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MICRO-BIOSTRATIGRAPHY OF SOME UPPER CRETACEOUS SUCCESSIONS IN THE EASTERN DESERT, EGYPT

Ahmed Sami El-Dawoody

Faculty of Science, Cairo University, Egypt

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ABSTRACT

This paper deals with the biostratigraphic significance of nannofossil species recorded from some Maastrichtian rocks in the Eastern Desert, Upper Egypt. Careful study of these calcareous nannoflora and their stratigraphic occurrences have resulted in precise dating of the different rock units, and in further refinement of the nannobiozonal schemes still vaguely defined in Egypt. Four nannobiostratigraphic zones might be established, arranged from the base to top as: Quadrum trifidum zone (Campanian-Maastrichdan), Arkhangelskiella cymbiformis zone (early-middle Maastrichtian), Lithraphidites quadratus zone (middle-late Maastrichtian) and Nephrolithus frequens zone (most late Maastrichtian).

Such Maastrichtian nanno-biozones are easily equated with the planktonic foraminiferal Globotruncana, fornicate zone, Globotruncana ganssen zone and Globotruncana esnehensis zone of the same succession. Their occurrences in other parts of Egypt as well as in different parts of the world indicate that they could be successfully used for biozonation and transoceanic correlation.

The succession was divided into distinct litho and biostratigraphic units related mostly to Campanian-Maastrichtian and Maastrichtian ages. Besides, microfacies studies on thin sections representing Duwi Phosphate and L. Dakhla Shale formations were carried out. The paleoenvironmental conditions that prevailed during sedimentation were interpreted in accordance.

INTRODUCTION

In Upper Egypt and around the Nile Valley, the Classic Maastrichtian section is that of Gebel Owaina, southeast of Esna, while the most famous sections are that of Gebel Duwi, and Esh El Mellaha (W. Mellaha & G. Tarboul) on the Red Sea Coast, Eastern Desert, Egypt (Fig. 1) The succession as a whole is mostly developed in shale and marl facies with few limestone interbeds. Some .investigations advocating the absolute conformity between the Late Cretaceous and Early Tertiary in .Southern Egypt in general.

Youssef (1954) described Gebel Owaina section, introducing some micro and megafossils separated from its different units. He assigned, the shale succession overlying the phosphate beds to the Maastrichtian, while its upper part and the overlying chalk to the Danian. He considered the sequence at Gebel Owaina to be conformable throughout. Nakkady (1957) carried out an extensive study on the foraminifera of Late Cretaceous-Early Tertiary sections from widely separated areas in Egypt and their stratigraphic relationships. He considered the Chalk and the overlying Esna shale to be conformable and the Cretaceous-Tertiary contact lies at different levels in different sections. Again, he reviewed the biostratigraphy of the Upper Senonian and Paleocene, trying to correlate them with corresponding units in different parts of the world. He stressed on what he described as Campanian, Maastrichtian, Danian & Montian.

In 1961, Said gave the results of his studies in Gebel Owaina section, pointing out that the lower shale unit, equated with his newly introduced formational name of the Dakhla Shale is of Maastrichtian age in its lower part and of Lower Paleocene age in its upper part. A further discussion on the Dakhla Shale and Esna Shale "Sharawna Shale and Owaina Shale of El-Naggar 1966" at the type locality of the Esna Shale in Gebel Owaina, their distributions, lithological variations and their age was given by Said (1962, 1990) and El-Naggar (1966, 1970).

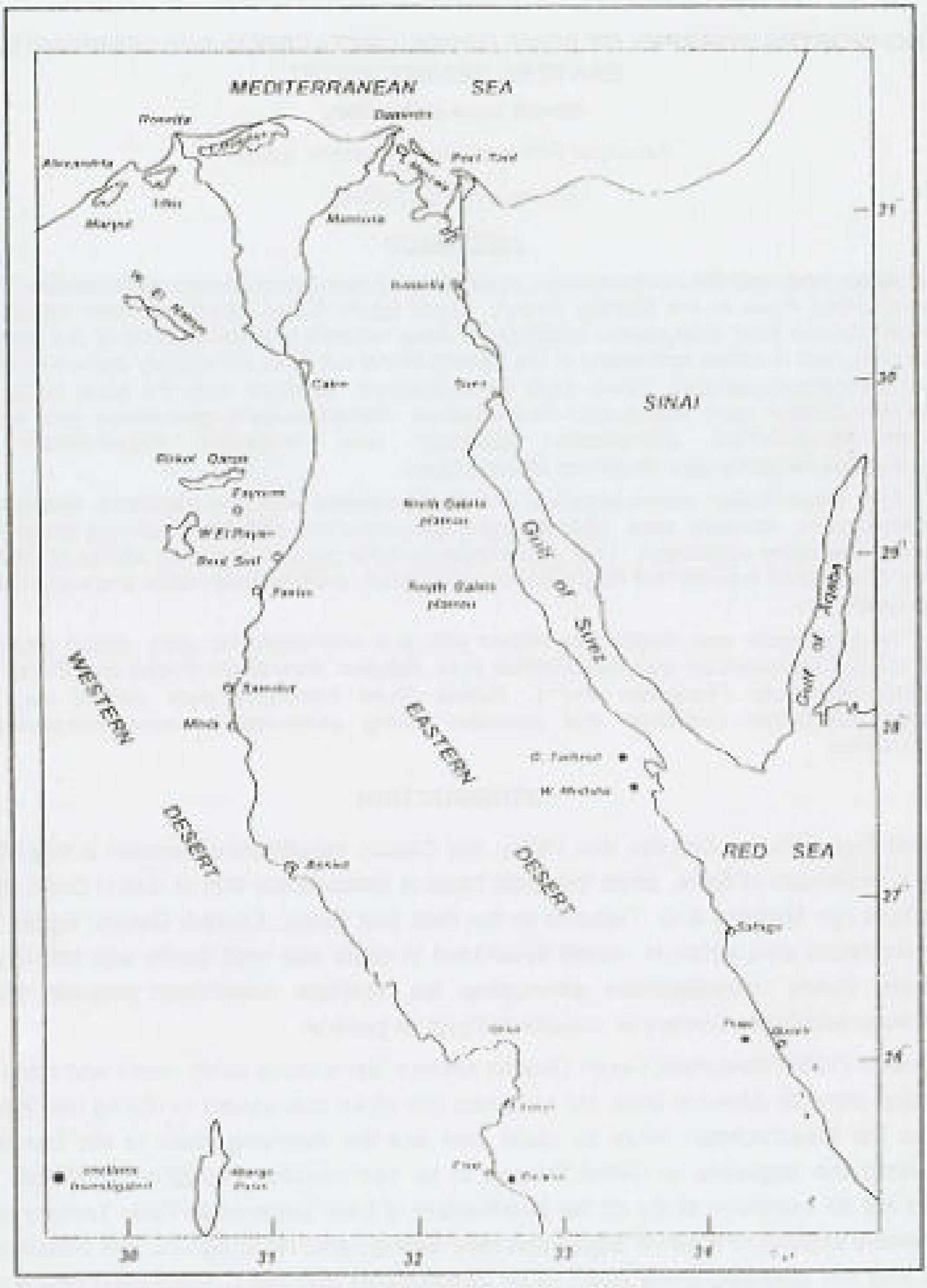

Fig. (1) LOCATION MAP

Recently, the accumulation of knowledge has emphasized the value of planktonic foraminifera as guide fossils for stratigraphical zonation, for regional as well as world-wide correlation. The most important microbiozones are those developed in Trinidad (Bolli, 1959), in Pademo d'Adda section, Italy. (Bolli & Cita, 1960), in general (Bolli, 1966), in the Nile valley Egypt (Said & Sabry. 1964, El-Naggar, 1966, Beckmann *et al.*, 1969) and some others. However, the nannoflora which co-exist with foraminifera should be identified and used to interpret the stratigraphy of the succession. Moreover, the stratigraphical ranges of the nannoflora could be established in the light of the planktonic foraminiferal zonation, thus ending a long controversy about their ranges.

A number of localities in Europe and America were thoroughly studied for their nannofossils and the results have been quite affectivily used for stratigraphic purposes. Particularity useful range charts have been presented in the last twenty years by many authors. Among them, Martini must be singled out for his notable contributions on the nannopaleontology and nannobio-stratigraphy of the Cretaceous – Tertiary succession. In a series of publications (1961-1976), Martini described and commented on the stratigraphic value of the calcareous nannoflora. The most useful investigations along this line are those by Stradner (1961, 1963), Bramlette & Sullivan (1961), Bramlette & Martini (1964), Stradner, in Stradner, Adamiker & Maresch (1968), Reinhardt (1966), Perch-Nielsen (1968, 1972), Bukry (1969, 1973), Perch-Niesen (1985) ...... and some others.

In Egypt, El-Dawoody gave the first information on the occurrence of calcareous nannoplankton from Duwi Range, near Quseir. In 1970, he studied the microbiostratigraphy of some sections from Upper and Lower Egypt with special emphasis on calcareous nannoplankton. This was followed by different investigations toward this goal, the following are worth mentioning; Kerdany (1969), Shafik & Stradner (1971), El- Dawoody & Barakat (1973), Perch-Nielsen *et al.* (1978), Faris (1985, 1997), El-Dawoody & Marzouk (2003), and last but not least El-Dawoody (1987-2002).

This work deals with the nannobiostratigraphy of the Upper Cretaceous sediments in Owaina, Duwi and Esh El Mellaha stratigraphic sections, Upper Egypt. It is an attempt to introduce well established biozones that could be followed in future research work around the Nile Valley and generally allover the Egyptian Territory. The present study aims to redefine the well known biostratigraphic units and to establish more precisely their true stratigraphic relationships. The biostratigraphic subdivisions and their correlation with comparable successions in other .parts of the world is also achieved.

Microfacies studies of thin sections prepared from the indurated rock samples were carried out to clarify the paleoenvironmental conditions that prevailed during the sedimentation of these rock units. The rock stratigraphic units treated in this study start chronologically with the Quseir Variegated Shale and Nubia Sandstone followed by the Duwi Phosphate, then the L. Dakhla Shale (Sharawna Shale of El-Naggar, 1966). The first two units represent the Campanian-Maastricntian Succession, while the third unit comprises the microfossiliferous part of the section denoting a Maastrichtian age. These rock units are distinct, applicable and easily recognizable in the field. They are briefly described, arranged from the base upwards, as follows:

1- Quseir Variegated Shale and Nubia Sandstone

This lowermost unit was recognized by Youssef (1957) in the Quseir area as a formation and was named the Nubia Sandstone. Wherever the base is exposed, the transgressive Nubia Sandstone beds rest unconformably over the basement rocks. The sandstone beds of this formation occupy many of the topographic lows in the general Quseir area.

