rocks of the formation are affected by diagenesis such as dolomitization ,dissolution and recrystallization. The Kifil formation rocks do not have any skeletal grains and affected by recrystallization only .

The microfacies analysis of Mishrif formation reveals that the formation consists of: mudstone, wackestone, packstone, grainstone and boundstone deposited in the fore environments extend from for reef, back reef to: open marine, reef, shoals platform margin, restricted environment. The Kifil formation divided into tow lithological facies these are limestone and evaporite and we recognized mudstone microfacies only deposited in restricted environment and represents the Mishrif reservoir cap rocks .

The research illustrated that the upper contact of Mishrif formation is gradational and conformable with Kifl formation with evidence from a gradual changes from limestone to anhydrite. In this study was considered the evaporites and limestone to Kifil formation. The Kifil formation is presence by thickness (7m) in the Amara Oilfield .

1. Introduction

The Cenomanian-early Turonian Mishrif formation is the one most important reservoir in the southern of Iraq .The rock succession of the Mishrif formation consist mainly of limestone and dolomitic limestone

whereas the succession of the Kifl formation consist of evaporates and limestone. The thickness of the Mishrif formations ranging between 376-395m and for Kifl formation 5-7.5m (Table 1).

Table (1) The top, bottom and thickness of the Mishrif and Kifl formations in the studied wells .

Wells	Coordinates (UTM)		Formation	Top (m)	Bottom (m)	Thickness (m)
	E	N				
AM.11	699 500	3518 250	Mishrif	2880	3276	395
			Kifl	2873	2880	7
AM.5	701 350	3518 450	Mishrif	2896	3291	395
			Kifl	2888.5	2896	7.5
AM.9	696 073	3518 952	Mishrif	2873	3252	376
			Kifl	2868	2873	5

The aim of this study is to determine the microfacies of the studied formations and the depositional environments of 3 boreholes in Amara oilfield by

studying the petrographical and stratigraphic characteristics of 105 thin sections from AM11, AM5and AM9 and to prepare the depositional model

by using Petral 2015 software and, also determined the contact between Mishrif and Kifl formations in the study area .

The Mishrif formation first described in well Zubair-3 in the south of Iraq by [1], [2]. Which [3] Suggested that the upper boundary represent end of Cenomanian-Turonian cycle. As explained [4] highly heterogeneity in the formation, While[5] Studied Mishrif formation in Missan and recognized six depositional environment, Finally[6] subdivision Mishrif formation to six environment depending on the Log Analysis .

The Mishrif formation underlying Rumaila formation were originally described in south of Iraq in well (Zubair 3). The contact between the Mishrif and Rumaila formations is gradational, as the upper

contact between the Mishrif and Kifl formations. However, in many oilfields such as (West Qurnah), the Mishrif formation is unconformably overlain by the Khasib formation, where the Kifl formation is absent [7]. In the South of Iraq, where the Kifl formation is present (*i.e.* in the basin roughly to the west of the Musalyib-Nahr Umr palaeoridge) the upper contact is conformable. But where the Kifl is missing the top of the Mishrif formation is signalized by an unconformity [8] as show in (figure 2)

2. Location of the study area

The study area is located in Amara oil field about (10 Km) southeast of Amara city the center of Missan province southern Iraq (Figure 1).

