*EIGHTH INTERNATIONAL CONFERENCE*
*ON THE GEOLOGY OF AFRICA*
*P-P VII-27 - VII-54 (NOV. 2015) ASSIUT-EGYPT*

# BIOSTRATIGRAPHIC ZONATION AND EOCENE CHLOROPHYTAL ALGAE, ASSIUT-MINIA STRETCH, NILE VALLEY, EGYPT

**Sobhi A. Helal* and Ahmed W. Hussein**
*Geology Department, Faculty of Science, Fayoum University, Fayoum, Egypt*
**Corresponding author: Sah04@fayoum.edu.eg*

## ABSTRACT

**The Early and Middle Eocene rocks at Assiut-Minia stretch are shallow marine limestones. These rocks consist of three rock units namely, Drunka, Minia and Samalut formations. Four algal and larger foraminiferal zones are recorded from these rocks namely in stratigraphic order *Ovulites pyriformis*/*Ovulites arabica*, *Nummulites planulatus*, *Alveolina oblonga*/*Orbitolites complanatus* and *Nummulites gizehensis* zones. Also, these rocks are characterized by high-diversified green algal floras (both Bryopsidales and Dasycladales). Nine Dasycladales taxa are identified (six of species-level and three of genus-level). They are *Belzungia silvestrii* (Pfender) Massieux, *Cymopolia elongata* (Defrance), *Furcoporella diplopora* Pia, *Niloporella subglobosa* Dragastan & Soliman, *Clypeina* cf. *rotella* Yu-Jing, *Acicularia robusta* Dragastan & Soliman, *Dissocladella* sp., *Cymopolia* sp. and *Neomeris* sp. A total of nine Bryopsidales (seven of species-level and two of genus-level) are recorded. They are represented by *Ovulites pyriformis* Schwager, *Ovulites arabica* (Pfender), *Ovulites morelleti* Elliott, *Ovulites marginulata* (Lamarck), *Ovulites elongata* Lamarck, *Halimeda nana* Pia, *Halimeda praemonilis* Morellet, *Halimeda* sp. and *Ovulites* sp. The paleoecological importance of the described algae is also discussed and deduced.**

**Keywords: Biostratigraphy, green algae, Eocene, Nile Valley, Egypt.**

## 1. INTRODUCTION

The area under study skirts the Nile Valley from the west in the vicinity of Assiut between Abu-Tig and Mallawi between latitudes 26º 27´ & 27º 42´ N. and longitudes 30º 41´ & 31º 15´ E. **(FIG.1).** The studied sequence belongs to the Early and Middle Eocene age. The recorded fossils are mainly belonging to the large foraminifera (e.g. Alveolinids, *Orbitolites* and *Nummulites*) and the benthonic fossil calcareous algae (chlorophytes and rhodophytes).

The biostratigraphy of the surrounding areas was studied by several authors among them; Bishay (1966), Kenawy and El-Baradei (1977), Philobbos and Keheila (1979), Boukhary *et al.* (1982), Youssef *et al.* (1982), Boukhary and Abdel Malik (1983), Keheila (1983), Keheila *et al.* (1990) and Helal (1999).

The main goals of this work is to make a biostratigraphic classification of this Early-Middle Eocene succession and to provide a detailed paleontologic study of the well-preserved fossil green algae. As the calcareous algae are most conveniently studied in thin sections, three hundreds and fifty thin sections were paleontologically analyzed for their microfloral content.

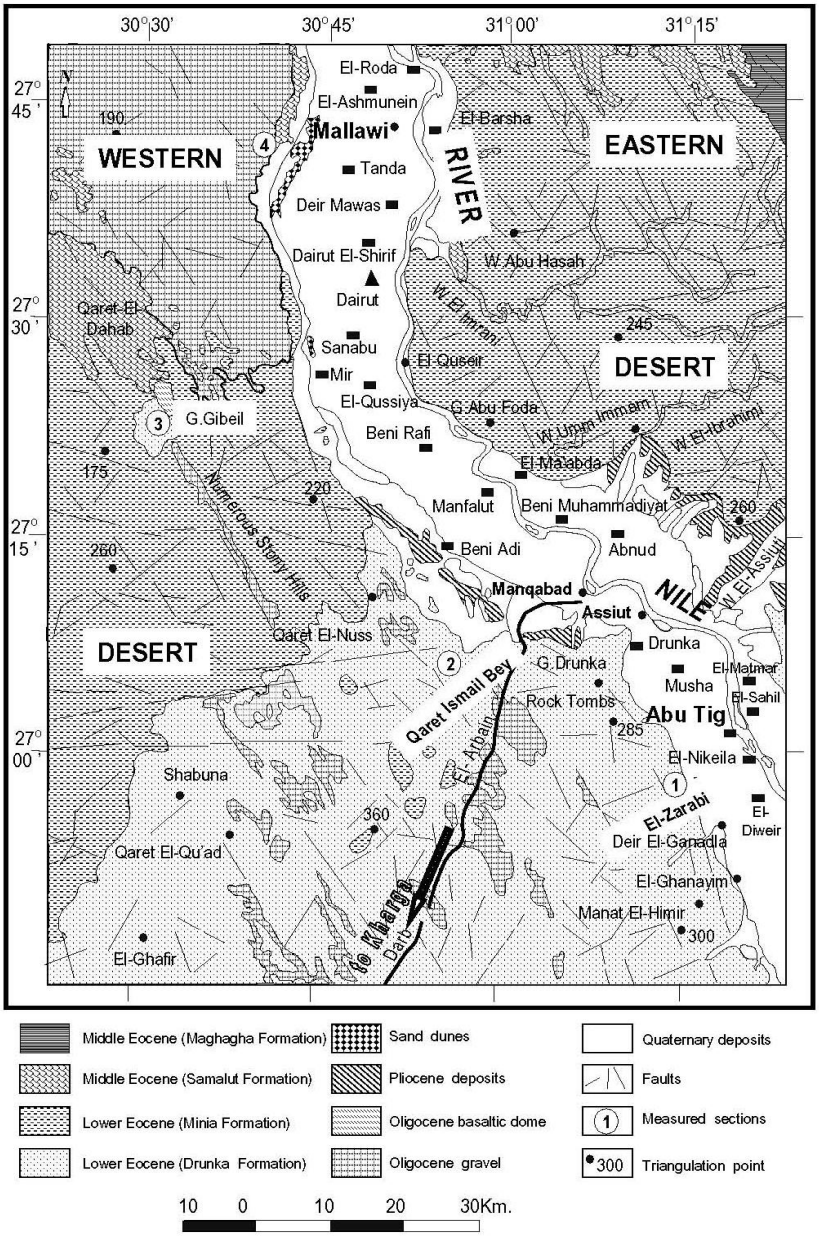



**Fig. 1: Geological map of the study area (modified after EGPS and Conoco, 1987)**

## 2. MATERIALS AND METHODS

About 300 rock samples were collected from four stratigraphic sections within the study area **(FIG.1)** from south to north; (1) El-Zarabi (south of Abu-Tig), (2) Ismail Bey (southwest of Assiut), (3) Gebel Gibeil (southwest of El-Qussiya) and (4) Mallawi (southwest of Mallawi). The carbonate succession of the present area is subdivided into Drunka (Early to Late Ypresian), Minia (Late Ypresian) and Samalut (Lutetian) formations **(TABLE 1)**. The main lithologic characteristics of the recognized rock units and the proposed depositional environments are summarized in **TABLE 2.** As the calcareous algae are most conveniently studied in thin sections, three hundreds and fifty thin sections were paleontologically analyzed for their microfloral content.

## 3. BIOSTRATIGRAPHIC ZONATION

On the basis of the distribution pattern of the recorded floral and faunal content, four zones are proposed **(TABLE.3)**. These floral and faunal zones are correlated as shown in **FIG.2.** The distribution charts of the recognized taxa building up these zones are presented in **FIGS.4-7.**

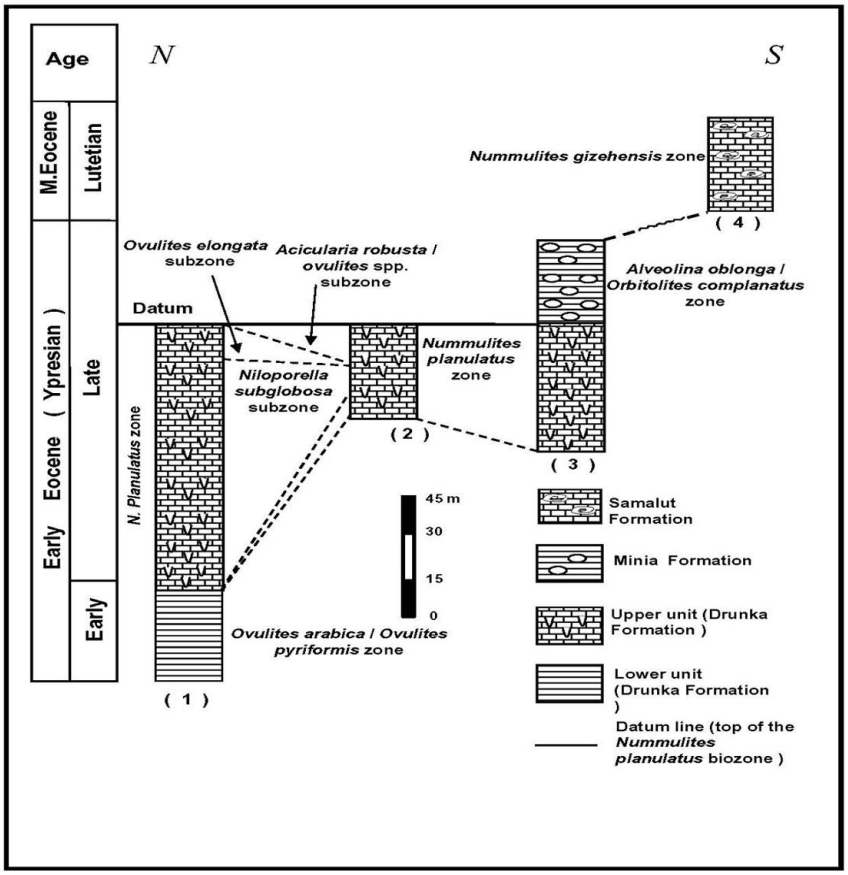



**Fig. 2: Biostratigraphic correlation of the fauni and flori zones.**

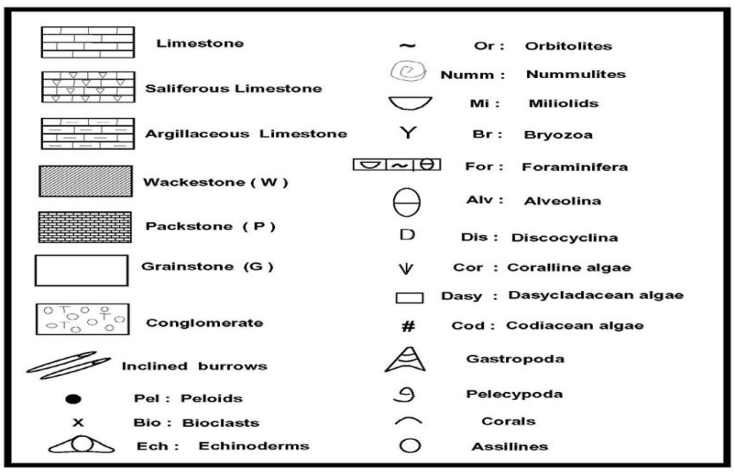



**Fig. 3 Legend for the carbonate constituents of the studied sections.**

**3.1 *Ovulites arabica*/*O. pyriformis* algal Zone (acme zone):**

It is the oldest zone recognized in the Eocene succession of the study area. This zone (34 m) is defined by the high percentages of both *Ovulites arabica* (Pfender) and *O. pyriformis* Schwager. It is conformably underlies the *Nummulites planulatus* Zone. This zone is equivalent to the lower algal zone (Early Ypresian) described from the Drunka Formation in the Nile Valley by Dragastan & Soliman (2002).

The fossil content of this zone is essentially composed of *Ovulites arabica* (Pfender) and *O. pyriformis* Schwager. Other fossil associated within this zone are *O. morelleti* Elliott, *Acicularia robusta* Dragastan & Soliman, *Halimeda praemonilis* Morellet, *Niloporella subglobosa* Dragastan & Soliman, *Lithoporella melobesioides* Fosile, *Ovulites* sp., *Halimeda* sp. and *Cymopolia* sp. The associated foraminiferal assemblage is represented by *Orbitolites complanatus* Lamarck, *Quinqueloculina* sp., *Nummulites* sp. Besides the previous fossils, the coprolite *Favreina* sp. is also recognized. On the basis of the fossil association and its stratigraphic attitude, the age of this zone is suggested herein as late Early Ypresian.

