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Lithostratigraphy and biostratigraphy of planktic and benthic foraminifera (Oligocene-Early Miocene), Kurdistan Region, Northeastern Iraq

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The lithostratigraphy and biostratigraphy are carried out for the first time in the Pungalla section and have not previously been described. Forty samples were collected for this study in the Sulaimaniyah area, Kurdistan Region, Iraq. The study succession is located within the low-folded zone. The lithology of the succession here is composed of massive fossiliferous limestone, marly limestone, bedded highly joined and fractured oolitic limestone, and coralline limestone. For the first time, these rock units are described in detail. It is possible to attribute them to the Shurau, Tarjil, Bajwan, Anah, Jeribe, and Fatha formations. It bears a frequent number of benthic and planktic foraminifera and other fossil groups such as echinoid fragments, bryozoans, calcareous algae, bivalve, gastropods, and coral that are concentrated within the rock units. Six foraminiferal biozones were identified in the studied section: *Austrotrillina paucialveolata- Austrotrillina brunni* Assemblage Zone (SBZ21); *Praerhapydionina delicata- Peneroplis evolutus* Concurrent-Range Zone (SBZ22A-BZ22B); *Meandrospina anahensis- Austrotrillina asmariensis* Assemblage Zone (SBZ23); *Austrotrillina howchini- Peneroplis farsensis* Interval Zone (SBZ24); *Ammonia beccari- Dendritina rangi* Assemblage Zone (SBZ250); and *Paragloborotalia opima-Dentoglobigerina prasaepis* Assemblage Zone (P21). These marker foraminifers' biozones suggest an Oligocene to early Miocene age. They are correlated with comparatively well-known biozones from other parts of the Tethys region, which shows a good comparison.

Keywords: Oligocene-Lower Miocene; Foraminifera; Stratigraphy; Sulaimaniyah; Northeast Iraq.

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Introduction

Pungalla village is a well-known landmark located at the south-west limb of the Mamlaha anticline, situated to the south of Sulaimanyah city, northeastern Iraq (Fig. 1). It is a prominent structure consisting mainly of Paleogene-Neogene rocks. Cahuzac and Poignant (1997) clarified that Oligocene-Miocene shallow-marine deposits of the Tethys region consist of diagnostic benthic foraminifera such as Miogypsinids, Lepidocyclinidae, Austrotrillinidae, Soritidae, and Nummulitidae that are used for biostratigraphic zonation and regional correlations. The Kirkuk Group is represented by Oligocene carbonate successions in Iraq, and the earliest researcher to record Oligocene-Miocene successions in the Kirkuk area is Henson (1948, 1950). Ctyroky and Karim, (1971) studied the stratigraphy and paleontology of the Oligocene and Miocene strata near Anah town, in the Euphrates valley, and defined *Miogypsinoides complanata* in the Anah Formation as being of Late Oligocene age. Youkhana and Hradecky (1977) recorded the existence of some Oligocene formations (Shurau, Baba, Bajawan, Azkand and Anah formations) around the Bamu anticline. Behnam (1979) studied stratigraphy and paleontology of the Oligocene – Miocene strata in the Khanaqin area (East Iraq) and described, for the first time from exposed rocks in the area, six Oligocene formations (Shurau formation from the Lower Oligocene, Tarjil, Baba, and Bajwan formations from the Middle Oligocene, and Anah and Azkand formations from the Upper Oligocene).

Buday (1980) confirmed the presence of nine formations in the Kirkuk Group succession.

Muhammad (1983) studied the biostratigraphy of the formations in the Kirkuk Group in the Kirkuk and Bai Hassan areas. Ghafor (2004; 2010; 2011; 2014; 2015; 2022a; 2022b, 2023, 2024) explained the larger foraminifera of Oligocene-Miocene rocks in northeastern Iraq. Ghafor and Ahmad (2019; 2021) clarified that there are Oligocene-Miocene rocks in the Sangaw area. Ghafor and Karim (2014) studied the biostratigraphy of the Oligocene succession in the High Folded Zone. Ghafor and Muhammed (2005; 2007; 2011) and Muhammad and Ghafor (2008) studied the biometric analysis for *Lepidocyclina* (*Nephrolepidina*) and Miogypsinid for the first time in Iraq. Al-Banna (2008) studied the Oligocene-Miocene boundary in northern Iraq and revised the previously assigned upper sub-cycle of the Upper Oligocene age (Chattian), suggested by Bellen et al. (1959), into a Lower Miocene age (Early Aquitanian). Ghafor et al. (2014) explain the existence of Oligocene age in the High Folded Zone. Biostratigraphy, microfacies, paleoenvironment, and paleoecological studies of the Baba Formation in Kirkuk Oil Field have been studied by Ghafor and Najaflo (2022). Ghafor and Rashidi, 2023; Ghafor et al., 2023, 2025, clarify that Baba and Anah formations are rich in benthic foraminifera and used as a tool for biostratigraphy, microfacies, and depositional environments. Ghafor et al. (2023) studied the benthic foraminifera of the Late Oligocene from the Kirkuk oil fields in Iraq.

This work focuses on the enhancement of the lithostratigraphic units and biostratigraphic value of the planktic and large benthic foraminifera taxa found in the Oligocene–Early Miocene rocks of the Pungalla section, northeastern Iraq.

In particular, the main goals of this paper are as follows:

1. To present a detailed lithologic description of the lithostratigraphic units and determine the rock unit formations.
2. To characterize the planktic and larger foraminiferal assemblages, assigning ages for each formation.
3. To try to correlate the larger foraminiferal assemblages from the Pungalla section with the PZ and SBZ of the Tethyan realm.

Geological Setting

The studied section is located within the low folded zone, specifically in the Butmah-Chamchamal subzone, which represents the NE unit of the foothill zone. According to Jassim and Goff (2006), the NE boundary of this zone lies along the SW flanks of the anticlines of the high folded zone that includes Haibat Sultan and Qara Dagh, and it is topographically the highest part of this zone (Fig. 2).

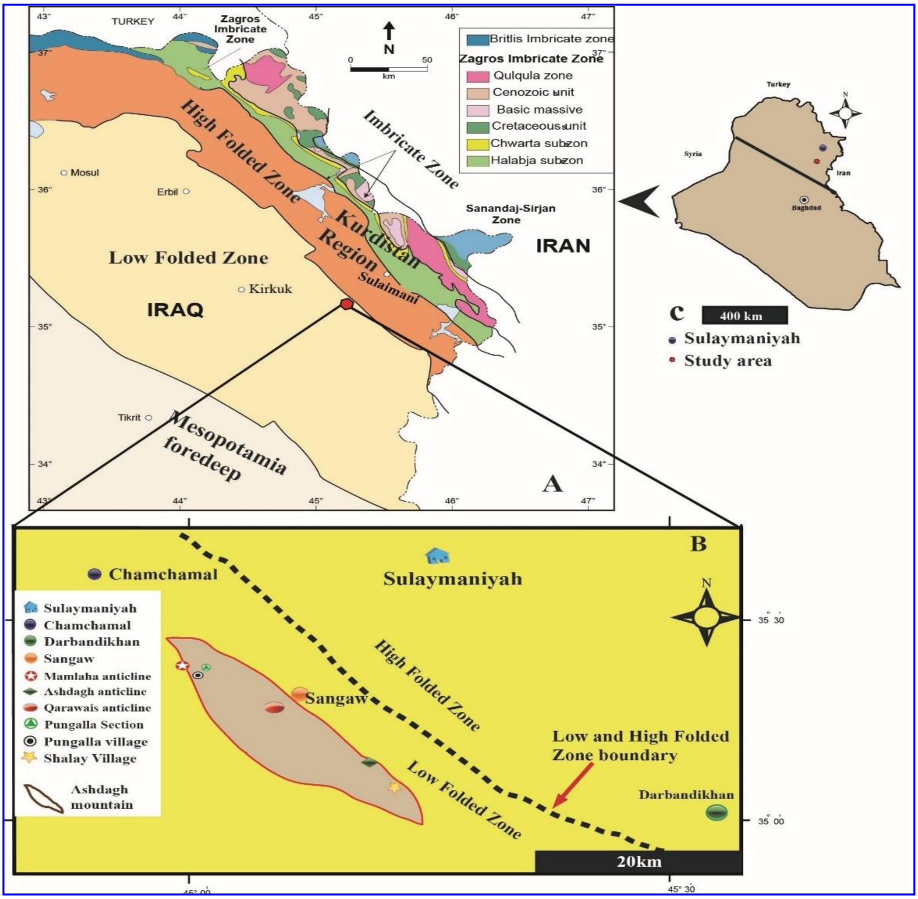

Fig. 1. Location map of the studied section: A, Tectonic map of Iraq. after Al-Kadhimi et al. 1996). B & C, Location map of the study area.

Oligocene sediments are absent on the Butma-Chamchamal Subzone, on the High Folded Zone, over most of the southwest part of the Balambo-Tanjero Zone, and on the Northern Thrust Zone. The large uplift during Oligocene time in the NE of Iraq and in the west of Iraq causes non-deposition of Oligocene sediments over most of the Rutba Subzone, the Salman Zone, and the Zubair and Euphrates Subzones of the Mesopotamian Zone, while the greatest thickness of the Oligocene sequence is more than 370 m thick between the Kirkuk and Kor-Mor structures in NE Iraq (Jassim and Goff, 2006).

