



Microfaunal Assemblages and microfacies of Nummulitic Limestone of Naopurdan Group from Chwarta Area, Sulaimaniya Governorate, Northern Iraq

Hyam Saleh Daoud

College of Engineering, Irrigation Department, University of Sulaimani, Kurdistan Region-Iraq,

E-mail: hyam.daoud@univsul.edu.iq

Article info	Abstract
Original: 2 February 2019 Revised: 16 March 2019 Accepted: 21 May 2019 Published online: 20 June 2019 Key Words: Large foraminifera. microfacies. Paleocene-Eocene. Paleoenvironment.	Thirty-one samples were collected from nummulitic limestone of the Naopurdan Shaly Group of Paleocene-Early Eocene at the northern part of Chwarta town. Thirty-three thin sections were prepared and analyzed under a binocular microscope. Four main depositional microfacies Packstone, Floatstone, Boundstone, and Wackestone have been recognized. Thirty-two species of benthic foraminifers and algae were recorded; most of them were identified for the first time. The new species of microfossil assemblages identified comprises <i>Nummulites</i> sp., <i>N. kdjokdjokartae</i> , <i>N. globulus</i> , <i>N. mammilatus</i> , <i>N. subirregularis</i> , <i>Alveolina violae</i> , <i>A. stercusmuris</i> , <i>A. frumentiformis</i> , <i>A. fornasinii</i> , <i>A. cf. sakaryaensis</i> , <i>Assilina laminose</i> , <i>A. granulosa</i> , <i>Discocyclina ranikotensis</i> , <i>D. dispansa</i> , <i>Lepidocyclina sumatrensis</i> , <i>L. parva</i> , <i>Cuvillierina sireli</i> , <i>Thalmanitta madrugensis</i> , <i>Nephrolepidina</i> sp., <i>Idalina sinjarica</i> , <i>Cymopolia ellongata</i> , <i>Quinqueloculina</i> , <i>Biloculina</i> , <i>Pseudohatigerina</i> sp., <i>Asterocyclina ferrandesi</i> n. sp. and <i>Eulepidina dilatata</i> . Besides these species, nine levels of distribution of microfauna were established and based on the microfossil assemblages and microfacies, the new paleoenvironments of deposition from the subtidal to outer ramp have been determined. In addition, the age Late Paleocene (Selandian) to Early Eocene (Lower Lutetian) was confirmed.

Introduction

The aim of this study is to determine the microfauna assemblages, microfacies and environmental deposition of nummulitic limestone outcropping in Chwarta area. The studied section is located at the north-west corner of Chwarta town in Sulaimaniya Governorate at the Latitude and longitude of: 35°43'34.24"N 45°34'21.78"E respectively (Figure 1). The thickness of the section is 33 meter and consists of massive milky to pale grey limestone with mediums hardness and intensely fractured and sheared. The lower part of the section is covered by soil while the middle and upper part are well exposed (Figure 1). The studied limestone belongs to the Naopurdan Shaly Group of Paleocene-Early Eocene age and consists mostly of flysch and nummulitic limestone deposited in a fore-arc region [1]. The name Naopurdan Shaly Group was first time used by Bolton (1958d) who describes the lowermost tectonic unit of the Thrust Zone of Iraq at Naopurdan village in the Rawanduz River Valley (type locality). According to Al-Qayim et al. (2012) [2] the section under study is within the domain of the Zagros Suture Zone. Buday (1980) [3] divided this group into two subgroups: 1. Naopurdan-Type Subgroup composed of the intercalated volcanic unit and sedimentary rocks and 2. Sidekan-Type Subgroup consisting only of sedimentary rocks. Bolton (1958d) [4] divided the Naopurdan-Type Subgroup into six units from the bottom to the top. Despite the difficulties of thickness' estimation of this group, but it is indicated to be in the range of 2500-3000 m. The limestone under study

belongs to the second unit mentioned by the above author from the bottom. According to Jassim and Goff (2006) [1] the Naopurdan Group was deposited in marine setting on the SW margin of the Paleogene volcanic arc before the Neo-Tethys to be closed. These bodies of nummulitic limestone are mentioned by Al-Qayim et al. (2012) [2] as a sequence of the slope to shallow carbonate platform, showing intensive microfaults, microfractures, and stylolites. These microdeformations are showing very clearly in the thin sections as seen in (Figures 4, 5, 6, 7) and are often proven by deformation of microfossils (Figure 5). Mirza et al. (2016) [5] studied Naopurdan limestone from Chwarta region for geochemical assessment; however, they have also mentioned some species of Nummulites and Alveolinids but without details about them. According to Jassim and Goff (2006) [1] the identified species of large benthic foraminifera in nummulitic limestone are represented by: *Alveolina* sp., *Alveolina oblonga* d'Orbigny, *Discocyclina roberti* Douville, *Nummulites atacicus* Leymerie, *Nummulites aturicus* Joley and Leymerie, *Nummulites* cf. *striatus* Brugeure, *Assilina* sp. and *Orbitolites complanatus* Lamarck and in related to its environment, these authors mentioned that it was deposited in the shoal setting, indicating a Paleocene-Early Eocene age. Kharajiany (2018) [6] studied the Eocene sequence composed of (marlstone/ shale, siltstone, and sandstone with limestone interlayers and slightly metamorphosed shale/slate) in the Naopurdan Group near Betwat village and assigned the Lutetian Stage to it. The mentioned studied section by Kharajiany (2018) [6] differs entirely by composition and fossil constituents from the section in this study. According to Bolton (1958d) [4], the Naopurdan-Type Subgroup is divided into six units in ascending order with suggested thickness of 2500-300 m and these units differ one from another clearly by lithology and composition, while their age is assigned in Paleocene-Oligocene. The nummulitic limestone of this study belongs to the second unit from the bottom at the interval of 500-650 m, this means that there are 2300 meters of Naopurdan Group deposits above the studied section and this is a clear indication of the difference in age from one unit to another.

