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PLANKTONIC FORAMINIFERA AND NANNO-BIOSTRATIGRAPHY OF SOME PALEOGENE ROCKS IN WEST CENTRAL SINAI, EGYPT

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Abstract

This paper describes and illustrates the calcareous nannoplankton (Discoasters) recorded in samples collected from the Paleogene rocks at Wadi Nukhul, Wadi Feiran and Wadi Belayim exposures, West Central Sinai, Egypt. Twenty-eight species of discoasters belonging to two genera of the Family Discoasteromonadaceae and Order Coccolithophorales are defined. A discussion about their stratigraphic occurrences is presented. Ten nannofossil biozones were proposed and arranged from top to base as the following:

10-*Discoaster saipanensis* Zone (part). 9-*Discoaster tani nodifer* Zone.
8-*Reticulofenestra umbilica* Zone. 7-*Nannotetrina fulgens* Zone.
6-*Discoaster sublodoensis* Zone. 5-*Discoaster lodoensis* Zone.
4-*Tribrachiatus orthostylus* Zone. 3-*Discoaster binodosus* Zone.
2-*Tribrachiatus controtus* Zone. 1-*Discoaster multiradiatus* Zone.
(1-2) Late Paleocene; (3-5) Early Eocene; (6-10) Middle Eocene

Such nannobiozones were equated with the planktonic foraminiferal zones of the same age. Both microbiostratigraphic zones were found to be of correlatable value with those in other parts of the world. The zonation based on nannofossil species proposed here increased the stratigraphic resolution which can presently be achieved using both planktonic foraminifera and calcareous nannoplanktonic.

Introduction

The highly fossiliferous Paleogene rocks of Egypt were the subjects of numerous stratigraphical and paleontological studies. However, no satisfactory biostratigraphical classification of these rocks was established and their correlation with the type sections in Europe proved to be very difficult. The difficulty has been explained by the fact that, the rich macro fauna of these rocks are strictly localized in nature, and can hardly be correlated with the faunas of corresponding strata outside the Tethyan region. As a result, the limits of the various stages and substages of the Paleogene were differently interpreted by the various authors.

Recently, the rich microfossil content of these rocks has been dealt with by many authors, Martini (1970-1971) El-Dawoody (1970-1994), Perch-Nielsen (1985), Faris (1991), Faris & Strougo (1992) El-Dawoody & Elewi (1994), El-Dawoody & Morsi (1998) and last but not least El-Dawoody (1998). However, the accumulation of knowledge during the last decades has emphasized the value of planktonic foraminifera as well as calcareous nannoplanktonic as guide fossils for stratigraphical zonation, and for regional as well as worldwide correlation.

Thus in the present study the calcareous nannoplanktonic and co-existent planktonic Foraminifera are identified and are used to interpret the stratigraphy of the region. These two types of fossils provided a sound basis for zonation of the succession and its correlation with type sections and with the known calcareous nannoplanktonic and planktonic foraminiferal zones elsewhere. Moreover, the stratigraphical ranges of calcareous nannoplankton could be established in the light of the planktonic foraminiferal zonation, thus ending along controversy about their ranges.

The rich calcareous nannoplankton and planktonic Foraminiferal populations encountered in some Paleogene successions measured out of Wadi Nukhul and Wadi Feiran and Belayim surface sections, West-Central Sinai. Egypt (Fig. l), has helped to clear this confusion and to establish the morphological characteristics and the stratigraphical range of each of these species.

Material and Technique:

Three sections were measured along east west lines by the use of the compass and tape (Fig. l), arranged from north to south as follows:

1-Wadi Nukhul Surface Section

The section is situated six kilometers southeast of Abu Zeinima town, eastern coast of the Gulf of Suez (Fig. 2). The Eocene section (Lat. 29° 01' 00", Long. 33° 09' 49") was measured along the lower course of Wadi Nukhul that cuts through the cliffs and low hills of Eocene limestones and shales, which border the Wadi till it reaches mouth near the shore of the Gulf.

The area under investigation is a fault block bounded by two parallel faults trending in NW-SE direction. The fault blocks dip to

NE by amount ranges between 7-20°. The Eocene section in Wadi Nukhul is cut at its base by a basalt dyke. The measured incomplete section at Wadi Nukhul amounts to 406 m. thick. Sampling was made at 2-m. interval.

2. Wadi Feiran Surface Section:

This sequence lies to the south of Gebel Nazazzat, West Central Sinai (Lat. 28° 43' 00", Long. 33° 16' 30"), amounts to 395m in thickness. The samples have been collected at an average of one sample per about 2m.

3. Wadi Belayim Surface Section:

The section is located near Gebel Abu Durba and in face of the Belayim bay. The Eocene section (Lat. 28° 35' 30", Long. 35° 25' 00") amounts to 212 m. and its sampling was made at 4 m. interval.

Biostratigraphic Zonation and Correlation

Many workers dealt with Paleogene Foraminiferal zonations all over the world. Bolli (1957, 1966), Stainforth et al. (1975) Blow (1979) and Toumarkine & Luterbacher (1985) are the pioneers who proposed a number of planktonic Foraminiferal zones applicable in many parts of the world. The definition of the regional zone proposed by Stainforth et al. (1975) depend upon the reliable concept of "datum levels" determined as the first occurrence datum (FOD) and last occurrence datum (LOD) will be followed in this study. The absence or scarcity of index species and longer vertical range of some taxa causes the difficulties encountered.

1. ***Planorotailites pseudomenardii* zone** (= *Globorotalia pseudomenardii* zone) - Late Paleocene (Landenian)

Bolli (1957) was the first to define this zone from Trinidad but now it is recognized internationally. It was defined as the total range of the taxon *Planorotailites* (Bolli). The same zone definition is applied here for the upper part of this zone at Wadi Belayim surface section.

2. ***Morozovella velascoensis* zone** (= *Globorotalia velascoensis* zone) - Late Paleocene (Landenian)

Bolli (1957) was the first to define this zone from Trinidad but now recognized internationally. It was defined on the basis of the last occurrence of *Planorotailites pseudomenardii* at base while the top was defined on the basis of extinction of *Morozovella velascoensis*. The same zone definition is applied here in this study. The upper-most part lies within the Esna Formation. At Wadi Belayim surface section, it is represented by samples No. 3 & 4 (Fig. 3).

3.***Morozovella subbotinae* zone** (= *Globorotalia rex* zone)–Early Eocene (Ypresian):

Morozovella subbotinae (Morozova) is a senior synonym of *Globorotalia rex* Martin. This is essentially the *G. rex* zone of Bolli (1957, 1966) although his original definition assumed no overlap in ranges of *G. velascoensis* and *G. rex*. In the present study, the zone is defined as the interval from the extinction of *M. velascoensis* to the first occurrence of *M. aragonensis*.

This zone is conformable with the underlying *M. velascoensis* zone at Wadi Belayim surface section. The zone occupies the lowest part of the Thebes Formation. At Wadi Belayim surface section, samples No. 5 & 6 represent the zone.

4. ***Morozovella formosa formosa* zone** - (= *Globorotalia formosa formosa* zone) - Early Eocene (Ypresian):

Bolli (1957) first established this zone in Trinidad. The base of the zone was defined at the appearance of the nominate species while the definition of the top was not very clear and later on defined by Bolli (1966) as the first appearance of *G. taroubensis* and *G. turgida* forms which are difficult to identify with confidence. At Wadi Belayim surface section, the zone occupies the lower argillaceous limestone part of the Thebes Formation (samples No. 7 & 8).