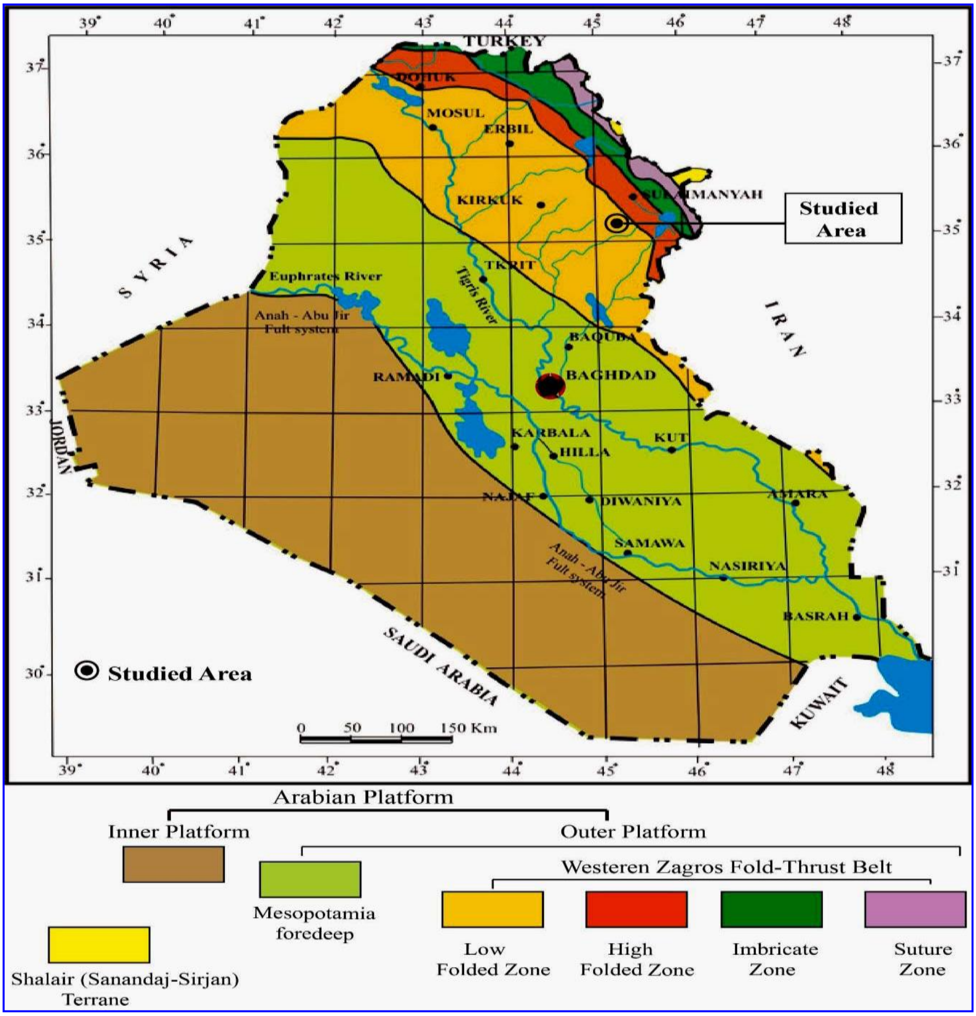

Fig. 2. Tectonic divisions of Iraq (Fouad 2015).

The stratigraphic correlation chart showing the position of the Baba and Azkand formations in southern, western, and northern Iraq in the geologic column of Iraq is depicted in (Fig. 2) (Harland et al., 1990 and El Diasty et al., 2016). Formations from the Cretaceous units have been studied and discussed by numerous authors (Kassab, 1976, 1977, 1978, 1979; Ghafor, 1988; Bakkal et al. 1993; Ghafor, 1993; Ghafor et al., 2004; Ghafor, et al., 2023; Ghafor and Mohialdeen 2016-, 2018; Ghafor, et al., 2024; Ghafor et al.,2012; Ghafor and Karim 1999-; Ghafor and Baziany, 2009). Formations from the Paleogene units have been studied and discussed by numerous authors (Al-Fattah et al., 2017, 2018, 2020a, 2020b; Al-Taee, et al., 2024a, 2024b, 2024c; Al-Qayim et al., 2014-; Ghafor & Al-Qayim 2021a,b-; Al-Qayim and Ghafor 2022; Ghafor and Muhammad, 2022, 2023a,b-, 2025). Formations from the Cretaceous / Paleogene boundary units have been studied and discussed by numerous authors (Kassab et., 1986; Ghafor, 1988-; Al-Shaibani, et al., 1993; Ghafor, 2000; Sharbazeri et al., 2009, 2011; Al Nuaimy et al., 2020;-, Ghafor et. al, 2024). Formations from the Neogene units have been studied and discussed by numerous authors (Ghafor, 2004, Ghafor and Muhammad, 2005, 2006; Muhammad and Ghafor, 2008; Ghafor, 2010; Ghafor 2014, Ghafor, 22a, Ghafor and Najaflo. 2022-, Ghafor 2022b; Гафр и др., 2025; Qafor et al., 2025).

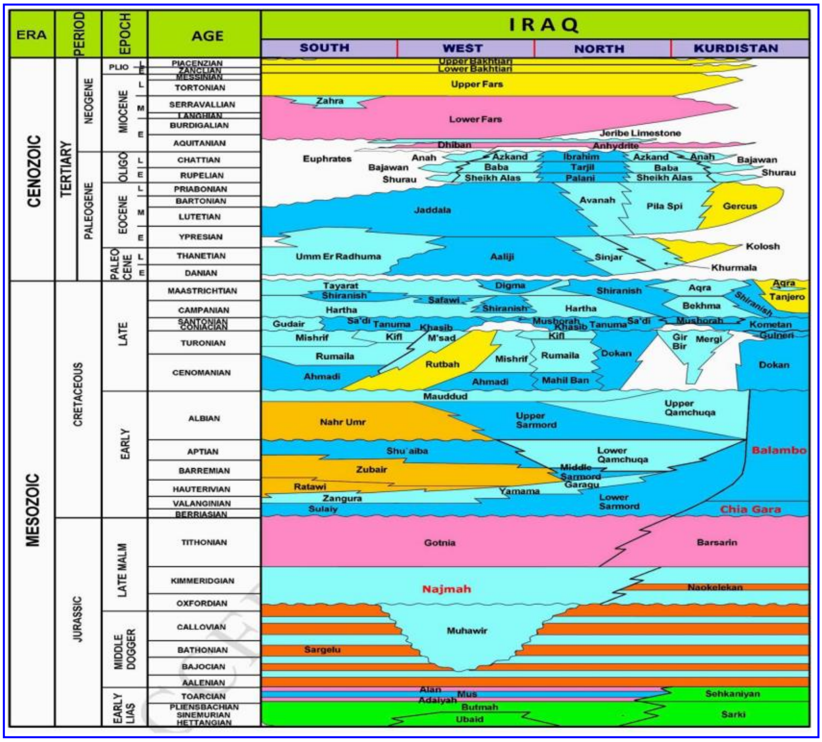

Fig. 3: Stratigraphic correlation chart and the position of the Paleogene -Neogene formations in southern, western, and northern Iraq (Kurdistan Regin), in the geologic column of Iraq (After Harland *et al.*, 1990 and El Diasty *et al.*, 2016). The area of Iraqi Kurdistan has been modified.

Materials and Methods

The Pungalla section cropping out in the northern part of Ashdagh Mountain is measured and sampled. A total of 40 samples were analyzed for the identification of planktic and benthic foraminifera (Figs. ٤ and ٥). Planktic foraminiferal taxa have been mainly identified in the washed residues from 10 grayish blue marly limestones. Larger foraminiferal analyses were carried out in a total of 100 thin sections from 37 grey massive highly fractured limestone and marly limestone samples. Loeblich and Tappan (1988) taxonomic classification is mainly used for planktic foraminiferal analyses. The taxonomic analyses of large benthic foraminifera are based on (Drooger 1993; Sirel et al.; 2013; Serra-Kiel et al. 2016; Roozpeykar and Moghaddam, 2016)

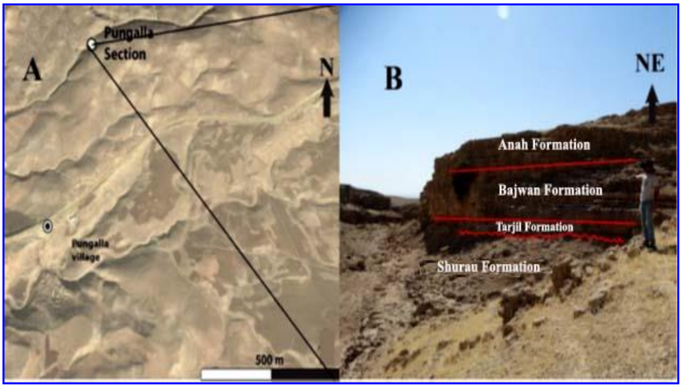

Fig.4. A. Satellite map of the Pungalla-section, Mamlaha anticline. B. Pungalla-section, Shows exposed lithostratigraphic units.

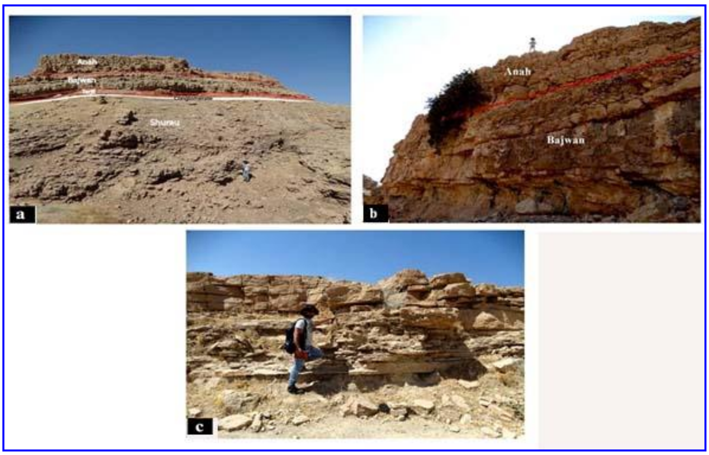

Fig. 5. Field photographs showing: - a. Shurau, Tarjil, Bajwan, and Anah formations, at the Pungalla section, Ashdagh Mountain. b. Bajwan and Anah formations at the Pungalla section, Ashdagh Mountain. c. parallel lamination in Jeribe Formation at the Pungalla section, Ashdagh Mountain

Results and Discussion

Stratigraphy

Six lithostratigraphic units were found for the first time in the study area, which are from older to younger: - (Fig. ٦).