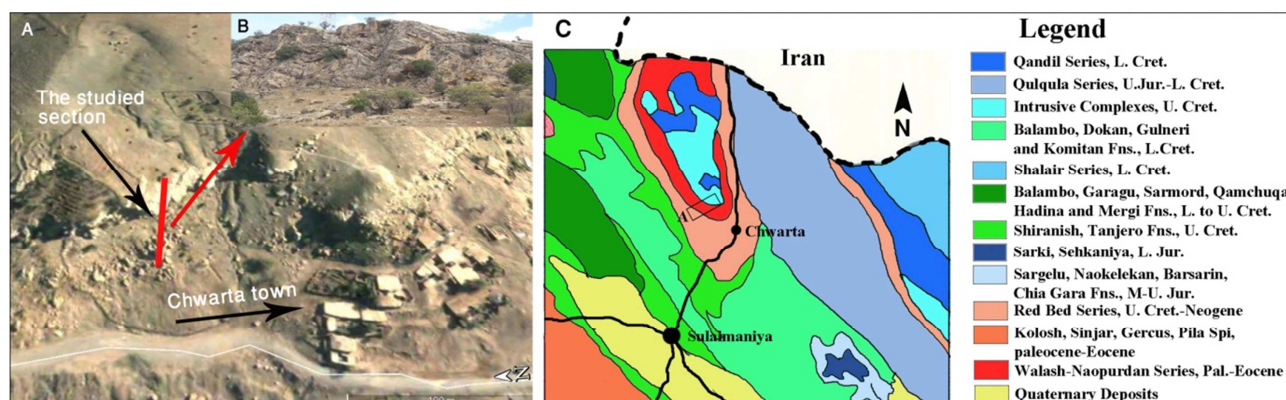


Figure-1: A- Google Image of the location of studied section near Chwarta town, B- Field photo of the studied section, C- Geological map of Iraq, scale 1:1000000, Sheet No. 1 (Modified from Sissakian, 2000) [7].

Material and methods

The studied succession is formed of milky to light grey limestone and its lower part is covered by soil. It is located in the northern part of Chwarta town, 25km to the northeast of Sulaimaniya city (Figure 1). The outcrop of the Naopurdan Group was sampled at 0.5-2.0 m intervals according to the lithology changes of each level. A total of thirty-three samples of milky and light grey fossiliferous limestone are taken (Figure 2). Thirty-four thin sections (3×4 cm up to 4×5 cm) and several polished samples were prepared (Figure 3). The thin sections were analyzed under a binocular stereo-microscope for determination of carbonate microfacies and microfossil assemblages. A total of thirty species of foraminifera and two species of red and green algae are identified. Besides, four main carbonate microfacies types and seven subtypes of these facies are differentiated according to the classification of Dunham (1962) [8] and Embry and Klovan (1972) [9]. The photomicrographs of fossils and microfacies were taken using a Sony camera, while the processing of these photomicrographs was done with Adobe Photoshop CS4.



Figure-2: Sampled succession.

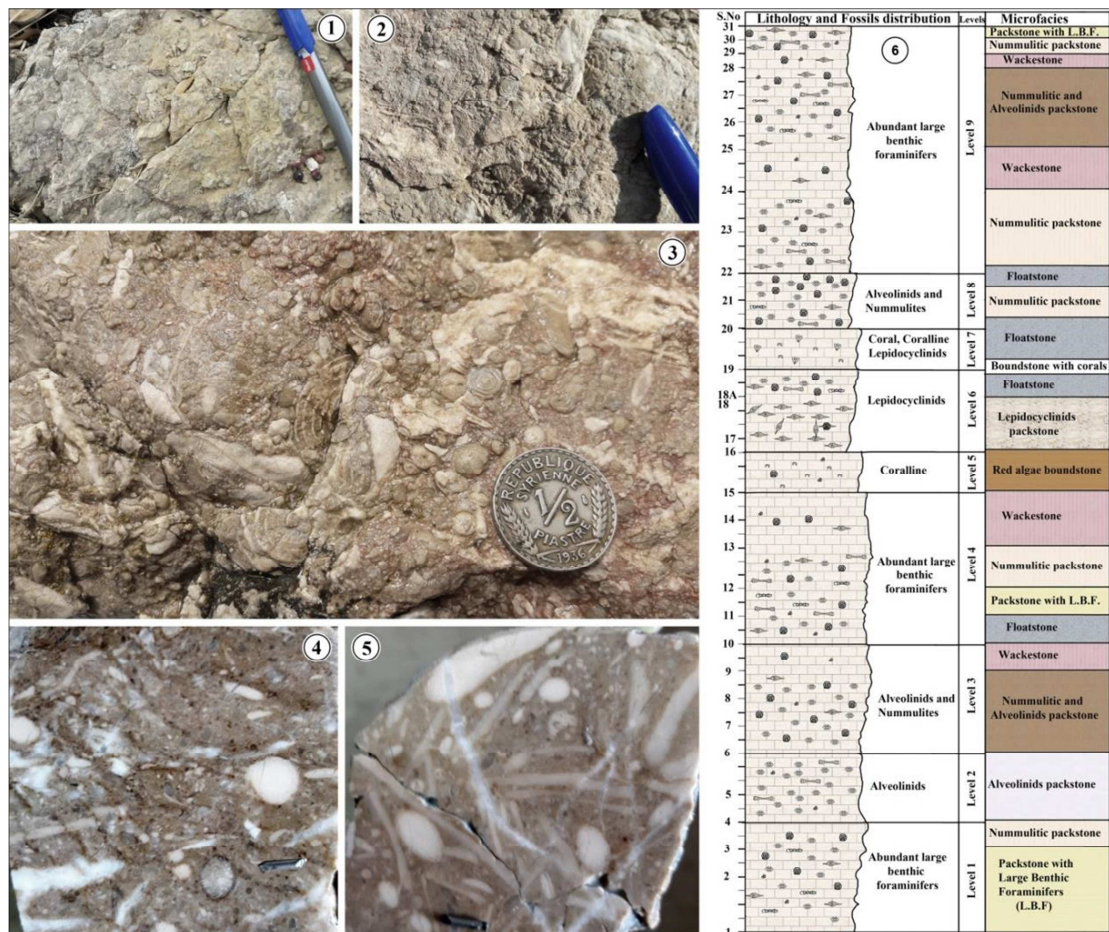


Figure-3: Field photos and polished samples, 1-2-3- in the field showing abundant foraminifera (Alveolids, nummulites, lepidocyclinids and orbitolites). 4-5- are polished samples with scale of 5mm. 6- Biostratigraphical column showing microfacies, and distribution of microfossils in the studied section.