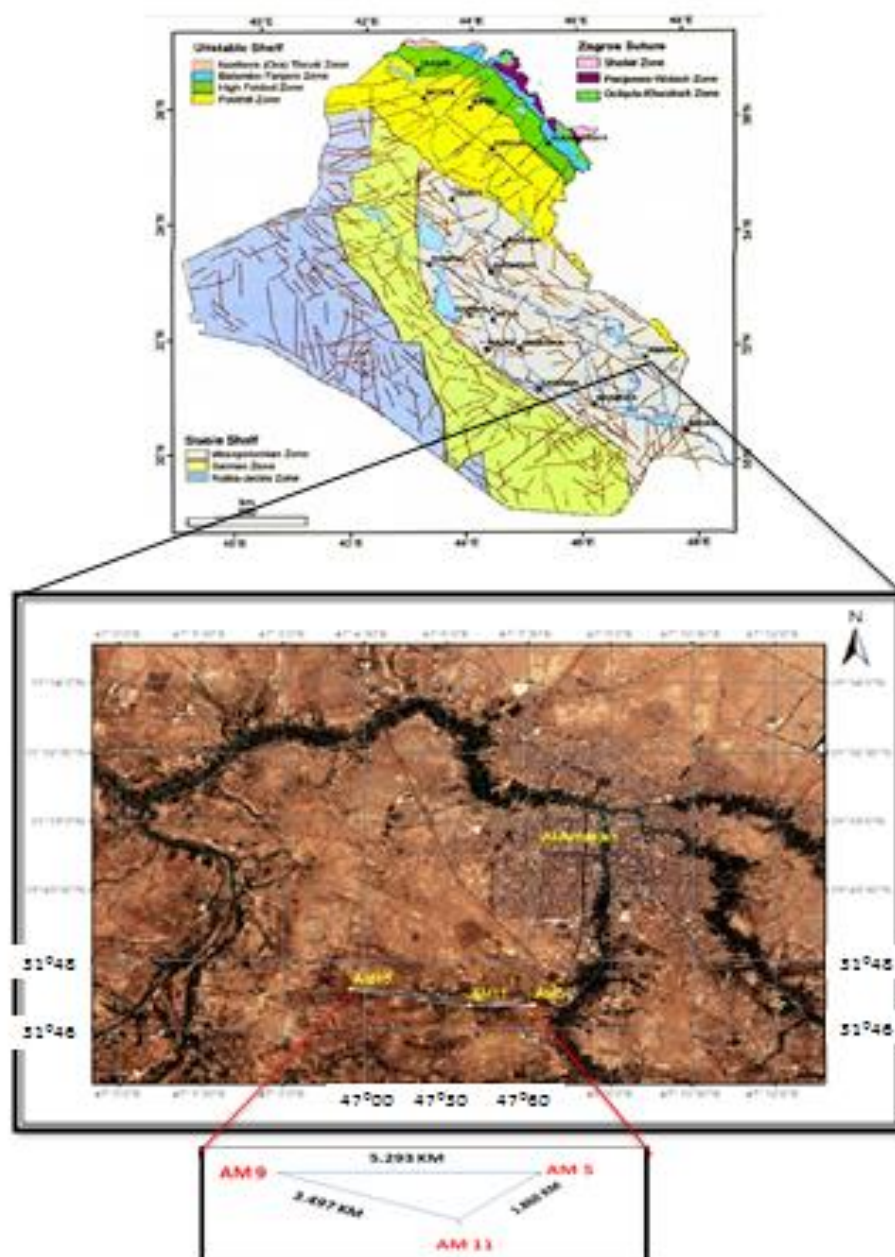


Figure 1: Tectonic subdivision of Iraq [8] and focusing in well studied area location with a Satellite image from (Sentinel-2 satellites) in Amara oil field

3. Tectonic Framework of the Amara Oil field

Missan province is located in Tigris subzone a part of Mesopotamian Zone .It contains wide synclines and narrow anticlines trending often NW-SE compatible by long normal faults [8].

It is border by the Foothill Zone (in NE) and by long gravity gradient and line of residual gravity anomalies between Qalat Saleh (in SE) and Fallujah (in NW).

The western boundary coincides with a palaeoridge that influenced sedimentation in the Mesopotamian Zone from Late Jurassic time as in (figure 3),separating inner shelf facies in the SW from outer shelf facies to the NE. The Tigris subzone contains two NW-SE trending groups of lines anticlines of relatively low expansion associated with longitudinal faults and at EW transversal trend. These anticlines lie on the Ramadi Musaiyib and the Tikrit-Amara

Fault Zones of the Najd fault System and on the Kut-Dezful fault. Were tectonically active from the Late Jurassic onwards[8].

The Mishrif formation underlying Rumaila formations were originally described in south of Iraq in well (Zubair 3). The contact between the Mishrif and Rumaila formations is gradational, as the contact between the Mishrif and Kifl formations.

However, in many oilfields such as(West Qurnah), the Mishrif formation is unconformably overlain by the Khasib formation, where the Kifl formation is absent [7]

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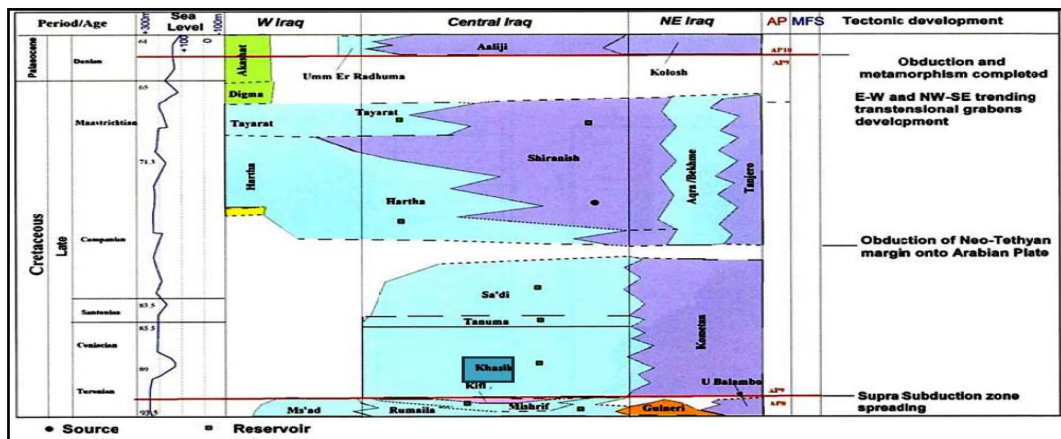


Figure 2: Stratigraphic correlation of studied formations in Late Early Turonian-Danian Megasequence[2]

