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Sedimentary Basin Reconstruction and Tectonic Development of Paleocene-Eocene Succession, Southern Iraq, by Geohistory Analysis

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Abstract

The Paleocene-Early Eocene sequence is represented by Aliji and Umm Er Radhuma formations, while the Middle-Late Eocene sequence is represented by Jaddala and Dammam formations. The Rus Formation has been described and its basin was analyzed separately because it was deposited during the regression period (Middle Eocene), which is a transitional period between these two cycles.

This study includes analysis of the geohistory of this succession, interpretation of the changes of the accumulation, and calculation of subsidence rates. The results were compared with the space available to explain the basin development. The study site included the boreholes of Garraf-84 and 92, Halfaya-1, Nasirya-13 and 40, and Noor-5 at the Mesopotamian Block, in addition to the Ratawi-8, Tuba-15, Rumaila-217, Zubair-45, and West Qurna-60 at the Basra Block.

The Aliji basin was characterized by the decrease in accommodation values to the northeast direction and the increase in all the other parts of the study area. A comparison of the setting of this basin with the Umm Er Radhuma basin gives a clear evidence of the tectonic impact coming from the northeast. During the Middle Eocene stage, we notice that the basin was affected by comprehensive uplifting processes. This led to the generation of a very shallow basin (Rus basin) with the exposure of the northern part of the basin during the regression stage.

The Middle-Late Eocene basin is represented by a transgression stage with high subsidence, where the sea level had been raised and covered the northeastern and eastern parts of the studied area by deep sea deposits (Jaddala Formation). While the other parts of the study area were characterized by shallow sediments of Dammam Formation. This period ended with a clear tectonic uplift occurring in the northeastern parts and decreasing towards the southwest. This confirms the reactivation of the tectonic action from the northeast, represented by the continental collision.

All these sources of evidence indicate that the study area is divided into a northern part and a southern part. Both of these parts are separated by a major tectonic lineament extending from the West Qurna oil field to the Nasiriya oil field, which confirms the presence of the tectonic boundary between the Mesopotamian block and the Basra block. In addition, there exists a secondary tectonic boundary that divides the Mesopotamian block into two parts, the first is to the east and the other is to the west. The results showed that the eastern side was most affected by the collision of the Iranian Plate with the Arabian Plate, which led to its uplift, while the western side was less affected by this tectonics evidence.

Keywords: - Basin Reconstruction, Tectonic Development, Paleocene-Eocene, Geohistory analysis, Southern Iraq

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إعادة بناء الحوض الرسوبي والتطور التكتوني لتتابع باليوسين – الإيوسين من خلال تحليل التأريخ الجيولوجي ، جنوب العراق

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الخلاصة

يتمثل تتابع لعصر الباليوسيني–الأيوسيني المبكر بتكوينات عليجي وأم ارضمة ، وتتابع الإيوسين الأوسط المتأخر الذي يتمثل بتكوينات جدالة والدمام. تم وصف تكوين الرص وتحليل حوضه بشكل منفصل لأنه تم ترسيبه خلال فترة التراجع البحري خلال الأيوسين الأوسط والتي هي فترة انتقالية بين هاتين الدورتين.

تضمنت هذه الدراسة تحليل التأريخ الجيولوجي لهذه التتابعات وتفسير التغيرات في معدلات الترسيب والتجلس ومقارنتها بحيز الترسيب المتاح لتفسير تطور الحوض ، في بئر الغراف 84 و 92 وحلفايا 1 والناصرية 13 و 40 و نور 5 في كتلة بلاد ما بين النهرين ، بينما رطاوي 8 و طوبا 15 و الرميلة 217 و الزبير 45 وغرب القرنة 60 في كتلة البصرة.

تميز حوض العليجي بانخفاض قيم حيز الترسيب المتاح في اتجاه الشمال الشرقي وزيادة في جميع الأجزاء الأخرى من منطقة الدراسة. تعطي مقارنة موقع هذا الحوض مع حوض أم ارضمة دليلاً واضحًا على التأثير التكتوني القادم من الشمال الشرقي. خلال مرحلة العصر الأيوسيني الأوسط ، نلاحظ أن الحوض قد تأثر بعمليات الرفع الشاملة. أدى ذلك إلى تكوين حوض ضحل جدًا (حوض الرص) مع انكشاف الجزء الشمالي من الحوض خلال مرحلة التراجع البحري.

يمثل حوض العصر الأيوسيني الأوسط الى المتأخر مرحلة تقدم بحري مع تجلس عالي، حيث ارتفع مستوى سطح البحر وغطى الأجزاء الشمالية الشرقية والشرقية من المنطقة المدروسة بواسطة رواسب أعماق البحار (تكوين جدالة). بينما تميزت أجزاء أخرى من منطقة الدراسة برواسب ضحلة لتكوين الدمام. انتهت هذه الفترة بارتفاع تكتوني واضح حدث في الأجزاء الشمالية الشرقية وانخفض باتجاه الجنوب الغربي. هذا يؤكد إعادة تنشيط الحركة التكتونية من الشمال الشرقي ، ممثلة بالاصطدام القاري.

كل هذه الأدلة تشير إلى أن منطقة الدراسة مقسمة إلى قسم شمالي وجنوبي. كلا الجزأين مفصولين بخط تكتوني رئيسي يمتد من حقل نفط غرب القرنة إلى حقل نفط الناصرية ، مما يؤكد وجود الحدود التكتونية بين كتلة بلاد ما بين النهرين وكتلة البصرة. بالإضافة إلى وجود حد تكتوني ثانوي يقسم كتلة بلاد ما بين النهرين إلى قسمين ، الأول يقع إلى الشرق والآخر للغرب. وأظهرت النتائج أن الجانب الشرقي كان الأكثر تأثرا من اصطدام الصفيحة الإيرانية مع الصفيحة العربية مما أدى إلى رفعها ، بينما كان الجانب الغربي أقل تأثرا بهذا الفعل التكتوني.

1. Introduction

The Middle Palaeocene-Eocene represents the Arabian Plate Megasequence 10 (AP10) which deposited during a period of renewed subduction and volcanic arc island activity associated with final closure of the Neo-Tethys Ocean. This led to uplift along the northeast margin of the Arabian Plate with the formation of ridges and basins, generally of NW-SE trend in Northern and Central Iraq and East-West trend in Western Iraq [1].

The Paleocene-Eocene succession in the southern part of Iraq has been an unconformity overlaid with Cretaceous succession. While the upper contact of this succession was an unconformity in the Latest Eocene [2].

The Middle Palaeocene-Eocene Megasequence (AP10) was divided into two sequences by regional unconformity presence during the Middle Eocene. These sequences are the Palaeocene-Early Eocene sequence and Middle-Late Eocene sequence [2, 1]. The Palaeocene-Early Eocene sequence in the studied area consists of three formations, which are Aliji, Umm Er Radhuma, and Rus formations. The Middle-Late Eocene sequence consists of two formations, namely Jaddala and Dammam formations.

The area of study is located within the southern part of the Mesopotamian Zone in the south of Iraq

(Figure-1). The studied boreholes are distributed upon the tectonic division as follows: the boreholes of Garraf-84 and 92, Halfaya-1, Nasirya-13 and 40, and Noor-5 at the Mesopotamian Block, in addition to Ratawi-8, Tuba-15, Rumaila-217, Zubair-45, and West Qurna-60 at the Basra Block.