Results and discussion

1. Microfacies

The main microfacies types identified in the studied section are characterized by the presence of various microfauna and micrite as matrix. These microfacies are represented by: packstone, floatstone, boundstone and wackestone. Each of these microfacies type includes some other subtypes according to the main frequency components as showing below:

1. Packstone: this type of microfacies consists mostly of large benthic foraminifers, whether combined or containing predominantly one type of foraminifers. Further, it contains fragments of other fossils such as red algae or small form of foraminifers. The packstone involves five subtypes as showing in (Figures 4, 5):

a. Packstone with large benthic foraminifers consists of different species of large foraminifers especially, alveolinids, nummulites, discocyclinids and orbitolinids that are the most common fossils characterizing this microfacies. This subtype of microfacies occupies the lower and upper part of the succession.

b. Nummulitic packstone contains mostly nummulites of different sizes and appears in four levels of the section, lower, middle and upper part.

c. Alveolinids packstone occupies the Alveolinids Level in the lower part of the section and it is characterized by the dominance of very preserved species of alveolinids.

d. Packstone of alveolinids and nummulites mainly consisting of these two types of large foraminifers and appears in the lower and upper part of the section.

e. Lepidocyclinids packstone is consisting approximately of lepidocyclinids in the middle part of the section, forming the Lepidocyclinids Level with very well preserved forms.

2. Floatstone (more than 10 percent larger grains >2 mm and contains micrite matrix according to the definition of Dunham (1962) [8] and Embry and Klovan (1972) [9]). This microfacies type contains large orbitolites, nummulites, lepidocyclinids, and alveolinids. This microfacies is extended at the height between 10-25 m in the lithological column alternating with another type of microfacies (Figures. 4, 5).

3. Boundstone consists of components were bound together during deposition and it's about corals and red algae. This facies is subdivided in red algae boundstone and corals boundstone (Figure 5), but they are spread only in two narrow levels in the middle of the succession. The red algae are represented by well-preserved coralline (*Lithothamnion* sp.). Besides, other fossils of foraminifers that are generally scattered in the micritic matrix, in the interspaces between red algae and corals or between both.

4. Wackestones represented by few forms of foraminifera, sometimes well preserved, fragments of bryozoans and other non-identifiable fragments. This facies occurs in tree levels as shown in Figure 5.

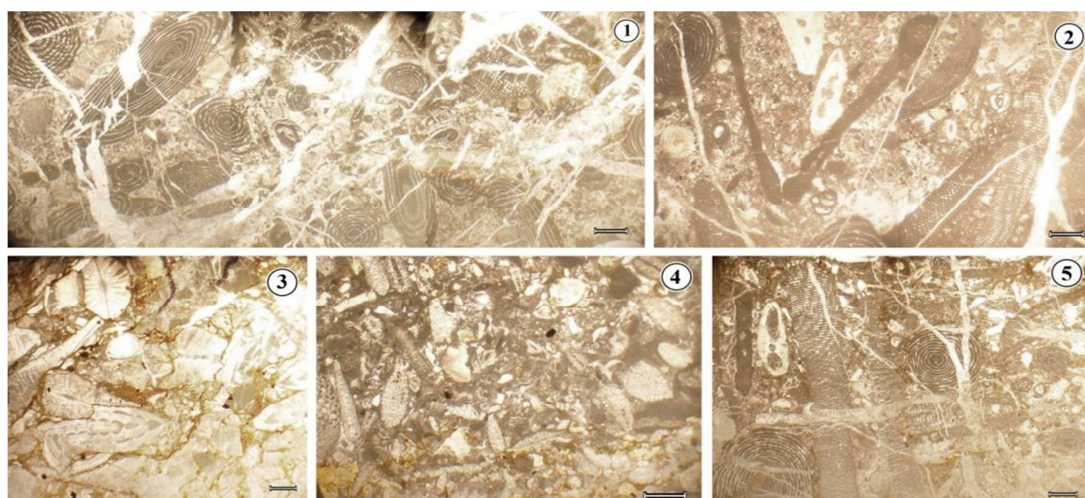


Figure-4: 1- Alveolinids packstone (S. 5), 2- Floatstone consists of orbitolites, nummulites, and alveolinids (S. 11), 3- Nummulitic packstone (S. 30), 4- Packstone of lepidocyclinids and nummulites (S. 18), 5- Floatstone of lepidocyclinids, orbitolites and alveolinids (S. 20). The scale is 1 mm.