The Nubia Sandstone is overlain by a series of unfossiliferous variegated shales and clays, mainly composed of multicoloured shales intercalated by fine-grained sandstone bands at the base. The colour varies from greenish grey to green, blue, and sometimes reddish brown. Youssef (1957) studied these shales and introduced the name Quseir Variegated Shale for the succession.

The thickness of these shales reaches 150 meters at Gebel Duwi. These shales are somewhat similar in lithology and colour to the overlying shales containing the phosphate bands.

2- Duwi Phosphate

A succession of phosphatic lenticular bands, shales, marls and limestones overlies the Quseir Variegated. Shale with a general conformable relationship. In Quseir, this formation is given the name Duwi Formation by Youssef (1957).

El-Naggar (1966) considers similar phosphate deposits in the Esna-Idfu region as a formation and named it the Sibaiya Phosphate which is comparatively much reduced in thickness. In El-Naggar's opinion, this Phosphate either represents a dwarfed Duwi formation or corresponds only to a part of that Formation.

The Duwi Phosphate extends in a conspicuous scarp for about 40 Km on the western side of the Duwi Range, underlying the Sharawna Shale with Ostrea vesicularis Zittel and Pecten farafrensis Zittel. It crops out also to the north, northwest and south of Gebel Duwi, attaining a thickness of about 150 meters.

3- Dakhla Shale

On top of the Duwi phosphate formation follows the Dakhla shale which is of wide geographical extent, and could be traced along the stable shelf of Egypt from the southern Oases in the west to Quseir district in the east. It could be also traced along the western scarp of the Nile and southwestward along the Kurkur – Dungul stretch. These shales are described by Said (1961), with its type locality, along the scarp north of Mut, Dakhla oasis. They are formed of yellowish, to greyish shales becoming marly at base and attaining a thickness of 130 mts. at its type locality.

The Dakhla shales are of remarkably constant lithological characters. Sometimes, it changes laterally in facies, almost entirely or at least in part to chalk or chalky limestones as in the Farafra area, Abou Minqar district and north Wadi Qena. This variation was pointed out by Kerdany (1969) and he called it as the "Khoman Chalk". This formation may be equated with the "Sudr Chalk" formation of Ghorab (1961).

The Dakhla shale unit assumes a thickness of 140-160 mts. at Gebel Owaina but with a characteristic conglomeratic bed (sample. No. 18/Ow. exceeding 2.5 mts. in thick.) (Fig. 2), while it attains around 150-170 mts. at Gebel Duwi (Fig. 3).

BIOSTRATIGRAPHIC ZONATION

The oldest fossiliferous rocks in the studied sections are those of the major part of the Maastrichtian at Gebel Duwi. This succession overlies the phosphate beds that contain some minute forms of foraminifera which could'nt be identified with certainty. The calcareous nannoplankton content, on the other hand, seems to be rare, sometimes common but without diagnostic forms except for Quadrum trifidum (Stradner).

The biostratigraphic zonation proposed here for the Upper Cretaceous succession is based on a system of zonation using the calcareous nannoflora. Rich assemblages with highly distinctive nannofossils have been described from a number of horizons and some of those formal zone names already in common usage have been applied to this interval. This leads to establish an interregional correlation for the Campanian / Maastrichtian – Maastrichtian succession of the classic sections investigated. The recorded flora build up the frame-work of this trial, substantiate with other stratigraphic tools.

Fourty two species of calcareous nannoflora were recognized in the outcrop samples of Duwi/Owaina sections, Eastern Desert, Egypt. Twenty species from Gebel Duwi and Twenty two species from Gebel Owaina (sixteen species of which encountered in the L. Cretaceous – E. Paleocene of Gebel Owaina) were known to characterize their stratigraphy, identified and fully described by El-Dawoody (1978). The most-common species of which are given in two general distribution charts; the first is concerned with the Campanian / Maastrichtion - Maastrichtian nannofossils of Duwi section and the second represents the Maastrichtian nannofossils of Owaina section (Figs. 4a,4b). Within this frame, the present author proposes the following calcareous nannoplankton zones for the Upper Cretaceous deposits of the region under investigation:

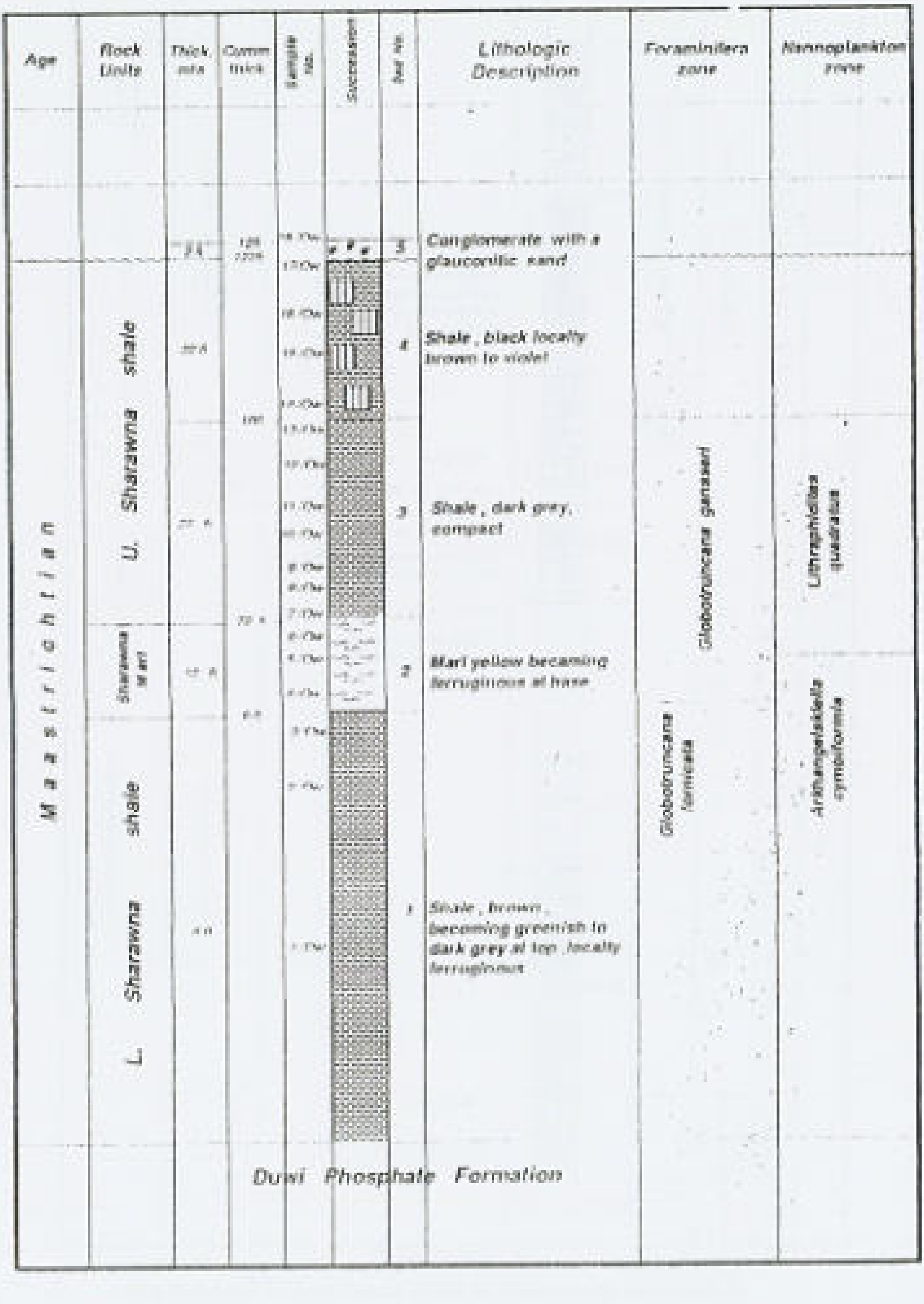

Fig.(2) Columnar section of the Upper Cretaceous (Maastrichtian) Succession in Gebel Owaina, Nile Valley, Egypt.

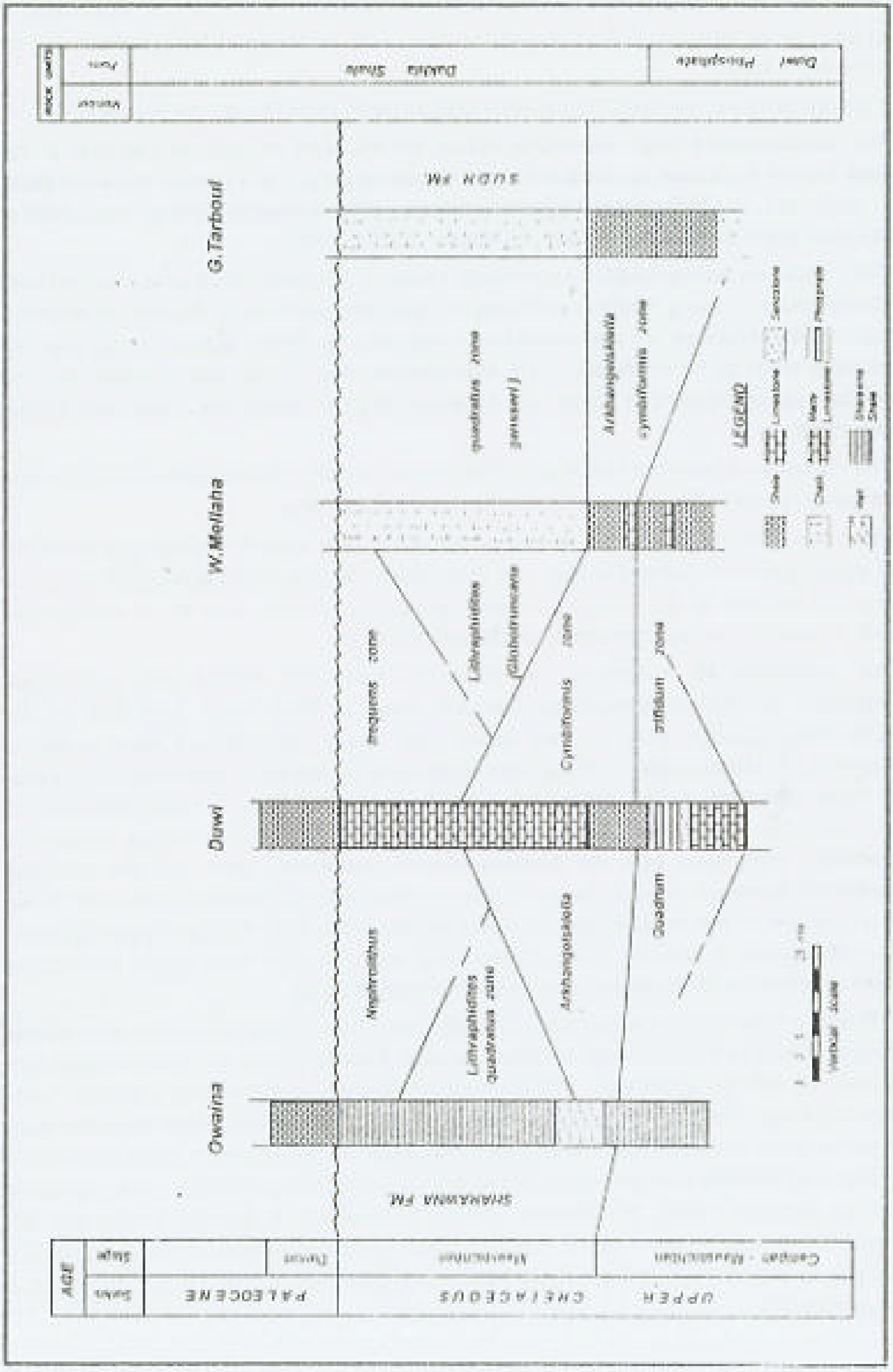

Fig. (5) Biostratigraphic correlation chart of the upper cretaceous succession in the eastern desert, Egypt

2. Maastrichtian:

The major part of the Sharawna Formation at Gebel Owaina, together with its equivalents at Gebel Duwi in the east and Esh El-Mellaha section in the north are of Maastrichtian age for the following reasons:

It conformably overlies the Campanian – Maastrichtian Duwi Phosphate Formation.