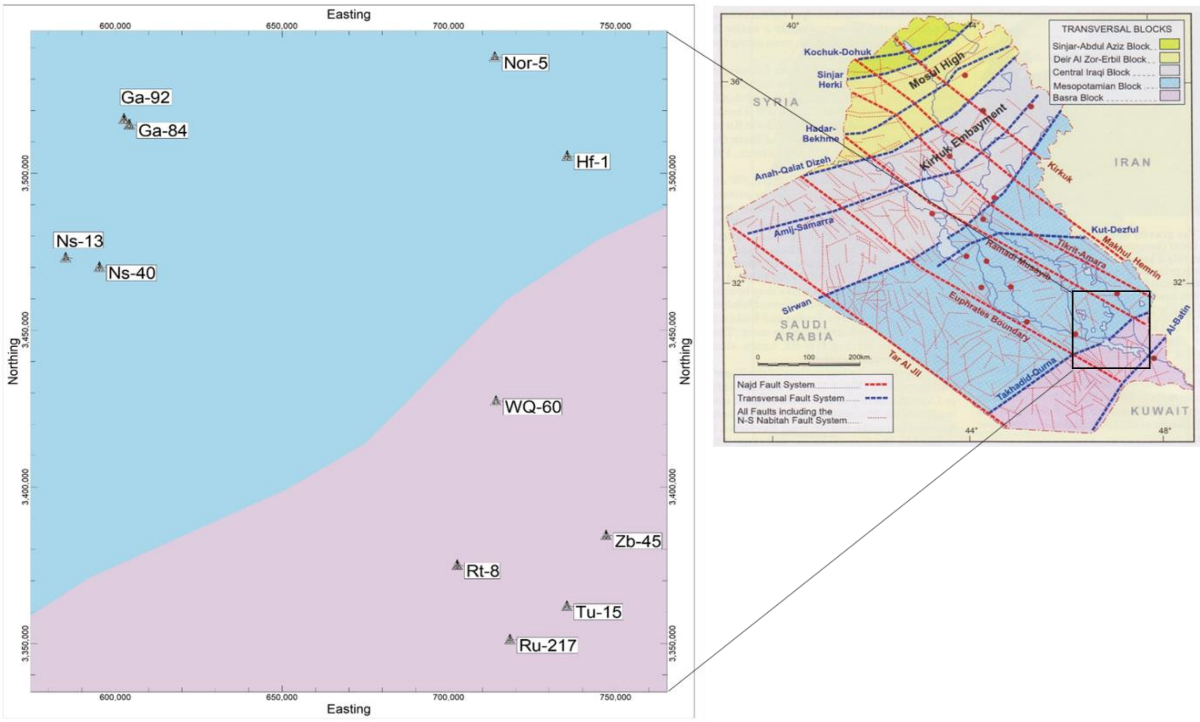


Figure -1 Location map of the studied area showing the tectonic subdivisions, according to [3].

The aim of this study is to interpret the Paleocene - Eocene basin development through a geohistory analysis. The initial thickness and subsidence analysis were used to find the changes in accommodation and, consequently, their effects on sequence development.

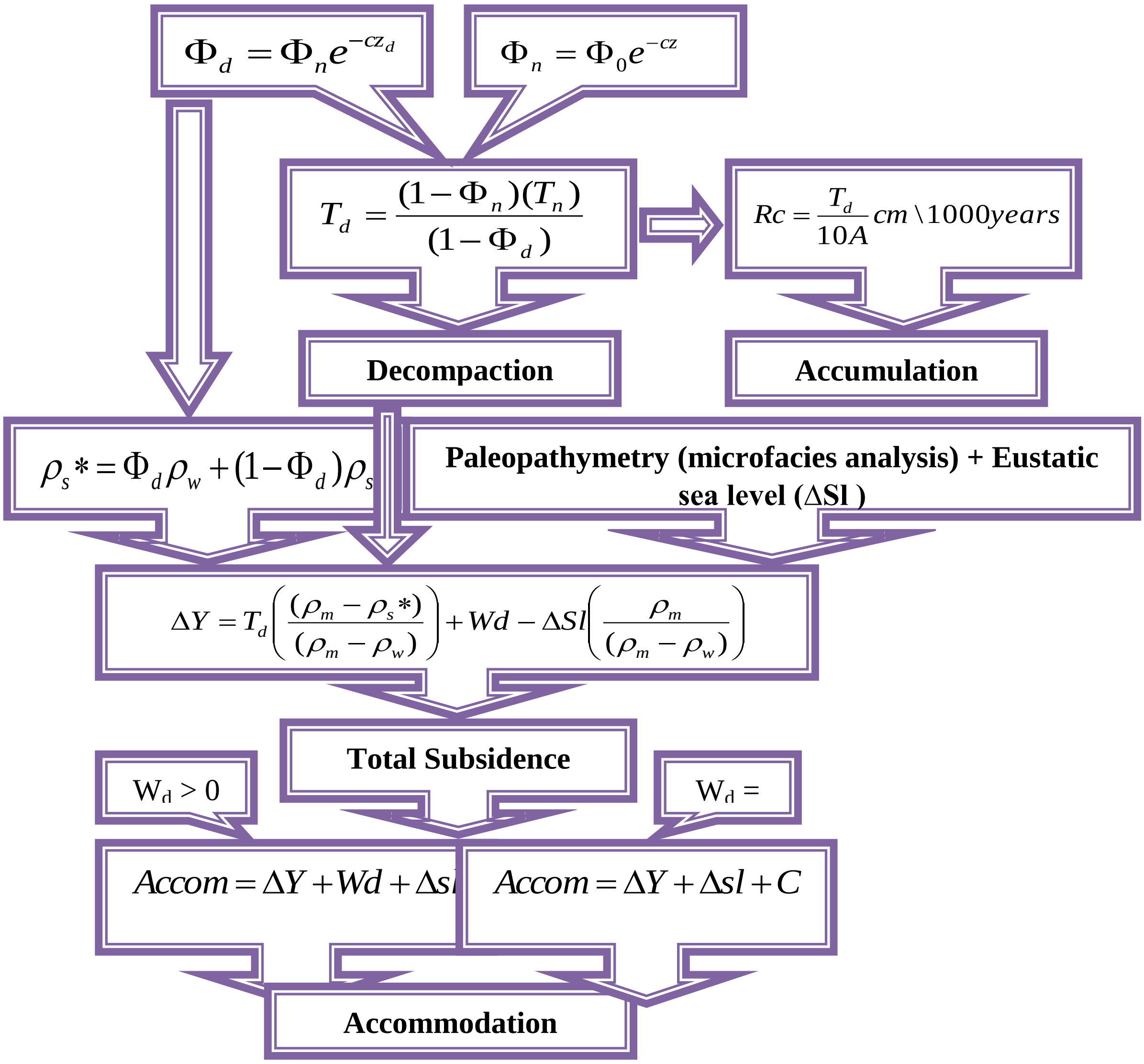
A sedimentary basin consists of strata of different lithologies deposited in different time intervals. The main data in the burial history are, therefore, the thickness and the lithology of each layer and the time of the horizons separating the layers. A horizon is taken to be a surface in the basin of a particular time, and the precise term is, therefore, chronohorizon. There is an extensive nomenclature for stratigraphic classification, but here we will not need more terms than those of horizon and formation. A formation is here simply the layer between two consecutive horizons [4].

A burial history usually has breaks or gaps in the stratigraphical record, either because of lack of deposition or because of erosion. Such a gap in a sequence of sedimentary rocks is a hiatus, and an erosion process can partly or completely remove several layers. It is often difficult to reconstruct what has been eroded; especially, regional erosion processes make it difficult to find places where thickness information is preserved [4].

The purpose of geohistory analysis (restoration of the initial thickness) is to calculate and remove the effects of load compaction, sediment loading, changes in paleobathymetry, and sea level changes. When backstripping is combined with the search for information on the development of the depositional system, the term geohistory analysis (or burial history) is commonly used [5].

