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Palaeoenvironments and sequence development of the Upper Palaeogene-Lower Neogene Succession in Kirkuk, Bai Hassan and Khabaz oil Fields, Northern Iraq

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Abstract
Microfacies analysis of the Upper Palaeogene-Lower Neogene succession which include Jaddala, Palani, Sheikh Allas, Shurau, Tarjil, Baba, Bajwan, Ibrahim, Azkand, Anah and Jeribe formations within Kirkuk area led to the recognition of many microfacies. They were grouped into nine facies associations ranging from supratidal to basin setting. These facies associations were deposited within a rimmed shelf with a barrier reef during the Palaeogene and a steepened ramp setting with fringing patch reef during the Neogene. The digenetic imprints on the recognized microfacies are prominent and dominated by cementation, neomorphism, dolomitization, precipitation of authigenic minerals, dissolution (leaching), compaction, mechanical degredation, micritization and geopitalstractures.

The Upper Palaeogene-Lower Neogene succession is represented by a 2nd order cycle, It includes five 3rd order cycles within the shallowing upward upper part (The highstand systems tract) of this cycle. Cycles A and B were deposited during the Oligocene and present in the wells of Kirkuk oil field and bounded below by a transgressive surface and above by Type1 sequence boundary, Cycles C and D were deposited during the Aquitanian Early Miocene and found in Khabaz Field only and bounded below and above by a Type1 sequence boundary. These cycles were formed where the tectonic component was the major controlling factor on their development, This have caused successive episodes of relative sea level rises and stillstands, followed by sea level fall. Another 3rd order cycle within the Jeribe Formation was identified at Bai Hassan and Khabaz fields, this cycle is bounded below and above by a Type1 sequence boundary and also represent a brief episode of relative sea level rise followed by a major fall eroding most of the formation.

The development of the Upper Palaeogene-Lower Neogene succession went through three main stages. The first stage was represented by the deposition of the basinal Jaddala and Palani formations (Eocene-Early Oligocene) all over the study area. The second stage was characterized by the basin trend being to the south toward the Khabaz Field and the reef buildup was located near Kirkuk Field and an interfingering took place between the Sheikh Allas and Palani formations deposited as a 3rd order cycle (A) therefore the fore reef and reef of Sheikh Allas and the back reef Shurau were deposited as a second 3rd order cycle (B) in Kirkuk Field only whereas the deposition of the basinal facies of the Palani Formation continued in both Bai Hassan and Khabaz areas. The third stage took place during the Aquitanian Early Miocene where a positive area developed as the Baba Dome and the Bai Hassan Field were uplifted with Avanah and Khurmala domes in Kirkuk Field; therefore the Bajwan and Baba formations (Late Oligocene) became subject to erosion, and the Khabaz Field represent the area of reef buildup, and the depositional system was changed from the shelf to ramp setting. During the Langhian new transgression took place where the Bai Hassan and Khabaz areas represent a tidal flat and the Jeribe Formation was deposited, whereas the Kirkuk Field was a positive area.

Key words: Palaeoenvironments, sequence stratigraphy, Upper Palaeogene-Lower Neogene, Kirkuk Oil Field.

Introduction
The Upper Palaeogene-Lower Neogene succession in the Kirkuk, Bi Hassan, and Khabaz oil fields area Northern Iraq were studied through six selected wells (K-243, K-227, BH-90, BH-138, Kz-23, and Kz-29). Collection of 280 samples was made with reference to lithological and textural variations, The collected samples were thin sectioned and stained with Alizarin Red S using [1] method. More than 730 thin sections were described and interpreted, together with several hundred thin sections previously prepared by the North Oil Company. Fig.1 shows the coordinates and the location of the study area. The studied succession consist of eleven formations including the Middle-Late Eocene Jaddala Formation; the Rupelian Early Oligocene Palani, Sheikh Allas and the Shurau formations; and the Chattian Late Oligocene Tarjil, Baba and Bajwan formations, they belong to the Upper Palaeogene succession. The Lower Neogene succession includes the Ibrahim, Azkand and Anah formations (Aquitanian Early Miocene) and the Jeribe Formation (Langhian Early Middle Miocene). There are several published studies on upper Palaeogene-Lower Neogene successions covering their sedimentology and stratigraphy such as [2,3,4] others are mostly unpublished PhD and MSc theses. Fossils, lithoclasts, peloids, and ooids form the main allochems of the Upper Palaeogene–Lower Neogene succession. Foraminiferas especially Miliolids, Peneroplids, *Archias*, *Lepidocyclina* and Rotalids are the most common indicating the warm shallow environment of the Sheikh Allas, Shurau, Baba, Bajwan, Azkand, Anah and Jeribe formations while the *Globigerina*, *Globorotalia*, *Globigerapsis* and *Globigerinoides* indicate the deep environments of the Jaddala, Palani, Tarjil and Ibrahim formations. Next in abundance are red and green algae. Other fossils of less importance include Molluscs, Echinoids, Ostracods and Gastropods.

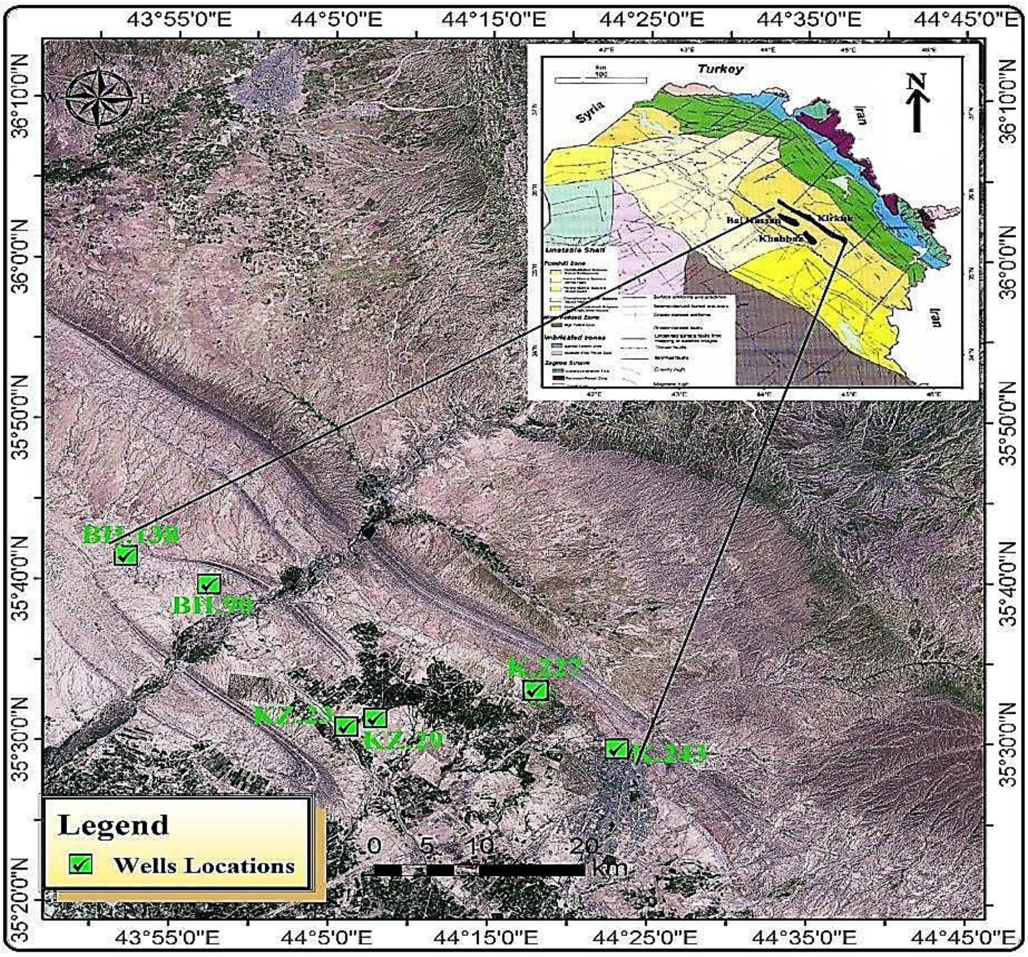

Figure 1 location map and tectonic setting of the study area.

