Nannofossils from the Middle-Upper Eocene Strata of Egypt

(with 2 plates and 1 figure)

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Abstract

Samples collected from the Eocene strata of Gabal Mokattam, Burg El Arab Well, Betty Well and Gazalat Well (North Western Desert) were investigated for their microfaunal content. They yield many different associations of calcareous nannofossils and planktonic foraminifera. The present paper deals with the calcareous nannofossils encountered in the studied samples. These minute fossils are used here as a new tool for biostratigraphic zonation of the Eocene strata in Egypt.

Introduction

Generally, the Middle Eocene rocks cover a large area of the surface of Egypt. They are mainly composed of thick marine limestones and marls, indicating fairly deep water conditions especially to the north of Egypt. The Lutetian strata are divided into two well known formations; the Minia Formation (SAID, 1960) at the base and the Mokattam Formation (ZITTEL, 1883) at the top.

The Upper Eocene deposits are totally different from those of the Middle Eocene. Instead of calcareous and marly sediments in the latter, we have sandstones, grits and shales, all highly coloured and ochreous, containing fossils representing neritic or even litoral origin.

To the east of Cairo, at Gabal Mokattam, the middle and upper Eocene strata are well represented and repeatedly studied by many geologists. The writer has collected many samples from this classical section; he received others from the Eocene section of Beni Suef area (about 200 Km. south of Cairo in the Nile Valley), and some drill-cores from Burg El Arab-, Betty- and Ghazalat wells (North Western Desert).

These samples were investigated for their microfaunal content. They yielded many different associations of calcareous nannofossils and planktonic foraminifera.

The present paper deals with the biostratigraphic zonation of the Egyptian Middle and Upper Eocene deposits by means of calcareous nannoplankton.

Burg El Arab Formation is a new formational name given here for the first time to designate the open marine facies of the lower Lutetian strata in Egypt. It is considered equivalent to the reefal facies of the Minia Formation (type section of the Egyptian lower Lutetian, SAID, 1960).

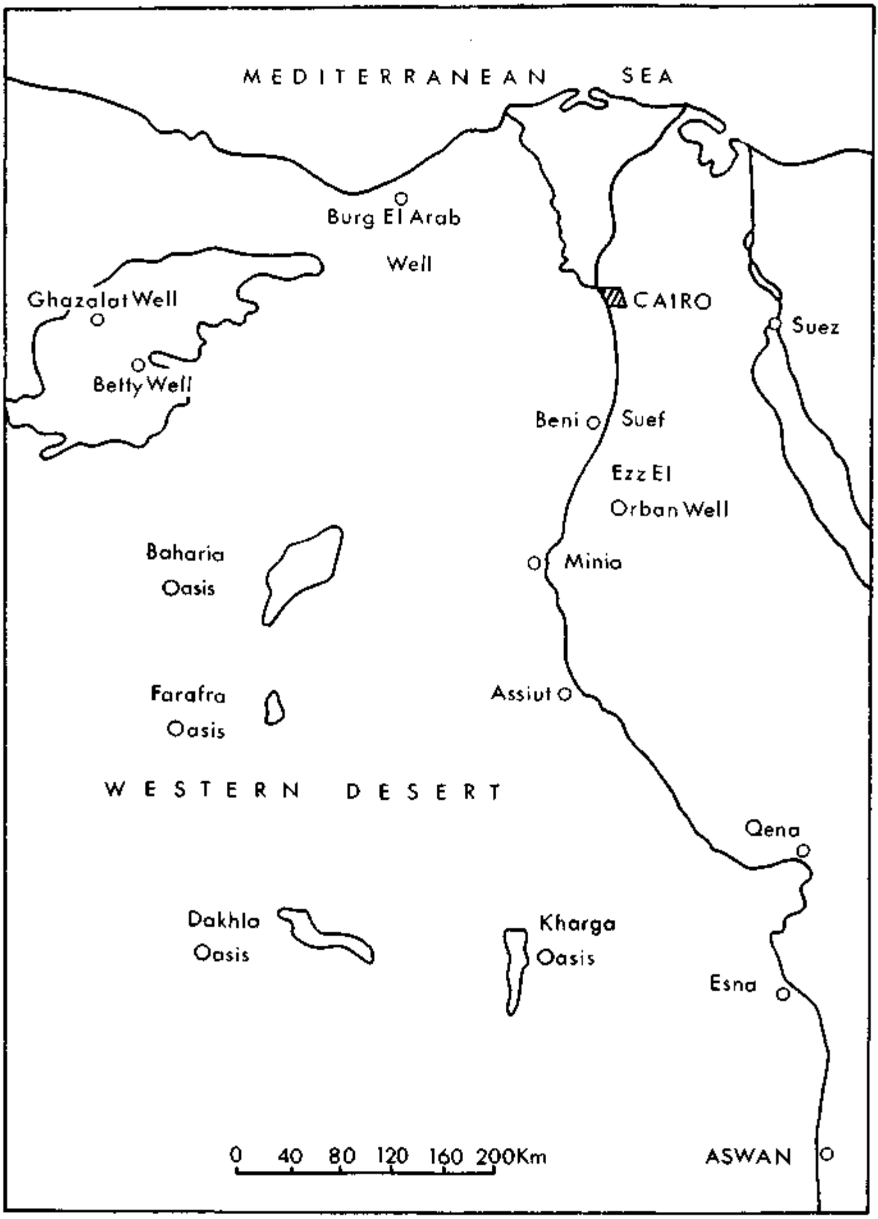

Fig. a

1. General stratigraphy

1.1 Middle Eocene

The stratigraphic sequence of the Middle Eocene deposits in the present study is differentiated from base to top as follows:

Burg El Arab Formation

The studied core samples from Burg El Arab well, depth 5020 to 5124 ft., are mainly composed of marls and shaly limestones, representing facies related to open sea conditions. They attain about 100 ft. thickness containing the following planktonic foraminiferal species and calcareous nannoplankton:

Planktonic foraminifera:

Globigerapsis kugleri
Globigerina frontosa
Globigerina yeguaensis
Globorotalia bullbrooki
Globorotalia lehneri
Globorotalia spinulosa
Truncorotaloides rohri
Truncorotaloides topilensis

Calcareous nannoplankton:

Genus: *Discoaster* TAN SIN HOK, 1927
D. binodosus
D. gemmifer
D. lodoensis
D. mirus
D. sublodoensis

Genus: *Chiasmolithus* HAY, MOHLER & WADE, 1966
C. bidens
C. grandis

Genus: *Chiphragmalithus* BRAMLETTE & SULLIVAN, 1961
C. spinosus

Genus: *Coccolithus* SCHWARZ, 1894
C. eopelagicus
C. solitus

Genus: *Cyclococcolithus* KAMPTNER, 1954
C. spp.