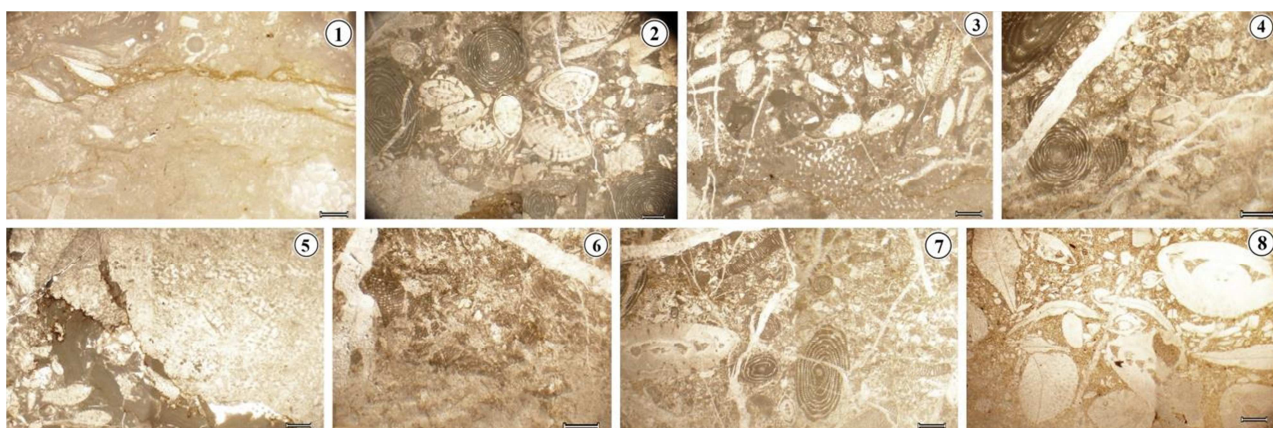


Figure-5: 1- Red algae boundstone (S. 16), 2- Floatstone of nummulites and alveolinids (S. 22), 3- Lepidocyclinids packstone (S. 17), 4- Packstone of alveolinids and nummulites (S. 6), 5- Corals and red algae boundstone (S. 19), 6- Wackestone (S. 10), 7- Packstone of alveolinids and nummulites (S. 28), 8- Packstone of lepidocyclinids and nummulites (S. 31). The scale is 1 mm.

2. Microfossils

The main identified microfaunal assemblages in the studied section are represented by foraminifera, mostly large benthic foraminifers (nummulites, alveolinids, assilnids, discocyclinids, and orbitolites). Besides, the calcareous algae, benthic sessile organisms such as corals and bryozoans were also identified. According to the appearance of the fossils in the studied succession, nine levels could be identified starting from the lower part to the upper one of the succession (Figure 3). Each level is characterized by the abundance of some types of microfauna. Some levels are repeated on the lithological column, this is due to the change of the sediment deposition conditions and biota environment changes. The identified levels are described below as follows:

Level 1 is dominated by large benthic foraminifers consisting mostly of nummulites, alveolinids, assilnids, discocyclinids and other small microfossils such as miliolids. The thickness of this level is 4 m.

Level 2 is characterized by the abundance of large well-preserved alveolinids with minor percentages of other microfauna represented by nummulites and orbitolites. The thickness is 2.5 m.

Level 3 is made up entirely of alveolinids and nummulites with very few forms of others microfossils with a thickness of 4 m, but in the upper part, almost one meter is deficient in fossils forming a wackestone.

Level 4 is dominated also by large benthic foraminifers as in level 1 with a thickness of 5.5 m. The upper part of this level is represented by wackestone with rare microfauna.

Level 5 is distinguished by the red algae composed of coralline and appearance of *Lithothamnion* sp., forming a boundstone microfacies with 1.5 m thick.

Level 6 is very rich in Lepidocyclinids, usually exceptionally large ones with thick of 3 m. The lower part consists of packstone and upper part of floatstone.

Level 7 is represented by 1.5 m of corals, red algae and large lepidocyclinids in the upper part forming a floatstone microfacies with a boundstone in the lower part.

Level 8 is dominated by alveolinids and nummulites as in level 3 with thick of 2 m.

Level 9 is the upper part of succession and characterized by the abundance of large forams (nummulites, lepidocyclinids, discocyclinids, orbitolites, assilnids, miliolids). In this level, there are two beds of 1.5 m and 0.5 m that are poor in microfauna and are represented by wackestone microfacies.

The following thirty-two species of large benthic foraminifers and algae were identified in the studied section of which six, seven and nineteen species belong to the Nummulites, alveolinids and other different genera respectively.

Nummulites kdjokdjokartae Martin, 1881 (Figure 6); *Nummulites globulus* Keymerie, 1846 (Figures 6, 7); *Nummulites atacicus* Leymerie, 1846 (Figures 6, 7); *Nummulites mammilatus* Fichtel and Moll, 1798 (Figure 7); *Nummulites subirregularis* De la Harpe (Figure 7); *Nummulites* sp. (Figure 7); *Alveolina* sp. (Figure 6); *Alveolina violae* CHECCHIA-RISPOLI, 1905 (Figure 6); *Alveolina elliptica* SWERBY, 1840 (Figure 6);

Alveolina stercusmuris Mayer-Eymar, 1886 (Figure 6); *Alveolina frumentiformis* Schwager, 1883 (Figure 7); *Alveolina fornasinii* Checchia-Rispoli (Figure 7); *Alveolina cf. sakaryaensis* Sirel (Figures 7, 8); *Assilina laminosa* Gill, 1953 (Figure 7); *Assilina granulosa* d'Archiac 1847 (Figure 8); *Discocyclina ranikotensis* Davies, 1927 (Figure 6); *Discocyclina dispansa* Sowerby (Figure 8); *Lepidocyclina sumatrensis* Bradi (Figure 8); *Lepidocyclina parva* Oppenoorth (Figure 8); *Cuvillierina sireli* Inan (Figure 6); *Thalmanitta madrugeensis* Cushman and Bermudez (Figure 6); *Nephrolepidina sp.* (Figures 6, 8); *Idalina sinjarica* Grimsdale (Figure 6); *Orbitolites complanatus* Lamark, 1801 (Figure 7); *Orbitolites sp.* (Figure 7); *Cymopolia elongata* Defrance (Figure 7); *Quinqueloculina* (Figure 7); Bryozoan (Figure 7); *Biloculina* (Figure 8); *Pseudohatigerina sp.* (Figure 8); *Eulepidina dilatata* Mchelotti 1861 (Figure. 8); *Asterocyclina ferrandezii* n. sp. (Figure 8); *Lithothamnion sp.* (Figure 8).

