# STRATIGRAPHY OF THE OLIGOCENE – EARLY MIOCENE EXPOSED FORMATIONS IN SINJAR AREA, NW IRAQ

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## ABSTRACT

Sinjar Mountain is an outstanding structural and geomorphic feature in the northwestern part of Iraq. It forms a long anticline in which the oldest exposed rocks belong to Cretaceous age represented by Shiranish Formation. The exposed succession includes rocks of many formations, which range from Cretaceous to Late Miocene. The presence of Oligocene rocks, however, has been a matter of debate. The main aim of this study is to prove the presence or otherwise of the Oligocene formations in Sinjar anticline. To achieve that, the planktonic foraminifera of an exposed section, starting from the top of Jaddala Formation (Eocene), were utilized to interpret the biostratigraphy, and zonation of the sections.

The planktonic foraminiferal assemblages of the section were found to represent the Early Miocene (Aquitanian – Early Burdigalian) of *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4), *Globoquadrina dihescens praedehiscens-Globoquadrina dehiscens dehiscens* Zone (N.5), and *Catapsydrex stainforthia-Catapsydrex disimilis* Zone (N.6). Sparse fauna representing the *Globigerina angulisaturalias-Paragloborotalia opima opima* Zone (N.2) of Late Oligocene age, representing Ibrahim Formation, which is unconformably overlain by the Serikagni Formation. The Jeribe Formation of early Middle Miocene age of *Globorotalia barisanensis* Zone (N.9) overlies the Serikagni Formation; the contact is also marked by a major erosional unconformity.

The regional geology, including data from the drilled oil wells in the nearby areas, was also reviewed, in order to delineate the extension of surface and subsurface basin of the Oligocene rocks. Moreover, many recently published articles that suggest the presence of Oligocene formations in Sinjar anticline were argued and it was found that the exposed studied sections belong mainly to the Early Miocene Serikagni Formations, with presence of a few centimeters of Oligocene rocks only.

## طباقية التكوينات الجيولوجية المتكشفة من عمر الاوليگوسين – المايوسين في منطقة سنجار، شمال غرب العراق

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**المستخلص**

جبل سنجار ظاهرة تركيبية وجيومورفولوجية فريدة من نوعها في شمال غرب العراق ويكون طية محدبة طويلة تتكشف فيها صخور ابتداء من عمر الطباشيري متمثلة بتكوين الشيرانش. يضم المقطع المتكشف تكوينات جيولوجية عديدة من عمر الطباشيري والى المايوسين المتأخر. ان وجود او عدم وجود صخور عائدة لعمر الاوليگوسين هو موضوع نقاش علمي. وان الهدف الرئيسي لهذه الدراسة هو التأكد من موضوع هذا النقاش العلمي وأثبات وجود او عدم وجود صخور الاوليگوسين في جبل سنجار.

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لإثبات وجود أو عدم وجود صخور الاوليگوسين في منطقة سنجار، استخدمت متحجرات الفورامنيفيرا الطافية في مقطع من منطقة سنجار، شمال غرب العراق لتحديد العمر و معرفة الأنطقة الحياتية للصخور المتكشفة في المقطع المدروس وابتداء من اعلى تكوين جدالة، من عمر الأيوسين والى أسفل تكوين الفتحة من عمر المايوسين الأوسط. أتضح ان الصخور المتكشفة في المقطع تعود الى عمر المايوسين المبكر (Aquitanian – Burdigalian) وتحتوي على ثلاثة أنطقة حياتية، وهي من الاقدم الى الاحدث:

1 - *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4)
2 - *Globoquadrina dihescens praedihescen Globoquadrina dihescens dihescens Zone* (N.5)
3 - *Catapsydrex disimilis-Catapsydrex stainforthia* Zone (N.6)

كما يضم المقطع المدروس متحجرات قليلة تمثل النطاق
*Globigerina angulisuturalis-Paragloborotalia opima opima* Zone (No.2)

التابع لعمر الاوليگوسين المتأخر من تكوين ابراهيم المتواجد بتماس لاتوافقي مع تكوين سريگاگني. أما في الطبقات العليا فتكوين جيريبي (عمر المايوسين الأوسط) المتمثل بنطاق *Globorotalia barisanensis* يكون بتماس لاتوافقي مع تكوين سريگاگني.

كذلك تم مراجعة الجيولوجيا الأقليمية والأبار النفطية المحفورة في المناطق المجاورة لطية سنجار لمعرفة الأمتداد السطحي وتحت السطحي لصخور ألمايوسين و الاوليگوسين. كما تم مناقشة عدة دراسات حديثة منشورة تشير الى وجود صخور الاوليگوسين في منطقة سنجار. واكدت هذه الدراسة بان الصخور المتكشفة في طية سنجار تعود الى عمر المايوسين المبكر المتمثلة بتكوين سريگاگني مع وجود سنتمترات قليلة من صخور تعود الى عمر الأوليگوسين.

**INTRODUCTION**

The Sinjar area, located in northwest of Iraq, has its unique structural and geomorphological setting with exposed rocks as old as Cretaceous, whereas in nearby areas only Miocene rocks are exposed. The given stratigraphic succession since Bellen *et al*. (1959) and all later authors (Ma'ala, 1977; Jassim *et al*., 1984 and 1990; Sissakian, 2000, among others), do not include Oligocene rocks in the studied area. However, recently some authors (Al-Mutwali and Al-Banna, 2002 in Ismail, 2005; Al-Banna *et al*., 2010 among others) reported the presence of Oligocene rocks with different formations and thicknesses, but a little information have been given on the biostratigraphy and environment of deposition of the mentioned formations. The micro fauna and the regional geology of this area were investigated in details for the first time in this paper. The studied area is located in northwest Iraq, within Mosul Governorate, in Sinjar Mountain (Fig.1). However, to cover the aim of this study; the stratigraphy of the whole Low Folded Zone of Iraq was reviewed. The following works were executed in the studied area.

– Ma'ala (1977), executed regional geological mapping of Sinjar anticline and surroundings. He didn't recognize Oligocene rocks in the area.
– Karim (1978), studied the exposed Early Miocene rocks in Sinjar anticline, with both lower and upper contacts; recognized a few centimeters of Late Oligocene rocks.
– Jassim *et al.* (1984), reported in “The Regional Geology of Iraq” the absence of Oligocene rocks in Sinjar anticline.
– Jassim *et al.* (1984 and 1990) and Sissakian (2000), compiled the geological map of Iraq, at scale of 1: 1000 000 and didn't show Oligocene rocks in Sinjar anticline.
– Al-Ani (2005), carried out sedimentological study for the whole Miocene rocks, with both lower and upper contacts and didn't recognize Oligocene rocks.
– Ismail (2005), reported the presence of Oligocene rocks in Sinjar anticline.
– Jassim and Goff (2006), reported in “The Regional Geology of Iraq” the absence of Oligocene rocks in Sinjar anticline.

– Al-Banna *et al*. (2010), studied the exposed Neogene rocks in Sinjar anticline and recognized Oligocene rocks.
– Sissakian and Al-Jubori (2011), revised the exposed rocks in the Iraqi Low Folded Zone, which includes Sinjar anticline and found no Oligocene rocks. Moreover, they discussed, in details the absence of the Oligocene rocks, in the area.

The main aims of this study are: to delineate the exact age of the exposed rocks in the studied sections, to establish the planktonic foraminiferal zones, and to discuss the differences and the facts between what is published recently and the present work concerning the presence or otherwise of the Oligocene rocks in Sinjar anticline.

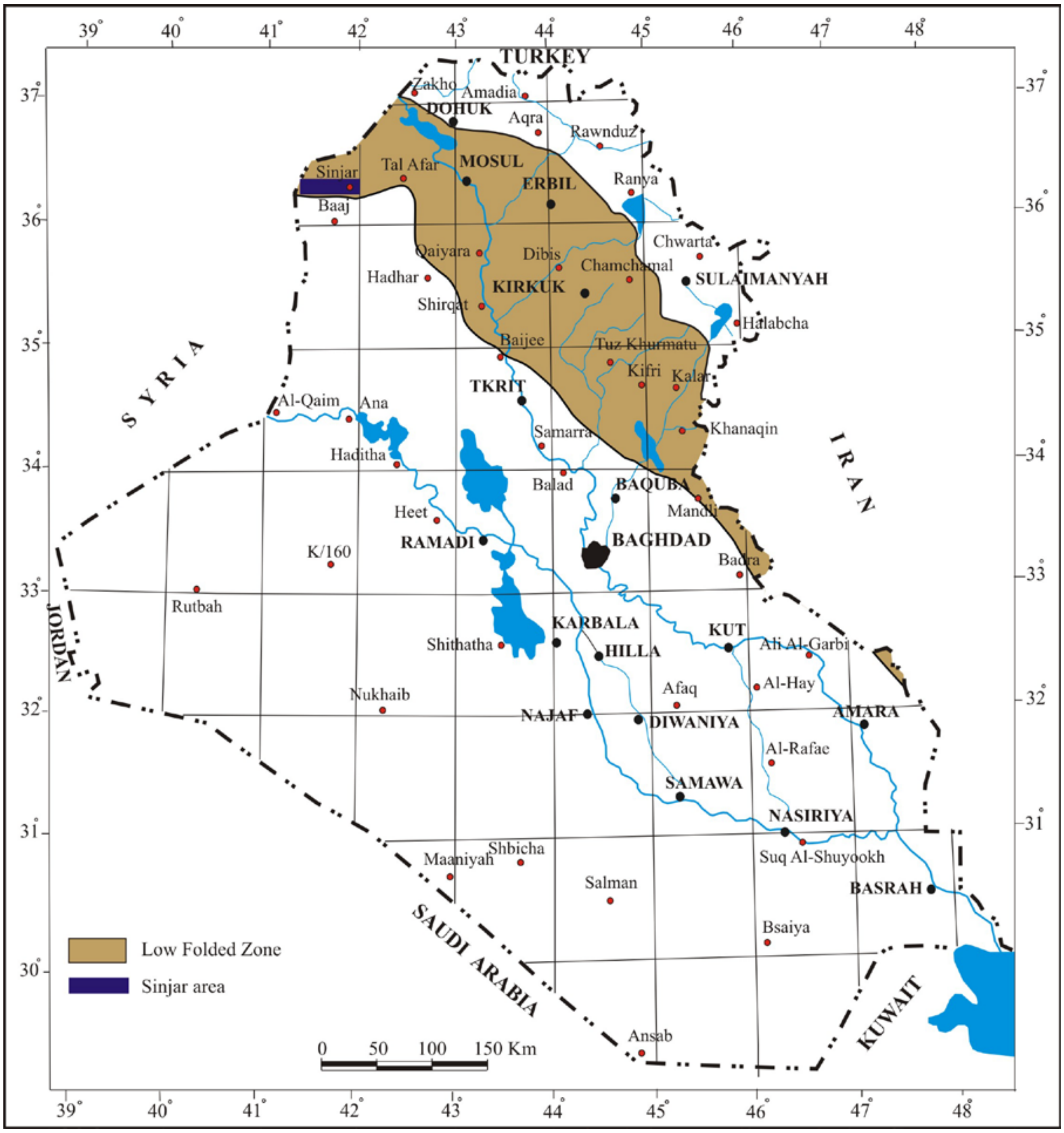


Fig.1: Location map of the studied area and the Iraqi Low Folded Zone

## REGIONAL GEOLOGY

Al-Kadhimi *et al*. (1996) and Fouad (2010), stated that Sinjar anticline is located within the Low Folded Zone of the Outer Platform, which belongs to the Arabian Plate. The exposed rocks within this zone range in age from Cretaceous to Pliocene, with different Quaternary sediments. However, Cretaceous – Oligocene rocks are not usually exposed in the Low Folded Zone, only Neogene rocks are exposed. Cretaceous – Oligocene rocks are exposed in Qara Chough anticline and in Sinjar anticline. However, it is not certain that Oligocene rocks are exposed in the latter.

### ▪ Stratigraphy

The regional geology and stratigraphy of the exposed rocks in Sinjar anticline have been described briefly hereinafter, based on previous works (Bellen *et al*., 1959; Ma'ala, 1977; Karim and Bartlett, 1978; Karim, 1978; Jassim *et al*., 1984 and 1990; Sissakian, 2000; Ismail, 2005; Al-Banna *et al*., 2010; Sissakian and Al-Jubori, 2011, among others). The formations of Middle Miocene age, starting from Fat'ha Formation are not mentioned, because they are well known.

**– Shiranish Formation (Late Campanian – Late Maastrichtian):** In Sinjar anticline, Ma'ala (1977) divided the formation into three units. **Lower Unit**: Consists of thinly to thickly bedded, blue to grey marl and marly limestone, with ammonites, the thickness is about 80 m. **Middle Unit**: Consists of numerous intercalations of very hard intraformational fragments with marly limestone. The fragmented beds are brownish grey in color, fine grained, thinly bedded (20 – 70 cm). The marly limestone and limestone beds are light grey in color, well thinly bedded. Several beds (about 14) intraformational fragments of marly limestone with sandy matrix occur too, the thickness of this unit is about 405 m. **Upper Unit**: Consists of light yellowish grey, fairly soft marl and marly limestone, occasionally includes limestone beds of sandy texture, the thickness of this unit is 80 m. The thickness of the formation in Sinjar vicinity is 565 m.

**– Aaliji Formation (Late Paleocene – Early Eocene):** In Sinjar vicinity, the formation consists of greenish grey shale. However, large parts of the formation exhibits interfingering with Sinjar Formation, in such areas, the Aaliji Formation consists of marly limestone, which grades into sandy marl with scattered chert nodules and glauconite grains. This succession is overlain by poorly sorted conglomeratic limestone. Greenish brown calcareous sandstone horizons also occur. The thickness of the formation in Sinjar vicinity ranges between (20 – 46) m (Ma'ala, 1977).

**– Sinjar Formation (Late Paleocene – Early Eocene):** In Sinjar anticline, Ma'ala (1977), divided the formation into three units. **Lower Unit**: Consists of massive, fine crystalline limestone alternated with thinly bedded limestone. Locally, in the lowermost 5 m, grayish light brown ferruginous, coarse grained calcareous sandstone was observed. The thickness of this unit is 80 m. **Middle Unit**: Consists of massive, aphanitic fossiliferous limestone, the thickness of this unit is 107 m. **Upper Unit**: Consists of aphanitic, well bedded limestone. The thickness of this unit ranges between (14 – 50) m. In many localities, the uppermost part (43.5 m, near Haligh village) is considered as Avanah Formation, the contact is marked by a conglomerate horizon. The thickness of the formation in Sinjar vicinity ranges between (176 – 201) m.

