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The Planktonic Foraminiferal Biostratigraphy of the Palani Formation (Lower Oligocene) in Well K-218, Kirkuk Oilfield, Northeast Iraq

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ABSTRACT

Thirteen cutting samples were collected from the Palani Formation in the Baba Dome of the Kirkuk Oilfield area, well no. (K-218), northeastern Iraq. The thickness of the Palani Formation is 60 m, between the intervals (600-540m). The studied section is characterized by abundant, rich, good preservation, and diversified planktonic foraminifera assemblage fossils. Fourteen species related to three genera are identified, not showing marked differences in their foraminiferal content, they are: *Pseudohastigerina micra*, *Cassigerinella chipolensis*, *Globigerina tapuriensis*, *Globigerina gortanii*, *Globigerina ampliapertura*, *Globigerina sellii*, *Globigerina yeguaensis*, *Globigerina euoperura*, *Globigerina praebulliodes*, *Chiloguembelina cubensis*, *Globigerina angustiumbilicata*, *Globigerina prasaepis*, *Globigerina galavisi.* According to the stratigraphic ranges of identified species, two planktonic foraminiferal biozones are established; these are from the lower (oldest) to the upper (youngest) of the section:
Gassigerinella micra Interval Range Biozone (O1).
Globigerina ampliapetura Interval Range Biozone(O2).
These biozones are correlated and compared with different studies of similar ones in different parts of the world. The biostratigraphy study assigned the Early Oligocene (Rupelian) age of the Palani Formation in the present study. The palaeoenvironmental study of Palani Formation in the studied section, based on Planktonic foraminifera contents and the lithologic characteristics, is referred to as a sub-tropical of low low-energy deep open marine (from outer shelf to slope) environment.

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الطباقيه الحياتية للفورامنيفيرا الطافية لتكوين بلاني (الاوليكوسين الاسفل) في بئر (K-218)، حقل كركوك النفطي، شمال شرق العراق

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الملخص

تم جمع (13) نموذجاً من الفتات الصخري من تكوين بلاني في بئر (K-218) في قبة بابا في حقل كركوك النفطي، شمال شرقي العراق. يبلغ سمك التكوين 60 متراً ما بين الاعماق (600-540) متراً. اظهرت النماذج وفرة بانواع الفورامنفير الطافية الجيدة الحفظ والكثيرة التنوع. تم تصنيف (14) نوعاً تعود الى (3) اجناس من الفورامنيفيرا الطافية وهي كما يأتي: *Pseudohastigerina micra, Cassigerinella chipolensis, Globigerina Globigerina tapuriensis,Globigerina gortanii, ampliapertura, Globigerina sellii, Globigerina yeguaensis, Globigerina euoperura,Globigerina praebulliodes, Chiloguembelina cubensis Globigerina angustiumbilicata, Globigerina prasaepis, Globigerina galavisi.*

استنادا الى المدى الجيولوجي للانوع المشخصة في الدراسة الحالية، تم تقسيم تكوين بلاني الى نطاقيين طباقيين حياتيين للفورامنفيرا الطافية وهي (من الاسفل الاقدم الى الاعلى الاحدث) كالتالي:

Gassigerinella micra Interval Range Biozone (O1).

Globigerina ampliapetura Interval Range Biozone (O2).

تمت مضاهاة الانطقة الحياتية في الدراسة الحالية مع دراسات سابقة داخل وخارج العراق. استنادا الى ذلك حُدد عمر تكوين بلاني في الدراسة الحالية بالاوليكوسين المبكر عمر (Rupelian). كما وحُددت بيئة تكوين بلاني اعتماداً على انواع الفورامنفيرا الطافية والمواصفات الصخرية في المقطع المدروس ببيئة البحر المفتوح العميقة شبه الاستوائية ذات الطاقة الواطئة (من الرصيف الخارجي نحو المنحدر).

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Introduction

The study well no. K-218 of the Kirkuk Oilfield lies near Kirkuk City, Baba Dome, northeastern Iraq, with coordinates of latitude 39° 33' 91" N and longitude 43° 74' 57" E (Fig. 1).

Cenozoic stratigraphy has been the subject of detailed study since the first petroleum reservoir in Cenozoic sediments in Iraq. Typically, Iraq's largest hydrocarbon resource was built up in the Oligocene carbonate succession of the Kirkuk Group, which belongs to the Megasequence AP11 of Late Eocene- Recent (Jassim and Buday, 2006).

The Palani Formation was first described by van Bellen (1956; in van Bellen et al., 1959) from a stratotype section in Kirkuk (well no. K-85), which is situated on the Tarjil plunge of the Kirkuk-structure (64 m thick). It lies between drilled depths of 973 to 1036 meters. It comprises globigerinal dolomitic marly limestone. van Bellen et al. (1959) reported that the age of the Palani Formation (Early Oligocene) within the lower sequence of the Oligocene series

was dependent on its stratigraphic position between the Jaddala Formation (Middle Eocene) beneath it and the intercalating Sheikh Alas Formation (lower Oligocene) above it.