This zone is defined as the interval from the first occurrence of *M. aragonensis* to the first occurrence of *Acarinina pentacamerata* (= *Globigerina aspensis* of some authors). The last occurrence of *Morozovella formosa formosa, M. formosa gracilis* and *M. marginodentata* is within this zone. The first occurrence of *Globorotalia inaequispira* was recorded near the top of the *M. formosa formosa* zone.

5. ***Morozovella aragonensis* zone** (= *Globorotalia aragonensis* zone) - Early Eocene (Ypresian)

Bolli (1957) originally recorded this zone from the Lizard springs Formation of Trinidad. In the present study, the zone is defined as the interval from the first occurrence of *Acarinina pentacamerata (Globigerina aspensis* of some authors) to the first occurrence of *Trunorotaloides cerroazulensis frontosa* (= *Globigerina boweri* of some authors).

In Wadi Belayim surface section, the shallow marine water conditions prevailed during the zone. The section is either barren of planktonic faunas, or with small benthonic or large forams as *Nummulites* spp. as well as other mega fossils in association. Accordingly, the top of *M. aragonensis* could not be determined in Wadi Belayim surface section. The recorded samples with planktonic cover the interval between samples No. 9 & 17 and lie within the Early Eocene section of the Thebes Formation.

6. ***Acarinina pentacamerata* zone** (= *Globorotalia palmerae* zone) - Early- Middle Eocene (Ypresian-Lutetian)

Krasheninnkov (1965) originally introduced this zone as a subzone corresponding to *G. palmerae* zone of Bolli (1957), which is not recognizable in many parts of the world. At Wadi Nukhul, the base of this zone could be defined as the first occurrence of *Trunorotaloides cerroazulensis frontosa* (Subbotina), whereas its top could be determined on the basis of the first occurrence of *H. aragonensis* or *T. topilensis*. Shallow marine nummulitic facies prevailed in the area where the planktonic Foraminifera or calcareous Nannoplanktonic of this zone could not be recognized within the top of the Thebes Formation, or the base of the Samalut Formation at Wadi Belayim. In turn, the top of the zone could not be determined accurately.

The absence of the nominate species which is commonly known to delineate the basal Middle Eocene as *Hantkenina* makes difficult the delineation of the top of *A. pentacamerata* zone. However, some authors do not prefer to use genus *Hantkenina* as a nominate zonal taxon because it may appear latter on within the Middle Eocene.

7. ***Hantkenina aragonensis* zone** (Bolli, 1957) Middle Eocene (Lower Lutetian)

Interval from the first occurrence of *H. aragonensis* to the first occurrence of *G. mexicana*. Alternative criteria for the base are the extinction of *A. soldadoensis soldadoensis* and first appearance of common typical *A. bullbrooki*. In the present studied section of Wadi Nukhul, due to the scarcity as well as the sporadic and badly preserved *Globigerinatheka* spp., the top of the zone has been modified according to Stainforth *et al.* (1975) to be on the basis of the first occurrence of *T. cerroazulensis pomeroli, M. lehneri* and *S. yeguensis*.

The zone is recorded in Wadi Nukhul surface section from the Darat Formation and covers the interval between samples No.114-140. This zone and the younger overlying zones are not recorded in Wadi Belayim surface section.

8. ***Globigerinatheka subconglobata / Morozovella lehneri* zone** (= *Globigerapsis kugleri/Globorotalia lehneri* zone) - Middle Eocene (Lutetian):

The *Globigerinatheka subconglobata subconglobata* zone is essentially the *Globigerapsis kugleri* zone of Bolli (1957, 1966) as slightly modified by Beckman *et al.* (1969). To accord with the current taxonomic revisions, Toumarkine & Bolli (1970) changed the name to Globigerinatheka kugleri zone almost simultaneously by Proto Decima & Bolli (1970) and.

Stainforth *et al.* (1975) defined this zone as the interval from the first occurrence of *Globigerinatheka mexicana* to the last occurrence of *Globorotalia aragonensis*. However, they reported in their range chart (Fig. 13, p.64) the first occurrence of *T. cerroazulensis pomeroli* and *M. lehneri* at the base of their *G. subconglobata subconglobata* zone. The last occurrence of *H. aragonensis* is at the top of the nominate zone. In the present study, the top of *G. subconglobata subconglobata* zone could not be determined exactly due to the paucity of fossil indices known to define it.

The *G. subconglobata subconglobata* zone combined with the overlying *M. lehneri* zone. The base of these two combined zones is determined by the first occurrence of *G. mexicana, G. index T. cerroazulensis pomeroli, M. lehneri S. ouachitaensis ciperoensis H. dumblei* and *H. mexicana.* The top of the combined zones is defined by the last occurrence of *S. frontosa, A. broedermanni* and *A. pentacamerata*, which coincides more or less with the first occurrence of *T. cerroazulensis cerroazulensis.*

Beckman *et al.* (1969) defined the top of *M. lehneri* by the last occurrence of *G. broedermanni, G. pentacamerata, G. frontosa G. inaequispira, G. higginsi, H. mexicana* and *H. dumblei.* As mentioned above, the concept of Beckman *et al.* is applicable concerning Wadi Nukhul surface section. The *G. subconglobata subconglobata / M. lehneri* zones cover the interval between samples No. 141-180 from the Khaboba Formation.

9. *Truncorotaloides rohri* zone - (Bolli, 1957) - Middle Eocene (Lutetian)

This zone comprised *T. rohri* zone and *O. beckmanni* zone (= *P. mexicana* of some authors). The *O. beckmanni* taxon is absent from the studied section at Wadi Nukhul, Sinai. However, the limits of the nominate zone could be determined approximately at its base by the last occurrence of *S. frontosa. A. broedermanni, A. pentacamerata* and *G. higginsi* as compared with other localities outside Egypt. The first occurrence of *S. pseudoampliapertura, S. pseudovenezuelana* and *H. alabamensis* more or less near the top of the assumed *O. beckmanni* zone in Wadi Nukhul surface section.

The base of the *T. rohri* has been defined by the first occurrence of *S. pseudoampliapertura, S. pseudovenezuelana* while the top is indefinite due to the absence of *G. semiinvoluta* and *T.*

cerroazulensis cunialensis which are commonly associated with Late Eocene fossils. This zone covers the interval between samples No.196-227 and is represented by the whole Tanka Formation at Wadi Nukhul surface section. It represents the last recorded planktonic foraminiferal zone within the Eocene succession of the studied sections.

The recorded nanno-biozones are arranged from the older to younger; the markers of each zone are discussed and reference is made to its author, the datum indicators and most common species as well as the reference type locality. Such species of *Discoasters* recognized in the outcrop samples in the sections studied were identified and fully described. These species are given in a general distribution chart (Fig 3). Within this frame the present study propose the ten calcareous nannoplankton zones for the Paleogene deposits of the region under investigation.

These are: *Discoaster multiradiatus* zone and *Tribrachiatus contortus* zone (Late Paleocene), *D. bindosus* zone, *T. orthostylus* and *D. lodoensis* zone (Early Eocene), *D. sublodoensis* zone. *Nannotetrina fulgens* zone, *Reticulofenestra umbilica* zone. *D. tani nodifer* zone and *D. sainpanensis* zone (part) (Middle Eocene). The Late Paleocene zones are discussed here in:

1- *Discoaster multiradiatus* zone:

This zone was first used by Bronnimann and Stradner (1960) in the Havana area, Cuba *(Discoaster multiradiatus / Marthasterites* *contortus* zone). Bramlette & Sullivan (1961) introduced this zone from the lower part of Lodo Formation (Unit 2), Fresno County, and California.

Hay & Mohler (1967) defined this zone as the interval from the first occurrence of *Discoaster multiradiatus* Bramlette & Riedel to the first occurrence of *Marthasterites bramlettei* Bronniman & Stradner.