Hottinger (1997) [10] illustrates that the Upper Paleocene and Lower Eocene are characterized by an increase in generic variety and an abrupt diversification of various species respectively. The development and accumulation of nummulites in the late Paleocene to the lower Oligocene are well recorded in the carbonate deposits along the palaeomargins of the Tethys Ocean [11]. The paleoenvironmental conditions in this time intervals such as increasing in oligotrophy and sea-surface temperature led to the new suitable conditions for developing larger foraminifera [12].

Usually, as proven by studies, nummulites occur in high-energy of marine environments such as shoals, fore-reef and storm deposits [13]. The *Assilina granulosa* d'Archiac, *Assilina laminosa* Gill, *Nummulites ataticus* Leymerie and *Nummulites mamillatus* Fichtel and Moll found in the studied succession are typical of Late Paleocene and Early Eocene [14]. The species of *Nummulites ataticus* are Index species of Early Eocene and the large flat ones usually occur near shore [15]. Some previous studies specified that *Discocyclina ranikotensis* Davies ranges from the Late Paleocene to Early Eocene [16] and [17].

According to Serra-Kiel *et al.* (1998) [18], the species *Cuvillierina sireli* Inan indicates Early Paleocene age (Selandian), such species were found in Sierra Espuna area in Spain and Eastern Pontides in Turkey [19]. The species *Idalina sinjarica* ranges between Early Thanetian to Early Ilerdian [18]. The species *Orbitolites complanatus* is reported to the Lutetian in Jahrum Formation in Shiraz (Iran) and in Yozgat Region in Turkey [20] and [21] respectively. Whereas Özgen-Erdem (2008) [22] reported it in Ilerdian from Tosya Region (Turkey). The species of *Nummulites globulus*, *Nummulites kdjokdjokartae*, *Nummulites subirregularis* are index species suggested the Lower Eocene according to Mirza *et al.* (2014) [23]. The species *Alveolina violae*, *Alveolina frumentiformis*, *Alveolina stercusmuris*, *Alveolina elliptica* are reported to the Lower Eocene [24]. The species *Alveolina fornasinii*, *Assilina laminosa* are assigned in the Lower Ilerdian [25] while *Alveolina cf. sakaryaensis* confined to the Middle Ilerdian [26] and *Asterocyclina ferrandezii* n. sp. in Ypresian [27]. The species *Cuvillierina sireli*, *Idalina sinjarica* and *Orbitolites complanatus* were identified by Daoud (2012) [28] in Upper Paleocene-Early Eocene from Sinjar Formation in SW Sulaimaniya city (Iraq).

In this study, according to the distributions of large benthic foraminifera and based on the comparison with the previous studies, we assigned age of Late Paleocene (Selandian) to Early-Eocene (Ypresian-Lower Lutetian) to the studied succession of Naopurdan Group.