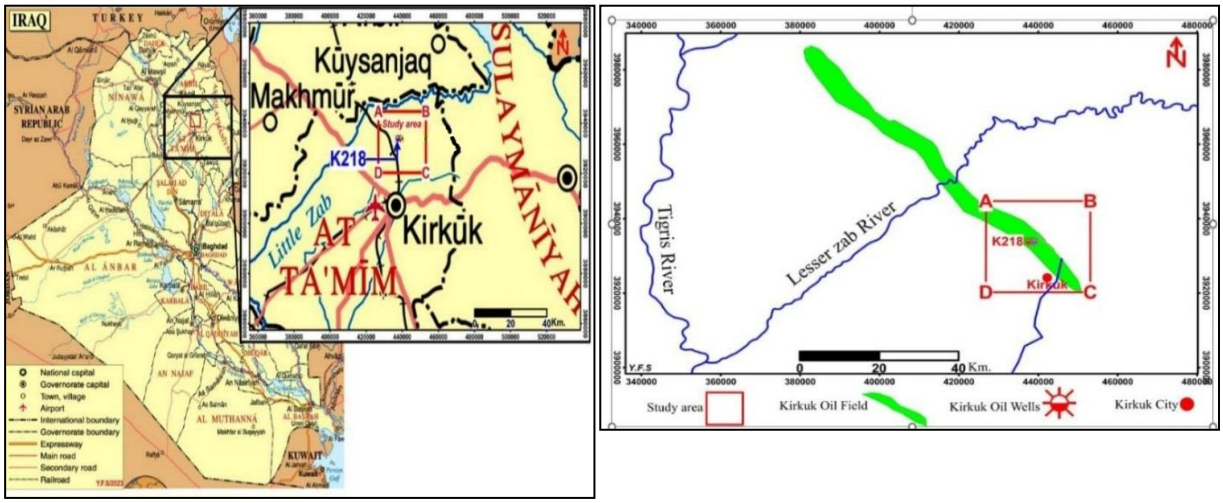


Fig. 1. Location of the studied well No. K-218, Kirkuk Oilfield (modified from the United Nations, 2014).

Determining the age of the Palani Formation unit is challenging. The Palani Formation (Early Oligocene) lies in a conformable relationship under the Sheikh Alas Formation and unconformably over the Jaddala Formation (van Bellen et al., 1959). On the other hand, Ditmar and the Iraqi-Soviet Team (1971) suggested a Late Eocene age for the Palani Formation unit. Thus, the age of the formation could range from late Eocene to early Oligocene (Jassim and Buday, 2006).

Full Oligocene successions in Iraq were initially described by van Bellen (1956; in van Bellen et al., 1959) as existing in the Kirkuk, Bai Hassan, and Qara Chauq Dagh structures. The same authors established lower, middle, and upper sequences of the Oligocene series in Iraq.

Most of the Oligocene deposits in Iraq disappeared, except in Kirkuk and Anah regions (Tatar, 1988), Sinjar Uplift (Ismail, 2006), and Mountain Ashdagh (Kharajiany, 2008). They are characterized by their limited nature and lack of spread, reducing their thickness as well as some problems regarding the stratigraphy of the boundaries of this cycle (Buday, 1980). van Bellen et al. (1959) split the Oligocene succession on a fossil basis into nine formations attributed to three sequences of the Oligocene series.

However, the lithological and palaeontological criteria are dependent, and additional studies have revised the age, such as (van Bellen et al., 1959; Mohammed, 1983; Al-Eisa, 1992; Al-Banna, 1997; Al-Banna et al., 2002; Al-Banna and Al-Mutwali, 2002; Al-Banna, 2004; Al-Banna, 2008; Al-Banna et al., 2010).

The Oligocene series sequence revealed that facies have been changed from deep basinal facies to reef/back reef facies according to van Bellen et al. (1959) on the basis of lithological and well log correlations (Table 1). Ditmar and the Iraqi-Soveit Team (1971) revised van Bellen's work by diagnosing two sequences instead of three. The formations were grouped into two cycles: the Anah, Azkan, Bajwan, and Baba formations in the upper cycle, whereas the Palani, Sheikh Alas, Shurau, and Tarjil formations in the lower cycle (Table 1).

The Palani Formation is one of nine formations within the Oligocene successions assigned to the Kirkuk Group, which represents the sequence of the Oligocene stage included within the (Latest Eocene-Oligocene) sequence of the Supersequence AP11 (Jassim and Buday, 2006).

Supersequence AP11 is subdivided into three sequences: (Latest Eocene-Oligocene), (early Middle Miocene and Latest Miocene-Recent). Both breaks define boundaries of the latest Eocene-Oligocene sequence according to Jasim and Buday (2006) as shown in Figure 2.

Regarding the age determination in previous studies and depending on the position of the Palani Formation over the Jaddala Formation (Middle to Late Eocene) and under the Sheikh Alas Formation (Early Oligocene), the age of the Palani Formation has been suggested as Oligocene age by (van Bellen et al.,1959; Ditmar et al., 1971; Al-Mutwali and Al-Banna, 2002; Kharaijany, 2008; Al-Banna, 2008; Al -Banna et al. 2010; Al-Jwaini, 2015; OEC, 2019; Al-Rubai and Al-Mutwali, 2021) suggested (Late Eocene) age, and (Jassim and Buday, 2006) assigned its age range from the latest Eocene to the early Oligocene.

Al-Banna et al. (2010) suggested that the Oligocene-Miocene contact lies between the Tarjil and Ibrahim formations units. Three sedimentary cycles are included in the Oligocene series: the first cycle includes early Oligocene (Rupelian age) for (Palani, Sheikh Alas, and Shora) formations that were deposited in upper Bathyal to intertidal environments; the second cycle includes the (Tarjil, Babah, and Bajwan) formations (Chattian age); and the third cycle represents the (Anah, Azkand, and Ibrahim) formations (Aquitanian) age as shown in Table (2).

Table 1: A- Kirkuk lithostratigraphic unit with ages and facies (van Bellen et al., 1959), B- Oligocene lithostratigraphic units and facies (Ditmar et al., 1971).