**3.2 *Nummulites planulatus* foraminiferal Zone (total range zone):**

The *Nummulites planulatus* Zone is defined by the total range of the *N. planulatus* (Lamarck). The lower boundary of this zone coincides with the upper boundary of the lower unit of the Drunka Formation. It is underlain by the *Ovulites arabica*/*O. pyriformis* algal zone at El-Zarabi section and overlain by the *Alveolina oblonga/Orbitolites complanatus* foraminiferal zone of the Minia Formation at Gebel Gebeil. It measures about 99.75 m at El-Zarabi section, 35.5 m at Ismail Bey section and 48.5 m at Gebel Gibeil section. This zone is correlated with the *Nummulites planulatus* Zone of Bishay (1966) described from Wadi El-Assiuti area, *N. planulatus* Zone of Aref (1982) from the area southeast of Assiut and *N. planulatus/N. burdigalensis* Zone of Keheila *et al.* (1990) from the area southeast of Sohag.

The fossil assemblage of this zone comprises the following foraminiferal taxa: *Nummulites planulatus* (Lamarck), *Orbitolites complanatus* Lamarck, *Nummulites* sp. and *Quinqueloculina* sp., while the associated algae includes *Ovulites arabica* (Pfender), *O. pyriformis* Schwager, *O. marginulata* (Lamarck), *O. elongata* Lamarck, *O. morelleti* Elliott, *O.* sp., *Niloporella subglobosa* Dragastan & Soliman, A*cicularia robusta* Dragastan & Soliman, *Halimeda praemonilis* Morellet, *H.* sp., *Cymopolia* sp., *Neomeris* sp. and *Lithoporella melobesioides* Fosile.

*Nummulites planulatus* was defined from the Late Ypresian of Switzertland (Schaub, 1951) and France (Pomerol, 1973). It was described from the Late Ypresian from different localities of Egypt (Kenawy & El-Baradei, 1977; Kenawy *et al.*, 1988; Keheila, 2000; Sheleby *et al.*, 2000 and Dragastan & Soliman, 2002). According to the above discussion beside its stratigraphic position, the *N. planulatus* zone is assigned to the Late Ypresian age. The vertical variation in the distribution of the associated calcareous algae within the *N. planulatus* Zone allows its subdivision into three algal acme subzones; the *Niloporella subglobosa* Subzone (lower), *Ovulites elongata* Subzone(middle) and the *Acicularia robusta/Ovulites* spp. Subzone (upper).

**3.2.1 *Niloporella subglobosa* algal subzone:**

This subzone is defined as the interval enriched with the *Niloporella subglobosa* Dragastan & Soliman. This subzone is recorded from the upper unit of the Drunka Formation exposed at El-Zarabi section (88m), where it conformably overlies the

*Ovulites arabica/O. pyriformis* algal zone and underlies the *O. elongata* algal subzone. It is also recorded from the middle part of Ismail Bey section with a total thickness of 9.5m, where it is conformably overlain by the *Acicularia robusta/Ovulites* spp. algal subzone. This subzone is correlatable with the *Carpathoporella occidentalis* Zone described from the environs of Sohag (Keheila *et al.*, 1990).

**3.2.2 *Ovulites elongata* algal subzone:**

This subzone is recognized as the interval characterized by the high abundance of *Ovulites elongata* Lamarck beside the *Nummulites planulatus* (Lamarck). The *Ovulites elongata* Subzone is represented by the uppermost 11.75 m of the upper unit of the Drunka Formation exposed at El-Zarabi section. The lower boundary of this subzone is delineated at the upper part of the *Niloporella subglobosa* Subzone, while the upper boundary is delineated at the end of El-Zarabi section. This subzone is correlatable with the *Ovulites elongata* Zone of Keheila (1983 & 2000).

**3.2.3 *Acicularia robusta*/*Ovulites* spp. algal subzone:**

This subzone is defined by the high abundance of the *Nummulites planulatus* (Lamarck), beside the dominance of *Acicularia robusta* Dragastan & Soliman and *Ovulites* spp. It is identified from the uppermost 14.5 m of the upper unit of the Drunka Formation exposed at the Ismail Bey section. This subzone overlies conformably the *Niloporella subglobosa* algal subzone at Ismail Bey section.

**3.3 *Alveolina oblonga*/*Orbitolites complanatus* foraminiferal zone (interval zone):**

This zone is confined to the Minia Formation and attains about 31.5 m. It is marked by the first appearance of *Alveolina oblonga* d'Orbigny. It conformably overlies the *Nummulites planulatus* Zone of the upper unit of the Drunka Formation at Gebel Gibeil. The foraminiferal fossil assemblage of this zone is composed mostly of *Alveolina oblonga* d'Orbigny and *Orbitolites complanatus* Lamarck. The algal assemblage is represented by *Belzungia silvestrii* (Pfender) Massieux, *Furcoporella diplopora* Pia, *Cymopolia elongata* (Defrance), *Clypeina* cf. *rotella* Yu-Jing, *Acicularia robusta* Dragastan & Soliman, *Cymopolia* sp., *Neomeris* sp., *Dissocladella* sp., *Halimeda praemonilis* Morellet, *Halimeda nana* Pia, *H.* sp., *Ovulites morelleti* Elliott, *O.* sp., and *Lithoporella melobesioides* Fosile.

This zone can be correlated with the Late Ypresian *Alveolina oblonga*, *Orbitolites complanatus* and *Belzungia borneti* zones proposed by Keheila (1983) from the area northeast of Assiut. Hottinger (1974) recorded the *Alveolina oblonga* d'Orbigny from the Late Ypresian of the main Tethyan sea (Southern Spain, Italy, Turkey and Egypt). Kuss & Herbig (1993) assigned the *Alveolina oblonga* Zone recorded from the area northeast of Egypt to the Late Ypresian (Cuisian) age. The *Orbitolites complanatus* Zone recorded from the Minia Formation outcropped northeast of Assiut was dated to the Late Ypresian (Keheila, 1983). According to the fossil content, this zone is assigned to the Late Ypresian age.

**3.4 *Nummulites gizehensis s.l* foraminiferal zone (total range zone):**

This zone is defined to cover the stratigraphic interval of the nominate taxon. The stratigraphic range of the *Nummulites gizehensis s.l* confines to the Samalut Formation. It is the youngest zone recorded from the study area. It is confined to the Samalut Formation. The associated foraminifera are mainly *Assilina* sp., *Discocyclina* sp. and *Quinqueloculina* sp. The fossil algae are represented by

*Lithoporella melobesioides* Fosile, *Lithothamnium* sp. and *Halimeda* sp. The present *Nummulites gizehensis s.l* Zone can be correlated with that recognized from the Samalut Formation of the Nile Valley (Assiut-Minia) by Khalifa *et al.* (1986). The *N. gizehensis* Zone was dated back to the Lutetian age (Mansour & Philobbos, 1983 and Kenawy *et al.*, 1993). In the present study, the zone is assigned to the Middle Eocene (Lutetian) in accordance with the previous studies.

## 4. TAXONOMY AND DESCRIPTION OF THE GREEN ALGAE

Eighteen chlorophytal algal taxa are identified and systematically studied as summarized in **TABLE (4)**. The systematics of the chlorophytal green algae is based on the classification of Pia (1920) that was subsequently modified by Deloffre & Génot (1982), Bassoullet *et al.* (1983), Deloffre & Granier (1991 & 1993), Dragastan & Soliman (2002) and Granier *et al.* (2012). The Generic and specific distinction of the studied taxa are based on criteria including the shape and type of the thalus, the shape of the central stem and the shape and size of the first and second order branches.

Divsion CHLOROPHYTA
Class CHLOROPHYCEAE
Order DASYCLADALES
Family THYRSOPORELLACEAE Granier & Bucur in Granier *et al.*, 2012
Tribe THRYSOPORELLIDAE Pfender &Massieux, 1966
Genus *BELZUNGIA* Morellet, 1908
*Belzungia silvestrii* (Pfender, 1940)

**(FIG.8 A-E)**

1960 *Thrysoporella silvestrii* Pfender- Elliott, p.227-230.
1966 *Thrysoporella silvestrii* Pfender- Pfender & Massieux, p.113, pl.1, figs.1,2.
1978 *Belzungia silvestrii* (Pfender)- Elliot, p.690.
1983 *Belzunngia borneti* Morellet- Keheila, pl.3, figs.5&6 and pl..4, figs.5&6.
1985 *Trinocladus* sp.- Khalifa, p.585, pl.1, fig.8.
1987 *Belzungia silvestrii* (Pfender) Massieux- Bandel & Kuss, p.24, pl.5, fig.8.
1987 *Thyrsoporella silvestrii* (Pfender)- Khalifa, p.87, pl.2, figs.17,18.
1989 *Belzungia silvestrii* (Pfender) Massieux- Kuss & Lepping, p.315, figs.9a,b.
1990 *Belzungia silvestrii* (Pfender) Massieux- Strougo *et al.*, p.68, pl.2, fig.2.
1993 *Belzungia silvestrii* (Pfender) Massieux- Kuss & Herbig, p.272, pl.2, figs.1-3.
1997 *Neomeris Johnsoni* Khalifa- Basta, pl.8, fig.3.
2000 *Belzungia silvestrii* (Pfender) Massieux- Keheila, p.166, pl.3, fig.H.

**Occurrence:** The dasycladacean green alga *Belzungia silvestrii* is recognized only from the *Alveolina oblonga/Orbitolites complanatus* Zone that was delineated from the Minia Formation. It is rare (<2.5%) to predominant (>40%) through Gebel Gibeil. The highest percentage of *Belzungia silvestrii* (55%) is recorded from the middle part of Gebel Gibeil.

**Description and dimensional data:** The genera *Belzungia*, *Thyrsoporella* and *Trinocladus* are structurally similar. The discrimination between them depends upon general characters of the thallial tissue, the details of the branching and the dimentional data (d/D). Massieux (1966) stated that the *Belzungia silvestrii* is characterized by the irregular arrangement of its secondary branches. In the present work, thin sections of diverse orientations showing that the length (L) of the thallus of *Belzungia silvestrii* is reaching up to 2.6 mm. The average external diameter of the thallus (D) is 0.72 mm. It consists of elliptical to spherical unsegmented bodies

with medium, spherical to cylindrical and slightly-calcified central stem. The average diameter of the central stem (d) in the transversal sections is 0.39 mm. The ratio d/D = 54%. The central stem exhibits a rounded edge with a moderately thick wall. It bears a series of parallel to semi-parallel primary branches. The primary branches are thick and their diameter ($p_1$) ranges from 0.046 to 0.06 mm. They are occurring in regular whorls. Each of them ends with a package of irregular secondary branches. The secondary branches, in turn, end in a terminal hair representing clusters of tertiary branches. The diameter of the secondary branches ($p_2$) ranges from 0.021 to 0.033 mm (i.e. the primaries are thicker than the secondaries). The sporangia are mainly globular and surrounded by the secondary branches. The average diameter and height of sporangia are 0.12 and 0.25 mm respectively. Perforation is sharp. Calcification is strong around the sporangia and envelopes the second order branches.

**Distribution and stratigraphic range:** *Belzungia silvestrii* was first defined by Pfender (1940) from the Lower Eocene succession of the Nile Valley. It was also recorded from the Lower Eocene rocks of Egypt by Pfender & Massieux (1966), Bandel & Kuss (1987), Kuss & Lepping (1989), Strougo *et al.* (1990) and Kuss & Herbig (1993) recorded this species from the Lower Eocene sediments of the Eastern Desert of Egypt. Outside Egypt, this species was recorded from the Eocene rocks of Bretagne and Contentin (Morellet, 1917 & 1940), from the Eocene of Somali (Pfender & Massieux, 1966) and from the Paleocene rocks of Kurdistan (Elliott, 1978). Deloffre & Genot (1982) stated that the stratigraphic range of the *Belzungia silvestrii* ranges from the Paleocene to the Lower Eocene.

Family TRIPLOPORELLACEAE Pia, 1920

Genus *DISSOCLADELLA* Pia, 1936

*Dissocladella* sp.

**(FIG.8 F-H)**

**Occurrence:** It is rare at the middle part of the *Alveolina oblonga/Orbitolites complanatus* Zone (Minia Formation) at Gebel Gibeil.

**Description and dimensional data:** The thallus is elongate to cylindrical with L reaches up to 2 mm and average D = 0.48 mm and with elliptical to spherical central stem (average d = 0.27 mm), from which two orders of branches are arisen. The ratio d/D = 56%. Such branches arrange perpendicular to the central stem. The diameter of the primary branches ($p_1$) = 0.025-0.047 mm and that of the secondary branches ($p_2$) = 0.008-0.15 mm. The present *Dissocladella* spp. may be segments of *Dissocladella longijangensis* Mu & Wang.

**Distribution and stratigraphic range:** *Dissocladella* sp. was discerned from Egypt by Kuss & Herbig (1993) from the Cuisian of the Northern Galala, Eastern Desert.