Hay & Mohler's definition is followed here, and the zone is recorded in the Esna Formation in Wadi Belayim where the top of the zone could be delimited. At Wadi Belayim the recorded top part of the zone spans the interval between samples (1-4) and it is correlatable with the *Planorotalites pseudomenardii* at its lower part, as well as with *Morozovella velascoensis* Foraminiferal zones.

The most common fossil assemblage of this zone includes *Discoaster barbadiensis* Tan Sin Hok, *D. binodosus* Martini, and *D. multiradiatus* Bramlette & Riedel.

The recorded *Discoaster multiradiatus* zone from the studied surface section at Wadi Belayim is equivalent to the same zone of Hay & Mohler (1967) from Pont Labau, France; it is approximately equivalent to the upper part of *D. multiradiatus*, and the lower part of *M. bramlettei / M. contortus* zones of Sadek (1971) from Egypt; to *D. multiradiatus* zone (NPO) of Martini (1971 to the same zone *D. multiradiatus* (CP8) with its two subzones *C. bidens* (CP8a), and *C. eodela* (CP8b) of Bukry (1973, 1975) as well as Okada & Bukry

(1980); it is equivalent to the *D. multiradiatus* zone of Proto Decima *et al.* (1975) from Possagno section, northern Italy; and at last to the same zone of Perch-Nielsen *et al.* (1978) from Egypt.

2- *Tribrachiatus contortus* zone (= *M. contortus* zone):

Hay & Mohler (1967) defined this zone as the interval from the first occurrence of *Marthasterites bramlettei* Bronnimann & Stradner to the last occurrence of *M. contortus* (Stradner).

This definition is applied here in this work. The zone was recorded from the Esna Formation at Wadi Belayim surface section. This zone spans the interval of samples (5-6) and it is correlatable with the *M. subbotinae* zone.

The most common fossil assemblage of this zone includes: *Discoaster binodosus* Martini; *D. diastypus* Bramlette & Sullivan, *D. lodoensis* Bramlette & Ridel, *D. mirus* Deflandre, *D. nobilis* Martini, *D. salisburensis* Stradner, *Tribrachiatus bramlettei* (Bronnimann & Stradner) and *T. contortus* (Stradner).

The recorded *T. contortus* from the Early Eocene at Wadi Belayim surface section is approximately equivalent to the *D. multiradiatus* zone of Bramlette & Sullivan (1961) from California; to the *M. contortus* zone of Hay & Mohler (1967) from Pont Labau, France; to *M. contortus* zone (NPIO) of Matini (1971); it is equivalent to the upper part of *M. bramlettei / M. contortus* zone of Sadek (1971) from Egypt; to *M. contortus* zone of El Dawoody (1970) from Gebel Duwi section, Egypt; to the lower part of *D. diastypus* zone of Bukry

(1973, 1975), Okada & Bukry (1980) in the low latitude coccolith biostratigraphical zonation: to the *T. contortus* zone of Proto Decima *et al.* (1975) from Passagno section, northern Italy; to *T. contortus* zone of El Dawoody (1977) from Gebel El Teir section, Egypt; and at last to *M. contortus* zone of Perch-Nielsen *et al.* (1978) from Egypt.

El Dawoody & Morsi (1998) previously studied the Early & Middle Eocene zones on the same succession. A biostratigraphical correlation of the previously mentioned calcareous nannoplanktonic within the Paleogene of the study sections in SouthWestern Sinai (Fig. 4), was introduced.

Genus: Discoaster Tan Sin Hok, 1927

Discoaster barbadiensis Tan Sin Hok

(Pl. 1, fig. 9)

1927 ***Discoaster barbadiensis*** Tan Sin Hok, Proc. Sect. Sci. K. Akad. Wet. 30:415.

Remarks: Multirayed discoasters with a central spine and straight radial sutures separating 10-18 rays.

Stratigraphic range: Originally known in the Tertiary of Indonesia and West Indies (Barbados). This form is recorded from the Early Eocene of Wadi Nukhul as well as the Paleocene-Early Eocene of Wadi Belayim sections.

Discoaster binodosus Martini

(Pl. l, fig. l)

1958 *Discoaster binodosus* Martini; Senckenb. Leth. 39:362, pl.4, figs. 18-19.

Remarks: This asterolith has 6-8 and rarely 10 separated rays, with nudged tips flanked by two lateral nodes.

Stratigraphic range: Originally described from the Eocene sediments of Germany. This form is recorded from the Early-Middle Eocene at Wadi Nukhul, as well as the Early Eocene at Wadi Belayim surface sections.

***Discoaster deflandrei* Bramlette & Riedel**

(Pl. 1, fig.7)

1954 *Discoaster deflandrei* Bramlette & Riedel; J. Paleont., 28:339, pl. 39, fig. 6.

Remarks: Asterolith with large central disc and usually six but rarely five short broadly bifurcating rays.

Stratigraphic range: Originally described from the Upper Eocene-Miocene of West Indies (Cuba, Trinidad), Eocene of Austria and Spain (Mariana Island). This form is recorded from the Early-Middle Eocene of Wadi Nukhul, as well as the Early Eocene of Wadi Belayim sections.

Discoaster diastypus Bramlette & Sullivan

(Pl. l, fig. 8)

1961 *Discoaster diastypus* Bramlette&Sullivan; Micropaleont., 7:159, pl.11, figs. 6-11.

Remarks: Asteroliths with nine to sixteen sharply pointed rays joined through most of their length. The rays are symmetrical and the central area pierced by a heavy stem.

Stratigraphic range: Originally recorded in the Lower Eocene of California. Trinidad and France. This form is known in the Early Eocene of Wadi Belayim surface section.

Discoaster distinctus Martini

(P1. 2, fig. 7)

1958 *Discoaster distinctus* Martini; Senckenb. Leth.. 39:363, pl.4, fig.17.

Remarks: Asteroliths have usually six and rarely five of seven rays terminating with a deep notch.

Stratigraphic range: Originally recorded from the Eocene of NW Germany, the Lower- and Middle Eocene of California, Eocene of France and Lower-Upper Eocene of Italy. This form is recorded from the Early-Middle Eocene of Wadi Nukhul section.

Discoaster gemmifer Stradner

(P1.1, figs. 4, 5)

1961 *Discoaster gemmifer* Stradner; Erdol Zeitschr., 77:86

Remarks: Specimens with largely terminations than *Discoaster distinctus* Martini, and with a more obtuse and broader notch seem to be referable to *D. gemmifer* Stradner.

Stratigraphic range: This form has been reported from the Middle Eocene of France, Austria and Mexico. It is recorded from the Early Eocene of Wadi Belayim surface section .

Discoaster lodoensis Bramlette & Riedel

(P1.1, figs.11, 12)

1954 *Discoaster lodoensis* Bramlette & Riedel; J. Paleont., 28:398, pl.39, fig. 3.

Remarks: Asteroliths usually have six curved rays and rarely seven. This species differs from *Discoaster saipanensis* Bramlette & Riedel in having longer, thinner and more curved rays.

Stratigraphic range: Recorded from the Early Eocene of Denmark, California. France, Cuba and various parts all over the world. It is recorded from the Early Eocene of Wadi Belayim surface section.

Discoaster mediosus Bramlette & Sullivan

(P1.2, figs.3, 4)

1961 *Discoaster mediosus* Bramlette & Sullivan; Micropaleont., 7: 161, pl. 12, figs. 7-8.

Remarks: its large central disk and small, nearly parallel-sided rays distinguish this species.

Stratigraphic range: Originally recorded in the Paleocene-Lower Eocene sediments of California. It is recorded from the Late Paleocene-Early Eocene sediments of Wadi Belayim surface section.