I. Shuaru Formation

Shurau Formation was described by (Bellen et al. 1959) in Kirkuk well-109, which is about 18 m thick, composed of about 5.5 m of grey dense limestone and 13 m of porous coralline limestone, fossils in the type locality are relatively rare, but abundant miliolids, rare *Rotalia viennoti* and a few Algae occur, apart from the typifying fauna of *Austrotrillina howchini*, *Austrotrillina paucialveolata* and *Archaias operculiniformis*. In the Kirkuk field Shurau Formation is underlain by Sheikh Alas Formation conformably and unconformably overlain the Baba Formation. This unit of back-reef facies of the Sheikh Alas and Palani formations in the lower Oligocene (Henson, 1950). The Shurau Formation in the studied section is approximately 13 meters thick. The Tarjil Formation overlies this formation unconformably and the lower contact is not exposed (Fig. 5a).

II. Tarjil Formation

This formation is described by (Bellen et al. 1959), in the Kirkuk area well- 85, which is about 107 m thick, composed of slightly dolomitized globigerina marly limestone. The Tarjil Formation crops out in Qara Chauqh-Dagh area which consists of 20 m thickness of hard, yellowish-grey limestone overlain by thick-bedded limestone with these fossils *Nummulites* sp., *Lepidocyclina* sp., *Rhapydionina* sp., *Rotalia viennoti*, *Lenticulina* sp., gastropods, echinoids, algae, bryozoan, and bivalves (Bellen et al., 1959).

Tarjil Formation is recorded from the Pungalla section, which is composed of one-meter-thick bluish-grey marly limestone represents the lower part of the Formation (Fig. ٥b). The upper boundary is conformable with the Bajwan Formation, and the lower contact is unconformable with the Shurau Formation, which is indicated by a thin layer of the conglomerate bed, rich in microfossils.

III. Bajwan Formation

The Bajwan Formation was first defined by Bellen (1956) in Kirkuk Well-109. It consists of tight miliolid limestone alternating with more porous, patchily dolomitized coralline algal reef limestone. This formation contains relatively abundant coral fragments and thin argillaceous limestone beds (Bellen et al. 1959), with a thickness of about 39 meters. This unit in its type locality is conformably underlain by the Baba, and overlain by the Lower Fars Formation unconformably (Hensom, 1950). (Bellen et al. 1959), found different types of fossils in this formation, such as *Actinacis* sp., Anthozoa sp. indet., bryozoa sp. indet., *Corallinacaea* sp. indet., and, *Praerhapidionina delicata*. Occasionally, *Borelis pymaea*, *Meandropsina anahensis* and *Rotalia viennoti*. The Middle Oligocene age has been adopted for this formation. Bajwan Formation has been found in the studied section, which consists of milky white thick-bedded fossiliferous limestone, with tight, cream-colored, back-reef miliolid limestones, alternating with more porous, partly dolomitized, rotalid algal reef limestones with fairly abundant coral fragments. The thickness is varied, in the Pungalla section, is about 5m and is underlain conformably by the basinal Tarjil Formation and overlain conformably by the reefal Anah Formation (Fig. 5a, b).

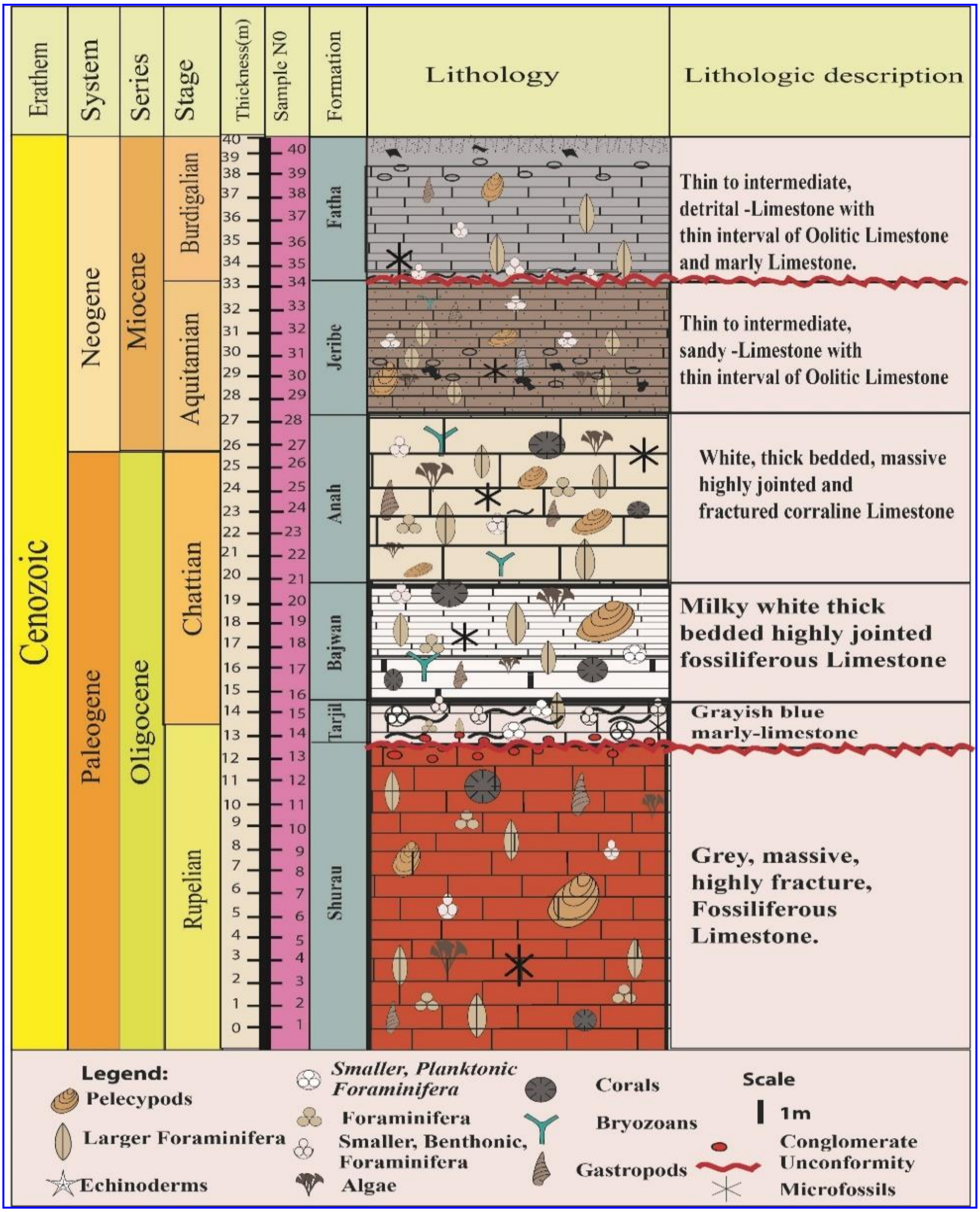

Figure 6. Lithostratigraphic column of Oligocene- Miocene rock units from Pungalla section.

IV. Anah Formation

Bellen (1956) studied the Anah Formation for the first time in the Euphrates River, about 15 km east of Nahiyah village, close to Anah. It is composed of limestone, grey, breccious, recrystallized, detrital and coralline, and its thickness in the type section is about 45 m. Bellen et al. (1959) identified these fossils in the formation: algae, anthozoa, bryozoa, echinoidea, mollusca and abundant foraminifera: *Archaias* sp., *Austrotrillina howchini*, *Borelis pygmaea*, *Heterostegina* cf. *assilinoides*, *Miogypsinoides complanata, Rotalia viennoti,* and miliolids. Late Oligocene age was recorded by Abid (1983). Anah Formation crops out in the studied section and is about 7 m thick and composed of white, thick-bedded, highly jointed, and fractured coralline limestone in the Pungalla section (Fig. ٥b). It is overlain by the Jeribe Formation conformably and underlain by the Bajwan Formation conformably.

V. Jerebi Formation

Damesin (1936), was the first to mention this formation, which is represented by 73 meters of massive, recrystallized, dolomitized limestone, that is rich in *Amphistegina* sp., *Borelis melo* var. *curdica*, *Elphidium* sp., *Nonion* sp., *Rotalia beccarii,* chilostomellids, dendritinids, miliolids, ostracods, lithophyllid,, fragmentary gastropods, lamellibranchs and echinoids,*? Clausinella* sp. (Be3llen et al., 1959. The Jeribe Formation in the studied section is composed of thin to intermediate highly jointed and fractured sandy limestone beds with a thin interval of oolitic limestone that is six meters thick. (Fig. 5c). This unit is overlain unconformably by the Fatha Formation, as indicated by the gap in the upper part of the unit, and underlain conformably by the Anah Formation.