**– Jaddala Formation (Early – Late Eocene):** In Sinjar vicinity, Ma'ala (1977), divided the formation into two units. **Lower Unit**: Consists of well bedded shale intercalated with thinly bedded marly limestone, with chert nodules. **Upper Unit**: Consists of well bedded marly limestone, with horizons of chert, alternating with laminated marl. The thickness of the formation in Sinjar vicinity is 517 m.

**– Avanah Formation (Early – Late Eocene):** In Sinjar vicinity, Ma'ala (1977), described the formation as alternation of nummulitic limestone and marly limestone. The thickness ranges between (10 – 82) m and (10 – 32) m, in the southern and northern limbs of Sinjar anticline, respectively.

**– Palani Formation (Early Oligocene):** Al-Mutwali and Al-Banna (2002) in Ismail (2005) and Al-Banna *et al*. (2010), mentioned that the Palani Formation is exposed in Sinjar anticline with a thickness of 4 and 10 m, respectively. The formation consists of dolomitized, globigerinal marly limestone.

**– Tarjil Formation (Middle Oligocene):** Al-Mutwali and Al-Banna (2002) in Ismail (2005) and Al-Banna *et al*. (2010), mentioned that the Tarjil Formation is exposed in Sinjar anticline with a thickness of 197 m and 147 m (in Jaddala section), respectively, and consists of white marly limestone.

**– Ibrahim Formation (Middle – Late Oligocene):** Karim and Bartlett (1978), stated that a Late Oligocene of 2 cm. thick is newly found within the lower conglomerate in Jebel Gaulat, Sinjar area they believe it belongs to Ibrahim Formation. Abawi and Maroof (1988) in Ismail (2005), mentioned that the formation is exposed in Sharaf Al-Deen vicinity within the northern limb of Sinjar anticline with a thickness of 72.5 m, and aided Middle – Late Oligocene age for the formation.

**– Serikagni Formation (Early Miocene):** In Sinjar Mountain Ma'ala (1977), recognized four lithological units, these are: **1)** Thinly bedded marly limestone alternated with thin beds of sandy limestone. This succession is overlain by conglomerate (0.2 – 2 m thick) and calcareous sandstone (0.5 – 1 m thick). The conglomerate consists of angular to subrounded chert fragments range in size between (30 – 50) cm and well rounded limestone pebbles range in size between (5 – 10) cm. **2)** Well bedded marly limestone alternated with thinly bedded marl. **3)** Thinly bedded limestone. **4)** Thinly bedded marly limestone alternated with thinly bedded fine crystalline limestone. Moreover, he mentioned that the Euphrates Formation forms tongues within the Serikagni Formation. The thickness is 305 m and 150 m in the eastern and western parts of Sinjar Mountain, respectively.

**– Euphrates Formation (Early Miocene):** In Sinjar anticline, it consists of three layers (0.3 – 1 m thick, each) of fine crystalline limestone, separated by green marly limestone layers (5 – 10 m thick). The thickness in Sinjar vicinity ranges between (2 – 30) m (Ma'ala, 1977).

**– Dhiban Formation (Early Miocene):** In Sinjar anticline, the formation consists of thick beds of gypsum interbedded with marly limestone and fine crystalline limestone. The thickness ranges between (40 – 100) m (Ma'ala, 1977).

**– Jeribe Formation (Middle Miocene):** In Sinjar anticline, the formation consists of four main lithological units; from bottom to top: **1)** Thickly bedded, fossiliferous limestone, which is underlain by (1.5 – 2) m thick basal fragmented limestone. The thickness of this unit is 24 m. **2)** Alternation of dolomitic limestone and chalky limestone, both are laminated to thinly bedded. The thickness of this unit is 39 m. **3)** Bedded to massive conglomeratic limestone. The thickness of this unit is 38 m. **4)** Fossiliferous limestone, occasionally with aphanitic and fossiliferous limestone. The thickness of this unit is 25 m. The thickness in Sinjar vicinity ranges between (100 – 126) m (Ma'ala, 1977).

▪ **Basin Configuration**

The basin configuration, in the Low Folded Zone, since the Eocene Epoch is reviewed, to delineate the depositional environment, and the effect of tectonics on the type of sediments during deposition in the basin. The review starts from the Eocene to give an idea about the basin prior to the Oligocene Epoch.

During the **Middle Paleocene – Early Eocene** (61.7 – 48.6 Ma), a foredeep was developed, which progressively migrated towards the southwest; it occupied the entire Low Folded Zone, extending over Mushurah (northeast of Sinjar), Mosul, Kirkuk and Chia Surkh. This basin was filled by the open marine marls of Aaliji Formation (Jassim and Buday in Jassim and Goff, 2006), forming the first post-rift sediments; followed by the deposition of Sinjar and Khurmala formations. The former was deposited in shallow water reef, fore-reef and lagoon environments, whereas the latter was deposited in restricted lagoons. In Sinjar anticline, Ma'ala (1977), reported the presence of tongues of Aaliji Formation within the Sinjar Formation. This could be explained by the presence of a contact between the foredeep and the neighboring reef complex environment in which Sinjar Formation was deposited. This could also be attributed to the presence of transversal fault that divided Sinjar anticline into blocks.

During the **Middle – Late Eocene** (40.4 – 33.9 Ma), the Neo-Tethys was narrowed and closed during the final phase of subduction. A foredeep basin was developed southwest of the Low Folded Zone; this foredeep was separated from the basin to the southwest by a belt of nummulitic limestone shoals of Avanah Formation (Jassim and Buday in Jassim and Goff, 2006). After gradual rise of the sea level, the carbonates of the Jaddala Formation were deposited in the open marine basin, in the extreme western limits of the Low Folded Zone in Iraq. Alongside the foredeep, and within shallow lagoons, the Pila Spi Formation was deposited, and also in the extreme northern and northeastern margins of the involved area, along a continuous ridge that formed an obstacle for the deposition of the Gercus Formation farther southwards, in the present days Low Folded Zone area (Sissakian, 2000).

At the end of the **Eocene** and during the **Oligocene** (33.9 – 23.0 Ma)**,** the main intraplate basin became narrower due to the tilting of west Arabia, and uplift of the High Folded Zone. Therefore, great sea level drop was witnessed; consequently, the eastern shore line receded to the southwest boundary of the Low Folded Zone. The closed Neo-Tethys was a narrow seaway in which carbonates were deposited. The Oligocene basin was relatively narrow, thick fringing reefs developed along the western and eastern shorelines of the basin. Thin marls were deposited in the centre of the basin, which was starved of sediment supply (Jassim and Buday in Jassim and Goff, 2006). However, the Oligocene basin was not relatively so narrow, as claimed by Jassim and Buday in Jassim and Goff (2006). According to the new acquired data about the exposure limits of the Oligocene rocks, the shore line was extending more towards northeast up to the present day Qara Dagh Mountain (Khanqa *et al*., 2009) and extends northwestwards alongside the present day contact between Low Folded and High Folded Zones. Bellen *et al*. (1959), also claimed the presence of Oligocene exposures in the extreme northeastern margins of the Low Folded Zone at Aj Dagh and Sagirma Dagh, south and southeast of Sulaimaniyah, near Qara Dagh.

During **Early – Middle Miocene** (23.0 – 11.6 Ma)**,** the Savian movements caused development of broad and shallow basins in which carbonates were deposited, with wide closed basins (lagoons) in which evaporates were deposited. However, the northwards extensions of the lagoons in which Fat'ha (ex-Lower Fars) Formation was deposited, manifested by different sediment types. The primary component of the Fat'ha Formation, the gypsum, was not deposited in the extreme parts of the basin and even if it was deposited, it forms thin layers as compared with those beds present in the central typical lagoonal part. Moreover, reddish brown clastics; claystone, siltstone and even fine sandstones were deposited within the Fat'ha Formation, forming the main constituents. It is believed that this is attributed to the basin configuration and sediments supply, where the environment for deposition of gypsum was not prevailing. The same case is observed in the Iraqi Western Desert, where the Fat'ha Formation passes to another formation; recently recognized by Sissakian *et al*. (1997), and called the Nfayil Formation.

## OLIGOCENE FORMATIONS IN IRAQ

The Oligocene formations, in Iraq form a complex reef system, including back-reef, reef and fore-reef sediments, which are normally developed in three cycles during Early, Middle and Late Oligocene. However, not always, the three components are present in each cycle; this is attributed to the change in the basin configuration and upwards tectonic movement, which contributed to the oscillation of the eustatic sea level. Therefore, in a certain locality one or even two of the basic components of one cycle are missing. However, in certain areas the whole cycle is missing, which means non-deposition of Early, Middle or Late Oligocene cycle. This very complex system is clear from the surface exposures in Qara Chough anticline and the acquired oil wells data (Al-Sammarai and Al-Mubarak, 1978 and I.P.C., 1963). Moreover, in some exposures, as in Atshan anticline, west of Mosul, where Avanah Formation underlies the Euphrates Formation, the contact is marked by 15 m of breccia indicting the absence of Oligocene rocks (Mohi Al-Din *et al*., 1977), whereas Oligocene rocks are present in Alan and Ibrahim anticlines (I.P.C., 1963), towards north and west of Atshan anticline, respectively. Moreover, they are present in Mishraq anticline, southeast of Mosul, and were encountered in Al-Khafsan well (Ma'ala *et al*., 1987). This very complex situation of presence and/ or absence of Oligocene rocks indicates the activity of Mosul High, which has an uneven shape, as manifested by the irregular shape of the Oligocene basin, which gave very irregular surface and subsurface extensions of Oligocene formations (Figs.2 A, B and C).

The Oligocene basin, in Iraq is oriented in a NW – SE direction (Figs.2 A, B and C). But, since Bellen *et al*. (1959) many works on stratigraphy has been carried out in Sinjar area (Karim, 1978); Karim and Bartlett (1978); Amer (1979); Jassim and Karim (1984); Jassim *et al*. (1984); Isho in Al-Samaraie *et al*. (1993) and Jassim and Goff (2006). They all indicated the absence of all the cycles of the Oligocene of the surface section, of Sinjar vicinity.

The exposure areas of the three main Oligocene cycles are mentioned briefly hereinafter.

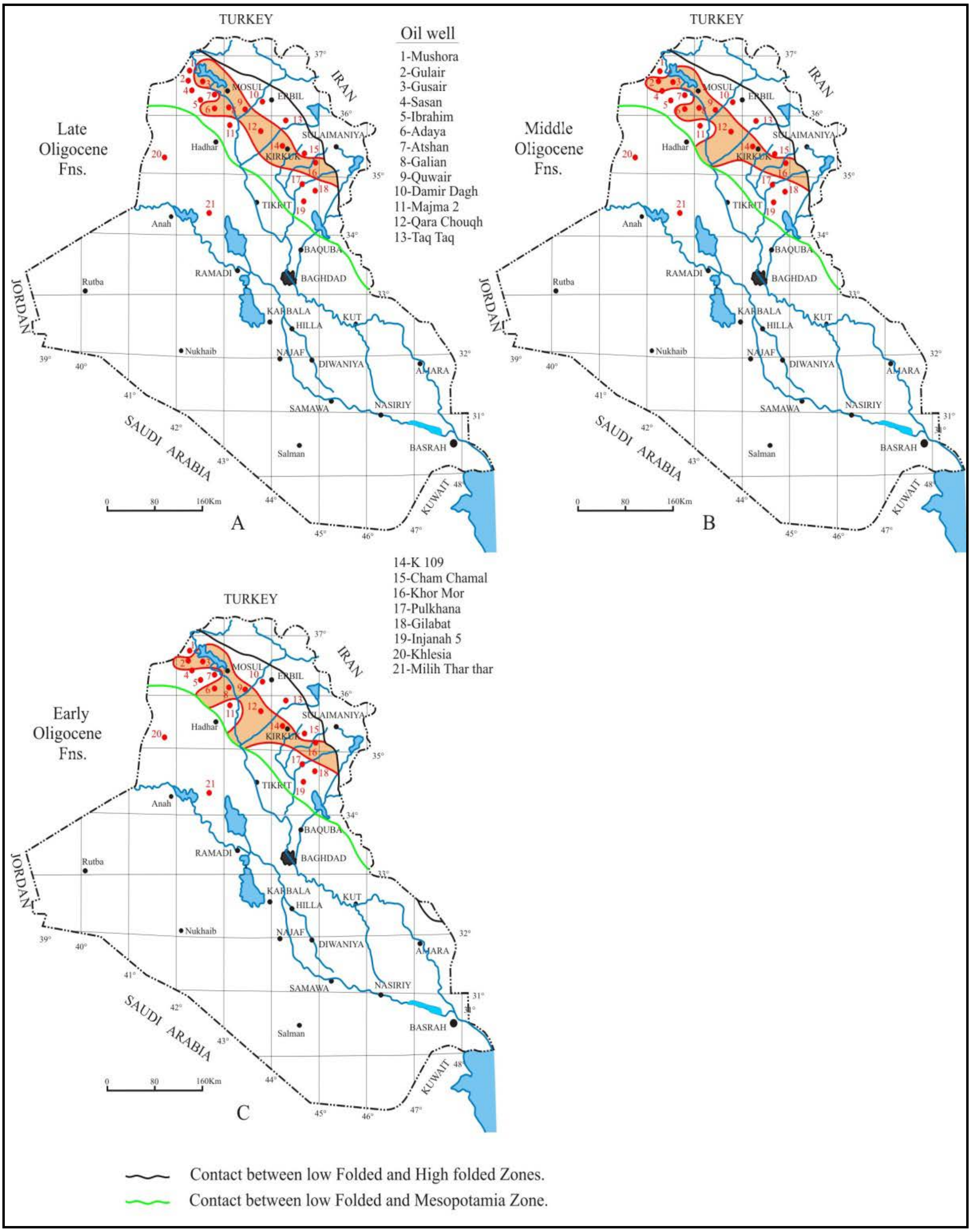


Fig.2 (A, B and C): Geographical distribution of Early, Middle and Late Oligocene formations (after Sissakian and Al-Jubori, 2011)
(Oil well data after I.P.C, 1963)

▪ **Lower Oligocene Cycle**

This cycle includes three formations, Palani, Sheikh Alas and Shurau.

– **Palani Formation:** The Palani Formation was first described by Bellen (1956), from Kirkuk structure in oil well K 85, as the type locality, which is defined by the coordinates: 44° 25' 28" E, 35° 26' 42" N (Bellen *et al*., 1959).