2. Materials and requirements of geohistory analysis

Several types of stratigraphic and tectonic data are needed to conduct geohistory and definition of subsidence analyses. These data include stratigraphic units showing the present-day thickness for the studied succession, extracted from the geological final reports and previous studies of the studied oil fields. Information about the types of lithologies, ages of units, and estimated paleo-water depths were collected from the geological studies for the stratigraphic sequence of Iraq. In addition, there are several assumptions and uncertainties that are built into this analysis. Most of these problems can be overcome if thick stratigraphic sections of relatively shallow-water deposits are used and only long-term, larg-scale changes are studied [6]. The flow diagram (Figure-2) shows the steps of the geohistory analysis. For further discussion see, e.g., [7- 16].



Φ_n is new porosity (compacted porosity), Φ_0 is the porosity when (Z = 0) (surface porosity), c is coefficient, where Φ_0 and c values are, respectively, as follows: for shale 0.5, =5*10-4; sandstone 0.4, $3*10^{-4}$; limestone (grainstone,reef) 0.4, $3*10^{-4}$ and other limestone=0.5, $5*10^{-4}$.

Φ_d is the decompacted porosity, Z is depth of burial,

T_d is decompacted thickness (m), Tn is initial thickness (m),

W_d is paleodepth water (m), ΔSl is changes in sea level (m),

ρ_m is mantle density (2.8 $g.cm^{-3}$), ρ_w is water density (1.04 $g.cm^{-3}$), ρ_{s*} is corrected sediments density,

ρ_s is uncorrected sediments density (Sand 2.65, lime 2.71, shale 2.72, and evaporate 2.97 $g.cm^{-3}$)

Figure -2 Procedure diagram showing the steps and equations of the geohistory and subsidence analyses [17]

According to Sharland [2], in the Paleocene - Eocene succession, the lower boundary represented the end Cretaceous collusion, that is the ophiolite obduction and tectonics on the northern Arabian

plate margin. The upper boundary is synchronous with the Red Sea rifting and collusion of the Arabian continent and Eurasia [18]. The uplift in the Zagros Mountains caused a shifting in the southwest facies belts and a closure of the Neo-Tethys [19,20,21].
In the Early Paleocene, basinal facies, which were established by marine flooding over the foreland wide area-in the late Paleocene to early Eocene carbonate - evaporite sequence (Dammam, Jaddala, Rus, Umm Er Radhuma, and Aailiji formations) (Figure-3), were deposited in shallow and fore deep environment, during events of rapid erosion, lowering , and subsidency of the ophiolite sedimentary structures along the eastern margin of the Arabian Plate .
During subduction, volcanic arc activity associated with closure Neo- Tethes in the middle Plaeocen – Eocene were deposited, represented by Aaliji and Jaddala formations and a major transgression caused basinal deep. Dammam, Um Er Radhuma and Rus formations represent shallow open marine environment, reflecting a fluctuating and flooding surface (mfs). These are determined by marls rich with planktonic foraminifera of late Paleocene age and bounded by deep or basin facies of TST [2]. High frequency regression with high eustatic sea level occurred during the early Paleocene to late Eocene [22]. In the late Eocene, the sea regressed with unconformity, causing the absence of deposits over the area.

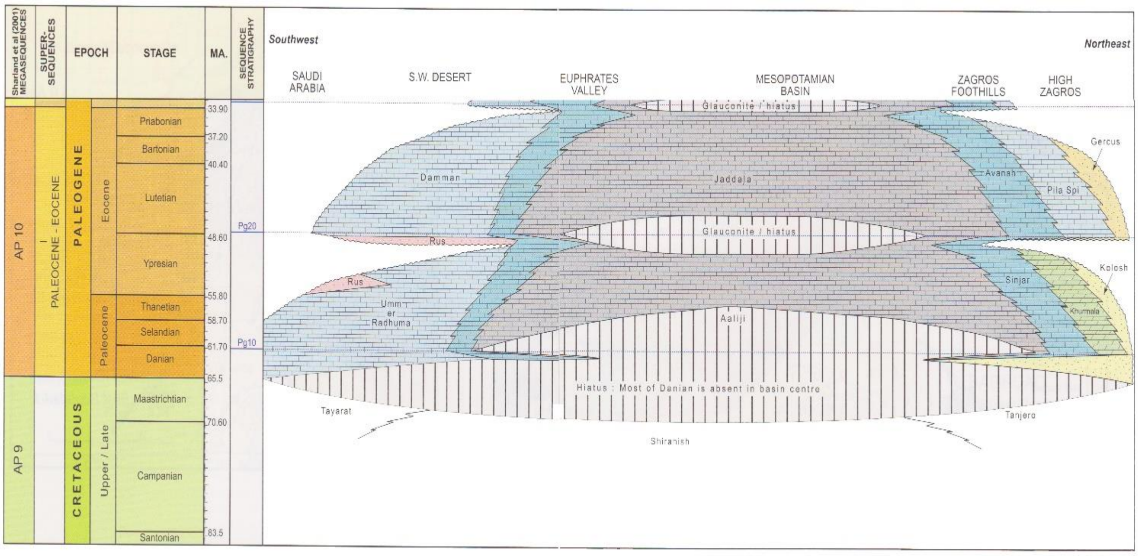


Figure 3-Chronostratigraphic section of Paleocene – Eocene succession in Iraq, Modified after Bellen *et al*. 1956 and 1958 by [23]

The Aliji Formation is widespread in the Foothill and Mesopotamian zones in Iraq (Figure- 3). It was introduced by Bellen in 1950 [24] from the type locality in northwestern Syria. The supplementary type section for Iraq was introduced in well Kirkuk-109 of the Foothill Zone [24], which comprises grey and light brown argillaceous marl, argillaceous limestone, and shale with occasional microscopic fragments of chert and rare scattered glauconite. Silty and sandy beds occur towards the north and northeast, where the formation gradually passes into the clastic Kolosh Formation. Towards the southeast and west, the formation is composed predominantly of limy globigerinal mudstone. Chalky and argillaceous limestone beds occur where the formation passes laterally into the Umm Er Radhuma Formation.

The Umm Er Radhuma Formation was described by Steineke and Bramkamp in 1952 [24] from the type locality at the Umm Er Radhuma wells in Saudi Arabia. A supplementary type section for Iraq was introduced by Owen and Nasr [25] in well Zubair 3 southern Iraq, which comprises anhydrite and white to buff dolomitic microcrystalline porous limestone; chert occurs in the upper part.
The Rus Formation was first defined by Bramkamp in 1964 [24] from the type section on the SE flank of the Dammam dome in Eastern Saudi Arabia. A supplementary type section was introduced by Owen and Nasr [25] in well Zubair-3 in the Mesopotamian Zone of Southern Iraq, where the formation consists predominantly of anhydrite with some unfossiliferous limestone, blue shale, and marl.

The Rus Formation represents the oldest recognized formation in the borehole. It is dominated by dolomite, marl, and gypsum with 14.1 m thick (drilling depth 115.9 – 130 m). This formation is not exposed on the surface, but it is encountered in most subsurface wells of south and southwest Iraq [26]. While in the central part of Iraq, it consists mainly of evaporites and subordinate carbonates. The evaporites are characterized by nodular structure (compound wispy, wispy, structureless, and mosaic structures) with some laminated structures [27].

The Jaddala Formation (Late Lower Eocene to Upper Eocene) is unconformably underlying the Oligocene succession and unconformably overlying the cretaceous succession. This formation was described first by Henson in 1940 [24] as consisting of marly and microporous (chalky) limestone and marl with occasional thin intercalations of oolitic, peloidal grainstone. This Formation does not belong to the Oligocene succession, but it is important to understand the depositional and tectonic settings for the Palani basin.