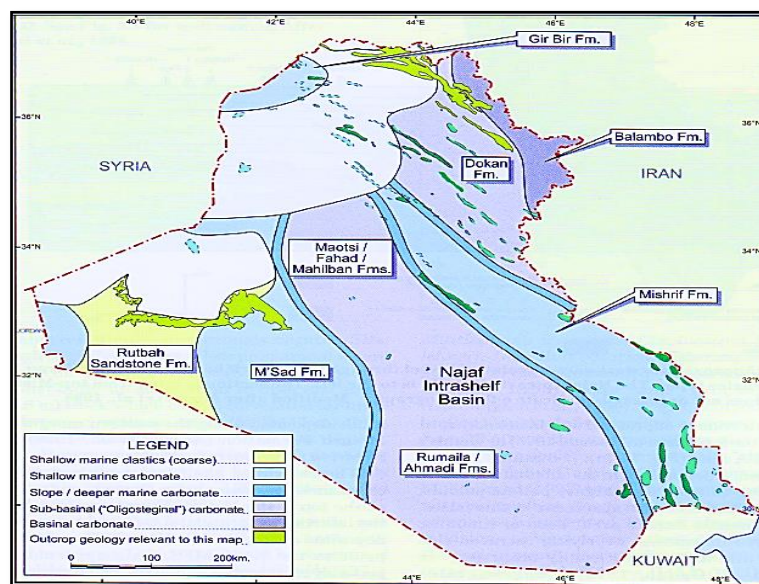


Figure 3: Paleogeography of Latest Albian-Early Turonian in Iraq from [2]

4. methodology

Core samples were collected from studied wells the sampling were done with each lithology change observed . From AM11 well for (87) slide. A standard core logging sheet was used to described the available core .Detailed analysis were conducted to identified lithology, textures, mineralogy ,and fauna. (18) Cutting samples were collected from Well AM9 .One thin section were prepared from cutting and core plug at the GEOSURVE laboratory .

Total 105 thin sections were selected for detailed microfacies study under polarizing microscope after stained by red alezarine S stain. The petrographic observations ,lithology ,mineralogy ,textures, diagenesis and oil show were recorded (Figure 4) in order to describe the microfacies and interpret depositional environment for the studied formations . 2D and 3D facies model were constructed using Petral-2015 Software.

5. Result and Discussion

Carbonate microfacies observed in the studied wells were classified on the base of Dunham classification[9], has been matched with Wilson[10] Standard Microfacies (SMF) and Facies Zones (FZ).

5-1. Mishrif Formation Microfacies

The lithology of the Mishrif formation is consists of limestone and dolomitic limestone. The formation are divided into (5) main microfacies and these are divided into (13) submicrofacies they are listed below as show in figure (3) .

5-1-1. Mudstone Microfacies (M)

This microfacies characterized by skeletal grains ranging from (0 to10%) and extend from the depths (3276 - 2880) and form the main microfacies for Mishrif Formation in studied wells. This Microfacies divided into(3) submicrofacies these are as below:

5-1-1a. Rudist Mudstone Submicrofacies (RM1)

This submicrofacies is consists of about (8%) skeletal components of rudist bioclasts embedded in micrite matrix with thickness about (21m) extend from depth (3255 to 3276 m) and at the lower contact with Rumila Formation at depth 3276m. This submicrofacies affected by dolomitization (Figure 5) .Pores are Intercrystalline and intrapartical types ranging (1-2%), oil show is low. According to [10] this submicrofacies represents (SMF24) in (FZ 8) deposited restricted interior platform.

5-1-1-b. Barren Mudstone Submicrofacies (MM2)

This submicrofacies consists only homogenous micrite. It is missing of any fossils extending from (3236 to 3254 m and 3062 to 3080m) in wells (AM11,AM9) thickness (18m). The micrite is recrystallized into microspar and affected by dolomitization with high oil show (Figure 6).

Main pore space in this submicrofacies is intercrystalline type and filled by low oil show According to [10] this microfacies is similar to the standard Microfacies (SMF23) which deposited in (FZ8) in restricted interior platform .

5-1-1c. Benthonic Mudstone Submicrofacies (BM3)

This submicrofacies consists of benthonic foraminifera, ostracodes ,rudist vascular, in micrite matrix or microsparite with isopachous cement extends from (2979 to 3061m) in wells (AM11,AM9) thickness (80m). Dolomitization is the dominant diagenesis affected and the predominated dolomite fabric are mosaic and flouting rhomb texture to a lesser extent (Figure 7) .

Micro fracture and intercrystalline are the main pores ranging (3-4%) oil show is medium to high .According to [10] this microfacies is represents standard microfacies (SMF12-BS) which deposited in (FZ5) reef platform .

5-2. Wackestone Microfacies (W)

This microfacies is consists of skeletal grains more than (10)% with mud supported [9] . this microfacies recognized in Mishrif Formation in all studied wells with skeletal components from (11-40%) and subdivided into two submicrofacies.

5-2-a. Rudist and Benthonic Foraminifera Wackestone Submicrofacies (R-BW1)

This submicrofacies includes skeletal grains from Rudist bioclasts and Benthonic foraminifera embedded in microspare or micrite groundmass .

This facies characterized by high presence of bituminous limestone, with common presence of pyrite and hematite with thickness about (146 m) in wells (AM11,AM9) from depth (3089 to 3235)m .Recrystallization and Dolomitization affected this submicrofacies. In addition chemical compaction and micro stylolite are recognized (Figure 8). Oil show are moderate. According to [10] this microfacies is similar to the standard Microfacies (SMF12-S) which deposited in (FZ7) in open marine interior platform.