According to Bellen *et al*. (1959), the Palani Formation is exposed only in Northern Dome of Qara Chough anticline, especially near Palani village. Al-Samaraie and Al-Mubarak (1978), however, did not ascertain the presence of the formation, during the regional geological mapping in the vicinity. Jassim and Buday in Jassim and Goff (2006), mentioned the presence of the formation depending on Bellen *et al*. (1959). Al-Mutwali and Al-Banna (2002) in Ismail (2005) and Al-Banna *et al*. (2010), mentioned that the Palani Formation is exposed in Sinjar anticline.

– **Sheikh Alas Formation:** The Sheikh Alas Formation was first described by Bellen, (1956); the type locality is in Qara Chough anticline near Sheikh Alas village (Bellen *et al*., 1959). It is defined by the coordinates: 43° 35' 30" E, 35° 54' 38" N.

The Sheikh Alas Formation is exposed in the core of the northern dome of Qara Chough anticline and in the deeply cut valleys in the central dome of Qara Chough anticline. Moreover, it is also exposed in the Western Desert, of Iraq in wadi Swab (Jassim *et al*., 1984; Jassim and Karim, 1984; Al-Hashimi and Amer, 1985; Majid and Veizer, 1986, and Sissakian, 2000).

– **Shurau Formation:** The Shurau Formation was first described by Bellen (1956); its type locality is in Kirkuk structure, oil well K 109, which is defined by the coordinates: 44° 18' 55" E, 35° 33' 08" N (Bellen *et al*., 1959).

The Shurau Formation is exposed in the deeply cut valleys and core of the Northern Dome of Qara Chough anticline and the western limb of Bammu anticline. However, recently, some Oligocene formations were recognized from other localities, south west of Sulaimaniyah, such as Aj Dagh and Sagirma (Khanqa *et al*., 2009). It is also exposed in the Iraqi Western Desert at Wadi Swab (Al-Hashimi and Amer, 1985).

▪ **Middle Oligocene Cycle**

This cycle includes three formations Tarjil, Baba and Bajwan formations.

– **Tarjil Formation:** The Tarjil Formation was first described by Bellen (1956), from Kirkuk structure in oil well K 85, as the type locality, which is defined by the coordinates: 44° 25' 28" E, 35° 26' 42" N (Bellen *et al*., 1959).

The Tarjil Formation is exposed in the southern limb of the southern dome of Qara Chough anticline and southeastern limb of Bezniyan – Bawgaru anticline; along the Iraqi – Iranian international borders, and possibly in Bammu anticline (?), in the same vicinity. According to Al-Mutwali and Al-Banna (2002) in Ismail (2005) and Al-Banna *et al*. (2010), it is also exposed in Sinjar anticline.

– **Baba Formation:** The Baba Formation was first described by Bellen (1956) in (Bellen *et al*., 1959), from Kirkuk structure in oil well K109 as the type locality, which is defined by the coordinates: 44° 18' 55" E, 35° 33' 08" N.

The Baba Formation is exposed in Qara Chough anticline; only in deeply cut valleys, in Shaloradar anticline and southwestern limb of Bawgaru anticline, in Khanaqin vicinity. However, it is exposed in the Iraqi Western Desert at Wade Khazga, Wade Fuhaimi and Wade Kheshkhash near Anah town (Karim and Ctyroky, 1971 and Sissakian, 2000).

**– Bajwan Formation:** The Bajwan Formation was first described by Bellen (1956) in (Bellen *et al.*, 1959), from Kirkuk structure in oil well K109 as the type locality, which is defined by the coordinates: 44° 18' 55'' E, 35° 33' 08'' N.

The Bajwan Formation is exposed in the central and northern domes and northeastern limb of the southern dome of Qara Chough anticline, and along the Iraqi – Iranian international borders in Bammu, Shaloradar and Bawgaru anticlines. According to Bellen *et al*. (1959), the Bajwan Formation is exposed in Aj Dagh and Darbandi Sagirma, southwest of Qara Dagh. However, Khanaqa *et al*. (2009), mentioned the possible occurrence of Anah/ Ibrahim formations in the aforementioned locations, instead of Bajwan Formation.

- **Late Oligocene Cycle**

This cycle includes three formations: Ibrahim, Azkand, and Anah.

**– Ibrahim Formation:** The Ibrahim Formation was defined by Bellen *et al*., (1959), from subsurface section well Ibrahim No.1 in Sheikh Ibrahim Structure of the Foothill Zone, NW Mosul. No outcrop section is documented elsewhere; only few centimeters were found between two major unconformaties, in Jebel Gaulat, Sinjar area NW Iraq, for the first time by Karim (1978). According to the executed regional geological mapping of the Low Folded Zone, by the Iraq Geological Survey, the Ibrahim Formation was not found exposed on surface. However, Abawi and Maroof (1988) in Ismail (2005), mentioned that the formation is exposed in Sharaf Al-Deen vicinity within the northern limb of Sinjar anticline with a thickness of 72.5 m, and claimed a Middle – Late Oligocene age for the formation. Moreover, they suggested that the mentioned locality could be a supplementary type section for the Ibrahim Formation. The authors are not in accordance with them, because Ma'ala (1977) could hardly miss such a thickness during executing of the regional geological mapping of Sinjar anticline, with a group of field geologists and paleontologists.

**– Azkand Formation:** The Azkand Formation was first described by Bellen (1956), from Azkand valley in the southern dome of Qara Chough anticline, about 6 Km N 60° E of the Azkand village (Bellen *et al*., 1959); the coordinates were not defined. The Azkand Formation is exposed in Qara Chough anticline. Recently, some Oligocene formations were recognized from other localities, southwest of Sulaimaniyah, such as Aj Dagh and Sagirma (Khanaqa *et al*., 2009).

**– Anah Formation:** The Anah Formation was introduced by Bellen (1956); the type locality lies 15 Km east of Nahiyah village, west of Anah, along the Euphrates River; it is defined by the coordinates: 43° 37' 25'' E, 34° 58' 00'' N (Bellen *et al*., 1959).

The Anah Formation is exposed in Qara Chough and Anah anticlines and along the Iraqi – Iranian international borders in Shaloradar and Bawgaru anticlines, and traces along Bezniyan anticline. According to Al-Banna (1997) in Sissakian and Al-Jubori (2011), the Anah Formation is exposed in Butmah East anticline. During the regional geological mapping carried out by Taufiq and Domas (1977), in Butmah anticline, the base of the Fa'tha Formation was not found (Not exposed); therefore, the assumption of Al-Banna (1997), is doubtful, and the formation is not encountered in all drilled oil wells in Butmah anticline (I.P.C., 1963).

## BIOSTRATIGRAPHY

### ▪ General

Since Bellen (1956) in Bellen *et al*. (1959), many works have been carried out in Sinjar area by the following authors: Ma'ala (1977); Karim and Bartlett (1978); Karim (1978); Amer (1979); Jassim and Karim (1984); Jassim *et al*. (1984); Isho in Al-Samaraie *et al*. (1993); Al-Ani (2005) and Jassim and Goff (2006). They all stated the absence of the Oligocene Epoch, but Al-Banna *et al*. (2010), changed the stratigraphy of Sinjar area dramatically based on inadequate biostratigraphic and stratigraphic evidences. In Gaulat surface section, Al-Banna *et al*. (2010), found the whole section to be of Oligocene Epoch (Rupelian – Chattian Stage), which is represented by Tarjil Formation, and the top 7 m of the section belongs to Ibrahim Formation of the Aquitanian – Burdigalian Stage of Early Miocene age.

The detailed work of Karim and Bartlett (1978) and Karim (1978), and the present work in Gaulat, revealed the following facts that indicate the presence of a very thin (few centimeters) of Late Oligocene layer of Ibrahim Formation overlain and underlain by two major unconformities. A basal erosional episode occurred in the Middle Eocene – Late Oligocene between *Acarinina bullbrooki* Zone and uppermost part of *Turborotalia amplipertura* Zone (N.1), while the upper erosional episode occurred during the Late Oligocene – Early Miocene, between *Globigerina angulisuturalis-Paragloborotalia opima opima* Zone (N.2), and *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4). It is clear that the entire Oligocene is represented by a few centimeters of sediments (Karim and Bartlett, 1978), which belong to the upper part of planktonic zone (N.2).

The following abbreviations are used in this study: *Turborotalia*: *Tur. Globigerina*: *G*., *Globigerinoides*: *Glg*., *Globorotalia*: *Glb*., *Paragloborotalia*: *Pgr*., *Catapsydrax*: *C*., *Globoquadrina*: *Glq*.

### ▪ Lithology

Forty one samples were collected from outcrop along the strike valley of the Jable Gaulat in the Singar area, at 42° 00' 00" E, 36° 34' 14" N (Fig.3).

The stratigraphic boundaries from this study were based on the occurrence of major unconformities and the presence and/ or absence of planktonic foraminiferal index species.

The Oligocene – Miocene boundary is indicated by a major erosional unconformity. The basal conglomerate unit (10 cm thick) is composed of poorly sorted, angular whitish brown glauconite and lithic pebbles (diameters, 0.8 – 0.2 cm) with abundant planktonic and few benthonic, worm tubes which vary in length from 0.1 – 0.2 cm, echinoid spines and few shell fragments mainly *Cardium* sp. in a mud matrix.

Beds from 0.1 – 13.85 m thick are composed of yellowish – brownish white marly limestone with abundant planktonic and few benthonic forarm, ostracods, echinoid spines, sponge spicules, glauconite and iron oxide. Beds from 13.85 – 69.37 m thick are composed of brownish white thinly bedded marly limestone, hard with abundant planktonic forarm, echinoid spines, glauconite and iron oxide interbedded with soft beds of green marl with abundant planktonic and few benthonic forarm. At the 69.37 – 268.42 m level the beds are composed of whitish brown, hard marly limestone with abundant planktonic and benthonic forarm, rare ostracods, chert nodules and iron oxide interbedded with whitish brown, green soft marl rich with abundant planktonic and benthonic forarm, bone fragments and glauconite. Beds from 268.42 – 284.92 m thick are composed of white recrystallized porous coralline marly limestone, hard interbedded with thin horizon of marl, with abundant planktonic forarm and chert nodules. At the 284.92 – 289.92 m level the beds are composed of whitish recrystallized marly limestone with abundant *Quinquleoculina* sp. and ostracode. This unit belongs to the lagoonal Euphrates Formation, which interfingers here with the Serikagni Formation.

Beds at the 289.92 – 303.88 m level are composed of thinly bedded white very fine crystalline marly limestone, hard with planktonic and benthonic forarm, ostracods, eponides and echinoid spines. Beds at the 303.88 – 330.38 m level are composed of thinly bedded white hard recrystallized limestone with planktonic and benthonic forarm, ostracods, gastropods, iron oxide and forms like worm tubes or bryozoa. Beds at the 330.38 – 366.28 m level are composed of fine crystalline white foraminiferal limestone interbedded with hard silicified limestone, clayey with rare ostracods. The lower Miocene – Early Middle Miocene boundary is indicated by a major unconformity at the 366.28 m level. The strata overlying the unconformity consist of a brecciated, semibrecciated thinly laminated recrystallized porous limestone, with abundant shell fragments and lithic pebbles of dolomitic fossiliferous clayey limestone. This bed is 12 m thick. The upper two meters at the 378.28 – 380.28 m level belong to the Jeribe Formation. They are characterized by a hard, grayish white, marly dolomitic shelly dolomitic limestone.

- **Late Oligocene – Early Miocene Boundary**

The Late Oligocene – Early Miocene boundary is marked by a major erosional unconformity at the base of the stratigraphic section, and on the first occurrence of the Aquitanian datum *Globigerinoides quadrilobatus primordius* BLOW and BANNER (Fig.4.1a and b) cited at the base of planktonic zone (N.4), which is estimated between (26 – 24) my. B.P., and the extinction of the Oligocene species *Globigerina angulisuturalis* BOLLI ( Fig.4.2), *Paragloborotalia opima opima* BOLLI, *Globigerinoides datum* BOLLI, has been chosen by the "Comite du Neogene" in 1959 as forming an easily recognizable isochron for the inter-regional correlation of the base of the Lectostratotype Aquitanian, and thus the base of the Miocene. The Lectostratotype of the Aquitanian is located in the Valley of Saucats, Aquitains, SW France. For further reading on the Oligocene – Miocene boundary see: Aker (1955), Drooger (1956), Bandy (1964), Berggren (1969a and b); Blow (1969); Bolli *et al*. (1989); Berggren *et al*. (1995); Nazik (2004); Berggren and Pearson (2005) and Hays (2011).

The Oligocene faunas are *Globigerina angulisuturalis* BOLLI (Fig.4.2), *Turborotalia ampliapertura* BOLLI (Fig.4.3), *Paragloborotalia opima opima* BOLLI, and other fauna: *Globigerina praebulloides praebulloides* BLOW (Fig4.4), *Globigerina rohri* BOLLI (Fig.4.5), *G. venezuelana* HEDBERG (Fig.4.6), *Chiluguembelina* cf. *cubensis* (PALMER) (Fig.4.7), *Paragloborotalia opima nana* BOLLI, *Catapsydrax dissimilds* (CUSHMAN and BERMUDEZ) (Fig.4.8), *C. unicava* BOLLI (Fig.4.9) and *C.* sp. (Fig.4.10).