A						B				
Age		Sed cycle	Facies			Age	Sed cycle	Facies		
			Back Reef	Fore Reef	Off Shore			Back Reef	Fore Reef	Off Shore
Oligocene	Late	Upper	Anah Formation	Azkand Formation	Ibrahim Formation	Oligocene	Upper	Anah and Bajwan Formations	Azkand and Baba Formations	Ibrahim and Tarjil Formations
	Middle	Middle	Bajwan Fn	Baba Fn	Tarjil Fn					
	Early	Lower	Sharau Formation	Shekh Alas Formation	Palani Formation		Lower	Sharau Formation	Shekh Alas Formation	Palani Formation
Sed cycle: Sedimentary cycle										

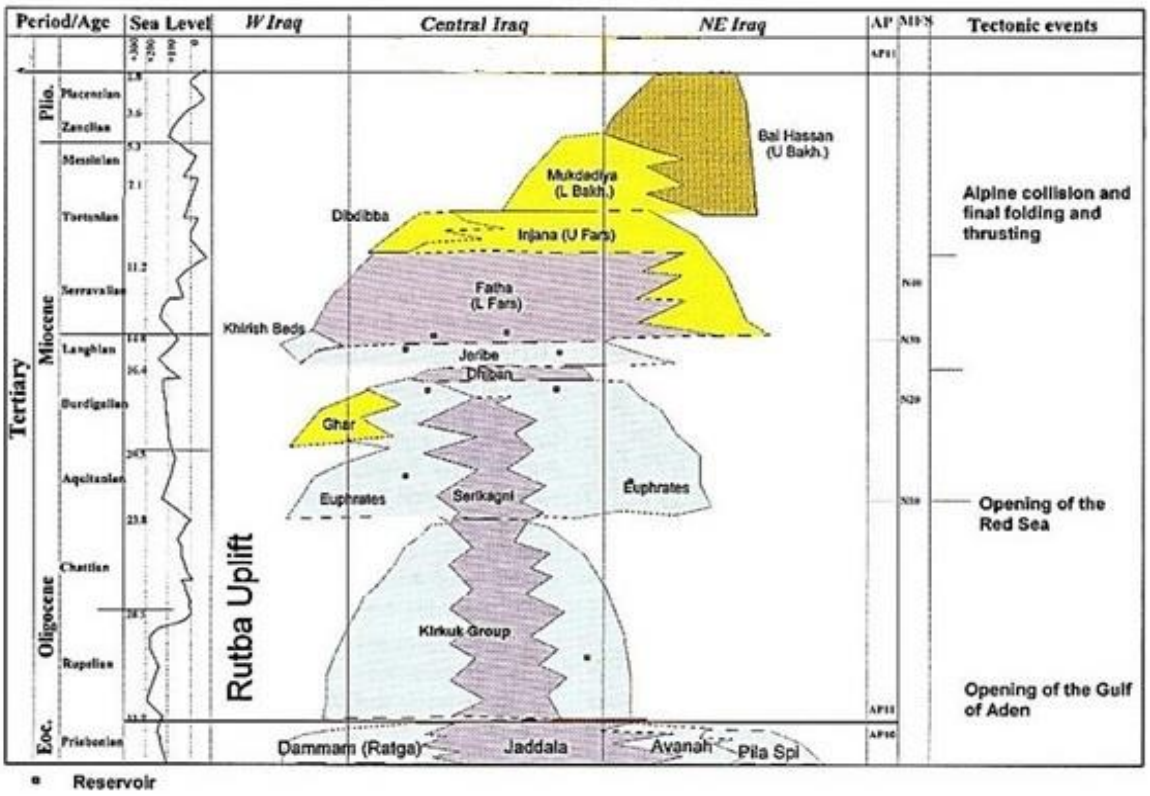


Fig. 2. Stratigraphic correlation of supersequence AP11 formations (excluding Quaternary) (Jassim and Buday, 2006).

The current study aims to identify the planktonic foraminifera species within the studied section, determine the biostratigraphy based on the floating masses of planktonic foraminifera in order to solve the age problem of the Palani Formation, and finally to give palaeoenvironmental interpretation depending on the identified planktonic foraminiferal species and lithological description.

Materials and Methodology

Thirteen cutting samples were collected from the studied interval between 600 and 540 m in well no. (K-218) of the Kirkuk Oilfield (Fig. 2). Approximately 30 g of each sample was weighed, crushed, boiled for 30-120 min, then cooled and washed with water, after that each sample was dried over a heat source and placed in several sieves with size ranges (40-60-80-100-120) mesh for separating into equal sizes to facilitate the picking process. Then, all the samples were placed in the ultrasonic device for a few seconds. All the samples were picked and mounted on microslides for identification under a binocular microscope.

Geological setting and lithostratigraphy

The well (K-218) in the Baba Dome is a part of the Kirkuk Oilfield within the Kirkuk structure in the unstable shelf zone of the Arabian Platform (Buday, 1980). This Zone contains the Kirkuk Embayment, which has significant subterranean features and surface folds that nearly always run in a NW-SE direction and is the largest transverse block. The anticlines in this deep block are relatively long and thin and are frequently linked to reverse and normal faults ranging from 100-200 km long. Nonetheless, they are distinctly shorter on elevated parts of the block in the NW. Wide synclines packed with dense (Pliocene-Quaternary) sediments split the anticlines from one another (Jassim and Buday, 2006) (Fig. 3).

The Palani Formation is included within (Latest Eocene-Recent) Megasequence (AP-11), which corresponds with the collision of Neo Tethyan terrains along the northern and eastern edges of the Arabian Plate resulting in the closure of this ocean at the end of the Eocene, in

addition to the creation of the Aden Gulf in the Oligocene (Sharland et al., 2001; Jassim and Buday, 2006).