The forementioned planktonic associations of calcareous nannofossils and foraminifera point to lower Lutetian age. On the western side of the Gulf of Suez, in Ezz El Orban well (160 Km. south of Suez, see the index map), a formation representing an open marine facies (150 ft. thick) and of lower Lutetian age, similar in that respect to the present formation of Burg El Arab well, is recorded by BARAKAT & FAHMY (1968).

Globigerapsis kugleri Zone — which is related to the lower Lutetian in many parts of the world — has been encountered in Burg El Arab Formation and detected from other subsurface sections in the western desert.

It means, that Burg El Arab Formation has a wide geographic distribution, since it is traceable in the subsurface of the western desert and present in the Gulf of Suez. The present writer thinks that this formation could be synchronic with the Minia Formation (type section of the lower Lutetian in Egypt).

However, Burg El Arab Formation represents an open marine facies, differing genetically from the reefal facies of the Minia Formation. Hence a new formational name is introduced here to represent the open marine facies of the lower Lutetian in Egypt.

Mokattam Formation

SAID & MARTIN (1964) subdivided the Mokattam Formation into four members as follows from top to base:

Guishi member

Upper Building stone member

Nummulites gizehensis member

Lower Building stone member

The age of the lower three members is upper Lutetian and the upper most unit (Guishi member) is Bartonian.

Samples collected from the Upper Building stone member, at Gabal Mokattam and at Beni Suef area in the Nile Valley, were found to be highly fossiliferous with a well known group of calcareous nannofossils, termed as *Discoaster barbadiensis/saipanensis* association.

The following is a list of the planktonic foraminifera and calcareous nannoplankton encountered in the basal part of the Mokattam Formation:

Planktonic foraminifera

(Beni Suef area):
Globigerina boweri
Globigerina praebulloides
Globorotalia lehneri
Globorotalia spinulosa
Globorotalia spinulionflata
Globigerinatheka barri
Hantkenina dumblei
Truncorotaloides rohri
Truncorotaloides topilensis

Calcareous nannoplankton:

Genus: *Discoaster*
D. aster
D. barbadiensis
D. niloticum
D. saipanensis
D. quinarius
D. spp.
Genus: *Braarudosphaera*
B. discula
B. bigelowi

These faunal associations point to Upper Lutetian age.

1.2. Upper Eocene

Maadi Formation

Conformably overlying the Mokattam Formation, the Maadi Formation (SAID, 1962) is made up of a series of easily identified, well developed, brownish sandy limestones, marls and shales. These sediments are exposed along Gabal Mokattam cliffs east of Cairo.

Samples collected from this stratigraphic horizon at Gabal Mokattam area, were found to contain badly preserved forms of calcareous nannofossils. The occurrence of these minute fossils could be considered as a direct result of reworking of the older strata.

However, other marly samples collected from a similar stratigraphic unit at Heit El Ghorab area — a longitudinal ridge located 3 Km. south of the Sphinx — yielded the following calcareous nannoplankton:

Genus: *Discoaster*
- *D. barbadiensis*
- *D. crassus*
- *D. plebeius*
- *D. saipanensis*
- *D. spp.*

Genus: *Micrantholithus*
- *M. flos*

Genus: *Trochoaster*
- *T. simplex*

It is of interest to record here, that the planktonic foraminiferal species are totally absent in the sediments of Maadi Formation. The occurrence of the above mentioned calcareous nannoplankton — which are related to planktonic organisms — could be explained by reworking.

2. Nannoplankton Zonation of the Eocene Sediments in Egypt

Several papers have been published on the nannoplankton zonation of the Eocene sediments in different parts of the world, Austria, Czechoslovakia, Poland, Switzerland, France, Gulf Coast, the Carribean-Antillean area, California etc..

The nannoplankton zonation introduced by HAY et al. (1967) represents the most outstanding one, and has been followed lateron by many authors. Their zonation of the Paleocene — Eocene strata in SW France is as follows:

Isthmolithus recurvus	Zone	
Discoaster tani nodifera	Zone	
Chiphragmalithus quadratus	Zone	
Discoaster sublodoensis	Zone	
Discoaster lodoensis	Zone	
Marthasterites tribrachiatus	Zone	
Discoaster binodosus	Zone	
Marthasterites contortus	Zone	. . . . Eocene
Discoaster multiradiatus	Zone	
Heloilithus riedeli	Zone	
Discoaster gemmeus	Zone	
Heliolithus kleinpelli	Zone	
Fasciculithus tympaniformis	Zone	. . . . . . Paleocene
Cruciplacolithus tenuis	Zone	. . . . Danian
Markalius astroporus	Zone	. . U. Maestrichtian

As the present paper deals only with the calcareous nannoplankton encountered in the Egyptian Eocene sediments, we shall discuss the nannoplankton-zone recognized in these deposits beginning from base to top as follows:

2.1 Marthasterites tribrachiatus Zone

Cuba

As originally proposed by BRÖNNIMANN & STRADNER (1960), *Marthasterites tribrachiatus* Zone was based on the calcareous nannoplankton encountered in the Capdevila Formation of the Habana area, Cuba. It is characterized by the joint occurrence of *Marthasterites tribrachiatus* and *Discoaster lodoensis*. Other common species include:
Discoaster distinctus
D. binodosus
D. barbadiensis

United States (California)

Under the name "*Discoaster tribrachiatus* Zone", this zone is introduced by BRAMLETTE & SULLIVAN (1961) in their paper on the "Coccolithophorids and related Nannoplankton of the Early Tertiary in California". They stated "the name *Discoaster tribrachiatus* Zone seems appropriate for strata included in biostratigraphic Unit 3 and its equivalents elsewhere, as the species is locally restricted to this unit". They proved that Unit 3 (*Discoaster tribrachiatus* Zone) of the Lodo Formation includes strata that could be correlated well with the Ypresian Stage (Lower Eocene).

France

HAY & MOHLER (1967) defined *Marthasterites tribrachiatus* Zone as the "interval from the first occurrence of *Discoaster lodoensis* to the last occurrence of *Marthasterites tribrachiatus*. It is found that, in the section exposed south of Pau, SW France, the beds, that can be observed in the Tuilerie de Gan, belong to the top of the *Marthasterites tribrachiatus* Zone.

Germany

In 1959, MARTINI proposed a nannoplankton-zonation for the Eocene strata in NW Germany. The "Unter Eozän 3" of MARTINI seems to belong to the *Marthasterites tribrachiatus* Zone, as forms of *Marthaterites tribrachiatus* occur in abundance in this unit.