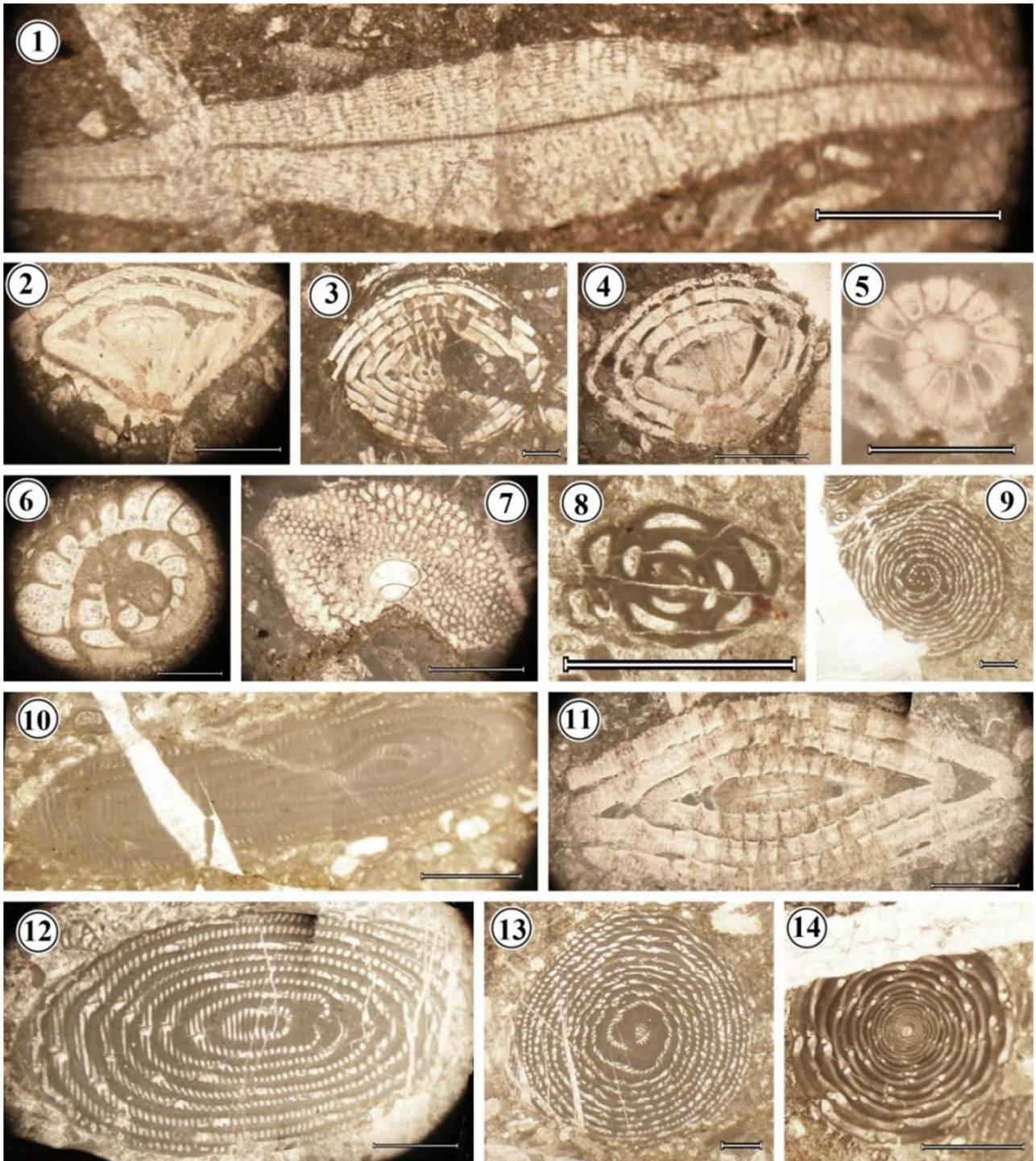


Figure-6: 1- *Discocyclus ranikotensis* Davies, 1927, axial section (Sample 31), 2- *Nummulites kdjokdjokartae* Martin, 1881(S. 1), 3- *Nummulites globulus* Keymerie, 1846 (S. 4), 4- *Nummulites globulus* Keymerie, 1846, axial section (S. 18A), 5- *Cuvillierina sireli* INAN, equatorial section (S. 12), 6- *Thalmanitta madrugensis* Cushman and Bermudez, equatorial section (S. 3), 7- *Nephrolepidina* sp., oblique section, megalospheric embryos, most of them are in oblique section (S. 17), 8- *Idalina sinjarica* Grimsdale, axial sections (S. 5), 9- *Alveolina* sp., subaxial section (S. 11), 10- *Alveolina violae* Checchia-Rispoli, 1905 (S. 4), 11- *Nummulites atacicus* Leymerie, 1846, axial section (S. 9), 12- *Alveolina elliptica* Swerby, 1840 (S. 6), 13- *Alveolina elliptica* Swerby, 1840, Horizontal view (S. 3), 14- *Alveolina stercusmuris* Mayer-Eymar, 1886 (S. 7). The scale is 1 mm.