The Eocene sediments were deposited during the final phase of subduction and the closure of the remnant Neo-Tethys Ocean [1]. The Dammam Formation was first described by Bramkamp in 1941 from the Dammam dome in East Saudi Arabia [24] where it comprises limestones (chalky, organodetrital or dolomitic), dolomites, marls and shales; it was divided into five informal members. The total thickness of this formation is 150 m in Najaf area and decreases to the south of Iraq.
Owen and Nasr, 1958, described the supplementary type section in well Zubair-3 of the Mesopotamian Zone. The Dammam Formation consists mainly of neritic shoal limestones often recrystallised and/or dolomitised, nummulitic in the lower part and milliolids-bearing in the upper part [1].
Figure-4 shows the studied succession distribution and thickness in two lithologic sections.

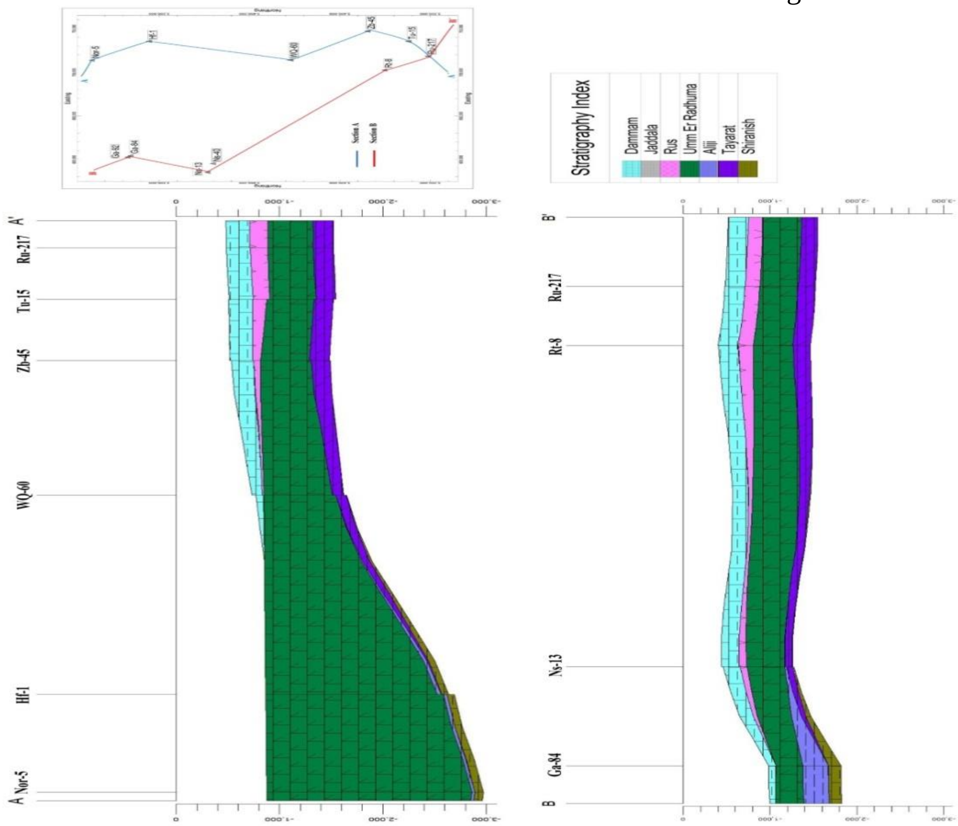


Figure 4-The distribution and thickness of Paleocene - Eocene succession in two lithologic sections

3. Basin Reconstruction and Analysis

After the application of the geohistory procedure, the decompacted thickness values were reconstructed as a real thickness distribution and the hiatus time (eroded units) was recalculated for the Rupelian (Early Oligocene) succession (Table-1, Figure-5).

Table -1 Backstripping and decompacted (restored) present thickness of the studied succession in well Nasiriya-40.

Formation	Depth (m)	Present thicknes s (m)	Initial thickness and porosity (restored)									
Dibdiba	0	0	T=0									
			Ø=0									
Injana	305	305	T=318.1m									
			Ø=0.47									
Fatha	387	82	84.30	T=84.60m								
			0.13	Ø= 0.15								
Jeribe	434	47	54.83	57.43	T=58.05m							
			0.30	0.37	Ø= 0.40							
Ghar	434	0	0	0	0	T=0 m						
			0.13	0.14	0.15	Ø= 0.15						
Kirkuk Group	434	0	0	0	0	0	T=0 m					
			0.35	0.38	0.40	0.4	Ø= 0.4					
Dammam	642	208	251.51	276.75	295.26	309.08	323.54	T=338.69m				
			2.27	0.34	0.36	0.37	0.37	Ø= 0.37				
Jaddala	642	0	0	0	0	0	0	0	T=0 m			
			0.32	0.40	0.42	0.43	0.43	0.43	Ø= 0.5			
Um Er Radhuma	709	67	71.45	74.34	76.73	78.84	81.00	83.23	83.57	T=83.91 m		
			0.09	0.12	0.12	0.13	0.13	0.13	0.15	Ø= 0.15		
Rus	1154	445	587.11	726.07	879.48	1051.90	1258.13	1504.79	1688.81	1895.33	T=2077.57 m	
			0.21	0.26	0.27	0.28	0.28	0.28	0.33	0.33	Ø= 0.34	
Aliji	1154	0	0	0	0	0	0	0	0	0	0	T=0 m
			0.22	0.28	0.29	0.30	0.30	0.3	0.35	0.35	0.37	Ø= 0.5

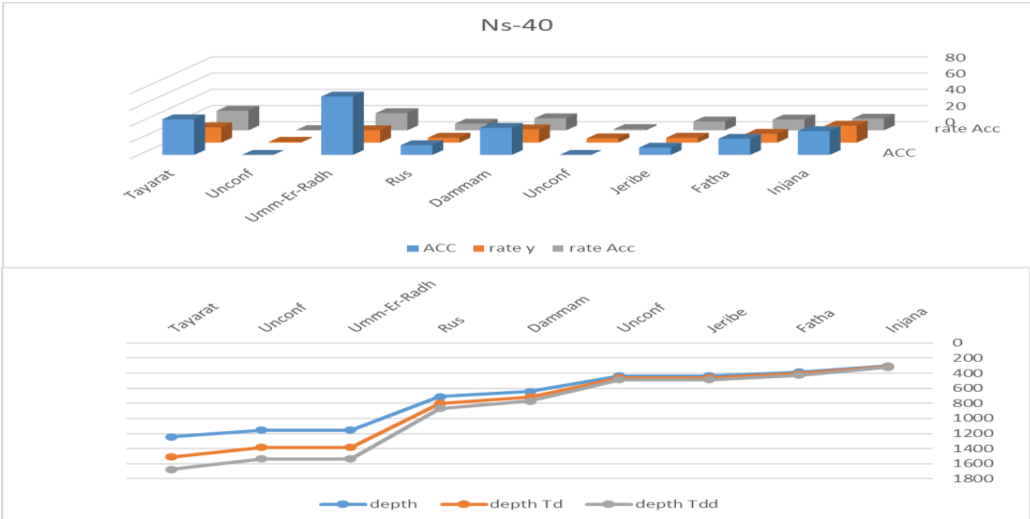


Figure -5 Geohistory curve showing the time – thickness relationship before and after the decompacted processing of the studied succession.

3.1 Paleocene – Early Eocene basin

The basin of the Paleocene – Early Eocene succession (Aliji and Umm Er Radhuma formations) is characterized by two main depocenters; the first is near Gharaf oil field to the north west of study area with decompacted thickness of about 930m, while the second is to the south east near West Qurna oil field with decompacted thickness of about 900m (Figure-6).