The Globotruncana and Heterohelix faunal assemblages present in that part of the Sharawna Shale are known to characterize the Maastrichtian in many parts of the world (Bolli, 1959, 1966 etc.). A similar assemblage is recorded from the Maastrichtian of other parts of Egypt (Said, 1961; Said & Sabry, 1964; El-Naggar, 1966; ... etc.).

The calcareous nannoplankton assemblage known in Sharawna Shale was recorded from the Maastrichtian of many localities including the type Maasttrichtian of Holland (Bramlette & Martini, 1964). Analyses of the assemblage recorded by these authors show that our assemblage tends to be of Middle - Late Maastrichtian age. It was also recorded from the Upper Cretaceous deposits of Texas and Arkansas (Gartner, 1968) and Texas and Europe (Bukry, 1969).

The macrofauna recorded in that part of the section facilitate its correlation with equivalent Maastrichtian strata in Egypt, in the Middle East and North Africa.

This stage characterize the 68 meters of the major Sharawna Formation just below the basal conglomerate in Gebel Owaina. The black shale capping the Maastrichtian section is barren with respect to its microfaunal and nannofloral content. Due to its stratigraphic position, however, it is suggested to be of Maastrichtian age.

The underlying 42 meters of the Sharawna Formation contain rich microfaunal assemblages of 'the Globotruncana fornicate zone in their lower part and of the Globotrunoana gansseri zone in their upper part: These assemblages were known to characterize the Maastrichtian in many parts of the world as well as in different parts of Egypt (Bolli, 1959, 1966; Bolli & Cita, 1960; Said, 1961; Bronnimann & Rigassi, 1963; Said & Sabry, 1964; El-Naggar, 1966; Beckmann et al. 1969; ... etc.). The corresponding nannofloral assemblages comprising both the Arkhangelskiella cymbiformis zone and the overlying Lithraphidites quadratus zone in Gebel Owaina (or Nephrolithus frequens zone in G. Duwi) were recognized in the Maastrichtian of many localities including the type Maastrichtian of Holland (Bramlette & Martini, 1964). These were also recorded from Upper Cretaceous deposits in several other localities in Europe, America and Egypt.

In Egypt, a Maastrichtian assemblage characteristic to such zone was recorded by Shafik & Stradner (1971) in the Chalk unit of Gebel Tarbouli, Eastern Desert. At Gebel Owaina, this zone matches with the upper part of Globotruncana gansseri zone denoting a Middle – Late Maastrichtian age. The upper boundary of such zone is not well defined. It lies within the non-fossiliferous black shale part, thus lacking the taxa useful for its delineation. Such nannofossil zone might be equated with the upper part of Arkhangelskiella cymbiformis zone previously known by Kerdany (1969), El-Dawoody (1970), El-Dawoody & Barakat (1973) and El-Dawoody & El-Dawy (1998). A trial for a sort of interregional correlation of the Maastrichtian calcareous nannoplankton zones in Egypt with their equivalents in other parts of the world is shown in Figure 6.

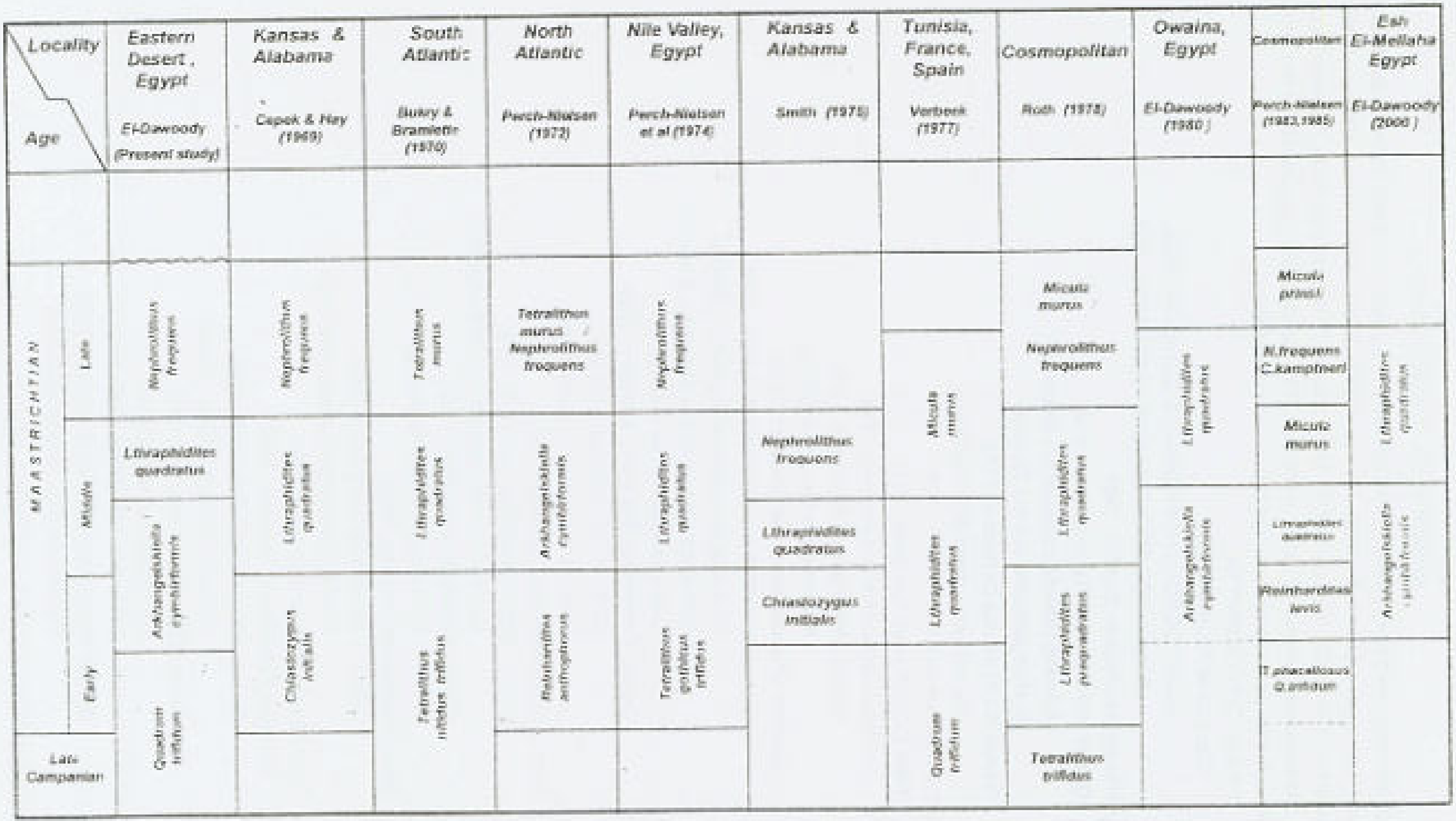

Fig. (6) Correlation of the Maastrichtian calcareous nannoplankton zones in Egypt with their equivalent in other parts of the world.

NANNOFOSS1L CLASSIFICATION

Several attempts have been made in the past thirty five years, especially those of Stradner (in Stradner, Adamiker & Maresch (1968), Gartner (1968), Bukry (1969), Perch-Nielsen (1985) & El-Dawoody (1990, 2002). Because of the limited scope of the present study, however, any of these classifications will not be given prefeence. The suprageneric assignment of the genera together with the index species recognized in this paper follows:

Phylum CHRYSOPHYTA
Class CHRYSOPHYCEAE
Order COCCOLITHOPHQRALES SCHILLER, 1926
Suborder COCCOLITHINEAE KAMPTNER, 1928

Family Arkangelskiellaceae BUKRY, 1969.
Genus: Arkhangelskiella Vekshina, 1959
Arkhangelskiella cymbiformis Vekshina
Arkhangelskiella obliqua Stradner
Genus: Kamptnerius Deflandre, 1959
Kamptnerius magnificus Deflandre

Family Coccolithaceae KAMPTNER, 1928
Tribe Coccolitheae Kamptner, 1958
Subtribe Coccolithinae Kamptner, 1958
Genus: Watznaueria Reinhardt, 1964
Watznaueria barnesae (Black)
Subtribe Rhabdosphaerinae Stradner, 1968
Genus: Cretarhabdus Bramlette & Martini, 1964
Cretarhabdus conicus Bramlette & Martini
Cretarhabdus crenulatus Bramlette & Martini
Cretarhabdus romani (Gorka)
Genus: Deflandrius Bramlette & Martini, 1964
Deflandrius columnatus Stover
Deflandrius intercisus (Deflandre)
Tribe Cribrosphaerelleae Stradner, 1968
Genus: Cribrosphaerella Deflandre, 1952
Cribrosphaerella ehrenbergi (Arkhangelsky)
Genus: Nephrolithus GORKA, 1957
Nephrolithus frequens (Aberg)
Tribe Pontosphaereae Hay, 1966
Genus: Pontosphaera Lohmann, 1909
Pontosphaera multicarinata (Gartner)
Tribe Zygosphaereae Kamptner, 1958
Subtribe Zygolithinae Stradner, 1968
Genus: Ahmuellerella Reinhardt, 1964
Ahmuellerella octoradiata (Gorka)
Genus: Eiffellithus Reinhardt, 1965
Eiffellithus eximius (Stover)
Eiffellithus turriseiffeli (Deflandre)
Genus: Vekshinella Loeblich & Tappan, 1963
Vekshinella crux (Deflandre & Fert)

Family Zygodiscaceae HAY & MOHLER, 1967

Genus: Chiastozygus Gartner, 1968

Chiastozygus litterarius (Gorka)

Genus: Zygodiscus Bramlette & Sullivan, 1961

Zygodiscus pseudenthophorus Bramlette & Martini

Zygodiscus spiralis Bramlette & Martini

Family Microrhabdulaceae DEFLANDRE, 1963

Genus: Lithraphidites Deflandre, 1963

Lithraphidites carniolensis Deflandre

Lithraphidites quadratus Bramlette & Martini

Genus: Microrhabdulus Deflandre, 1959

Microrhabdulus decoratus Deflandre

Microrhabdulus stradneri Bramlette & Martini

Family Thoracosphaeraceae SCHILLER, 1930

Genus: Thoracosphaera Kamptner, 1927

Thoracosphaera imperforata Kamplner

Thoracosphaera operculata Bramlette & Martini

Incertae sedis:

Genus: Micula Vekshina, 1959

Micula staurophora (Gardet)

Genus: Quadrum Prins & Perch Nielsen, 1977

Quadrum trifidum (Stradner)

The following short comments and the selected synonyms are rather fragmentary. Besides, the straligraphic ranges of the most common nannofossil species encounlered here are introduced (Figs. 4a, 4b). Only the zonal nannofossil species are discussed herein.