5-2-b. Benthonic Wackestone Submicrofacies (BW2)

This submicrofacies is dominated by Benthonic foraminifera forming (15-20%) from the total constituents (Figure9) embedded in micrite-microspare groundmass with thickness (4m) from (2941 to 2945 m)in wells (AM11,AM9,AM5). Diagenesis processes recrystallization cementation (Blocky, Drusy) dissolution and compaction affected this microfacies and pore space are channel , fracture, mold , intrapartical, about (6-8 %). Oil show high, According to [10] this microfacies is similar to the standard microfacies (SMF12-S) which deposited in FZ6 in platform margin sand shoals.

5-3. Packstone Microfacies (P)

This microfacies is consists of skeletal grains more than (40)% with grain supported [9]. it was divided in this study into (4) submicrofacies

5-3-a. Rudist Packstone Submicrofacies (RP1)

This submicrofacies consisting mainly of Rudist more than(60%) from the total constituents, and lesser amount of benthonic foraminifera (Figure 10), embedded in sparite , from depth (2939 to 2940 m) thickness (2m) in wells (AM11,AM9). No pore space

are seen, oil show is low. Cementation are the main diagnosis process present as blocky and granular cement. According to [10] this microfacies is similar to the standard Microfacies (SMF13) which deposited in (FZ6) platform margin sand shoals.

5-3-b. Milioid Packstone Submicrofacies (MP2)

This submicrofacies is characterized by abundance of skeletal components which include high diversity of benthonic high content of Milioid genus, benthonic foraminifera, green alga, and some coral and Rudist fragments. Thickness (6m) from depth (2928 to 2934 m and 2937 to 2938.5 m) in wells (AM11,AM9). Diagenesis process such as neomorphism, dissolution, cementation and physical compaction deformed some skeletal components fauna. Oil show is high-medium. According to [10] this microfacies is similar to the standard Microfacies (SMF18) which deposited in (FZ8) Restricted platform (Figure 11).

5-3-c. Benthic Packstone Submicrofacies (BP3)

This submicrofacies Consisting of benthic foraminifera (figure 12) in high diversity about (60-65 %) and some proportion and Rudist, red alga embedded in microsparite.

Deeply (2928 to 2929 m, 2880 to 2890m) thickness (12m,) in wells study, diagenesis represent by recrystallization, dissolution cementation presence by (Blocky, syntaxial), physical compaction deformation all skeletal grains.

Pore space summarized by mold interpartical, channel, fracture channel and vug pore space ranging (7%), in ranging (1-2%) oil show high.

According to [10] this microfacies is similar to the standard Microfacies (SMF18) which deposited in (FZ7) open marine environment mud losses from (2881– 2901m) 10m³ during coring and gas bubbles flow [11].

5-4. Grainstone Microfacies

According [9] this microfacies consist of more than (90%) skeletal grain with grain support. In Mishrif formation it was divided into (2) submicrofacies.

5-4-a. Rudist Grainstone Submicrofacies (RG1)

These submicrofacies are forming Rudist bioclast which is the unicomponent existent about (90-92%) and embedded in ground mass from sparite (figure 13).

Thickness (32m) from (2946 to 2978 m) in (AM11) well, pores mainly fracture and intrapartical ranging from (4-5%) oil show ranges from low-medium, cementation forming granular cement.

According to [10] this microfacies is similar to the standard Microfacies (SMF5) which deposited in (FZ4) slope environment. This microfacies is interpreted to be a fore-reef slope deposit.

5-4-b. Benthonic Foraminifera Grainstone Submicrofacies (BG2)

Involved in submicrofacies benthic foraminifera, vascular Rudist (Figure 14) Ostracodes, Brachiopod in high diversity, embedded in microspore - psedospore.

At depth (2874 m) thickness (1m) in wells (AM11,AM9), that affected cementation forming isopachous cement, physical compaction are presence by tangential contact, pore space take on intrapartical, channel and vug in rate (10%) oil show is low.

According to [10] this microfacies is similar to the standard Microfacies (SMF10) which deposited in (FZ7) open marine environment.

5-5. Boundstone Microfacies (B)

Autochthonous horizon growth skeletal grains occupies (85-90%) from coral or Stromatolite therefore on this basis it was divided into (2) submicrofacies :-

5-5-a. Stromatolitic Rudist Boundstone Submicrofacies (SRB1)

This submicrofacies Content Stromatolite (Figure 15) in addition Rudist and coral bioclasts by rate (7-9 %). Found at depth (3081 to 3088 m, 2978.5- 2979 m) thickness (7m) in (AM11) well. Diagenesis process mainly recrystallization, dissolution, dolomitization make up spotted mosaic, pores resulted, vug pores ranging (4-5%) oil show is high. According to [10] this microfacies is similar to the standard Microfacies (SMF20) which deposited in (FZ7) open marine.