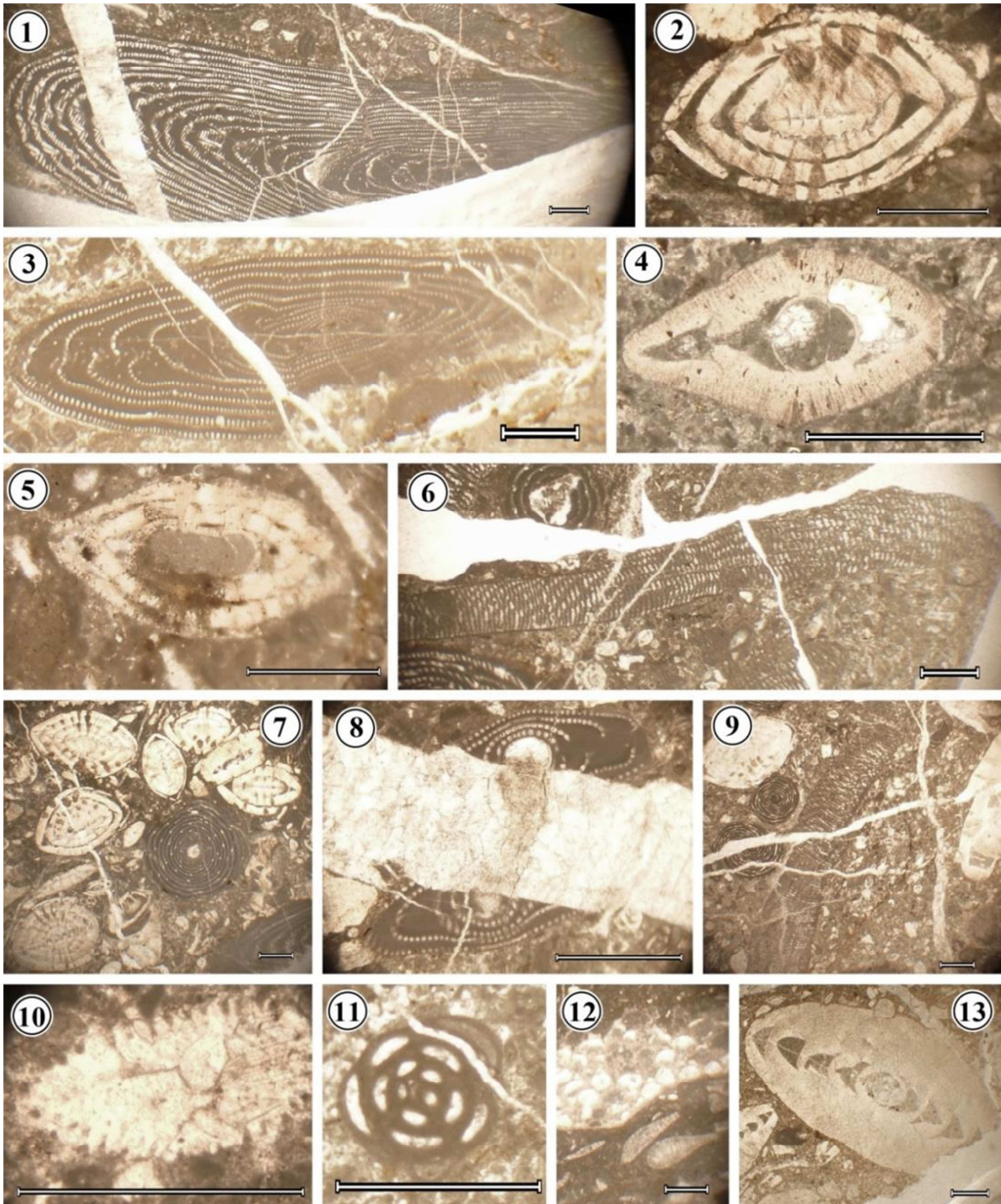


Figure-7: 1- *Alveolina frumentiformis* Schwager, 1883 (S. 11), 2- *Nummulites mammilatus* FICHTEL and Moll, 1798 (S. 4), 3- *Alveolina frumentiformis* SCHWAGER, 1883 (S. 2), 4- *Nummulites subirregularis* De la Harpe (S. 15), 5- *Nummulites* sp. (S. 8), 6- *Orbitolites complanatus* Lamark, 1801 (S. 11), 7- *Nummulites globulus* Keymerie, 1846 in upper part and *Alveolina stercusmuris* Mayer-Eymar, 1886, in center. (S. 22), 8- *Alveolina fornasinii* Checchia-Rispoli (Early Cuisian), in upper part and *Alveolina* cf. *sakaryaensis* SIREL (Ilerdian), in lower part (S. 11), 9- *Orbitolites* sp. (S. 18A), 10- *Cymopolia elongata* Defrance, showing coarse spary calcite cavity filling (S. 8), 11- *Quinqueloculina* (S. 11), 12- Bryozoan (S. 16), 13- *Assilina laminosa* Gill, 1953 (S. 31). The scale is 1 mm.

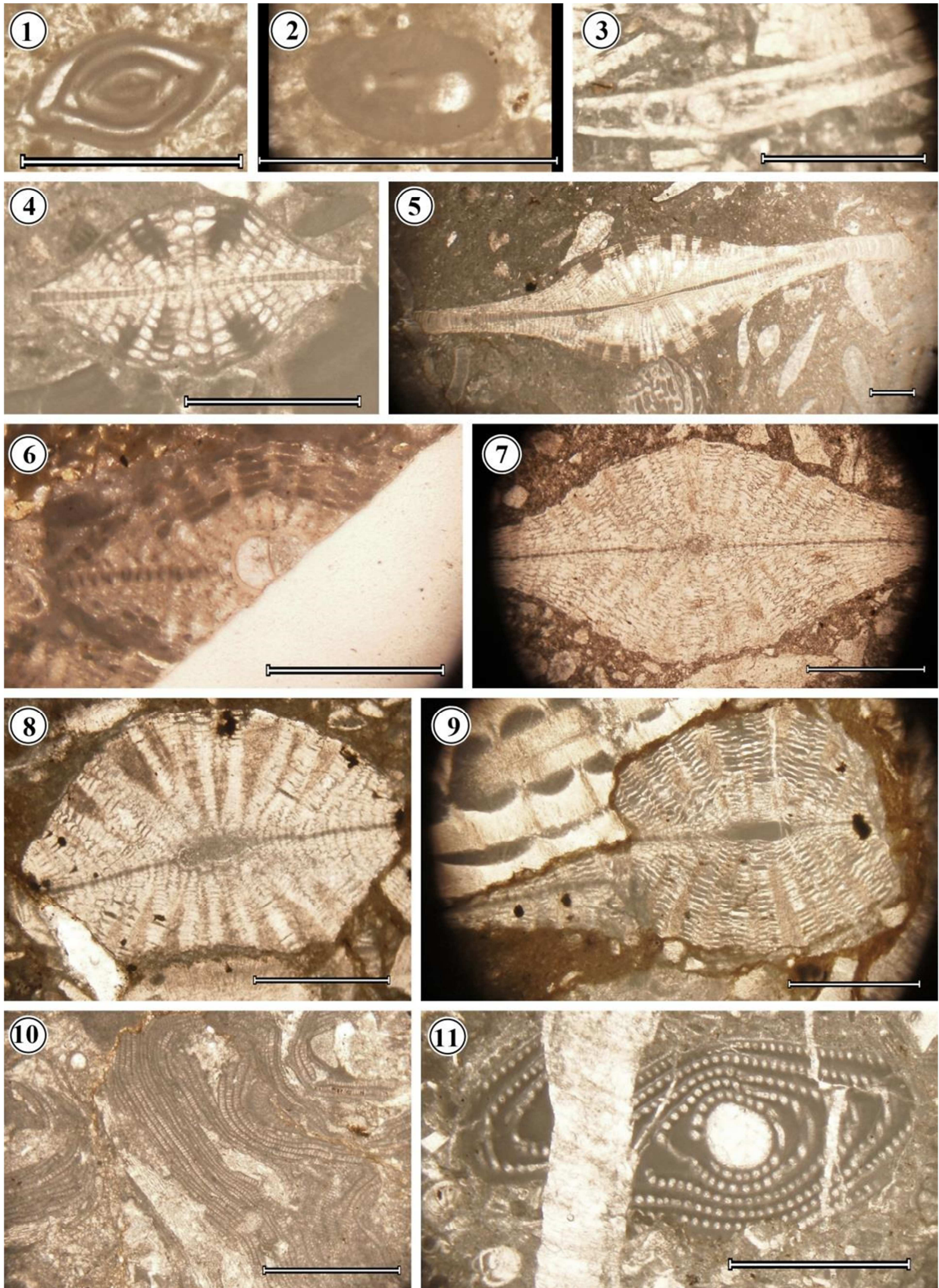


Figure-8: 1- *Biloculina* (S. 11), 2- *Pseudohatigerina* sp. (S. 11), 3- *Assilina granulosa* d'ARCHIAC 1847 (S. 12), 4- *Lepidocyclus sumatrensis* Bradi, vertical section (S. 12), 5- *Nephrolepidina* sp. (S. 16), 6- *Eulepidina dilatata* Mchelotti 1861 (S. 18), 7- *Discocyclus dispansa* Sowerby, 1840, axial section (S. 31), 8- *Asterocyclus ferrandesi* n. sp., vertical section (S. 30), 9- *Lepidocyclus parva* Oppenoorth, vertical section (S. 30) 10- *Lithothamnion* sp. (S. 16), 11- *Alveolina* cf. *sakaryaensis* Sirel (Ilerdian) (S. 18A). The scale is 1 mm.