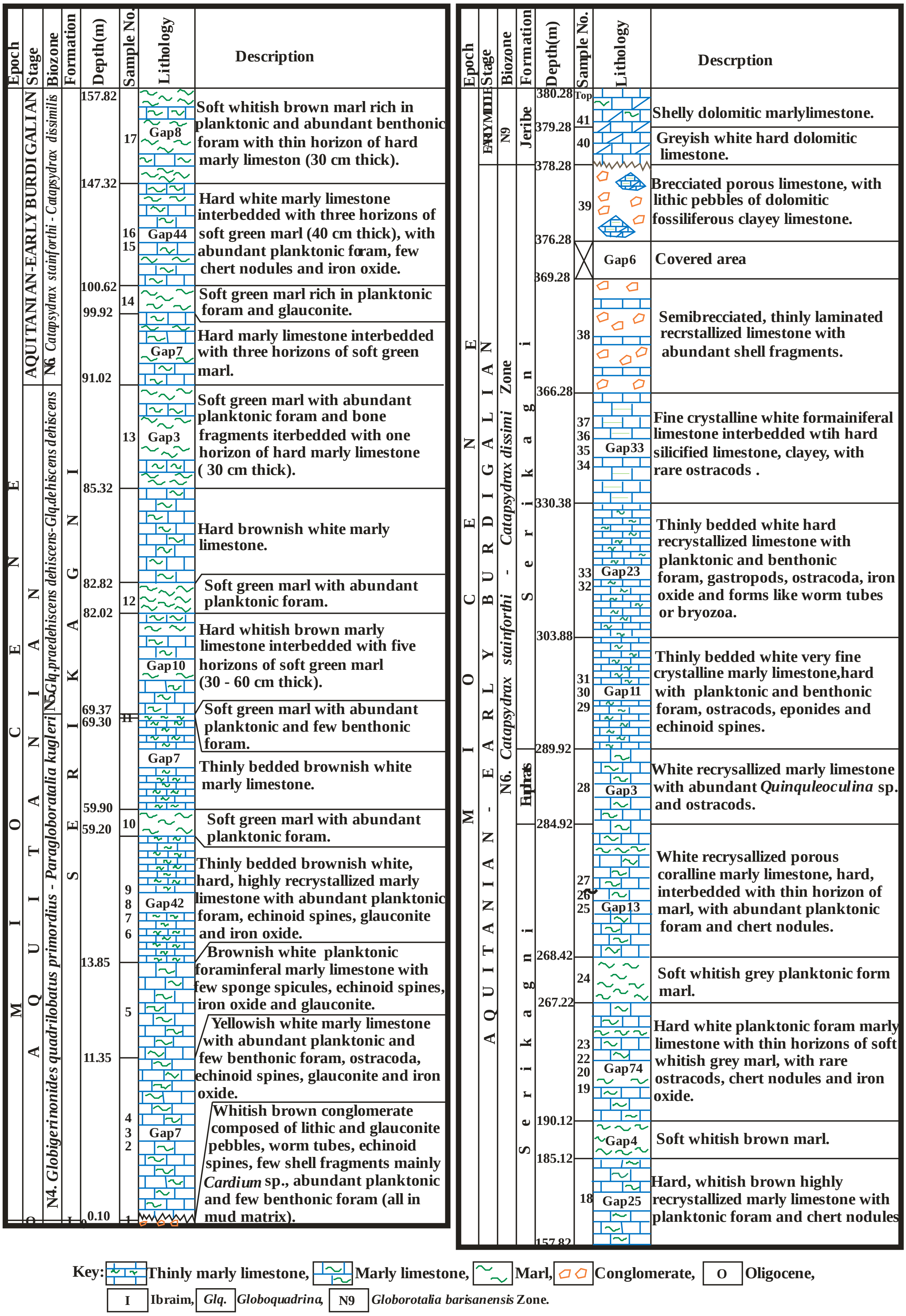


Fig.3: Stratigraphic column of the studied section (Scale 1 cm = 1 m)

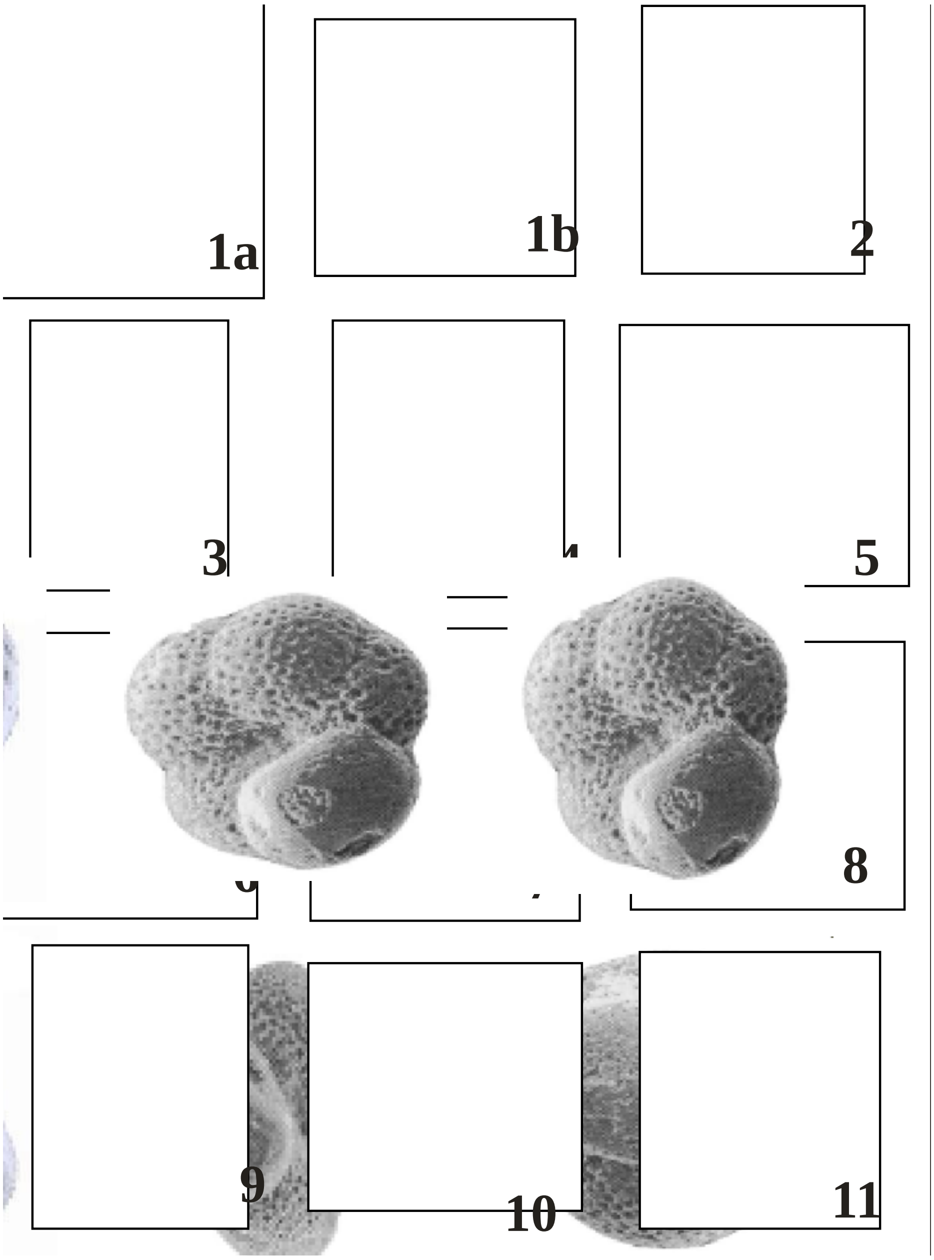


Fig.4: The studied foraminifera

1. *Globigerinoides quadrilobatus primordius* BLOW and BANNER, a. Spiral view, X70,
2. *Globigerina angulisuturalis* BOLLI, Umbilical view, X140.
3. *Turborotalia ampliapertura* BOLLI, Umbilical view, X70.
4. *Globigerina praebulloides praebulloides* BLOW, Umbilical view, X70.
5. *Globigerina rohri* BOLLI, Umbilical view, X140.
6. *Globigerina venezuelana* HEDBERG, Umbilical view, X140.
7. *Chiloguembelina* cf. *cubensis* (RALMER), X140.
8. *Catapsydrax dissimlis* (CUHMAN and BERMUDEZ), Umbilical view, X70.
9. *Catapsydrax unicava* BOLLI, Umbilical view, X140.
10. *Catapsydrax* sp., Umbilical view, X70.
11. *Globigerina ouachitaensis ciperoensis* BOLLI, Umbilical view, X140.

▪ **Oligocene – Early Miocene Boundary in Jebel Gaulat**

The Oligocene – Early Miocene boundary in Jebel Gaulat, Sinjar area, NW Iraq is marked between the planktonic zone N.2 *Globigerina angulisuturalis-Paragloborotalia opima opima*, and *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4). The work of Karim and Bartlett (1978), and the present study, indicate that a very poor Late Oligocene section is present in the studied area. This section is overlain and underlain by major unconformities. The basal erosional episode occurred in the Middle Eocene – Late Oligocene; between *Acarinina bullbrooki* Zone and the upper part of *Globigerina ampliapertura* Zone.

▪ **Early Miocene – Middle Miocene Boundary**

The Early Miocene – Middle Miocene boundary is placed at the first appearance of the Early – Middle Miocene index species, *Globorotalia barisanensis* LEROY of planktonic zone (N.9). This is substantiated by the appearance of *Globorotalia* cf. *mayeri* CUSHMAN and ELLISOR, *Glb*. *zealandica* HORNIBROOK, *Globigerinoides bispherica* TODD, *Glb.* cf. *itiayeri* CUSHMAN and ELLISOR, *Glb. scitula scitula* (BRADY) and *Glb. semivera* (HORNIBROOK).

The work of Amer (1979), in Jaddala section, found that the whole section belongs to the Serikagni Formation of Aquitanian − Burdigalian stage of Early Miocene, and divided the formation into two planktonic zones:

*a-* *Globorotalia kugleri* Zone (N4)
*b-* *Catapsydrex distimiliss* Zone (N5, N6, and N7)

Al-Ani (2005) studied three sections at Gaulat, Jaddala and Bara in Sinjar area, and found that all sections belong to the Early Miocene. Isho in Al-Samaraie *et al*. (1993), revised all executed work in Sinjar area and reached the same conclusion as Karim (1978) and Amer (1979).

## BIOSTRATIGRAPHY AND FORAMINEFERAL ZONATION

The planktonic foraminifera are the best useful guide fossils for biostratigraphic subdivisions in the Mesozoic and Cenozoic Eras, because they are passively transported in the water mass by oceanic currents. Planktonic foraminifera have been utilized to establish the zonation of Paleogene – Neogene; from areas around the world, as well as the recent deep sea drilling project in the Atlantic and Pacific Oceans and the Mediterranean Sea have been established by: Cushman and Stainforth (1945); Cushman and Todd (1945); Cushman and Stevenson (1948); Stainforth (1948 and 1960); Aker (1955); Drooger (1956, 1964 and 1966); Blow (1956, 1959 and 1969); Bolli (1957, 1959, 1964, 1966 and 1970); Drooger and Magne (1959); Jenkins (1960, 1967, 1975 and 1977); Eames *et al*. (1962); Bandy (1963, 1964, 1966, 1969a and b); Bartlett (1964, 1967 and 1968); McTavish (1966); Bandy and Chierici (1966); Poag (1966); Bandy and Wade (1967); Berggren (1969a, b and c, 1970, 1971, 1972a and b, and 1977a and b); Bandy *et al*. (1969); Beckmann *et al*. (1969); Cita *et al*. (1970); Postuma (1971); Bizon (1972); Bartlett and Hamdan (1972); Berggren and Amdurer (1973); Kennett (1973); Molinsky (1973); Berggren *et al*. (1974); Kader (1975); Kennett and Vella (1975); Berggren *et al*. (1976); Berggren and Haq (1976); Krasheninnikov and Pflaumann (1978); Bielak and Briskin (1978); Bolli *et al*. (1989); Azhar *et al*. (1992); Berggren *et al*. (1995); Pearson and Chaisson (1997); Steininger *et al*.(1997); Nazik (2004); Berggren and Pearson (2005); Sancay *et al.* (2006); Bassi *et al.* (2007); Kharajiany (2008); Vaziri-Moghaddam *et al*. (2010); Işik and Hakyemez (2011); Medhat and Abdulhakam (2011); Hays (2011) and Moghaddam *et al*. (2013).

The planktonic foraminifera of the Miocene Section (0.1 – 381.28 m thick) at Jebel Gaulat in Sinjar area is composed of 12 genera and 63 species of *Catapsydrax*, *Globorotalia*, *Globigerina*, *Globigerinoides* and *Globoquadrina* Zones, within the section are indicative of Early Miocene (Aquitanian – Early Burdigalian) age indicating the Serikagni Formation (Fig.5).

The Early Miocene Zones are:

**a.** *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4, Aquitanian, 0.1 – 69.37 m.), with the index species, *Globigerina ouachitaensis ciperoensis* BOLLI (Fig.4.11), *G. rohri* BOLLI (Fig.4.5), *G. trilocularis* D'ORBIGNY, *G. praebulloides praebulloides* BLOW (Fig.4.4), *Chiloguembelina* cf. *cubensis* (PALMER) (Fig.4.7), *Catapsydrax dissimilis* (CUSHMAN and BERMUDEZ) (Fig.4.8), *C. unicava* BOLLI (Fig.4.9) and other fauna: *Globigerinoides quadrilobatus primordius* BLOW and BANNER (Fig.41a and b), *Globigerina ciperoensis* BOLLI, *Paragloborotalia kugleri* BOLLI (Fig.6.1a and b), *Pgr. siakensis* (LEROY) (Fig.6.2a and b), *Pgr. opima nana* BOLLI, *Globigerinlla. obesa* BOLLI (Fig.6a, b and c), *Hastergerina siphonifera praesiphonifera* BLOW (Fig.6.4a and b) and *Globoquadrina dehiscens praedehiscens* BLOW and BANNER (Fig.6.5).

**b.** *Globoquadrina dehiscens praedehiscens-Globoquadrina dehiscens dehiscens* Zone (N.5, Aquitanian, 69.37 – 91.02 m.), with the index species *Globoquadrina dehiscens praedehiscens* BLOW and BANNER (Fig.6.5), *Glq. altispira* (CUSHMAN and JARVIS) (Fig.6.6), *Globigerina woodi* JENKINS (Fig.6.7), and other fauna: *Globigerina angustiumbilicata* BOLLI (Fig.4.2), *Catapsydrax dissimilis* (CUSHMAN and BERMUDEZ) (Fig.5.8), *Paragloborotalia siakensis* LEROY (Fig.6.2), *Globigerinella obesa* BOLLI (Fig.6.3), *Globoquadrina dehiscens dehiscens* (CUSHMAN, PARK and COLLINS) (Fig.7.1), *Glq. baroemoenensis* (LEROY) (Fig.7.2), *Glq. altispira globularis* BERMUDEZ (Fig.7.3) and *Globigerinoides immaturus* LEROY.

