PRJ, Vol. 7 (January 1995); P. 75–93, 5 FIGS, 3 PLATES

CRETACEOUS BIOSTRATIGRAPHY AND PALAEOGEOGRAPHY OF NORTH EGYPT AND NORTHEAST LIBYA

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الطبقية الحياتية والجغرافيا القديمة لصخور الحين الكريتاسي المبكر والمتأخر بشمال مصر وشمال شرقي ليبيا

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هناك تشابه كبير بين الحشود البالينولوجية وحشود المنخربات ، التي ترجع إلى الحين الكريتاسي المبكر والمتأخر، بشمال مصر وشمال غربي ليبيا. وقد تحكم في نمط الرسوبيات بهذه المنطقة ومحتواها البالينوجي ومستحاثات المنخربات موقع الشاطئ القديم لبحر التيش.

وقد تمّ إعداد مجموعة من الخرائط تمثل الجغرافيا القديمة لعدة فترات زمنية أثناء الحين الكريتاسي وذلك بناء على نطاقات المستحاثات البالينوجية والمنخربات. وقد إستنتج من هذه الخريطة أيضاً مراحل تجاوز وانحسار مياه البحر أثناء ذلك الحين.

كما قسمت الرسوبيات الأبتية ـــ السينومانية بشمال مصر وليبيا إلى أجزاء بناء على محتواها من حبوب اللقاح والأبواغ والسوطيات الدوارة. وتدل بالينومورفات الحين الكريتاسي الأوسط على ظروف ترسيبية محصورة ودور فاعل للرسوبيات المستمدة من اليابسة في الأحواض الترسيبية ، الأمر الذي وقف حائلاً أمام عدم وفرة المنخربات الهوائم بشمال مصر وشمال شرقي ليبيا وفي حوض سرت في ذلك الوقت. وقد تميزت المرحلة السينومانية بوجود أعداد كبيرة من المنخربات القاعية ذات الأصداف الملتحمة من الجنس Thomasinella ، كما شملت البالينومورفات المرشدة أنماط الألتيراتات والجنس Afropollis والنوع Classopollis brasiliensis .

وتوضح الرسوبيات التورونية ـــ الماسترخية إنتقالاً واضحاً إلى بيئة بحرية مفتوحة وانتشار المنخربات الهائمة وبعض السوطيات الدوارة وحبوب اللقاح والأبواغ .

ABSTRACT

The Cretaceous palynological and foraminiferal assemblages from northern Egypt show an intimate resemblance to their respective counterparts from northeastern Libya. The Lower Cretaceous to Cenomanian deposits in northern Egypt and Libya were subdivided and dated by means of pollen, spores and dinoflagellates. The Neocomian is distinguished palynologically from the Late Jurassic by the first occurrence of ***Impardecispora*** *and* ***Pilosiporites trichopapillosus*** *spores.* ***Dicheiropollis etruscus*** *is a characteristic late Neocomian–Barremian guide pollen as in northern Gondwana. The Barremian is also characterized by the first incoming of* ***Ephedripites*** *pollen and primitive angiosperm pollen like* ***Clavatipollenites***, ***Asteropollis***, ***Retimonocolpites*** *and* ***Liliacidites****. The percentage of angiosperm pollen increases during the Aptian;* ***Afropollis***, ***Brenneripollis***, *and tricolporate pollen appear. The Albian microflora is dominated by* ***Crybelosporites pannuceous***, ***Afropollis jardinus***, ***Balmeisporites*** *and* ***Ephedripites****. Tricolporate angiosperm and elater-bearing elements are present in the middle to late Albian and become abundant in the early-middle Cenomanian. The Aptian-Albian palynomorphs indicate restricted marine conditions and high terrestrial input into the sedimentary basins. These conditions prevented the full development of planktonic foraminiferal assemblages in northern Egypt as well as in western Libya and the Sirt Basin.*

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The Cenomanian is often characterized by the occurrence of large agglutinated benthonic foraminifer ***Thomasinella****, in addition to guide palynomorphs such as* ***Afropollis****,* ***Stephanocolpites****,* ***Dichastopollenites*** *and* ***Classopollis brasiliensis****. The Turonian–Maastrichtian sediments show a sharp environmental shift towards open marine conditions with abundant and well diversified planktonic foraminiferal and only subordinate dinoflagellates, pollen and spores.*

The Cretaceous sediments with their palynological and foraminiferal contents are greatly influenced by the position of the ancient shoreline of the Tethys Sea. On the basis of the palynological and foraminiferal zonation and other stratigraphical and sedimentological data available, a chronological series of maps reconstructing the Cretaceous shorelines have been prepared. The maps also provide information about the transgression-regression phases of the Cretaceous.

INTRODUCTION

The Cretaceous has been one of the main targets of oil exploration in Egypt and Libya. The Cretaceous strata are widely distributed in the area as surface exposures or concealed under the surface as recorded in many wells. In general, the Lower and Upper Cretaceous strata are represented by two main facies, the continental to shallow marine "Nubian" facies of the Lower Cretaceous and the typical deep marine shale and carbonate facies of the Upper Cretaceous.

A large quantity of new sedimentological, micropalaeontological, palynological and palaeogeographical data from the Mesozoic strata of northern Egypt and northeastern Libya have contributed to a better understanding of the transgression/regression cycles in this part of the African continent.

The aim of the present paper is to present a report on the Cretaceous biostratigraphy based on published and unpublished palynological and foraminiferal data from northern Egypt and northeastern Libya including the Sirt Basin.

1 CRETACEOUS BIOSTRATIGRAPHY

Many papers dealing with Cretaceous palynological and foraminiferal data from Egypt have been published, e.g. Beckmann *et al.* (1969), Abdel-Kireem (1971, 1986), Soliman and Sultan (1976), Saad and Ghazaly (1976), Urban *et al.* (1976), Saad (1978), Sultan (1978, 1985, 1986, 1987), Aboul Ela (1978, 1979), Abdel-Kireem and Abdou (1979), Abdelmalik *et al.* (1981), Schrank (1982, 1983, 1984a, 1984b, 1984c, 1987, 1988, 1991, 1992), Penny (1986, 1988a, 1988b, 1989, 1991), Sultan and Aly (1986), Abdel-Kireem and Ibrahim (1987), Abdel-Kireem and Sultan (1988), El-Shamma (1988), El-Shamma and Arafa (1988), Abdel Mohsen (1991), El-Beialy *et al.* (1990), Omran *et al.* (1990) and Abdel-Kireem *et al.* (1993).

Relatively few palynological and foraminiferal works on the Cretaceous of Libya have been published. Early Cretaceous to Cenomanian palynomorphs from NE Libya have been treated by Batten and Uwins (1985), Thusu and Van Der Eem (1985), Thusu *et al.* (1988) and Uwins and Batten (1988). The most important and valuable foraminiferal works have been published by Barr and Gohrbandt (1967), Phillips 1969, Barr (1971, 1972), Barr and Hammuda (1971) and Eliagoubi (1979).

I.1 Neocomian

The Lower Cretaceous deposits of both Egypt and Libya are usually barren of planktonic foraminifera. Consequently, palynomorphs have been most commonly used for biostratigraphical subdivisions.

Neocomian marginal marine sediments (Cyrenaica and Matruh Basins) can be distinguished by the dinocysts *Phoberocysta neocomica*, *Pseudoceratium pelliferum*, *Oligosphaeridium complex*, *Muderongia simplex*, and *Cyclonephelium distinctum*. Contemporaneous terrigenous spores include *Impardecispora apiverrucata* and *Pilosisporites trichopapillosus*.

The deposits of the upper Neocomian are distinguished by the first appearance of the gymnosperm pollen *Dicheiropollis etruscus* and the angiosperm pollen *Clavatipollenites hughesii*. The latter angiosperm species was recorded only in the upper Neocomian of NE Libya (Thusu *et al.* 1988).

I.2 Barremian

Barremian miospore spectra from Egypt and Libya were recorded by Saad (1978), Abdelmalik *et al.* (1981), Thusu and Van Der Eem (1985), Sultan (1986), Penny (1986, 1991), Schrank (1987), Thusu *et al.* (1988), Uwins and Batten (1988), El-Shamaa and Arafa (1988), El Sheikh and Aly (1988), El-Beialy *et al.* (1990) and Omran *et al.* (1990).