Petrography

Petrographic study revealed that the Upper Palaeogene-Lower Neogene successions consist mainly of various skeletal and none skeletal grains as below:

Skeletal grains: planktic foraminiferas are common in the basinal facies of the studied successions. These planktic faunal assemblages are usually interpreted to indicate a low-energy, open-marine and outer-shelf environments below wave base [5]. Planktonic foraminifera are abundant within the lower part of the studied successions such as Jaddala, Palani, Tarjil and Ibrahim formations. They include *Globigerina, Globorotalia, Globigerapsis, Globigerinoides, Hantikenina* and *Chilloguembelina* in addition to *Histogerina miora, Nodosaria*. Benthic foraminifera of various sizes are the most common skeletal grains in the studied successions, particularly increasing in slope, lagoonal and intertidal environments. There associations are with less abundance in shoal, fore and back reef environments, benthic foraminifera are most abundant in the studied wells relative to planktons; they are common within upper parts of studied successions like Sheikh Allas, Shurau, Baba, Bajwan Azkand, Anah and Jeribe formations. Most common benthic foraminifera are *Nummulites, Lepidocyclina, Archias, Astrotrillina,* Miliolidae *Peneroplis, Denderitina rangi*. Other bioclasts included molluscs shell fragment, Encrusting algae, Ostracods, Gastropods, Coral, Rotalids, *Echanoides* and *Textularia* existed as well**.**

Non-skeletal grains: Peloids are the main non-skeletal grains range in size from silt to sand sizes. Some peloids are probably micritized ooids. Peloids are characteristic constituents of carbonate sediment laid down in shoal and subtidal environments, respectively [6]. Intraclasts are interpreted to be reworked grains within the subtidal and intertidal environment arising from current agitation. Ooids are valuable paleoenvironmental proxies for water energy, temperature and depth [7].

Micrite: represented by microcrystalline calcite size less than 4 µm which mostly was agglutinated like peloids. They appear with clotted texture as the most common in most of the studied boreholes .

Spray calcite cement: different types of spray calcite cements have been recognized throughout Upper Palaeogene-Lower Neogene successions such as drusy, blocky and syntaxial cement.

Microfacies associations

The microfacies of the Upper Palaeogene-Lower Neogene successions are classified using the scheme of [8] and [9], which is modified from [10] and [11]. In addition, [12] terminologies are also used, and the microfacies are based on [13] model of rimmed shelf, and [14] for ramp. Accordingly, 30 microfacies and 15 subsidiary microfacies are recognized in the studied successions.

Palaeoenvironments

Two palaeoenvironments have been responsible for the deposition of Jaddala Formation. They are Deep-sea environment that characterized by Planktonic Foraminifera Mudstone microfacies (PFM) and Toe of slope environment that characterized by Planktonic Foraminifera Wackestone microfacies (PFW). Most fossils abundant in these microfacies are planktonic fossils such as *Globigerina, Globorotalia*, *Globigerapsis*, *Hantikenina* and *Chilloguembelina*. They are characterized by high diversity of species.

The deposition of the Palani and Tarjil formations were controlled by two palaeoenvironments: Deep-sea environment that was represented by Planktonic Foraminifera Mudstone (PFM), and Deep shelf environment that was responsible for the deposition of Planktonic Foraminifera Wackestone microfacies (PFW). Most fossils abundant in these microfacies are planktonic fossils such as *Globigerina* and *Globorotalia*.

Microfacies analysis of Baba/Tarjil interbedded zone in BH.138Well indicates that the intervening between these formations took place within Slope environment that was represented by deposition of Planktonic-Benthic bioclastic foraminiferal Wackstone microfacies (PBsW) and Benthic bioclastic Packstone microfacies (BsP).

Two palaeoenvironments controlled the microfacies distribution of the Sheikh Allas Formation, and three palaeoenvironments were responsible deposition of the Baba Formation. Platform margin sand shoals environment was responsible deposition of Oolitic Grainstone submicrofacies (OG) in Baba Formation. Platform-margin reefs environment that represented by in-situ Coral bioherm Boundstone microfacies (CB) in the form barrier reef belt. Slope environment that represented by the deposition of Nummulitic-Coralline red algae Wakestone-Packstone microfacies (NRWP) near the organic reef body in the upper part of the slope as fore reef and Benthic Grainstone submicrofacies (BG) in addition to the deposition of Benthic Bioclasts Packstone (BsP) and Bioclasts Wackestone microfacies (BsW).

Two palaeoenvironments were responsible for the deposition of Shurau and Bajwan formations. Shallow lagoon with restricted circulation environment: controlled the distribution of Packstone and Grainstone microfacies such as Benthic Wackestone-Packstone microfacies (BWP) with Miliolids and attached foraminifera within the Shurau Formation, Pelodial Grainstone (PG) with Peloids, Miliolids, Ostracods, *Pseudocyclumina, Discorbis* and shells of Pelecypods, and Bioclasts-Lithoclasts Packstone submicrofacies (BsLP) with shell fragments, Echinoderm plates and spines fragments of green algae, Rotalid debris, *Peneroplis, Archias SP., Heterolina, Spiroloculina* and Ostracods, in addition to lithoclasts in Bajwan Formation. Lagoon with open circulation environment: that characterized by Bioclastic Packstone microfacies (BsP), Miliolids Packstone submicrofacies (MP) with Miliolids, *Austrotrilinapauchialeveoalta, Quinqueloculina SP., Peneroplisevolutus, Peneroplis SP., Discorbis, Dendertinarangi*, Gastropods, and shell fragments; Nummulitic Packstone submicrofacies(NP) with *Nummulites SP., peneroplisthomasi* Henson, Gatropods, shell fragments and debris of thick walled Rotalids; and Rotalids Grainstone submicrofacies(RG) with Rotalids debris, Miliolids, *Austrotrilinahowchini, Peneroplidae, Rotaliavennoti, Bolevina*, peloids and fragmented benthic fossils.

The distribution of the Chattian Late Oligocene microfacies suggest a similar depositional environments with those of Rupelian Early Oligocene and imposes a barrier reef that separate the deep sea, slope and fore-reef platform margin reef environments from the shallow marine environments whereas the nature and distribution of Aquitanian Early Miocene microfacies indicates that the deposition took place within steepened ramp, and they are compatible with the common microfacies assumed by [13] which was modified by [14] for carbonate ramp.

Two palaeoenvironments were responsible for the deposition of the Ibrahim Formation: Deep shelf within Outer ramp characterized by *Globigerinoides* Wackestone-Packstone microfacies (GWP), Basinal environment that represented by *Globorotaliakugleri* mudstone microfacies.