**c.** *Catapsydrex stainforthia-Catapsydrex dissimilis* Zone (N.6, Aquitanian – Early Burdigalian,91.02 – 366.28 m.), with the index species, *Globigerinoides quadrilobatus altiaperontura* BOLLI (Fig.5.1a and b), *Glg. quadrilobatus trilobus* (REUSS) (Fig.7.6), *Glg. oblique* BOLLI (Fig.7.7a and b), *Globorotalia peripheronda* BLOW and BANNER, *Globoquadrina incrusta* AKER, and others, *Catapsydrax stainforthia* BOLLI (Fig.7.8), *C. dissimilis* (CUSHMAN and BERMUDEZ), *C. incrusta* AKER, *C. unicava* BOLLI (Fig.5.9), *Globigerinoides quadrilobatus immaturus* LEROY (Fig.7.9), *Globigerina foliata* BOLLI (Fig.8.1), *G. juvenilis* BOLLI (Fig.8.2), *G. woodi* JENKINS (Fig.6.7), *G. bulloides* D'ORBIGNY (Fig.8.3), *G. praebulloides occulosa* BLOW and BANNER (Fig.8.4), *G. praebulloides leroyi* BLOW and BANNER, *Globorotalia clemenciae* BERMUDEZ (Fig.8.5), *Glb. saginata* JENKINS (Fig.8.6), *Glb. scitula praescitula* BLOW, and *Globorotaloides suteri* BOLLI. (Fig.8.7a, b and c).

| Age | O | M I O C E N E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Formation | I | S e r i k a g n i | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Jeribe | |
| Biosones | | N4 | | | | | | | | | | N5 | | N6: *Catapsydrex disimilis - Catapsydrex stisnforthia* Zone | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 |
| Depth Interval (m) / Planktonic Species | 0.10 | 1.50 | 3.50 | 8.95 | 11.75 | 19.55 | 32.35 | 42.15 | 52.75 | 59.90 | 69.37 | 82.82 | 91.02 | 100.62 | 117.82 | 135.82 | 151.52 | 166.22 | 191.12 | 201.62 | 222.22 | 242.22 | 260.22 | 268.42 | 281.02 | 282.02 | 282.92 | 289.92 | 291.42 | 291.88 | 303.88 | 316.88 | 330.38 | 344.38 | 350.38 | 358.68 | 366.28 | 369.28 | 378.28 | 379.28 | 380.28 |
| *Turborotalia cf. cubensis* | o | A | o | | | X | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Tur. ampliapertura* | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Tur.*cf. *ampliapertura* | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Globigerina angulisuturalis* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *G.augustiumbilicata* | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *G.bulloides* | | | | | | | | | | | | | | | | | A | | | | | | | o | | | | o | | | | | | | | | | | | | o |
| *G.ciperoensis* | | | | | | o | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | |
| *G.eamesi* | | | | | | | | | | | | | | | | | | o | | | | | | | o | N | N | | | | | | | | | | | | | N | |
| *G.foliata* | | | | | | | | | | | | | | | | | o | | | | | | | | o | | | | | | | | | | | o | | | | | |
| *G.juvenilis* | | | | | | | | | | | | | | o | o | o | o | | | | X | o | | o | o | | | | | | | | | | | | | | | | |
| *G.ouchitaesis ciperoensis* | | | o | o | | A | o | | | X | o | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *G.praebulloides leroyi* | | | | | | | | | | | | | | X | | o | o | | | | | | | o | | | | | | | | | | | | | | | | | |
| *G.praebulloides occulasa* | | | | | | | | | | | | | | o | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| *G.praebulloides praebulloides* | X | | | | | o | o | | | o | o | | | X | o | | o | | | | | | | o | o | | | o | | | | | | | | o | | | o | | |
| *G.rohri* | o | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *G.trilocularis* | | | | | | | | | | | | | o | o | | | | | | | | | | X | | E | E | | | | | | | | | o | | | | E | |
| *G.*cf.*trilocularis* | | | o | | | | | | | | | | | X | | | X | | | | | | | o | | | | o | | | | | | | | | | | | | |
| *G.venezuelana* | o | | | | | | | | | | | | A | A | X | | o | | | | | | o | | | | | o | | | | | | | | | | | | | o |
| *G.*cf.*woodi* | | | | | | o | | | | | | | o | | o | | | | | | o | | | o | o | | | | | | | | | | | | | | | | |
| *G.*spp. | o | | o | o | o | o | X | X | X | | | | | X | o | o | o | o | | | o | | | X | o | | | | o | X | | | | | | o | | | | | o |
| *Acarinina bullbrooki* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Globorotalia barisanensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | o |
| *Glb.clemenciae* | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glb.continuosa* | | | | | | | | | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | |
| *Glb.lehneri* | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glb.*cf.*mayeri* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | o |
| *Glb.peripheronda* | | | | | | | | | | | | | | X | | | | | o | | A | | A | | o | R | R | | | | | | | | | | | | | R | |
| *Glb.*cf.*peripheronda* | | | | | | | | | | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | o |
| *Glb.praescitula* | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glb.saginata* | | | | | | | | | | | | | | | | | o | | | | | | | o | | | | o | | | | | | | | | | | | | |
| *Glb.scitula scitula* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | o |
| *Glb.semivera* | | | | | | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | | o |
| *Glb.zealandica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | o |
| *Glb.*spp. | o | | o | o | | o | X | X | X | o | o | o | X | X | | | | o | | | o | o | o | | o | | | | o | X | | | | | | | | | | | o |
| *Paraglobrotalia kugleri* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pgr.* cf.*kugleri* | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pgr.pseudokugleri* | | | | | | X | | | | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pgr.opima nana* | o | o | | | o | | | | | | | | | | | o | | | | | | | | | | R | R | | | | | | | | | | | | | R | |
| *Pgr.*cf.*opima nana* | o | | o | o | | X | | | | o | o | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | |
| *Pgr.opima opima* | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pgr.siakensis* | | | | | | o | | | | | | | X | | X | X | | | o | | o | o | o | X | o | | | | | | | | | | | o | | | | | o |
| *Globigerinella obesa* | | | | | | | | | | | | | o | | o | X | A | | | | | | X | A | A | | | o | | | | | | | | | | | | | o |
| *Glo* .cf. *obesa* | o | | | | o | o | | | | | | | | | | | | o | | | | | | o | | | | | | | | | | | | | | | | | |
| *Globoquadrina altispira* | | | | | | | | | | | | | A | X | | | o | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glq.altispira globosa* | | | | | | o | | | | | | | o | | | | | | | | X | | | | | A | A | | | | | | | | | | | | | A | |
| *Glq.altispira globularis* | | | | | | | | | | | | | X | | | | | | | | | | | o | | | | | | | | | | | | | | | | | |
| *Glq.baroemoenensis* | | | | | | | | | | | | | A | A | | | o | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glq.dehiscens dehiscens* | | | | | o | o | | | | | | A | A | A | | | X | | | | | | | | o | | | | | | | | | | | | | | | | |
| *Glq.dehiscens praedehiscens* | | | | o | o | o | | | | o | | | A | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glq.laremeui* | | | | | | | | | | | | | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glq.*spp. | | | | | | | | | | | | | A | A | o | | | o | | | | | | | | | | | | | | | | | | | | | o | | |
| *Globigerinoides bispherica* | | | | | | | | | | | | | | | | | | | | | | | | | | B | B | | | | | | | | | | | | | B | o |
| *Glg.obliqua* | | | | | | | | | | | | | | | | | | | | | | | | X | o | | | | | | | | | | | | | | | | |
| *Glg.quadrelobatus altiapertura* | | | | | | | | | | | | | | | | | A | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glg.quadrelobatus immaturus* | | | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | | | | | | | o |
| *Glg.quadrelobatus primordius* | o | X | o | X | X | A | | | | A | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glg.quadrelobatus trilobus* | | | | | | | | | | | | | | | | | | | | | | | | A | X | | | o | | | | | | | | | | | | | |
| *Glg.*cf.*quadrelobatus trilobus* | | | | | | | | | | | | | | | | | | | | | | | | o | o | | | | | | | | | | | | | | | | |
| *Glg.*spp. | o | o | | X | o | o | | X | X | | | o | | o | o | | X | | o | o | o | | o | X | o | | | | | A | | | | | | o | | | | | o |
| *Catapsydrax dissimilis* | X | X | X | A | A | X | o | | | | o | | A | A | A | o | A | | | | o | | o | A | A | | | | | | | | | | | A | | | o | | |
| *C.incrusta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C.stainforthi* | | | | | | | | | | | | | | A | o | o | o | | | | o | | o | X | | | | | | | | | | | | | | | | | |
| *C.unicava* | X | | | o | o | o | | | | | o | | | X | | | | | | o | | | | X | X | | | | | | | | | | | | | | | | |
| *C.*sp. | o | | o | X | | o | | | | o | o | | X | | | | A | | o | | | o | | | | | | | | | | | | | | | | | | | |
| *Globigerinita* sp. | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glob.dissimili ciperoensis* | o | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hastergerina siphonifera praesiphonifera* | | | | | | | | | | | | | o | o | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *H.*sp. | | | | | | o | | | | o | | | | | | | o | | | | | | | | | | | | | | | | | | | | | | | | |
| *Globortaloides suteri* | | | | | | | | | | | | | | X | o | | o | | | | X | | | X | o | | | o | | | | | | | | | | | | | |
| NUMBER OF GENERA | 10 | 4 | 6 | 6 | 6 | 9 | 3 | 3 | 3 | 8 | 5 | 3 | 7 | 7 | 7 | 6 | 8 | 4 | 4 | 2 | 7 | 4 | 6 | 8 | 8 | | | 5 | 2 | 3 | | | | | | 4 | | | 4 | | 3 |
| NUMBER OF SPECIES | 22 | 5 | 9 | 10 | 9 | 22 | 5 | 3 | 3 | 11 | 8 | 3 | 17 | 21 | 13 | 9 | 22 | 5 | 4 | 2 | 12 | 5 | 9 | 24 | 19 | | | 9 | 2 | 3 | | | | | | 7 | | | 4 | | 15 |

Key: A=Abundant, X=Common, o= Rare, I=Ibrahim, O=Oligocene, N4=*Globigerinoides quadrilobatus primordius - Paragloborotalia kugleri* Zone
N5=*Globoqurdrina dishescens praedihescen - Globoquradrina dihescens dihescens* Zone
Samples 31-35, 37-38 contain abundant planktonic foram in thin section

Fig.5: Planktonic foraminifera distribution chart

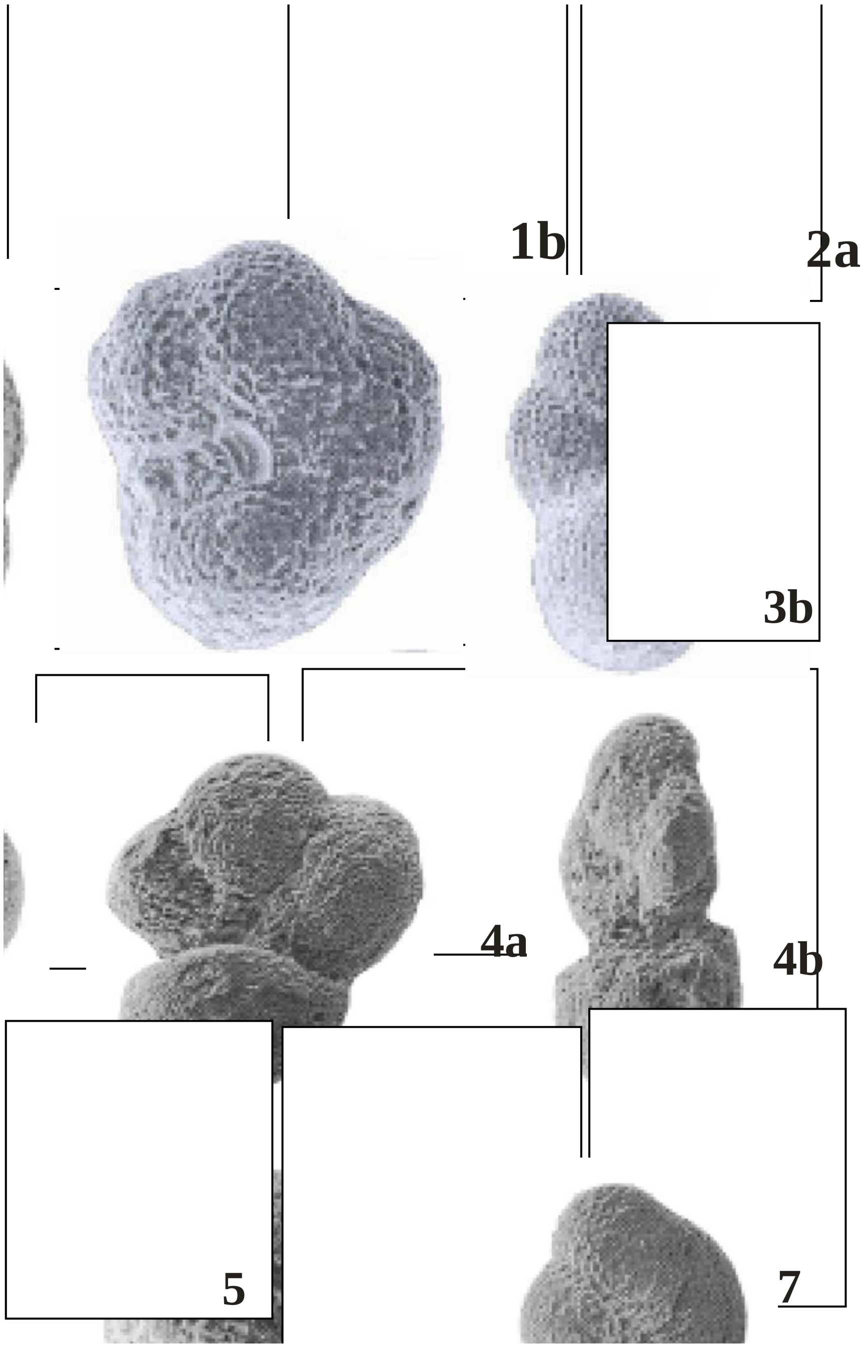


Fig.6: The studied foraminifera

1. *Paragloborotalia kugleri* BOLLI, a-Umbilical view, X140, b-Spiral view, X140
2. *Paragloborotalia siakensis* LEROY, a-Umbilical view, X140, b-Spiral view, X140
3. *Globigerinella obesa* BOLLI, a-Umbilical view, X140. b-Side view, X140. c-Spiral view, X140
4. *Hastergerina siphonifera praesiphonifera* BLOW, a-Umbilical view, X70, b-Spiral view, X70
5. *Globoquadrina dehiscens praedehiscens* BLOW and BANNER, Umbilical view, X140
6. *Globoquardrina altispira* (CUSHMAN and JARVIS), Umbilical view, X140
7. *Globigerina woodi* JENKINS, Umbilical view, X140