The most striking element in the late Neocomian-Barremian is the gymnosperm pollen *Dicheiropollis etruscus*. In the Barremian, *Ephedripites* and the first angiospermous pollen such as *Clavatipollenites*, *Asteropollis*, *Liliacidites*, *Retimonocolpites*, *Stellatopollis barghoornii*, and *Tucanopollis crisopolensis* appear. The dinocysts are represented by *Pseudoceratium anaphrissum*, *P. retusum*, *Coronifera oceanica*, *Cerbia tabulata*, *Systematophora silyba*, *Cribroperidinium edwardsii* and *C. orthoceras* as recorded in assemblage IB (marine) from NE Libya (Uwins and Batten, 1988).

I.3 Aptian

The Aptian palynoassemblage comprises the new incoming angiosperms of the reticulate monocolpate or monocolpate-derived types such as *Brenneripollis*, *Schrankipollis* (formerly "*Retimonocolpites*"), the *Clavatipollenites/Asteropollis* group, *Afropollis operculatus*, *A. zonatus* and *Reyrea polymorpha*. The first tricolpate pollen also occur. The marine Aptian sediments are characterized by a dinoassemblage with *Pseudoceratium regium*, *P. securegerum*, *P. retusum*, *Aptia polymorpha*, *A. plera*, *Subtilisphaera ventriosa*, *Florentinia mantellii*, *Odontochitina aperculata*, *Cribroperidinium edwardsii*, *C. orthoceras* and *Kiokansium hydra*.

I.4 Albian

The most noteworthy feature of the Albian miospore spectra in Egypt as well as in Libya is the first appearance of *Crybelosporites* (Perotrilites) pannuceus (Gabonisporis sensu Batten and Uwins 1985, Uwins and Batten 1988) and *Balmeisporites holodictyus*. *Ephedripites jansonii* and *Afropollis jardinus* are also present. Elaterate pollen (*Elaterosporites*, *Elatercolpites* and *Elateroplicites*), tricolporate and tricolporoidate pollen characterize the late Albian.

The dinocyst assemblage of the Albian is characterized by *Xenascus ceratioides*, *X. plotei*, *Coronifera alberti*, *Oligosphaeridium porosum*, *O. djenn*, *Spiniferites multibrevis*, *Subtilisphaera perlucida*, *S. terrula*, *S. zawia*, *Trichodinium* spp., *Xiphophoridium alatum*, *Cyclonephelium vannophorum* and *Palaeohystrichophora infusorioides*. The latter species is of Vraconian age in the Tethyan province (Williams and Bujak, 1985; Uwins and Batten, 1988).

The Albian sediments in northern Egypt and Libya are usually barren of foraminifera as is the case in the older Lower Cretaceous sediments except in the area of northern Cyrenaica where abundant planktonic foraminifera diagnostic of the *Ticinella roberti* Zone (Albian) were recorded from the lower Hilal Shale (Barr and Hammuda, 1971).

I.5 Cenomanian

Early to middle Cenomanian sporomorphs are characterized by the first appearance of the polycolpate pollen *Stephanocolpites* and the gymnosperm *Classopollis brasiliensis* while circumaperturate pollen (*Dichastopollenites*) and triporate angiospermous pollen characterize the late Cenomanian. Other important sporomorphs extending from the late Albian to the early and middle Cenomanian include: elaterate pollen (*Elaterosporites*, *Elaterocolpites*, *Elateroplicites*, *Galeacornea* and *Sofrepites*) and *Cretacaeiporites polygonalis*.

The late Cenomanian of northern Gondwana is distinguished by the occurrence of the marker triporate pollen *Triorites africaensis* (Jardine and Magloire, 1965; Herngreen, 1973, 1975; Jardine *et al.*, 1974; Belsky *et al.*, 1975; Brenner, 1976; Boltenhagen, 1980; Lawal and Moullade, 1986; Muller *et al.*, 1987; Lawal, 1991). Unfortunately, this species has not been recorded until now in either Egypt or Libya, but similar triporates such as *Triporopollenites* and *Proteacidites* were recorded from the late Cenomanian of the Western Desert of Egypt (Ibrahim, 1986, 1992). Most of the dinocyst assemblages recorded from the Cenomanian are long-ranging species (Uwins and Batten, 1988; Ibrahim, 1992) such as *Florentinia resex*, *F. radiculata*, *F. mantellii*, *F. laciniata*, *F. clavigera* in addition to *Cyclonephelium vannophorum*.

There are no published palynological data for the upper Cenomanian and younger strata of Libya. However, the planktonic and benthonic foraminifera are the most reliable biomarkers for the Late Cretaceous of the working area.

The marine Cenomanian sediments in both Egypt and Libya are characterized by the occurrence of the large-sized agglutinated index foraminifer *Thomasinella* (Barr and Gohrbandt, 1967; Abdel-Kireem and Sultan, 1988; Andrawis, 1990; Hataba and Ammar, 1990; Abdel-Kireem *et al.*, 1993). The Cenomanian planktonic biomarkers *Rotalipora* spp. were recorded only from the Marsa al Hilal area (Barr, 1972). Other planktonic foraminifers characteristic of the Egyptian Cenomanian are *Hedbergella delrioensis*, *H. planispira*, *H. simplex*, *Heterohelix moremani*, *Praeglobotruncana delrioensis* and *Globigerinelloides ultramicra* (Abdel-Kireem *et al.*, 1993).

I.6 Turonian

Turonian palynological data in NE Africa are scarce. Recent studies (Schrank 1991, 1992; Ibrahim 1992) have shown that the Turonian sediments are characterized by an association of large members of the *Foveotricolpites giganteus-F. gigantoreticulatus* group with triporate and tricolporate pollen. *Classopollis*, the elaterates and other Cenomanian types are no longer present. Turonian dinocysts in northern Egypt include *Spiniferites porosus*, *S. ramosus*, *Dinogymnium vozzhennikovae*, *Florentinia* spp., *Odontochitina striatoporifera*, *Silicisphaera torulosa*, *Kleithriasphaeridium readei*, *Litosphaeridium siphoniphorum* and *Cordosphaeridium latispinosum*.

As a result of the deep marine conditions prevailing during the Turonian, the planktonic foraminiferal assemblage became rich and diversified. Abdel-Kireem *et al.* (in press) divided the Turonian into three planktonic zones, namely the *Whiteinella Archaeocretacea*, *Praeglobotruncana helvetica* and *Marginotruncana schneegansi* zones which they equated with the *Praeglobotruncana helvetica* and the *Globotruncana sigali* zones of Libya (Barr, 1972).

I.7 Coniacian

The spinose tetrad of *Droseridites senonicus* repesents an index pollen for the Coniacian to Santonian of northern Gondwana (Jardine and Magloire, 1965; Belsky *et al.*, 1975; Jan Du Chêne *et al.*, 1978; Morgan, 1978; Mebradu, 1982; Sultan, 1985; Sultan *et al.*, 1986; Lawal and Moullade, 1986; Odébdódé, 1987; Salard-Cheboldaeff, 1990; Abdel Mohsen, 1991; Schrank, 1992). Furthermore, tricolpor(oid)ates, triporates and the *Foveotricolpites giganteus-F. gigantoreticulatus* group are also present in the Coniacian sediments (Schrank 1987, 1991, 1992, Ibrahim, 1992).

In the marine microfloras the following dinocytes made their first appearance in the Coniacian: *Odontochitina porifera, Dinogymnium undulosum, D. albertii, D. longicornis, D. heterocastatum, D. cretaceum, D. microganulosum, Trigonopyxidia ginella* and *Hystrichosphaeridium atlasiense* (Ibrahim, 1992).

The Coniacian planktonic foraminiferal assemblage is represented by *Dicarinella primitiva, D. concavata, Marginotruncana coronata* and *Archaeoglobigerina cretacea.* The first two species are the zonal marker species for the Coniacian-early Santonian (Abdel-Kireem *et al.*, in preparation).