Genus: Arkhangelskiella Vekshina, 1959

Arkhangelskiella cymbiformis Vekshina

(pl. 1, fig. 1)

1912 "Coccolith of unknown affinities" Arkhangelsky, pl. 6, fig. 24.

1959 Arkhangelskiella cymbiformis Vekahina, p. 66, pl. 1, fig. 1, pl. 2, fig. 3.

Remarks: This species shows characters mentioned for the monotypic genus. The central area is divided into 4 quadrants by sutures sub-parallel to major and minor axes of the ellipse. Each quadrant is further subdivided by sutures at about 45o to the major and minor axes and secondary additional sutures. The perforations in the central area appear to lie along these sutures.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) deposits of Siberia. Abundant throughout the major part of the Maastrichtian Sharawna formation in Gebel Owaina. Few reworked specimens occur in the Paleocene conglomeratic bed of that locality. Individuals of this species are frequently present throughout the Arkhangelskiella cymbiformis zone at Gebel Duwi. Few specimens in the Paleocene strata are considered to be reworked because of association with few specimens of other Cretaceous forms.

Genus: Lithraphidites Deflandre, 1963

Lithraphidites quadratus Bramlette & Martini

1964 Lithraphidites quadratus Bramlette & Martini, p. 310, pl. 6, figs. 16, 17, pl. 7, fig. 8.

Remarks: Some specimens of Lithraphidites carniolensis Deflandre are somewhat thicker, more delicate and less elongate. These are short but have wider keels than long ones. They appear to grade into Lithraphidites quadratus Bramlette & Martini characterized by the abrupt tapering to pointed ends and the discontinuation of the keel to the tip of the specimen.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) of U.S.A. (Alabama), Denmark, France, Netherlands and Tunesia. This species is commonly restricted to the "topmost part of Middle Sharawna Marl together with the overlying Upper Sharawna Shale in Gebel Owaina.

Genus: Nephrolithus Gorka, 1957

Nephrolithus frequens Gorka

(pl. 2, fig. 2)

1957 Nephrolithus frequens Gorka; Acta paleont. Polon., 2; 263 pl. 5, Fig. 7.

Remarks: Such a species generally kidney - shaped. The rim is of two alternating rows of crystals intercalating each other. Central area occupied by ring - shaped structures composed of imprecating crystals of clock - wise orientation.

Stratigraphic range: Originally described from the Upper Cretaceous (Maastrichtian) of Poland. In Egypt, it occurs in Gebel Duwi, representing the zonal marker of the Nephrolithus frequens Zone of Late Maastrichtian.

Genus: Quadrum Prins & Perch Nielsen, 1977

Quadrum trifidum (Stradner)

(pl. 1, fig. 8)

1961 Tetralithus gothicus trifidus Stradner, in Stradner & Papp, p. 124, text – fig. 23 (3).

1973 Tetralithus trifidus Stradner, Roth, p. 728, pl. 18, figs. 6, 7.

1977 Quadrum trifidum (Stradner). Prins & Perch-Nielsen, in Manivit et al., p. 178.

1977 Quadrum trifidum (Stradner). Verbeek, p. 123, pl. 12, fig. 11.

Remarks: Such species has forms with three and with four elements, which start their range at the same level and are generally considered to belong to one species. The three and four armed forms of Tetralithus gothicus Deflandre are also found together. Because specimens with four arms are more frequent in Spain and those with three arms more frequent in Tunisia, it seems likely that the number of arms depended on ecological circumstances. For these reasons both forms are considered to belong to the same species.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) of France. This species is commonly restricted to the topmost part of the Duwi Phosphate denoting a Campanían – Early Maastrichtian age in Gebel Duwi.

PALEOECOLOGIC IMPLICATIONS

The hard beds, which are unfavourable for any appropriate washing techniques, were thin sectioned and studied for their microfacies. A series of monographs were published dealing with microfacies of many parts of the world (Scholle, 1978).

In Egypt, several authors were engaged in the Cretaceous – Tertiary microfacies including: Barakat & Tewfik (1966), Ghorab & Ismail (1969), Barakat & El-Dawoody (1973) and El-Dawoody & Aboul Karamat (1993) are the most prominent. The terminology proposed by Folk

(1962) and Dunham (1962) in describing the different carbonate rock types is followed here in the present study. Dunham's classification is essentially textural and is most valuable when used in a purely descriptive way for lithified rocks.

Textural maturity is implied in that the least mature varieties are richer in mud matrix. However, depositional deductions based on these textural characters alone need great care. The indurated interbeds were thin-sectioned and microscopically examined. The study of such rock samples was found necessary to throw more light on the evolutionary history of the sedimentation basin. The paleoenvironmental conditions that prevailed during sedimentation of the different lithostratigraphic units were interpreted.

1. Variegated Shale (pl. 3, fig. 1)

Very fine grained, argillaceous matter, microcrystalline, with ferruginous streaks and irregular patches, slightly arenaceous and poorly micaceous, unfossiliferous. This facies is recorded at the basal part of Gebel Duwi.

Paleoenvironment: Inner neritic, with relatively shallow water conditions, not far from a nearby landmass.

2. Sandy Shale (pl. 3, fig. 2)

Highly siliceous, angular to subrounded sand grains, ill-sorted, with some phasphatic grains highly stained with iron oxides, and few glauconitic granules, unfossiliferous. This facies is known through the Duwi Phosphate (sample No. 3) in Gebel Duwi.

Paleoenvironment: Shallow marine, where phosphatic materials have been accumulated.

3. Fossiliferous Micrite (pl. 2, fig. 3)

Very line grained, cryptocrystalline with undifferentiated organic remains together with some phosphatic grains, arranged nearly parallel to the direction of lamination. Such fades is found in the upper part of the Duwi Phosphate (sample No. 3a) at Gebel Duwi.

Paleoenvironment: Neritic, with calm conditions of sedimentation "low agitated bottom conditions".

4. Phosphatic Biosparite (pl. 3, fig. 4)

Mainly composed of phosphatic remains in the form of plates, granules and rounded bodies embedded in a groundmass of microcrysta-lline carbonates and in parts it is sparry calcite. Phosphatic granules are mostly well sorted and they exhebit straight extenction with micaceous inclusions. This facies is known in Duwi Phosphate formation, just below the uppermost phosphatic bed.

Such a type of association reflects an inner neritic environment that have been strongly affected by high level of energy caused by waves. Secondary crystallization may have taken place and gave rise to the sparry texture.

5. Phosphatic Biomicrite (pl. 3, fig. 5)

Fine grained, highly fossiliferous, with benthonic foraminifera mainly represented byretaild forms together with well preserved phosphatic remains such as vertebrae and ribs. This facies caps the Duwi Phosphate of the Maastrichtian part in Gebel Duwi.

Paleoenvironment: Mixed environment in which marine transgression gently overlapped the phosphatic bioherms.

6. Heterohelix Biomicrite (pl. 3, figs. 6, 7)

Microcrystalline, highly fossiliferous, with planktonic and benth-onic foraminifera. The planktonics are mainly represented by Heterohelix spp., Glohotruncana spp., Globigerinas and globorotalias. The benthonics are represented by Bolivina sp., together with rotalid forms and lagenid forms. Typical Heterohelix biomicrites are recorded from the Dakhla Shale formation at Gebel Duwi, samples 23/D - 25/D. Such a type of association reflects deep water conditions of warm sea with normal salinity where planktonic elements are the most abundant.

7. Globorotalia Biomicrite (A) (pl. 1, fig. 8)

Fine grained and cryptocrystalline, highly fossiliferous with plank-tonic forams particularly Round-Keeled Globorotalias together with Globigenna spp. They are completely replaced by fine grained calcite filling up their interior cavities. Benthonic forams are also common and they are habhazardly distributed in the rock section. This facies is known in Dakhla Shale formation at Gebel Duwi, samples 20/D, 21/D.

Such a type of facies reflects deep water deposit of at least semi-pelagic character with abundance of planktonic calcareous microfauna.

The following paragraphs are concerned with the relationship between the organisms met with in thin sections and their habitat medium. This paleoecological analyses elucidate the conditions under which sedimentation took place. Moreover, fossil organisms and the sediments in which they are embedded are frequently good indicators for the evaluation and adaptation of the organisms to the conditions that dominated during their life.

Since this paleoecologic study is based on wide spaced stratigraphic sections, measured and sampled from different localities, it is preferred to treat each section separately. The paleoecologic conditions were interpretted for each section during a certain stratigraphic time and they are continued in another section for the next stratigraphic interval, till the whole investigated sequence is elucidated. The Duwi section embraces the stratigraphic interval between the Late cretaceous and the Paleocene.

Upper Cretaceous deposits are composed of multicolored shales, unfossili-ferous, slightly to moderately sandy and phosphatic in part. These shales are intercalated by fine argillaceous and poorly fossiliferous calcareous interbeds. These lithological characters indicate deposition in a relatively shallow and stagnant or toxic bottom conditions that prevailed during the Campanian time. Shortly after the outset of the Maastrichtian in Duwi district, further shallowing took place resulting in the development of a lacustrine environment. This have been strongly affected by waves and current action and participated in the accumulation of phosphatic remains in the form of plates, granules and rounded bodies. Shallowing of the basin continued on, and the phosphatic beds have been deposited. Next to this phase, inundation took place and outer neritic conditions prevailed.