Family DASYCLADACEAE Kützing, 1843

Tribe CYMOPOLIEAE Valet, 1968

Genus *CYMOPOLIA* Lamouroux, 1816

*Cymopolia elongata* (Defrance, 1825)

**(FIG.8 I&J)**

1974 *Cymopolia elongata* (Defrance)- Genot & Poignant, p.70, pl.2, figs.1-6.
1978 *Cymopolia kurdistanensis* Elliott- Elliott, p.154, pl.10, fig.3.
1980 *Cymopolia elongata* (Defrance)- Genot, p.17, pl.1, figs.1-12 & pl.3, figs.6-9.
1987 *Cymopolia pacifica* Johnson- Khalifa, p.90, pl.1, fig.11.
1989 *Cymopolia elongata* (Defrance)- Kuss & Leppig, p.317, figs.9d,e.

1991 *Cymopolia* sp. –Herbig, pl.1, figs.5-7.
1993 *Cymopolia elongata* (Defrance)- Kuss & Herbig, p.272, pl.2, figs.4-8.
2000 *Cymopolia elongata* (Defrance)- El-Gamal & Youssef, p.1425, pl.2, fig.E, pl.3, figs.A-C.

**Occurrence:** *Cymopolia elongata* is restricted to the Minia Formation, whereas it is rarely observed in the middle part of the *Alveolina oblonga/Orbitolites complanatus* Zone at Gebel Gibeil.

**Description and dimensional data:** The cross sections of the *Cymopolia elongata* show that the thallus develops as branching segmented bodies that are elliptical to spheroid in shape with well-rounded peripheries. It exhibits average D = 0.55 mm. The plant consists of an elliptical central stem (average d = 0.31 mm) (d/D = 56%), from which short and thick-walled primary and secondary branches arise. The hollow of the central stem is usually filled with micrite that may be converted into micro- and pseudospar due to the aggrading neomorphism. Each primary branch (average $p_1$ = 0.03 mm) has usually two second order branches (average $p_2$ = 0.017 mm), surrounding the ovoid to spheroidal sporangia (average diameter = 0.28 mm). Sporangia are ovoid, spherical or pyriform, growing at the end of the pronounced secondary branches. Calcification is almost absent around the central stem.

**Distribution and stratigraphic range:** Elliott (1968) reported that the *Cymopolia elongata* was identified from the Upper Paleocene-Lower Eocene of the Middle East Genot (1980) described the *C. elongata* from the Thanetian carbonates of the Parisian Basin. From Egypt, the *C. elongata* was identified from Upper Paleocene to Lower Eocene carbonate sequence of northeast Egypt (Kuss & Leppig, 1989; Kuss & Herbig, 1993 and El-Gamal & Youssef, 2000).

*Cymopolia* sp.

**(FIG.8K)**

**Occurrence:** It is predominant in the basal part of the *Nummulites planulatus* Zone (*Niloporella subglobosa* Subzone) of El-Zarabi section and the middle part of Ismail Bey section and rare in the *Alveolina oblonga*/*Orbitolites complanatus* Zone.

**Description and dimensional data:** The strongly-calcitized thallus (average D = 1 mm) of the transversal sections is cylindrical to elliptical with ovoidal central stem (average d = 0.5 mm). The ratio d/D = 50%. The primary branches are long and thick (average $p_1$ = 0.52 mm), from which thick secondary branches arise (average $p_2$ = 0.28 mm). The intensive recrystallization results in obliterating the details of the thallus, thus the specific name of the taxa is impossible to be defined.

Family TRIPLOPORELLACEAE Pia, 1920
Tribe MACROPORELLINEAE Pfender & Massieux, 1966
Genus *FURCOPORELLA* Pia, 1918
*Furcoporella diplopora* Pia, 1918

**(FIG.8 L&M)**

1940 *Furcoporella diplopora* Pia- Pfender, pp.242-243
1956 *Furcoporella diplopora* Pia- Elliott, p.331, pl.2, figs.5,6.
1966 *Furcoporella diplopora* Pia- Pfender & Massieux, p.128, pl.4, figs.8,9.
1979 *Furcoporella diplopora* Pia- Racz, p.721, fig.2.
1987 *Furcoporella diplopora* Pia- Khalifa, p.88, pl.2, figs.9, 13, 14.
1993 *Furcoporella diplopora* Pia- Kuss & Herbig, p.274, pl.6, figs.4-5 & 7-8.

**Occurrence:** *Furcoporella diplopora* is restricted to the middle part of the *Alveolina oblonga*/*Orbitolites complanatus* Zone (Minia Formation), whereas it is recorded with percentage not exceed than 2.5% of the rock.

**Description and dimensional data:** *Gymnocodium nummuliticum*, *Furcoporella diplopora* and *Griphoporella arabica* are closely related. Elliott (1956) noticed that the *Furcoporella diplopora* has the largest dimensions among the three above-mentioned species. In the studied *Furcoporella diplopora*, the thallial tissue (L = up to 2.3 mm and average D = 0.44 mm) is cylindrical, unsegmented and strongly calcified around the hollow central stem. The average diameter of the center stem (d) = 0.2 mm. The ratio d/D = 45%. Short and thick primary branches (average $p_1$ = 0.06 mm) are developed, which pass into two thin secondary branches (average $p_2$ = 0.017 mm). Globular sporal verticlis with average diameter = 0.05 mm are horizontally arranged with short primary canals. These pores are found at right angles to the axial area.

**Distribution and stratigraphic range:** *Furcoporella diplopora* was recorded from the ?Middle Eocene carbonates of Gebel El-Teir, opposite Minia (Khalifa, 1987) and from the Lower Eocene of the north Eastern Desert (Kuss & Leppig, 1989 and Kuss & Herbig, 1993). Outside Egypt, Pia (1918) was the first to identify this species from the Upper Paleocene to Middle Eocene of Austria. Bassoullet *et al.* (1983) defined and described this species from the Middle East and China.

Family TRIPLOPORELLACEAE Pia, 1920
Tribe DASYCLADEAE Pia, 1920
Genus *NILOPORELLA* Dragastan & Soliman, 2002
*Niloporella subglobosa* Dragastan & Soliman, 2002
**(FIG.8 N-Q)**

1983 *Carpathoporella occidentalis* Dragastan- Keheila, pl.5, fig.12.
1986 *Sarfatiella* sp.- Segonzac *et al.*, p.506, pl.2, fig.2.
1990 *Carpathoporella occidentalis* Dragastan- Keheila *et al.*, p.163, figs. 11D-G.
1990 *Sarfatiella* sp.- Radoičić, pl.10, figs.5-7.
1993 *Acicularia* sp.- Kuss & Herbig, pl.6, fig.16.
2002 *Niloporella subglobosa* n.sp.-Dragastan & Soliman, pp.7-9, pl.3, fig.1-12.

**Occurrence:** *Niloporella subglobosa* is rare in the lower unit of the Drunka Formation at El-Zarabi section (*Ovulites arabica*/*Ovulites pyriformis* Zone). Its percentage ranges from 2.5% to > 40% in the upper unit of the Drunka Formation exposed at El-Zarabi, Ismail Bey and Gebel Gibeil sections (*Nummulites planulatus* Zone). The highest percentage of *Niloporella subglobosa* (40%) is recorded at the basal part of the upper unit of the Drunka Formation at El-Zarabi section.

**Description and dimensional data:** Dragastan & Soliman (2002) mentioned that the new species *Niloporella subglobosa* is correlated with *Morelletopora nammalensis* Varma and *Piania niniyurensis* Gowda but with some difference in the shape and arrangement of the ampoules. In the present work, the thallus (L = up to 1.5 mm and average D = 0.75 mm) is well-developped, unsegmented, cylindrical, crossed by axial siphons bearing numerous euspondyle verticils, sometimes heavily-recrystallized. In the transversal sections, the axial siphon is surrounded by 6-10 globular ramifications. The central stem (axial cavity) is spheroidal in cross sections and exhibits average d = 0.35 mm. The ratio d/D = 47%. The supposedly fertile laterals ramifications (ampullae) are globular to subglobular and present in widely-spaced whorls. Their average diameter is about 0.2 mm. They are flattened in the longitudinal sections and widen at the tips and support a cortical membrane.

**Distribution and stratigraphic range:** *Niloporella subglobosa* was introduced by Dragastan & Soliman (2002) from the Lower Eocene Drunka Formation exposed in the area between Qena and Sohag, Egypt.

Family DASYCLADACEAE Kützing, 1843
Tribe NEOMEREAE Pfender & Massieux, 1966
Genus *NEOMERIS* (Pia, 1920) Bassoulet *et al.*, 1979
*Neomeris* sp.
**(FIG.9 A)**

**Occurrence:** It is predominant from one bed at the middle part of the *Nummulites planulatus* zone of the upper unit of the Drunka Formation at both Ismail Bey and Gebel Gibeil sections. Also, it is rare from the middle part of the *Alveolina oblonga*/*Orbitolites complanatus* Zone of the Minia Formation.

**Description and dimensional data:** The test is strongly recrystallized, subcylindrical with no annular narrowing. The thallus is characterized by its egg-shaped, globular, calcreous capsules (sporangia) with average diameter = 0.16 mm. Such sporangia are separated by infertile branches that are often overprinted by the diagenetic alterations.

**Distribution and stratigraphic range:** Different species of *Neomeris* (*N. avellanensis*, *N. plagnensis*, *N. cf. reticulata*, *N. scrobiculata*, *N. cf. tyrrhenica*, *N. budaense*, *N. johonsoni* and *N. mirensis*) were identified from the Upper Paleocene to Lower Eocene limestones of the Nile Valley and north Eastern Desert of Egypt (e.g. Khalifa, 1985; Khalifa *et al.*, 1986; Mansour *et al.*, 1987 and Kuss & Hebrig, 1993). Such species was noticed from the Late Paleocene to Ypresian of Morocco, Sardinia and Iran (Deloffre *et al.*, 1977 and Granier *et al.*, 2012).

Family POLYPHYSACEAE Kützing, 1843
Tribe CLYPEINEAE Elliot, 1968
Genus *CLYPEINA* (Michelin, 1845) Bassoulet *et al.*, 1978
*Clypeina* cf. *rotella* Yu-Jing, 1976
**(FIG.9 B)**

1990 *Clypeina haglani* Radoičić- Radoičić, pl.3, figs.1-5.
2002 *Clypeina* cf. *rotella* Yu-Jing- Dragastan & Soliman, p.9, pl.2, fig.2.

**Occurrence:** It is rare and defined from the *Alveolina oblonga*/*Orbitolites complanatus* Zone of the Minia Formation.

**Description and dimensional data:** Thallus is recrystallized showing about 18-20 sporangial ramifications. It shows small disc with average D = 0.96 mm, average d = 0.5 mm and d/D = 52% with globular fertile capsules (sporangia) with average diameter = 0.15 mm.

**Distribution and stratigraphic range:** Dragastan & Soliman (2002) identified this species from the Lower Eocene Drunka Formation of south Assiut (Egypt).

Tribe ACETABULARIEAE Decaisne, 1842
Genus *ACICULARIA* d'Archiac, 1843
*Acicularia robusta* Dragastan and Soliman, 2002
**(FIG.9 C)**

1990 *Acicularia* sp.- Radoičić, pl.12, fig.6.
1994 *Acicularia* sp.- Herbig & Fechner, figs.5&6C.
2002 *Acicularia robusta* n.sp.- Dragastan & Soliman, p.12, pl.1, figs.4&5.

**Occurrence:** *Acicularia robusta* was perceived from all the studied sections. The highest percentage of this species (45%) was recorded in the lowermost bed of *Acicularia robusta/Ovulites* spp. Subzone (*Nummulites palnulatus* zone), that is recognized from the upper part of the Drunka Formation at Ismail Bey section.

**Description and dimensional data:** *Acicularia robusta* was first named by Dragastan & Soliman (2002) who stated that the species of the genus *Acicularia* are identified by the shape of their fertile ampoules. Numerous sporangiphore bioclasts are recorded herein. They are calcified and rounded in the transversal sections to elongated in the other sections with flattened tops and bottoms. Such sporangiphores are composed of 6-20 spherical fertile ampoules (cyst cavities) with average diameter = 0.014 mm. These cyst cavities are thick and concentrically arranged around the periphery.

**Distribution and stratigraphic range:** The new species *Acicularia robusta* was distinguished from the Upper Ypresian carbonates of the Drunka Formation of the Nile Valley, Egypt (Dragastan & Soliman, 2002).

Class BRYOPSIDOPHYCEAE
Order BRYOPSIDALES
Family UDOTEACEAE Feldman, 1946
Genus *OVULITES* Lamarck, 1816
*Ovulites pyriformis* Schwager, 1883
**(FIG.9 D-F)**

1989 *Ovulites pyriformis* Schwager- Kuss & Leppig, p.324, fig.10c.
1990 *Ovulites maillolensis* Morellet- Keheila *et al.*, p.163, figs.11Q-S.
2000 *Ovulites maillolensis* Morellet- El-Gamal & Youssef, p.1427, pl.4, fig.f.
1993 *Ovulites pyriformis* Schwager- Kuss & Herbig, p.277, pl.5, fig.11.
2002 *Ovulites pyriformis* Schwager- Dragastan & Soliman, p.14, pl.4, figs.4-7.