I.8 Santonian

The palynologic transition from the Coniacian to the Santonian stage is difficult to assign by means of pollen and spores. It was determined, however, by the dinocyst assemblage where the Santonian is characterized by the first evolutionary appearance of *Spinidinium sverdrupianum, Gillinia hymenophora* and *Alisogymnium euclaense* which are associated with *Glaphyrocysta divaricata, Dinogymnium sibiricum,* and *Amphigymnium cooksoniae.*

The early Santonian planktonic foraminiferal assemblage is similar to that of the Coniacian and is dominated by *Dicarinella concavata.* Upper Santonian sediments seem to be absent in the studied sections due to the absence of the late Santonian zonal planktonic species *Dicarinella asymetrica* as previously recorded by Abdel-Kireem and Ibrahim (1987) and Abdel-Kireem *et al.* (1993).

I.9 Campanian–Maastrichtian

Palynologically it is difficult to distinguish between the Campanian and Maastrichtian because they are characterized by similar microfloras. These were studied in Egypt by Aboul Ela (1978); Sultan, (1985), Abdel Mohsen (1987), El-Beialy and Kora (1987), Schrank (1984b, 1984c, 1987, 1988, 1991, 1992), Schrank and Perch–Nielsen (1985), and Ibrahim (1992). The Campanian–Maastrichtian pollen assemblage can easily be distinguished from older assemblages by the presence of pollen such as *Crassitricolporites brasiliensis, Spinizonocolpites echinatus, Echitriporites, Retidiporites, Syncolporites, Periretisyncolpites* and *Echimonocolpites.*

The Campanian–Maastrichtian phytöplanktonic assemblage is represented by *Phelodinium tricuspis, Cannosphaeropsis utinensis, Isabelidinium cretaceum, I. cooksoniae, Dinogymnium muticum, D. digitus, D. acuminatum, Thalassiphora pelagica, Amphigymnum cooksoniae, Cerodinium granulostriatum, Odontochitina porifera, O. operculata, Cladopyxidium saeptum, Conosphaeridium striatoconus, Spiniferites* spp., *Florentinia spp.,* and *Glaphyrocysta* spp.

On the other hand, the planktonic foraminiferal assemblages recorded from the Campanian–Maastrichtian in Egypt and Libya are readily distinguishable. The Campanian planktonic foraminiferal assemblage is characterized by *Globotruncanita elevata, Globotruncana ventricosa, G. linneianna, G. mariei, Globotruncanita calcarata, G. subspinosa, Contusotruncana fornicata, C. morozovae, Rugoglobigerina rugosa, Globigerinelloides prairehillensis, Heterohelix globulosa, H. striata, H. semicostata* an *Pseudotextularia elegans* (Barr, 1972; Abdel-Kireem and Abdou, 1979; Abdel-Kireem, 1986; Abdel-Kireem and Ibrahim, 1987; Andrawis 1990; Abdel-Kireem *et al.* ,1993).

The Maastrichtian planktonic foraminiferal assemblage is characterized by *Globotruncana aegyptiaca, G. arca, G. bulloides, G. falsostuarti, G. orientalis, Globotruncanita stuarti, G. stuartiformis, Gansserina gansseri, Contusotruncana contusa, Abathomphalus mayaroensis* and other distinctive forms (Barr, 1972; Eliagoubi, 1979; Abdel-Kireem and Abdou, 1979; Abdel-Kireem 1986; Abdel-Kireem *et al.*, 1993).

II CRETACEOUS PALAEOGEOGRAPHY

The Cretaceous Period in coastal NE Africa witnessed four major transgressive cycles during the Aptian, Cenomanian, Coniacian and Campanian–Maastrichtian. The Cretaceous palaeogeography of Egypt and/or Libya in general was dealt with many authors, notably: Said (1962), Barr (1972), El Shazly (1977), Van Houten (1980), Van Houten *et al.* (1984), Klitzsch and Wycisk (1987), Luger and Schrank (1987), Thusu *et al.* (1988), Uwins and Batten (1988), Klitzsch and Squyres (1990) and Said (1990). The following sections give a generalized palaeogeographic picture (Figs 1–4) of the limits and extension of the Tethys in NE Africa during the Cretaceous Period.

II.1 Neocomian–Barremian

The Lower Cretaceous sedimentation in northeast Africa was dominated by a major regressive phase

(Van Houten, 1980). The uplands in the south supplied significant amounts of sandy material to form widespread non-marine to marginal or shallow marine deposits along the unstable pericratonic margins towards the north (Thusu *et al.*, 1988).

The Lower Cretaceous "Nubian" facies in northern Egypt and NE Libya, including southeast Sirt Basin, is the most extensively developed facies encountered in numerous deep wells. In the northern Western Desert this facies is represented by the Alam El Buieb Formation or Burg El Arab Formation. In general, this "Nubian" facies consists mostly of multicoloured sandstone and shale and overlies the Pre-Cambrian basement and the Palaeozoic sediments or the Jurassic strata, while underlying the marine Upper Cretaceous shales and carbonates.

Biogeographically, two main facies are distinguishable for the Early Cretaceous in northern Egypt and NE Libya:

(1) A marginal marine facies in the northern Western Desert, i.e. Matruh Basin (Sidi Barrani and Matruh Formations) and the Cyrenaica Basin (including Jabal Al-Akhdar trough) with dinocytes, acritarchs, tasmanitids and microforaminiferal linings in certain horizons suggesting periodic incursion of the Tethys onto the platform. In this period the Tethys shoreline did not exceed lat 31°N (Fig. 1).

(2) A non-marine to fluviatile facies with miospores and dark brown terrestrial humic kerogen (wood and cuticle). These deposits are usually referred to the "Nubian" Formation (or Messak Formation in NE Libya). The Lower Cretaceous non-marine sands have provided reservoirs for several major oil fields in the Egyptian Western Desert and the Sirt Basin.

II.2 Aptian

The Aptian in northern Egypt and NE Libya shows the first major transgressive cycle of the Cretaceous Period. These marine conditions allowed the deposition of carbonates, the dolomites of the Alamein Formation, followed by the shales of the Dahab Formation in the northern Western Desert. On the other hand, a large part of the southern Western Desert was under the influence of a shallow sea where the Abu Ballas Formation was deposited.

In Libya, continental conditions allowed the deposition of the Lower Cretceous continental beds (alluvial and fluviatile sediments) of the wood-bearing