VI. Fatha Formation

The Lower Fars Formation was renamed by the Fatha Formation in Iraq by Al-Rawi et al. (1992), and was originally described by Buskm et al. (1918) from the Masjd Suliman area in the Fars Province, Iran. In Iraq (Henson, 1950) and (Elder, 1958), the type section of this formation near Makhul Mountain is about 445 meters thick. The common fossils in the type locality were *Clausinella lamidei*, *Elphidium* sp., *Rotalia beccari*, miliolids, ostracods, etc., useful fossil indices are *Clausinella* spp. and *Ostrea latimarginata*, and it is likely from the middle Miocene period. (Henson, 1950). The Fatha Formation in the type section is composed of thin to intermediate detrital - limestone, with a thin interval of oolitic limestone and marly limestone. In the Pungalla section, the thickness of this unit is about 5-6 m. This refers to the lowermost part of the formation. The Fatha Formation starts with thin-bedded fossiliferous marly limestone and is overlayed by the Jeribe Formation conformably.

Biostratigraphic Analysis

The stratigraphic distribution of planktic and large benthic foraminifera from the Pungalla section, allowed us to document the range of these species and attribute them to the Oligocene-Early Miocene. This was based on seventeen species from five genera of planktic foraminiferas and thirty-four species from twenty-three genera of benthic foraminifera. (Figs. ٧-12). The studied section is subdivided into one planktic foraminifera zone and five Shallow Benthic Zones;- (SBZ21, SBZ22A, SBZ22B, SBZ23, SBZ24, and SBZ25) (Fig. 13), and the shallow benthic zones were studied for the first time by Cahuzac and Poignant (1997) and Serra-Kiel et al. (1998).

The recognized biozones are correlated with comparatively well-known biozones from other parts of the Tethys region which showed a good comparison between the biostratigraphic zones established in this study with the other studies. (Fig. 1٤ and 1٦). The biostratigraphic content of each lithostratigraphic unit is provided below, from the oldest to the youngest.

Austrotrillina paucialveolata- austrotrillina brunni assemblage zone (SBZ21)

This biozone is characterized by the assemblage of the nominate taxa (*Austrotrillina paucialveolata*, and *Austrotrillina brunni*). It is rich of benthic formaminifera, such as *Austrotrillina paucialveolata*, *Austrotrillina brunni*, and *Praerhapydionina delicata*. This Biozone starts from sample number 1, and ends in sample number 14, it is characterized by 13 m of section, sample no. 12, and 13; g-h, *Austrotrillina paucialveolata* Grimsdale, 1952, equatorial section, sample no. 2, and 10; i, *Textularia* sp., sample no. 2; j, *Idalina pignattii* n. sp. Gallardo-Garcia & Serra-kiel, Uncentered longitudinal sections, sample no. 13; k, *Archaias* sp., sample no. 4; l, *Spiroloculina* sp., axial section, sample no. 3. reef/back-reef Shurau Formation. The common taxa of this zone are represented by, *Praerhapydionina delicata*, *Idalina pignattii*, *Auttrotrillina paucialveolata*, *Austrotrillina brunni*, *Bigenerina* sp., *Neorotalia viennoti*, *Pyrgo* sp., *Triloculina tricarinata* , *Triloculina trigonula* k, *Spiroloculina* sp., *Textularia* sp., *Valvulina* sp., *Quinqueloculina* sp., *Rotalia viennoti*, *Sphaerogypsina* sp., *Praebullalveolina* sp., *Ditrupa* sp., and green algae. This biozone is the time equivalentthe to *Nummulites vascus- Nummulites fichteli* assemblage zone of Laursen et al., (2009) and Moghaddam et al., (2019) acorrelateslate with biozones o Al-Banna et al. (2010), which indicates Rupelian (Early Oligocene) in age.

Paragloborotalia opima- Dentoglobigerina prasaepis assemblage zone (P21).

The biostratigraphic interval of this zone is characterized by the assemblage of the nominate taxa (*Paragloborotalia opima*, *Dentoglobigerina prasaepis* and it is rich in planktic foraminifera such as *Dentoglobigerina prasaepis*, *Dentoglobigerina galavisi*, *Dentoglobigerina sellii*, *Paragloborotalia opima*, which is about 1-2 m thick from sample number (14-16), which represents basinal Tarjil Formation, and it is formed due to the sudden rise of sea level after a period of no deposition or unconformity, so you can see both benthic and planktic foraminifera due to mixing environments. The most diagnostic species include: *Dentoglobigerina tripartita*, *Dentoglobigerina sellii*, *Dentoglobigerina baroemoenensis*, *Dentoglobigerina globosa*, *Dentoglobigerina eotripartita*, *Dentoglobigerina binaiensis*, *Dentoglobigerina venezuelana*, *Dentoglobigerina galavisi*, *Dentoglobigerina prasaepis*, *Dentoglobigerina sellii*, *Globigerina ampliapertura*, *Globigerina Ciperoencis*, and *Globorotalia opima opima*. This planktonic foraminiferal assemblage indicates the P21 Zone (Berggren and Pearson 2005). This biozone correlated with *Globigerina angulisuturalis/Paragloborotalia opima opima* concurrent range zone (P21 of Blow, 1969, 1979; P21 of Berggren, 1969; Berggren and Miller, 1988), it corresponds to Rupelian- Early Chattian in age.

Praerhapydionina delicata- peneroplis evolutus concurrent-range zone (SBZ22A-SBZ22B).

It is characterized by the concurrent-range of the nominate taxa (*Praerhapydionina delicate* and *Peneroplis evolutus* Henson). This biozone started by the First Appearance Datum (FAD) of *Peneroplis evolutus*, in sample number 16, and ended by the Last Appearance Datum (LAD) of *Praerhapydionina delicata*, in sample number 21, This zone is 5 m thick of reef/back- reef Bajwan Formation. The common taxa in this zone are: (*Archaias kirkukensis*, *Archaias asmaricus*, *Archaias hensoni*, *Archaias* sp., *Praerhapydionina delicata*, *Austrotrillina striata*, *Austrotrillina asmeriensis*, *Austrotrillina* sp., *Austrotrillina brunni*, *Meandrospina anahensis*, *Peneroplis evolutus*, *Peneroplis thomasi*, *Spiroloculina cylindracea*, *Neorotalia viennoti*, *Pyrgo* sp., *Textularia* sp., *Valvulina* sp., *Quiqueloculina* sp., *Spirolina* sp., *Rotalia viennoti*, also contains other fossils: (echinoid fragments, bryozoa, red algae, bivalve fragments, and coral). This biozone is time equivalent to biozones *Praerhapydionina delicata-Austrotrillina howchini- Peneroplis evolutus* assemblage zone (BZ3) of Al-Banna et al. (2010) and equivalent to *Miogypsinoides complanatus* zone of Serra kiel et al., (2016) and to *Archaias asmaricus-Archaias hensoni* biozone of Laursen et al. (2009). It corresponds to Chattian in age.

Meandrospina anahensis - austrotrillina asmariensis assemblage zone (SBZ23).

The biostratigraphic interval of this zone is characterized by the assemblage of the nominate taxa (*Meandrospina anahensis*, and *Austrotrillina asmariensis*). It consists of benthic foraminifera, such as, *Meandrospina anahensis*, *Austrotrillin asmariensis*, *Archaias asmaricus*, which satrts in sample number 21, and ended in sample number 28. The zone comprises 7 m from sample number (21-28) of rback-reefreef Anah Formation, characterized by the rich Larger Benthic Foraminifera (LBF): (*Archaias kirkukensis*, *Archaias asmaricus*, *Archaias hensoni*, *Archaias* sp., *Austrotrillina howchini*, *Austrotrillina striata*, *Austrotrillina asmeriensis*, *Austrotrillina* sp., *Austrotrillina brunni*, *Meandrospina anahensis*, *Peneroplis evolutus*, *Peneroplis thomasi*, *Spiroloculina cylindracea*, *Pyrgo* sp., *Triloculina tricarinata*, *Triloculina trigonula*, *Textularia* sp., *Valvulina* sp., *Quinqueloculina* sp., *Idalina* sp., *Rotalia viennoti*, *Nummulites bouillei*, and the non- foraminifera assemblage includes *Lithoporella melobesoides*, echinoid fragments, bryozoa, red algae, bivalve fragments, and coral. This zone is correlated with the upper part of *Archaias asmaricus-Archaias hensoni* biozone of Laursen et al. (2009) and Moghaddam et al. (2019), and to the lower part of bio-zone of *Miogypsinoides complanatus* zone of Serra Kiel et al. (2016), and to the upper part of the biozone *Miogypsinoides banatamensis* of Serra Kiel et al. (2016). This biozone corresponds to Chattian-Early Aquitanian in age.

Austrotrillina howchini – peneroplis farsensis interval zone (SBZ24).

Biostratigraphic interval of this zone is characterized by the interval of the nominate taxa (*Austrotrillina howchini*, and *Peneroplis farsensis*). This zone is formed by the Last Appearance Datum (LAD) of *Austrotrillina howchini* at the base of the zone in sample 28, and the Last Appearance Datum (LAD) of *Peneroplis farsensis* at the top of the zone in sample 34. It is characterized by a 6 m thick lagoonal Jeribe Formation from the sample (28-34), which characterized by the presence of: (*Peneroplis farsensis, Ammonia beccari, Dendritina rangi, Miogypsina* sp., *Pyrgo* sp., *Textularia* sp., *Valvulina* sp.), and, the other fossils of bivalve fragments. This zone is correlated with the upper part of *Miogypsina-Peneroplis farsensis-Eulepidina* sp., biozone (part) of Laursen et al., (2009), and Moghaddam et al. (2019), and to the lower part of bio-zone of *Miogypsinoides bentamensis* zone (part) of Serra kiel et al. (2016), and to *Austrotrillina howchini – peneroplis farsensis* biozone of (Qader, 2020). This biozone corresponds to Aquitanian in age.