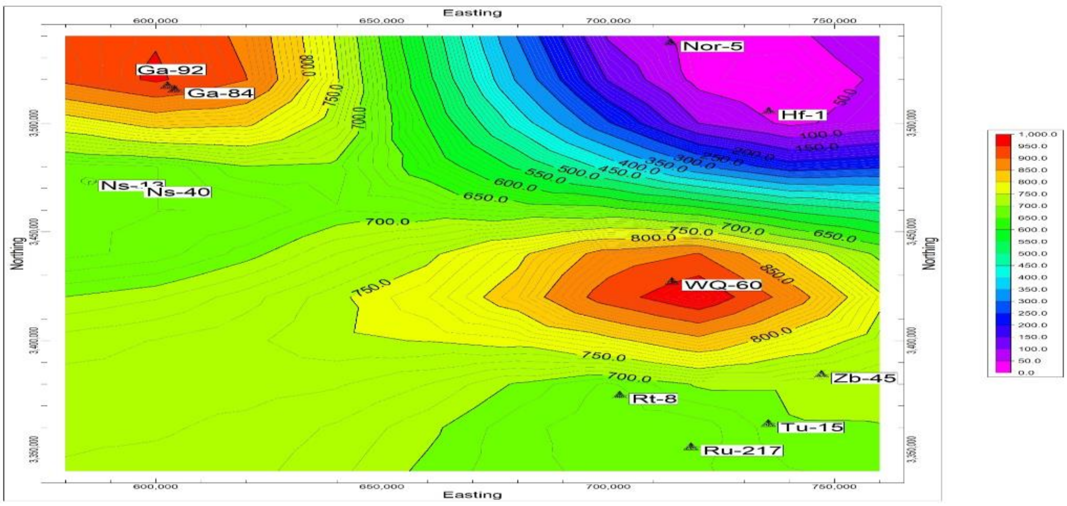


Figure -6 Decompacted isopach map for the Paleocene – Early Eocene succession showing the basin depocenters.

To determine the paleogeographic features for the Paleocene – Early Eocene basin, we must rebuild the Late Cretaceous basin by calculating the total subsidence with the rate of deposition and then the available space of deposition.

The total subsidence map for this succession shows that the northern and northeastern parts consist of an uplift area (Figure-7) near Noor and Halfaya oil fields. The high subsidence area appeared to the northwestern region in Gharaf oil field and near Tuba and Rumaila oil fields, in addition to West Qurna oil field. While the minimum values of subsidence are located in other regions. Therefore, the paleogeography for the Aliji and Umm Er Radhuma basin is represented by the ecologic accommodation.

The Aliji basin was characterized by the decrease in accommodation values to the northeast direction and their increase in all the other parts of the study area (Figure-8A). A comparison of the setting of this basin with the Umm Er Radhuma basin gives clear evidence of the tectonic impact coming from the northeast. Figure-(8B) shows the occurrence of a clear uplifting in the northern part of the study area in the Umm Er Radhuma Basin in general, and the uplifting of the northeastern part in particular.

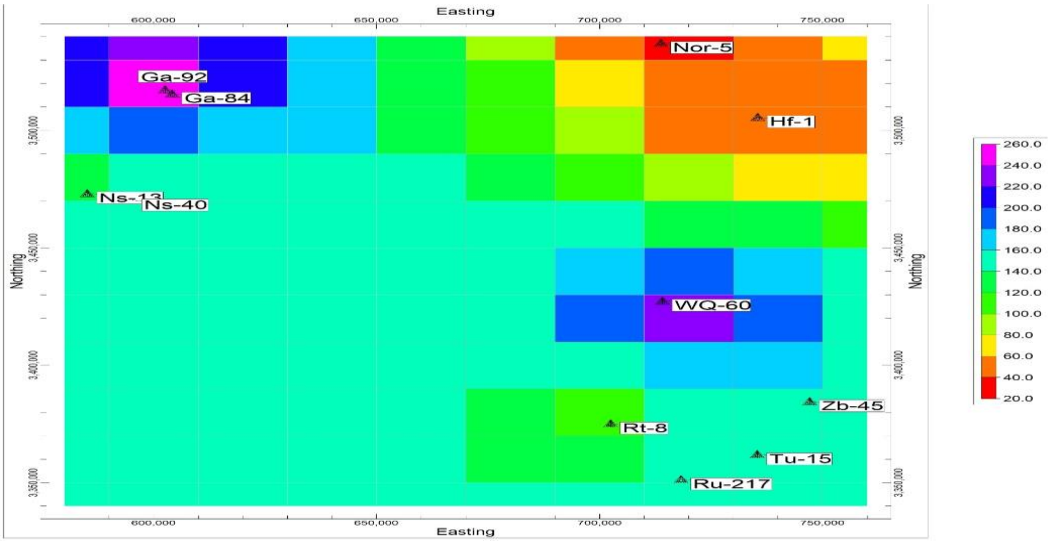


Figure 7-Total subsidence map for the Aliji and Umm Er Radhuma basin showing the high subsidence area (Purple) and the uplifted area (Red)

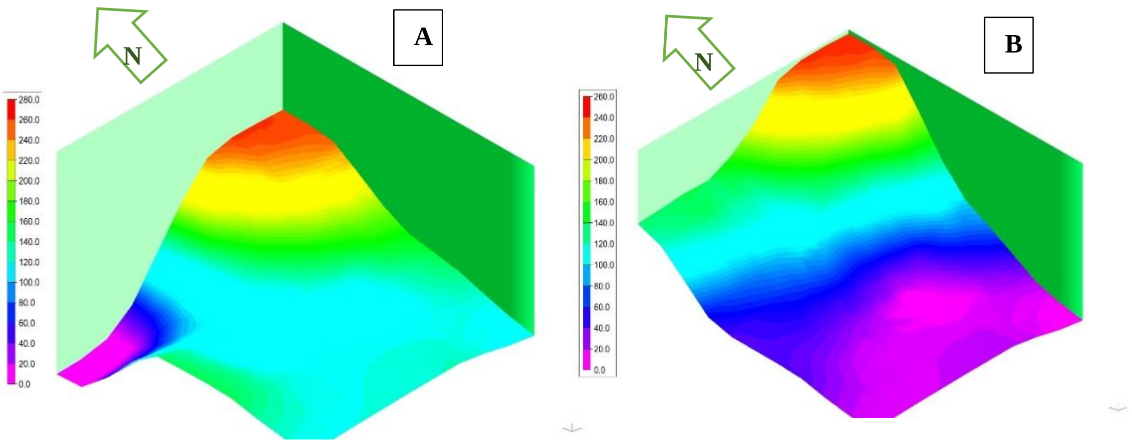


Figure 8- 3D paleogeography diagram (real accommodation) for the Aliji basin (A) and Umm Er Radhuma basin (B).

3.2 Early Eocene

The Late Ypresian Stage showed the beginning of the Rus deposition [24]. In the Early Eocene time, a local NW-SE trending basin was developed within the Umm Er Radhuma belt, extending from

Kifl in the NW to the Dammam structure in eastern Saudi Arabia in the South. This basin was filled by lagoonal evaporitic sediments of the Rus Formation [1].

Rus basin

The decompacted thickness of the Rus Formation demonstrated that its depositional basin is characterized by one huge depocenter that extends from Nasiriya oil field to southern Iraq. It is characterized by an initial thickness of about 120m in Nasiriya and the surrounding area, which increases to the south and southeast to 260m in Ratawi oil field (Figure-9), whereas it is missing to the northern part of the study area.