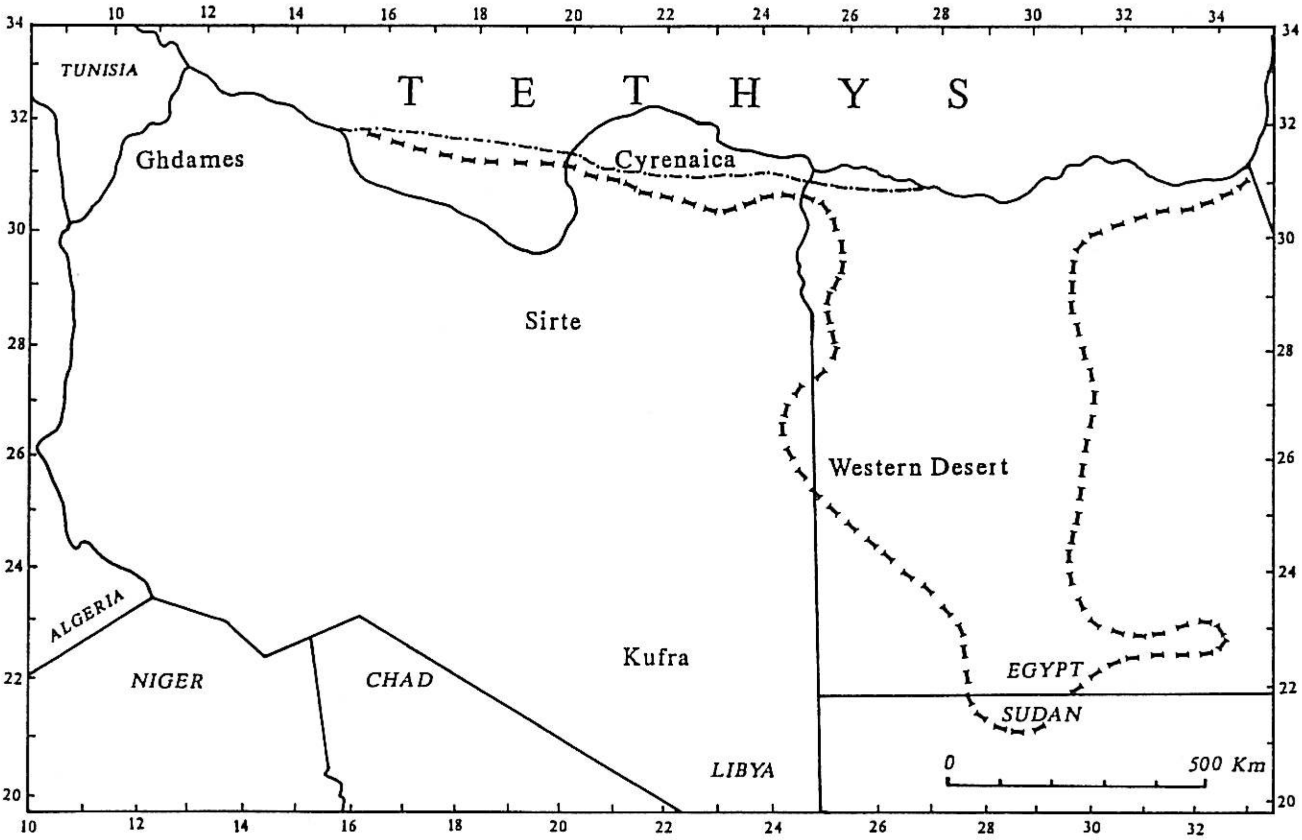

FIG. 1. A map showing the position of the tethys shorelines during the Neocomian-Barremian and Aptian in Egypt and Libya (based on Baarr, 1972; Klitzsch and Wyeisk, 1987; Uwins and Batten, 1988; Said, 1990, and others).

Chicla Formation covering most of the southern region (Barr and Weegar, 1972). An exception is the Jabal Akhdar trough across northern Cyrenaica (Barr, 1972) which was deposited under marine conditions. The Tethys shoreline during the Aptian was restricted to the area north of approximately 30.5°N in NE Libya and may have reached to lat 29°N in the northern Western Desert of Egypt. An Aptian Tethyan arm invaded most of the Western Desert to lat 21°N (Klitzsch and Wycisk, 1987; Said 1990, see Aptian shoreline Fig. 1).

II.3 Albian

The Albian, in general, represents a regressive phase in which the Tethys withdrew northward as in pre-Aptian time. Except in the Matruh, Sidi Barrani and the Cyrenaica areas, fluvial deposits which resulted from the eroding of an elevated massif to the south were formed in most of Egypt and Libya. Marine deposits, represented by carbonates and shales in and around the Matruh and Cyrenaica basins, were formed in areas north of lat. 30.5°N (Albian shoreline, Fig. 2). This palaeogeographical picture was supported by Barr and Hammuda (1971) who have described planktonic foraminiferal taxa from the lower part of the Hilal Shale belonging to the *Tricinella roberti* Zone (Albian).

II.4 Cenomanian

The Cenomanian stage witnessed the second major marine phase in large parts of northern Egypt and Libya (Fig. 2).

The formation of the Sirt Basin commenced at the dawn of the Cenomanian (Berggren, 1969; Barr, 1972). The Sirt Basin Arch underwent extreme tensional stress. This positive area collapsed into a series of alternating grabens and horst blocks generally oriented NNW–SSE. Several of the principal grabens are about 150 to 200 miles in length and 25 to 30 miles in breadth (Barr, 1972). These dimensions and orientations are similar to contemporaneous structures in the Gulf of Suez which was differentiated at the same time into its eastern and western embankments, the sites of the shallow marine Raha and Galala Formations. In northern Sinai, the thick marine calcaerous sediments of the Halal Formation were deposited, while in the northern Western Desert the Baharija Formation was formed and comprises tidal flat, estuarine to fluviatile deltaic deposits with frequent marine intercalations (Dominik, 1985). In the

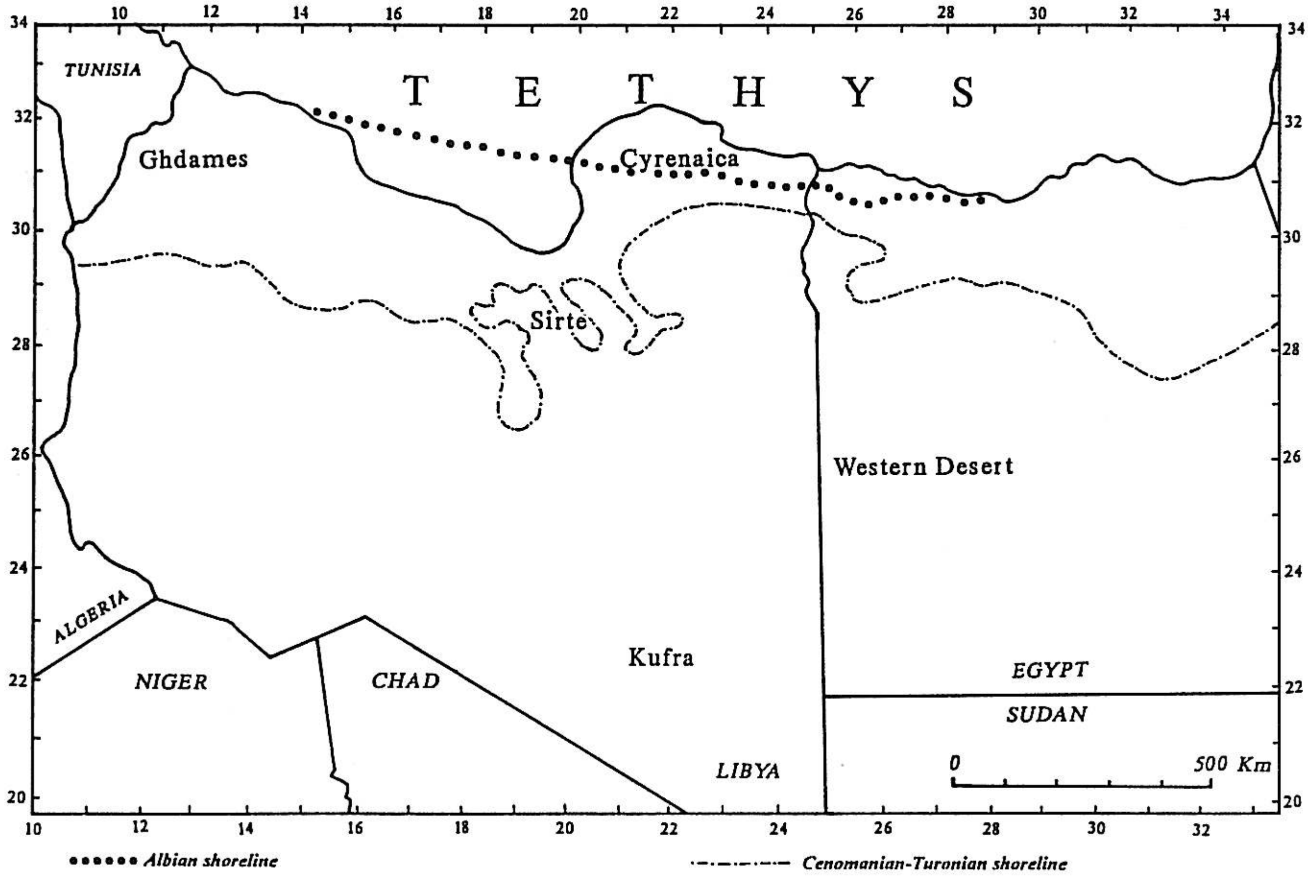

FIG. 2. A map showing the position of the Tethys shorelines during the Albian and Cenomanian-Turonian in Egypt and Libya (based on Barr, 1972; Van Houten, 1980; Klitzsch and Wycisk, 1987; Uwins and Batten, 1988; Said 1990; and others).

late Cenomanian, the marine influence was even stronger resulting in the deposition of the lower part of the Abu Roash Formation "member G" in the subsurface, which is equivalent to the El-Heiz Formation in the south (Hanter, 1990).