Austria

According to STRADNER & PAPP (1961), *Marthasterites tribrachiatus* Zone is represented by a section exposed in the Mattsee area, Salzburg, Austria, with an association of microfauna containing *Globorotalia* *aragonensis* (Lower Eeocene). In the Hagenbach Valley, STRADNER (1969) proposed two new subzones which can be discerned within the *Marthasterites tribrachiatus* Zone as follows:

Scyphosphaera tubicena subzone
Scyphosphaera columella subzone

Italy

HAY & MOHLER (1967) deduced that the *Marthasterites tribrachiatus* Zone extends stratigraphically from the upper part of the *Globorotalia formosa formosa/Globorotalia aragonensis* Zone to the lower part of the *Hantkenina aragonensis Zon*e of BOLLI & CITA (1960). These zones are recorded from the Eocene section located at Paderno d'Adda area, Italy.

Slovakia

In 1968, SAMUEL & BYSTRICKA introduced their "*Marthasterites tribrachiatus* + *Discoaster lodoensis* Zone". It is found that this zone is correlated with *Globoratalia aragonensis* Zone of Lower Eocene age.

Egypt

Marthasterites tribrachiatus Zone has been recorded by SADEK & ABD EL RAZIK (1970) from Lower Eocene strata related paleontologically to the *Globorotalia subbotinae* Zone (BECKMANN et al., 1967) = *Globorotalia wilcoxensis* Zone of EL NAGGAR (1967). On account of its stratigraphical occurrences in many localities in Egypt, *Marthasterites tribrachiatus* Zone represents the basal part of the Ypresian. It is of interest to record here, that *Marthasterites tribrachiatus* seems to be restricted to this zone and usually occurs without *Discoaster lodoensis*.

2.2 Discoaster lodoensis Zone

Cuba

Originally proposed by BRÖNNIMANN & STRADNER (1960) from the Middle Eocne strata of Cuba.

France

HAY & MOHLER (1967) regarded *Discoaster lodoensis* Zone as Early Eocene and define it as "the interval from the last occurrence of *Marthasterites tribrachiatus* to the first occurrence of *Discoaster sublodoensis*.

Germany

A typical *Discoaster lodoensis* Zone assemblage of calcareous nannoplankton is encountered in the "unteres Ober Eozän" of MARTINI (1959). Other common species include:

Discoaster barbadiensis
D. septemradiatus
D. distinctus
D. binodosus binodosus

D. plebeius
D. germanicus
D. nonaradiatus
Trochoaster simplex
Micrantholithus flos

Austria

Discoaster lodoensis Zone is exposed at Oberkreuzstetten near the Hipplinger Heide north of Vienna (HEKEL, 1968). The strata are assigned to the lower Lutetian age with a nannoplankton assemblage containing *Discoaster lodoensis* without *Marthasterites tribrachiatus.*

Italy

The middle part of the *Hantkenina aragonensis* Zone of BOLLI & CITA (1960) is found to correspond to the *Discoaster lodoensis* Zone (HAY & MOHLER, 1967). It is well known, that *Hantkenina aragonensis* Zone represents the lower Lutetian in Italy, Trinidad, Egypt, and many other countries.

Poland

Discoaster lodoensis Zone is recorded in the Flysch of the Polish outer Carpathians (BIEDA, 1966, RADOMSKI, 1967) and it is assigned to the lower Lutetian age.

Slovakia

According to SAMUEL & BYSTRICKA (1968) the *Discoaster lodoensis* Zone represents the lower Lutetian. They described this zone as "*Discoaster*-Zone" containing *Discoaster lodoensis* without *Marthasterites tribrachiatus.* The following planktonic foraminiferal species were found to occur in this zone:

Globigerina senni
Globigerina boweri
Globorotalia renzi
Globorotalia spinulosa

Egypt

In the present paper, the writer introduces *Discoaster lodoensis* Zone, which is detected in Betty Well (North Western Desert). This zone is located in strata, assigned to the upper Ypresian age, containing a typical calcareous nannoplankton assemblage of *Discoaster lodoensis* Zone without *Marthasterites tribrachiatus,* the same as in Austria and Slovakia. From the stratigraphical point of view, *Discoaster lodoensis* Zone is correlated here with the *Globorotalia formosa formosa* Zone and *Globorotalia aragonensis* Zone of BECKMANN et al. (1967), representing the upper part of the lower Eocene strata in Egypt. However, forms of *Discoaster lodoensis* are observed to occur not only in the Ypresian, but also in some Lutetian strata e. g., Gabal Mokattam Formation; this led to the conclusion that *Discoaster lodoensis* Zone may be ranging from the Ypresian to the Lutetian.

2.3. Discoaster sublodoensis Zone

France

The *Discoaster sublodoensis* Zone is defined by HAY et al. (1967) from their studies on the Eocene strata in France, as "the interval from the first occurrence of *Discoaster sublodoensis* to the first occurrence of *Chiphragmalithus quadratus*.

Austria

In 1968, HEKEL reported the occurrence of *Discoaster sublodoensis* from the upper part of the "Obere Coccolithenschiefer" in the Flysch north of Vienna. This seems to be the youngest part of the Flysch sediments in the sequences of that area (STRADNER, 1969).

Slovakia

In the middle part of the "*Discoaster*-Zone" of SAMUEL & BYSTRICKA (1968) in the middle Lutetian of Slovakia, *Discoaster barbadiensis* and *Discoaster saipanenis* are found to be characteristic. STRADNER (1969, p. 428) stated "as *Discoaster sublodoensis* and *Discoaster saipanensis* are two very closely related species with rather similar outline, it might be rather a matter of different interpretation than of different species". Accordingly, the middle part of the "*Discoaster*-Zone" seems to be equivalent to *Discoaster sublodoensis* Zone.

Egypt

Discoaster sublodoensis Zone is detected in Ghazalat Well (North western desert) at a depth of 1112—1132 ft. The strata contain planktonic foraminiferal assemblages, characteristic of the lower Lutetian. *Discoaster sublodoensis* Zone corresponds to Burg El Arab Formation (see p. 109) representing the lowest part of the Lutetian in Egypt. It seems equivalent to the *Globorotalia bullbrooki* Zone and *Globigerapsis kugleri* Zone of BECKMANN et al. (1967).

2.4. Discoaster barbadiensis/saipanensis Zone

In the nannoplankton zonation of HAY et al. (1967) the upper part of the Lutetian strata (Middle Eocene) is represented by *Chiphragmalithus quadratus* Zone and *Discoaster tani* Zone. Those two zones are not detected in Egypt.

However, this part of the Eocene deposits, which is well known in the Egyptian stratigraphy as "Mokattam Formation", is characterized by the abundance of both *Discoaster barbadiensis* and *Discoaster saipanensis* species.

For this stratigraphic unit, the name *Discoaster barbadiensis/saipanensis* Zone may prove appropriate and seems to be recognizable as a zonal unit in many localities in Egypt (Nile Valley and Western Desert). It is of interest to record here that *Discoaster barbadiensis/saipanensis* Zone represents not only part of the upper Lutetian (Middle Eocene), but also the lower part of the Bartonian (Upper Eocene) in Egypt.