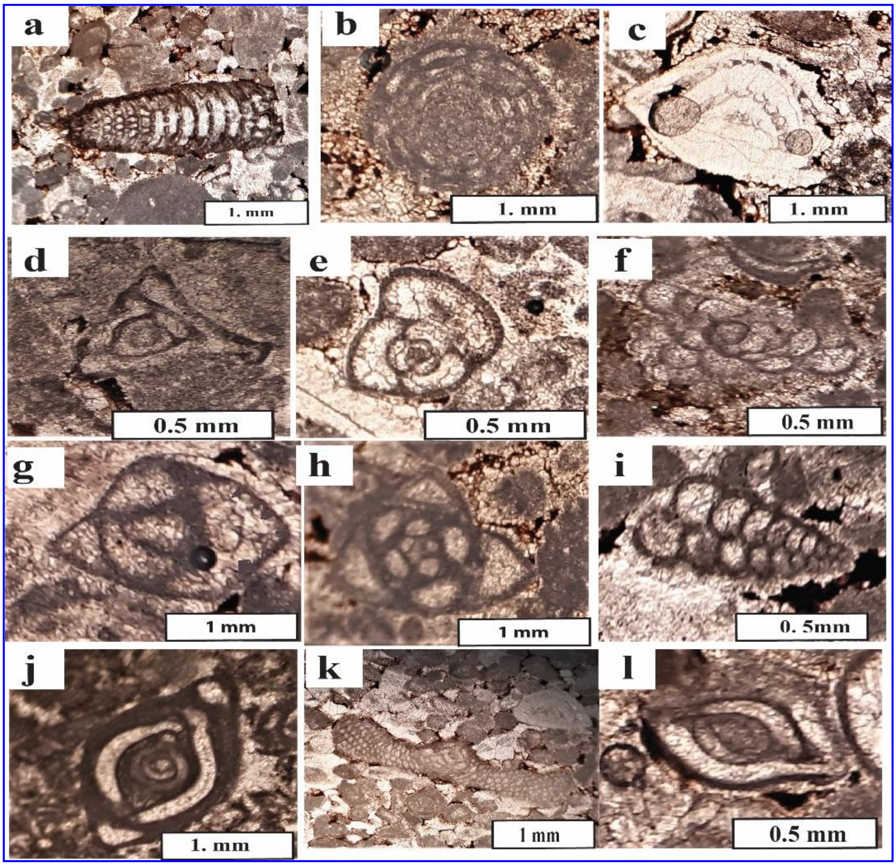

Fig. 7. a, *Praerhapydionina delicata* Henson, 1950, oblique longitudinal sections, sample no. 3; b, *Borelis* sp. subequatorial section, sample no. 6, and 7; c, *Neorotalia viennoti* (Greig, 1935), subaxial section, sample no. 3; d, *Triloculina tricarinata* (d'Orbigny, 1826), equatorial section, sample no. 7; e *Triloculina trigonula* (Lamarck, 1804), equatorial section, sample no. 10; f, *Planorbulina* sp., subaxial

Ammonia beccari- dendritina rangi assemblage zone (SBZ25).

The biostratigraphic interval of this zone is characterized by the assemblage of the nominate taxa, which include (*Ammonia beccari*, and *Dendritina rangi*). It is represented by *Ammonia beccari*, and *Dendritina rangi*, which consist of a 6 m thick layer of lacustrine Fatha Formation in sample (34-40), characterized by the presence of *Ammonia beccari*, *Dendritina rangi*, *Neorotalia viennoti*, *Pyrgo* sp., and bivalve fragments. This zone is correlated with the upper part of *Ostrea latmarginata* zone of Bellen et al. (1959), *Borelis melo curdica-Borelis melo melo* zone of *Laursen* et al. (2009) and Moghaddam et al. (2019). This biozone corresponds to Burdigalian in age.

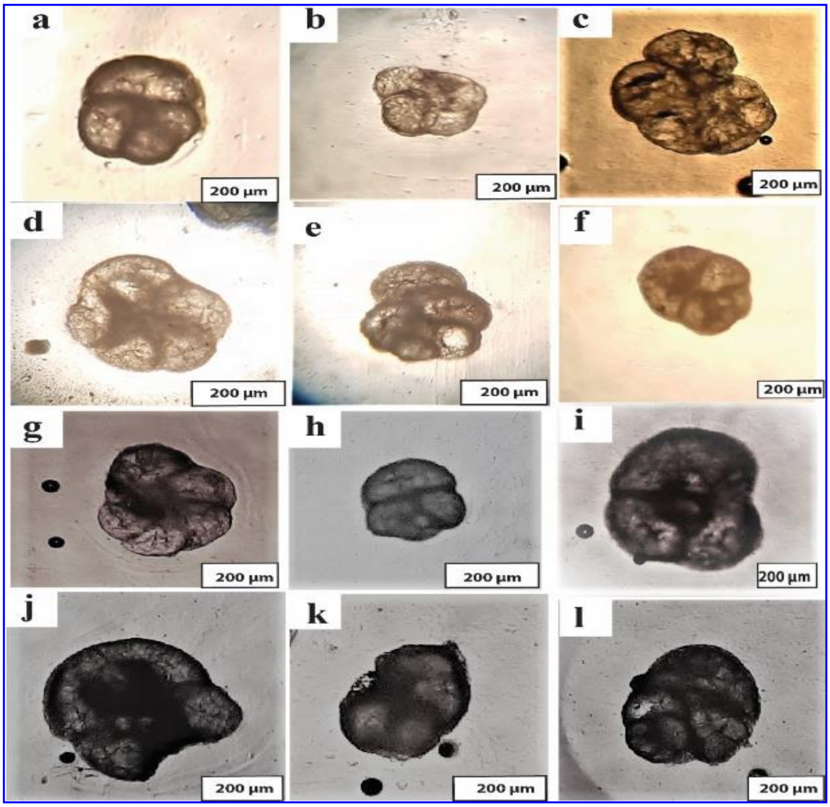

Fig. 8. a. *Globigerina ampliapertura* Bolli 1957, sample no. 14; b-c, *Globigerina ciperoensis* (Bolli, 1954), sample no. 15; d. *Dentoglobigerina venezuelana* (Hedberg, 1937), sample no. 14; e. *Dentoglobigerina globularis* (Bermúdez, 1961), sample no. 15; f. *Dentoglobigerina galavisi* (Bermudez, 1961), sample no. 14; g. *Dentoglobigerina globosa* (Bolli, 1957), sample no. 15; h. .*Dentoglobigerina baroemoenensis* (LeRoy, 1939), sample no. 14; i. *Dentoglobigerina tripartita* (Koch, 1926), sample no. 15; j. *Dentoglobigerina eotripartita* Pearson, Wade, and Olsson (2018), sample no. 14; k. *Dentoglobigerina binaiensis* (Koch, 1935), sample no. 15; l. *Dentoglobigerina* sp., sample no. 14.