In north Libya, the Cenomanian transgression caused the deposition of shallow marine carbonates together with subordinate amounts of clay, lime clay and sand along the grabens of the Sirt Basin. Along the edges of these troughs, sabkhas developed locally, resulting in the deposition of dolomite and evaporites (Barr, 1972). In northeastern Libya (Cyrenaica) the sea advanced a short distance to the south of the Lower Cretaceous basin. The Cenomanian is represented by deep marine shales belonging to the lower part of Hilal Shale (Barr and Hammuda, 1971; Barr and Weegar, 1972) while farther south, the shallow marine deposits are represented by carbonates (Ain Tobi Limestone) and marls of the lower Jardas Formation (late Cenomanian).

II.5 Turonian

The marine conditions that prevailed during the late Cenomanian continued into the Turonian in both northern Egypt and Libya, as suggested by the abundance of planktonic foraminifera.

The marine Turonian in the Gulf of Suez area is represented by a lower shale unit, the Abu Qada Formation, and an upper solid limestone unit, the Wata Formation. In the subsurface of the northern Western Desert the Turonian is represented by the Abu Roash D, E and F members.

In the Sirt Basin, the Turonian embayments largely became areas of sabkha evaporitic deposition. In the northern Sirt Basin, western Libya and northern Cyrenaica, shallow marine carbonate (Argub Carbonate) and thin bedded carbonates, shale, anhydrite, and siltstone (Etel Formation) were formed (Barr and Weegar, 1972).

II.6 Coniacian

The Coniacian represents the third major transgressive cycle over most of Egypt and Libya following a minor regression at the end of the Turonian (Fig. 3). In northern Egypt and Libya the Coniacian sediments were deposited under fairly deep water, open marine conditions, as suggested by planktonic foraminifera and dinocysts which became increasingly abundant.

The marine Coniacian in northern Egypt and in

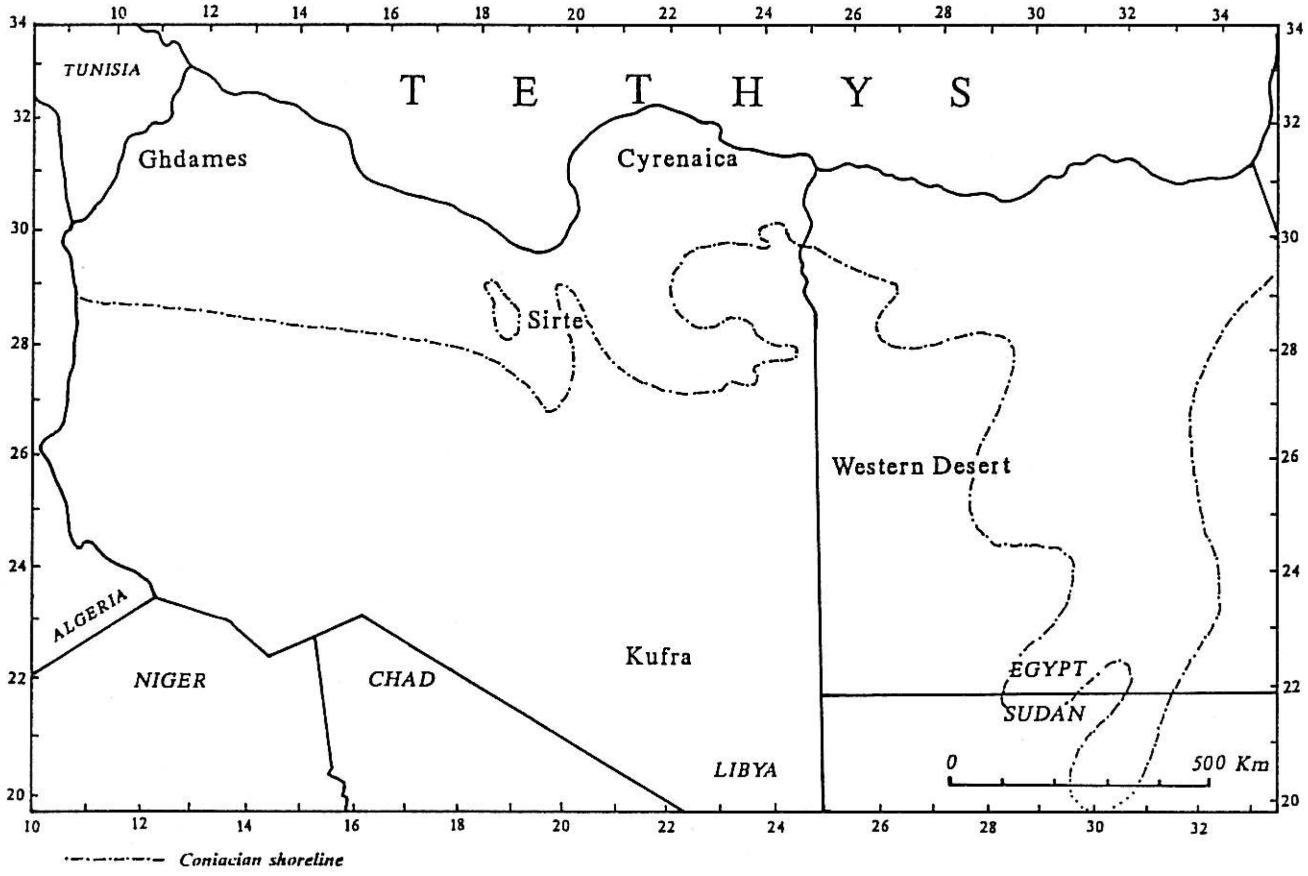

FIG. 3. A map showing the position of the Tethys shoreline during the Coniacian in Egypt and Libya (based on Barr, 1972; Klitzsch and Wycisk, 1987; Said, 1990; and others).

the Gulf of Suez area is represented by the Abu Roash B and C members and by the Matulla Formation, respectively, while in the Nile embayment and in the Wadi Qena area shallow marine epicontinental deposits alternate with fluvial sediments of the Timsah and Hawashiya Formations (Said, 1990).

In parts of the northern Sirt Basin argillaceous carbonates and clays were deposited. In the Marsa al Hilal area of northern Cyrenaica about 183 m of the upper Hilal Shale and 18.3 m of the basal Atrun Limestone belong to the Coniacian (Barr, 1972).

II.7 Santonian

During the early Santonian a short time regression took place which was followed by a renewed transgression. While the Santonian sea advanced far to the sourth covering most of northern Egypt and Libya, a number of small areas remained emergent as islands in northern Egypt and the Sirt Basin (Fig. 4). This explains the absence of Santonian deposits in most deep wells of the northern Western Desert (Abdel-Kireem and Ibrahim, 1987; Hanter 1990; Abdel-Kireem *et al.*, 1993).

In the Gulf of Suez the Santonian is represented by the St Anthony Chalk and by the upper beds of Matulla Formation (Said, 1990). In the northern, Western Desert the Santonian is represented by the Abu Roash "A" member which is recorded only in those basins which became clearly distinct between the major highs.

In Sirt Basin and northeastern Libya a considerable thickness of dark brown clays and shales (Rachmat Formation, Coniacian–Santonian) were deposited with rare planktonic foraminifera and common small *Neobulimina* (Barr, 1972).

II.8 Campanian–Maastrichtian

During the Campanian–Maastrichtian the sea had reached its maximum sothern extension as a result of the fourth and last major transgressive phase of the Cretaceous Tethys (Figs 4, 5). The transgression reached its maximum extent during the middle to late Maastrichtian.