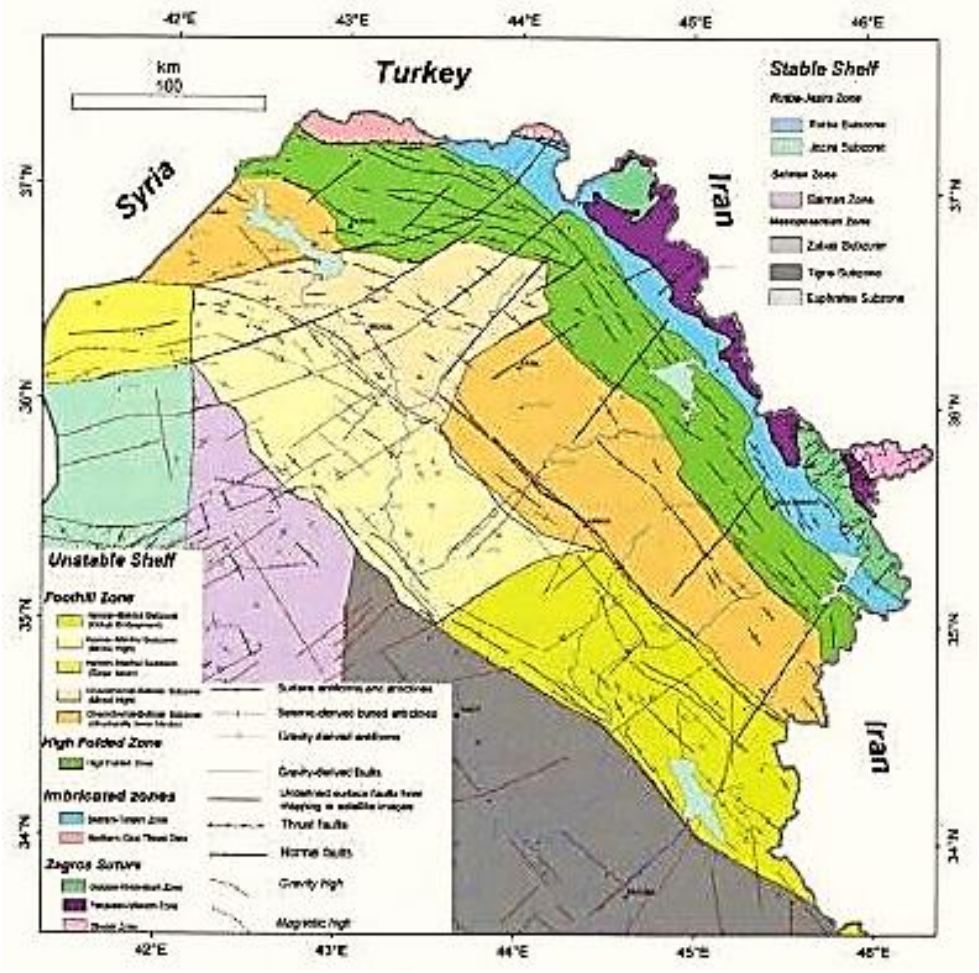


Fig. 3. Structural map of the main structural zones in the unstable Shelf Zone in Iraq (Buday and Jassim, 1984).

In northern Iraq, (Late Eocene) palaeogeography and depositional history patterns persisted throughout the Oligocene (Al-Banna et al., 2010; Al-Mawla et al., 2023; Simo et al., 2023; Al-Mawla et al., 2024). The limestones known as fore reef and back reef shoals habitually formed two northeast-trending belts that were divided into relatively small, deep-water basins that had globigerinal marl (Dunington, 1958; in van Bellen et al., 1959). The basin's western and eastern shorelines featured the development of thick fringing reefs. In the center of the basin, where there was no available sediment, thin marls were deposited (Fig. 4). Locations of the Oligocene basin include the Mesopotamian Zone, the Jezira Subzone, the Makhol-Himrin subzone of the Foothill Zone, and the northern edge of the Rutba subzone. Oligocene uplift occurred in the Selman Zone as well as the Euphrates and Zubair subzones of the Mesopotamian Zone. Only the very high Qara Chauq structure of the Foothill Zone and the Euphrates valley between Hadietha and Anah include outcrops of the Oligocene formations. Al-Hashimi (1974) and Jassim et al. (1984) reported that the Late Oligocene Shurauh and Sheikh Aalas formations are along the Wade Hauran, east and northeast of Rutba, and northwest of the Ga'ara depression. Other Oligocene sediments in Iraq are found south of the Sirwan River in Jabal Sinjar and Jabal Bamu areas near the country's border with Iran. According to Jassim and Buday (2006), Oligocene sediments are absent from the Butmah-Chemchemal Subzone in northeastern Iraq, where the High Folded Zone exists (Abdula and Al-Badrani 2023). The majority is of the southeastern portion of the Balambo-Tanjero Zone, and the northern Thrust Zone (Jassim and Buday, 2006).