Plate 1

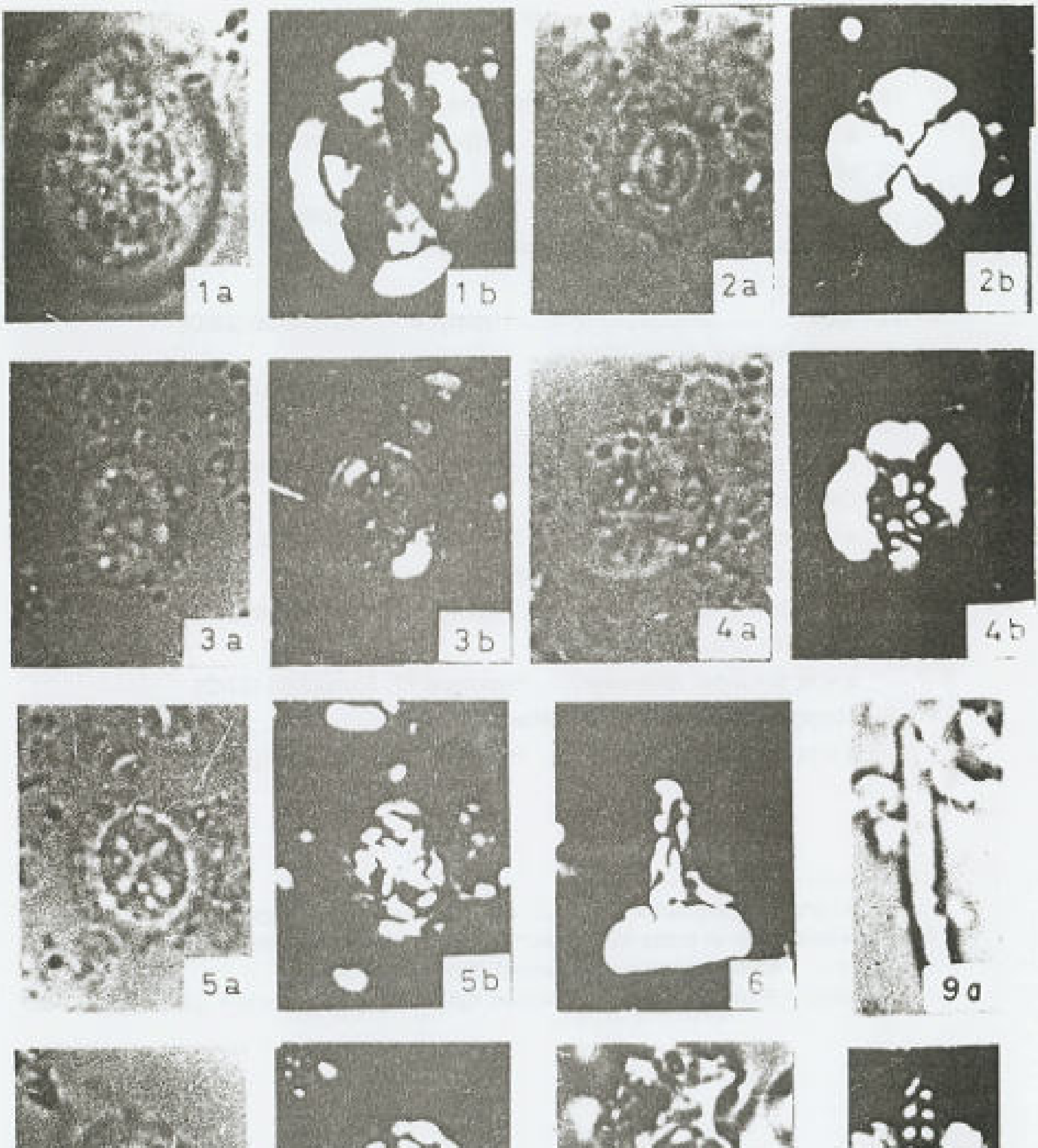

PLATE 1

Figure

1- *Arkhangelskiella cymbiformis* Vekshina
a = nl, b = x-nic; proximal view ... Hypotype 2, Sample 86 (23/D).
2- *Watznaueria barnesae* (Black)
a = nl, b = x-nic; distal view ...... Hypotype 9, Sample 88 (25/D).
3- *Cretarhabdus crenulatus* Bramlette & Martini
a = nl, b = x-nic; proximal
view .... Hypotype 11, Sample 86 (23/D).
4- *Cretarhabdus romani* (Gorka)
a = nl, b = x-nic; distal view ...... Hypotype 12, Sample 88 (25/D).
5- *Deflandrius columnatus* Stover
a = nl, b = x-nic; distal view ...... Hypotype 14, Sample 88 (25/D).
6- *Deflandrius columnatus* Stover
x-nic; side view .... Hypotype 15, Sample 88 (25/D).
7- *Deflandrius intercisus* (Deflandre)
a = nl, b = x-nic; distal view ...... Hypotype 16, Sample 88 (25/D).
8- *Quadrum trifidum* (Stradner)
a = nl, b = x-nic; side view ...... Hypotype 17, Sample 86 (27/D).
9- *Microrhabdulus decoratus* (Deflandre)
a = nl, b = x-nic; side view ...... Hypotype 38, Sample 86 (23/D).

All photomicrographs (Pls. 1, 2) are reproduced at a magnification of 2500 x. For the explanation of these micrographs, the following abbreviations are used:
nl = Photomicrograph, normal light + green filter
x-nic = Photomicrograph, polarized light with crossed nicols + yellow filter

Plate 2

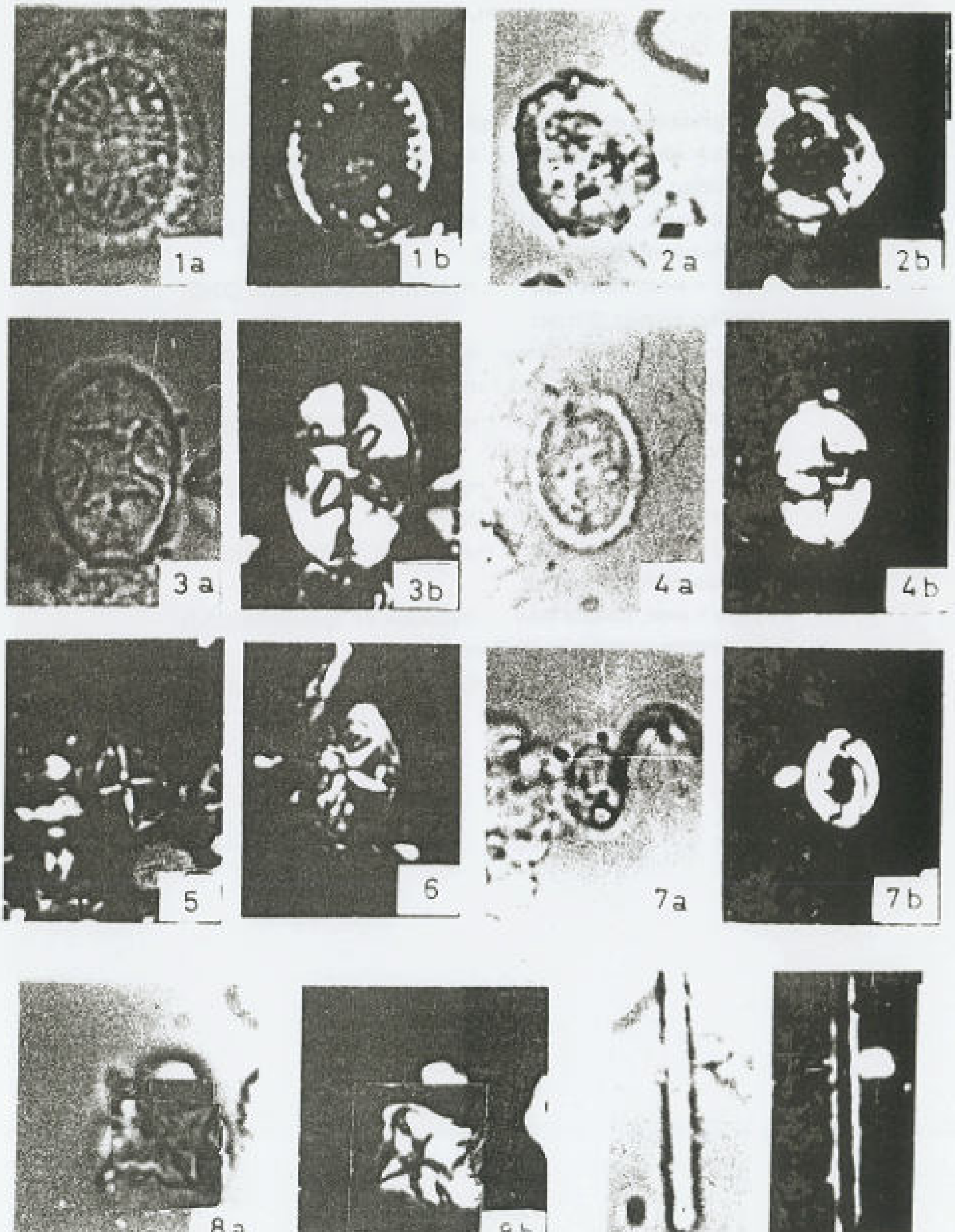

PLATE 2

Figure

1- *Cribrosphaerella ehrenbergi* (Arkhengelsky)
a = nl, b = x-nic; distal view ...... Hypotype 18, Sample 88 (25/D).
2- *Nephrolithus frequens* (Aberg)
a = nl, b = x-nic; proximal view .. Hypotype 21, Sample 86 (23/D).
3- *Eiffellithus turriseiffeli* (Deflandre)
a = nl, b = x-nic; distal view ...... Hypotype 23 Sample 86 (23/D).
4- *Eiffellithus eximius* (Stover)
a = nl, b = x-nic; proximal view.. Hypotype 27, Sample 88 (25/D).
5- *Vekshinella crux* (Deflandre & Fert)
x-nic; distal view .... Hypotype 30, Sample 86 (23/D).
6- *Chiastozygus litterarius* (Gorka)
x-nic; proximal view .... Hypotype 33, Sample 86 (23/D).
7- *Zygodiscus spiralis* Bramlette & Martini
a = nl, b = x-nic; distal view .... Hypotype 34, Sample 86 (23/D).
8- *Micula staurophora* (Gardet)
a = nl, b = x-nic; oblique view .... Hypotype 41, Sample 86 (23/D).
9- *Lithraphidites carniolensis* (Deflandre)
a = nl, b = x-nic; side view .... Hypotype 40, Sample 86 (23/D).