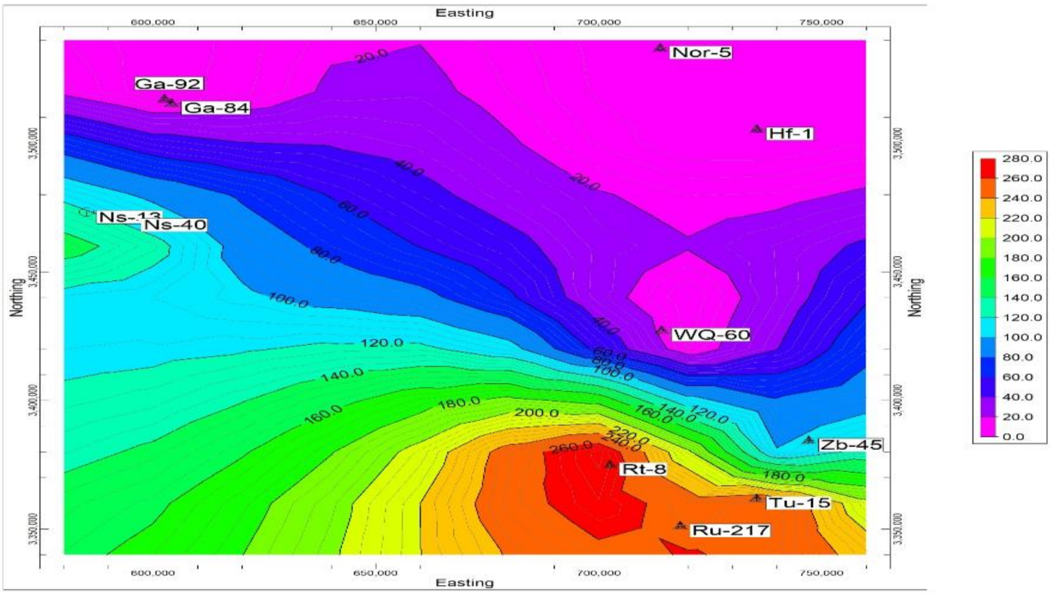


Figure -9 Decompacted isopach map for the studied area showing the Rus Formation thickness and depocenters.

The total tectonic subsidence map for Rus basin shows high subsidence values in Tuba and Rumaila oil fields, while moderate values are found in Ratawi, Zubair, West Qurna, and Nasiriya oil fields. The uplifted area appeared in the northern part of the studied area near Gharaf, Noor, and Halfaya oil field (Figure-10).

During this stage, we noticed that the basin was affected by a comprehensive uplifting processes (Figure-11) that led to the generation of a very shallow basin (Rus basin) with the exposure of the northern part of the basin during the regression stage.

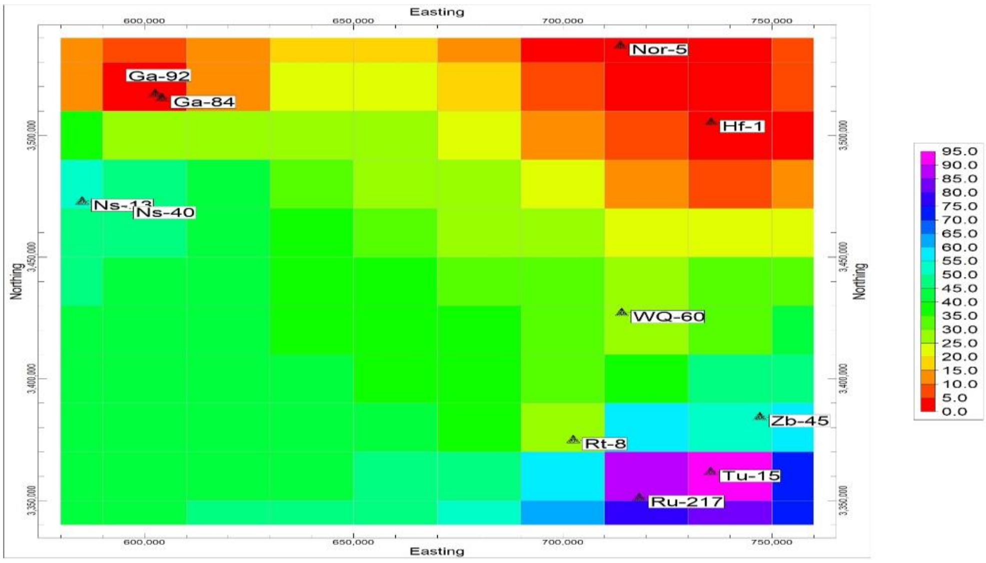


Figure 10-Total subsidence map for the Rus basin showing the high subsidence area (Purple) and the uplifted area (Red).

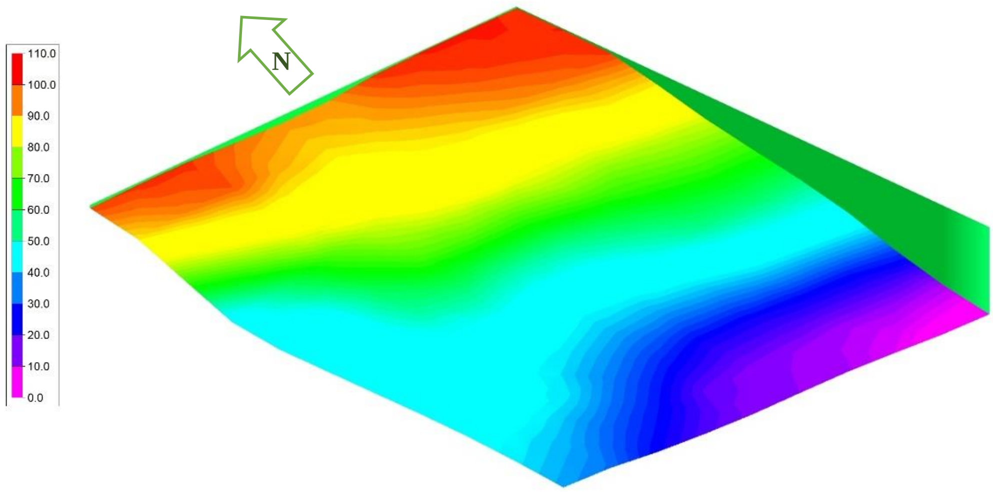


Figure 11-3D paleogeography diagram (real accommodation) for the Rus basin.

3.3 Middle-Late Eocene

The Lutetian – Priabonian stage represents the interval time for the deposition of the Jaddala and Umm Er Radhuma formations [1, 24].

The decompacted thickness map of this succession shows three main depocenters; the first depocenter is to the northeast near Halfaya oil field, the second is in the west of the study area near Nasiriya oil field, and the third is to the southeast near Tuba oil field (Figure-12).

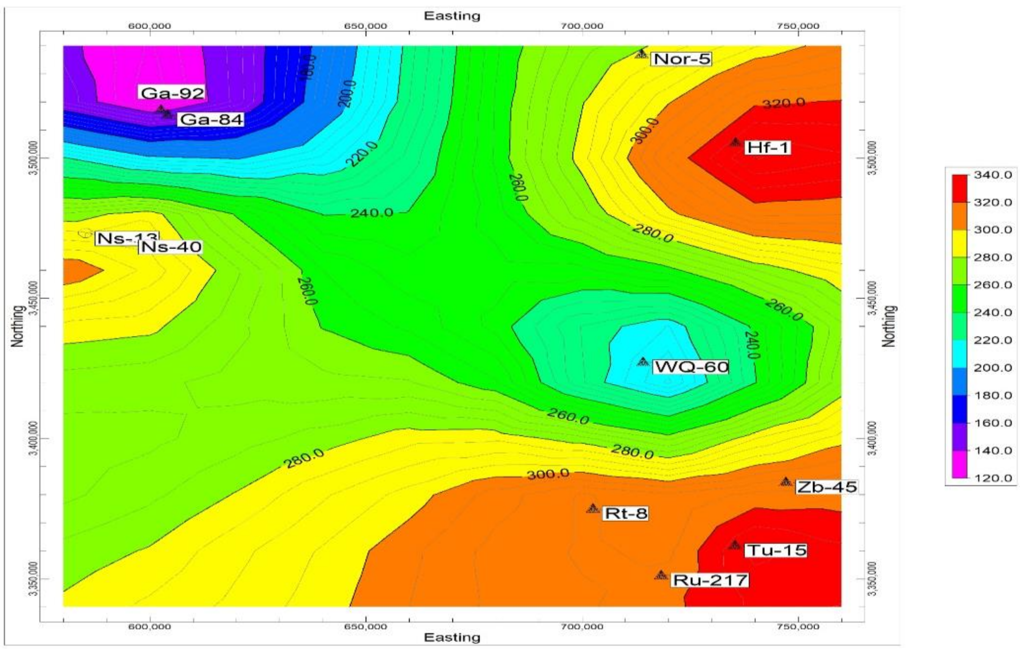


Figure -12 Decompacted isopach map for the studied area showing the Dammam and Jaddala thickness and depocenters.