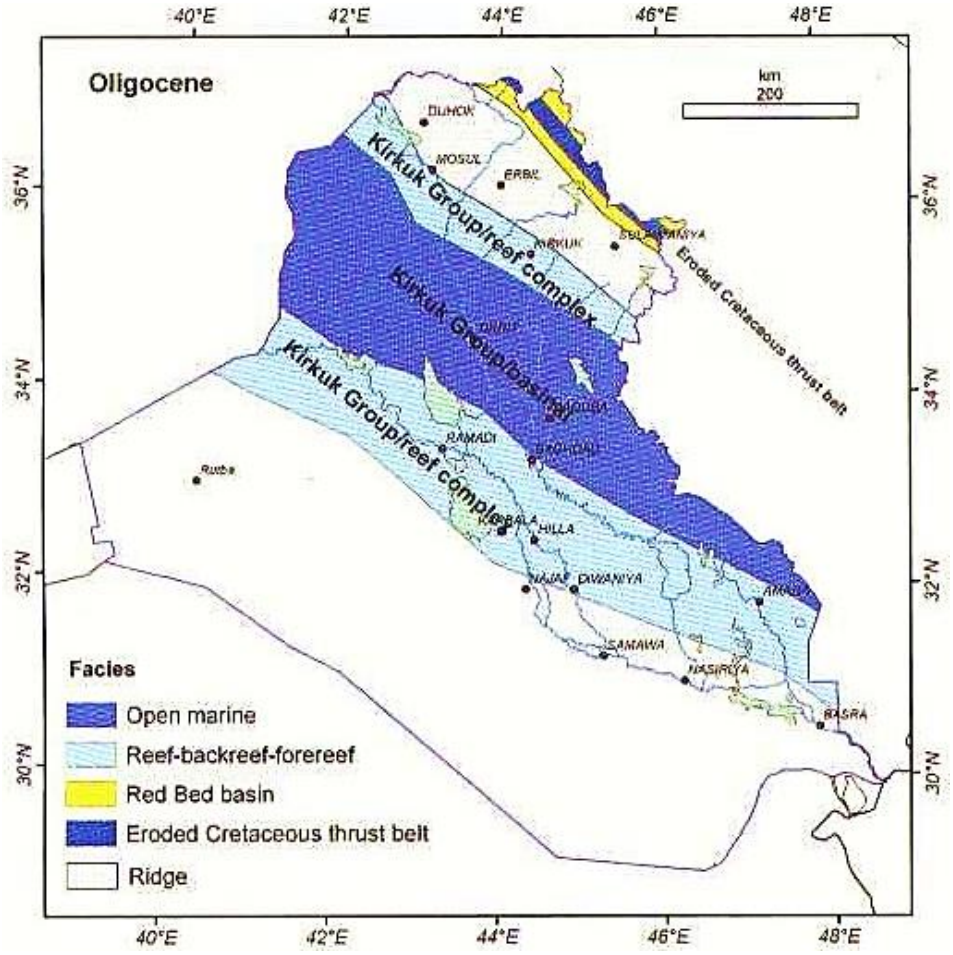


Fig. 4. Oligocene palaeogeography (Jassim and Buday, 2006).

The Palani Formation unit occurs in Baba Dome in the southeastern anticline and rests on the Avanah Formation. The Tarjil and Sheikh Alas Formations are located above the Palani Formation in Baba Dome to the southeast and northwest, respectively. The Palani Formation is 80 m thick and is located in the Nehrawan structure southeast of Baghdad. The Palani Formation is exposed at the surface only in the Qara Chauq structure. Numerous wells contain it (Jassim and Buday, 2006).

The Palani Formation in the current study's well No. (K-218) in Kirkuk field has a thickness of approximately 60 m between 600 and 540 m depths. It is typically composed of sequences of limestone, with the lower portion being Globigerinal marly limestone and the top part being dolomitic and nummulitic limestone. According to Al-Jwaini (2015), Jassim and Buday (2006), the upper Palani Formation contact in this section is conformable with the Sheikh Aalas Formation (Lower Oligocene), whereas its lower contact has an unconformity with the Jaddala Formation (Middle Eocene) (Fig. 5).