Two main facies characterize the Campanian–Maastrichtian sediments in NE Africa. (1) The deep marine facies to the north of lat. 28°N represented by chalky limestones, the Sudr in northern and central Sinai and the Gulf of Suez area, and the Khoman

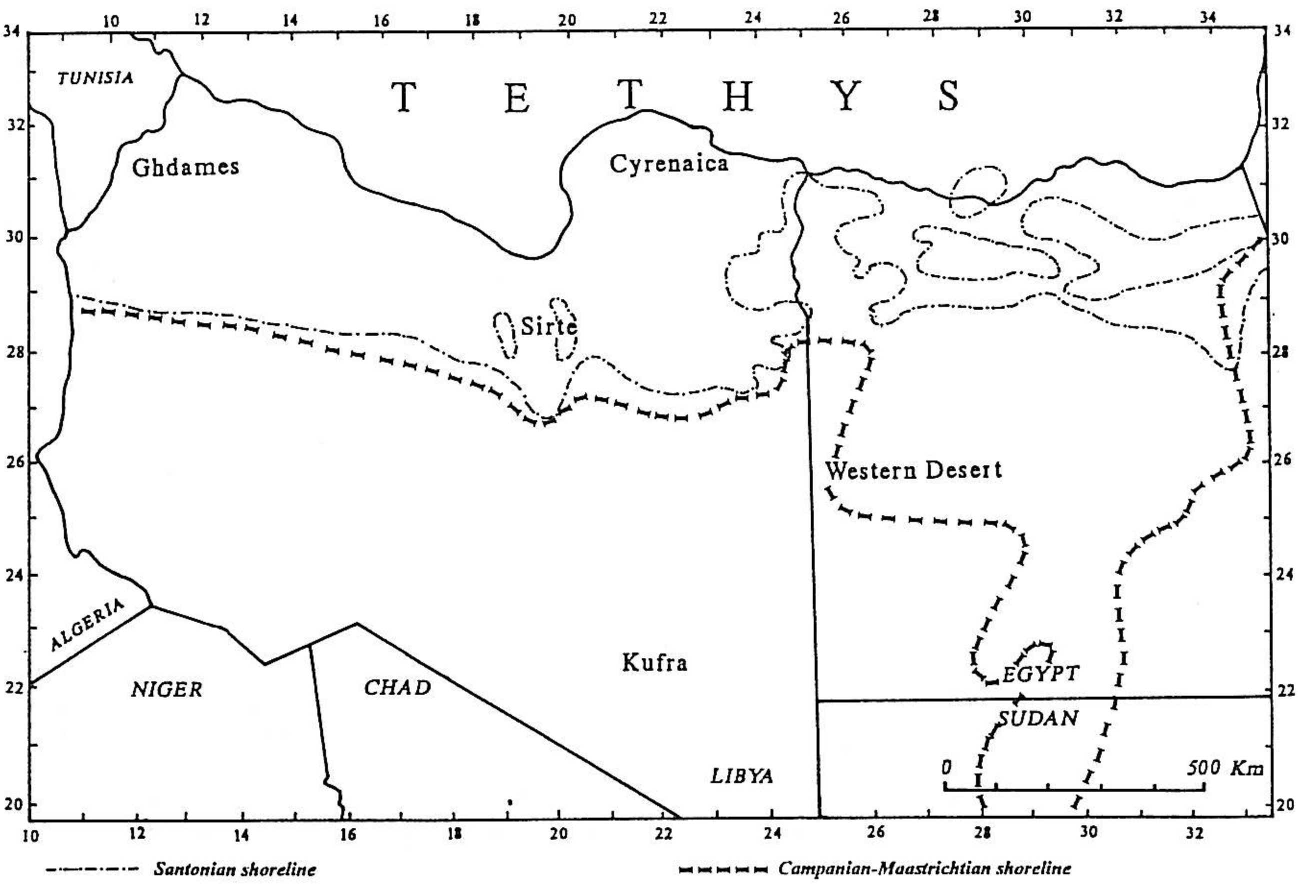

FIG. 4. A map showing the position of the Tethys shorelines during the Santonian and Campanian-Maastrichtian in Egypt and Libya (based on Barr, 1972; Litzsch and Wycisk, 1987; Said, 1990; and others).

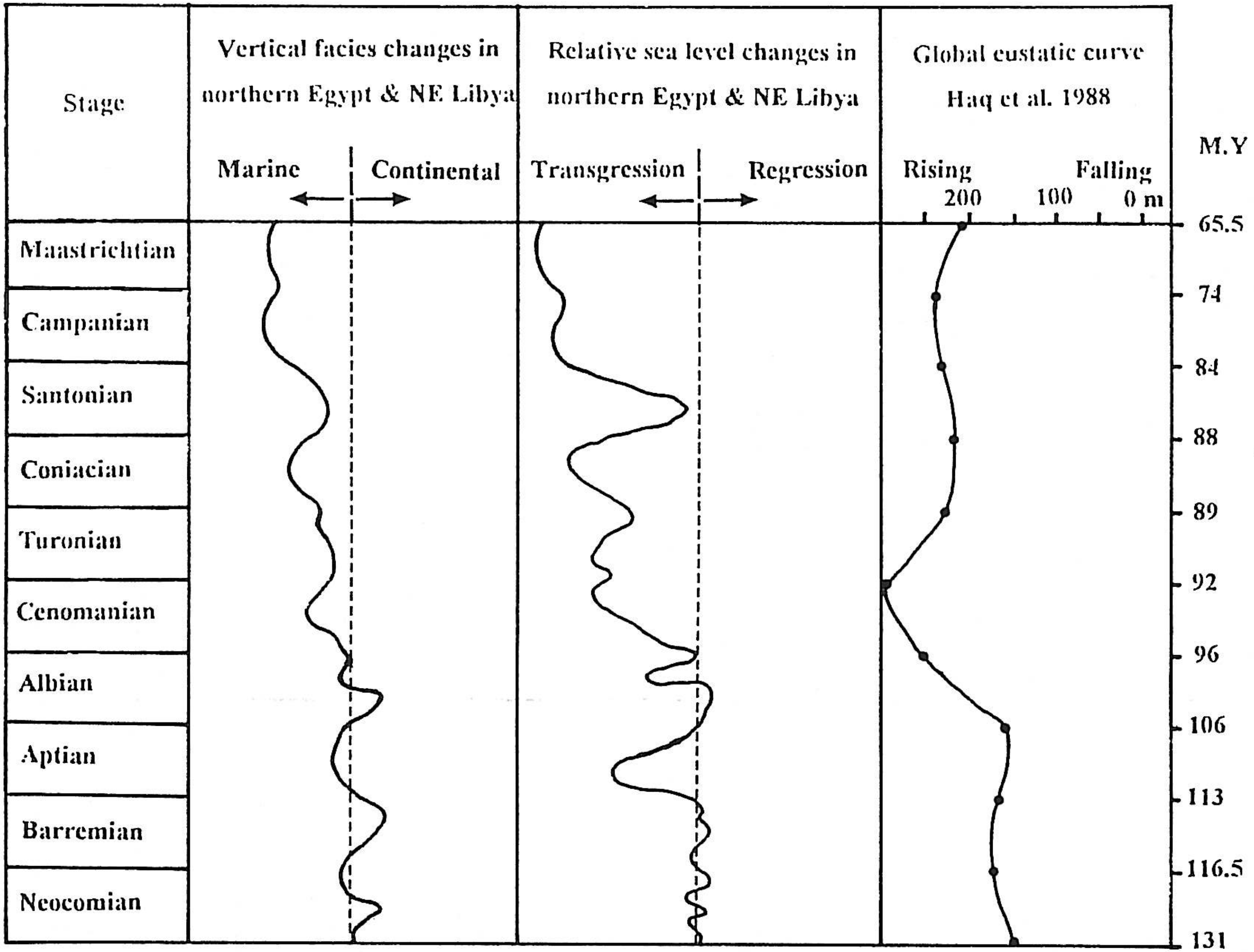

FIG. 5. Reconstructed Cretaceous transgression-regression phases in northern Egypt and NE Libya with the global eustatic sea level changes, after Haq *et al.*, 1988.

Formation in northern Eastern and Western Desert. (2) The shallow marine facies to the south of lat. 28°N represented by phosphate deposits (Duwi Formation) and shales (Rakhiyat, Quseir and Dakhla formations). In the Gulf of Suez the Campanian marl section includes phosphatic beds and was named Gebel Thelmet Formation (Brown limestone by oil company geologists).

In northern Libya the Campanian–Maastrichtian sediments are represented by dark brown clays in the lower Campanian and by calcereous shales (Sirte Shale) in the upper Campanian–Maastrichtian. The Maastrichtian is represented by limestone (Atrun Limestone-Kalash Limestone-Waha Limestone) with a high percentage of planktonic foraminifera which suggests an open sea, neritic environment of deposition (Barr and Weegar, 1972).