Plate 3

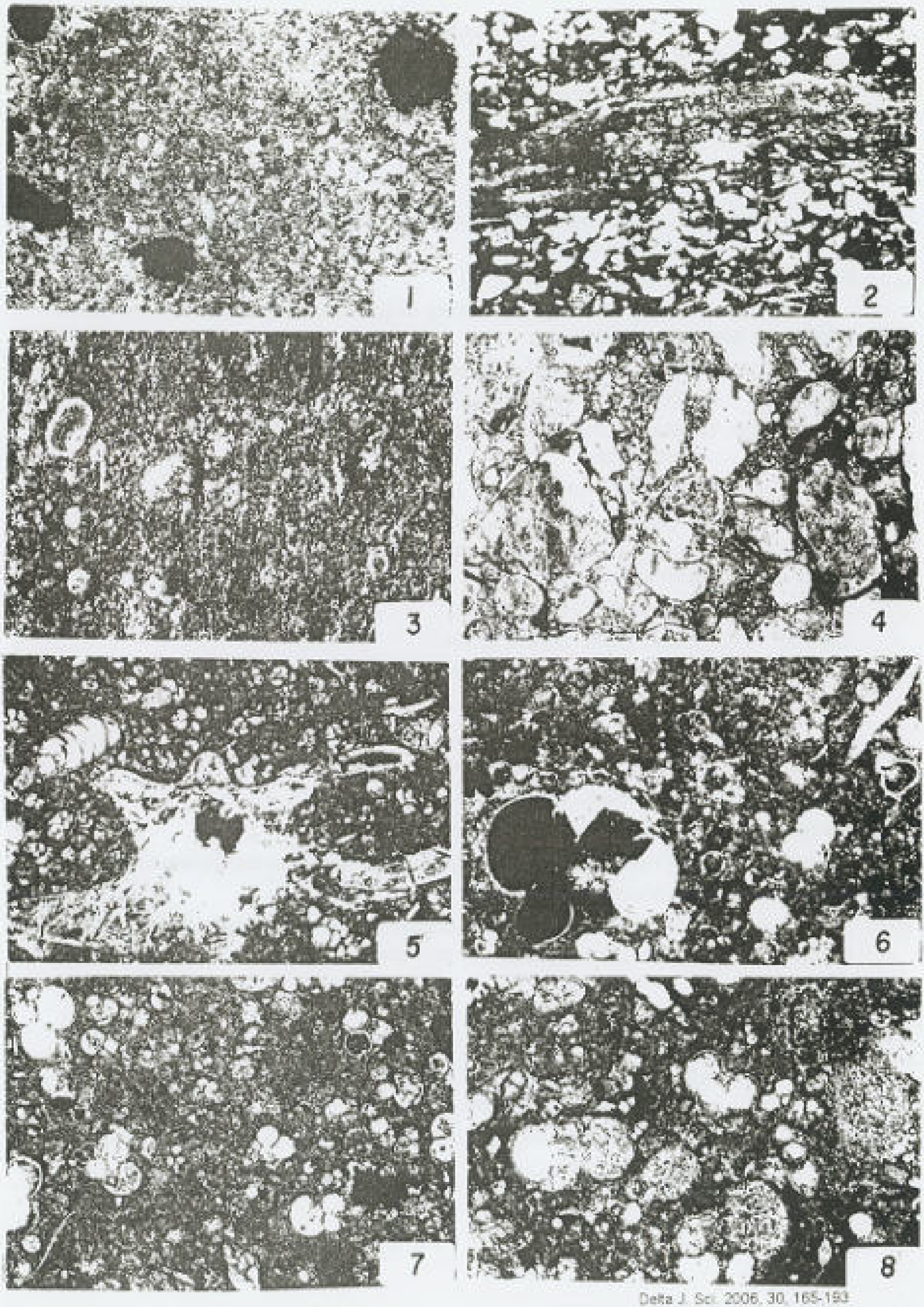

PLATE 3

Fig. 1 : *Variegated shale* (60 X)

Very fine grained, slightly arenaceous, with ferruginous streaks and irregular patchs, unfossiliferous.

Age : Campanian.

Locality : Gebel Duwi, sample 100.

Environment : Inner neritic, with relatively shallow water conditions not far from a nearby landmass.

Fig. 2 : *Sandy shale* (60 X)

Highly siliceous, sand grains being angular to sub-rounded, with some phosphatic grains, unfossiliferous.

Age : Campanian – Maastrichdan.

Locality : Gebel Duwi, sample 96 (3).

Environment : Shallow marine, where the phosphatic material have been accumulated.

Fig. 3 : *Fossiliferous Micrite* (100 X)

Very fine grained, exhibiting ± regular fine bands, with undifferentiated organic remains together with some phosphatic grains? arranged nearly parallel to the direction of lamination.

Age : Campanian – Maatrichtian.

Locality : Gebel Duwi, sample 95 (3a).

Environment : Neritic, with calm conditions of sedimentation.

Fig. 4 : *Phosphatic Biosparite* (30 X)

Medium grained, fossiliferous, mainly composed of phosphatic remains in the form of plates, granules and rounded bodies embedded in a sparry calcite matrix.

Age : Campanian – Maastrichtian.

Locality : Gebel Duwi, sample 94 (3b).

Environment : Inner neritic, affected by high level of energy caused by waves.

Fig. 5 : *Phosphatic Biomicrite* (30 X)

Fine grained, fossiliferous, with benthonic Foraminifera mainly represented by rotalid forms, together with well preserved phosphatic remains such as vertebrae and ribs.

Age : Maastrichtian.

Locality : Gebel Duwi, sample 90 (27/D).

Environment : Mixed environment in which marine reansgression gently overlapped the phosphatic bioherms.

Fig. 6 : *Heterohelix Biomicrite* (100 X)

Fine grained, highly fossiliferous, with abundant planktonic and benthonic Foraminifera. Planktonics represented by *Heterohelix* spp. and *Globotruncana* spp.

Age : Maastrichtian.

Locality : Gebel Duwi, sample 88 (25/D).

Environment : Outer neritic, no coarser terrigenous material accumulated.

Fig. 7 : *Heterohelix Biomicrite* (100 X)

Fine grained, highly fossiliferous, with abundant planktonic Foraminifera. represented by *Heterohelix* spp., *Globotruncana* spp., Globigerinas and Globorotalias, loosely packed in a carbonate matrix.

Age : Maastrichtian.

Locality : Gebel Duwi, sample 88 (25/D).

Environment : Outer neritic, no coarser terrigenous material accumulated.

Fig. 8 : *Globortalia Biomicrite* (A) (100 X)

Fine grained, highly fossiliferous, with abundant planktonic Foraminifera particularly *Round-keeled Globorotalias*, together with *Globigerina* spp. Benthonic Foraminifera common.

Age : Early Paleocene (Danian).

Locality : Gebel Duwi, sample 84 (21/D).

Environment : Deep marine, of at least semi-pelagic character.

Fig. (5) Biostratigraphic correlation chart of the upper cretaceous succession in the eastern desert, Egypt

Fig. (6) Correlation of the Maastrichtian calcareous nannoplankton zones in Egypt with their equivalent in other parts of the world.

SUMMARY AND CONCLUSIONS

The investigation of the Late Cretaceous in the four surface sections Eastern Desert in Upper Egypt: Gebel Duwi and Esh El Mellaha Range (W. Mellaha & G. Tarboul) Red Sea Coast, Gebel Owaina on the Nile Valley was undertaken. This lead to the classification of such succession into the following rock stratigraphic units; arranged from top to base as:

Owaina Shale

~~~~ 3- Dakhla Shale ~~~~

Sharawna Shale

2- Duwi Phosphate

1- Quseir Variegated Shale and Nubia Sandstone

These rock units have a regional distribution and be used as a basis for detailed mapping.

This succession was zoned on the basis of its nannofossil content. The proposed zones were correlated with those recognized in other parts of the world, arranged from top to base as:

4. Nephrolithus frequens Zone
3. Lithraphidites quadratus Zone
2. Arkhangelskiella cymbiformis Zone
1. Quadrum trifidum Zone

The study of stratigraphic ranges of the planktonic foraminifera found contemporaneous with these nannoflora in such succession aided in delineating three microbiostratigraphic zones. These zones were equated with the previously mentioned nannobiozones through a high resolution biostratigraphy. Furthermore, both biostratigraphic zonations were correlatable with corresponding successions in other parts of the world This sort of study results in a number of interesting conclusions:

A comprehensive nannopaleontologic study of the Upper Cretaceous Lower Tertiary succession comprises a detailed taxonomy for the nannofossil assemblages recorded (El-Dawoody, 1978). This led to the identification of around 30 nannofossil species belonging to 18 genera in Duwi/Owaina sections, the most-common of which are related to the physical stratigraphy of the area under investigation through two clearly drawn distribution charts (Figs. 4a, 4b).

The lowest formations cropping out in the studied region are at Gebel Duwi/Owaina - Esh el Mellaha sections. These are the Variegated Shale and Phosphate formations which may be dated, on the basis of megafossils and of nannofossils (Quadrum trifidum Zone) rather than microfossils, as of Campanian – Maastrichtian.

The Sharawna Formation is of Maastrichtian age. It is character-ized by two nannofossil assemblages representing a lower Arkhangelskiella cymbiformis Zone and an upper Lithraphidites quadratus Zone. The Arkhangelskella cymbiformis Zone falls within the globotruncana gansseri / Heterohelix globulosa Zone at Gebel Duwi, occupies the lower part of such zone in both Owaina and Esh ElMellaha Range, to the north, all are of an Early-Middle Maastrichtian age. The Lithraphidites quadratus Zone occupies the upper part of Globotruncana gansseri Zone in the latter sections, the two zones are of Middle-Late Maastrichtian age.

In Gebel Duwi, on the other hand, the Lithraphidites quadratus Zone disappears, due to the presence of an intraformational conglomerate, and the Nephrolithus frequens Zone
~~~~

directly overlies the Arkhangelskiella cymbiformis Zone. The disappearance of the topmost Nephrolithus frequens Zone toward the north is due to the presence of an intraformational conglomerate, but of higher level than those found in Gebel Duwi. This is achieved by the presence of incomplete Globotruncana esnehensis Zone at the tompost part of the Late Cretaceous at Gebel Owaina on the Nile Valley.

The Black shales capping the Sharawna Formation are barren in their microfossil and nannofossil contents, but with an arenaceous foraminiferal assemblage in few thin calcareous bands intercalating these shales. Such an assemblage marks the Maastrichtian (Late Cretaceous) in many parts of the world. The presence of a conglomeratic bed with reworked Maastrichtian fossils and some glauconites between the Maastrichtian and Early Paleocene in Gebel Owaina shows that an uplift mast have occurred at the end of the Late Cretaceous.