5-5-b. Coral Boundstone Submicrofacies (CB2)

This submicrofacies content Rogues coral growth and Rudist bioclast (Figure 16). Thickness (0.5 m) in (2945.5 and 2938.5m) in the (AM11,AM9) wells affected by diagenesis physical compaction recognized by (3set) calcite cleavage, cementation (Blocky cement). Dissolution rustling intrapartical and channel pore space about (7-9%) oil show is low. According to [10] this microfacies is similar to the standard Microfacies (SMF7) which deposited in (FZ5) slope or fore reef environment.

5-5-d. Stromatolite Coral Boundstone Submicrofacies (SCB3)

Boundstone submicrofacies is very distinctive by containment it coral (figure 17), moreover Stromatolite and Rudist. All these are complete not destroyed. Found at depth from (2935 to 2936.5) thickness (1.5m) in (AM11,AM9) wells, affected by dissolution and vug pore space in (4%) with medium oil show. According to [10] this microfacies is similar to the standard Microfacies (SMF7) which deposited in (FZ5) platform margin reef. The stromatolite is distinctive feature in cretaceous platform [12].

5-6. Kifl Formation Microfacies

The Microfacies which characterized by inhomogeneity with Mishrif Formation is specific in bottom by mud losses from (2881 m) (85m³) during coring [11] and (MA Unites the first units in Mishrif formation).

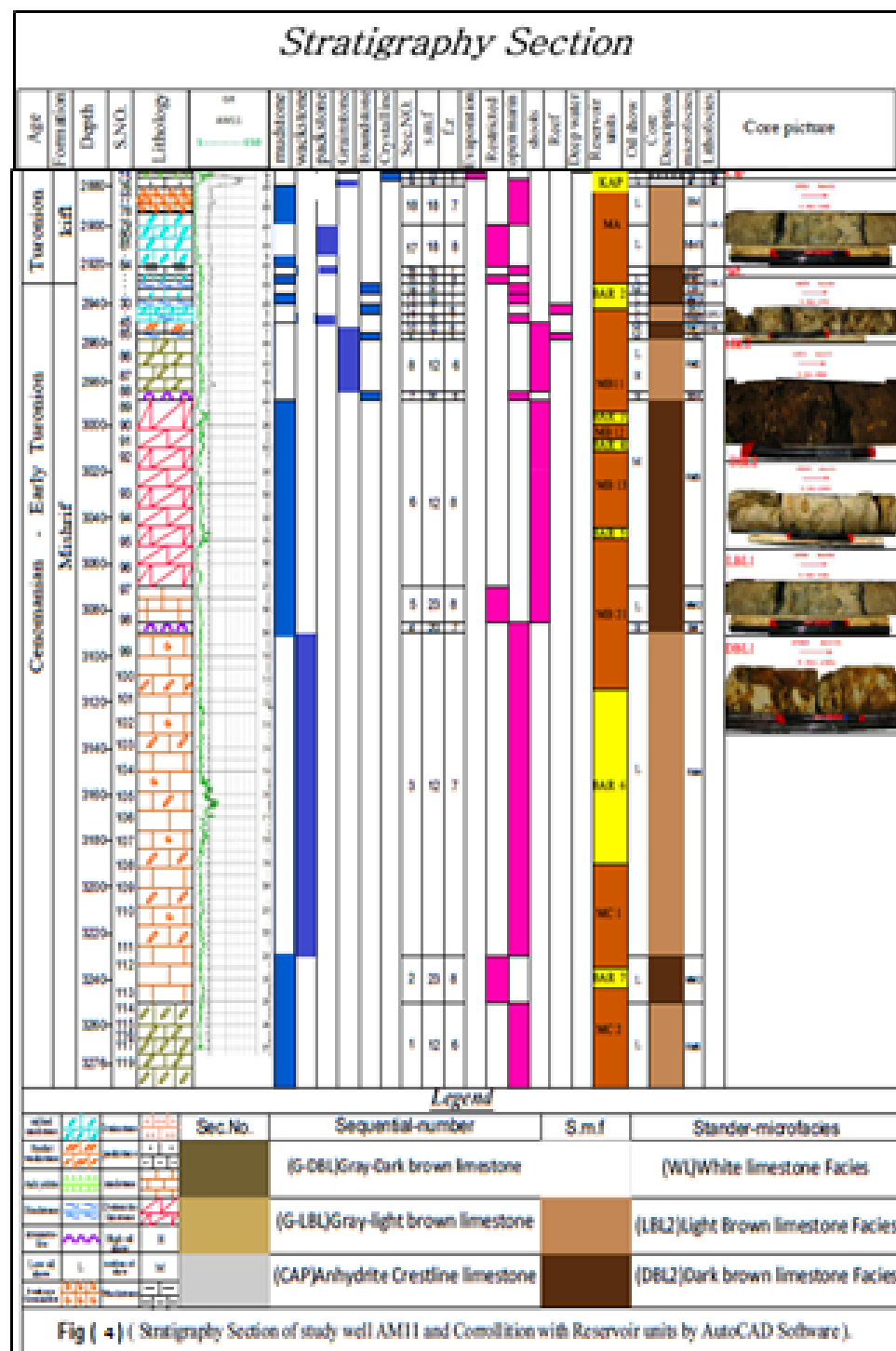
The top determined by high Gamma ray value in (2874 m) practical observation by core sample and slide test it confirms (Anhydrite) total thickness (7 m) that may be returned to Kifl formation. Lithologically it is divided into two parts:

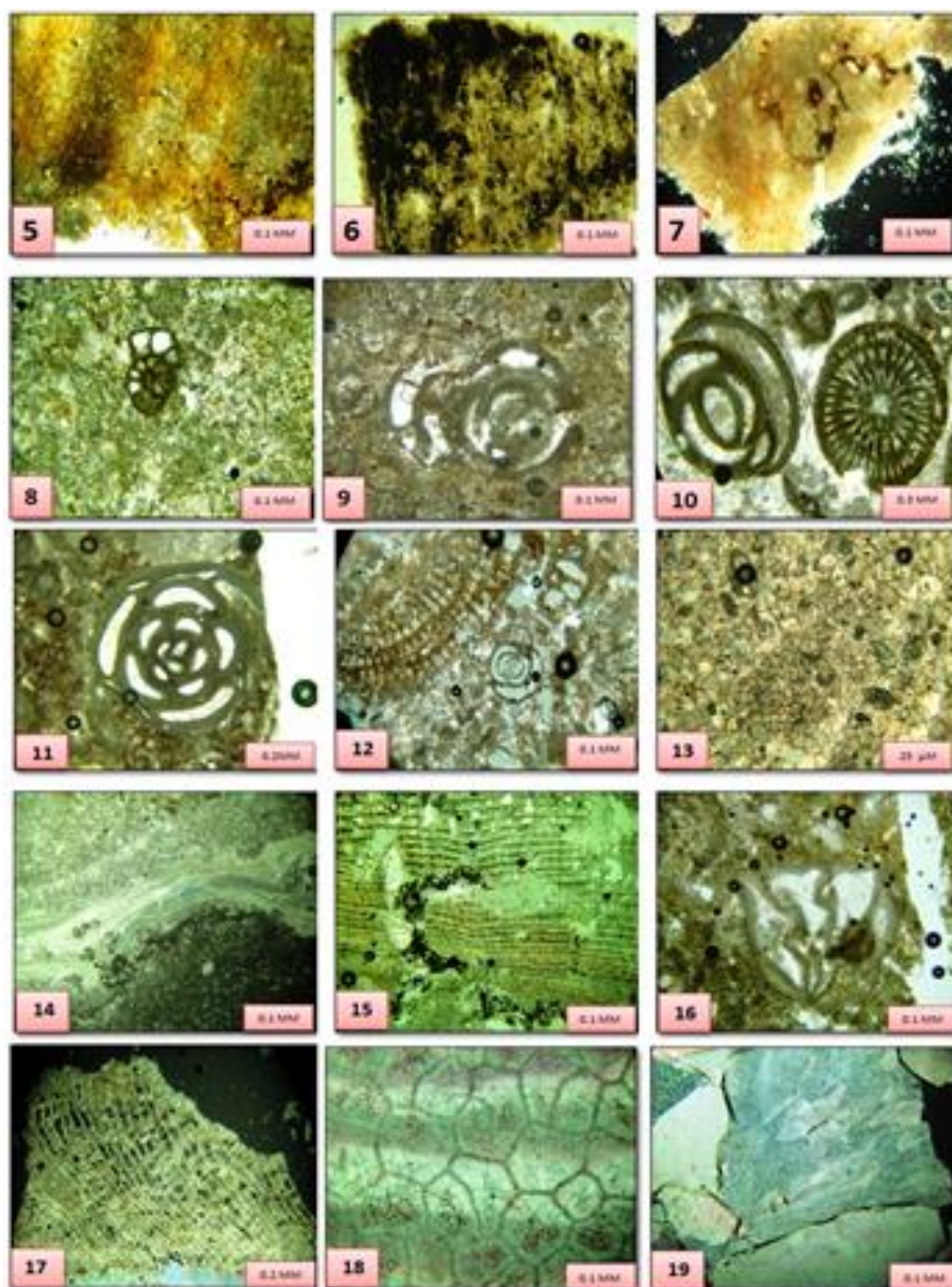
5-6-a. Evaporate-Lithofacies (CAP)

This lithofacies in core description represent by anhydrite (CAP) facies at the bottom of Kifil Formation core consists from large crystals or nodules of evaporites. It is very important bed represent Mishrif reservoir cap rock (Figure 18).

5-6-b. Dolomitized Limestone Lithofacies- This lithofacies consist from dolomite (Figure 19) white color with large crystal of calcite [13]. This lithofacies completely without any fauna which is affected by

dolomitization and recrystallization is the dominant diagenesis affected by the limestone of the formation. According to Danhum Classification this lithofacies can be considered as dolomitized mudstone found at depths (2873-2874) thickness (2m) in (AM11) well. According to [10] this microfacies is similar to the standard Microfacies (SMF23) which deposited in (FZ9) in evaporate interior platform.