CONCLUSIONS

In northern Egypt and NE Libya the Cretaceous sedimentary sequences with their microflora and microfauna have a more or less similar depositional picture. The Cretaceous sea level and the vertical facies changes in northern Egypt and NE Libya were compared with the global eustatic sea level changes of Haq *et al.*, 1988. The detailed studies on the Cretaceous microfloral and foraminiferal contents of northern Egypt and NE Libya led to the following conclusive remakrs:

(1) The Neocomian–Barremian in Egypt and Libya was dominated by a major regressive phase. Two facies could be distinguished: (a) a non-marine to fluviatile "Nubian" facies with its peculiar spores and pollen, and (b) a marginal marine facies containing dinocysts as well as pollen and spores. The Neocomian terrigenous spores include *Impardicispora apiverrucata* and *Pilosisporites trichopapillosus*. The gymnosperm pollen *Dicheiropollis etruscus* is the most striking element in the late Neocomian-Barremian. In the Barremian, *Ephedripites* and the first angiospermous pollen appear. The dinocysts include *Phoberocysta neocomica*, and *Muderongia simplex* in the Neocomian, while the Barremian is distinguished by *Pseudoceratium anaphrissum*, *P. retusum*, *Coronifera oceanica*, *Cerbia tabulata*, and *Cribroperidinium*.

(2) The Aptian Tethys shoreline was restricted to the area north of approximately 30.5°N in NE Libya and Egypt. A Tethyan arm invaded most of the Western Desert to lat. 21°N. The Aptian palynoassemblage includes *Brenneripollis*, *Afropollis zonatus*, *A. operculatus* and *Reyrea*. The Aptian dinoassemblage is dominated by *Pseudoceratium*, *Aptia polymorpha*, *A. plera*, *Subtilisphaera ventriosa*, *Odontochitina operculata*, and *Kiokansium hydra*.

(3) The Albian in general represents a regressive phase in which the Tethys withdrew northwards as in pre-Aptian time. The Albian sediments in northern Egypt and Libya are usually barren of foraminifera as is the case of the older Lower Cretaceous sediments. The Albian palynomorphs in Egypt as well as in Libya are represented by *Crybelosporites (Perotrilites) pannuceus* and *Balmeisporites holodictyus*, *Ephedripites jansonii* and *Afropollis jardinus*. Elaterate pollen, tricolporate and tricolporoidate pollen characterize the late Albian. The dinocyst assemblage of the Albian is characterized by *Xenascus ceratioides*, *X. plotei*, *Oligosphaeridium porosum*, *O. djenn*, *Spiniferites multibrevis*, *Subtilisphaera perlucida*, *S. terrula* and *S. zawia*.

(4) The Cenomanian showed the second major marine transgression in large parts of northern Egypt and Libya. The formation of the Sirt Basin commenced at the beginning of the Cenomanian. Early to middle Cenomanian sporomorphs are characterized by the polycolpate pollen *Stephanocolpites* and the gymnosperm *Classopollis brasiliensis*, while circumaperturate pollen (*Dichastopollenites*) and triporate angiospermous pollen characterize the late Cenomanian. The marine Cenomanian sediments in both Egypt and Libya are characterized by the occurrence of the large-sized agglutinated index foraminifer *Thomasinella*. The Cenomanian planktonic biomarkers *Rotalipora* spp. were recorded only from the Marsa al Hilal area, NE Libya. The Egyptian Cenomanian planktonic biomarkers are characterized by *Hedbergella*, *Heterohelix* and *Praeglobotruncana delrioensis*.

(5) The marine conditions that prevailed during the late Cenomanian continued into the Turonian in both northern Egypt and Libya. The Turonian sediments are characterized by an association of large members of the *Foveotricolpites giganteus-F. gigantoreticulatus* group. Turonian dinocysts in northern Egypt include *Spiniferites porosus*, *S. ramosus* and *Dinogymnium vozzhennikovae*. The recorded planktonic foraminifera are distinguished by the zonal marker species *Whiteinella archaeocretacea*, *Praeglobotruncana helvetica* and *Marginotruncana schneegansi*.

(6) The Coniacian represents the third major transgressive cycle over most of Egypt and Libya. The Coniacian sediments were deposited under fairly deep water, open marine conditions, as suggested by planktonic foraminifera and dinocysts which became increasingly abundant. *Droseridites senonicus* with the *Foveotricolpites giganteus-F. gigantoreticulatus* group are the index pollen recorded from the Coniacian sediments. The following dinocysts made their first appearance in the Coniacian: *Odontochitina porifera*, *Dinogymnium undulosum*, *D. albertii*, *D. longicornis*, *D. heterocastatum*, *D. cretaceum*, *D. microgranulosum* and *Trigonopyxidia ginella*. The Coniacian planktonic

foraminiferal assemblage is characterized by the zonal markers *Dicarinella primitiva* and *D. concavata.*

(7) The Santonian sea advanced far to the sourth covering most of northern Egypt and Libya, but a number of small areas remained emergent as islands in northern Egypt and the Sirt Basin.

The dinocysts are characterized by the first evolutionary appearance of *Spinidinium sverdrupianum, Gillinia hymenophora* and *Alisogymnium euclaense.*

The early Santonian planktonic foraminiferal assemblage is similar to that of the Coniacian and is dominated by *Dicarinella concavata.* Upper Santonian sediments seem to be absent in the studied sections due to the absence of the late Santonian zonal planktonic species *Dicarinella asymetrica.*

(8) During the Campanian–Maastrichtian the sea had reached its maximum southern extension as a result of the fourth and last major transgressive phase of the Cretaceous Tethys. The transgression reached its maximum extent during the middle-late Maastrichtian.

The Campanian–Maastrichtian pollen assemblage can easily be distinguished from older assemblages by the presence of pollen such as *Crassitricolporites brasiliensis, Spinizonocolpites, Echitriporites, Retidiporites* and *Periretisyncolpites.* The phytoplanktonic assemblage is represented by *Phelodinium tricuspis, Cannosphaeropsis utinensis, Dinogymnium acuminatum, D. digitus, D. muticum, Thalassiphora pelagica, Amphigymnium cooksoniae* and *Cerodinium granulostriatum.*

On the other hand, the Campanian planktonic foraminiferal assemblage is characterized by *Globotruncanita elevata, Globotruncana ventricosa* and *Globotruncanita calcarata.* The Maastrichtian planktonic foraminiferal assemblage is characterized by *Globotruncana aegyptiaca, G. falsostuarti, Gansserina gansseri, Contusotruncana contusa* and *Abathomphalus mayaroensis.*