**Occurrence:** This species is recorded frequently from the Drunka Formation at both El-Zarabi and Ismail Bey sections. The highest percentage of *Ovulites pyriformis* (45%) is recorded at the lower part of the lower unit of the Drunka Formation at El-Zarabi section (*Ovulites arabica/Ovulites pyriformis* algal zone).

**Description and dimensional data:** *Ovulites pyriformis* exhibits the largest diameter among the other species of *Ovulites* (Kuss & Herbig, 1993). In the present study, *Ovulites pyriformis* is characterized by its pear shape (average D = 1.6 mm). It has a thin cortex (0.02 mm), which is pierced by very short siphons. The average diameter of the central cavity (d) = 1.3 mm. The ratio d/D = 81%.

**Distribution and stratigraphic range:** Kuss & Herbig (1993) identified the *Ovulites pyriformis* from the Upper Paleocene to Lower Eocene strata of the lagoonal facies of Sinai and the Southern Galala on both sides of the Gulf of Suez. Dragastan & Soliman (2002) described this species from their lower algal zone described from the Drunka Formation exposed at the Nile Valley and dated this zone to the late Early Ypresian.

*Ovulites arabica* (Pfender, 1938)
**(FIG.9 G & H)**

1966 *Ovulites arabica* (Pfender)- Massieux, pp.240-242, tab.1.
1968 *Griphoporella arabica* (Pfender)- Elliott, p.51, pl.12, figs.1&3.
1989 *Ovulites arabica* (Pfender)- Kuss & Leppig, p.323, fig.11a.
1991 *Ovulites arabica* (Pfender)- Herbig, p.33, pl.8, fig.5.
1992 *Ovulites* sp.- Radoičić, pl.8, fig.10.
1993 *Ovulites arabica* (Pfender)- Kuss & Herbig, p.277, pl.5, figs.10, 13-14 & pl.8, fig.6.
2002 *Ovulites arabica* (Pfender)- Dragastan & Soliman, p.12, pl.4, figs.1-3.

**Occurrence:** This species is realized from the Drunka Formation at both El-Zarabi and Ismail Bey sections with variable percentages. The highest percentage of *Ovulites arabica* (55%) is recorded at the upper part of the lower unit of the Drunka Formation at El-Zarabi section (*Ovulites arabica/Ovulites pyriformis* algal zone).

**Description and dimensional data:** *Ovulites arabica* is characterized from *O. pyriformis* by its thicker cortex. In oblique sections, the plant is circular with average diameter D = 1.2 mm. It has a thin calcitizied cortex (0.075 mm). This cortex is perforated by vertical crossing minute canals (short siphons). The average diameter of the central cavity (d) = 0.82 mm. The ratio d/D = 68%.

**Distribution and stratigraphic range:** *Ovulites arabica* was defined firstly by Pfender (1938) from the Middle Eocene of Egypt and Lower Eocene of Morocco. It was recognized from the Upper Paleocene/Lower Eocene of north Eastern Desert, Egypt (Kuss & Leppig, 1989). Also, it is identified from the Illerdian limestones of south Assiut, Nile Valley, Egypt (Dragastan & Soliman, 2002).

*Ovulites morelleti* Elliott, 1955

**(FIG.9 I & J)**

1986 *Ovulites morelleti* Elliott- Khalifa *et al.*, pp.152&153, pl.1, figs.6-9.
1987 *Ovulites morelleti* Elliott- Bandel & Kuss, p.25, pl.5, fig.5.
1987 *Ovulites morelleti* Elliott- Khalifa, p.89, pl.2, figs.1&2.
1987 *Ovulites morelleti* Elliott- Mansour *et al.*, p.132, pl.1, fig.6.
1989 *Ovulites morelleti* Elliott- Kuss & Leppig, p.323, figs.10f&g.
1990 *Ovulites morelleti* Elliott- Radoičić, pl.11, figs.2&3.
1993 *Ovulites morelleti* Elliott- Kuss & Herbig, p.277, pl.5, figs.9&12.
2000 *Ovulites morelleti* Elliott- El-Gamal & Youssef, p.1428, pl.2, fig.A & pl.4, figs.D&E.

**Occurrence:** This species is discerned from both the *Ovulites arabica/Ovulites pyriformis* algal zone (<2.5%) and the *Nummulites palnulatus* zone (up to 5%) of the Drunka Formation exposed at El-Zarabi and Ismail Bey sections. Also, it is recorded with percentage < 2.5% from the *Alveolina oblonga*/*Orbitolites complanatus* zone of the Minia Formation.

**Description and dimensional data:** Thallus is segmented. It is elongate in the longitudinal sections and circular to tabular in the cross sections. The wall of the thallus is insignificantly perforated with straight and radial pores. The average L reaches up to 2.5 mm, the average outer diameter (D) = 1.4 mm, the average inner diameter (d) = 0.6 mm and d/D = 43%.

**Distribution and stratigraphic range:** *Ovulites morelleti* was distinguished from the Upper Ypresian Drunka Formation of the Nile Valley, Egypt (Mansour *et al.*, 1987). It was described from the ?Middle Eocene Minia Formation of the Nile Valley (Khalifa *et al.*, 1986 and Khalifa, 1987). Also, it is recorded from the Upper Paleocene to Lower Eocene of north Eastern Desert (Bandel & Kuss, 1987 and Kuss & Herbig, 1993 and El-Gamal & Youssef, 2000). Outside Egypt, Elliott (1955) and Radoičić (1990) identified this species from the Upper Paleocene to Middle Eocene of the Middle East and the subsurface of the Western Iraq Desert respectively.

*Ovulites marginulata* (Lamarck, 1801) Lamarck, 1816

**(FIG.9 K)**

1966 *Ovulites marginulata* Lamarck- Massieux, pp.241-244, pl.1, figs.1-4.
1970 *Ovulites marginulata* Lamarck- Deloffre, p.355, pl.1, figs.1-8.

1993 *Ovulites marginulata* Lamarck- Kuss & Herbig, p.277, pl.8, figs.7&8.
2002 *Ovulites marginulata* Lamarck- Dragastan & Soliman, p.14, pl.4, figs.8-11 & pl.6, fig.5.

**Occurrence:** It is constrained to the *Nummulites planulatus* Zone of the Drunka Formation. Its highest percentage (10%) was observed at the middle part of Ismail Bey section.

**Description and dimensional data:** The thallus segment is of ovoid to pear shape with average outer diameter (D) = 0.85 mm and average inner diameter (d) = 0.78 mm and d/D = 92%. Such thallus is walled by thin cortex with diameter = 0.014-0.025 mm. The cortical film is cut by very fine, tabular siphons. In the oblique tangential section, it is obvious that the siphons are arranged in rows.

**Distribution and stratigraphic range:** Deloffre (1970) ascertained this species from the Lower Eocene of the French Pyreneés. *Ovulites marginulata* was known from central High Atlas region of Morocco (Trappe, 1992). Kuss & Herbig (1993) and Dragastan & Soliman (2002) defined this species from the Ypresian limestones of north Eastern Desert and Nile Valley respectively.

*Ovulites elongata* Lamarck, 1816

**(FIG.9 L-N)**

1966 *Ovulites elongata* Lamarck- Massieux, pp.241&241, tab.1.
1983 *Ovulites elongata* Lamarck- Bassoullet *et al.*, p.540, pl.12, figs.1&2.
1990 *Ovulites elongata* Lamarck- Keheila *et al.*, p.163, figs.11O&U.
1990 *Ovulites elongata* Lamarck- Strougo *et al.*, p.68, pl.1, figs.1&2.
2000 *Ovulites elongata* Lamarck- Keheila, p.166, pl.3, fig.H.
2002 *Ovulites elongata* Lamarck- Dragastan & Soliman, p.16, pl.5, figs.1-6.

**Occurrence:** *Ovulites elongata* is limited to the *Nummulites planulatus* Zone of the Drunka Foramation at El-Zarabi section. The highest percentage of *Ovulites elongata* (25%) is recorded at the uppermost part of this section (*Ovulites elongata* algal subzone).

**Description and dimensional data:** In longitudinal sections, the thallus is long, cylindrical and intensely calcitizied with average L = up to 1.7 mm. The cross sections are heavily micritized exhibiting circular shape with average diameter (D) = 0.225 mm. The average diameter of central cavity (d) = 0.175 mm. The ratio d/D = 78%. The cortical layer is very thin, that is punctured by short siphons (0.05 mm).

**Distribution and stratigraphic range:** This species was apprehended from the Ypresian-Lutetian carbonates of the Nile Valley and north Eastern Ddesert (Keheila *et al.*, 1990; Strougo *et al.*, 1990; Keheila, 2000 and Dragastan & Soliman, 2002). It was identified from the Ypresian of Morocco (Bassoulett *et al.*, 1983).

*Ovulites* sp.

**Occurrence:** It is recognized from the *Ovulites arabica/Ovulites pyriformis* algal zone of the Drunka Formation at El-Zarabi section with percentage not exceed 2.5%. It is also noticed from the *Nummulites planulatus* Zone at El-Zarabi, Ismail Bey and Gebel Gibeil sections with highest percentage reaches up to 45% at the middle part of Gebel Gibeil. Also, it is rarely recorded (<2.5%) from the *Alveolina oblonga*/*Orbitolites complanatus* Zone of the Minia Formation.

**Description and dimensional data:** Thallus is segmented with small globular to cylindrical bodies. In cross sections, it is differentiated into dark central stem and thin outer cortex. Thallus is perforated by numerous fine pores. The dimensional

data of this genus doesn't correspond to any of the aforementioned *Ovulites* species, therefore, no specific name can be attained.

Family HALIMEDACEAE Link, 1832
Genus HALIMEDA Lamouroux, 1812
*Halimeda nana* Pia, 1932
**(FIG.9 O-Q)**

1955 *Halimeda nana* Pia- Elliott, p.131, pl.1,fig.3.
1983 *Halimeda nana* Pia- Bassoulett *et al.*, pp.499-490, pl.7, figs.5&6.
1986 *Halimeda nana* Pia- Segonzac *et al.*, p.502, pl.I, figs.1,2, 5,7&8.
1993 *Halimeda nana* Pia- Kuss & Herbig, p.277, pl.5, figs.1-5&8 &pl.8, figs.4-5&9-10.

**Occurrence:** It is rare (<2.5%) from the middle part of *Alveolina oblonga*/*Orbitolites complanatus* Zone of the Minia Formation.

**Description and dimensional data:** Thallus is segmented with L reaches up to 2.2 mm and average outer diameter D = 0.9 mm. It is heavily recrystallized (calcitizied and/or micritized). In cross sections, the segment has a discoidal shape with undulating edges and cut by circular to ovoidal medullar filaments. In vertical sections, the central cavity consists of thick, tabular filaments (0.07 mm), which continue to bifurcated threads of the cortex.

**Distribution and stratigraphic range:** *Halimeda nana* was recorded from the Upper Paleocene to Lowe Eocene of Egypt and Morocco (Kuss & Leppig, 1989 and Kuss & Herbig, 1993).

*Halimeda praemonilis* Morellet, 1940
**(FIG.9 R & S)**

1968 *Halimeda praemonilis* Morellet- Johnson, p.43, pl.30, fig.3.
1977 *Halimeda praemonilis* Morellet- Deloffre *et al.*, p.43, pl.6, figs.1&2.
1986 *Halimeda praemonilis* Morellet- Khalifa *et al.*, p. 153, pl.1, figs.15,20&22.
1990 *Halimeda praemonilis* Morellet- Keheila *et al.*, p.163, figs.11A,M&T.
1990 *Halimeda praemonilis* Morellet- Radoičić, pl.12, figs1&2.

**Occurrence:** *Halimeda praemonilis* is present (2.5-5%) to abundant (10-20%) from the *Nummulites planulatus* zone of the Drunka Foramation at El-Zarabi section and is rare (<2.5%) from the *Alveolina oblonga*/*Orbitolites complanatus* of the Minia Formation at Gebel Gibeil.

**Description and dimensional data:** Thallus is composed of tufts of segmented branching stems with L reaches up to 5.5 mm and average diameter (D) = 1 mm. The segment is leaf-like, subcylindrical to subconical, which is strongly micritized. The internal structure is composed of medullar, tabular filaments in the longitudinal sections. The filaments are finer and shorter towards the outer surface of the segment.

**Distribution and stratigraphic range:** *Halimeda praemonilis* was comprehended from the Lower-Middle Eocene of the Nile Valley and Eastern Desert (Khalifa *et al.*, 1986 and Keheila *et al.*, 1990).

*Halimeda* sp.
**(FIG.9 T)**

The highest percentage of *Halimeda* sp. (25%) was recorded from the middle part of *Alveolina oblonga*/*Orbitolites complanatus* of the Minia Formation. It is also

identified from the *Nummulites planulatus* Zone of the Drunka Foramation at El-Zarabi section and the *Nummulites gizehensis s.l* Zone of the Samalut Formation with percentage not exceed than 10%. The thallus is heavily calcitized, accordingly, the specific name is impossible to be determined.

## 5. PALEOECOLOGICAL PARAMETERS

The most suitable conditions for the growth of green algae are the shallow to very shallow, semi-restricted to restricted, clear water and warm marine limy platform areas (Elliott, 1955 and Neumann & Land, 1975 and Granier, 2012).