Discoaster mirus Detlandre

(P1. 1, figs.2, 3)

1954 *Discoaster mirus* Deflandre (in Deflandre & Fert): Ann. Paleont., 40:168, fig. 118.

Remarks: Asteroliths with six-eight rarely nine heavy rays, have two terminal and two lateral nodes, mostly obscured by the overgrowth materials.

Stratigraphic range: Originally recorded from the Lower Middle Eocene of France, Italy, Austria, Poland and elsewhere. This form is recorded from the Early Eocene of Wadi Nukhul as well as the Early Eocene of Wadi Belayim surface sections.

Discoaster multiradiatus Bramlette & Riedel

(P1.2, fig. 5)

1954 *Discoaster multiradiatus* Bramlette & Riedel; J. Paleont., 28:396, pl.38. fig. 10.

Remarks: Asteroliths consist of more than fifteen wedges like rays, the distal ends of which are blunt or rounded. In the center there can be a blank area or knob.

Stratigraphic range: This excellent index fossil was originally described from the Velasco Shale of Mexico. It had been found in California as well as many Paleocene strata in man) parts of the world. In the studied sections, this species is found to range through the Late Paleocene at Wadi Belayim surface section.

Discoaster nobilis Martini

(P1.2, fig. 1)

1961 *Discoaster nobilis* Martini; Senckenb. Leth., 42:11, P1.2, fig. 23; p1.5, fig.51.

1961 *Discoaster falcatus* Bramlette&Sullivan; Micropaleont., 7:159, p1.11, figs. 14-15.

Remarks: This species is distinguished from *Discoaster mediosus* Bramlette & Sullivan by the more or less asymmetric, slightly curving rays, with ridges near their convexly curved sides.

Stratigraphic range: Originally recorded from the Paleocene sediments of France, Upper Paleocene of North Atlantic Ocean and Italy. This form was reported from the Late Paleocene-Early Eocene of Wadi Belayim section.

Discoaster saipanensis Bramlette & Riedel

(P1.2, fig. 2)

1954 *Discoaster saipanensis* Bramlette & Riedel; J. Paleont., 28:398, p1.39, fig.4.

Remarks: Stellate asteroliths of six-eight rarely five shapely pointed rays closely related to *Discoaster lodoensis* Bramlette & Riedel.

Stratigraphic range: Originally known in the Upper Eocene of Spain. It was recorded from the Upper Eocene of Germany, Middle Eocene of CSSR, France, Italy and Atlantic Ocean. In the studied sections, it is recorded from the Middle Eocene of Wadi Nukhul surface section.

Discoaster salisburgensis Stradner

(P1. 1, fig. 10)

1961 *Discoaster salisburgensis* Stradner; Erdol Zeitschr., 77:84, figs. 77-78.

Remarks: A multirayed rosette like asterolith. It is very similar to *Discoaster barbadiensis* Tan Sin Hok, but differs mainly in having a wider central area and less number of rays in average.

Stratigraphic range: Originally recorded in the Paleocene sediments of Austria. It was also recorded from the Paleocene-Lower Eocene of CSSR, Poland and Lower Eocene of Italy. This form is known to range throughout the Late Paleocene-Early Eocene of Wadi Belayim surface section.

Discoaster sublodoensis Bramlette & Sullivan

(Pl. 1, fig. 13)

1961 *Discoaster sublodoensis* Bramlette&Sullivan; Micropaleont., 7: 162, pl. 12, fig. 6.

Remarks: A very distinctive small asterolith with five, rarely six sharply pointed rays, joined through about half of their length, and straight radiating in the separated outer part.

Stratigraphic range: Originally known from the Middle Eocene of Texas, France, CSSR, Italy and various parts of the world. This form is known to range throughout the Early-Middle Eocene of Wadi Nukhul surface section.

Discoaster surculus Martini & Bramlette

(P1. 2, fig. 6)

1963 *Discoaster surculus* Martini & Bramlette; J. Paleont., 37:854, pl. 104, figs. 10- 12.

Remarks: Asterolith with a stellate knob in the middle of the central area, six rayed from the knob small ridges extend to the margin between the rays on one side of the asterolith and along the arms on the other side.

Stratigraphic range: This species had recorded in the Pliocene of the experimental Mohole sequence, where it is common. Also found in various deep-sea cores of Pliocene strata. It was found rarely in the Early Eocene of Wadi Belayim as it was considered as derived form younger strata.

Discoastcr tani Bramlette & Riedel

1954 *Discoaster tani* Bramlette & Riedel; J. Paleont. 28:397, p1. 39, fig. 1.

Remarks: Asteroliths have five-six thick, straight-sided rays that terminate in either flat or slightly notched ends, with a stellate central knob. This character is not clear in the studied specimens, which may be due to a sort of overgrowth.

Stratigraphic range: Originally recorded from the Upper Eocene sediments of northern Spain. This form is recorded from the Middle Eocene of Wadi Nukhul surface section.

Discoaster tani nodifer Bramlette & Riedel

(P1. 2, fig. 8)

1954 *Discoaster tani nodifer* Bramlette & Riedel; J. Paleont., 28:397, pl.39, fig.2.

Remarks: A five rayed asterolith, distinguished by the presence of distinct paired nodes on each ray and in slight enlargement of the ends of the rays with more conspicuous terminal notches that are obscured by overgrowths in the studied material.

Stratigraphic range: Originally recorded from the upper Eocene of Alabama. USA. It was also recorded from the Upper Eocene of New Zeeland, Spain, Hungary, and Black Sea. This form is recorded from the Middle Eocene of Wadi Nukhul surface section.

Discoaster trinus Stradner

(P1. 1, fig. 6)

1961 *Discoaster trinus* Stradner; Erdol Zeitschr., 77:85, fig.79.

Remarks: The astrolith of this species seems to be composed of two triradiate units symmetrically super-imposed on one another; with six rays expanding towards their terminations and bear a slight terminal notch.

Stratigraphic range: Originally recorded from the Middle Eocene of Austria. Middle Eocene to Middle Oligocene of Alabama. This form is recorded from the Early-Middle Eocene of Wadi Nukhul as well as the Early Eocene of Wadi Belayim surface sections.

Genus: Tribrachiatus Shamrai, 1963

Tribrachiatus bramlettei (Bronnimann & Stradner)

(P1. 2, fig. 10)

1960: *Martaaterites bramlettei* Bronnimann & Stradner; Erdol Zeitschr., 76:366, figs. 17-20; 23-24.

1975: *Tribrachiatus bramlettei* (Bronnimann & Stradner) Proto-Decima, Roth & Todesco, Schweiz. Paleont. Abh., 97:49, pl.4, figs. 17-18.

Remarks: The borderlines of specimens recorded are straight, thus resembling a low bipyramidal body, which has been, shifted about 60 degrees upon the symmetry plane.

Stratigraphic range: This species was originally recorded from the upper Paleocene rocks in Cuba, California and Switzerland. It is recorded to range throughout the Early Eocene of Wadi Belayim in surface section.

Tribrachiatus contortus (Stradner)

(P1. 2, fig. 9)

1958 *Discoaster contortus* Stradner; Erdol Zeitschr., 74: 6:187, figs. 35 36.

1959 *Marthastelites contortus* (Stradner) Deflandre; Rev. Micropaleont., 2:139

1975 *Tribrachiatus contortus* (Stradner) Proto Decima, Roth and Todesco; Schweiz. Paleont. Abh., 97:49, pl.4, fig.22.

Remarks: The recorded specimens from Wadi Belayim show variation in the form of species and also different degrees of shifting upon the connecting plane thus suggest some relations with *Tribrachiatus bramlettei* (Bronnimann & Stradner).

Stratigraphic range: Originally recorded from the Upper Paleocene rocks of Austria. It is reported from the Early Eocene of Wadi Belayim surface section.