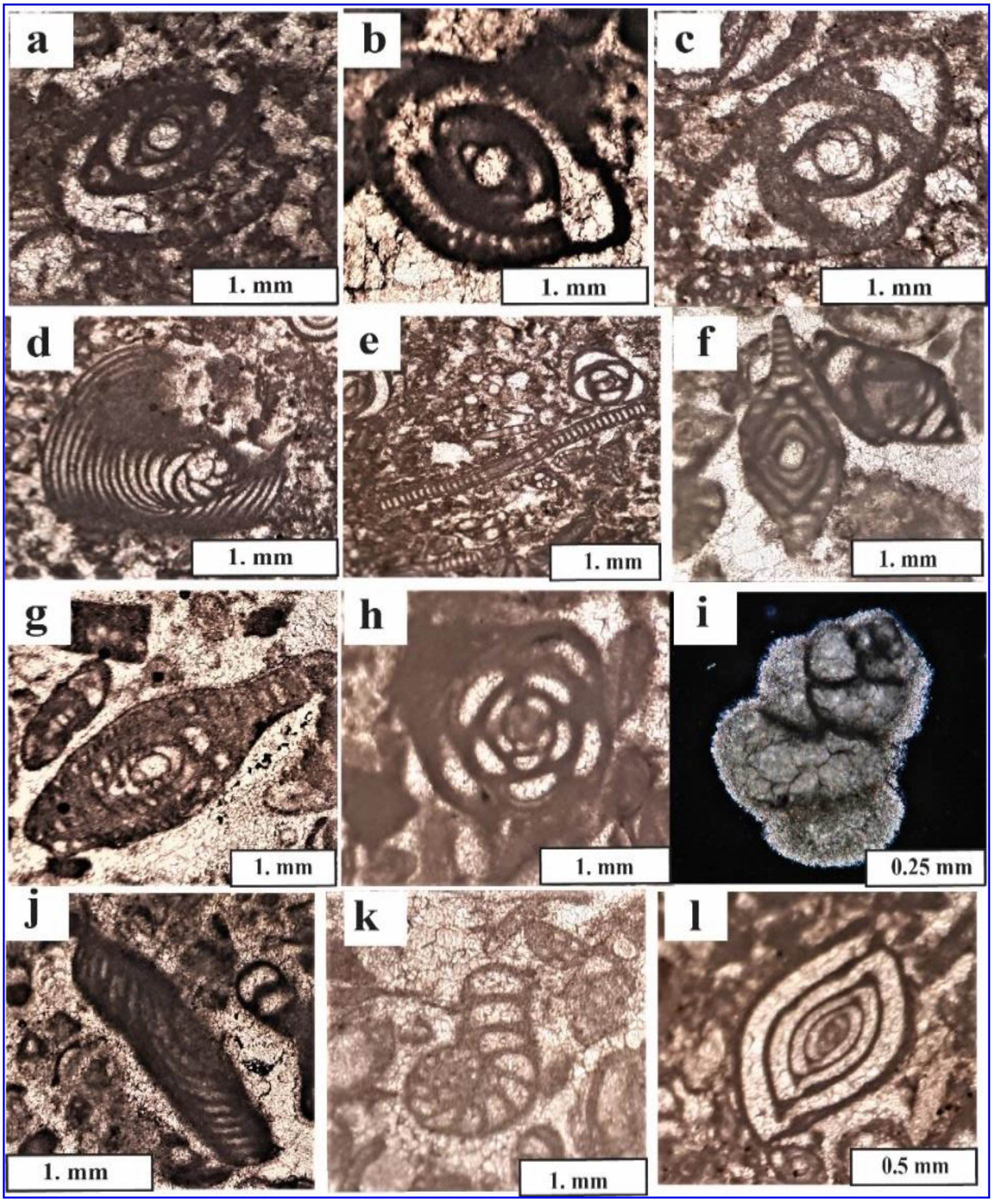

Fig. 9 Benthic Foraminifera from the Bajwan Formation. *a. Austrotrillina brunni* Marie, 1955, equatorial section, sample no. 16; b. *Austrotrillina asmariensis* Adams, 1968, equatorial section, sample no. 19; c. *Austrotrillina striata* Todd & Post, 1954, equatorial section, sample no. 18; d-e. *Peneroplis evolutus* Henson, 1950, oblique-equatorial section, sample no. 18; f. *Peneroplis thomasi* Henson, 1950, subaxial section, sample no, 20; g. *Archaias asmaricus* Smout and Eames, 1958, subaxial section, sample no. 20; h. *Quinqueloculina* sp., equatorial section, sample no. 19; i. *Valvulina* sp., subaxial section, sample no. 20; j. *Meandropsina anahensis* Henson, 1950, Oblique section, sample no. 18; k. *Spirolina cylindracea* Lamarck, 1804, equatorial section,laxial section, sample no. 18; l. *Spiroloculina* sp., axial section, sample no. 18.

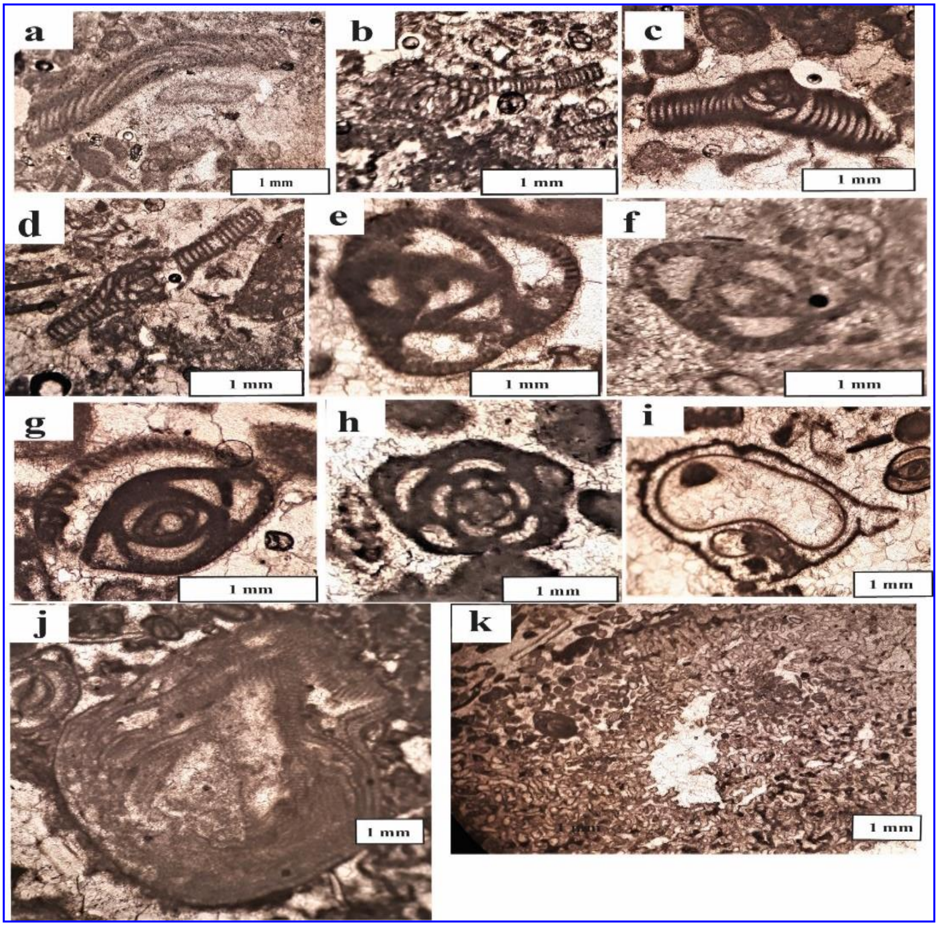

Fig. 10. Benthic Foraminifera from the Anah Formation.a.*Archaias kirkukensis* Henson, 1950, Oblique equatorial section, sample no. 22; b-c. *Archaias hensoni* Smout and Eames, 1958, b. subaxial section, sample no. 22; d. *Peneroplis thomasi* Henson, 1950, axial section, sample no. 23; e. *Austrotrillina asmariensis* Adams, 1968, equatorial section, sample no. 22; f-g. *Austrotrillina howchini* (Schlumberger 1893), equatorial section, g- subequatorial section, sample no. 23; h. *Quinqueloculina* sp., equatorial section, sample no. 25; i. Gastropoda shell, sample no. 25; j. *Lithoporella melobesioides* Foslie, D. Basso, et al. (2019), sample no. 23; k. Coral, sample no. 25.

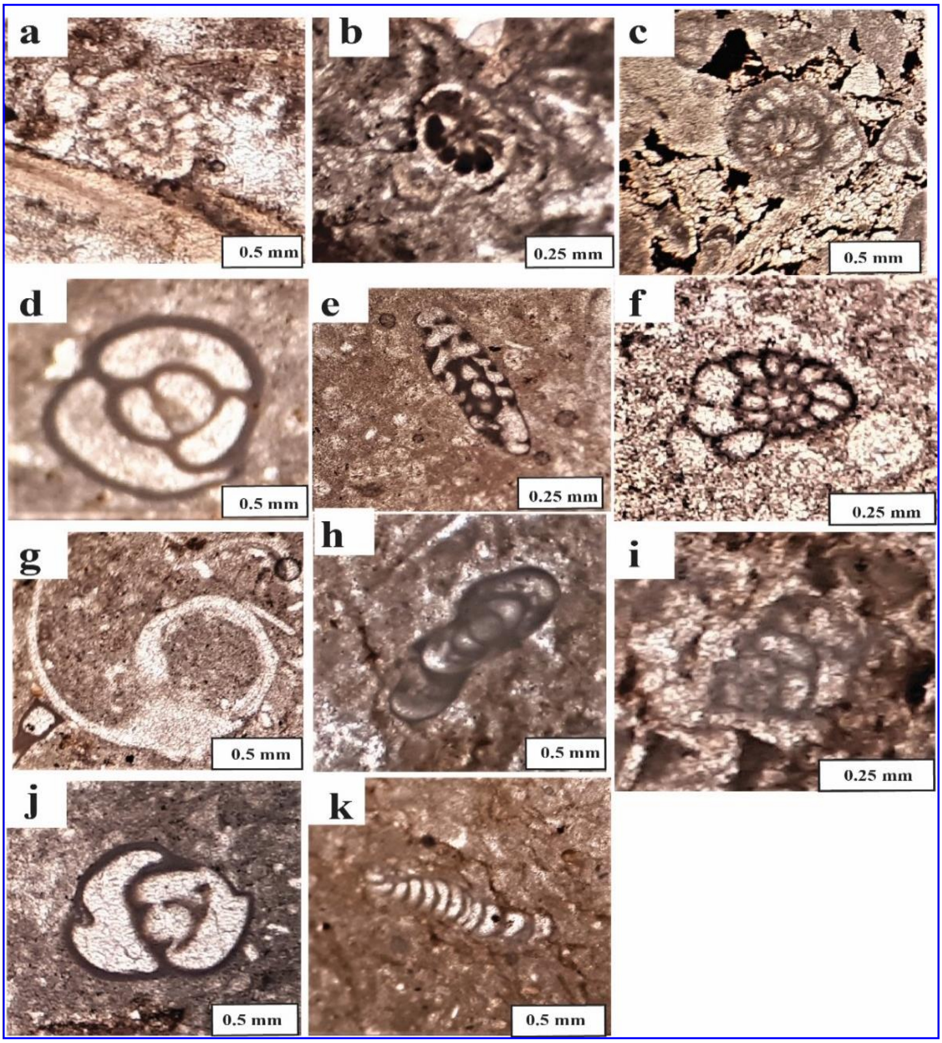

Fig. 11. Benthic Foraminifera from the Jeribe Formation.a-b. *Ammonia beccarii* (Line, 1758; e-subaxial section, fequatorial section, sample no. 32; c. *Peneroplis farsensis* Henson, 1950, equatorial section, sample no. 32; d. *Triloculina trigonula* Lamarck, 1804, equatorial section, sample no. 31; e-f-h. *Dendritina rangi* d'Orbigny emend. Fornasini, 1904, axial section, sample no. 33; g. Gastropoda shell, the gastropod has a geometric shape and the outer shell of the gastropod has been replaced with fine calcite cement, sample no. 31; i. *Textularia* sp., sample no. 32; j. *Valvulina* sp., sample no. 31; k. *Spirolina cylindracea* Lamarck, 1804, subequatorial section, sample no. 32.