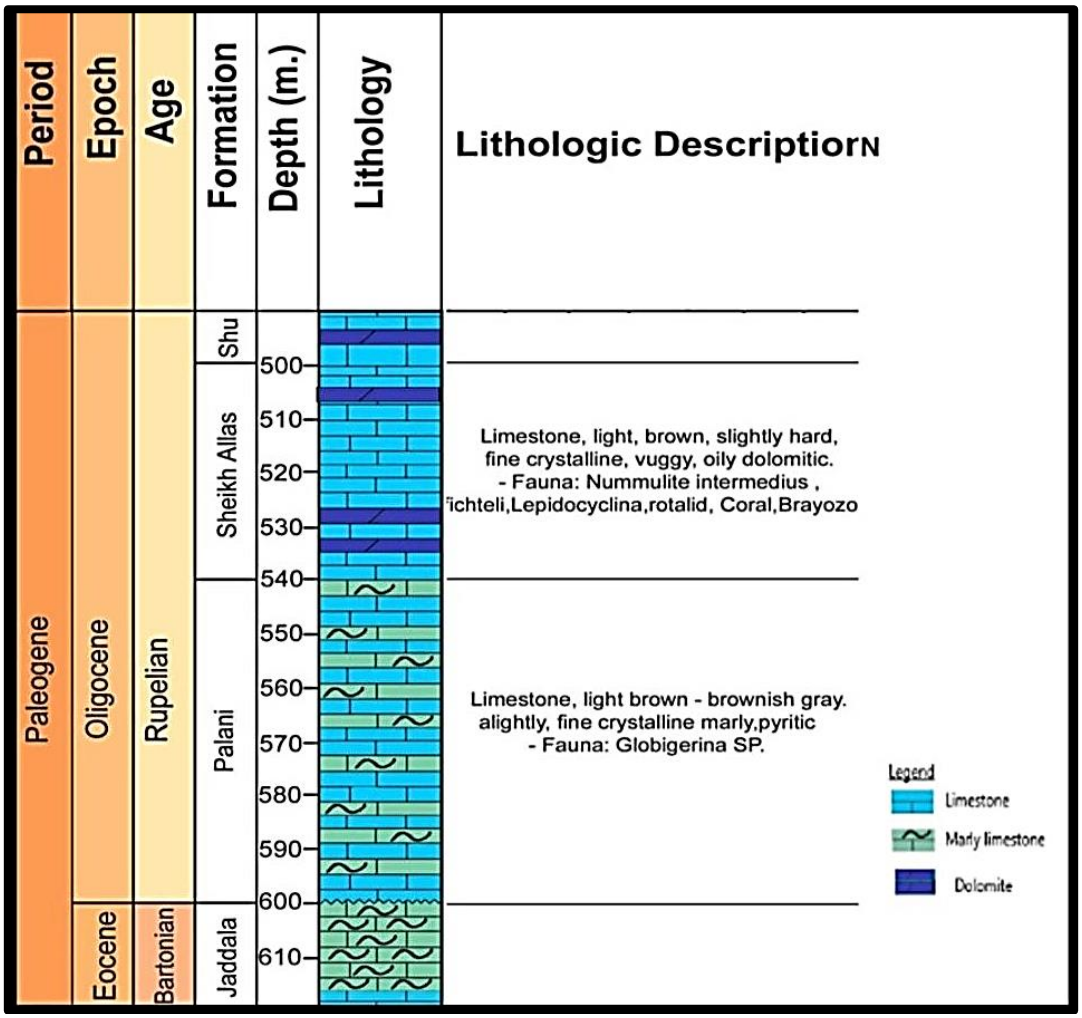


Fig.5. Stratigraphic succession of the Palani Formation in Baba Dome, Kirkuk Group, well no. (K- 218).

Biostratigraphy

Thirteen samples representing the Palani Formation from the subsurface section between intervals (600- 540 m) were collected. In the Baba Dome of the Kirkuk Oilfield, these samples are rich and dominated by well-preserved and diverse planktonic foraminifera fossils.

(14) species related to (3) marker genera are identified, showing no marked differences in their foraminiferal contents, and the present work permits the delimitation of two biozones (Table 2, Figs. 6 and 7). They are described from the bottom to the top of the section as follows:

1- Pseudohastigerina micra Interval Range Biozone (O1)
Definition:

The biostratigraphic interval between the highest occurrences of (Middle Eocene) planktonic foraminiferal index species such as *Acarinina topilensis, Morozevella lehneri, Truncorotaloides rohri, Morozovella spinulosa,* and *Morozovella crassata* of late Middle Eocene (Late Lutetian-Early Bartonian) age at the disconformity with the underlying Jaddala Formation, that defines the base of this zone, and the highest occurrence of the nominate species *Pseudohastigerina micra* that defines the top of the biozone.

Thickness:

Forty metres, consisting of limestone.

Assemblages:

Pseudohastigerina micra, Cassigerinella chipolensis, Globigerina tapuriensis, Globigerina gortanii, Globigerina ampliapertura, Globigerina sellii, Globigerina yeguaensis, Globigerina

euoperura, Globigerina praebulliodes, Chiloguembelina cubensis Globigerina angustiumbilicata, Globigerina prasaepis, Globigerina galavisi.

Remarks:

Wade et al. (2018) assigned that the *Globigerina* is a common genus in the Oligocene to Recent. Its first appearance is documented in the middle Eocene Zone E10 (Olsson et al., 2006), where it is relatively uncommon. The main radiation of this genus occurred in the Early Oligocene age. The former authors also remarked that the *Pseudohastigerina micra* is common in the upper Eocene, but it declined dramatically in size and abundance at the Eocene/Oligocene boundary.

Discussion:

The studied biozone is equivalent to the *Globigerina tapuriensis* biozone of Blow (1969-1979); the Lower part of the *Chiloguembelina cubensis* and *Pseudohastigerina barbadoensis* biozone (Berggren and Miller,1988); the *Cassigerinella chipolensis* biozone (Bolli and Saunders, 1985); the (P18) biozone (Gradstein et al., 2004); *the Pseudohastigerina* spp. biozone (p18) of sub-tropical scheme (Berggren et al., 1995); the *Pseudohastigerina naguewichiensis* biozone (O1) (Wade et al., 2011 and Wade et al., 2018), the *Pseudohastigerina naguewichiensis* (O1) biozone (Pearson et.al., 2018); and the lower part of the *Pseudohastigerina micra* biozone (Al-Banna et. al., 2010) in Iraq as shown in Table 2 and Figures 6 and 7.

Estimated age:

33.7- 32.0 Ma Early Oligocene (Early Rupelian).

2-Globigerina ampliapertura Interval Range Biozone (O2)

Definition:

The biostratigraphic interval between the Highest occurrence of a dominant species of *Pseudohastigerina micra* at the bottom of the zone and the highest occurrence of the nominate species, the *Globigerina ampliapertura,* at the top of the zone.

Thickness:

Twenty metres consisting of marly limestone.

Assemblages:

Globigerina ampliapertura, Cassigerinella chipolensis, Globigerina tapuriensis, Globigerina gortanii, Globigerina yeguaensis, Globigerina angustiumbilicata, Globigerina euapertura, Globigerina praebulloides, Chiloguembelina Cubensis, Globigerina sellii, Globigerina prasaepis, Globigerina galavisi, and Globigerina ciperoensis.

Discussion

This biozone is correlated with the *Globigerina sellii - Pseudohastigerina barbadoensis* biozone (Blow,1969- 1979); the upper part of the *Chiloguembelina cubensis* and *Pseudohastigerina barbadoensis* biozone (Berggren and Miller, 1988); the *Pseudohastigerina micra* biozone (Bolli and Saunders, 1985); the (P19) biozone of (Gradstein et al., 2004); the *Turborotalia ampliapertura* (P19) biozone of sub-tropical scheme (Berggren et al.,1995), the *Turborotalia ampliapertura* (O2) biozone (Wade et al., 2011),(Wade et al., 2018); the *Turborotalia ampliapertura* (O2) biozone (Pearson et al., 2018); and finally the *Globigerina ampliapertura* (Al-Banna et al., 2010) biozone in Iraq, as shown in Table (2) , Figure (6) and Figure (7).