Tribrachiatus orthostylus Shamrai

(P1.2, figs.12-15)

1954 *Discoaster tribrachiatus* Bramlette & Riedel; J. Paleont., 28:397, pl.38, fig. 11.

1959 *Mathasterites tribrachiatus* (Bramlette & Riedel); Deflandre; Rev. Micropaleont., 2:138, p1.2, fig. 1.

1963 *Tribrachiatus orthostylus* Shamrai; Ivz. Vyssh. Ucheb. Zaved. Geol. i Razv., 6:38, pl.2, figs. 13-14.

Remarks: Asteroliths with three rays radiating from an undifferentiated center. The tips are varying between rounded, nudged, pointed. In this study, the different forms with different tips classified into forms A, B, C.

Stratigraphic range: Originally described from the Lower Eocene of California and now known from the Lower Eocene of various parts all over the world. It is recorded from the Early Eocene of Wadi Belayim surface section.

Tribrachiatus robustus (Stradner)

(Pl. 2, fig.11)

1959: *Discoaster tribrachiatus* robustus Stradner; Erdol Zeitschr., 75:477, figs.4-9.

1967: *Mathasterites robustus* (Stradner); Moshkovitz, Jb. Geol. B.A., 110: 157, pl.4, figs. 4-6; pl.6, figs. 7,9.

Remarks: This species is similar to *Tribrachiatus orthostylus* Shamrai but the latter is more delicate, the three arms are more elongate and thinner. According to Stradner (in Stradner & Papp. 1961) *Marthasterites robustus* is the direct forerunner of *T. orthostylus* Shamrai (synonym: *M. tribrachiatus* Bramllette & Riedel).

Stratigraphic range: Known from the Upper Paleocene of Austria and Israel. It is recorded throughout the Early Eocene of Wadi Belayim surface section.

Summary and Conclusions

The Late Eocene was not recorded as revealed by the intensive study, which may be due to the pre-Miocene unconformity. The Late Paleocene Early Eocene contact at Wadi Belayim is conformable and represented by *Morozovella velascoensis/ M. subbotinae* planktonic foraminiferal zones.

The succession was divided into distinct litho and biostratigraphical units; and the distribution of such type of fossils allowed the subdivision of these sections into nine planktonic zones comparable with those proposed by Bolli (1957, 1966) from Trinidad, Stainforth *et al.* (1975) and Toumarkine & Luterbacher (1985). These zones are arranged from top to base as follows:

4.*Morozovella formosa formosa* zone.

3.*Morozovella subbotinae* zone.

2.*Morozovella velascoensis* zone.

1.*Planorotailites pseudomenardii* zone.

9. *Truncorotaloides rohri* zone.

8. *Globigerinatheka subconglobata subconglobata / Morozovella lehneri* zone.

7. *Hantkenina aragonensis* zone.

6. *Acarinina pentacamerata* zone.

5. *Morozovella aragonensis* zone.

An inventory of the stratigraphically useful calcareous Nannoplanktonic (Discoaster) species identified in the light microscope, and the list of Late Paleocene, Early and Middle Eocene fossils were included in the range chart.

The extent and correlation of calcareous Nannoplanktonic zones with planktonic foraminiferal zones, and with the litho logy of the sediments were discussed and were shown in the lithologic and biostratigaphic columnar sections (Figs. 2,3). All the sediment samples checked for calcareous Nannoplanktonic were listed in the appropriate positions in each section.

A total of twenty-eight species, which are the most common, belonging to two genera were recorded and covered the interval between the Late Paleocene-Early and Middle Eocene of Wadi Belayim and Wadi Nukhul sections, respectively. This type of fossils participated in building ten zones proposed by Martini (1970, 1971), Bukry (1973, 1975) Okada & Bukry (1980) Perch-Nielsen (1985) as well as El-Dawoody (1988-1998). The recorded zones are arranged from top to base as follows:

5. *Discoaster lodoensis* zone.

4. *Tribrachiatus orthostylus* zone.

3. *Discoaster binodosus* zone.

2. *Tribachiatus contortus* zone.

1. *Discoaster multiradiatus* zone.

10. *Discoaster saipanensis* zone (part).

9. *Discoaster tani nodifer* zone.

8. *Reticulofenestra umbilica* zone.

7. *Nannotetrina fulgens* zone.

6. *Discoaster sublodoensis* zone.

The correlation of these zones with their equivalents in and outside Egypt was given. The study of stratigraphic ranges of planktonic foraminifera found in contemporaneous with this nannoflora in such succession aided in delineating those microbiostratigraphic zones.

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PLATE 1

1- Discoaster binodosus Martini. W. Belayim, Sample No. 8

2- Discoaster mirus Deflandre.W. Belayim, Sample No. 7.

3- Discoaster mirus Deflandre. W. Belayim, Sample No. 9.

4- Discoaster gemmifer Stradner. W. Belayim, Sample No. 8.

5- Discoaster gemmifer Stradner. W. Belayim, Sample No. 3.

6- Discoaster trinus Stradner. W. Nukhul, Sample No. 141.

7- Discoaster deflandrei Bramlette & Riedel. W. Nukhul, Sample No. 141.

8- Discoaster diastypus Bramlette & Sullivan. W. Belayim, Sample No. 8.

9- Discoaster barbadiensis Tan Sin Hok. W. Belayim, Sample No. 9.

10- Discoaster salisburgensis Stradner. W. Belayim, Sample No. 1.

11, 12- Discoaster lodoensis Bramlette & Riedel. W. Belayim, Sample No. 9.

13- Discoaster sublodoensis Bramlette & Sullivan. W. Nukhul, Sample No. 27.

Figs, 4-7: 1500 X

PLATE 2

Figure:

1- Discoaster nobilis Martini. W. Belayim, Sample No. 8.

2- Discoaster saipanensis Bramlette & Riedel. W. Nukhul, Sample No. 227.

3,4- Discoaster mediosus Bramlette & Sullivan. W. Belayim, Sample No. 2.

5- Discoaster multiradiatus Bramlette & Riedel. W. Belayim, Sample No. 2.

6- Discoaster surculus Martini & Bramlette. W. Belayim, Sample No. 17.

7- Discoaster distinctus Martini. W. Nukhul, Sample No. 168.

8- Discoaster tani nodifer Bramlette & Riedel. W. Nukhul, Sample No. 225.

9- Tribrachiatus contortus (Stradner). W. Belayim, Sample No. 7.

10- Tribrachiatus bramlettei (Bronnimann & Stradner).W. Belayim, Sample No. 2.

11- Tribrachiatus robustus (Stradner). W. Belayim, Sample No. 3.

12- Tribrachiatus orthostylus Shamrai. Form B, W. Belayim, Sample No. 3.

13,14- Tribrachiatus orthostylus Shamrai. Form A, W. Belayim, Sample No. 7.

15- Tribrachiatus orthostylus Shamrai. Form C, W. Belayim, Sample No. 2.

All photomicrographs are reproduced at a magnification of 3500 X unless otherwise indicated, and have been taken under normal polarizing light.