Two palaeoenvironments were responsible for the deposition of Azkand Formation: Organic reef in mid-ramp environment that controlled the distribution of Coral Boundstone microfacies (CB), Fore reef in mid-ramp environment that represented by Coraline red algae Packstone microfacies (RP) and Rotalidal-Coraline red algae Packstone submicrofacies (RRP). This formation is intervening with both the underlying Ibrahim Formation and overlying Anah Formation. Microfacies study emphasized that the intervening between Azkand and Anah formations changes the status of barrier reef of Oligocene into fringing reef during Early Miocene and this agree with [15].

Two palaeoenvironments were responsible for the deposition of the Anah Formation: Open lagoon in inner-ramp environment where the Benthic Foraminiferal Wackestone-Packstone microfacies (BW-P) characterize this environment and Supratidal within Peritidal environment that controls the distribution of Lithoclastic Grainstone microfacies (LG).

The microfacies of Anah Formation were confined with Benthic Packstone and Lithoclastic Grainstone microfacies with less diversity of large porcelainous foraminifera where the main deposition of these microfacies took place in area between fringing reef and the shoreline similar to the fringing reef of Jamaica [16], so that the nature and distribution of Anah microfacies and its intervening with Azkand Formation could mean the barrier reef belt that existed in Oligocene Epoch was transformed to fringing reef during Early Miocene and this agree with [15].

Microfacies analysis of the Jeribe Formation showed that the deposition was took place within four environments: Supratidal flat in inner-ramp environment which was characterized by Quartz Grains bearing Mudstone microfacies (QM) and Dolomitized Mudstone microfacies (DM); Intertidal flat sediments within inner ramp environment which was represented by Pelecypods Packstone microfacies (PLP); Subtidal flat within inner ramp environment which was characterized by Benthic Foraminifera Wackestone microfacies (BFW); and Open lagoon environment which was characterized by Algal Wackestone microfacies with red algae (AW).

The distribution of these palaeoenvironments reflect that the deposition of Eocene and Oligocene studied successions were took place within Deep to shallow carbonate shelf platform, most probably on rimmed shelf setting were the reef is represented by barrier reef belt whereas it took place on steepened ramp and the microfacies were distributed within different zones, and the organic reef was represented as fringing reef during Early Miocene.

Sequence Development

The studied succession demonstrates the first sequence of Megasequence AP11 between Pg30 and Ng10 [17]; [18]; [4]; [19]; [20] and [21] (Fig.2).

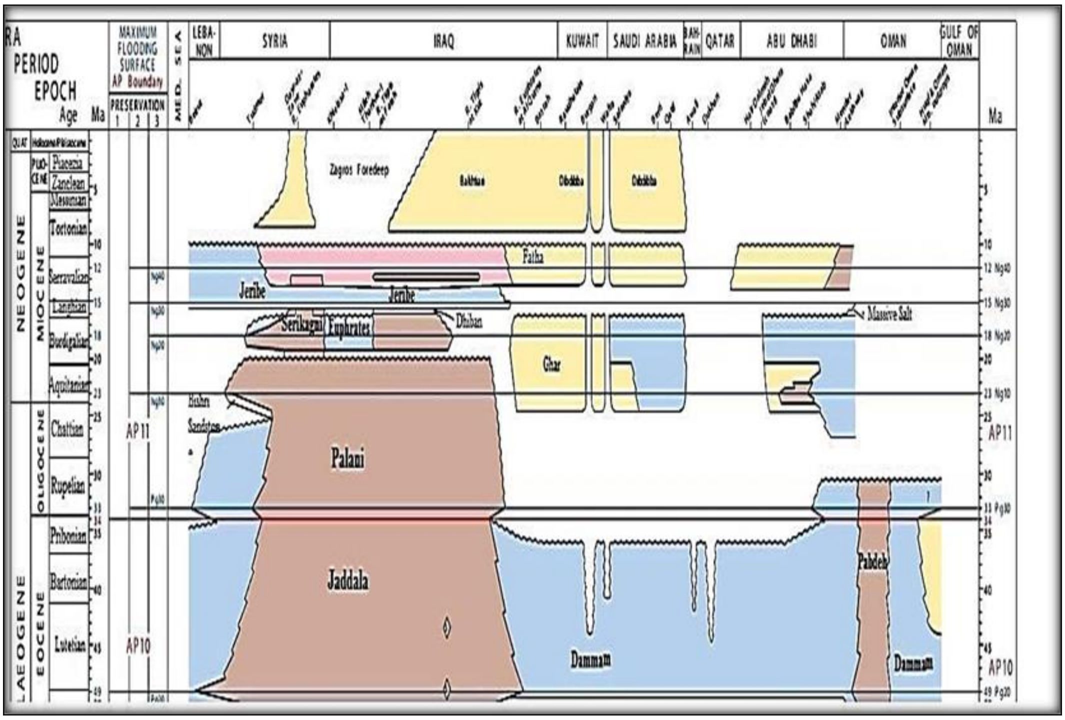

Figure 2 Chrono-sequence stratigraphy of the Arabian Plate during the Palaeogene and Neogene periods after [17]

An eroded surface known as the Supra Dammam unconformity separates the Eocene sequence AP10 from the Oligocene sequences AP11 [22] and the sequence boundary Type 1 (SB1) was developed. Correlative conformities in deeper, open-marine settings were placed directly beneath the shallowest water facies in the deeper, water succession and marking major relative sea level falls.

Gamma ray logs were used to trace sequence boundaries, high frequency sequences and some of the parasequences. Because of the controversy over the hierarchy of sequences in the Upper Palaeogene-Lower Neogene successions, sequences were picked on the basis of facies stacking pattern and bounding surfaces and has been defined by different hierarchical cycles. Each well was analyzed separately using the classification of hierarchical cycles authored by [23] [Table1].

Table 1 Classification of hierarchical stratigraphic cycles after [23]

Tectono-Eustatic/Eustatic Cycle Order	Sequence Stratigraphic Units	Duration (my)	Relative Sea Level Amplitude (m)	Relative Sea Level Rise/Fall Rate (cm/1,000 yr)
First	-	> 100	-	<1
Second	Supersequence	10-100	50-100	1-3
Third	Depositional Sequence Composite Sequence	1-10	50-100	1-10
Fourth	High Energy Sequence Parasequence and Cycle Set	0.1-1	1-150	40-500
Fifth	Parasequence, High Frequency Cycle	0.01-0.1	1-150	60-700

One 2nd order cycle represent whole succession in all studied wells with a thickness ranging (303-400 m). It includes five 3rd order cycles within the shallowing upward upper part of the whole 2nd order sequence. 3d order cycles A and B were deposited during the Oligocene in Kirkuk Field only while they were missing in both Bai Hassan and Khabaz fields. The 3rd order cycles C and D were deposited during the Aquitanian Early Miocene and found in Khabaz Field only while they are absent in both Kirkuk and Bai Hassan section. Another 3rd order cycle can be recognized within the Jeribe Formation during the Langhian Middle Oligocene in both Bai Hassan and Khabaz sections after a short hiatus caused missing of the Burdigalian Early Miocene (Figs.4 and 5). The deposition of these 3rd order cycles was controlled by the tectonic effects and uplifting of the study area.