Nannoplankton Zonation of the Lower Tertiary in Egypt

A G E			Planktonic zones in Egypt BECKMANN et al. (1967)	Nannoplankton Zonation KERDANY (1969)	Nannoplankton Zonation SADEK (1970)
Tertiary	Eocene	Bartonian (Upper)	*Cribrohantkenina danvillensis* *Globorotalia cerroazulensis* *Globigerapsis semiinvolutus*		
Tertiary	Eocene	Lutetian (Middle)	*Truncorotaloides pseudodubius* *Porticulasphaera mexicana* *Globorotalia lehneri* *Globigerapsis kugleri* *Globorotalia bullbrooki*		*Discoaster barbadiensis/ D. saipanensis* Zone *Discoaster sublodoensis* Zone
Tertiary	Eocene	Ypresian (Lower)	*Globorotalia aragonensis* *Globorotalia formosa formosa* *Globorotalia subbotinae*		
Tertiary	Paleocene	Landenian	Globorotalia *velascoensis* *Globorotalia pseudomenardii* *Globorotalia angulata*	*D. multiradiatus/ M. contortus* Zone *Heliolithus kleinpelli* Zone	*Discoaster lodoensis* Zone *Marthasterites tribrachiatus* Zone
Tertiary	Paleocene	Montian Danian	*Globorotalia uncinata* Globorotalia *trinidadensis* Globigerina *pseudobulloides*	*Cruciplacolithus tenuis* Zone	*M. bramlettei/ M. contortus* Zone *Discoaster multiradiatus* Zone

3. Systematic Descriptions

Two main groups of the calcareous nannoplankton can be discerned in the examined samples from the Eocene strata of Egypt: firstly the star and rosette-shaped forms known as *Discoasters*, and secondly elliptical, round, polygonal, and tubular forms known as *Coccoliths*.

The described forms are those recognized and determined with the help of the light microscope. Forms smaller than 4 micron are not considered, as such forms fall into the scope of the electronic microscope.

Ordo: *COCCOLITHOPHORALES* SCHILLER, 1926
Subordo: *Discoasterineae* KAMPTNER, 1967
Familia: *Discoasteromonadaceae* BURSA, 1965
Genus: *Discoaster* TAN SIN HOK, 1927
Discoaster aster BRAMLETTE & RIEDEL

(Plate 1, figure 1 and 14)

1954 *Discoaster aster* BRAMLETTE & RIEDEL, p. 400, pl. 39, fig. 7.
1961 *Discoaster aster* BRAMLETTE & RIEDEL; STRADNER & PAPP, p. 63, pl. 1, figs. 1—7.

Asterolith stellate with commonly five or six thick rays, which terminate in a rounded or bluntly pointed tip. The rays are somewhat irregular in outline due to their rather rugose surface.

Distribution: Originally recorded from the Paleocene of Austria (STRADNER & PAPP, 1961). However, the occurrence of *D. aster* in the Lutetian strata of Egypt indicates, that this species may occur throughout the lower Tertiary.

Discoaster barbadiensis TAN SIN HOK

(Plate 1, figures 2 and 3)

1927 *Discoaster barbadiensis* TAN SIN HOK, p. 119.
1954 *Discoaster barbadiensis* TAN SIN HOK; BRAMLETTE & RIEDEL, p. 398, pl. 39, figs. 5 a, b.
1961 *Discoaster barbadiensis* TAN SIN HOK; STRADNER & PAPP, p. 95, pl. 28, figs. 1, 2.
1967 *Discoaster barbadiensis* TAN SIN HOK; LEVIN & JOERGER, p. 172, pl. 3, fig. 17 a, b.

This species is characterized by having 9—13 rays joined throughout their length with bluntly pointed tips forming a serrate margin to the disc. The central area is always occupied by a prominent stem.

Distribution: *Discoaster barbadiensis* is recorded from many Eocene sections allover the world. This species is very common in the Middle-Upper Eocene strata of Egypt, characterizing the Mokattam Formation, hence *Discoaster barbadiensis/saipanensis* Zone is proposed by the present writer.

Discoaster binodosus MARTINI

(Plate 1, figure 4)

1958 *Discoaster binodosus* MARTINI, p. 362, pl. 4, figs. 18 a, b.
1961 *Discoaster binodosus* MARTINI; STRADNER & PAPP, p. 66, pl. 4, figs. 1—7, pl. 5, figs. 1—6.
1967 *Discoaster binodosus* MARTINI; RADOMSKI, p. 388.
1970 *Discoaster binodosus* MARTINI; SADEK & ABD EL RAZIK, p. 51, pl. 4, fig. 4.

Asteroliths with 6—9 rays with pointed or nodged tips. Each ray has always two lateral nodes.

Distribution: Commonly present in the Upper Paleocene-Lower Eocene sediments of many regions in the world. STRADNER & PAPP (1961) recorded forms similar to our specimens occuring in the Upper Lutetian strata of Austria. Therefore the upper limit of the occurrence of *Discoaster binodosus* is still uncerain (STRADNER, 1969).

Discoaster crassus MARTINI

(Plate 1, figure 5)

1959 *Discoaster crassus* MARTINI, p. 138.

Asteroliths consists of 6 sharply pointed rays, joined throughout their length.

Dirstribution: Originally recorded from the Upper Eocene of NW Germany (MARTINI, 1959). Commonly occurs in the Maadi Formation (Upper Eocene), at Heit El Ghorab area, near the Sphinx, Egypt.

Discoaster gemmifer STRADNER

(Plate 1, figure 6)

1961 *Discoaster gemmifer* STRADNER; STRADNER & PAPP, p. 69, pl. 8, figs. 1—10, pl. 9, figs. 1—5.
1968 *Discoaster gemmifer* STRADNER; SAMUEL & BYSTRICKA, p. 122.
1969 *Discoaster* cf. *gemmifer* STRADNER; STRADNER, p. 408, pl. LXXXII, figs. 5—10.

Asteroliths with 4—8 rays. It is characterized by its widely bifurcating tips with adjacent lateral nodes. This species resembles *D. deflandrei* and *D. distinctus* in having a similar outline.

Distribution: Very abundant in the Lower Eocene to the lower Middle Eocene (STRADNER, 1969). In Egypt, *Discoaster gemmifer* is common throughout the Lutetian strata. It is recorded in the Nile Valley, near Beni Suef area from Upper Lutetian sediments (HASSAN, SADEK & BOUKHARY, 1970) and detected by the present writer in the lower Lutetian strata of the North Western Desert, subsurface sections.