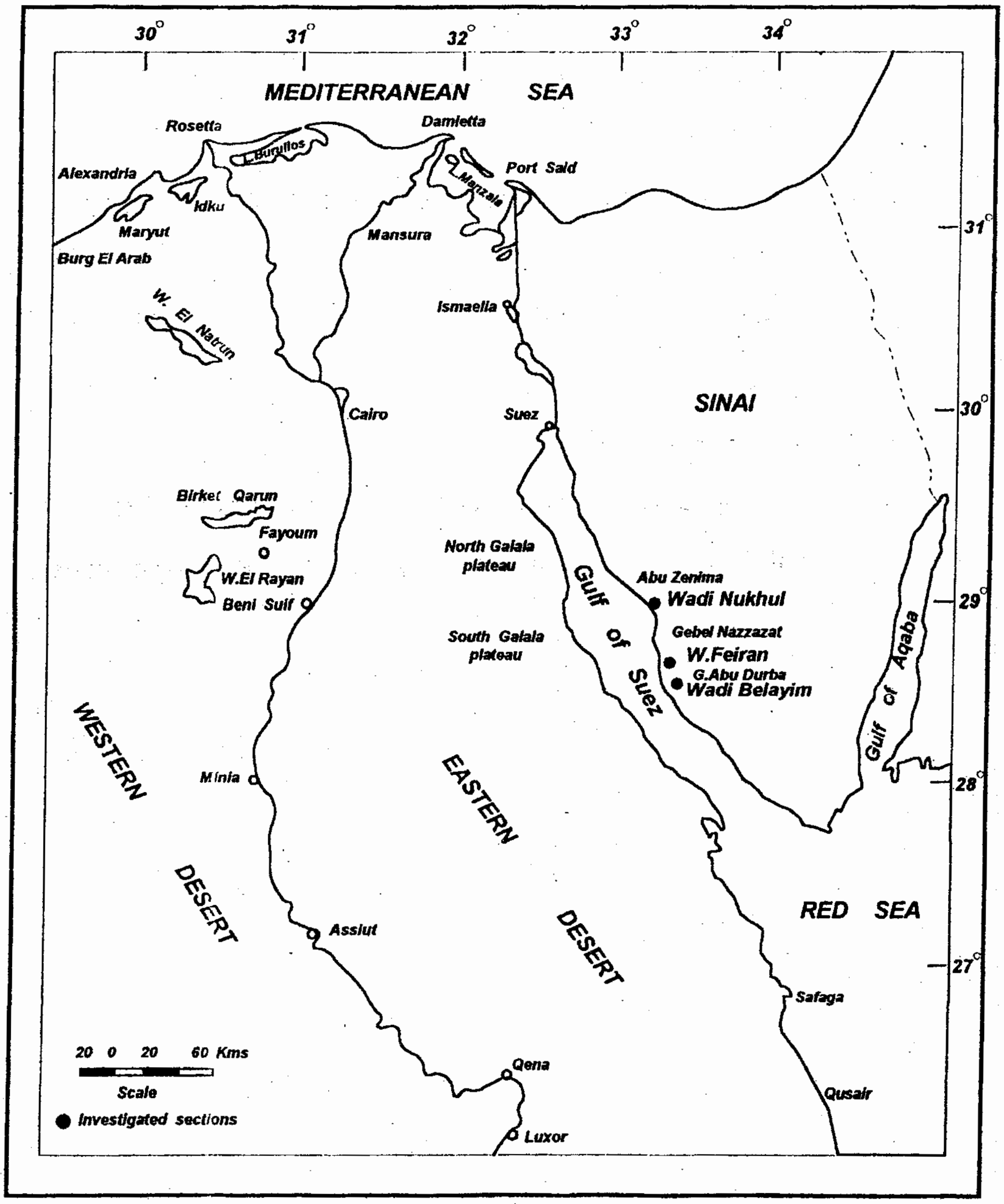
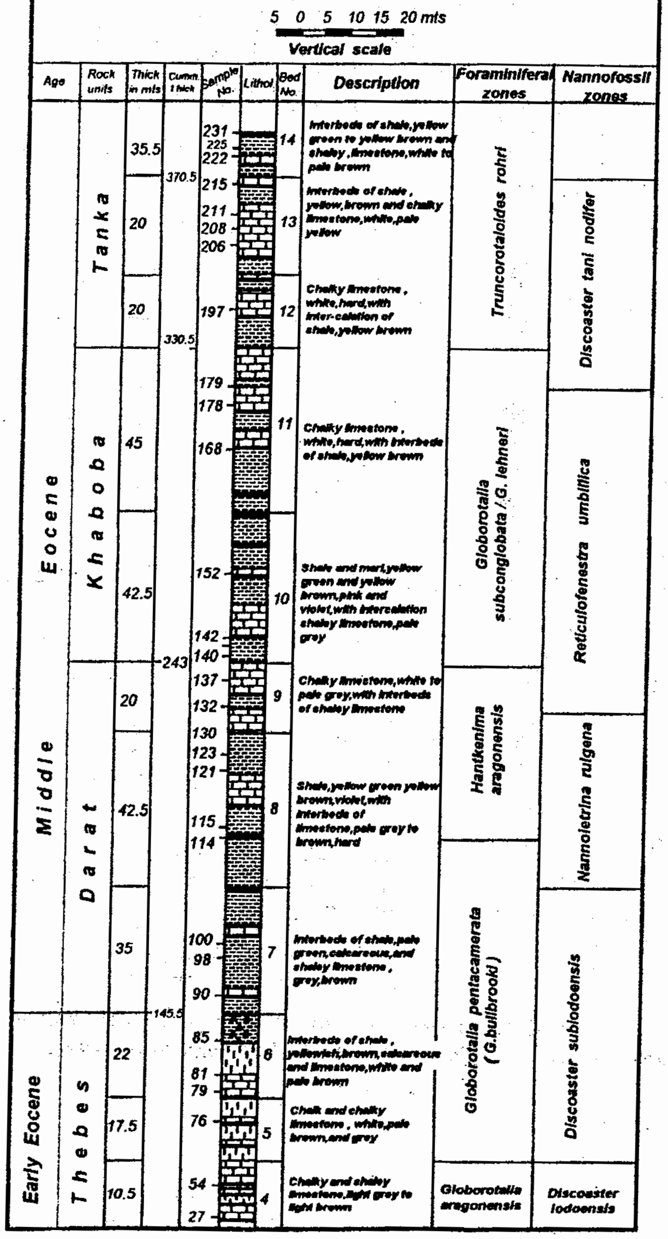