This 2nd order cycle reflects a major sea level rise where the Jaddala, Palani, Ibrahim, and Tarjil formations were deposited. These formations represent the (TST) of this cycle. It is bounded below by a transgressive surface (TS) which separate this sequence from the underlying Aaliji Formation. It consist of many microfacies of Planktonic Foraminifera Mudstone (PFM) and Planktonic Foraminifera Wackestone (PFW) of Jaddala and Palani formations in addition to Planktonic Mudstone-Wackestone (PMW) and Globigerinid Wackestone-Packstone (GWP) as well as *Globorotaliakugleri* Mudstone (GlrM) and *Globigerinoides* Wackestone-Packstone (GWP) of Ibrahim Formation that deposited as reterogradational parasequences with thickness (172-220 m), bounded above by a maximum flooding (MF) indicated by maximum deepening and followed upwards by a highstand systems tract (HST) with (125-180 m) thick consisting of an overall upward shallowing succession of many parasequences. It shows an upward transition from dark, poorly fossiliferous Mudstone and Wackestone with planktonic foraminifera into different microfacies with high diversity of benthonic foraminiferal such as Benthic Bioclasts Wackestone (BsW), Nummulitic-Coralline red algae Wakestone-Packstone (NRWP) and Coral Boundstone (CB) of Sheikh Allas Formation; Bioclastic Packstone (BsP) and Benthic Wackestone-Packstone (BWP) of Shurau Formation; Planktonic-Benthic bioclast foraminiferal Wackstone (PBsW) and Benthic bioclastic Packstone (BsP) of Baba / Tarjil interbedded zone; Bioclastic Wackstone (BsW), Coralline Red algae-Nummulites Packstone (RNP), Benthic Grainstone submicrofacies (BG), Oolitic Grainstone submicrofacies (OG) and Coral Boundstone (CB) of Baba Formation; Miliolid Packstone (MP) , Bioclastic Packstone (BsP), Bioclasts-Lithoclasts Packstone (BsLP), Nummulitic Packstone (NP) , Peloidal Grainstone (PG), Rotalids Grainstone (RG), Miliolidal Grainstone (MG) and Dolomitized Mudstone (DM) of Bajwan Formation; Coraline red algae Packstone (RP), Rotalidal-Coraline red algae Packstone (RRP) and Coral Boundstone (CB) of Azkand Formation; Wackestone-Packstone (WP) of Anah/Azkand interfingering zone; Benthic Foraminifera Wackestone-Packstone (BFWP), Lithoclastic Grainstone (LG) of Anah Formation; Algal Wackestone (AW), Benthic Foraminifera Wackestone (BFW), Pelecypodal Packstone (PLP) microfacies , Dolomitized Mudstone (DM) and Quartz Grains bearing Mudstone (QM) submicrofacies of Jeribe Formation deposited as progradational parasequences with (125-180 m) thick, it is bounded above by Type1 sequence boundary (SB1).

Within the highstand systems tract (HST) of this 2nd order cycle, five 3rd order cycles were recognized:

Cycle A

This cycle was identified in Kirkuk Field only with a thickness of (21-50 m). It represents the interbedded zone between the Palani Formation and the Sheikh Allas Formation in Kirkuk Field (Figs.3). This cycle start with (15-34 m) thick of transgressive systems tract (TST) consisting of Planktonic Foraminifera Mudstone (PFM) intercedes with thinly Benthic bioclasts Wackestone (BsW) deposited as a retrogradational parasequence, bounded below by a transgressive surface (TS) and above by a maximum flooding (MF) followed by (6-16 m) thick highstand systems tract (HST) composed of Benthic bioclasts Wackestone microfacies (BsW) deposited as a progradational parasequence limited by transegressive surface (TS) which separate this cycle from the overlying cycle B. Cycle A is almost symmetrical reflecting episodes of relative sea level rise and still stand.

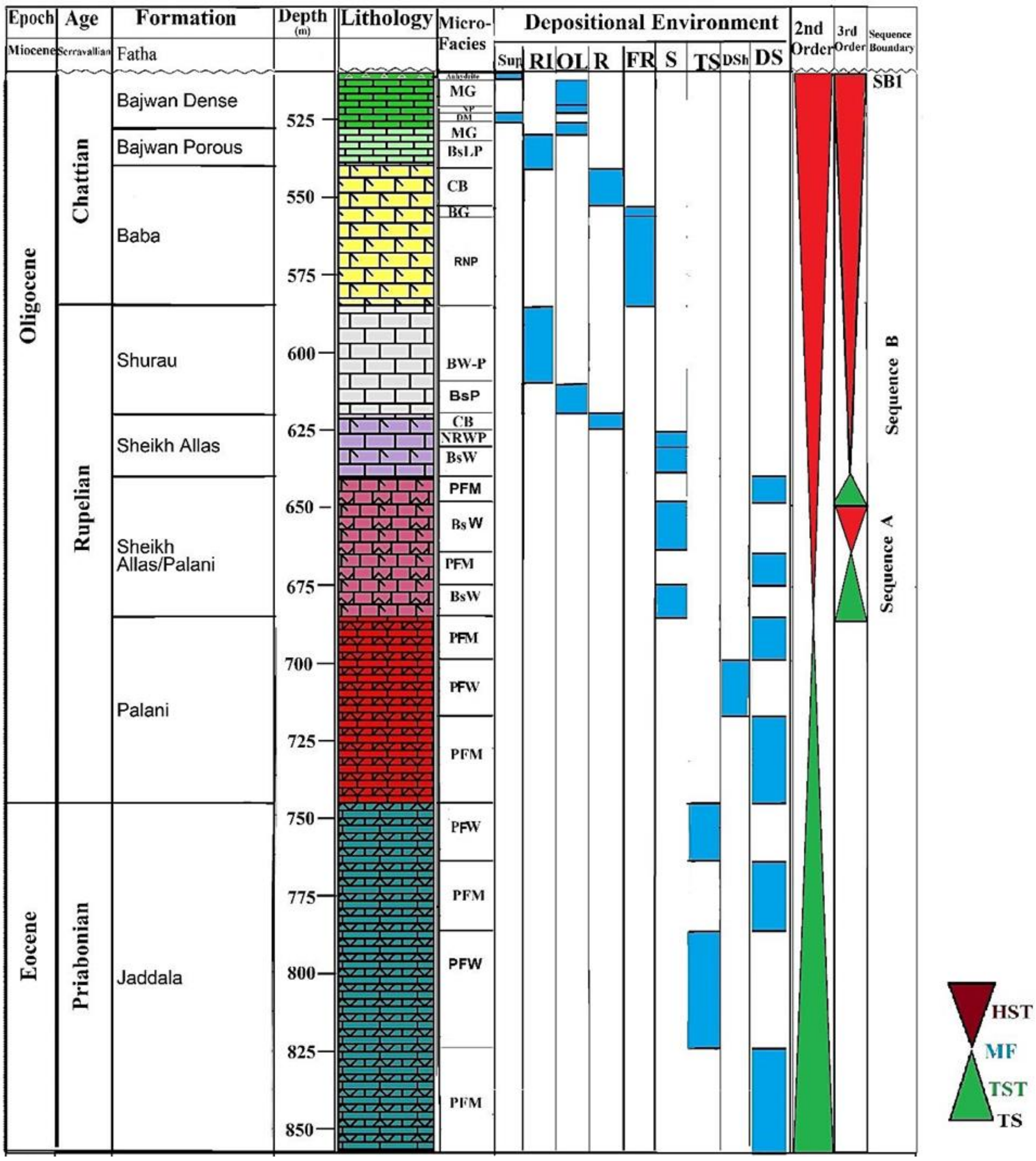

Figure.3 Sequence stratigraphic subdivision of the Upper Paleogene-Lower Neogene succession at K-243