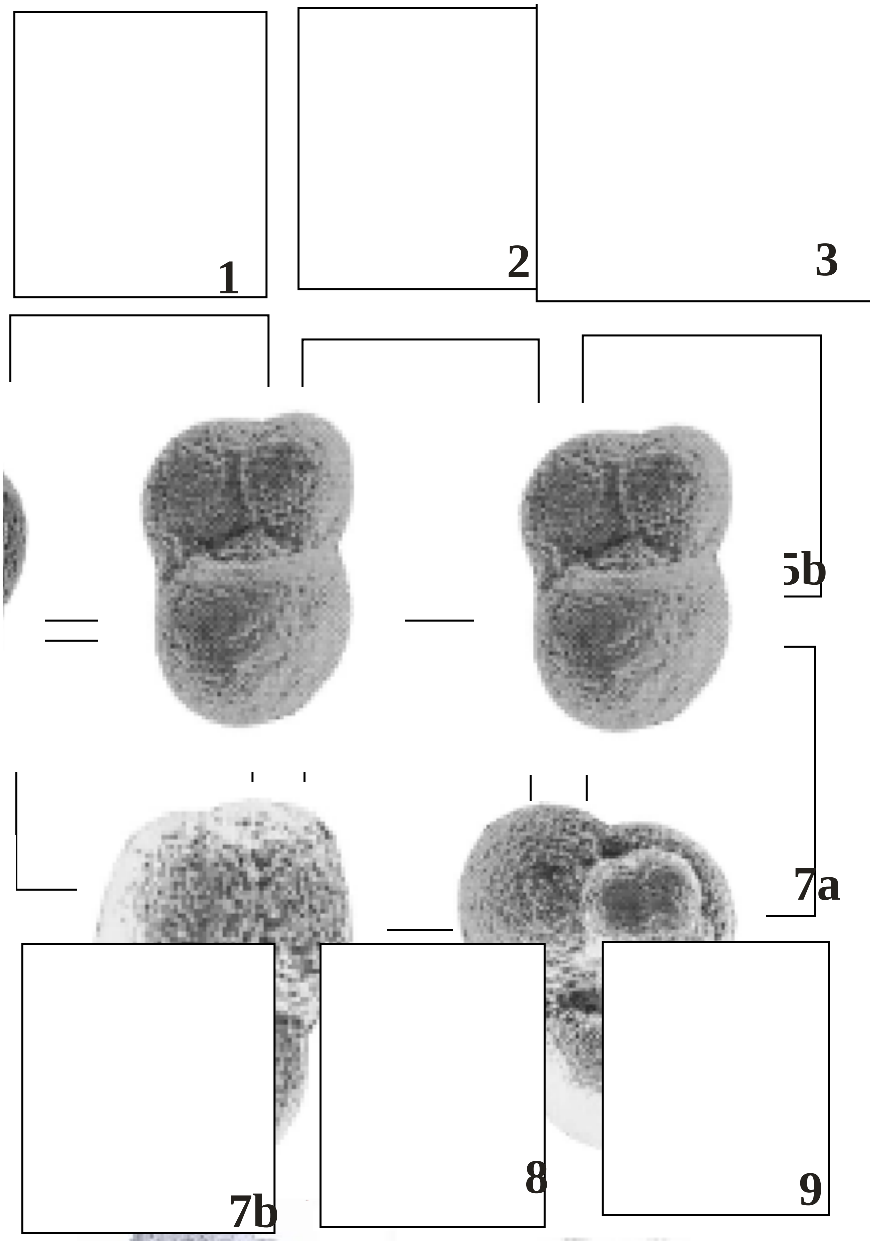


Fig.7: The studied foraminifera

1. *Globoquadrina dehiscens dehiscens* (CHAPMAN, PARK and COLLINS), Umbilical view, X70
2. *Globoquadrina baroemoenensis* (LEROY), Umbilical view, X70
3. *Globoquadrina altispira globularis* BERMUDEZ, Umbilical view, X140.
4. *Paragloborotalia* cf. *pseudokugleri* BLOW, Umbilical view, X140
5. *Globigerinoides quadrilobatus altiapertura* BOLLI, a-Spiral view, X70. b-Umbilical view, X70
6. *Globigerinoides quadrilobatus trilobus* (REUSS), a-Spiral view, X70, b-Umbilical view, X70
7. Globigerinoides *obliqua* BOLLI, a-Umbilical view, X70. b-Spiral view, X70
8. *Catapsydrax stainforthi* BOLLI. Umbilical view, X140
9. *Globigerinoides quadrilobatus immaturus* LEROY, Umbilical view, X70

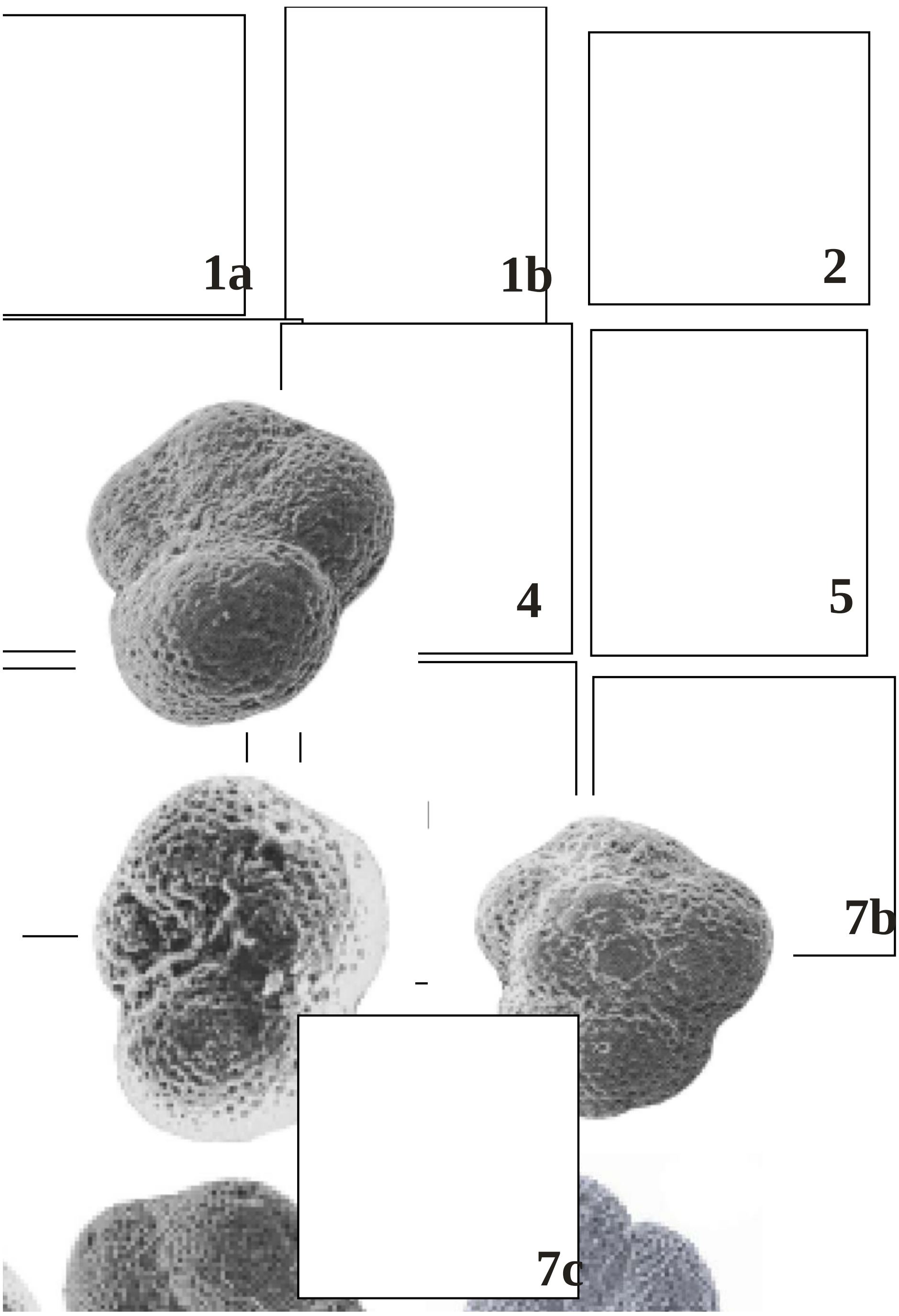


Fig.8: The studied foraminifera

1. *Globigerina foliata* BOLLI, a-Umbilical view, X70, b-Spiral view, X70
2. *Globigerina juvenilis* BOLLI, Umbilical view, X70
3. *Globigerina bulloides* D’ORBIGNY, Umbilical view, X70
4. *Globigerina praebulloides occulosa* BLOW and BANNER, Umbilical view, X70
5. *Globorotalia clemenciae* BERMUDEZ, Umbilical view, X70
6. *Globorotalia saginata* JENKINS, Umbilical view, X140
7. *Globorotaloides suteri* BOLLI, a-Umbilical view, X140. b-Spiral view, X140. c-Umbilical view, X140

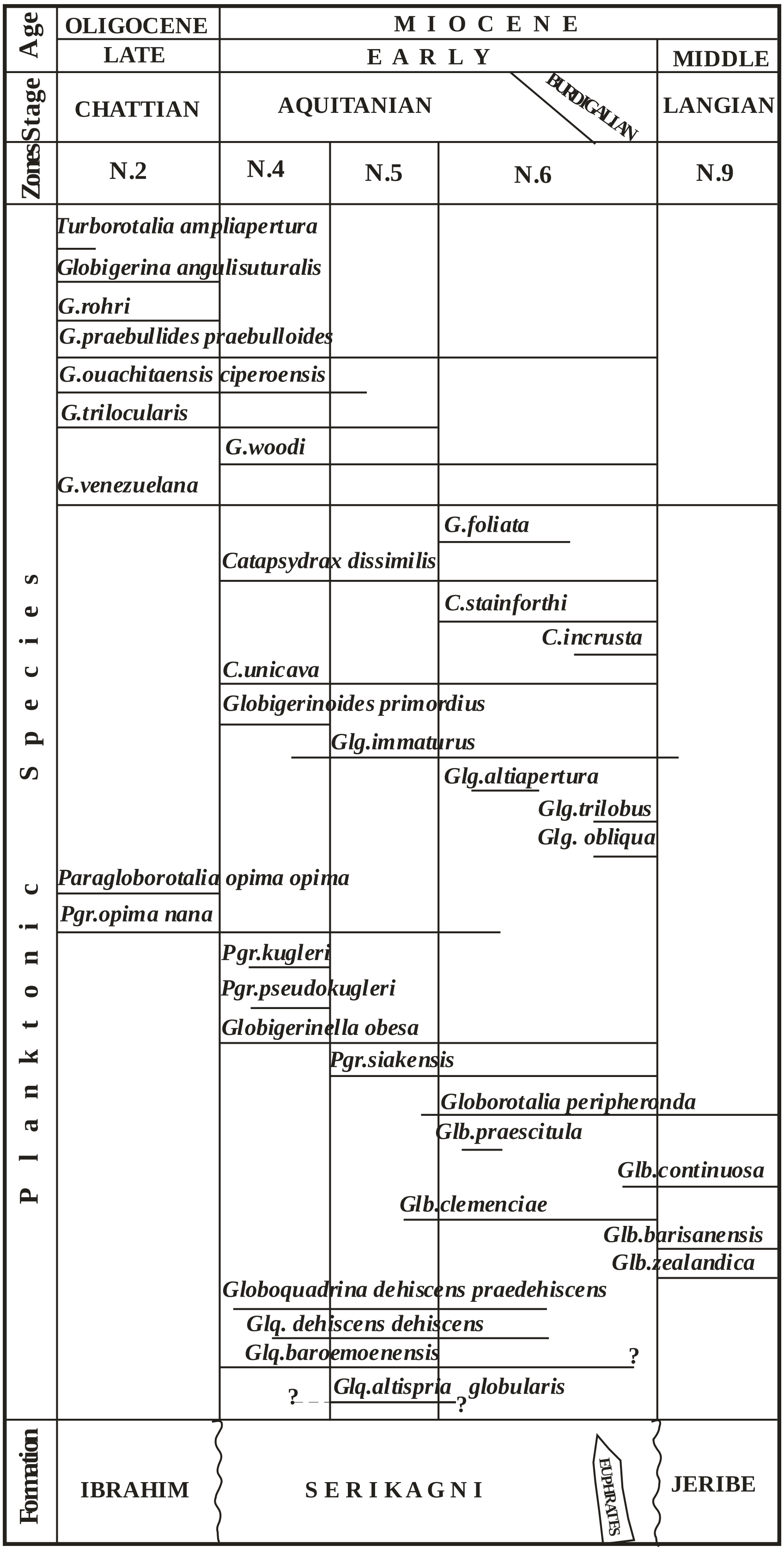


Fig.9: Stratigragraphic distribution of various species of *Turborotalia* (*Tur*.), *Globigerina* (*G*.), *Globigerinella* (*Glo*.) *Catapsydrax* (*C*.), *Globigerinoides* (*Glg*.), *Globorotalia* (*Glb*.), *Paragloborotalia* (*Pag*.) and *Globoquardrina* (*Glp*.).