Discoaster lodoensis BRAMLETTE & RIEDEL

(Plate 1, figure 9)

1954 *Discoaster lodoensis* BRAMLETTE & RIEDEL, p. 398, pl. 39, figs. 3 a, b.
1960 *Discoaster lodoensis* BRAMLETTE & RIEDEL; BRÖNNIMANN & STRADNER, p. 369.
1961 *Discoaster lodoensis* BRAMLETTE & RIEDEL; STRADNER & PAPP, p. 92, pl. 25, figs. 1—10, pl. 26, figs. 1—6.
1961 *Discoaster lodoensis* BRAMLETTE & RIEDEL; BRAMLETTE & SULLIVAN, p. 161, pl. 12, figs. 4 a, b, 5.
1967 *Discoaster lodoensis* BRAMLETTE & RIEDEL; HAY & MOHLER, p. 1523.
1969 *Discoaster lodoensis* BRAMLETTE & RIEDEL; STRADNER, p. 410, pl. LXXXI, figs. 1—8.

Asteroliths having usually a stellate outline with 6 to 7 rays. This species is characterized by the curvature of its rays in the same sense in the plane of the body of the asterolith. The central area is occupied by a short knob.

Distribution: Common in the Lower and Middle Eocene of many regions. In Egypt, *Discoaster lodoensis* commonly occurs in the Lower Eocene sections of the North Western Desert. However, this species is also noticed in some Lutetian sediments in the Nile Valley (Beni Suef Area, and Gabal El Mokattam).

Discoaster mirus DEFLANDRE

(Plate 1, figure 7)

1954 *Discoaster mirus* DEFLANDRE; DEFLANDRE & FERT, p. 168, text-fig. 118.
1961 *Discoaster mirus* DEFLANDRE; STRADNER & PAPP, p. 68, pl. 6, figs. 1—6, pl. 7, figs. 1—5.
1964 *Discoaster mirus* DEFLANDRE; STRADNER, p. 138, text-fig. 28.
1968 *Discoaster mirus* DEFLANDRE; SAMUEL & BYSTRICKA, pp. 122, 125, 126.
1969 *Discoaster mirus* DEFLANDRE; STRADNER, p. 410, pl. LXXXII, figs. 2, 3.

This species is characterized by having 6—8 rays which have two terminal and two lateral nodes.

Distribution: *Discoaster mirus* has been recorded from the lower Lutetian of Mexico, common in the Lutetian of Austria (STRADNER & PAPP, 1961). This species occurs in abundance in the lower Lutetian strata of Burg El Arab Well (North Western Desert, Egypt).

Discoaster saipanensis BRAMLETTE & RIEDEL

(Plate 1, figure 10)

1954 *Discoaster saipanensis* BRAMLETTE & RIEDEL, p. 398, pl. 39, fig. 4.
1961 *Discoaster saipanensis* BRAMLETTE & RIEDEL; STRADNER & PAPP, p. 90, pl. 22, figs. 5—7, 9.
1970 *Discoaster saipanensis* BRAMLETTE & RIEDEL; HASSAN, SADEK & BOUKHARY, p. 7, pl. 1, fig. 10.

This species is characterized by having 7—8 sharply pointed rays. The central area is occupied by a prominent knob.

Distribution: Originally recorded from the upper deposits of Saipan. Very common throughout the Lutetian of many regions. In Egypt, *Discoaster saipanensis* occurs abundantly in the upper Lutetian strata of Gabal Mokattam, east of Cairo (Egypt).

Discoaster sublodoensis BRAMLETTE & SULLIVAN

(Plate 1, figure 13)

1961 *Discoaster sublodoensis* BRAMLETTE & SULLIVAN, p. 162, pl. 12, fig. 6 a, b.

Asteroliths, with 5 sharply pointed rays, which are joined together through about half their length, and straight-radiating in the separated outer part. High part of each ray forms a ridge along one side, which turns sharply counter-clockwise (BRAMLETTE & SULLIVAN, 1961). The present forms of *Discoaster sublodoensis* recognized in Eocene samples from the Northwestern Desert, are very similar to those described and illustrated by BRAMLETTE & SULLIVAN (1961).

Distribution: Originally recorded from the Middle Eocene strata of California, Texas (U. S. A.) and France. *Discoaster sublodoensis* occurs abundantly in the Lower Lutetian sediments of many Eocene sections in the North Western Desert, hence the name *Discoaster sublodoensis* Zone is proposed here by the present writer to distinguish the lower Lutetian in Egypt.

Discoaster plebeius MARTINI

(Plate 1, figure 8)

1959 *Discoaster plebeius* MARTINI, p. 138.

This species is characterized by having 6 bluntly pointed rays. It is very similar to *Discoaster brouweri* TAN SIN HOK, however, the stratigraphic position of *D. brouweri* (Miocene) differs greatly from that of *D. plebeius* (Eocene).

Distribution: Very abundant in the Upper Eocene of Germany. Common in the Upper Eocene of the Maadi Formation at Heit El Ghorab area, near the Sphinx, Egypt.

Discoaster quinarius (EHRENBERG), BERSIER

(Plate 1, figure 11)

1854 *Actiniscus quinarius* EHRENBERG, pl. 19, fig. 46.
1939 *Discoaster quinarius* (EHRENBERG), BERSIER, p. 234, figs. 1—4.
1961 *Discoaster quinarius* (EHRENBERG), BERSIER; STRADNER & PAPP, p. 89, pl. 22, figs. 1—4.

Distribution: Common throughout the Lutetian strata of many regions. It is detected in the upper Lutetian strata (Upper Building Stone Member) near Beni Suef area and Gabal El Mokattam.

Discoaster sp. 1

(Plate 1, figure 12)

This species is characterized by having 6 rays, each ray has an enlarged end as seen in the figure. It resembles *Discoaster challengerie* in having a similar outline, however the stratigraphic occurrence is a point of discussion, since the present form is found in Upper Eocene strata of Gabal El Mokattam East of Cairo, while *D. challengeri* is recorded from the Miocene.

Discoaster sp. 2

(Plate 2, figure 1)

Asteroliths, having 6 sharply pointed rays, The central is somewhat large. This species is similar to *Discoaster saipanensis* in the general outline, however it differs in having no stem in the central disc. The present species is detected in the Upper Eocene samples of Heit El Ghorab area, near the Sphinx, Egypt.

Genus *Marthasterites* DEFLANDRE, 1959
Marthasterites tribrachiatus (BRAMLETTE & RIEDEL) DEFLANDRE

1954 *Discoaster tribrachiatus* BRAMLETTE & RIEDEL, p. 397, pl. 38, fig. 11.
1959 *Marthasterites tribrachiatus* (BRAMLETTE & RIEDEL), DEFLANDRE, pp. 138, 139.
1961 *Marthasterites tribrachiatus* (BRAMLETTE & RIEDEL); STRADNER & PAPP, p. 110, pl. 35, figs. 1—4, 7.
1967 *Marthasterites tribrachiatus* (BRAMLETTE & RIEDEL); HAY & MOHLER, p. 1522.
1969 *Marthasterites tribrachiatus* (BRAMLETTE & RIEDEL); STRADNER, p. 411, pl. LXXXIII, figs. 1—8.