Cycle B

This 3rd order cycle was distinguished only in Kirkuk Field too (Figs.3). It represents the upper part of the transitional zone between the Palani and Sheikh Allas formations, Sheikh Allas, Shurau, Baba and Bajwan formations with a thickness of (112-139 m). It is asymmetrical with thin transegressive systems tract (TST) consisting of Planktonic Foraminifera Mudstone (PFM) which represent a reterogradational parasequence (5-9 m) thick which bounded below by (TS) and above by a maximum flooding (MF) followed by a thick highstand systems tract (HST) with thickness (107-130 m) composed of relatively shallower facies of Benthic bioclastic Wackestone (BsW), Nummulitic-Coralline red algae Wakestone-Packstone (NRWP), Coral Boundstone (CB) of the Sheikh Allas Formation, Benthic bioclast Packstone (BsP) and Benthic Wackestone-Packstone (BWP) of Shurau Formation, Coraline red algae-Nummulites Packstone (RNP) and Benthic Foraminiferal Grainstone (BG), Coral Boundstone (CB) of Baba Formation, and Bioclasts-Lithoclasts Packstone (BsLP), Rotalids Grainstone (RG), Miliolidal Grainstone (MG), Nummulitic Packstone (NP), Dolomitized Mudstone (DM) of Bajwan Formation. At the end of this sequence, the deposition was terminated due to the uplifting of the area at Kirkuk Field and the upper boundary represent a large scale of hiatus where the sequences of Early Miocene (Aquitanian and Burdigalian) in addition to the sequences of the Early Middle Miocene (Langhian) were absent in Kirkuk Field representing Type1 sequence boundary (SB1) bounding the upper part of this sequence and separates it from the Serravallian Middle Miocene Fatha Formation. Cycle B reflects a short episode of relative sea level rise followed by long still stand.

Cycle C

This cycle was identified in Khabaz Field only (Fig.4), and it represents the Aquitanian Early

Miocene succession where it covered Formation as well as the lower and middle parts of the interbedded zone between the Ibrahim and the Azkand formation. It is (31.5-59m) thick. The *Globigerinoides* Wackestone-Packstone (GldWP) interceded with thin Coralline red algae Packstone (RP) deposited as reterogradational (TST) parasequence (23-55 m) thick, bounded below by Type1 sequence boundary surface (SB1) and above by a maximum flooding (MF) followed by (4-8.5 m) thick of Coralline red algae Packstone (RP) deposited as the progradational (HST) parasequence. This cycle is asymmetrical with relatively thicker (TST) reflecting long relative sea level rise followed by brief still stand.

Cycle D

This cycle has a thickness of (100.5-104 m). It includes the upper part of the Azkand/Ibrahim interbedded zone, Azkand Formation and the Anah Formation entirely in addition to the interfingering zone of these formations. The (TST) of this cycle is thin (Brief relative sea level rise) and consist of *Globigerinoides* Wackestone-Packstone (GldWP) deposited as a reterogradational parasequence with thickness (8-12 m) bounded below by (TS) and above by a maximum flooding (MF), tracked by a thick highstand systems tract (HST) (Long still stand) consisting of shallow microfacies of Coralline red algae Packstone (RP), Rotalid-Coraline red algae Packstone (RRP), Coral Boundstone (CB), Wackestone-Packstone (WP), Benthic Foraminiferal Wackestone-Packstone (BFWP) and Lithoclastic Grainstone (LG) deposited as a progradational parasequence (92-92.5 m) thick. Later the deposition was terminated due to a major fall in the relative sea level due to the uplifting of the study area which continued to the Langhian Early Miocene. As a result, at least (4.46 Ma) is missing between the Aquitanian Early Miocene and Langhian Middle Miocene and the Burdigalian Early Miocene succession was disappeared in Khabaz Field, so that Type1 surface boundary (SB1) bounded this cycle and separates the Aquitanian Early Miocene Anah Formation from the Langhian Middle Miocene Jeribe Formation (Fig. 4).

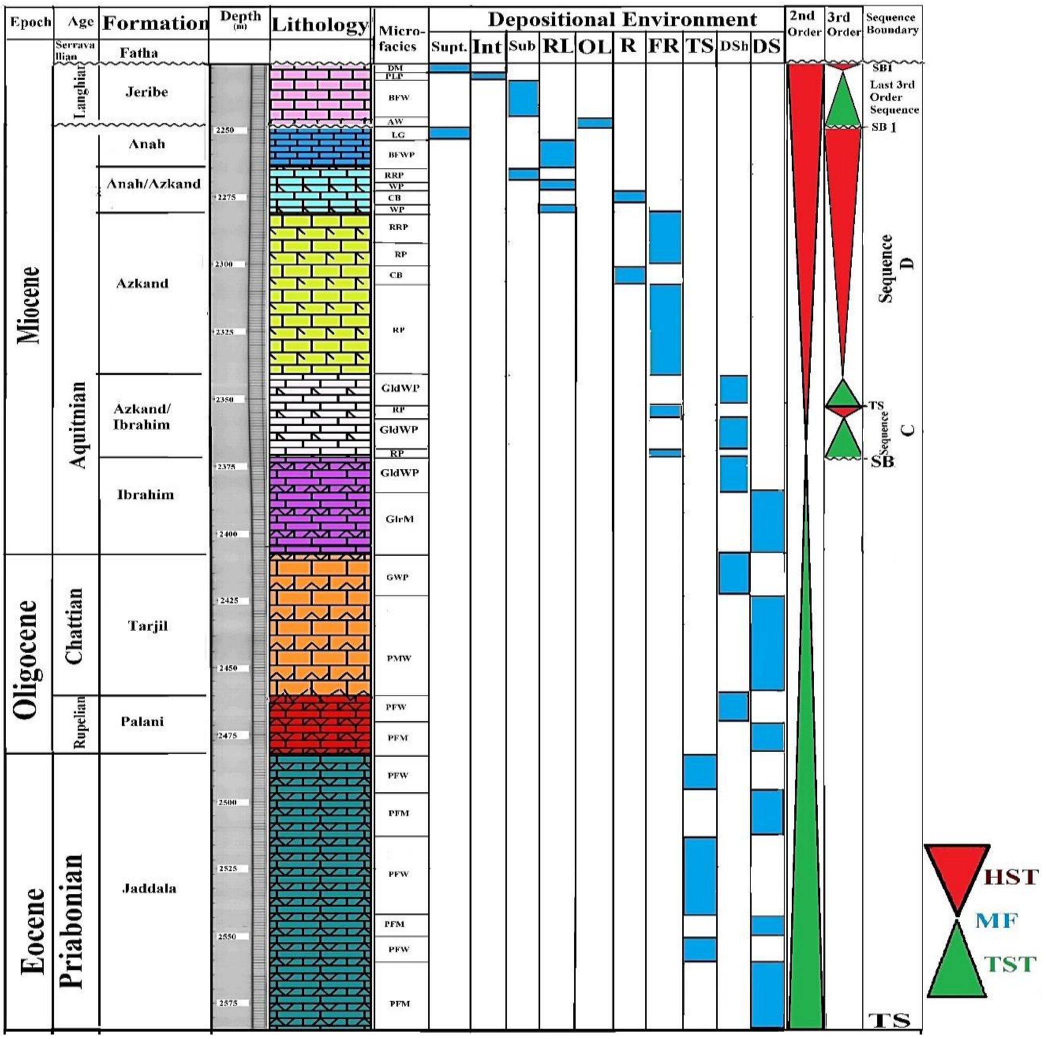

Figure.4 Sequence stratigraphic subdivision of the Upper Paleogene-Lower Neogene succession at KZ.29.