The total tectonic subsidence distribution in the study area for this stage shows high subsidence values in Halfaya and Noor oil fields to the northeast and Tuba to the southeast. While moderate values appeared in the other studied oil fields, except West Qurna oil field which represents an uplifted area (Figure-13)

The first stage of this period is represented by a transgression stage with high subsidence, where the sea level has been raised and covered the northeastern and eastern parts of the study area by deep sea deposits (Jaddala Formation)(Figure-14A). While the other parts of the study area were characterized by shallow sediments of Dammam Formation (Figure-14B).

This period ended with a clear tectonic uplift occurring in the northeastern parts and decreasing towards the southwest. This confirms the reactivation of the tectonic action from the northeast, represented by the continental collision.

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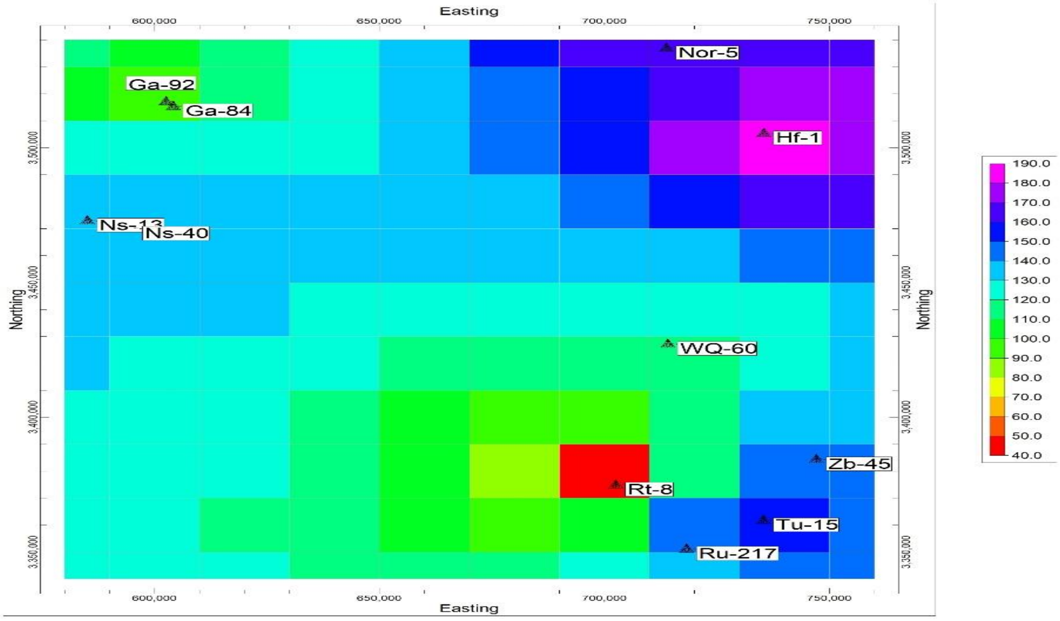

Figure -13 Total subsidence map for the Jaddala and Dammam basin showing the high subsidence area (Purple) and the uplifted area (Red)

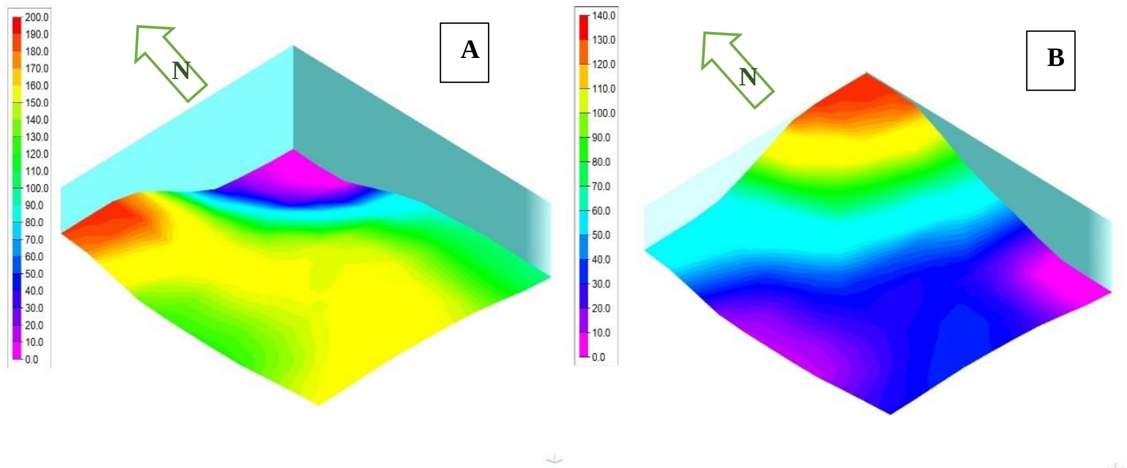

Figure -14 3D paleogeography diagram (real accommodation) for the Jaddala basin (A) and Dammam basin (B).

Conclusions

The Middle Paleocene-Eocene succession was divided into two sequences by the presence of regional unconformity during the Middle Eocene. These sequences are the Palaeocene-Early Eocene sequence, which represents Aliji and Umm Er Radhuma formations, and the Middle-Late Eocene sequence, which represents Jaddala and Dammam formations. The Rus Formation was described and its basin was analyzed separately because it was deposited during a regression period (Middle Eocene), which is a transitional period between these two cycles.

The basin of Aliji and Umm Er Radhuma succession during the Paleocene – Early Eocene is characterized by two main depocenters; the first is near Gharaf oil field to the north west of the study area and the second is to the south east near West Qurna oil field. The total values of subsidence for this basin demonstrated that the northern and northeastern parts of the study area, near Noor and Halfaya oil fields, were uplifted. Also, the high subsidence area appeared to the northwestern region in

Gharaf oil field and near Tuba and Rumaila oil fields, in addition to West Qurna oil field. While the minimum values of subsidence were found in the other regions.

The Rus basin is characterized by one huge depocenter that extends from Nasiriya oil field to southern Iraq. The total tectonic subsidence for Rus basin shows high subsidence values in Tuba and Rumaila oil fields, while moderate values are shown in Ratawi, Zubair, West Qurna, and Nasiriya oil fields. The uplifted area appeared in the northern part of the study area near Gharaf, Noor, and Halfaya oil field. During the Middle Eocene stage, we noticed that the basin was affected by comprehensive uplifting processes, that led to the generation of a very shallow basin (Rus basin) with the exposure of the northern part of the basin during the regression stage.