Asteroliths with triradiate form. The three rays are separated from each other with an angle of about 120. The rays are usually parallel-edged or slightly tapering, and their tips may be rounded or nodged.

D i s t r i b u t i o n : *Marthasterites tribrachiatus* is considered by the micropaleontologists as a guide fossil in the Lower Eocene strata of many regions. In Egypt, this species occurs in abundance in the Lower Eocene of Abou Had, Gabal Qweina, Loxur and Umm El Heutat area (Southern Egypt).

Subordo: *COCCOLITHINEAE* KAMPTNER, 1958
Familia: *Coccolithaceae* KAMPTNER, 1958
Tribus: *Coccolitheae* KAMPTNER, 1958
Genus: *Chiasmolithus* HAY, MOHLER & WADE, 1966
Chiasmolithus bidens (BRAMLETTE & SULLIVAN) HAY, MOHLER & WADE

(Plate 2, figure 6)

1961 *Coccolithus bidens* BRAMLETTE & SULLIVAN, p. 139, pl. 1, fig. 1.
1966 *Chiasmolithus bidens* (BRAMLETTE & SULLIVAN), HAY, MOHLER & WADE, p. 388.
1969 *Chiasmolithus bidens* (BRAMLETTE & SULLIVAN), HAY, MOHLER & WADE; STRADNER, p. 412, pl. LXXXV, figs. 9—11.

Elliptical placoliths, the central area of which is open and spanned by a diagonal cross. Sometimes, tooth-like projections are present in the central area.

D i s t r i b u t i o n : Recorded from the Paleocene and Eocene of many regions (California and Austria). This species occurs commonly in the Lower Eocene (Ypresian) and the lower Lutetian of Egypt.

Genus: *Chiphragmalithus* BRAMLETTE & SULLIVAN, 1961
Chiphragmalithus sp.

(Plate 2, figure 4)

Basket-like form, with cross septa dividing it into quadrants. The septa seem to be higher than the side wall, especially at the centre. Small minute spines are noticed around the peripheral margin, resembling in that respect *Nannotetraster spinosus* STRADNER.

Distribution: Common throughout the lower Lutetian strata of the North western Desert, Egypt (Betty, Ghazalat, and Burg El Arab Wells).

Genus: *Coccolithus* SCHWARZ, 1894

Coccolithus eopelagicus (BRAMLETTE & RIEDEL), STRADNER & EDWARDS

(Plate 2, figure 8)

1954 *Tremalithus eopelagicus* BRAMLETTE & RIEDEL, p. 392, pl. 38, figs. 2 a, b.
1968 *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL); STRADNER & EDWARDS, p. 15, pl. 6.
1969 *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL); STRADNER& EDWARDS; STRADNER, p. 413, pl. LXXXIV, fig. 11.

Placoliths, elliptical in shape, with larger distal and smaller proximal curved shields. This species is characterized by a longitudinal window occupying the central area.

Distribution: Common throughout the Lutetian of many regions allover the world.

Coccolithus solitus BRAMLETTE & SULLIVAN

(Plate 2, figure 7)

1961 *Coccolithus solitus* BRAMLETTE & SULLIVAN, pp. 140—142, pl. 2, figs. 4 a, b, c.
1964 *Coccolithus solitus* BRAMLETTE & SULLIVAN; SULLIVAN, p. 181, pl. 1, figs. 13 a, b.

Placoliths with closely appressed plates and relatively large central opening transversely spanned by a somewhat delicate x-shaped structure. The placoliths are distinguished from those of *Coccolithus bidens* in having more dilcate x-shaped structure.

Distribution: Originally recorded from the Middle Eocene of California, Lodo Formation (BRAMLETTE & SULLIVAN, 1961). Common in the lower Lutetian strata of Burg El Arab Well (North Western Desert, Egypt).

Genus: *Cycloccolithus* KAMPTNER, 1958

Cycloccolithus sp.

(Plate 2, figure 9)

Placoliths circular in outline having a distal shield larger than the proximal, with a central depression on the distal shield, producing the illusion of a perforation in the light microscope. The present specimens are very similar to those described and illustrated by KAMPTNER and known as *Cycloccolithus formosus*.

Distribution: Common in the lower Lutetian of many regions (Austria, and Czechoslovakia). Very common in Burg El Arab Formation (lower Lutetian in the subsurface Eocene sections in the North Western Desert, Egypt).

Tribus: *Zygosphaereae* KAMPTNER, 1958
Subtribus: *Zygolithinae* STRADNER, 1968
Genus: *Neococcolithes* SUJKOWSKI, 1961
Neococcolithes dubius (DEFLANDRE) BLACK

(Plate 2, figure 5)

1954 *Zygolithus dubius* DEFLANDRE, in DEFLANDRE & FERT, p. 149, figs. 43, 44, 68.
1964 *Chiphragmalithus dubius* (DEFLANDRE) SULLIVAN, p. 179, pl. 1, fig. 2.
1967 *Neococcolithes dubius* (DEFLANDRE), BLACK, p. 143.
1969 *Neococcolithes dubius* (DEFLANDRE), BLACK; STRADNER, p. 418, pl. LXXXVII, figs. 1—3.

Zygoliths elliptical in outline. The open central area is transversely spanned by an "H-shaped" rather than x-shaped structure, which extends higher than the rim.

Distribution: Originally recorded from the Lower Lutetian (Middle Eocene) of Donzacq, France. In California, U. S. A. this species occurs throughout the Lower and Middle Eocene strata. Very common in the Lower Lutetian strata (*Globoratalia bullbrooki* Zone and *Globigerapsis kugleri* Zone of BECKMANN et al., 1967) of Burg El Arab Well, North Western Desert, Egypt.

Familia: *Braarudosphaeraceae* DEFLANDRE, 1947
Genus: *Braarudosphaera* DEFLANDRE, 1947
Braarudosphaera bigelowi (GRAN & BRAARUD) DEFLANDRE

(Text-figure 1 a)

1935 *Pontosphaera bigelowi* GRAN & BRAARUD, p. 388, fig. 67.
1947 *Braarudosphaera bigelowi* (GRAN & BRAARUD), DEFLANDRE, p. 439, figs. 1—5.
1954 *Braarudosphaera bigelowi* (GRAN & BRAARUD), DEFLANDRE; in DEFLANDRE & FERT, pp. 165—166, pl. 10, figs. 8—13, pl. 13, figs. 7—9.
1961 *Braarudosphaera bigelowi* (GRAN & BRAARUD), DEFLANDRE; BRAMLETTE & SULLIVAN, p. 153, pl. 8, figs. 1 a, b, 2—5.
1969 *Braarudosphaera bigelowi* (GRAN & BRAARUD), DEFLANDRE; STRADNER, p. 420, text-fig. 3/2, 3.
1970 *Braarudosphaera bigelowi* (GRAN & BRAARUD), DEFLANDRE; HASSAN, SADEK & BOUKHARY, p. 4, pl. 1, fig. 1.