### 5.1 Salinity:

The Bryopsidales are living in an environment of normal marine to slightly variable salinity (Wilson, 1975 and Wray, 1977), while the Dasycladales are living in an environment of variable salinity (Wilson, 1975), mostly normal marine with less extent hypersaline to brackish (Wray, 1977). The carbonate succession of the area under consideration is believed to be deposited under normal marine to slightly hypersaline conditions as indicated by the dominance of the calcareous green algae.

### 5.2 Water depth:

Living Bryopsidales thrive best in shallow depths of the subtidal environment from low tide level and down to a range from 10-20 m (Wilson, 1975 and Wray, 1977). The alga *Halimeda* could not grow beyond the photic zone (70-90 m depth) (Roberts *et al.*, 1987 and Phipps and Roberts, 1988). It can grow and calcify at depths below 100m (Granier, 2012). Dasycladales flourish in shallow marine conditions (Elliott, 1968) with depth ranging from low tide to about 12 m (Pia, 1920 and Horowitz and Potter, 1971), 13-15 m (Wilson, 1975) and below the low tide to about 30 m, commonly < 5 m (Flugel, 1977 and Wray, 1977). Milliman (1974) stated that the dasycladacean algae are growing in depth not greater than 15-20 m. In the present work, the presence of high percentage of calcareous green algae within the studied carbonate sequence indicates that the water depth is shallow (average depth of about 20 m) within the photic zone below the turbulence zone. In this zone, the well-oxygenated water and the photosynthetic zone were available.

### 5.3 Temperature:

Most of the Bryopsidales live in warm water in the tropical area (25$^{o}$C + isotherm) (Johnson, 1961 and Wray, 1977). Few species of *Halimeda* live in the subtropical regions (Wray, 1977). In this respect, Roux (1985) revealed that the codiacean green algae are thriving best in warm conditions (minimum 18$^{o}$C). Living dasycladales are distributed in warm waters of tropical and subtropical areas and few species are living in temperate water (Flugel, 1977 and Wray, 1977). The dominance of green algae within the studied rock units suggests that they were deposited under warm and tropical to subtropical conditions.

### 5.4 Water energy:

The dominance of the calcareous green algae and unwinnowed thick micrite indicate a short lived current with low energy (Folk, 1962). Ginsburg *et al.* (1971) and Wilson (1975) revealed that the flourishing of the Bryopsidales does not require strong circulation. They are flourishing under low energy conditions below the intense water agitation (Wray, 1977). Living *Cymopolia* and *Neomeris* can be found in high energy (reef) environments (Granier, 1988). The Dasycladales are flourishing in an environment of low energy level below intense wave agitation

(Wray, 1977). Consequently, the studied carbonates are seemed to be deposited in quiet water conditions.

## 6. CONCLUSION

The Lower and Middle Eocene carbonate sequence of the Assiut-Minia stretch can be subdivided into one algal zone and three large foraminiferal zones. The *Ovulites arabica/Ovulites pyriformis* Zone (Early Ypresian) is confined to the lower unit of the Drunka Formation. The foraminiferal zones are represented by the following zones (from older to younger); *Nummulites planulatus* and *Alveolina oblonga/Orbitolites complanatus* zones of Late Ypresian age and *Nummulites gizehensis* Zone of Lutetian age. Furthermore, the *Nummulites planulatus* zone is subdivided into three algal subzones. These are (from base top); *Niloporella subglobosa* Subzone. *Ovulites elongate* Subzone and *Acicularia robusta/Ovulites* spp. Subzone.

A total of thirteen green algal species and five genera were identified, described, measured and discussed. They are *Belzungia silvestrii* (Pfender), *Cymopolia elongata* (Defrance), *Furcoporella diplopora* Pia, *Niloporella subglobosa* Dragastan & Soliman, *Clypeina* cf. *rotella* Yu-Jing, *Acicularia robusta* Dragastan & Soliman, *Dissocldella* sp., *Cymopolia* sp. and *Neomeris* sp., *Ovulites pyriformis* Schwager, *Ovulites arabica* (Pfender), *Ovulites morelleti* Elliott, *Ovulites marginulata* (Lamarck), *Ovulites elongata* Lamarck, *Halimeda nana* Pia, *Halimeda praemonilis* Morellet, *Halimeda* sp. and *Ovulites* sp. The paleoecological conditions of the studied rock units are deduced depending upon the ecology of the cholorophytal algae. Hence, the studied carbonate sequence was probably deposited in normal marine to slightly hypersaline conditions with shallow water depth (about 20 m) and warm and quiet water.

## REFERENCES

**Aref, M.A., 1982.** Micropaleontology and biostratigraphy of the Eocene rocks in the area between Assiut and Beni Suef, east of the Nile Valley, Egypt. Ph.D. Thesis, Assiut Uni., Assiut, Egypt, 277 p.

**Bandel, K., Kuss, J., 1987.** Depositional environment of the pre-rift stage of the Galala Heights (Eastern Desert, Egypt). Berliner geowiss. Abh. Berlin. (A), 78, 1-48.

**Bassoullet, J.P., Bernier, P., Conrad, R., Deloffre, R., Genot, P., Poncet, J., Roux, A. 1983.** Les algues Udoteacées du Paléozoique au Cénozoique. Bull. Cent. Res. Expl-Prod. Elf.-Aquitaine, 7 (2), 449-621.

**Bishay, Y., 1966.** Studies on the large foraminifera of the Eocene of the Nile Valley between Assiut and Cairo and SW Sinai. Ph.D. Thesis, Alexandria Uni., Alexandria, Egypt, 244 p.

**Boukhary, M.A., Abdel Malik, W.M., 1983.** Revision of the stratigraphy of the Eocene deposits in Egypt. N. Jb. Geol., Paleont., Mh. Stuttgart, 6, 321-337.

**Boukhary, M.A., Blondeau, A., Ambroise, D., 1982.** Etude sure les *Nummulites* de la region de Minia-Samalut, Valleé du Nil, Egypt. 8e Collog. Afr. Micropaleont., Paris (1980). Cah. Micropaleont. Paris, 65-78, 7 text-figs., 1 pl.

**Conoco Coral, 1987.** Geological map of Egypt, Scale 1: 500,000. Sheet no.11 (Geological map of Assiut area). The Egyptian General Petroleum Corporation.

**Deloffre, R., 1970.** Niveau à algues dans le Sparnacien de la région de Plagne (Petites-Pyrénées-Haute-Garonne) et observations sur le genre *Neomeris* Lamouroux, 1816. Bull. Cent. Res. Pau-SNPA, 4 (2), 353-379.

**Deloffre R., Granier B., 1991.**Hypothèse phylogénique des Algues Dasycladales.- Comptes-Rendus de l'Académie des Sciences, Paris, (II), 312, p. 1673-1676.

**Deloffre R., Granier B., 1993.** Inventaire des Algues Dasycladales fossiles. I° partie- Les Algues Dasycladales du Tertiaire.- Revue de Paléobiologie, Geneva, 11/2 (1992), p. 331-356.

**Deloffre, R., Génot, P., 1982.** Les Algues Dasycladales du Cénozoique. Bull. Cent. Res. Expl-Prod. Elf.-Aquitaine, Mém. 4, 1-247.

**Deloffre, R., Poignant, A.F., Teherani, K., 1977.** Algues calcaraires de l' Albo-Aptien au Paléocene de l' Iran central. Bull. Cent. Res. Expl-Prod. Elf.-Aquitaine, 1 (1), 29-57.

**Dragastan, O.N., Soliman, H.A., 2002.** Paleogene calcareous algae from Egypt. Micropaleontology, 48 (1), 1-30.

**El-Gamal, M.M., Youssef, E.A.A., 2000.** Calcareous algae from the Late Paleocene-Early Eocene Sequence, Galala Plateau, Gulf of Suez, Egypt. Proceed. 5th Int. Conf. Geo. Arab World, Cairo Uni., III, 1417-1432.

**Elliott, G.F., 1955.**Fossil calcareous algae from the Middle East. Micropaleontology, 1 (2), 125-131.

**Elliott, G.F., 1956.** Further records of fossil calcareous algae from the Middle East. Micropaleontology, 2 (4), 327-334.

**Elliott, G.F., 1968.** Permian to Paleocene Calcareous algae (Dasycladaceae) of the Middle East. Bull. Brit. Mus. Nat. Hist. (Geol.) Supplt, 4, 1-111.

**Elliott, G.F., 1978.** A new dasycladacean alga from the Paleocene of Kurdistan. Paleontology, 20 (3), 687-691.

**Flugel, E., 1977.** Fossil algae: Recent results and developments. Springer-Verlag, Berlin-Heidelberg-New York, 375 p.

**Folk, R.L., 1962.** Spectral subdivision of limestone types. In: W. E. Ham (ed.): Classification of carbonate rocks. Am. Ass. Pet. Geol., Mem.1, 62-84.

**Génot, P., 1980.** Les dasycladales du Paléocène supérieur et de l'Eocène du Bassin de Paris. Mém. Soc. Geol. France, 138, 40p.

**Ginsburg, R.N., Schroeder, J.H., Shinn, E.A., 1971.** Recent synsedimentary cementation in subtidal Bermuda reefs. In: Bricker, O.P. (ed.) carbonate cements John Hopkins Uni., studies in Geology, 19, 54-98.

**Granier B., 1988.** Algues Chlorophyceae du Jurassique terminal et du Crétacé inférieur en Alicante.- Mediterranea, Alicante, 5 (1986), p. 5-96

**Granier B., 2012.** The contribution of calcareous green algae to the production of limestones: a review. In : Basso D. & Granier B. (eds.), Calcareous algae and the global change: from identification to quantification.- Geodiversitas, Paris, vol. 34, n°1, p. 35-60. DOI: 10.5252/g2012n1a3.

**Granier B., Dias-Brito D., Bucur I.I., Tibana P., 2012.** online first. Brasiliporella, a new mid-Cretaceous dasycladacean genus: the earliest record of the Tribe Batophoreae.- Facies, Erlangen, vol. 59, n° 1, p. 207-220.

**Helal, S.A., 1999.** Early Eocene Alveolinidae from the area between Beni Shoquer and Dairut, Nile Valley, Egypt. Egy. J. Geol., 43 (2): 343-351, Cairo.

**Horowitz, A.S., Potter, P.E., 1971.** Introductory petrography of Fossils. Berlin-Heidelberg-New York; Springer-Verlag, 302 p.

**Hottinger, L., 1974.** Alveolinids, Cretaceous-Tertiary larger foraminifera. Esso Prod. Res. Eur Lab., 77 p., 24 text figs., 106 pls., Exxon Production Company, Houston, Texas.

**Johnson, J.H., 1961.** Limestone-building algae and algal limestones. Col. Sch. Mines., Golden, 297 p.

**Keheila, E.A., 1983.** Sedimentology and stratigraphy of the carbonate rocks in the area northeast of Assiut. Ph. D. Thesis, Assiut Uni., Assiut, Egypt.

**Keheila, E.A., 2000.** Stratigraphy of the Lower Eocene succession in the Northern and Southern Galala Plateaux, Eastern Desert, Egypt". Bull. Fac. Sci. Assiut Uni., Egypt, 29 (1F), 27-54.

**Keheila, E.A., Soliman, H.A., El-Ayyat, A.M., 1990.** Litho- and biostratigraphy of the Lower Eocene carbonate succession in Upper Egypt: evidence uplifting and resedimentation of the Paleocene section. J. Afr. Earth. Sci., 11 (1-2), 151-168.

**Kenawy, A.I., El-Baradei, N.M., 1977.** Early and Middle Eocene large foraminifera in the environs of Assiut, Egypt. Bull. Fac. Sci. Assiut Uni., Egypt, 6 (1), 247-295.

**Kenawy, A.I., Bassiouni, M.A., Khalifa, H., Aref, M.M. 1988.** Stratigraphy of the Eocene outcrops between Assiut and Beni Suef, Nile Valley, Egypt. Bull. Fac. Sci. Assiut Uni., Egypt, 17 (1F), 161-193.

**Kenawy, A.I., Mohamed, H.K., Mansour, H.H., 1993.** Biostratigraphic zonation of the Middle Eocene in the Nile Valley based on larger foraminifera. Zitteliana, 20, 301-309, Hagn/Herm- Festschrift.

**Khalifa, H., 1985.** New species of fossil algae from the Lower-Middle Eocene rocks, west and northwest of Assiut, Nile valley, Egypt. Arab Gulf Jour. Sci. Res., 3 (2), 579-593.

**Khalifa, H., 1987.** Coralline, dasycladacean and codiacean algae from the Middle Eocene rock succession at Gebel El-Mereir and G. El-Teir, Nile Valley, Egypt. Arab Gulf J. Scient. Res. Math. Phys. Sci., A5 (1), 75-96.

**Khalifa, H., Soliman, H.A., Keheila, E.A., 1986.** Fossil algae and biostratigraphy of the Middle Eocene rock succession at the southeast of Minia, Nile Valley, Upper Egypt. Arab Gulf Jour.Sci. Res., 4 (1), 141-157.