| Trinidad Bolli(1957,1966) | | East Africa Eames et al.(1962) | | Tropical Regions Blow(1969) | | | Postuma(1971) | Scotan Shelf Molinsky(1973) | Jebel Gaulat Karim(1978) | Western North Atlantic Miller *et al.* 1985 | Miller and Feigenson 1991 | Steininger *et al.* (G S S P ) 1997 | This Study |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M I O C E N E | *Globortalia barisanensis* / *Globorotalia praeorbulina glomerosa* | M I O C E N E A Q U I T A N I A N | *Globortalia barisanensis* | M I O C E N E — MIDDLE | N9 | *Orbulina stuuralis* *Globorotalia peripheronda* | *Globorotalia peripheronda* | N9. *Orbulina stuuralis* *Globorotalia peripheronda* | N9. *Globortalia barisanensis* | N9. *Globortalia barisanensis* | N9. *Globortalia barisanensis* | | N9. *Globortalia barisanensis* |
| | *Globigerinatella insueta* | | *Globigerinatella insueta*: *Globigerinoides bispherica* | LOWER | N8 | *Globigerinoides sicanus* / *Globigerinatella insueta* | *Globigerinatella insueta* | N8. *Globigreinatella sicanus* / *Globigerinatella insueta* | N8. | N8. | N8. | | N8. |
| | | | *Globigerinoides triloba* | | N7 | *Globigerinoides quadrilobatus trilobus* / *Globigerinatella insueta* | | N7. | N7. | N7. | N7. | | N7. |
| | *Clobigerina stainforthi* | | *Clobigerina stainforthi* | | N6 | *Globigerinatella insueta* / *Clobigerina dissimilis* | *Globigerinatella trilobus* | N6. *Globigerinatella insueta* *Clobigerina dissimilis* | N6. *Clobigerina stainforthi* *Clobigerina dissimilis* | N6. *Clobigerina stainforthi* *Clobigerina dissimilis* | N6. *Clobigerina stainforthi* *Clobigerina dissimilis* | | N6. *Clobigerina stainforthi* *Clobigerina dissimilis* |
| | *Clobigerina dissimilis* | | *Clobigerina dissimilis* | | N5 | *Globoquadria dehiscens praedehiscens* / *Globoquadria dehiscens dehiscens* | | N5. | N5. *Globoquadria dehiscens praedehiscens* / *Globoquadria dehiscens dehiscens* | N5. *Globoquadria dehiscens praedehiscens* / *Globoquadria dehiscens dehiscens* | N5. *Globoquadria dehiscens praedehiscens* / *Globoquadria dehiscens dehiscens* | *Globoquadria dehiscens dehiscens* | N5. *Globoquadria dehiscens praedehiscens* / *Globoquadria dehiscens dehiscens* |
| O L I G O C E N E | *Globorotalia kugleri* | | *Globorotalia kugleri* | | N4 | *Globigerinoides quadrilobatus primordius* / *Globorotalia kugleri* | *Globorotalia kugleri* | N4. | N4. *Globigerinoides quadrilobatus primordius* / *Globorotalia kugleri* | N4. *Globigerinoides quadrilobatus primordius* / *Globorotalia kugleri* | N4. *Globigerinoides quadrilobatus primordius* / *Globorotalia kugleri* | *Paregloborotalia kugleri* | N4. *Globigerinoides quadrilobatus primordius* / *Paregloborotalia kugleri* |
| | *Globigerina ciperoensis ciperoensis* | | *Globigerina ciperoensis ciperoensis* | O L I G O C E N E — UPPER | N3 | *Globigerina angulisuturalis* | *Globigerina angulisuturalis* | N3. *Globigerina angulisuturalis* | N3. | N3. | N3. | | N3. |
| | *Globorotalia apima apima* | | *Globorotalia apima apima* | | N2 | *Globigerina angulisuturalis* *Globorotalia apima apima* | | N2. *Globigerina angulisuturalis* *Globorotalia apima apima* | N2. *Globigerina angulisuturalis* *Globorotalia apima apima* | N2. *Globigerina angulisuturalis* *Globorotalia apima apima* | N2. *Globigerina angulisuturalis* *Globorotalia apima apima* | | N2. *Globigerina angulisuturalis* *Paragloborotalia apima apima* |

Fig.10: Comparisons of Oligocene – Miocene planktonic foraminiferal zones on the Jebel Gaulat with other localities

## CONCLUSIONS

This study acquired the following conclusions, concerning the presence or otherwise of Oligocene rocks in Sinjar vicinity.

- The Miocene planktonic foraminiferal assemblages and zones in the Serikagni Formation are comparable to those described from Trinidad (Bolli 1957 and 1966, and Bolli *et al*., 1989), East Africa (Eames *et al*., 1962), Tropical regions (Blow, 1969), Nova Scotia, Canada (Molinsky, 1973), Assam, India (Datti, 1995; Berggren *et al*., 1995, and Stephan and Leckie. 2003) (Fig.10).
- The planktonic foraminiferal assemblages in the Serikagni Formation are of Early Miocene (Aquitania – Burdigalian), belonging to the following zones.
  **a-** *Globigerinoides quadrilobatus primordius-Paragloborotalia kugleri* Zone (N.4)
  **b-** *Globoquadrina dehiscence praedehiscence-Globoquadrina dehiscence* Zone (N.5).
  **c-** *Catapsydrax stainfothia-Catpsydrax dissimilis* Zone (N.6).
- Oligocene planktonic foraminifera of *Globigerina angulisuturalis-Globorotalia opima opima* Zone (N.2), in the basal conglomerate indicate the existence of an unconformity between the Late Oligocene – Early Miocene, rather than what was formally believed to be an Eocene – Early Miocene boundary.
- Tongues of Euphrates or Dhiban Formation are present within the Serikagni Formation of Aquitanian – Burdigalian age.
- The basin configuration, regional geology, paleontological and biostratigraphical study in Sinjar area, at Gaulat, Bara, and Jaddala sections revealed that the studied sections belong to Early Miocene (Aquitanian – Burdigalian) and not to the Oligocene. Therefore, no Oligocene rocks are exposed in Sinjar anticline, except those very thin layers (few centimeters), which belong to Ibrahim Formation.

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## REFERENCES

Aker, W.H., 1955. Some planktonic foraminifera of the American Gulf Coast and suggested correlation with Caribbean Tertiary. J. Paleont., Vol.29, No.4, p. 647 – 664.

Al-Ani, A.A., 2005. Sedimentological studies of the Serikagni Formation in Sinjar Anticline. Unpub. M.Sc. Thesis. Baghdad University. 133 pp.

Al-Banna, N.Y., 1997. Sedimentology and stratigraphical study of the Lower - Middle Miocene, west Mosul. Unpub. Ph.D. Thesis, Mosul University, 177pp. (In Arabic).

Al-Banna, N.Y, Al-Mutwali, M.M. and Isamil, N.R, 2010. Oligocene stratigraphy in the Sinjar Basin, northwestern Iraq. Geo Arabia, Vol.15, No.4, p. 17 – 44.

Al-Hashimi, H.A.J. and Amer, R.M., 1985. Tertiary Microfacies of Iraq. GEOSURV, Baghdad, 56pp.

Al-Kadhimi, J.A.M., Sissakian, V.K., Fattah, A.S. and Deikran, D.B., 1996. Tectonic Map of Iraq, 2nd edit., scale 1: 1000 000. GEOSURV, Baghdad, Iraq.

Al-Samaraie, A.I. and Al-Mubarak, M.A., 1978. Report on the regional geological mapping of Makhmour – Kirkuk Area. GEOSURV, int. rep. no. 905.

Al-Samaraie, A.I., Kaddouri, N.A., Isho, W.Y., Tamar Agha, M.Y. and Said, F.S., 1993. Restudy of the Miocene sediment in Iraq. GEOSURV, int. rep. no.2214.

Amer, R.M., 1979. Biostratigraphy of Serikagni Formation in Sinjar Area, NW Iraq. GEOSURV, int. rep. no. 860.

Azhar, I.I., Bait, B., Justin, J.J., 1992. Geology of Sarawak Oligocene – Miocene Zonation. Annual. Geol. Conference of the Geol. Program and Abstract.

Bandy, O.L., 1963. Cenozoic foraminiferal zonation and basinal development in the Philippines, Bull. Amer. Assoc. Pet. Geol., Vol.47, No.9, p. 1733 – 1745.

Bandy, O.L., 1964. Cenozoic planktonic foraminiferal zonation. Micropaleontology. Vol.10, No.1, p. 1 – 17.

Bandy, O.L., 1966. Restriction of *"Orbulina daturn"*. Micropaleontology. Vol.12, No.1, p. 79 – 86.
Bandy, O.L.,1969a.Relationships of Neogene planktonic foraminifera to paleoceanography and correlation. In: P., Bronnimann and H.H., Renz (Eds.), Proc. 1st Int. Conf. Plank. Microfoss. Geneva, 1967, Vol.1, p. 46 – 77.
Bandy, O.L., 1969b. Middle Tertiary basin development, San Joaquin Valley, California. Bull.Geol. Soc. Amer. Vol.80, p. 783 – 820.
Bandy, O.L. and Chierici, M.A., 1966. Depth-temperature evaluation of selected California and Mediterranean bathyal foraminifera. Marinte Geol., Vol.4, p. 259 – 271.
Bandy, O.L. and Wade, M., 1967. Miocene – Pliocene – Pleistocene boundaries in deep water environments. Progr. Oceanography, Vol.4, p. 51 – 66.
Bandy, O.L., Vincent, E. and Wright, R.C., 1969. Chronological relationships of *Orbulina* to the *Globorotalia foshi* LINEAGE, Revista Espanola De. Micropaleontologia. Vol.1, No.2, p. 131 – 145.
Bartlett, G.A., 1964. A preliminary study of foraminiferal distribution on the Atlantic Continental Shelf, Southeastern Nova Soctia, Geol. Surv. Can. Paper 64-5, p. 1 – 19.
Bartlett, G.A., 1967. Planktonic foraminifera in the Oligocene – Miocene formations on the continental slope off Nova Soctia (abstract), World Plank. Conf. Geneva, p.10.
Bartlett, G.A., 1968. Mid – Tertiary stratigraphy of the continental slope off Nova Scotia, Maritime Sed. Vol.4, No.1, p. 22 – 31.
Bartlett, G.A. and Hamdan, A., 1972. The Canadian, Atlantic continental margin biostratigraphy, paleoecology and paleoceanography from Cretaceous – Recent. 24th Int. Geol. Congr. (Montreal), Proc. Sec. Vol.8, p. 3 – 10.
Bassi, D., Hottinger, L. and Nebelsick, J.H., 2007. Larger foraminifera from the Upper Oligocene of the Venetian area, North East Italy. Palaeontology, Vol.50, Part.4, p. 845 – 868.
Beckmann, J.P., El-Heiny, I.K., Kerdany, M.T., Said, R. and Biotti, C., 1969. Standard planktonic zones in Egypt. In: P., Bronnimann and H.H., Renz (Eds.), Proc. 1st Int. Conf. Plank. Microfoss. Geneva. 1967, Vol.1, p. 92 – 103.
Bellen, R.C., Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphy International. Asia, Fasc. 10a, Iraq, Paris. 333pp.
Berggren, W.A., 1969a. Biostratigraphy and planktonic foraminiferal zonation of the Tertiary system of the Sirte Basin and Libya, North Africa. In: P., Bronnimann and H.H., Renz (Eds.). Proc. 1st Int. Conf. Plank. Microfoss. Geneva. 1967, Vol.1, p. 104 – 120.
Berggren, W.A., 1969b. Paleogene biostratigraphy and planktonic foraminifera of Northern Europe. In: P. Bronnimann and H. H. Renz (Eds.), Proc. 1st Int. Conf. Plank. Microfoss. Geneva. 1967, Vol.1, p. 121 – 159.
Berggren, W.A., 1969c. Rates of evolution in some Cenozoic planktonic foraminifera. Micropaleontology. Vol.16, No.3, p. 1 – 37.
Berggren, W.A., 1970. Biostratigraphy of site 1 – 3, 6 – 7, Cenozoic foraminiferal fauna in: Maurice Ewing, J. Lamar Worzel *et al*., Initial Reports of the Deep Sea Drilling Project, Washington (U.S. Gov. Printing Office), Vol.1, p. 549 – 601.
Berggren, W.A., 1971. Tertiary boundaries and correlation. In: B.M., Funnel and W.R., Riedel (Eds.). The Micropaleontology of Oceans, p. 693 – 809.
Berggren, W.A., 1972a. A Cenozoic time-scale, some implications for regional geology and paleobiogeography. Lathia, Vol.5, p.195 – 215.
Berggren, W.A., 1972b. Cenozoic biostratigraphy and paleobiogeography of the North Atlantic. In: A.S., Laughton, W.A., Berggren *et a*l., Initial Reports of the Deep Sea Drilling Project, Leg 12, Washington (U.S. Gov. Printing Office), Vol.12, p. 965 – 1001.
Berggren, W.A., 1977a. Late Neogene planktonic foraminiferal biostratigraphy of Grande Rise (South Atlantic). Marine Micropaleontology. Vol.2, p. 265 – 313.
Berggren, W.A., 1977b. North Atlantic Cenozoic foraminifera. In: P.M.Swain (Eds.). Stratigraphic paleontology of the Atlantic Basin and Borderlands, p. 389 – 409.
Berggren, W.A. and Amdurer, M., 1973. Late Paleogene (Oligocene) and Neogene planktonic foraminiferal biostratigraphy of the Atlantic Ocean (Lat. 30º N – Lat. 30º S). Rev. Ital. Paleont., Vol.79, No.3, p. 337 – 392.
Berggren, W.A., Lohmann, C.P. and Poore, R.Z., 1974. Shore laboratory report on Cenozoic planktonic foraminifera, Leg. 22. In: Van der Broch, Christopher, C., *et al*. Initial Reports of the Deep Sea Drilling Project, Leg. 22, Washington (U.S.Gov. Printing Office), Vol.22, p. 635 – 655.
Berggren, W.A., Benson, R.H., Haq, B.U., Riedel, W.R., San Filipo, A., Schrador, N.J. and Tjalsma, R.C., 1976. The El-Cuervo section (Andalusia, Spain) micropaleontologic anatomy of an Early Late Miocene, lower bathyal deposit. Marine Micropaleontology, Vol.1, p. 195 – 247.

Berggren, W.A. and Haq, B.U., 1976. The Andaulsian Stage (Late Miocene): biostratigraphy, biochronology and paleoecology. Paleogeog. Paleoclimat. Paleoecology. Vol.20, p. 67 – 129.

Berggren, W.A., Kent, D.V., Swisher, C.C., III and Aubry, M.P., 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W.A., Kent, D.V., Aubry, M.P., and Hardenbol, J. (Eds.), Geochronolgy, Time Scales and Global Stratigraphic Correlation. Spec. Pub. Sepm. (Soc. Sediment. Geol.). Vol.54, p. 129 – 212.

Berggren, W.A. and Pearson, P., 2005. A revised tropical-subtropical Planktonic foraminiferal zonation. Jour. of Foraminiferal Research.Vol.35, p 279 – 298.

Bielak, L.E., and Briskin, M., 1978. Pleistocene biostratigraphy, chronostratigraphy and paleocirculation of the Southeast Pacific Central Water Core, R.C. 11-220, Marine Micropaleontology, Vol.2, p 51 – 94.

Bizon, G., 1972. Atlas des principaux foraminiférs palnctoniques due basin Mid – Oligocéne a Quaternaire. In: Technip (Ed.), p. 1 – 316.

Blow, W.H., 1956. Origin and evolution of the foraminiferal genus *Orbulina* D'ORBIGNY. Micropaleontology, Vol.2, No.1, p 57 – 70.