Estimated age:

32.0- 30.3 Ma. Early Oligocene (Late Rupelian).

Results:

All the biozones of the Palani Formation diagnosed in the studied section were proven to be formed during the lower Early Oligocene (Rupelian) age.

Palaeoenvironment

The lithological succession and abundance of the planktonic foraminiferal species of Gassigerinella chipolenis: Pseudohastigerina micra, Globigerina tapuriensis, Globigerina gortanii, Globigerina ampliapertura, Globigerina sellii, Globigerina galavisi, Globigerina ciperoensis, Globigerina yeguaensis, Globigerina euoperura, Globigerina praebulliodes, Chiloguembelina cubensis, Globorotalia angustiumbilicata, Globigerina prasaepis, identified in this study, indicate that the deposition was in a sub-tropical (Berggren et al., 1995), low-energy, deep basin marine environment (outer shelf to slope).

Depending on the planktonic species and lithological characteristics of the studied section, our conclusion of the depositional environment coincides with the previous sedimentological studies based on petrographical and microfacies analysis for the Palani Formation, which is referred to the deep marine (outer shelf basinal to slope) environment as follows: (Al-Hashimi and Amer, 1985; Majid and Vezer, 1986; NOC, 1986; Tatar, 1988; Jassim and Boday, 2006; Al-Tamimi, 2011;Ghafur, 2012; Al-Jwaini, 2015; OEC, 2019; Al-Rubai and Al-Mutwali, 2021; Ahmed et al., 2021; Aoudah et al.; 2022; Al-Bayati, 2023; and Hassan, 2023).

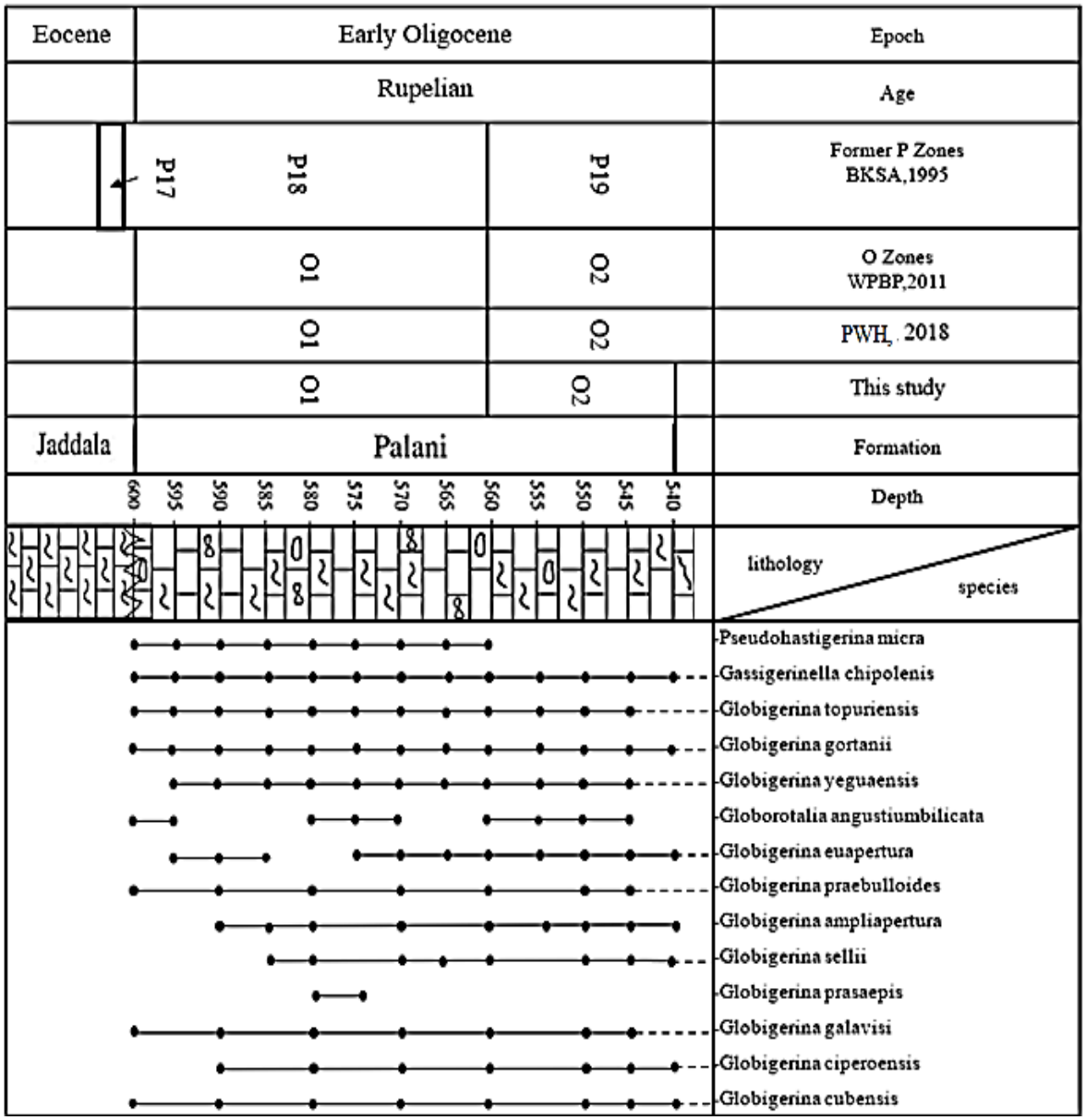
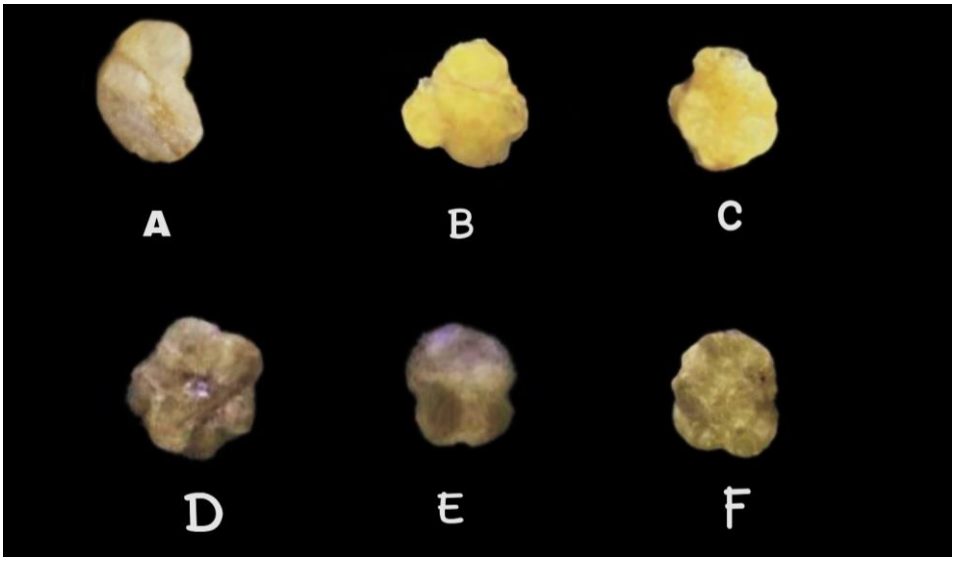