**Kuss, J., Herbig, H.G., 1993.** Biogeography, facies and taxonomy of Early Tertiary green algae from Egypt and Morocco. Bull. Soc. Pal. Ital., spec., 1, 249-280.

**Kuss, J., Lepping, U., 1989.** The Early Tertiary (Middle-Late Paleocene) limestones from the Western Gulf of Suez, Egypt. N. Jb. Geol. Paläont. Abh., 177 (3), 289-332.

**Mansour, H.H., Philobbos, E.R., 1983.** Lithostratigraphic classification of the surface Eocene carbonates of the Nile Valley, Egypt: A review. Bull. Fac. Sci. Assiut Uni., Egypt, 12 (2), 129-151.

**Mansour, H.H., Philobbos, E.R., Khalifa, H., Moustafa, H., 1987.** Geology of the area northeast of Sohag, Nile Valley, Egypt. Bull. Fac. Sci. Assiut Uni., Egypt, 16 (1), 111-137.

**Massieux, M., 1966.** Les algues du Nummulitique Egyptian et des terrains crétacées-Éocène des quelques régions mésogéennes. 2-éme partie, Etude Critique. Rev. Micropal., 9 (3), 135-146.

**Milliman, J. D., 1974.** Marine carbonate. Berlin, Springer-Verlag, 375 p.

**Morellet, L., 1917.** Note preliminaire sur les Dasycladacees de l'Eocéne de la Bretagne et du Contentin. C. R. Somm. Soc. Géol. Fr., 84 p.

**Morellet, L., 1940.** Etudes sur les algues calcaires de l'Eocéne du Contentin. Bull. Soc. Geol. Fr., 5 eme Ser., X, 201-206.

**Neumann, A.C., Land, L.S., 1975.** Lime mud deposition and calcareous algae in the Bight of Abco, Bahamas: A budget. J. Sed. Pet., 45 (4), 763-786.

**Pfender, J., 1938.** Contribution a la paléontologie des couches crétacées et Éocenes du Versant sud de l`Atlas de Marrakech (Maroc). In Moret, L., Ed., Notes et Mémoires de la service Mineralogique et de la Carte géologique Maroc, 49, 1-77.

**Pfender, J., 1940.** Les algues du Nummulitique Égyptien et des terrains Crétacées-Éocenes de quelques régions mésogéennes. Bulletin de la institute d' Egypte, 22, 225-250.

**Pfender, J., Massieux, M., 1966.** Les algues du Nummulitique Égyptien et des terrains Cretacées-Éocènes de quelques régions mésogéennes. Revue de Micropaleontologie, 9 (2), 111-135.

**Philobbos, E.R., Keheila, E.A., 1979.** Depositional environments of the Middle Eocene in the area southeast of Minia, Egypt. Ann. Geol. Surv., Cairo, Egypt, IX, 523-550.

**Phipps, C.W., Roberts, H.H., 1988.** Seismic characteristics and accretion history of *Halimeda* bioherms on Kalukalukaung Bark, Eastern Java Sea (Indonesia). Coral Reef, 6, 149-159.

**Pia, J., 1918.** Tthallophyta, dasycladaceae. In: Trauth, F. Das Eocänvorkommen bei radstadt in Pongau, Denkschr. Akad. Wiss. Wien, 95, Wien.

**Pia, J., 1920.** Die Siphoneae verticillatae vom Karbon bis Zur Kreide: Abhandlungen. Zool. - Bot. Gessell. Wien, 11, 1-263.

**Pomerol, C., 1973.** Ere Cènozoique (Tertiaire et Quaternaire). Stratigraphie et paleogeographie, Ere Cènozoique (Tertiaire et Quaternaire), Doin ed., Paris, 269 p., 235 text figs.

**Radoičić, R., 1990.** Paleogene dasyeladecean algae from the subsurface of the Western Iraqi Desert. Bull. De l'Académie serbe des sciences et des arts (sciences mathematiques et naturelles), Beograd, T. CII, 32, 91-103.

**Roberts, H.H., Phipps, C.W., Effendi, L., 1987.** *Halimeda* bioherms of the Eastern Java Sea, Indoensia. Geology, 15: 371-374.

**Roux, A., 1985.** Introduction, l'etude der algues fossiles paleozoiques (de la bacterie a la tectonique des plaques. Bull. Centres Rech. Explor. - Prod. Elf. Aquitaine, 9 (2), 465-499.

**Schaub, H., 1951.** Stratigraphie and paläontologie des Schlierenflysches mit besonderer Berücksichtigung der Paleocaenen und untereo Caenen Nummuliten und Assilinen. Schweiz. Paläont. Abh., 68, 11-217.

**Sheleby, A.I., Said, M.M., Eid, M.A., 2000.** Paleogene Lithostratigraphy of the area west of the Nile Valley between Qena and south Assiut. Annal. Geol. Surv., Cairo, Egypt, XXIII, 563-578.

**Strougo, A., Bignot, G., Abdallah, A.M., 1992.** Biostratigraphy and paleoenvironments of Middle Eocene benthic foraminiferal assemblages of northcentral Eastern Desert, Egypt. M. E. R. C. Ain Shams Univ., Cairo, Egypt, Earth Sci. Ser., 6, 1-12.

**Trappe, J., 1992.** Microfacies zonation and spatial evolution of a carbonate ramp: marginal Moroccan phosphate sea during the Paleogene. Geologische Rundschau, 81 (1), 105-126.

**Wilson, J.L., 1975.** Carbonate facies in geologic history. Springer-Verlag, Berlin, Heidelberg, New York, 471 p.

**Wray, J.L., 1977.** Calcareous algae. Elsevier Scientific Publishing Co., Amsterdam, Oxford, New York, 185 p.

**Youssef, M.M., Mansour, H.H., Philobbos, E.R., Osman, Z.L., 1982.** Contribution to the geology of the area northwest of Assiut, Egypt. Bull. Fac. Sci. Assiut Uni., Egypt, 11(1), 335-354.

## CAPTION OF FIGURES

**Fig. (1)** Geological map of the study area (modified after Conoco, 1987).
**Fig. (2)** Biostratigraphic correlation of the fauni and flori zones.
**Fig. (3)** Legend for the carbonate constituents of the studied sections.
**Fig. (4)** Distribution chart of algae and foraminifera at El-Zarabi section.
**Fig. (5)** Distribution chart of algae and foraminifera at Ismail Bey section.
**Fig. (6)** Distribution chart of algae and foraminifera at Gebel Gibeil section.
**Fig. (7)** Distribution chart of algae and foraminifera at Mallawi section.
**Fig. (8)** **A-E**. *Belzungia silvestrii*; A & B. transversal sections, C. oblique transversal section, D. longitudinal section, E. tangential section. **F-H**. *Dissocladella* sp.; F. (ov) oblique vertical section, (t) Tangential section, G. transversal section, H. oblique longitudinal section. **I & J**. *Cymopolia elongata*; cross sections. **K**. *Cymopolia* sp.; transversal section. **L & M**. *Furcoporella diplopora*; L. oblique transversal section, M. oblique longitudinal section. **N-Q**. *Niloporella subglobosa*; N. cross section, O. axial section, P. group of different sections, Q. oblique tangential section.
**Fig. (9)** **A**. *Neomeris* sp.; bioclasts. **B**. *Clypeina* cf. *rotella* Yu-Jing; cross section. **C**. *Acicularia robusta* Dragastan & Soliman; oblique section of gametophore with fertile ampoules. **D-F**. *Ovulites pyriformis* Schwager; cross sections. **G & H**. *Ovulites arabica* (Pfender); oblique sections. **I & J**. *Ovulites morelleti* Elliott; I. longitudinal section, J. horizontal section. **K**. *Ovulites marginulata* Lamarck; cross to tangential section. **L-N**. *Ovulites elongata* Lamarck; L & M. group of different sections (N.B. the effect of calcitization in L and micritization in M), N. oblique vertical section. **O-Q**. *Halimeda nana* Pia; O. vertical section, P & Q. oblique horizontal sections. **R & S**. *Halimeda praemonilis* Morellet; longitudinal sections. T. *Halimeda* sp.; tangential section.

## CAPTION OF TABLES

**Table 1.** Lithostratigraphic classification of the Eocene carbonate succession within the area under consideration.
**Table 2.** The main characteristics of the studied rock units and their depositional environments.
**Table 3.** Biostratigraphic zonation of the Early-Middle Eocene sequence of the study area.
**Table 4.** The identified green algal genera and species and their systematic classification.

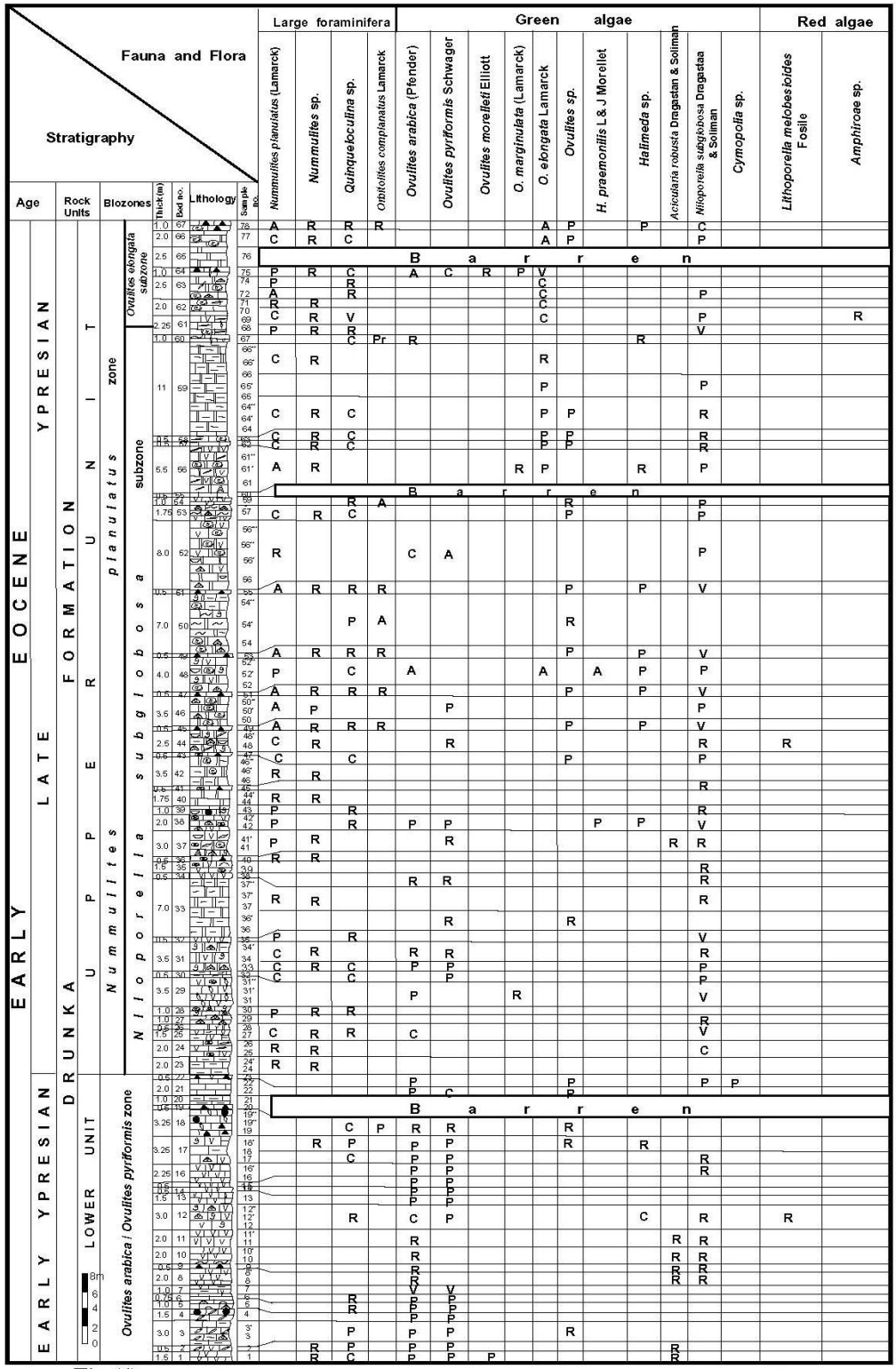
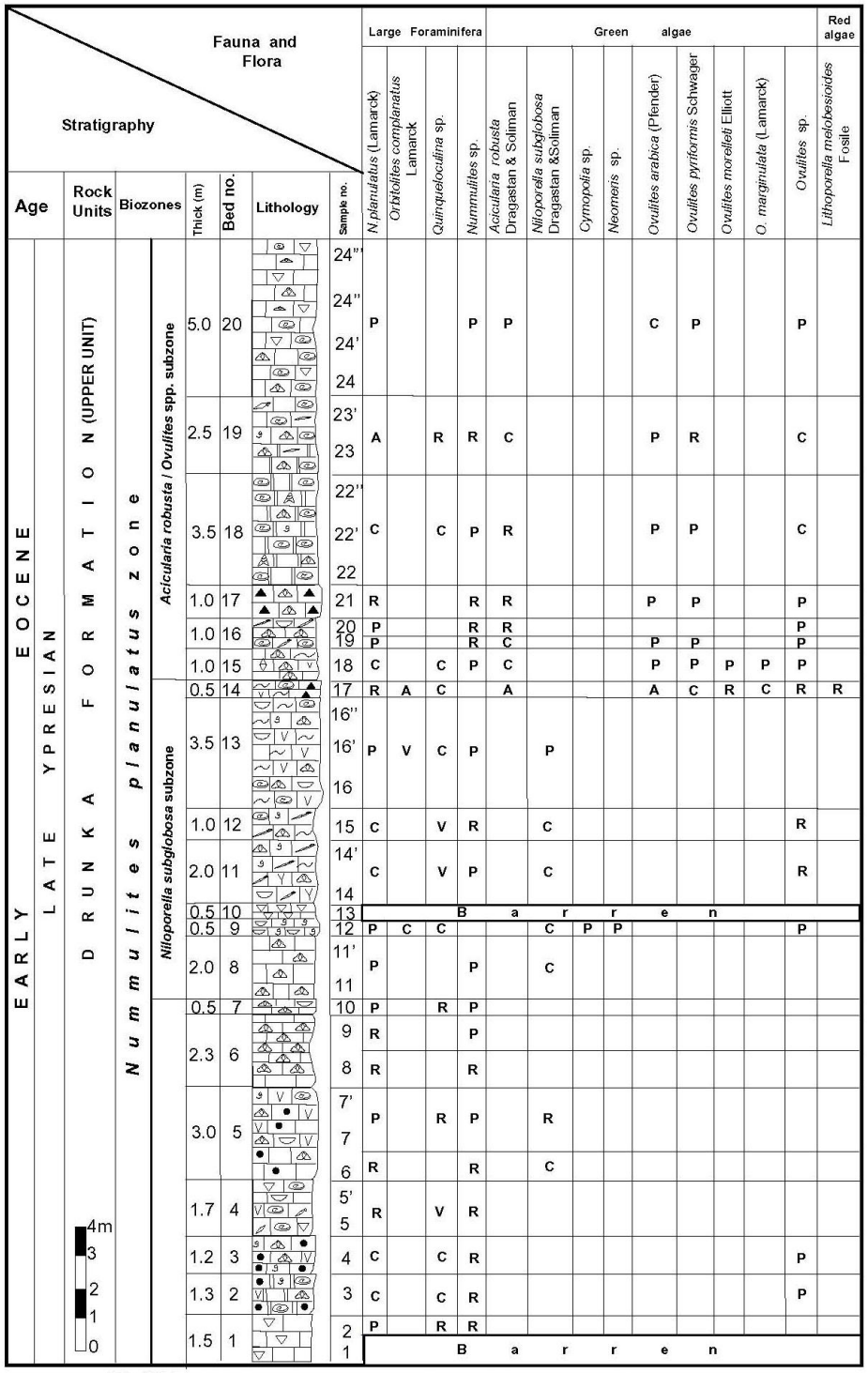