Fig.(1) Location map

Fig.(2) Columnar section of Wadi Nukhul, west central Sinai

Latitude 29°01' N
Longitude 33°10' E



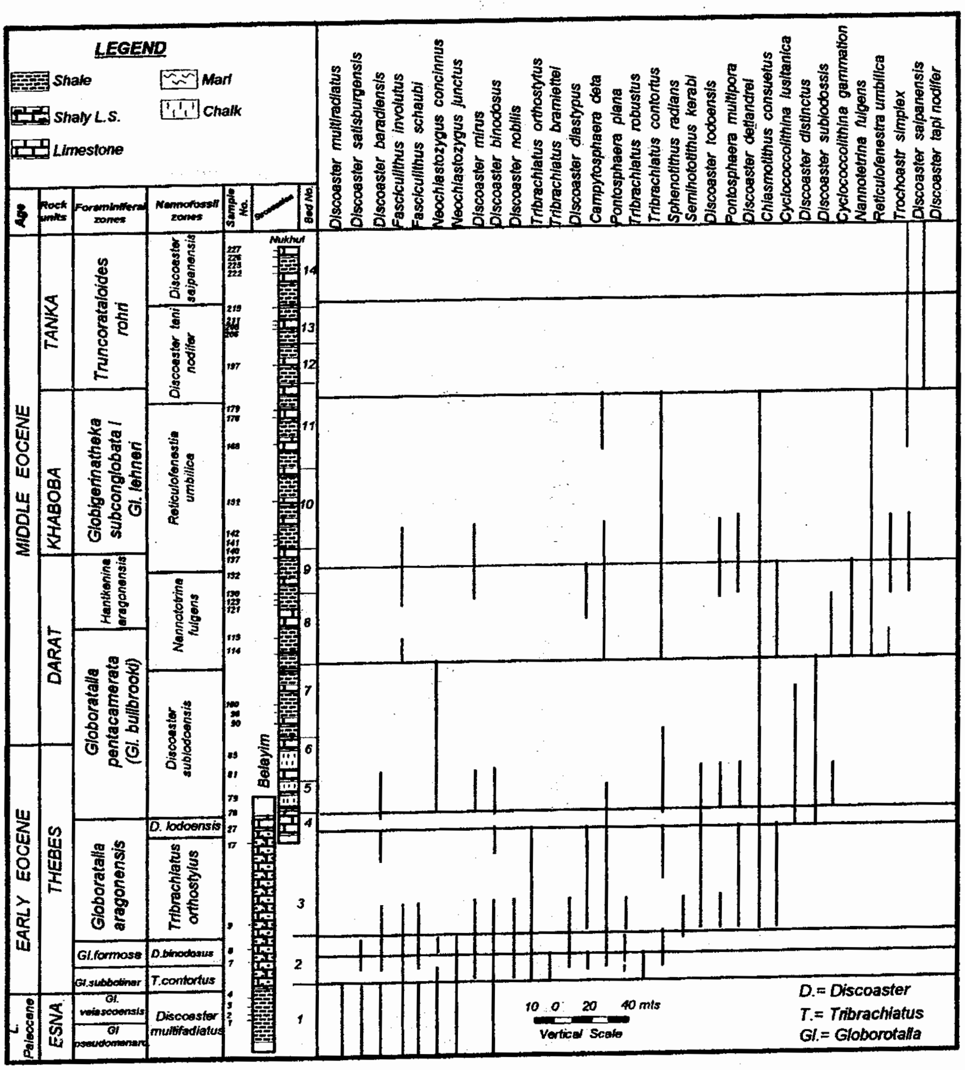


Fig.(3) Distribution of the most common species of Nannofossils in the Paleogene succession at Nukhul - Belayim, west central Sinai , Egypt.

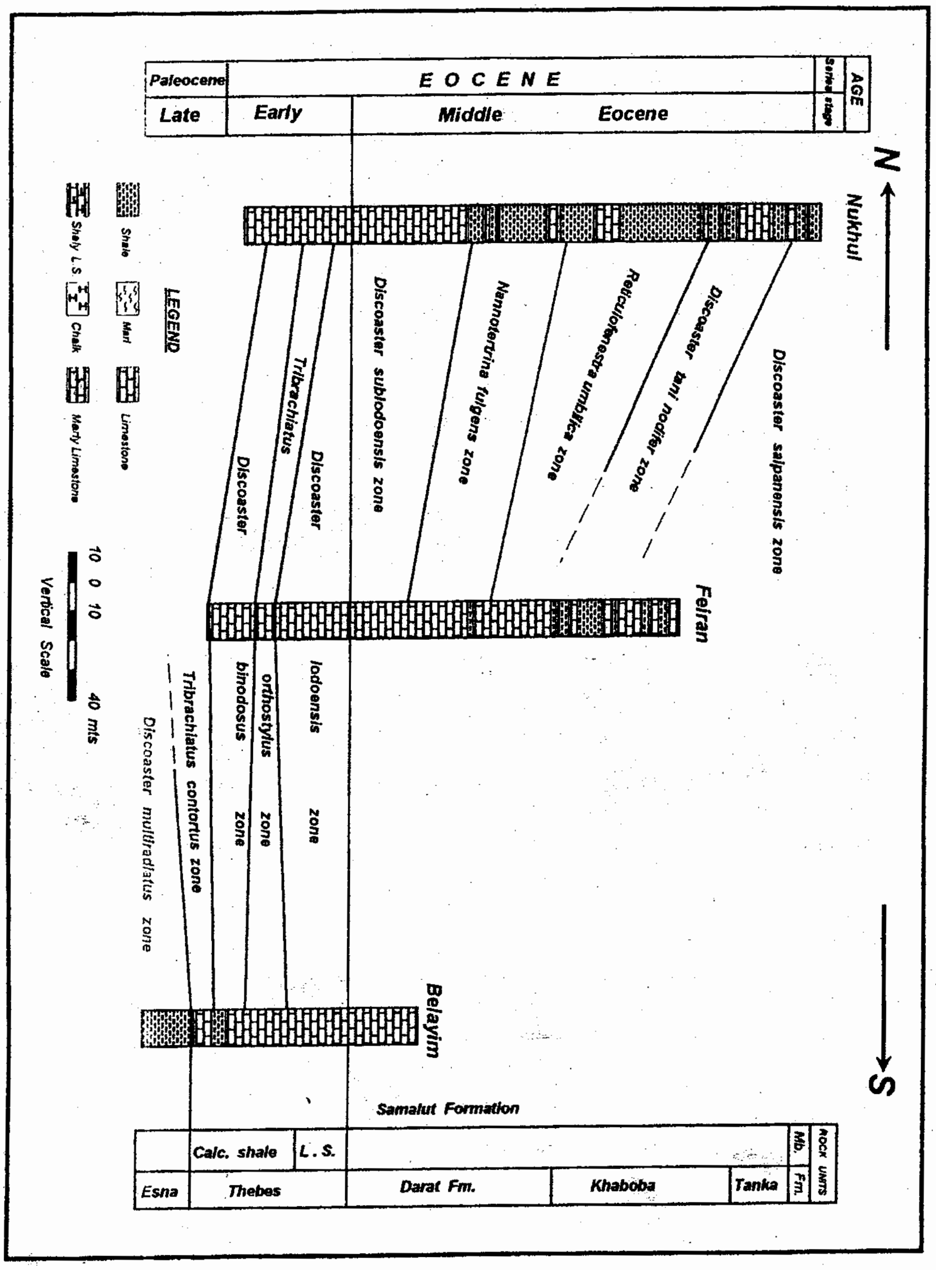


Fig.(4) Nannobiostratigraphic correlation chart of the Late Paleocene - Eocene succession in West Central Sinai, Egypt.