Fig. 6 Stratigraphic distribution of planktonic foraminifera (early Oligocene) in the Palani Formation in the studied section. (BKSA, 1995 = Berggren et al., 1995; WPBP, 2011= Wade et al., 2011; PWH, 2018=Pearson et al., 2018).

Table 2: Local and regional correlation of planktonic foraminifera and age of the Palani Formation. BKSA,1995= Berggren et al, 1995; WPBP, 2011=Wade et. al., 2011; PWH, 2018=Pearson et. al., 2018; *T. ampliapurture = Turborotalia ampliapertura.*

Age			Bolli, 1957,1966 Bolli & Premoli Silva, 1973	Blow, 1969, 1979	BKSA, 1995	PWH, 2018	WPBP,2011	Gradstein et al. (2004)	Al-Banna et al. (2010)	This study
Epoch		Stage								
Miocene			Gs. primordus	Gs.primordus-Gr.kugleri	*P22*	*M1a*	*Not discussed*	M1	*Gs. Primorus*	Not Study
Oligocene	Late	Chattian	Gr.kugleri			*O7*	*O6*	P22	*G. ciperoensis*	
			G.c.ciperoensis	G.anguli suturalis		*O6*				
	Early	Rupelian	Gr.opima opima	G.anguli suturalis - Gr.opima opima	*P21b*	*O5*	*O5*	P21		
					P21a Gl.angulisuturalis/Ch.cubensis	*O4 Gl.angulisuturalis/Ch.cubensis*	*O4 Gl.angulisuturalis/Ch.cubensis*			
			G.ampli apertura	G.ampli apurture	*P20 G.sellii*	*O3 D.sellii*	*O3 D.sellii*	P20	*G. ampliap urture*	
			P.micra-Cs.chipolensis	G.sillii-P.barbadoensis	*P19 T. ampliap urture*	*O2 T. ampliap urture*	*O2 T. ampliap urture*	P19	*Pseudohastigerina micra*	*O2 G. ampliap urture*
				G.tapuriensis	*P 18 T.cerroazulensis/ Pseudohastigerina spp*	*O1 P.nagewichiensis*	*O1 P.nagewichiensis*	P18		*O1 G. micra*
Eocene			P17	P17	P17	P17	P17	P17	P11	P11



(A) *Pseudohastigerina micra* (Cole), sample (2), umbilical view.

(B) *Globigerina ampliapertura* (Bolli), sample (7), spiral side.

(C) *Globigerina angustiumbilicata* (Bolli), sample (6), umbilical view.

(D)Globigerina *ciperoensis* (Bolli), sample (3), umbilical view.

(E, F) *Globigerina sellii* (Borsetti) sample (6), umbilical, spiral view.

Fig. 7. Significant planktonic foraminifera species of the Palani Formation in well No. K-218 in the Kirkuk Oilfield area.

Conclusion

1- Fourteen species related to three genera of Planktonic foraminifera are identified in the studied section of Palani Formation as follows:
Pseudohastigerina micra, Cassigerinella chipolensis, Globigerina tapuriensis, Globigerina gortanii, Globigerina ampliapertura, Globigerina sellii, Globigerina yeguaensis, Globigerina euoperura, Globigerina praebulliodes, Chiloguembelina cubensis Globigerina angustiumbilicata, Globigerina prasaepis, Globigerina galavisi.

2- The biostratigraphical study shows two biozones of Planktonic foraminifera from the lower (oldest) to the upper (youngest) of the Palani formation of the section:
   a- *Gassigerinella micra* Interval Range Biozone (O1)
   b- *Globigerina ampliapetura* Interval Range Biozone(O2).

3- These biozones are correlated and compared with different similar studies in different parts of the world. The biostratigraphy study assigned the Early Oligocene (Rupelian) age of the Palani Formation in the present study.

4- Based on the Planktonic foraminifera contents and the lithologic characteristics, the environment is referred to as the sub-tropical low-energy deep open marine (from outer shelf to slope).

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