Fig.(4)

**R** Rare (<2.5%) **P** Present (2.5-5%) **C** Common (5-10%) **A** Abundant (10-20%) **V** Very abundant (20-40%) **Pr** Predominant (>40%)


Stratigraphy
Fauna and Flora
Age
Rock Units
Biozones
Thick (m)
Bed no.
Lithology
Sample no.
Large Foraminifera
Green algae
Red algae
N planulatus (Lamarck)
Orbitolites complanatus Lamarck
Quinqueloculina sp.
Nummulites sp.
Acicularia robusta Dragastan & Soliman
Niloporella subglobosa Dragastan &Soliman
Cymopolia sp.
Neomeris sp.
Ovulites arabica (Pfender)
Ovulites pyriformis Schwager
Ovulites morelleti Elliott
O. marginulata (Lamarck)
Ovulites sp.
Lithoporella melobesioides Foslie
EARLY EOCENE
LATE YPRESIAN
DRUNKA FORMATION (UPPER UNIT)
Nummulites planulatus zone
Acicularia robusta / Ovulites spp. subzone
Niloporella subglobosa subzone
Barren
4m
3
2
1
0
Fig.(5)

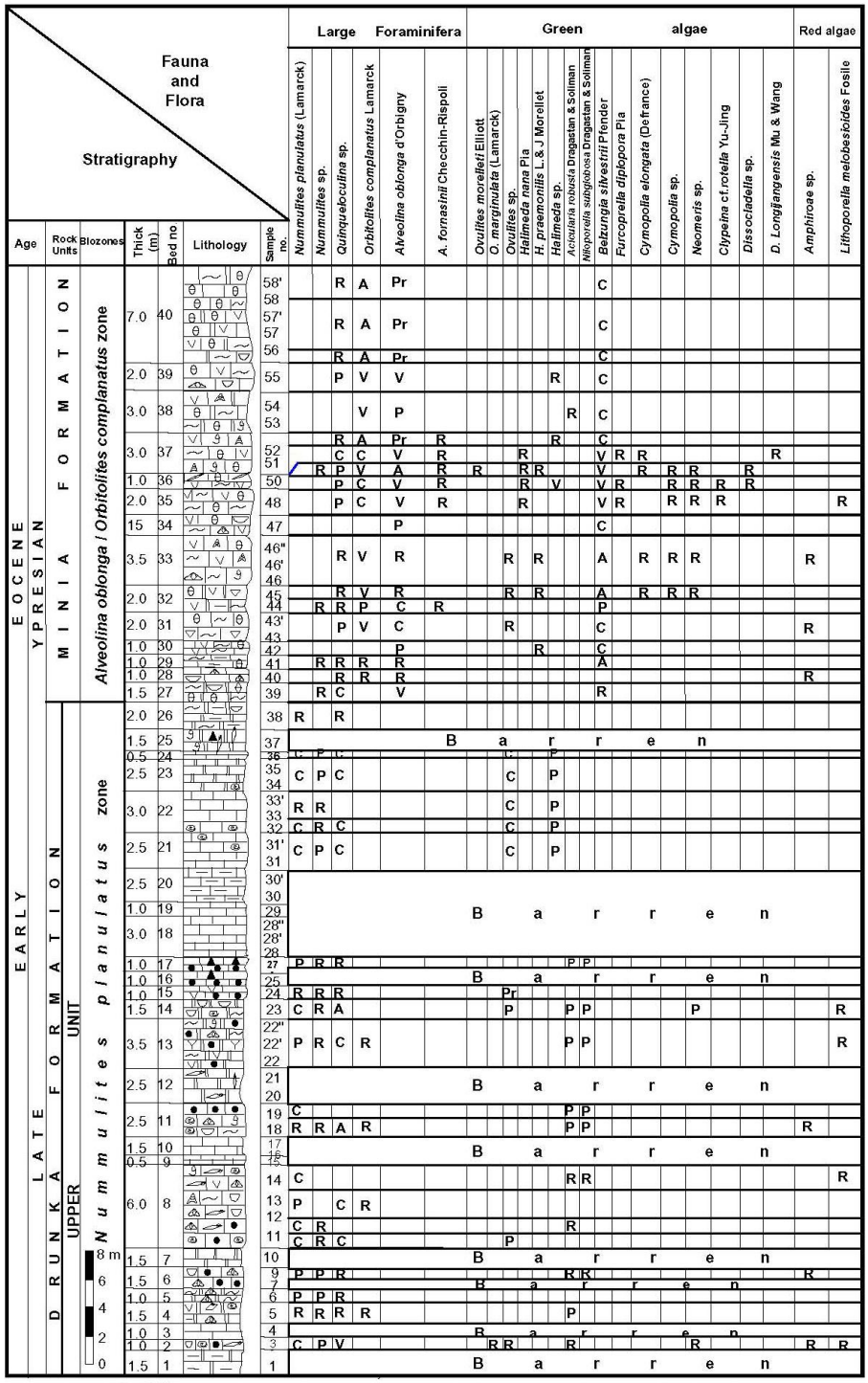

Fauna and Flora
Stratigraphy
Large Foraminifera
Green algae
Red algae
Nummulites planulatus (Lamarck)
Nummulites sp.
Quinqueloculina sp.
Orbitolites complanatus Lamarck
Alveolina oblonga d'Orbigny
A. fornasinii Checchin-Rispoli
Ovulites morelleti Elliott
O. marginulata (Lamarck)
Ovulites sp.
Halimeda nana Pia
H. praemonilis L. & J. Morellet
Halimeda sp.
Acicularia robusta Dragastan & Soliman
Nikoporella subglobosa Dragastan & Soliman
Belzungia silvestrii Pfender
Furcoprella diplopora Pia
Cymopolia elongata (Defrance)
Cymopolia sp.
Neomeris sp.
Clypeina cf. rotella Yu-Jing
Dissocladella sp.
D. Longjiangensis Mu & Wang
Amphiroae sp.
Lithoporella melobesioides Fosile
Age
Rock Units
Biozones
Thick (m)
Bed no
Lithology
Sample no.
EOCENE
EARLY
LATE
YPRESIAN
DRUNKA FORMATION
MINIA FORMATION
UPPER
Nummulites planulatus zone
Alveolina oblonga / Orbitolites complanatus zone
8 m
6
4
2
0

Fig. (6)