It was possible from the litho- and biofacies studies to recognize the depositional environments of the different formations. The Late Cretaceous succession was accumulated under variable conditions. It started with multi-colored shales reflecting shallow and stagnant or toxic bottom conditions. This is followed by lacustrine environment whereby phosphatic remains, organic granules and rounded bodies were allowed to settle down. Next to this phase, deepening took place and resulted in the formation of fine grained calcareous deposits.

The detailed correlation of the lithostratigraphic units as well as the nannoplankton zones and planktonic foraminiferal zones of the studied sections makes possible the more accurate correlation of other Upper Cretaceous sections in Egypt.

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الطبقية الحيوية الدقيقة لتتابع بعض صخور الطباشيرى العلوى بالصحراء الشرقية - مصر

أ.د. أحمد سامى الداودى

قسم الجيولوجيا، كلية العلوم، جامعة القاهرة، مصر.

يوضح هذا البحث أهمية الطبقية الحيوية للهوائم الكلسية الدقيقة التى سجلت من بعض صخور الطباشيرى العلوى-الباليوسين والتى جمعت من جنوب مصر. وأدت الدراسة الدقيقة لهذه الهوائم النباتية الجيرية وتواجدها الطبقى إلى تحديد عمر محدد للوحدات الصخرية المختلفة بالإضافة إلى توضيح الطبقية الحيوية للنانوس والتى لا تزال غامضة إلى حد ما فى مصر. عرفت ست نطاقات حيوية، رتبت من أعلى إلى أسفل، كالآتى:

٤- نطاق (Nephrolithus frequens
٣- نطاق (Lithraphidites quadratus — Late
٢- نطاق (Arkhangelskiella cymbiformis — Cretaceous
١- نطاق (Quadrum trifidum

قورنت هذه النطاقات الحيوية على أساس الهوائم الكلسية الدقيقة بنظيراتها نطاقات الفورامينيفرا الهائمة الآتية – نطاق Globotruncana esnehensis ونطاق Globotruncana gansseri ونطاق Globotruncana fornicata لنفس التتابع. يدل تواجد هذه النطاقات بأجزاء أخرى بمصر والعالم على استخدامهما بنجاح فى النطاقات الحيوية والمضاهاة عبر المحيطات.

وقد قورنت هذه النطاقات الحيوية للفورامنيفرا بمثيلاتها من النطاقات الحيوية للنانوبلانكتون بالنسبة لعلاقة هذه النطاقات الحيوية بالصفات الطبيعية للصخور المعروفة باسم الليثوستراتيجرافى، هذا إلى جانب دراسة السحنات الدقيقة للصخور عن طريق عمل وتجهيز قطاعات صخرية دقيقة لصخور متكونات Duwi Phosphate ومتكون L. Dakhla Shale (Sharawna Fm.) وكنتيجة لهذه الدراسة فقد أمكن استنتاج البيئات الترسيبية القديمة والسائدة أثناء ترسيب كل متكون على حدة.

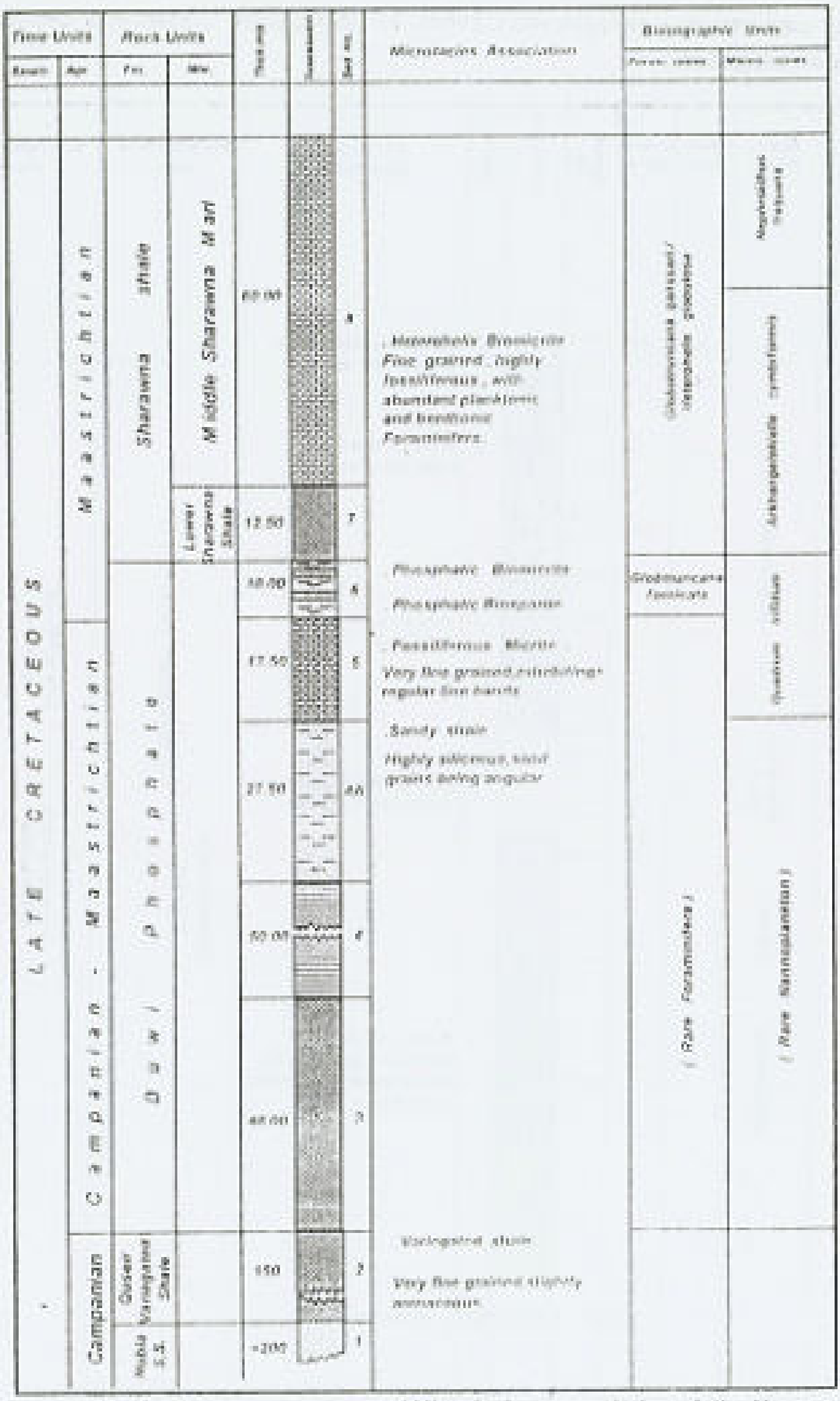

Fig.(3) Columnar section and Microfacies association of the Upper Cretaceous Succession in Gebel Duwi, Quseir District, Egypt.