Blow, W.H., 1959. Age, correlation and biostratigraphy of the Upper Tocuyo (San Lorenzo) and Pozen Formation, Eastern Falcon, Venezuela. Bull. Amer. Paleont., Vol.39, No.178, p. 67 – 251.

Blow, W.H., 1969. Late Middle Eocene – Recent planktonic foraminiferal biostratigraphy. In: P., Bronnimann and H.H., Renz (Eds.), Proc. 1st Int. Conf. Plank. Microfoss. Geneva. 1967, Vol.1, p. 199 – 422.

Bolli, H.M., 1957. Planktonic foraminifera from the Oligocene - Miocene Cipero and Lengua Formation of Trinidad. B.W.I.U.S. Nat. Mus. Bull. Vol.215, p. 97 – 124.

Bolli, H.M., 1959. Planktonic foraminifera as index fossils in Trinidad, West Indies and their valve for world wide stratigraphic correlation. Eclog. Geol. Helv., Vol.52, p. 627 – 637.

Bolli, H.M., 1964. Observation on the stratigraphic distribution of some warm water planktonic foraminifera in the young Miocene – Recent. Eclog. Geol. Helv., Vol.57, No.2, p. 451 – 552.

Bolli, H.M., 1966. The planktonic foraminifera in Well Badyjonegora – 1 of Java. Eclog. Geol. Helv., Vol.59, p. 449 – 465.

Bolli, H.M., 1970. The foraminifera of sites 23 – 31, legs 4. In: Richard, G., Bader, Report, D.Gerard, *et al*. Initial Reports of the Deep Sea Drilling Project, Leg. 4, Washington (U.S.Gov. Printing Office), Vol.4, p. 577 – 643.

Bolli, H.M., Sounders, J.B. and Perch-Nielsen, K. 1989. Planktonic stratigraphy, planktonic foraminifera, calcareous nannofossils and caponella. Cambridge, Earth Science, Series.

Cita, M.B., Nigrini, C., Gartner, S., 1970. Biostratigraphy. In: M.N.A. Paterson, N. Terence Edgar *et al*. Initial Reports of the Deep Sea Drilling Project, Leg. 2, Washington (U.S.Gov. Printing Office), Vol.2, p. 391– 411.

Cushman, J. A. and Stainforth, R.M., 1945. The foraminifera of the Cipero Marl Formation of Trinidad, British West Indies. Cushman Lab. Foram. Res. Spec. Publ. No.14, p. 1 – 75.

Cushman, J.A. and Todd, R., 1945. Miocene foraminifera from Buff Bay, Jamaica. Cushman Lab. Foram. Res. Spec. Publ. No.15, p. 1 – 73.

Cushman, J.A. and Stevenson, F.V., 1948. A Miocene foraminiferal fauna from Ecuador. Contr. Cushman Lab. Foram. Res., Vol.24, pt. 3, p. 50 – 68.

Datti, C.Rao., 1995. Late Oligocene – Early Miocene foraminiferal biostratigraphy and paleoenvironments of Maibang Jadiarea, North Cachar Hills of Assam, India. Marine Micropaleontology, Vol.26, Issue. 1 – 4, p. 281 – 285.

Drooger, C.W.,1956. Trans Atlantic correlation of the Oligocene – Miocene by means of foraminifera. Micropaleontology, Vol.2, No.2, p. 183 – 192.

Drooger, C.W., 1964.Problems of Mid-Tertiary stratigraphic interpretation. Micropaleontology, Vol.10, No.3, p. 369 – 374.

Drooger, C.W., 1966. Zonation of the Miocene by means of planktonic foraminifera, Comm. Med. Neogene Stratig. Proc. 3rd Session, Berne (1964), p. 40 – 50.

Drooger, C.W. and Mange, J., 1959. Miogypsinoids and planktonic foraminifera of the Algerian, Oligocene and Miocene. Micropaleontology, Vol.5, No.3, p. 273 – 284.

Eames, F.E., Banner, F.T., Blow, W.H. and Clarcke, W.I., 1962. Fundamentals of Mid - Tertiary Stratigraphical Correlation. Cambridge University. Press, p. 1 – 163.

Fouad, S.F., 2010. Tectonic Map of Iraq, scale 1: 1000 000, 3rd edit. GEOSURV, Baghdad, Iraq.

Hays, T.J., 2011. Teriary boundaries and correlations. In: Shackleton, N.I., Curry, W.B., Ritchar, C. and Bralowur, T.J. (edits). Proccedings od the Ocean Drilling Project. Scientific Result. Vol. 145.

I.P.C., 1963. Geological and Production Data. GEOSURV, int. rep. no. 130.

Işik, U. and Hakyemez, A., 2011. Integrated Oligocene – Lower Miocene larger and planktonic foraminiferal biostratigraphy of the Kahramanmaraş basin (Southern Anatolia), Turkey. Turkish J. Earth Scia. Vol.20, p. 185 – 212

Ismail, N.R., 2005. Biostratigraphy and sequence stratigraphy of Oligocene and Lower Miocene formations of Sinjar Basin, NW Iraq. Unpub. Ph. D. Thesis, Mosul University 222pp. (in Arabic).

Jassim, S.Z. and Karim, S.A., 1984. Final report on the regional geological survey of Iraq. Vol.4, ″Paleogeography″. GEOSURV, int. rep. no. 1448.

Jassim, S.Z., Karim, S.A., Basi, M.A., Al-Mubarak, M.A. and Munir, J., 1984. Final report on the regional geological survey of Iraq. Vol. 3, ″Stratigraphy″. GEOSURV, int. rep. no. 1447.

Jassim, S.Z., Al-Hashimi, A.H. and Hagopian, D.A., 1990. Geological Map of Iraq, scale 1: 1000 000, 2nd edit. GEOSURV, Baghdad, Iraq.

Jassim, S.Z. and Goff, J., 2006. Geology of Iraq. Dolin, Prague, 341pp.

Jenkins, D.G., 1960. Planktonic foraminifera of the Lakes Entrance Oil Shaft, Victoria, Australia. Micropaleontology, Vol.6, N.4, p. 345 – 371.

Jenkins, D.G., 1967. Planktonic foraminifera zones and new taxa from the Lower Miocene – Pleistocene of New Zealand. New Zealand Jour. Geol. Geophys., Vol.10, N.4, p. 1064 – 1078.

Jenkins, D.G., 1975. Cenozoic planktonic foraminiferal biostratigraphy of the Southwestern Pacific and Tasman Sea, DSDP. Log. 29. In: James, P. Kennett *et al*. Initial Reports of the Deep Sea Drilling Project, Leg.29, Washington (U.S.Gov. Printing Office), Vol.29, p. 449 – 467.

Jenkins, D.G., 1977. Lower Miocene planktonic foraminifera from borehole in the English Channel. Micropaleontology, Vol.23, No.3, p. 297 – 318.

Kader, D., 1975. Planktonic foraminifera from the Lower part of the Sentolo Formation, Central Java, Indonesia. Jour. Foram. Rea., Vol.5, No.1, p. 1 – 20.

Karim, S.A., 1978. Micropaleontology, biostratigraphy and paleoecology of the Serikagni Formation in Jebel Gaulat Area, NW. Iraq. Unpub. M.Sc. Thesis. Queen′s University, Kingston, Ontario, Canada. 101pp.

Karim, S.A. and Ctyroky, P., 1971. Stratigraphy of eastern and southern flanks at the Ga'ara high west desert, K160 area. GEOSURV, int. rep. no. 1185.

Karim, S.A. and Bartlett, G.A., 1978. Reinterpretation of the Jaddala Formation from the Jebel Gaulat, NW. Iraq. J.G.S.T., p. 1 – 22.

Kennett, J.P., 1973. Middle and Late Cenozoic planktonic foraminiferal biostratigraphy of the Southwestern Pacific DSDP, Leg 21. In: Burns, R.E., Andrew, J.E. Initial Reports of the Deep Sea Drilling Project, Leg 21, Washington (U.S.Gov. Printing Office), Vol.21, p. 575 – 639.

Kennett, J.P. and Vella, P., 1975. Late Cenozoic planktonic foraminifera and paleoceanography at DSDP, Sita 248 in the cool subtropical South Pacific. In: Kennett, J.P., Houtz,R..E. *et al.* Initial Reports of the Deep Sea Drilling Project, Leg. 29, Washington (U.S. Gov. Printing Office), Vol.29, p. 769 – 799.

Khanqa, P.A., Karim, S.A., Sissakian, V.K. and Kareem, K.H., 2009. Lithostratigraphic study of a Late Oligocene – Early Miocene succession, south of Sulaimaniyah, NE Iraq. Iraqi Bull. Geol. Min., Vol.5, No.2, p. 41 – 58.

Kharajiany, S.O.A., 2008. Sedimntary facies of Oligocene rock units in A shagh Mountain, Sangaw District, Kurdistan region, NE Iraq. Unpub. M.Sc. Thesis. Sulaimani University, 122pp.

Krasheninnikov, A.V. and Pflaumann, U., 1978. Zonal stratigraphy and planktonic foraminifera of Paleogene deposits of the Atlantic Ocean to the west of Africa. In: Yves Lancelot, Eugon Sebold, *et al*. Initial Reports of the Deep Sea Drilling Project, Washington (U.S.Gov.Printing Office), Vol.41, p. 613 – 681.

Ma'ala, K., 1977. Report on the regional geological mapping of Sinjar area. GEOSURV, int. rep. no. 860.

Ma'ala, Kh.A, Mahdi, A.H., Fouad, S.F., Lawa, F.A., Philip, W. and Al-Hassany, N., 1987. Report on the geological investigation for northern sector of the Fatha – Mosul Sulfur District. GEOSURV, int. rep. no. 1935.

Majid, A.H. and Veizer, J., 1986. Deposition and Chemical diagenesis of Tertiary carbonates, Kirkuk oil field, Iraq. AAPG, Bull. p. 898 – 913.

McTavish, R.A., 1966. Planktonic foraminifera from the Malaita Group, British Solomon Islands. Micropaleontology, Vol.12, No.1, p. 1 – 36.

Medhat, M.M. and Abdelhakam, A.B., 2011. Planktonic foraminifera biostratigraphy of the Lower and M idle Mocene successions of the Gulf of Suez, Egypt. Int. J. Aca. Res. Vol.3, Issue 4, 91pp.

Moghaddam, I.M., Moradi, A. and Rozpaykar, A., 2013. Microbiostratigraphy and sequence stratigraphy of Oligocene - Miocene Asmari Formation in South West of Lurestan, SW Iran. J. B. A. Sci. Res., Vol.3, No.3, p. 1045 – 1056.

Mohi Ad-Din, R.M., Sissakian, V.K., Yousif, N.S., Amin, R.M. and Rofa, S.H., 1977. Report on the regional geological mapping of Mosul – Tel Afar Area. GEOSURV, int. rep. no. 831

Molinsky, L., 1973. The biostratigraphy and paleoecology of the Oligocene and Miocene of the Canadian Atlantic continental margin off Nava Scotia. Unpub. M.Sc. Thesis. Queen′s University, Kingston, Ontario, Canada.169pp.

Nazik, A., 2004. Planktonic foraminiferal Biostratigraphy of the Neogene Sequence in the Adana Basin, Turkey and its correlation with standard biozones. Geological Magazine. Vol.141, p. 379 – 387.

Pearson, P.N. and Chaisson, P., 1997. Late Paleocene to Middle Miocene Planktonic foraminiferal of the Ceara Rise. In: Shackleton, N.I.; Curry, W.B.; Ritchar, C . and Bralowur, T.J. (edts). Proccedings od the Ocean Drilling Project. Scientific Result. Vol.145.

Poag, C.W., 1966. Paynes Hammock (Lower Miocene?) foraminifera of the Alabama and Mississippi. Micropaleontology, Vol.12, No.4, p. 393 – 440.

Postuma, J.A., 1971. Manal of Planktonic Foraminifera, Elsevier Publ. Co., 420pp.

Sancay, R.H., Bati, Z., Işik, U., Kiriçi, S. and Akça, N., 2006. Palynomorph, fpraminifera and calcareous nannoplanktonic biostratigraphy of Oligocene – Miocene sediments in the Muş basin, Eastern Anatolia, Turkey. Turkish J. Earth Sci. Vol.15, p. 259 – 319.

Sissakian, V.K., 2000. Geological Map of Iraq, scale 1: 1000 000, 3rd edit. GEOSURV, Baghdad, Iraq.

Sissakian, V.K., Mahdi, A.I., Amin, R.M. and Mohammed, B.S., 1997. The Nfayil Formation. A new Lithostratigraphic Unit of Middle Miocene age. Iraqi Geol. Jour., Vol.30, No.1, p. 61 – 66.

Sissakian, V.K. and Al-Jubori, B.M., 2011. Stratigraphy. In: The geology of the Low Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.5.

Stainforth, R.M., 1948. Description, correlation and paleoecology of Tertiary Cipero Marl Formation, Trinidad, B.W.I. Bull. Amer. Assoc. Petrol. Geol. Vol.32, No.7, p. 1292 – 1330.

Stainforth, R.M., 1960. Current status of trans Atlantic Oligocene – Miocene correlation by means of planktonic foraminifera. Rev. Micropaleontology, Vol.2, No.4, p. 219 – 230.

Steininger, F.F., Aubry, M.P., Berggren, W.A., Biolzi, M., Borsetti, A.M., Cartlidge, J.E., Cati, F., Corfield, R., Gelati, R., Iaccarino, S., Napoleone, C., Ottner, F., Rögl, F., Roetzel, R., Spezzaferri, S., Toteo, F., Villa, G. and Zevenboom, D., 1997. The global stratotype section and point (GSSP) for the base of the Neogene. Episodes. Vol.20, No.1, p. 23 – 28.

Stephan, A.N, and Leckie, R.M., 2003. Miocene planktonic foraminiferal biostratigraphy of Site 1143 and 1146, Leg. 184, South China Sea, web publication.

Taufiq, J.M. and Domas, J., 1977. Report on the regional geological mapping of Duhok – Ain Zala Area. GEOSURV, int. rep. no. 837.

Vaziri-Moghaddam, H., Seyrafian, A., Taheri, A. and Motiei, H., 2010. Oligocene – Miocene ramp system (Asmari Formation) in the NW of the Zagros basin, Iran: Microfacies, paleoenvironment and depositional sequence. Revista Mexicana de Ciencias Geológicas, Vol.27, No.1, p. 56 – 71.

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