5: fogged mosaic Rudist Mudstone Submicrofacies (RM1) 6: Non-fossiliferous Mudstone Submicrofacies (MM2), 7: Benthonic Mudstone Submicrofacies (BM3), 8: Rudist and Benthonic Foraminifera Wackestone Submicrofacies (R-BW1), 9: Benthonic Wackestone Submicrofacies (BW2), 10: Rudist Packstone Submicrofacies (RP1), 11: Benthonic foraminifera in Milioid Packstone Submicrofacies (MP2) 12: microsparite in Benthic Packstone Submicrofacies (BP3) 13: sparite ground mass Rudist Grainstone Submicrofacies (RG1), 14: vascular Rudist Benthic Grainstone Submicrofacies (BG2), 15: Stromatolitic Rudist Bindstone Submicrofacies (SRB1), 16: Coral Bindstone (CB2), 17: Stromatolite Coral Boundstone Submicrofacies (SCB3), 18: Chicken-Wire fabric in Kifl, 19: Crystalline Carbonate in Kifl formation.

Depositional environment of Mishrif and Kifl formation

The Mishrif formation started at the contact with Rumaila formation with mudstone microfacies which represent deposition in quiet and low energy environment. Thick succession of wackestone microfacies represent change in energy and deeper environment ending with stromatolite and coral grainstone and bounstone microfacies deposited in back reef and reef and fore reef environments then another cycle started till the end of the formation at the contact with Kifl formation.

The principle sedimentary microfacies of Mishrif formation in Amar Oil field was a Rimmed platform model summarized in open marine, restricted, shoals platform margin, and reef environment. Kifl formation deposited in restricted and evaporitic

environment depending on the litho- and microfacies analysis.

From core description and log diagnosis notable (2 m) in (2873) from massive anhydride and (5m) from limestone in (evaporate- mudstone Microfacies) at the depth (2873) until the beginning of the (AM) unit in (2880m) the study suggest it belong to Kifl formation.

According to [8] Kifl formation located supersequence V with unconformity and overlies Mishrif formation in supersequence IV, [14] it occurs in numerous wells in central and southern Iraq comprises of massive anhydrites and argillaceous limestone .

In addition the microfacies analysis clear up the unconformity in palaeoenvironment between evaporate Microfacies that located in (FZ9 at evaporitic environment) and mudstone Benthic Grainstone Submicrofacies (BG2) in (FZ 7 in open marine environment) the last represent the top of the (MA) reservoir unit the first reservoir unit in the Mishrif formation .

As pointed [15] anhydrites indicate extremist restriction and have been explain as near coastal muds deposited along the western of Mishrif basin in the Nasirya and Gharraf oil fields [16].

This research stresses continuity the restricted microfacies in the Amara field .The restricted shelf facies (anhydrite) in the top of Mishrif formation were probably deposited during the late K140 HST and lowstand prior to the K150 MFS, This uppermost unit probably represents a highly restricted environment and may be a lateral equivalent of Kifl formation [16].

These may correspond to the anomalous facies in the upper most Mishrif formation [1,17,18] note interval within the occur Mishrif formation in well Rumaila-36 (Rumaila field) [16].

Facies models in Mishrif formation

To build 3D model the facies model requires two key steps:

1- The facies analysis (such as facies characteristics and direction trend should be explained by sedimentological description).

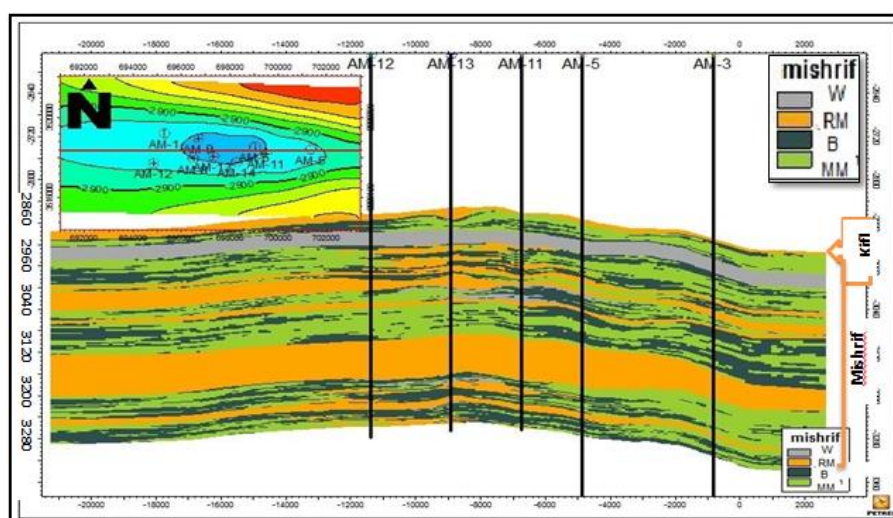
2- Application and placement this data on should be correlations of the simulation model. This model could be used for quality control and development plans [19] .

In the current study using algorithm Truncated Gaussian with trends for 2D,3D Geological Model for Mishrif formation in figures (20, 21) that was built depending on the results of the microfacies analyses and interpretation of sedimentary environments thin section , core description and log interpretation for five wells in the study area and geological reports in the petrel software[20]

From figure (2) produced units in the Mishrif formation are set at open marine , platform-margin environment consists of Grainstone, Packstone facies. The barriers unit are located in the restricted environment consist of mudstone and wackestone facies .