Uppermost 3rd order cycle (Jeribe Formation)

This cycle was identified in both Bai Hassan and Khabaz fields while it was not reached the Kirkuk Field because it was a positive area. It was deposited during the Langhian Middle Miocene after a break following deposition of the Chattian Late Oligocene Bajwan Formation in Bai Hassan Field and the deposition of Aquitanian Early Miocene Anah Formation in Khabaz Field and continued to the Langhian Middle Miocene where it covered the Jeribe Formation with (15-30 m) in thickness (Figs.5). It started with (12-24 m) thick of Algal Wackestone (AW), Benthic Foraminiferal Wackestone (BFW) and Pelecypodal Packstone (PLP) deposited as the reterogradational (TST) parasequence bounded below by Type1 sequence boundary (SB1) and by a maximum flooding (MF) above, followed by (2-6 m) thick progradational (HST) consisting of shallow marine microfacies such as Dolomitized Mudstone (DM) and Quartz Grains bearing Mudstone (QM). This cycle is bounded above by type1 surface boundary (SB1) that separates this cycle and the whole studied succession from the overlying Serravallian Middle Miocene Fatha Formation.

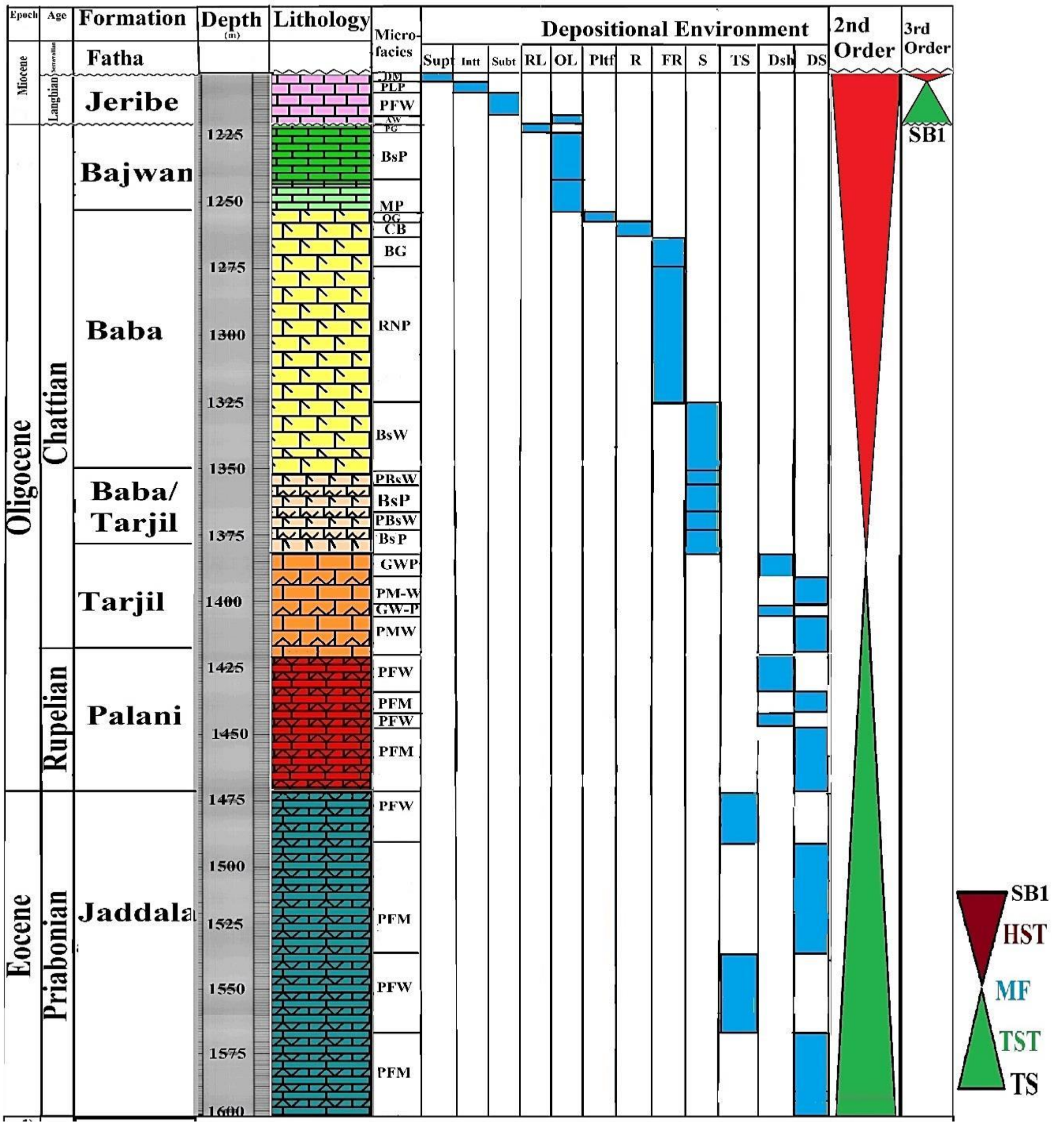

Figure.5 Sequence stratigraphic subdivision of the Upper Paleogene-Lower Neogene succession BH-138

Basin development

The deposition of the Upper Palaeogene-Lower Neogene successions in the study area was different from one area to another (Fig.6). The Priabonian Late Eocene succession represented by pelagic Jaddala Formation was deposited all over the study area; the Rupelian Early Oligocene represented by deposition of three formations in different palaeoenvironments, They include: the pelgic Palani Formation, reef-fore reef Sheikh Allas Formation, and back reef Shurau Formation in Kirkuk Field while only the pelgic Palani Formation was deposited in Bai Hassan and Khabaz Fields. The Chattian Late Oligocene represented by pelgic Tarjil Formation, reef-fore reef Baba Formation, and back reef Bajwan Formation in Bai Hassan and Kirkuk fields while only the Tarjil

Formation at Khabaz Field. The Aquitanian Early Miocene represented by pelagic Ibrahim Formation, reef-fore reef Azkand Formation and backreef Anah Formation are present in Khabaz Field only. The Burdigalian Early Miocene successions were absent completely all over the study area due to the uplifting and falling in the sea level.