This species is characterized by its pentalith form. The peripheral margin is pentagonal with somewhat rounded angles.

Distribution: Long ranging species as recorded from the Cretaceous to the Recent. Common in the Egyptian Eocene strata.

Braarudosphaera discula BRAMLETTE & RIEDEL

(Plate 2, figure 3, text-fig. 1 b)

1954 *Braarudosphaera discula* BRAMLETTE & RIEDEL, p. 394, pl. 38, fig. 7.
1961 *Braarudosphaera discula* BRAMLETTE & RIEDEL; BRAMLETTE & SULLIVAN, p. 153, pl. 8, figs. 6 a, b, 8.
1964 *Braarudosphaera discula* BRAMLETTE & RIEDEI; SULLIVAN, p. 188, pl. 8, fig. 2 a, b.

Pentaliths almost round in outline, tending slightly to be less pentagonal in shape. *Braarudosphaera discula* differs from *B. bigelowi* in the more rounded form of the pentaliths.

D i s t r i b u t i o n : It seems to be common in the Eocene of many regions, and particularly in the lower Middle Eocene (BRAMLETTE & RIEDEL, 1954). In Egypt, this species occurs abundantly in Burg El Arab Formation (Lower Lutetian in the North Western Desert, Egypt).

Genus: *Micrantholithus* DEFLANDRE, 1954
Micrantholithus flos DEFLANDRE

(Plate 2, figure 2)

1950 *Micrantholithus flos* DEFLANDRE, p. 1157, figs. 8—11.
1961 *Micrantholithus flos* DEFLANDRE; BRAMLETTE & SULLIVAN, p. 155, pl. 9, figs. 8 a, b.
1964 *Micrantholithus flos* DEFLANDRE; SULLIVAN, p. 189, pl. 9, figs. 5 a, b.
1965 *Micrantholithus flos* DEFLANDRE; SULLIVAN, p. 40, pl. 9, figs. 1—3.

Pentaliths star-shaped, consisting of 5 segments, the marginal sides of which are modified to produce short tapering rays. Our specimens are very similar to those illustrated by SULLIVAN (1965).

D i s t r i b u t i o n : Recorded from the Lutetian of Austria and from many Eocene sections in France and California. The present species is found in Upper Eocene strata of the Maadi Formation at Heit El Ghorab area, near the Sphinx, Egypt.

INCERTAE SEDIS
Genus: *Trochoaster* KLUMPP, 1953
Trochoaster simplex KLUMPP

(Plate 2, figure 10, 11)

1953 *Trochoaster simplex* KLUMPP, p. 385, pl. 4, fig. 2.
1958 *Trochoaster simplex* KLUMPP; MARTINI, p. 368, pl. 5, fig. 25.
1961 *Trochoaster simplex* KLUMPP; STRADNER & PAPP, p. 131, pl. 42, figs. 1—4, 6 a—d.

This species is characterized by having 6 thin elongate uniform, bluntly pointed rays which are attached to a ring in the central area.

D i s t r i b u t i o n : Recorded from the Eocene of Mexico, Upper Eocene of Germany and Austria. Common in the Upper Lutetian (Mokattam Formation) at Beni Suef area, and in the Upper Eocene sediments of the Maadi Formation at Hei El Ghorab area, near the Sphinx, Egypt.

Undetermined form
(Plate 2, figure 12)

A circular disc, having three obvious holes in the central part. These holes are arranged in a triangular position.

D i s t r i b u t i o n : Detected from Upper Eocene strata of the Maadi Formation, at Heit El Ghorab area, near the Sphinx, Egypt.

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PLATE 1

Fig. 1. *Discoaster aster* BRAMLETTE & RIEDEL, 2500 ×.
Figs. 2 and 3. *Discoaster barbadiensis* TAN SIN HOK, 2500 ×.
Fig. 4. *Discoaster binodosus* MARTINI, 2500 ×.
Fig. 5. *Discoaster crassus* MARTINI, 1700 ×.
Fig. 6. *Discoaster gemmifer* STRADNER, 2500 ×.
Fig. 7. *Discoaster mirus* DEFLANDRE, 2500 ×.
Fig. 8. *Discoaster plebeius* MARTINI, 2500 ×.
Fig. 9. *Discoaster lodoensis* BRAMLETTE & RIEDEL, 1700 ×.
Fig. 10. *Discoaster saipanensis* BRAMLETTE & RIEDEL, 2500 ×.
Fig. 11. *Discoaster quinarius* (EHRENBERG), BERSIER, 2500 ×.
Fig. 12. *Discoaster* sp. 1, 2500 ×.
Fig. 13. *Discoaster sublodoensis* BRAMLETTE & SULLIVAN, 2800 ×.
Fig. 14. *Discoaster aster* BRAMLETTE & RIEDEL, 2500 ×.