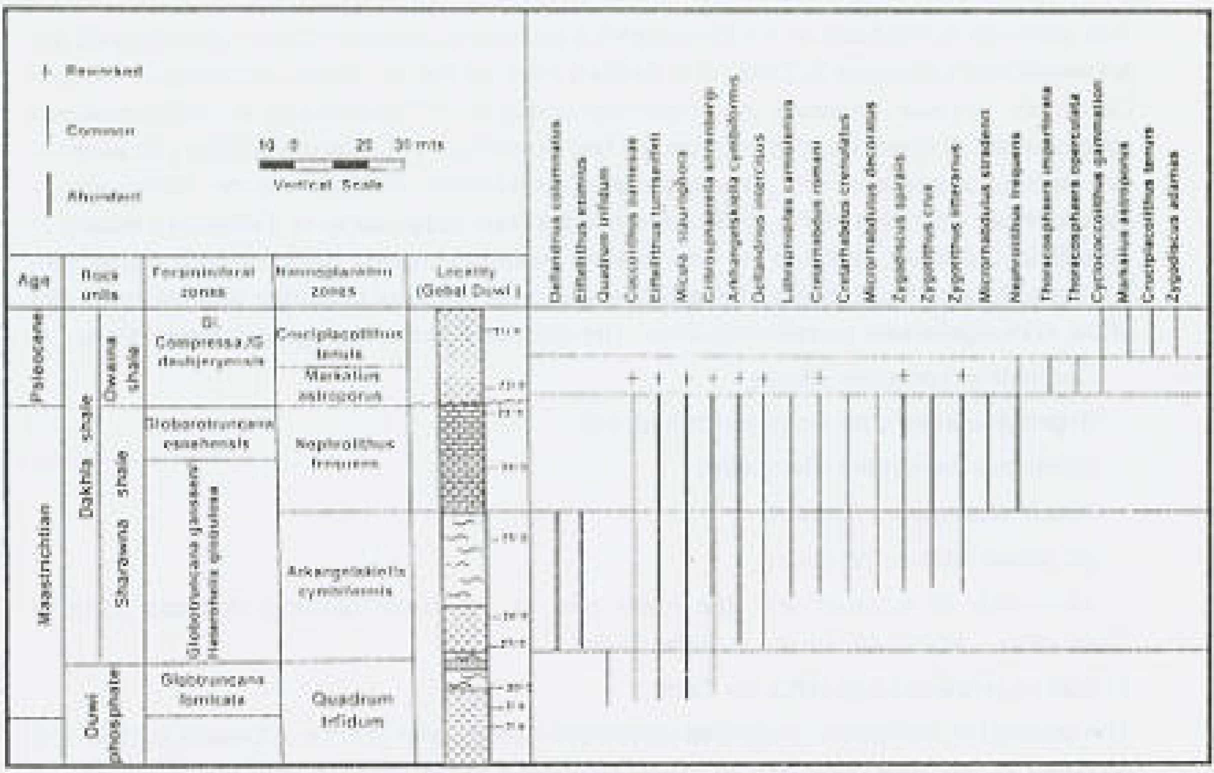

Fig.(4a) General distribution and frequency chart at Gebel Duwi

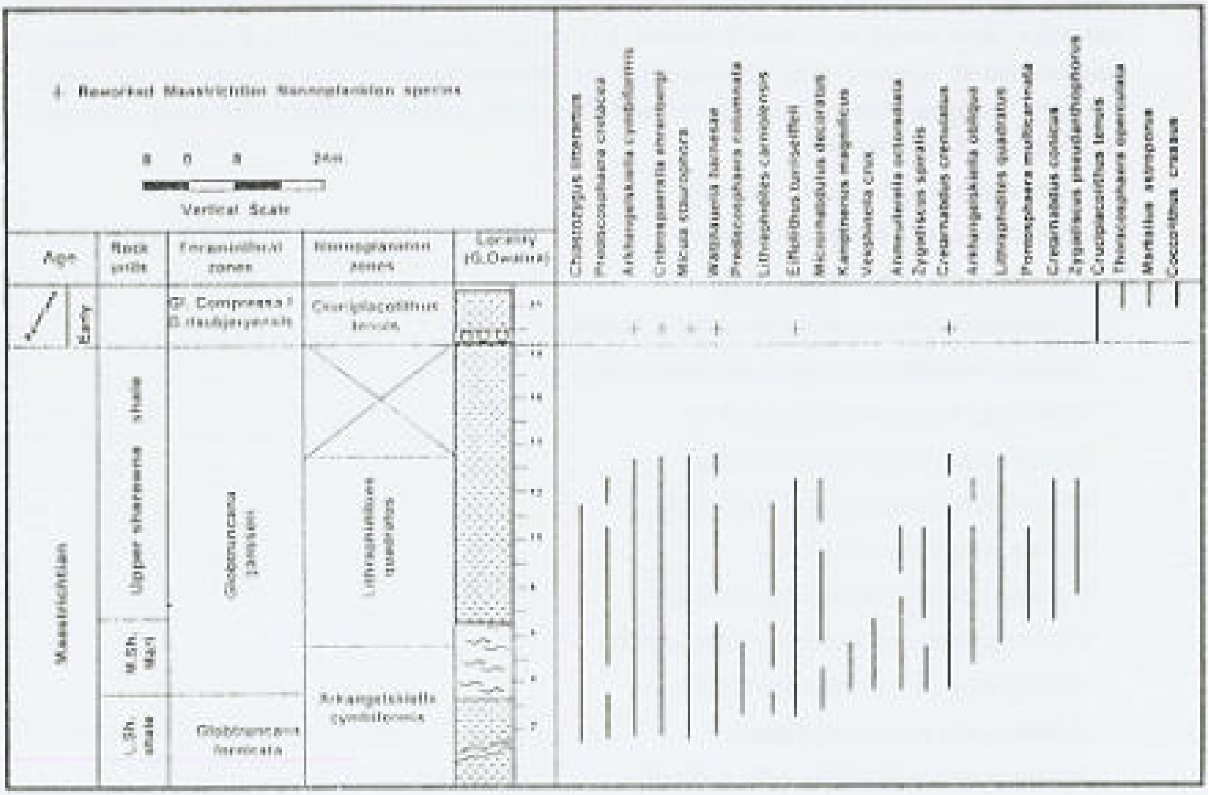

Fig.(4b) Distribution of the most common calcareous Nannoplankton species in the Maastrichtian at Gebel Owaina

1- Quadrum trifidum Zone:

This zone lies at the base of the Maastrichtion succession in Gebel Duwi just underlying the Arkhngelkiella cymbiformis Zone. It is defined here by the full range of Quadrum trifidum (Stradner), its lower boundary is unclear that is due to the presence of an intraformational conglomerate. It spans the interval from the first occurrence of Quadrum trifidum (Stradner) to the level of appearance of Arkhangelskiella cymbiformis Vekshina at the Campanian – Maastrichtian boundary. Roth (1973) described a total range zone of Tetralithus trifidus (= Tetralithus gothicus), which in the Kef section, Tunisia (Verbeek, 1977) extends higher than our Tetralithus gothicus (partial range) Zone. Our zone probably coincides with the lower part of the Arkhangelskiella cymbiformis Zone. The most-common and diagnostic species are:

Coccolithus barnesae (Black)

Cribrosphaerella ehrenbergi (Arkhangelsky)

Eiffellithus turriseiffeli (Deflandre)

Micula stauropkora (Gardet)

Quadrum trifidum (Stradner)

This zone is equated with the lower part of the Globolruncana fornicata zone of Campanian – Maastrichlian age in Gebel Duwi.

2- Arkhangelskiella cymbiformis Zone:

This represents the lowest recognized calcareous nannoplankton zone in Owaina section. It is recorded in the uppermost part of Lower Sharawna Shale together with the major part of Middle Sharawna Marl members of Gebel Owaina, assuming a thickness of around 16 meters. Such members are distinguished by the first flood of Arkhangelskiella cymbiformis Vekshina, after which this zone is coined. It is usually associated with multiple of calcareous nannoplankton species that characterize the Maastrichtian in many parts of the world, including the type Maastrichtian of Holland (Bramlette & Martini, 1964). The most –common and diagnostic species are:

Ahmuellerella octoradiala (Gorka)

Arkhangelskiella obliqua Stradner

Chiastozygus litterarius (Gorka)

Cretarhabdus crenulatus Bramlette & Martini

Cribrosphaerella ehrenbergi (Arkhangelsky)

Eiffellithus turriseiffeli (Deflandre)

Kamptnerius magnificus Deflandre

Microrhabdulus decoratus Deflandre

Micula staurophora (Gardet)

Prediscosphaera columnata (Stover)

Prediscosphaera cretacea (Arkhangelsky)

Vekshinella crux (Deflandre & Fert)

Watznaueria barnesae (Black)

Zygodiscus spiralis Bramlette & Martini

The zone under investigation may be correlated with Tetralithus nitidus trifidus zone of Bukry & Bramlette (1970), following them Cita & Gartner (1968) in the North Atlantic. The equivalent of the latter zone under the name Tetralithus gothicus trifidus zone was previously traced by Perch-Nielsen et al (1978) in the Nile valley, Egypt, the same locality of the present work. They applied such zone to the lowest part of their succession irrespective to the first appearence of the nominate species clearly shown by Roth & Thierstein (1972). In Gebel Owaina, the Arkhangelskiella cymbiformis zone coincides with the upper part of the planktonic foraminiferal Globotruncana fornicata zone together with the lowermost part of Globotruncana ganaseri zone denoting an Early – Middle Maastrichtian age. The boundary of such zone is marked by the first occurrence of Lithraphidites quadratus Bramlette & Martini.

3- Lithraphidites quadratus Zone:

This zone is met with in the next 32 meters within the upper most part of Middle Sharawna Marl together with the major part of Upper Sharawna Shale members just overlying the Arkhangelskiella cymbiformis zone in Gebel Owaina. It is defined here by the first occurrence of Lithraphidites quadratus Bramlette & Martini and corresponds to the full range of that marker species. The upper boundary of this zone is not well defined. Such zone is characterized by a calcareous nannoplankton assemblage, rich in species common in the Arkhangelskiella cymbiformis zone but without Kamptnerius magnificus Deflandre and Prediscosphaera columnata (Stover). Beside the distinctive marker species of the zone, the following species are also recorded:

Cretarhabdus conicus Bramlette & Martini

Lithraphidites carniolensis Deflandre

Pontosphaera multicarinata (Gartner)

Zygodiscus pseudanthophorus Bramlette & Martini

The Lithraphidites quadralus zone was first introduced by Cepek & Hay (1969) at its locality in Wilcox County, Alabama. It was defined as the interval from the first occurrence of Lithraphidites quadratus Bramlette & Martini to the first occurrence of Nephrolithus frequens Gorka. The definition of this zone as used here differs from that given by Cepek & Hay due to the lack of the nominate taxa characteristic to the top boundary of such zone. In Gebel Owaina, this zone spans the major upper part of the planktonic foraminiferal Globotruncana gansseri zone both of Middle – Late Maastrichtian age. It matches with the upper part of Arkhangelskiella cymbiformis zone previously known by El-Dawoody (1970) and El-Dawoody & Barakat (1973) in Duwi Range, Red Sea Coast. Again the Lithraphidites quadratus zone represents the youngest Maastrichtian nannofossil zone in Owaina section.

4- Nephrolithus frequens Zone:

This zone caps the Maastrichtian succession in Gebel Duwi just overlying the Arkhhngelkiella cymbiformis Zone. It is defined here by the full range of Nephrolithus frequens Gorka, its lower boundary is unclear that is due to the presence of an intraformational conglomerate. It spans the interval from the first occurrence of Nephrolithus frequens Gorka to the level of extinction of most Cretaceous species at the Cretaceous – Tertiary contact (Cepek & Hay, 1969). The late Maastrichtian of the type section belonges to the Nephrolithus frequens Zone, and has been shown to occur mainly in high latitudes Upper Maastrichtian (Martini & Worsley, 1971). The most-common and diagnostic species are:

Chiastozygus litterarius (Gorka)

Cretarhabdus conicus Bramlette & Martini

Lithraphidites carniolensis Deflandre

Microrhabdulus decoratus Deflandre

Nephrolithus frequens Gorka

Vekshinella crux (Deflandre & Fert)

Zygodiscus spiralis Bramlette & Martini

In Gebel Duwi, the Nephrolithus frequens Zone coincides with the planktonic foraminiferal Globotruncana esnehensis Zone giving rise to a Late Maasrichtian age.

A biostratigraphic correlation of the previously mentioned calcareous rannoplankton zones within the Upper Cretaceous succession in the Eastern Desert, Egypt is shown in Figure 5. The occurrence of the Egyptian nannobiozones recorded in the present study together with their thicknesses in meters are shown as follows:

Nannobiozones	Localities			
	Esh El Mellaha			
	G.Owaina	G.Duwi	Wadi Mellaha	G. Tarboul
4. Nephrolithus frequens Zone	----	25.00	----	----
3. Lithraphidites quadratus Zone	32.00	----	34.50	36.00
2. Arkhangelskiella cymbiformis	16.00	35.00	12.50	24.00
1. Quadrum trifidum Zone	----	25.00	5.00	----

CORRELATION AND AGE ASSIGNMENTS

This part is mainly concerned with the analysis of studied nannofloral assembmages within Duwi / Owaina / Esh El Mellaha stratigraphic sections. It makes possible the zoning of such sections in a way that would make the interregional correlations of the Upper Creta-ceous succession feasible.The recorded nannoflora, in corroboration with other microbiostratigraohic tools, build up the main skeleton of such trial. Accordingly chronostratigraphic units are encountered, their succession is as follows:

1. Campanian-Maastrichtian:

The Duwi Phosphate Formation did not yield any identifiable planktonic Foraminifera. Its calcareous nannoplankton content is only restricted to the minor uppermost part of the section which seems to be of Maastrichtian age. It is considered here as a transitional stage between the Campanian and Maastrichtian for the following reasons:

The Duwi Phosphate Formation is conformably overlain by a planktonic foraminiferal zone as well as calcareous nannoplankton zone correlatable with similar zones in other parts of the world, which are of Maastrictian age.

The varied vertebrate fauna of the Duwi Phosphate Formation occurs in Europe in strata of Coniacian – Campanian age.

Most of the recorded Pelecypod fauna were considered by various authors to be of Campanian age, except for a few forms which may range into the overlying Maastrichtian.

The Duwi Phosphate Formation could be correlated with similar deposits in the Esna – Duwi region, Kharga and Dakhla Oases, and with the corresponding deposits in the Middle East and North Africa. These deposits are considered to be of Upper Campanian age.