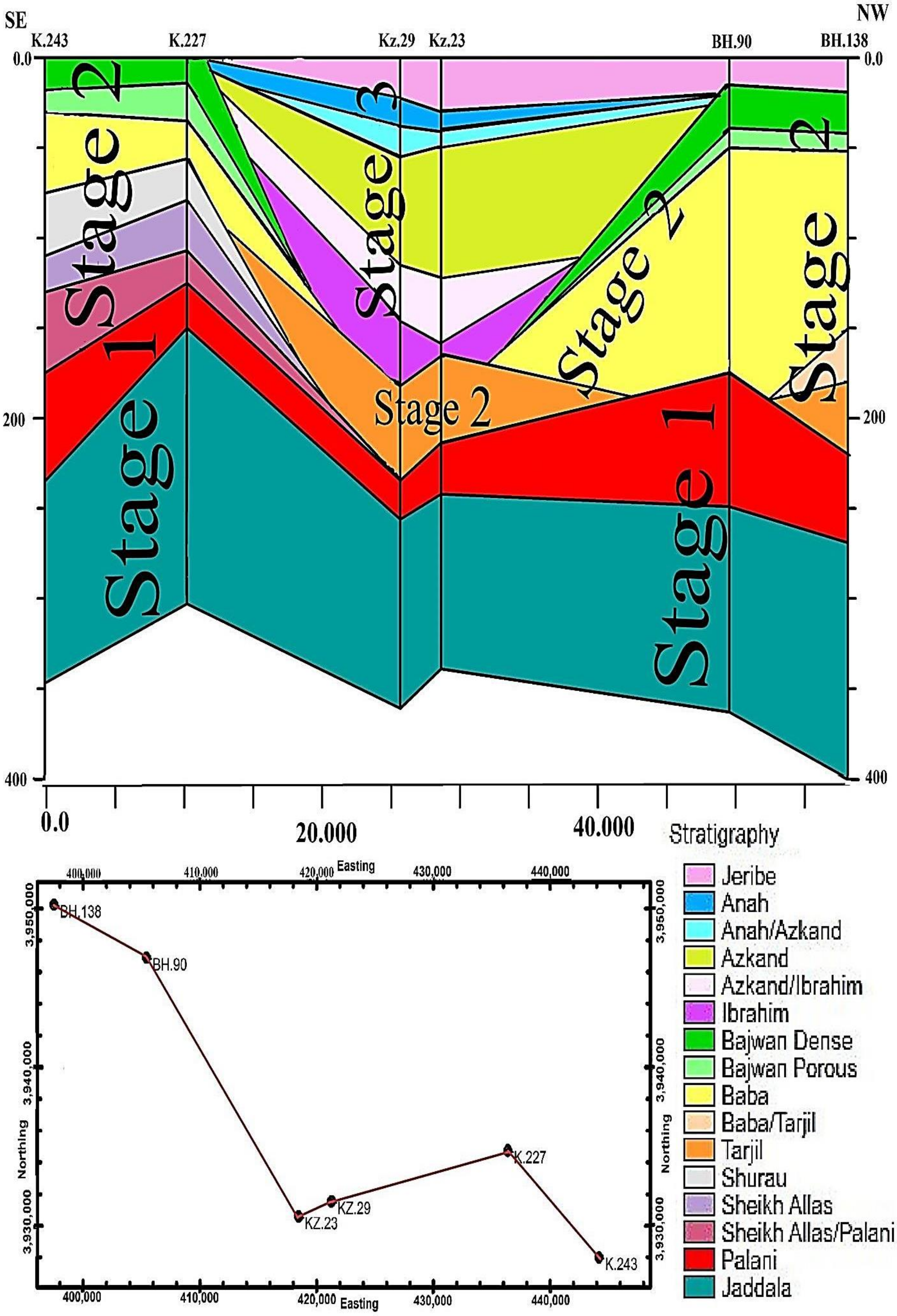

Figure.6 Stratigraphic cross section of the Upper Palaeogene-Lower Neogene Succession in the study area

The Langhian Middle Miocene succession represented by the Jeribe Formation is present in both Bai Hassan and Khabaz fields while it was absent in the Kirkuk Field. The manner of deposition and the basin development of these successions is discussed as below:

Stage 1

During the Middle-Upper Eocene the Jaddala Formation was deposited all over the basin in Kirkuk, Bai Hassan and Khabaz fields.

The Jaddala Formation covers the Aaliji Formation (Paleocene-Early Eocene) in all studied wells and the concentration of glauconite with pyrite between them in BH.138Well of Bai Hassan Field with increasing of Gamma ray log indicate to a regression after the deposition of Aaliji Formation followed by a major transgression during the Middle Eocene leading to the deposition of Jaddala Formation. The Jaddala Formation (Middle-Late Eocene) expands all over the study area whereas its equivalents were outside the study area. This was followed by a transgression in the Early Oligocene where the Palani Formation was deposited in Kirkuk, Bai Hassan and Khabaz areas.

Stage 2

In this stage, the basin trend was to the south toward the Khabaz Field and the reef buildup was located near Kirkuk Field and an interfingering took place between the Sheikh Allas and Palani formations deposited as a 3rd order cycle (A). Therefore, the fore reef and reef of Sheikh Allas and the back reef Shurau were deposited as a second 3rd order cycle (B) in Kirkuk Field only whereas the deposition of deep sea facies of the Palani Formation continued in both Bai Hassan and Khabaz areas.

In the Late Oligocene, the shoreline was abutting to Baba dome [15] while the Avanah and Khurmala domes were positive areas [24] and the basin trend was toward Khabaz Field. Therefore, Tarjil Formation (deep facies) was deposited in the Khabaz and Bai Hassan areas rather than Kirkuk Field (outside of the studied wells of Kirkuk Field toward Tarjil plunge south east Kirkuk Field) whereas the Baba Formation (reef and fore reef facies) was deposited in the Baba dome within Kirkuk Field as well in Bai Hassan Field. The deposition of the reef and fore reef Baba Formation lead to forming a distinct back reef lagoon behind the reef body and Bajwan Formation was deposited. The distinct shallow lagoon with restricted circulation is due to the formation of a barrier reef.

Stage3

During the Aquitanian Early Miocene, a positive area developed where the Baba Dome and the Bai Hassan Field were uplifted with Avanah and Khurmala domes in Kirkuk Field. Therefore, the Bajwan and Baba formations (Late Oligocene) became subject to erosion. On the other hand, the basin was trended toward the south and southeast while the Khabaz Field represent the area of reef deposition, and the depositional system changed from the shelf to ramp environments [15]. Thus, the Aquitanian (Ibrahim, Azkand and Anah) formations were deposited only in Khabaz Field as two 3rd order cycles (C and D) whereas Kirkuk and Bai Hassan were positive area during that time.

During the Burdigalian Early Miocene, all over study area was a positive area where no deposition took place.

During the Langhian Middle Miocene, a new transgression took place where the Bai Hassan and Khabaz in the study area represent a tidal flat and the Jeribe Formation deposited, whereas the Kirkuk Field was a positive area and the deposition of Jeribe Formation did not reach this area and the erosion continued to Bajwan Formation (Late Oligocene).

In general, the depositional basin of the Upper Palaeogene-Lower Neogene successions was in a recession phase where the shoreline shifted from Kirkuk then Bai Hassan and later to Khabaz during the Oligocene and Miocene respectively, where the whole study area was deep during the Middle and Late Eocene represented by Jaddala Formation, also in the beginning of the Early Oligocene represented by basinsl facies of Palani Formation, the reef and back reef facies were represented by Sheikh Allas and Shurau formations in the Kirkuk Field; then during the Late Oligocene the reef facies in Bai Hassan and Kirkuk fields are represented by Baba and Bajwan formations. During the Aquitanian Early Miocene the shoreline shifted toward Khabaz Field and the reef and back reef facies were deposited (Azkand and Anah formations within Khabaz Field only); The study area was a positive area during the Burdigalian Early Miocene and the basin trended was to the south and southeast outside the study area.