PLATE 1

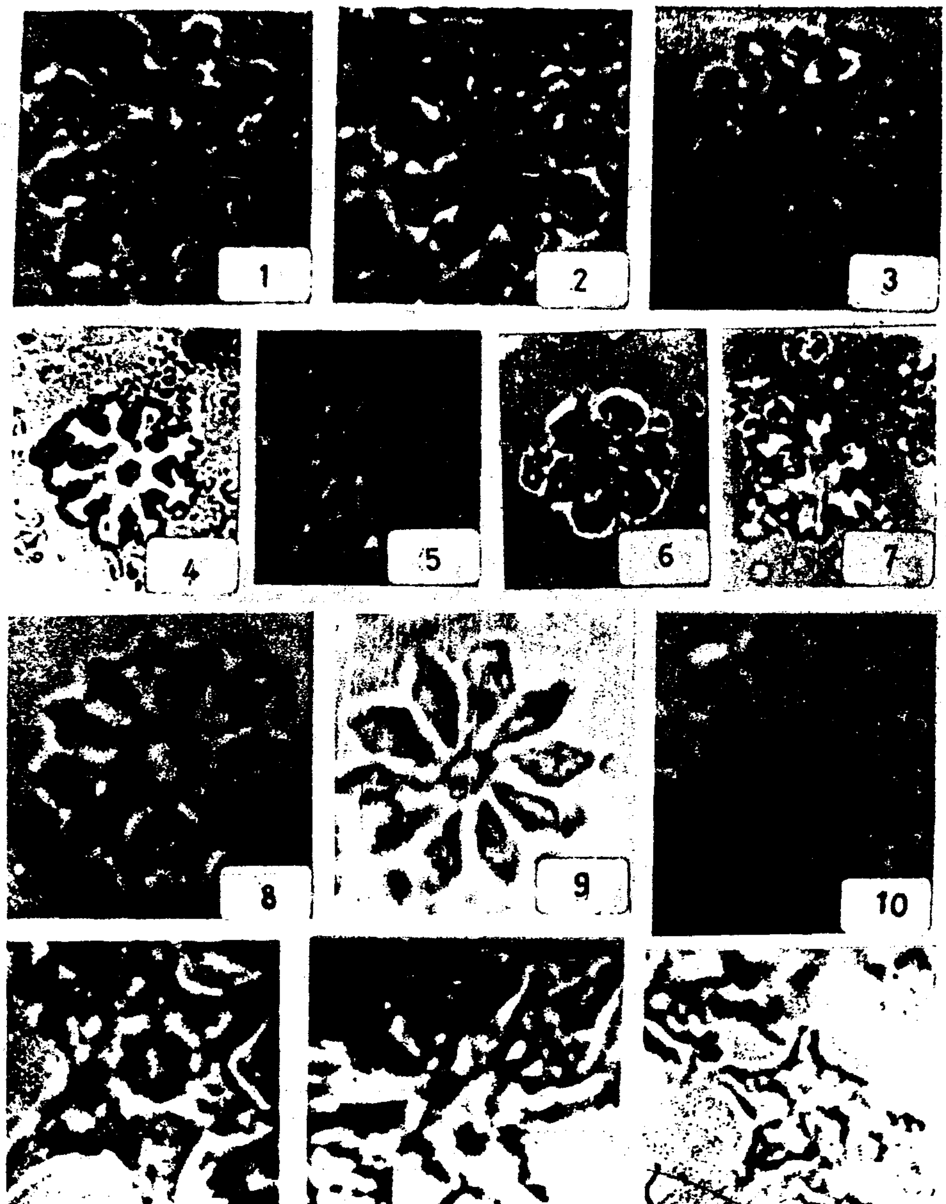
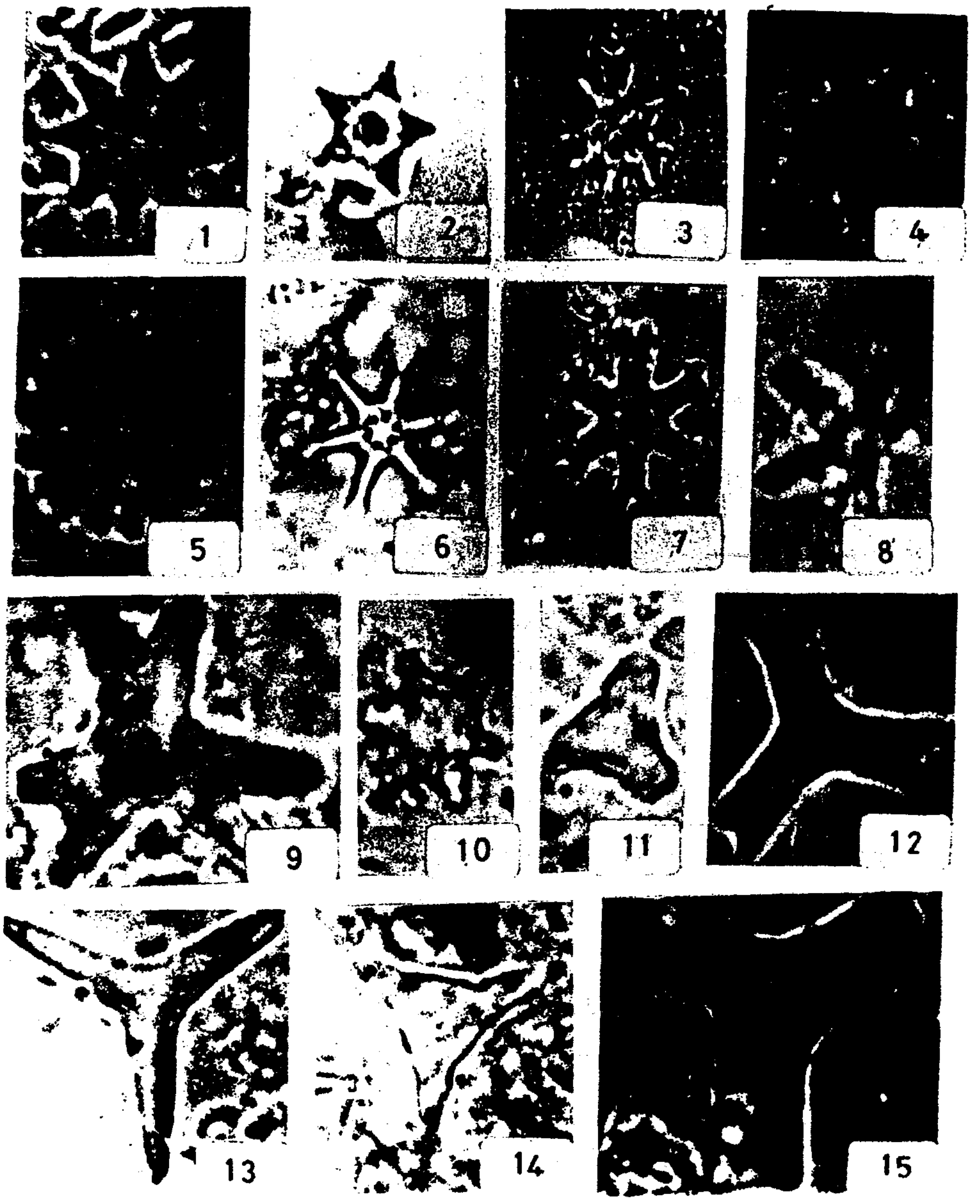


PLATE 2



الطبقية الحيوية للهوائم الجيرية الدقيقة (النانوس والفورامينيفرا) لبعض صخور الباليوجين فى غرب وسط سيناء

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الملخص

يصف ويعرض هذا البحث الهائمات الجيرية (الديسكواستر) المسجلة فى العينات التى جمعت من صخور الباليوجين بوادى نُخُل، وادى فيران ووادى بلاعيم، غرب وسط سيناء، مصر . ثمانية وعشرون نوعاً من الديسكواستر تتبع إلى جنسين من عائلة Discoasteromonadaceae، رتبة الـ Coccolithophorales قد تم تعريفها، وقد تم مناقشة تواجدها الإستراتيجرافى. وقد أمكن التعرف على عشرة نطاقات حيوية وهى مرتبة من أعلى إلى أسفل كالآتى:

١٠- نطاق الـ	Discoaster saipanensis Zone (part).	أيوسين متوسط
٩- نطاق الـ	Discoaster tani nodifer Zone	
٨- نطاق الـ	Reticulofenestra umbilica Zone.	
٧- نطاق الـ	Nannotetrina fulgens Zone.	
٦- نطاق الـ	Discoaster sublodoensis Zone.	
٥- نطاق الـ	Discoaster lodoensis Zone.	أيوسين سفلى
٤- نطاق الـ	Tribrachiatus orthostylus Zone.	
٣- نطاق الـ	Discoaster binodosus Zone.	
٢- نطاق الـ	Tribrachiatus controtus Zone.	باليوسين علوى
١- نطاق الـ	Discoaster multiradiatus Zone.	

قورنت نطاقات النانو الحيوية هذه بنطاقات الفورامينيفرا الهائمة ذات العصر نفسه وكلا النطاقات الحيوية وجدت ذات فائدة بالمضاهاة بمثيلاتها فى أماكن أخرى من العالم. توضح هذه النطاقات المقترحة فى هذا البحث التحليل الطبقى للقطاعات المدروسة والتى تم إنجازها باستخدام كل من الفورامينيفرا الهائمة والحفريات الجيرية المجهرية الدقيقة.