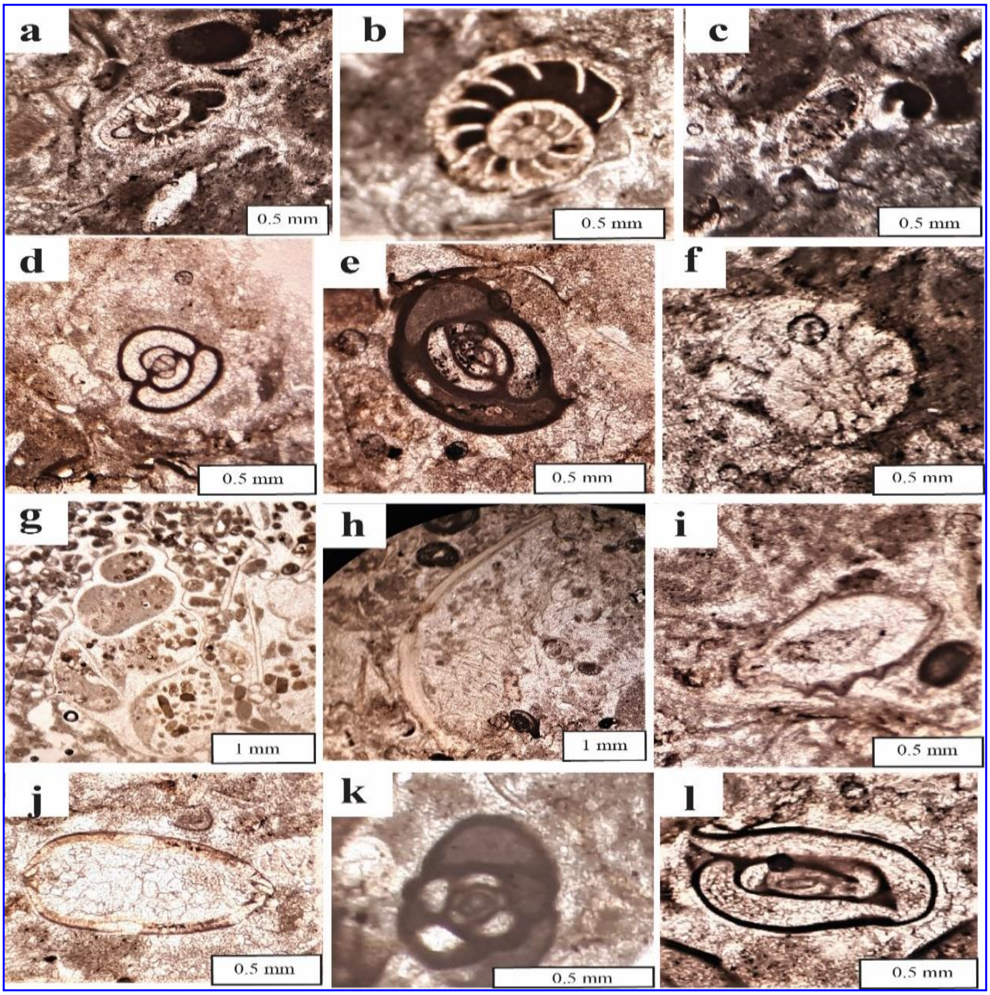

Fig. 12. Benthic Foraminifera from the Fatha Formation. a-b-c. *Ammonia beccarii* (Linne, 1758), a, and c axial section, bequatorial section, sample no. 35; d. *Pyrgo* sp., equatorial section, sample no. 35; e. *Triloculina trigonula* Lamarck, 1804, equatorial section, sample no. 35; f. *Dendritina rangi* d'Orbigny emend. Fornasini, 1904, equatorial section, sample no. 36; g. Gastropoda, sample no. (39); h. Pelecypoda, sample no. 35. i-j. bivalves (Ostracoda), sample no. 39; k. *Quinqueloculina* sp., equatorial section, sample no. 35; l. *Spiroloculina* sp., subequatorial section, sample no. 35.

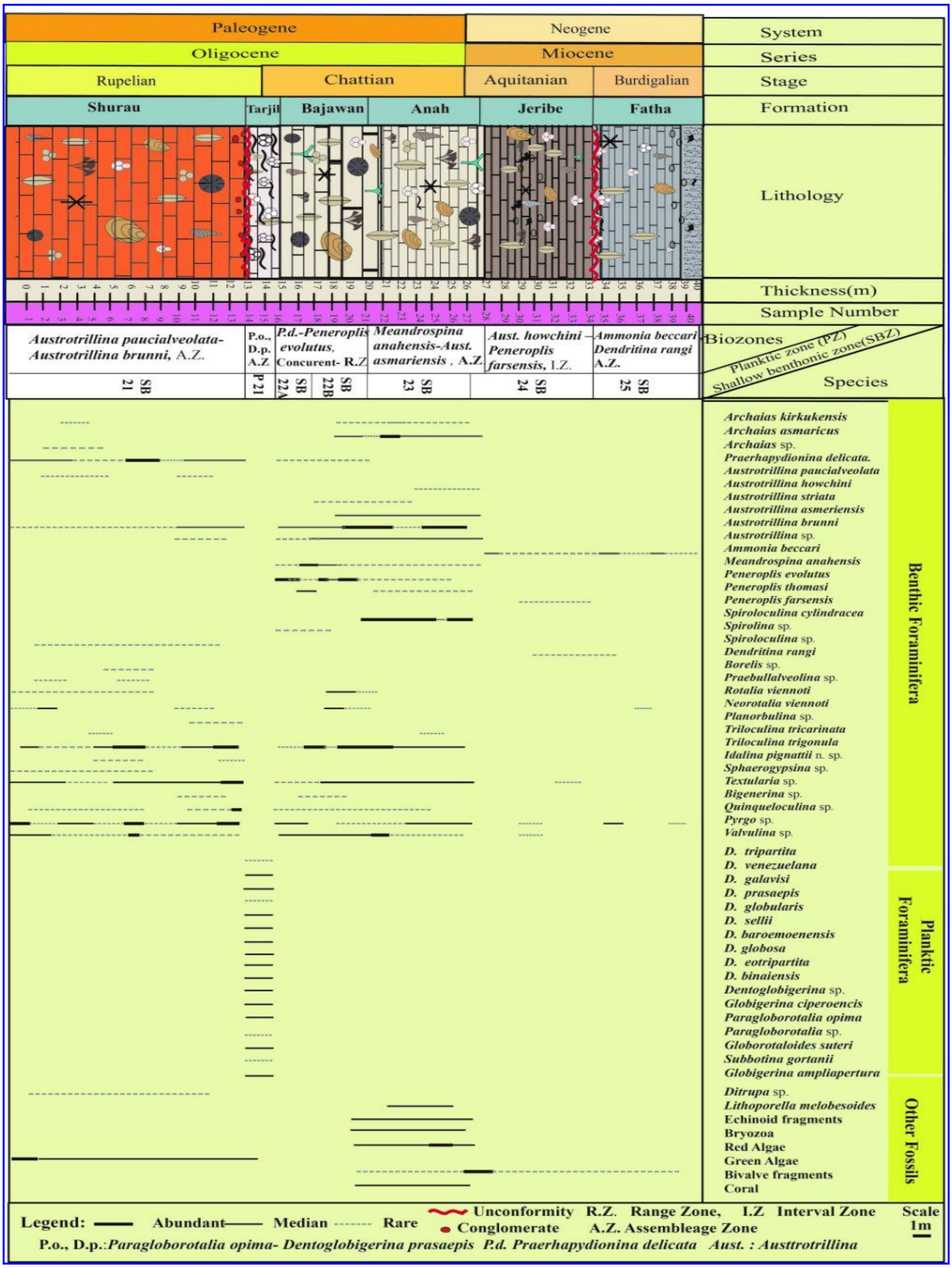

Fig. 13. Biostratigraphic range chart of Benthic Foraminifera, Planktic Foraminifera, and other fossils in the Pungalla section

Paleogene			Neogene			System
Oligocene			Miocene			Series
Rupelian	Chattian		Aquitanian		Burdigalian	Stage
Dentrophylum- Archaias kirkuknesis Austrotrillina Lepidocyclina delecata- Pauclalveolata Nummulites Nummulites inter Miogypsinoides-Lepidocyclina Nu. fichteli			Boreles melo curdica		Ostrea latmarginata	Bellen et al., 1959
Boreles pegmacus- Nummulites intermedius- Nummulites fichteli	Praehapydionina delicate- Austrotrillina howchini -peneroplis evolutus		Not studied		Not studied	Al Banna et al., 1950
Nummulites vascus- Nummulites fichteli- Nummulites vascus	Lepidicyclina (Eulepidina)dilatata Nummulites vascus- Nummulites fichteli-	Praehapydionina delicate-Archaias kirkuknesis	Austrotrillina howchini- Archaias hensoni		Austrotrillina asmariensis- Dendritina ranji	Qader, 2020
Nummulites vascus- Nummulites fichteli	Eulepidina dilatata- Nephrolepidina marginata	Praerhapydionina delicata- Peneroplis evolutus	Meandrospina anahensis- Austrotrillina asmariensis	Ammonia beccarii- Austrotrillina howchini	Dendritina rangi-Rotalia viennoti	Ghafor & Ahmad, 2021
Austrotrillina paucialveolata- Austrotrillina brunni	Praegloborotalia opima- Dentoglobigerina prasapeis	Praehapydionina delicate- Peneroplis evolutus	Meandrospina anahensis- Austrotrillina asmaricus	Austrotrillina howchini- Peneroplis farsensis	Ammonia beccari- Dendritina ranji	This study

Fig. 14. Correlation chart showing the biostratigraphic zones of this study with the other studies inside Iraq.