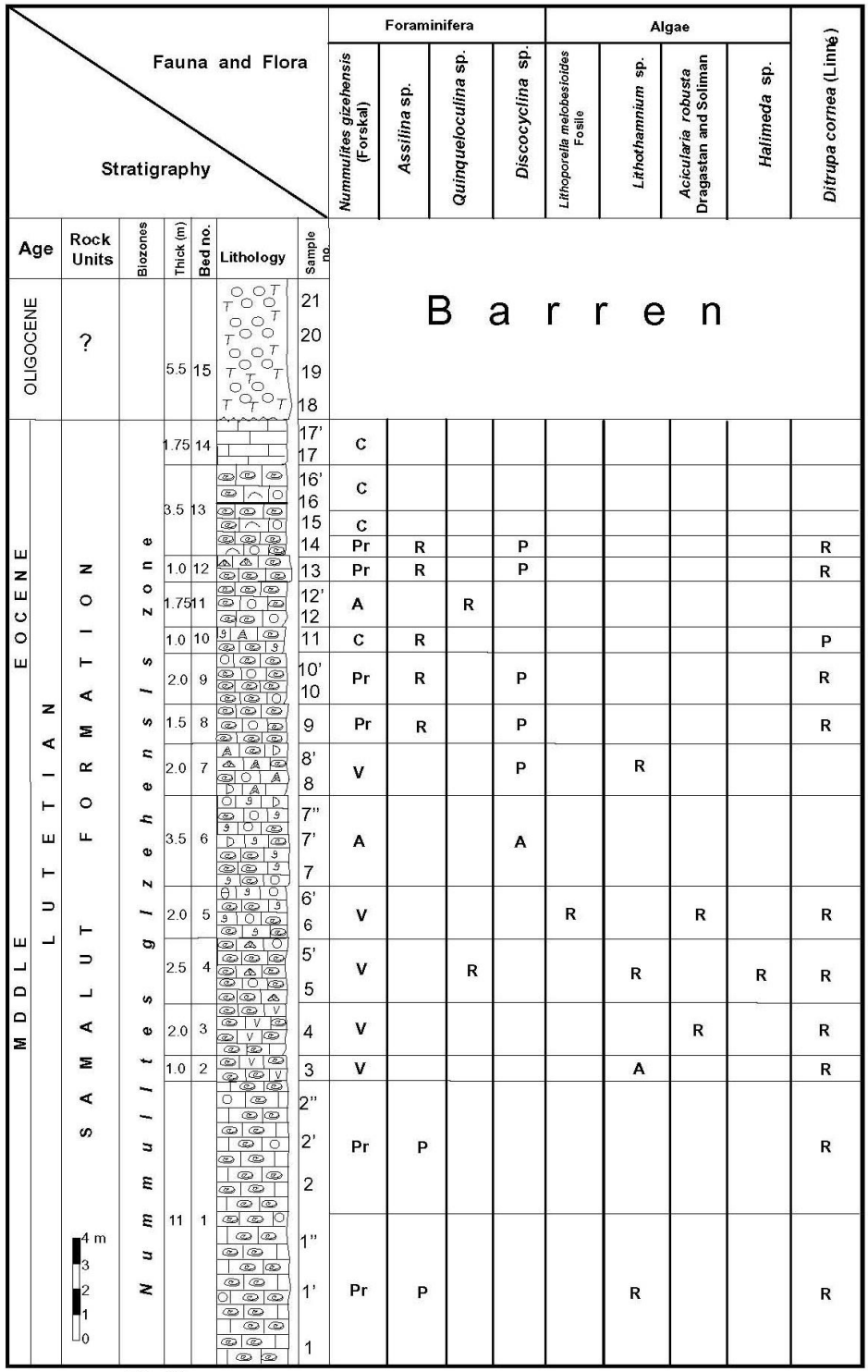
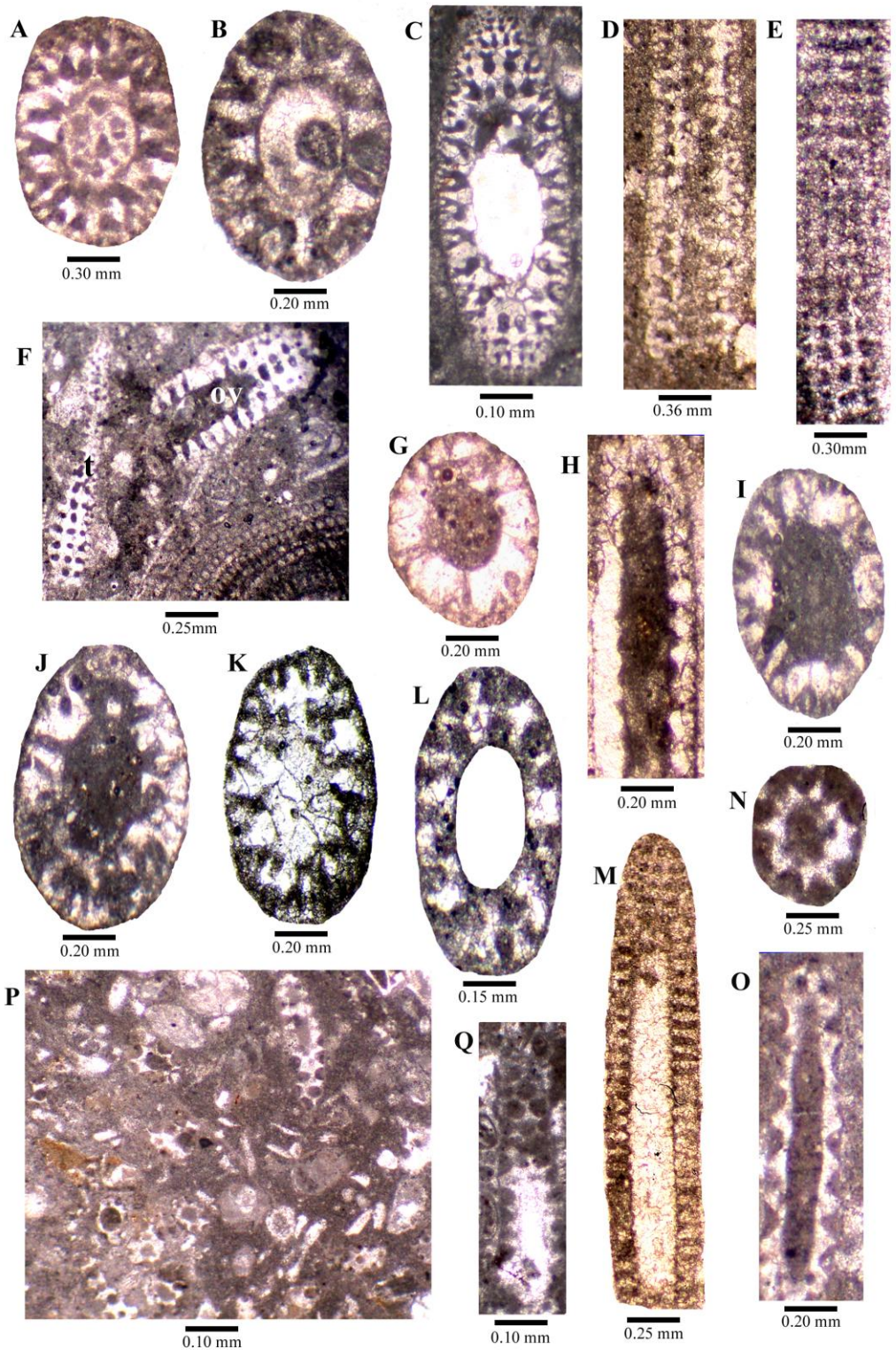

Fauna and Flora
Stratigraphy
Foraminifera
Algae
Nummulites gizehensis (Forskal)
Assilina sp.
Quinqueloculina sp.
Discocyclina sp.
Lithoporella melobesioides Fosile
Lithothamnium sp.
Acicularia robusta Dragastan and Soliman
Halimeda sp.
Ditrupa cornea (Linné)
Age
Rock Units
Biozones
Thick (m)
Bed no.
Lithology
Sample no.
OLIGOCENE
?
Barren
EOCENE
MIDDLE
LUTETIAN
SAMALUT FORMATION
Nummulites gizehensis zone
4 m
3
2
1
0

Fig.(7)


A
0.30 mm
B
0.20 mm
C
0.10 mm
D
0.36 mm
E
0.30mm
F
ov
t
0.25mm
G
0.20 mm
H
0.20 mm
I
0.20 mm
J
0.20 mm
K
0.20 mm
L
0.15 mm
N
0.25 mm
M
0.25 mm
O
0.20 mm
P
0.10 mm
Q
0.10 mm

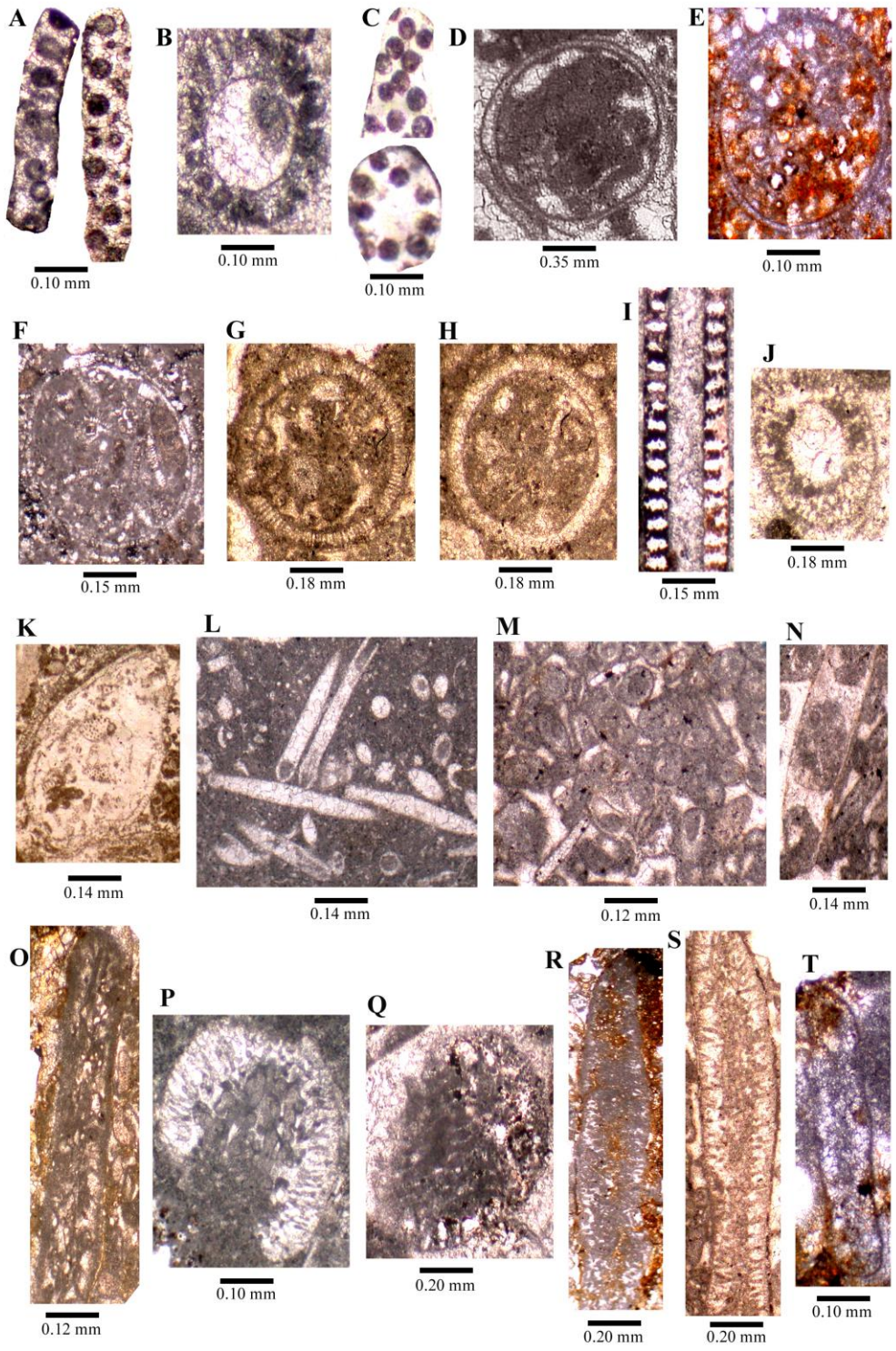

A
0.10 mm
B
0.10 mm
C
0.10 mm
D
0.35 mm
E
0.10 mm
F
0.15 mm
G
0.18 mm
H
0.18 mm
I
0.15 mm
J
0.18 mm
K
0.14 mm
L
0.14 mm
M
0.12 mm
N
0.14 mm
O
0.12 mm
P
0.10 mm
Q
0.20 mm
R
0.20 mm
S
0.20 mm
T
0.10 mm

**Table 1**

| SECTION / AGE | | EL-ZARABI | | ISMAIL BEY | | GEBEL GIBEIL | | MALLAWI |
|---|---|---|---|---|---|---|---|---|
| MIDDLE EOCENE | LUTETIAN | ---------- | | ---------- | | ---------- | | Samalut Formation (36.5 m) |
| EARLY EOCENE | LATE YPRESIAN | ---------- | | ---------- | | Minia Formation (31.5 m) | | ---------- |
| | | Drunka Formation (133.75 m) | Upper unit | Drunka Formation (35.5 m) | Upper unit | Drunka Formation (48.5 m) | Upper unit | ---------- |
| | EARLY YPRESIAN | | Lower unit | | ------- | | ------- | ---------- |

-------- not recorded

**Table 2**

| AGE / SECTION | | EL-ZARABI | | ISMAIL BEY | | GEBEL GIBEIL | MALLAWI |
|---|---|---|---|---|---|---|---|
| MIDDLE EOCENE | LUTETIAN | ---------- | | ---------- | | ---------- | *Nummulites gizehensis s.l* zone |
| EARLY EOCENE | LATE YPRESIAN | ---------- | | ---------- | | *Alveolina oblonga / Orbitolites complanatus* zone | ---------- |
| | | *Nummulites planulatus* zone | *Ovulites elongata* subzone | *Nummulites planulatus* zone | *Acicularia robusta/ Ovulites* spp. subzone | *Nummulites planulatus* zone | ---------- |
| | | | *Niloporella subglobosa* subzone | | *Niloporella subglobosa* subzone | | |
| | EARLY YPRESIAN | *Ovulites arabica/Ovulites pyriformis* zone | | ---------- | | ---------- | ---------- |

-------- not recorded

**Table 3**

| ROCK UNIT | LITHOLOGY | SEDIMENTARY STRUCTURES | FOSSIL ABUNDANCE | MAJOR TAXA | TEXTURES | DEPOSITIONAL ENVIRONMENT |
|---|---|---|---|---|---|---|
| Drunka Formation | Porous algal limestone with chert | Burrowing, ripple marks, wavy and lenticular bedding and massive to thick-bedded | Medium | Green algae, echinoids, nummulites & miliolids | Lime mudstone, wackestone, packstone and grainstone | Restricted shelf lagoon |
| Minia Formation | Aleveolinid and orbitiolinid limestone | Massive to thick-bedded and burrowed | High | Alveolines, orbitolites & green algae | Wackestone, packstone and grainstone | Alveolina-orbitolites-green algae bank |
| Samalut Formation | Nummulitic limestone | Unbedded massive of mound shape | Very high | Nummulites, bryozoa, discocycline & red algae | Wackestone, packstone and grainstone | Nummulitic bank |

**Table 4**

| DIVISION | CLASS | ORDER | FAMILY | TRIBE | GENERA & SPECIES |
|---|---|---|---|---|---|
| Cholorophyta | Cholorophyceae | Dasycladales | Dasycladaceae | Thyrsoporellidae | *Belzungia silvestrii*<br>*Dissocldella* sp. |
| | | | | Cymopolieae | *Cymopolia elongata*<br>*Cymopolia* sp. |
| | | | | Macroporellineae | *Furcoporella diplopora* |
| | | | | Dasycladeae | *Niloporella subglobosa* |
| | | | | Neomereae | *Neomeris* sp. |
| | | | Acetabulariaceae | Clypeineae | *Clypeina* cf. *rotella* |
| | | | | Acetaburlarieae | *Acicularia robusta* |
| | Bryopsidophyceae | Bryopsidales | Udoteaceae | ---------- | *Ovulites pyriformis*<br>*Ovulites arabica*<br>*Ovulites morelleti*<br>*Ovulites marginulata*<br>*Ovulites elongata*<br>*Ovulites* sp. |
| | | | Halimedaceae | ---------- | *Halimeda nana*<br>*Halimeda praemonilis*<br>*Halimeda* sp. |