The Middle-Late Eocene basin is characterized by three main depocenters; the first is to the northeast near Halfaya oil field, the second is in the west of the study area near Nasiriya oil field, and the third is to the southeastern near Tuba oil field. The total tectonic subsidence distribution in the study area for this stage shows high subsidence values in Halfaya and Noor oil fields to the northeast and Tuba to the southeast. While moderate values appeared in the other studied oil fields, except West Qurna oil field which represents an uplifted area.

The first stage of this period is represented by a transgression stage with high subsidence, where the sea level has been raised and covered the northeastern and eastern parts of the study area by deep sea deposits (Jaddala Formation). While the other parts of the study area were characterized by shallow sediments for Dammam Formation. This period ended with a clear tectonic uplift occurring in the northeastern parts and decreasing towards the southwest. This confirms the reactivation of the tectonic action from the northeast, represented by the continental collision.

All these sources of evidence indicate that the study area is divided into two tectonic parts; the first is a northern part and the second is a southern part. Both of these parts are separated by a major tectonic lineament extending from the West Qurna oil field to the Nasiriya oil field, which confirms the presence of the tectonic boundary between the Mesopotamian block and the Basra block. We also recorded the presence of a secondary tectonic boundary that divides the Mesopotamian block into two parts, the first is to the east and the second is to the west. The results showed that the eastern side was most affected by the collision of the Iranian Plate with Arabian Plate, which led to its uplifting, while the western side was less affected by this tectonics evidence.

References

1. S. Z. Jassim and T. Buday, **2006**. “Middle Palaeocene-Eocene Megasequence”. In Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 341pp. 2006a.
2. P. R. Sharland, R. Archer, D. M. Casey, R. B. Davies, S. H. Hall, A.P. Heward, A. D. Horbury and M. D. Simmons, “ The chrono-sequence stratigraphy of the Arabian plate”. GeoArabia Spec Publ.
3. S. Z. Jassim and T. Buday. **2006**.“Tectonic Framework”. In Jassim, S.Z.and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 341pp. 2006b.
4. W. Magnus, **2010**. “Physical Principles of Sedimentary Basin Analysis”. Institute for Energy Technology, Norway. Cambridge University Press. The Edinburgh Building, Cambridge CB2 8RU, UK, p 545. 2010.
5. G. Einsels, **2000**. “Sedimentary basins: evolution, facies, and sediment budget”, 2nd ed. Springer, Berlin, p 792, 2000.
6. G. L. Angevine, P. L. Heller, and C. Paola. **1990**. (Eds) “Quantitative sedimentary basin modeling”. American Association of Petroleum Geologists, Continuing Education Course Note Series 32. 132 p., 1990.
7. J. E. Van Hint, **1978**. “Geohistory analysis—application of micropaleontology in exploration geology”. *Am Assoc Pet Geol Bull*, **62**: 201–222,1978.
8. M. S. Steckler, A. B. Watts, “Subsidence of the Atlantic type continental margine off New York”. *Earth Planet Sci Lett*, **42**: 1–13, 1978.
9. J. G. Sclater, P. A. F. Christie, “ Continental stretching: an explanation of the post-mid-Cretaceous subsidence of the central North Sea basin”. *J Geophys Res*, **85**: 3711–3739, 1980.
10. J. Hardenbol, P. R. Vail, J. Ferrer, “Interpreting paleoenvironments, subsidence history, and sea level changes of passive margins from seismics and biostratigraphy”. *Oceanol Acta*, **3**(suppl v):33–44,1981.

11. D. A. Falvey and I. Deighton, **1982**. “Recent advances in burial and thermal geohistory analysis”. *J Aust Petrol Explor Assoc*, **22**: 65–81, 1982.
12. F. M. Gradstein, F. P. Agterberg, J. C. Brower, W. S. Schwarzacher. **1985**. Quantitative stratigraphy. Reidel, Dordrecht, p 598,1985.
13. T. M. Guidish, C. G. Kendall, St C, I. Lerche, D. J. Toth, R. F. Yarzab. **1985**. “Basin evaluation using burial history calculations: an overview”. *Am Assoc Pet Geol Bull*, **69**(1):92–105, 1985.
14. B. Haq, J. Hardenbol, P. Vail. **1987**. “Chronology of fluctuating sea levels since the Triassic”. *Science*, **235**:1156–1167, 1987.
15. K. A. Hegarty, J. K. Weissel, J. C. Mutter, **1988**. “Subsidence history of Australia's southern margin”. *Am Assoc Pet Geol Bull*, **72**: 615–635,1988.
16. M. S. Steckler, A. B. Watts, J. A. Thorne, **1988**. “Subsidence and basin modeling at the U.S. Atlantic passive margin”. In: Sheridan RE, Grow JA (eds) The geology of North America, vol.112, The Atlantic continental margin. US Geol Soc Am, Boulder, pp 399–415, 1988.
A. A. H. Al-Zaidy, **2013**. “Geohistory analysis and basin development of the Neogene succession, NE Iraq”. Arabian Journal of Geosciences, **6**(7): 2483-2500. 2013.
17. Z. R. Beydoun, and H.V. Dunnington, **1975**. “*The Petroleum Geology and Resources of the Middle East*”. Scientific Press Limited, Beaconsfield, U.K., 99 p., 1975.
18. Z. R. Beydoun, **1991**. “Arabian Plate hydrocarbon geology and potential-A Plate Tectonic Approach”. Studies in Geology, American Association of Petroleum Geologists, Tulsa, Oklahoma, USA, publication 33,77p., 1991.
19. S. Alsharhan, and A. E. M. Nairn, **1977**. “Sedimentary Basins and Petroleum Geology of the Middle East”. Elsevier, Amsterdam, 811pp., 1997.
20. J. C. Goff, R. W. Jones and A. D. Horbury, **1995**. “Cenozoic basin evolution of the Northern part of the Arabian Plate and its control on hydrocarbon habitat”. In: Al-Husseini MI (ed) Middle East petroleum Geosciences GEO 94, vol 1. Gulf Petrolink, Bahrain, pp 402–412, 1995.
21. B. Haq, A. Al-Qahtani, **2005**. “Phanerozoic cycles of sea-level change on the Arabian Platform, Jurassic-Neogene Arabian Platform Cycle Chart”. *GeoArabia, Gulf PetroLink, Bahrain*, **10**(2): 127–160, 2005.
22. A. M. Aqrawi, J. C. Goff, A. D. Horbury and F. N. Sadooni, **2010**. “*The petroleum Geology of Iraq*”. Scientific Press Ltd., 424pp, 2010.
23. R. C. Van Bellen, H. V. Dunnington, R. Wetzel, and D. Morton, **1959**. “Lexique Stratigraphique Internal Asie. Iraq”. Intern. Geol. Conger. Comm. Stratigr, 3, Fasc. lOa, 333p., 1959.
24. R. M. S. Owen and S. N. Nasr, “The stratigraphy of the Kuwait-Basrah area, in: Weeks G. L.**1958**. (editor) Habitat of Oil a Symposium”. Am. Assoc. Petr. Geol., Tulsa. 1958.
25. H. A. J. Al-Hashimi and R. M. Amer,**1985**. “*Tertiary Microfacies of Iraq*”. DGGSMI. Baghdad. 56p., 1985.
26. M. Y. Tamar-Agha, S. Ad. Saleh, **2016**. “Petrology, Mineralogyand Diagenesis of the Rus and Jil Formations(l-Eocene)in Najif and Samawa areas, Southern Iraq”. Iraqi Journal of Science, **57**(2C): 1504-1520, 2016.
27. N. K. Al-Habeeb and T. A. Al-Shammary, **2015**. “Petrography & Mineralogy of the Dammam Formation in Al-Najaf Governorate”. *Iraqi Journal of Science*, **56**(3A): 2024-2037, 2015.