Paleogene			Neogene			System
Oligocene			Miocene			Series
Rupelian	Chattian		Aquitanian		Burdigalian	Stage
Nummulites ficteli- Nummulites vascus	Archaias asmaricus-Archaias hensoni- Miogypsinoides complanatus		Miogypsina- Peneroplis farsensis Eulepidina sp.		Boreles melo curdica- Boreles melo melo	Laursen et al.,2009
Nummulites ficteli- Nummulites vascus- Spiroclupeus carpathicus- Eulepidina formoides- Austrotrillina brunni-Aust. Asmariensis-Aus. striata- Aust. paucialveolata	Miogypsinoides complanatus		Miogypsina bantamensis		________	Serra Kiel et al., 2016
Nummulites vascus- Nummulites ficteli	Lepidocyclina- Operculina- Ditrupa	Archaias asmaricus- Archaias hensoni- Miogypsinoides complanatus	Elphidium sp.14. Miogypsina sp.		Boreles melo curdica- Boreles melo melo	Moghaddam et al., 2019
Austrotrillina paucialveolata- Austrotrillina brunni	Praegloborotalia opima- Dentoglobigerina prasapeis	Praehapydionina delicate- Peneroplis evolutus	Meandrospina anahensis- Austrotrillina asmaricus	Austrotrillina howchini- Peneroplis farsensis	Ammonia beccari- Dendritina ranji	This study

Fig. 15. Correlation chart showing the biostratigraphic zones of this study with the other studies outside Iraq.

Oligocene			Age		a
Early	Middle	Late			
Lower	Middle	Upper	Sed. Cycle Sed. Cycle Cycle		
Shurau Formation	Bajwan Formation	Anah Formation	Reef/ Back -Reef	Facies	
Shekh Alsa Formation	Baba Formation	Azkan Formation	Fore Reef		
Palani Formation	Tarjil Formation	Ibrahim Formation	Off shore		

Oligocene		Age		b
Lower	Upper	Sed. Cycle		
Shurau Formation	Anah and Bajwan formations	Reef/ Back -Reef	Facies	
Shekh Alkas Formatins	Azkand and Baba formations	Reef -Fore		
Palani Formation	Ibrahim and Tarjil formations	Off -shore		

Figure 16. a, Lithostratigraphic units of Kirkuk Group subdivisions, based on age, facies, and relationships between reef/back reef-fore reef and offshore facies. (Bellen, et al., 1957) and b, Oligocene lithostratigraphic units and facies. after (Ditmar, et al., 1972)

Discussion

According to Bellen et al. (1959), the Early Oligocene cycle consists of the Palani, Sheikh Alas and Shurau formations, Middle Oligocene consists of Baba, Bajwan and Tarjil formations and Upper Oligocene consists of Anah, Azkand and Ibrahim formations extending through a variety of depositional environments, but, Shurau , Shekh Alas and Palani formations were recorded by Ditmar et al. (1971), as one cycle of Late Eocene age, and considered the, Palani and part of the Tarjil and Sheikh Alas formations as the lower cycle of the Oligocene and the upper cycle of the Oligocene consists of the Anah, Bajwan, Azkand, Ibrahim and Tarjil formations. (Fig. 17). But Sharland et al. (2004) and Al-Banna (2008), studied the Oligocene -Miocene cycles in detail and showed that the first cycle (Rupelian) consists of the Palani, Sheikh Alas and Shurau formations, and the lower part of the Tarjil Formation, the second cycle (Late Rupelian to Early Chattian) consists of the

Bajwan and Baba formation and upper part of the Tarjil Formation, and the Miocene cycles are subdivided into Anah, Azkand and Ibrahim formations (Aquitanian) and Euphrates, Serikagni and Dhiban formations and the lower part of the Jeribe Formation (Burdigalian) (Fig. 18). In the Darzila section of the Sangaw area, a study conducted by Ghafor and Ahmad (2021) clarified the stratigraphy of the Oligocene (Rupelian) which includes the Sheikh Alas Formation and the lower part of the Baba Formation. The Oligocene (Chattian) was found to consist of the upper part of the Baba Formation, Bajwan Formation, and the lower part of the Anah Formation. Additionally, the Early Miocene (Aquitanian-Burdigalian) was identified to comprise the Anah Formation, Jerebi Formation, and Fatha Formation. Kharagiany, (2008) said that the area is an isolated platform oceanic basin, with an a attached lagoon fore land basin. According to (Al-Qayim 2006, 2012), the Oligocene and Miocene successions are deposited on a carbonate platform at the Arabian northeastern margin, as a part of an inter-orogenic sag-interior basin during the evolution history of the Zagros Foreland basin. Hence, through the current study, for the first time, through the planktic and benthic foraminiferal assemblages of the high fracture limestone and marly limestone of the Pungalla section that was studied for the first time is that it is not a part of an inter-orogenic sag-interior basin during the evolutionary history of the Zagros Foreland basin as mentioned before because the biostratigraphic age from the Oligocene-Miocene succession is documented by the planktic and benthic foraminifera rich in porcelaneous taxa, including a remarkable group of fossils that has been introduced and referred to the SBZ21-SBZ25 (Rupelian—Burdigalian) (Sirel et al. 2013), and also rich in the planktic foraminifera that have been introduced and referred to the P21 (Blow, 1979). It is subdivided into six lithostratigraphic units, which we attribute to the Shurau, Bajwan, Tarjil, Anah, Jerebi, and Fatha formations (Fig. 17), since this is the first time these stratigraphic units have been recognized, described, and studied in detail. In addition to the biostratigraphic study of each rock unit, then determine and establish the age of the section by means of it, from the Oligocene to the early Miocene.

Conclusions

Our study is the first attempt to use taxa of benthic and planktic foraminifera in the Pungalla section. The Oligocene –Lower Miocene rock units in the Pungalla successions were subdivided into the following rock units, from old to young (Shurau; Tarjil; Bajwan; Anah; Jeribe and Fatha formations). Based on the thirty four species belonging to twenty three genera of benthic foraminifera, and seventeen species belonging to five genera of planktic, the studied section was subdivided into the following biozones, from old to young (*Austrotrillina paucialveolata*-*Austrotrillina brunni* assemblage zone; *Paragloborotalia opima*-*Dentoglobigerina prasaepis* assemblage zone.; *Praerhapydionina delicata*-*Peneroplis evolutus* concurrent-Range zone; *Meandrospina anahensis* -*Austrotrillina asmariensis* assemblage zone; *Austrotrillina howchini* –*Peneroplis farsensis* interval zone and *Ammonia beccari* assemblage zone). In addition to benthic and planktic foraminiferal assemblages, some species of other fossils are identified such as coral, algae, pelecypods, gastropods, bryozoa, and fragment and spines of echinoides. The five recognized biozones established in this study were correlated with the zonal schemes of the other biostratigraphic zones established in and outside Iraq.

Age			SBZ and P zone	Formation	Biozone
Miocene	Early	Burdigalian	SBZ25	Fatha Formation	*Ammonia beccari- dendritina rangi*
		Aquitanian	SBZ24	Jerebi Formation	*Austrotrillina howchini – peneroplis farsensis*
			SBZ23	Anah Formation	*Meandrospina anahensis - austrotrillina asmariensis*
Oligocene	Late	Chattian	SBZ22A-SBZ22B	Bajwan Formation	*Praerhapydionina delicata- peneroplis evolutus*
			P21	Tarjil Formation	*Paragloborotalia opima- Dentoglobigerina prasaepis*
	Early	Rupelian			
			SBZ21	Shurau Formation	*Austrotrillina paucialveolata- austrotrillina brunni*

Figure 17. Lithostratigraphic and Biostratigraphic units of Oligocene-Early Miocene subdivisions, Pungalla section, Ashdagh Mountain, Kurdistan Region, Northeastern Iraq.

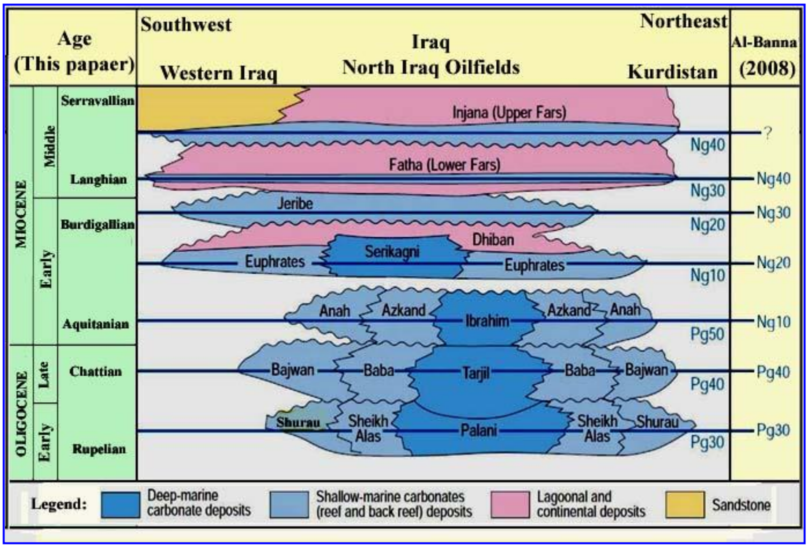

Figure 18. Sequence stratigraphy of Iraq. The Oligocene/Miocene boundary was tentatively interpreted as occurring between the Tarjil and Ibrahim sequences. Revised boundary the positions of Bellen et al. (1959), and maximum flooding surfaces (MFS) of Sharland et al. (2004); Al-Banna (2008).

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Declaration

Conflict of interest authors declare that they have no competing interests.

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