3. Palaeoenvironmental description

The reconstruction of palaeoenvironmental conditions for carbonate rocks can be done with the help of larger benthic foraminifera. Each abundance of fossil assemblage is related to their own environment on the carbonate platform or slope in marine settings. Also, the study of the microfauna, especially the foraminifera with other bioassociations in thin sections under the microscope, helps to recognize the palaeoenvironment.

The fossil assemblages in this study are represented by the abundance of large foraminifera (Alveolinids, Nummulites, Discocyclinids, Lepidocyclinids, Assilinids, and Orbitolites) with some levels of red algae and corals. These large foraminifera are divided into two groups, one group that includes imperforate foraminifera (Alveolina and Miliolids), and the other one comprises perforate foraminifera (i.e. Assilina and Nummulites). Generally, the first group lives in an environment near the shore while the second one indicates a deeper environment. If the two groups live together at the same time in that environment then it is assumed that there was no barrier. If the two groups are not present together in the rock, then there is assumed to be a barrier [15]. In our case, there is no a barrier reef between both inner and middle ramps because both groups are mixed in the rock, and the lack of a barrier led to the good circulation of water leading to an abundance of oxygen, as well as, the salinity is similar in the basin. Moreover, the identification of carbonate microfacies is helpful for establishing the conditions of the palaeoenvironment. Based on the microfacies analysis and microfossil assemblages, Surdashy (1997, 2001) [29], [30] studies the depositional environments of Naopurdan limestone from Chwarta-Mawat area and determined three major environments, deep shelf margin, open slope, and shallow water carbonates.

The main microfacies found in this study are packstone, wackestone, floatstone, and boundstone, all these microfacies have an appreciable amount of micrite as a matrix and that is a sign of low energy conditions in which the only micrite could settle down. The nummulitic packstone is mainly composed of nummulites and micrite as a matrix. The nummulites usually occur in subtidal-middle ramp environment that is suitable for micrite sedimentation. The packstone with a mixture of large benthic foraminifers points out open marine of normal salinity with low energy under wave base which gives the possibility of micrite deposition. This type of microfacies is interpreted to have deposited in the Middle ramp area [31].

The period of 13.8 Ma. between the late Paleocene (Selandian \approx 61.6 Ma) and Early Eocene (Ypresian \approx 47.8 Ma) is marked by long-term global warming [32]. This change in the global environment had an important effect on the biota in terms of diversity, shapes, and sizes. Towards the middle ramp, where the conditions of environment become suitable, the tests of perforate benthic foraminifera such as Nummulites, Discocyclina, and Assilina found in the studied section become large and flat due to the poor illumination indicating the oligotrophic zone [10] and [33].

Based on the distribution of microfacies and foraminifera, the depositional environment is considered as a carbonate ramp, including subtidal, shoal, middle and outer ramp environments as showing in (Figure 9) with a warm climate and high concentration of carbonate.

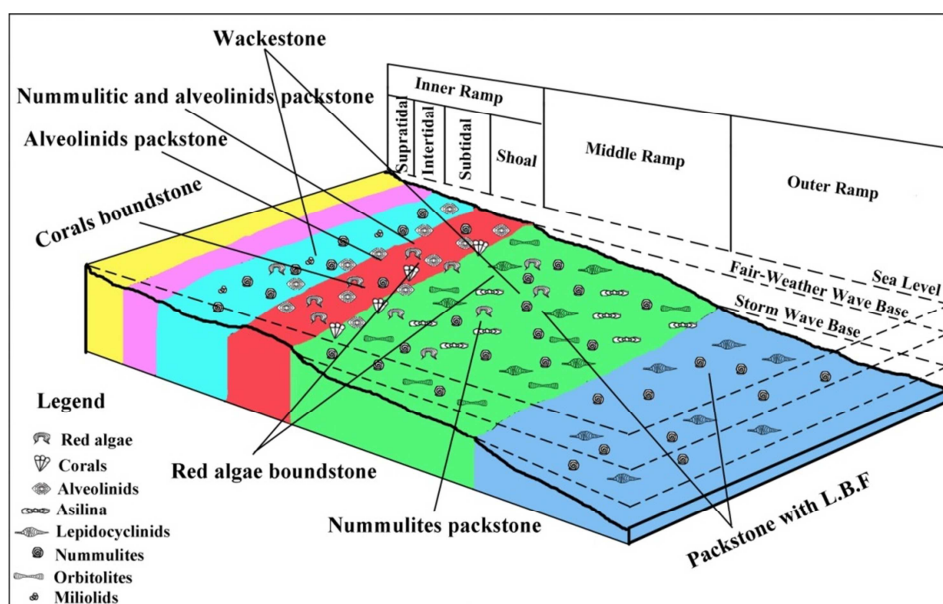


Figure-9: Proposed carbonate ramp model of the Naopurdan Group in the studied section in Chwarta town.

Conclusion

We can summarize the conclusions of this study in the following points:

1. Four main types of depositional facies and seven subtypes have been identified represented by wackestone, packstone, boundstone, and floatstone. The main facies' constituents are large benthic foraminifers.
2. In total, Thirty-two species were identified in the nummulitic limestone of Naopurdan Group of which twenty-six new species are identified for the first time in this limestone.
3. The microfossil assemblages, especially Nummulites, Alveolinids, Discocyclinids, red algae, Assilina and microfossils identified in the studied section indicate an environment on the carbonate ramp from subtidal to the outer ramp without any barrier reef.
4. According to the microfauna, the age of the studied Nummulitic limestone of Naopurdan Group can be assigned to the Late Paleocene (Selandian≈61.8 Ma)-Early Eocene (Ypresian-Lower Lutetian≈50 Ma).

Acknowledgements

We wish to express gratitude to Professor Dr. Kamal Haji Karim, for reviewing the manuscript and suggesting various valuable suggestions, as well as anonymous reviewers whose remarks helped to improve the manuscript.

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