Conclusions

The geometry, microfacies, and facies association of the Upper Palaeogene-Lower Neogene succession indicates deposition within a wide range of subenvironments within a carbonate platform. This platform was characterized by a rim due to a reef buildup represented by barrier reefs during the Late Eocene and Oligocene then it was changed into distally steepened ramp with patch reef during the Early Miocene due to the tectonic development of the area.

The Upper Palaeogene-Lower Neogene succession represent one 2nd order cycle bounded below by (TS) and by an (SB1) above. This 2nd order cycle include five 3rd order cycles, two of them (A and B) were identified in Kirkuk Field and bounded below by a (TS) and above by an (SB1). Third order cycles C&D are bounded above and below by an (SB1) and found at Khabaz section only. The uppermost 3rd order cycle which represent the Jeribe Formation was bounded by (SB1) in both lower and upper contacts and identified at Bai Hassan Field.

The studied succession was developed through three main stages; the first stage represents deposition of the basinal Jaddala Formation during the Upper Eocene all over the study area followed by deposition of the basinal facies of the Palani Formation. It represents a major sea level rise. The second stage represented by the beginning of sea level still stand which led to the upgrading growth during early

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Highstand systems tract of the carbonate shelf. As a result, during this stage, the reef facies prograded seaward and replaced by the fore reef - reef facies of Sheikh Allas Formation and by back-reef facies of Shurau Formation in Kirkuk Field only while the Palani Formation continued deposition in both Bai Hassan and Khabaz fields. In the same way Tarjil, Baba and Bajwan formations were deposited during the Late Oligocene in the study area where the reef facies prograded seaward and replaced by the fore reef - reef facies of Baba Formation and by back reef facies of Bajwan Formation in both Kirkuk and Bai Hassan fields. The third stage is represented by deposition of the Ibrahim, Azkand and Anah formations during the Aquitanian Early Miocene in Khabaz Field only due to the uplifting of both Kirkuk and Bai Hassan areas where transgression did not reach them. During the Burdigalian, the Khabaz Field was uplifted as Kirkuk and Bai Hassan fields as the transgression did not reach the whole studied area. Then, a new transgression during the Langhian Middle Miocene covered both Khabaz and Bai Hassan fields with shallow water but did not reach the Kirkuk Field, which led to the deposition of the Jeribe facies, this stage ended by a major sea level fall and unconformity surface bounded the top of the succession.

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البيئات الترسيبية وطباقية التتابع و تطور الحوض الرسوبي لتتابعات اعلى الباليوجين–اسفل النيوجين في حقول كركوك وباي حسن وخباز النفطية شمالي العراق

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الملخص

أدى تحليل السحنات المجهرية لتتابعات اعلى الباليوجين– اسفل النيوجين والتي تشمل تكوينات جدالة وبلاني وشيخ علاس وشوراو وتارجيل وبابا وباجوان وابراهيم وازقند وعانة في حقول كركوك وباي حسن وخباز ضمن نطاق الطيات المنخفضة شمال العراق الى تشخيص 30 سحنة دقيقة رئيسة تتضمن 15 سحنة دقيقة ثانوية والتي تتواجد ضمن 9 انطقة سحنية تتراوح من المناطق فوق المدية الى المناطق الحوضية ضمن الرصيف الكاربوناتي الحاجزي (Rimmed carbonate shelf) ذي الحيود الحاجزية (Barrier reef)، اما تلك العائدة لتتابعات النيوجين فإنها ترسبت ضمن المنزلق شديد الإنحدار (steepened ramp) ذات الحيود الهدبية (Fringing reef). إن ابرز العمليات التحويرية المؤثرة على السحنات الدقيقة المشخصة تمثلت بالسمنتة، والتشكل الجديد، والدلمتة، وترسيب المعادن موضعية النشأة، والإذابة (الخلب)، والإنضغاط، والتحطيم الميكانيكي، والمكرتة، ونركيب الجيوبيتل. تتألف تتابعات الباليوجين الأعلى–النيوجين الأسفل من دورة ترسيبية واحدة من الرتبة الثانية تتضمن خمس دورات ترسيبية ذات رتبة ثالثة في جزئها العلوي المتضخل نحو الأعلى (نظام المسار التراجعي) حيث ترسبت الدورتين (A) و (B) خلال فترة الأوليكوسين والمتواجدة ضمن مقاطع حقل كركوك النفطي والتي يحدها من الأسفل سطح تقدمي (TS) بينما يحدها من الأعلى حد تتابعي من النوع الأول، اما الدورتان (C) و (D) فقد ترسبتا خلال المايوسين المبكر (الأكويتاني) في حقل خباز فقط ويحدهما من الأسفل ومن الأعلى حد تتابع من النوع الأول، وقد نشأت هذه الدورات عندما كانت العوامل التكتونية هي المسيطر الرئيس في تطورها والتي سببت عدة فترات متعاقبة من ارتفاع مستوى سطح البحر النسبي والبقاء ساكنا (Stillstand) تبوعا بهبوط مستوى سطح البحر، اما الدورة ذات الرتبة الثالثة الأخيرة ضمن تكوين الجريبي فقد تم تشخيصها في حقلي باي حسن وخباز حيث يحدها من الأسفل ومن الأعلى حد تتابع من النوع الأول وهي تمثل فترة وجيزة لإرتفاع مستوى سطح البحر النسبي تبعها هبوط كبير تسبب في تعرية معظم التكوين. ان تطور تتابعات اعلى الباليوجين – اسفل النيوجين مرت بثلاث مراحل اذ تمثلت المرحلة الأولى بترسيب السحنات الحوضية لتكويني جدالة وبلاني (الإيوسين والأوليكوسين المبكر) في كل منطقة الدراسة ، بينما تمثلت المرحلة الثانية بتوجه الحوض نحو الجنوب الى جهة حقل خباز ونمو الحيد قرب حقل كركوك وحدوث تداخل بين تكويني بلاني وشيخ علاس تمثل بترسيب دورة (A) ذات الرتبة الثالثة لذا فإن سحنات الحيد وامام الحيد لتكوين شيخ علاس وسحنات خلف الحيد لتكوين شوراو قد ترسبت ممثلة دورة (B) ذات الرتبة الثالثة في حقل كركوك فقط بينما استمر ترسيب السحنات العميقة لتكوين بلاني في منطقتي باي حسن وخباز، اما المرحلة الثالثة فقد حدثت خلال المايوسين المبكر (الأكويتاني) وتمثلت بتطور المنطقة الموجبة عندما ارتفعت قبة بابا وحقل باي حسن ملتحقة بقبتي افانة وخورمالة في حقل كركوك لذا اصبح تكويني باجوان وبابا (الأوليكوسين المتأخر) عرضة لعمليات التعرية بينما مثل حقل خباز منطقة نمو الحيد، وتغير النظام الترسيبي من الرف (Shelf) الى المنزلق (Ramp) . في بداية المايوسين الأوسط (لانكيان) حدث تقدم بحري جديد غطى كلا من منطقتي خباز وباي حسن بالمياه الضحلة حيث مثلت المسطحات المدية (Tidal flat) التي رسبت السحنات الضحلة لتكوين الجريبي بينما لم تصل المياه حقل كركوك الذي كان يمثل منطقة موجبة.