From the 2D,3D Models noted the distance between AM12 to AM3 reached to (10.5 KM), The reef center located between (AM11, AM5) wells by the construction reef facies. The depocenter of the sedimentary basin specific in (AM5) well due to the general increase in facies thickening, and decreasing in facies thickness toward east in (AM3) well (fore reef environment) , Also note a decrease in thickness in back reef facies in towards the west in (AM11, AM13 ,AM9 , AM12) wells.

The facies pattern in the well study have a retrograde sequence start for beep facies environment (reef , platform margin) to (open marine, Restricted) shallow up which accompanied by an increase in grain size to up forming by progradation sea pattern .



Figure(20)2D Facies models of Mishrif and Kifl formations the W:BP3,MM2,SCB4,CB3,RP1,RW2, Submicrofacies sequence . RM: RW1, RM3,RG1 submicrofacies B: SRB1,CB3,SCB1 submicrofacies and MM:MP2,MM2 submicrofacies .

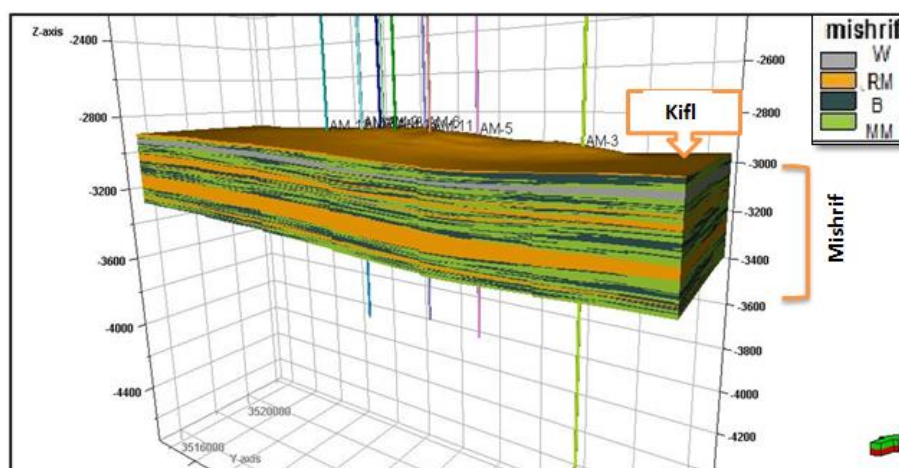


Figure (21) 3D Facies models of Mishrif and Kifl formations When the W:BP3,MM2,SCB4,CB3,RP1,RW2, Submicrofacies sequence . RM: RW1,RM3,RG1 submicrofacies B: SRB1,CB3,SCB1 submicrofacies and MM:MP2,MM2 submicrofacies .

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التحليل السحني لتكويني المشرف و الكفل في حقل العمارة النفطية/ جنوب العراق

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الملخص

بينت الدراسات الصخرية والبتروغرافية لتكويني مشرف وكفل في حقل العمارة النفطية للآبار (AM11,AM9,AM5) جنوب العراق ان تكوين المشرف يتألف بصورة اساسية من صخور الحجر الجيري والحجر الجيري الدولومائي بينما يتألف تكوين الكفل من المتبخرات والحجر الجيري الطيني وتخلو صخور التكوين من الحبيبات الهيكلية وغير الهيكلية. تتكون الحبيبات الهيكلية لتكوين المشرف من القاعيات البحرية متمثلة الرودست, الفورمنيغيرا, المرجان, المستروماتولات, الطحالب, الاوستراكودا, والكاستروبودا ويندر ظهور الحبيبات غير الهيكلية في التكوين وظهرت المعادن موضعية النشأة من البايارات وأكاسيد الحديد. يتألف.

بين تحليل السحنات الدقيقة لتكوين المشرف انه يتألف من سحنات الحجر الجيري الطيني, الحجر الواكي, والحجر المرصوص, والحجر الجيري الحبيبي والحجر الجيري المترابط الدقيقة التي ترسبت في بيئات الحيد, البحر المفتوح, والبيئة اللاكونية والساحلية. تأثرت صخور التكوين بالعمليات التحويرية مثل الازابة, الدلمة وإعادة التبلور. اما تكوين الكفل فقد تم تقسيمه الى سحنتين صخريتين هما سحنتي المتبخرات وسحنة الحجر الجيري الطيني الدقيقة فقط المترسبة في البيئة المنعزلة والتي تمثل صخور الغطاء لتكوين المشرف المتأثرة بعمليات إعادة التبلور فقط .

يتصف سطح التماس العلوي لتكوين المشرف بكونه متدرج و متوافق مع تكوين الكفل بدلالة التدرج البيئي والصخاري من سحنات الحجر الجيري الطيني الى سحنة المتبخرات والتي تمثل صخور الغطاء لخزان المشرف. في هذه الدراسة تم اعتبار صخور المتبخرات والحجر الجيري الطيني الذي يعلو تكوين المشرف عائدة لتكوين الكفل و يبلغ سمكه حوالي 7 متر في حقل العمارة قيد الدراسة.