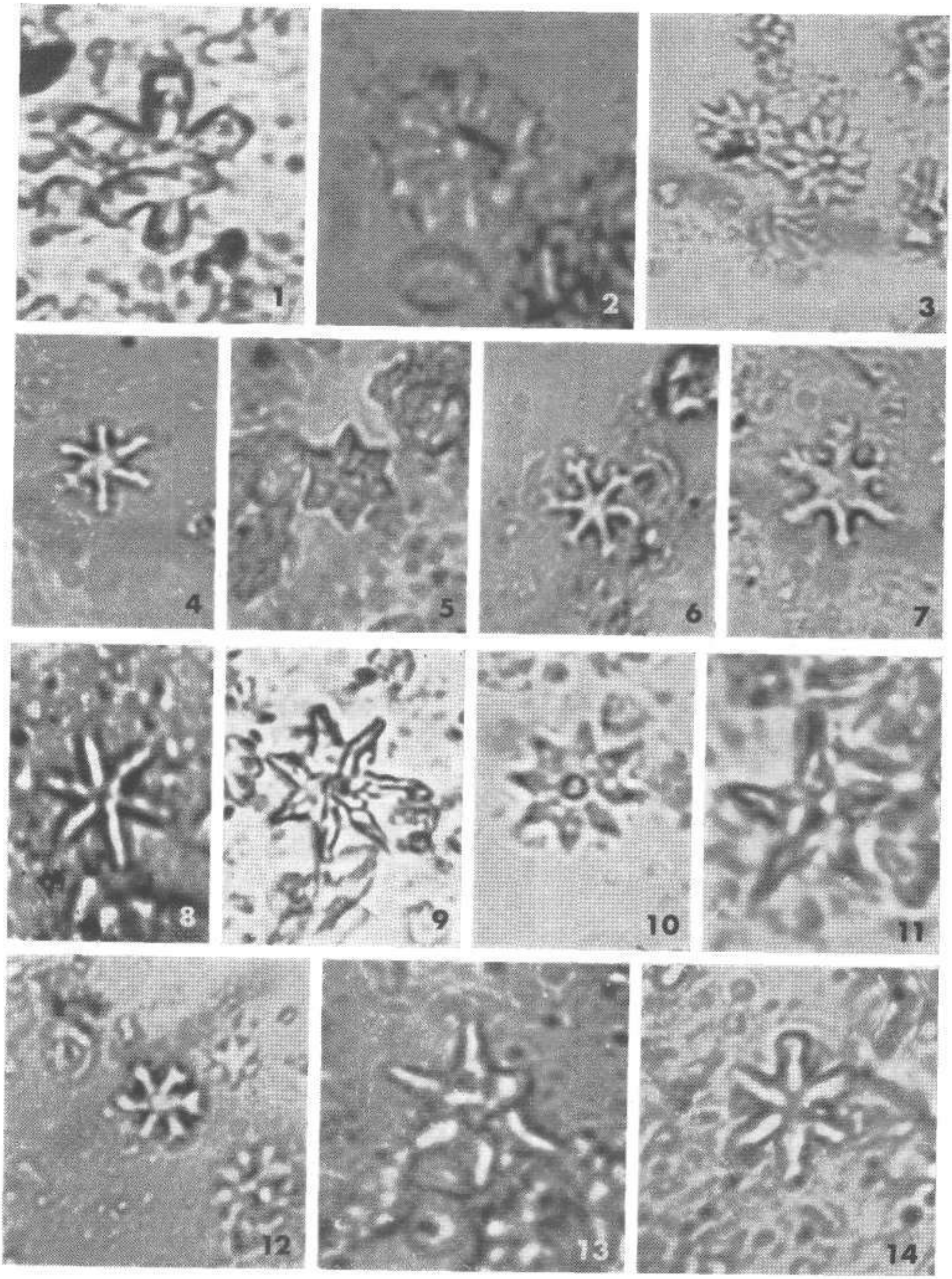
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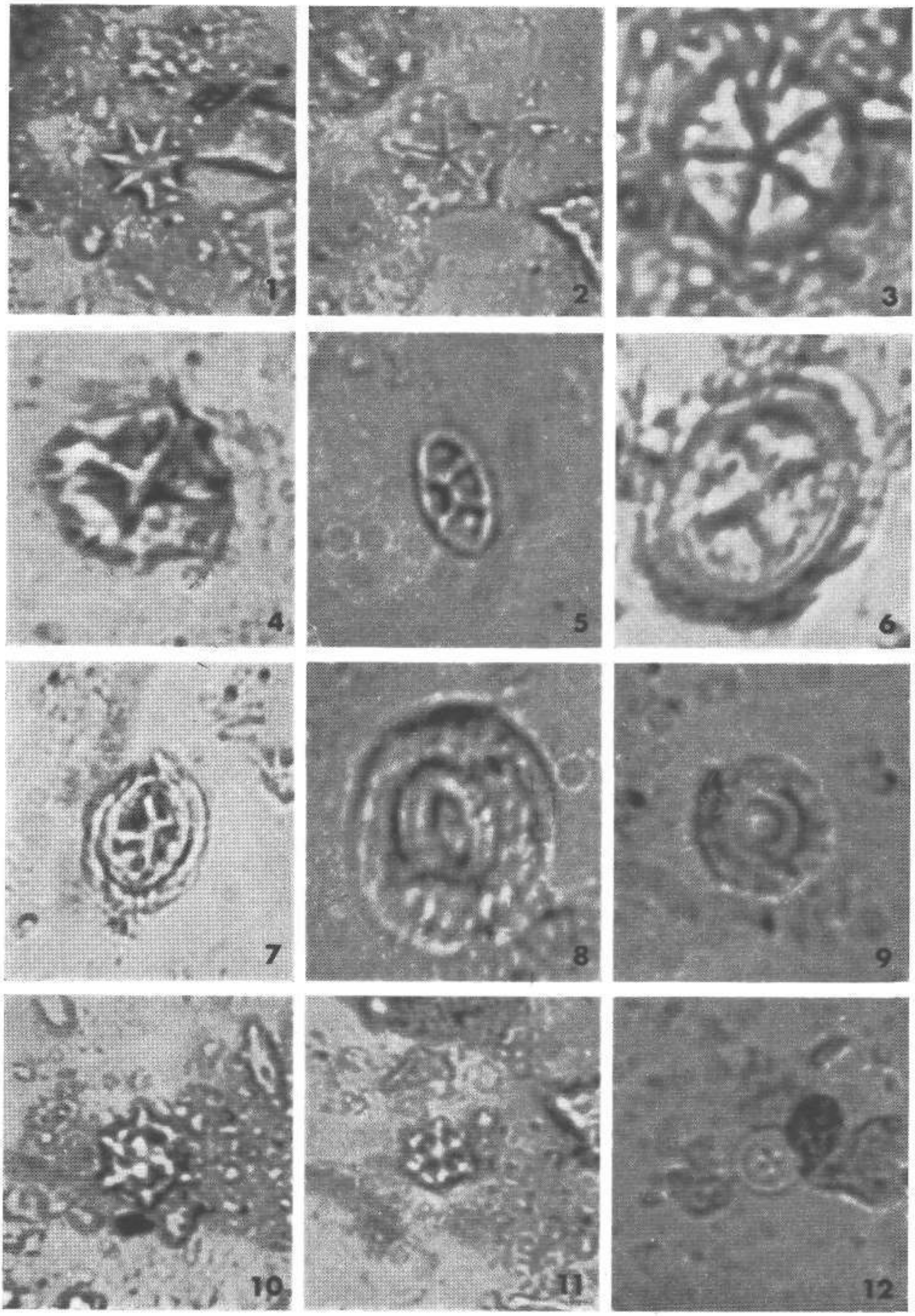
PLATE 2

Fig. 1. *Discoaster* sp. 2, 1700 ×.
Fig. 2. *Micrantholithus flos* DEFLANDRE, 1700 ×.
Fig. 3. *Braarudosphaera discula*, BRAMLETTE & RIEDEL, 2800 ×.
Fig. 4. *Chiphragmalithus* sp., 2500 ×.
Fig. 5. *Neococcolithes dubius* (DEFLANDRE), BLACK, 2500 ×.
Fig. 6. *Chiasmolithus bidens* (BRAMLETTE & SULLIVAN), HAY, MOHLER & WADE, 1700 ×.
Fig. 7. *Coccolithus solitus* BRAMULETTE & SULLIVAN, 2500 ×.
Fig. 8. *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL), STRADNER & EDWARDS, 1700 ×.
Fig. 9. *Cycloccolithus* sp., 1700 ×.
Figs. 10 and 11. *Trochoaster simplex* KLUMPP, 1700 ×.
Fig. 12. *Undetermined form,* 1700 ×.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