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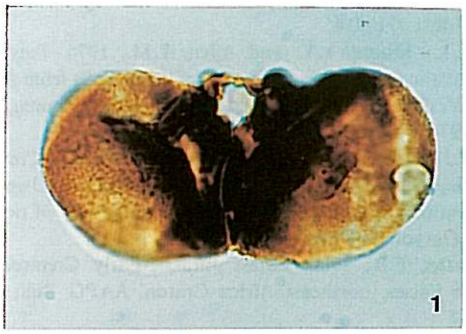
PLATE 1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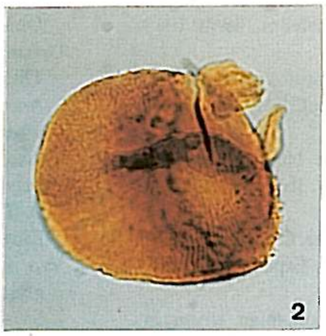
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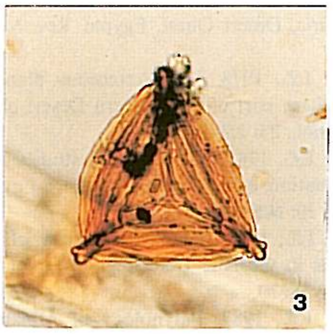
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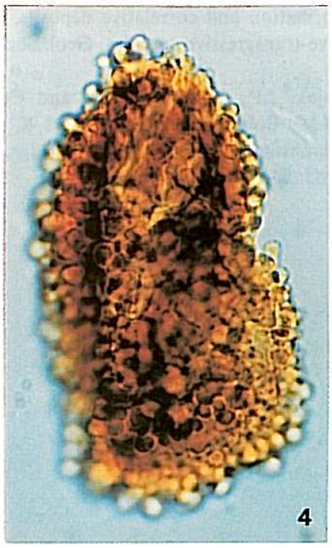
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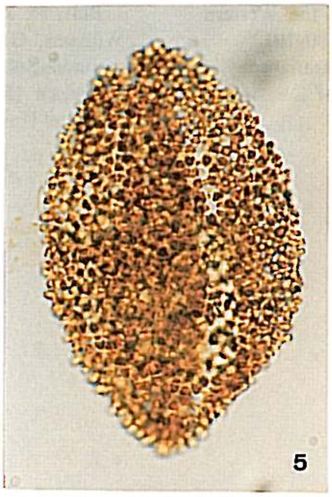
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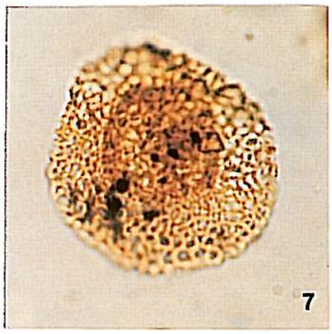
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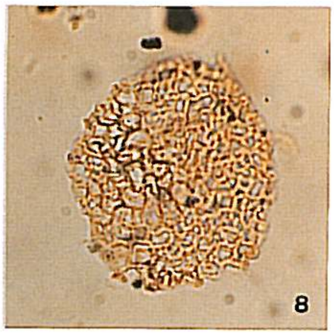
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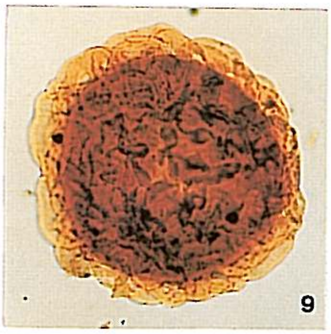
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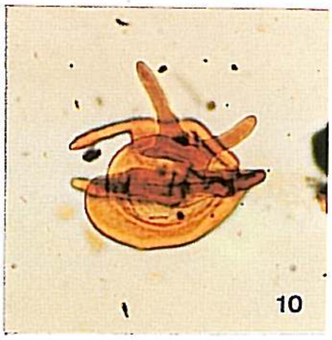
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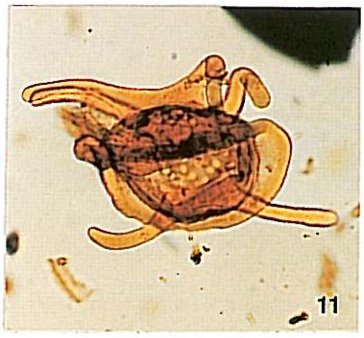
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PLATE 1

Fig. 1. *Dicheiropollis etruscus* Trevisian, 1972. Kahraman-1, Sample 149, 11800 ft., Slide 2, × 1000, (late Neocomian–Barremian).

Fig. 2. Half grain of *Dicheiropollis etruscus* Trevisian, 1972. Kahraman-1, Sample 143, 11460 ft., Slide 1, × 1000, (late Neocomian–Barremian).

Fig. 3. *Appendicisporites potomacensis* Brenner, 1963. Kahraman-1, Sample 118, 9250 ft., Slide 2, × 500, (Albian-Cenomanian).

Fig. 4. *Reyrea polymorphus* Herngreen, 1973. Kahraman-1, Sample 106, 8600 ft., Slide 2, × 1000, (Aptian-Albian).

Fig. 5. *Sellatopollis barghoornii* Doyle *et al.*, 1975. Kahraman-1, Sample 96, 7500 ft., Slide 2, × 1000, (Aptian-Cenomanian).

Fig. 6. *Ephedripites jansonii* (Pocock) Muller, 1968. Kahraman-1, Sample 96, 7500 ft., Slide 3, × 800, (Albian-Cenomanian).

Fig. 7. *Afropollis operculatus* Doyle *et al.*, 1982. Kahraman-1, Sample 115, 9030 ft., Slide 3, × 1000, (Aptian).

Fig. 8. *Afropollis aff. jardinus* Doyle *et al.*, 1982. Kahraman-1, Sample 110, 8700 ft., Slide 2, × 1000, (Aptian-Albian).

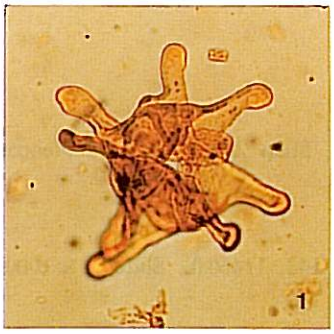
Fig. 9. *Crybelosporites pannuceus* (Brenner) S.K. Srivastava, 1977. Kahraman-1, Sample 82, 6900 ft., Slide 1, × 500, (Albian-Cenomanian).

Fig. 10. *Elaterosporites klaszi* (Jardine and Magloire) Jardine, 1967. Kahraman-1, Sample 82, 6900 ft., Slide 1, × 500, (Albian-Cenomanian).

Fig. 11. *Elaterosporites verrucatus* (Jardine and Magloire) Jardine, 1967. Kahraman-1, Sample 87, 7100 ft., Slide 2, × 500, (Albian-Cenomanain).

Fig. 12. *Elateroplicites africaensis* Herngreen, 1973. Kahraman-1, Sample 72, 6400 ft., Slide 1, × 500, (late Albian-Cenomanian).

PLATE 2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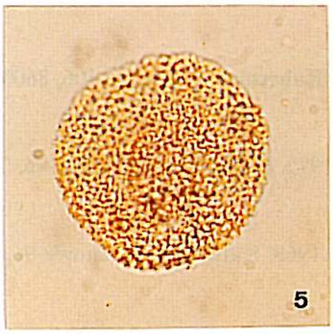
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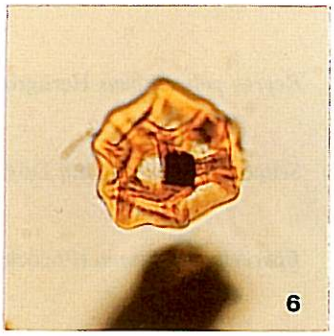
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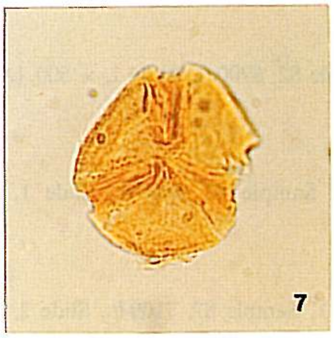
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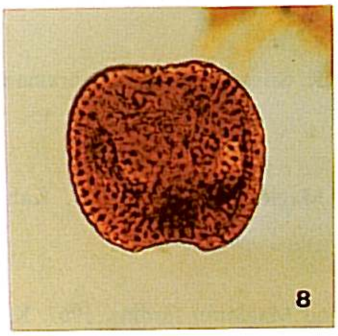
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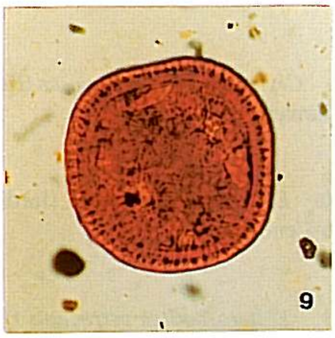
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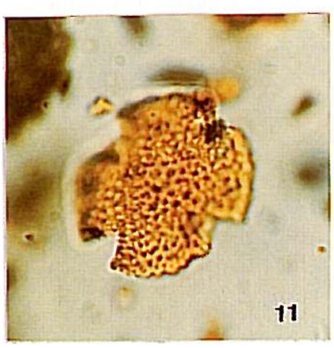
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PLATE 2

Fig. 1. *Elaterocolpites castelaini* Jardine and Magloire, 1965. Kahraman-1, Sample 74, 6500 ft., Slide 2, × 500, (late Albian–Cenomanian).

Figs 2, 3. *Galeacornea* cf. *causea* Stover, 1963, high and low focus. Kahraman-1, Sample 98, 7600 ft., Slide 2, × 800, (late Albian-Cenomanian).

Fig. 4. *Galeacornea clavis* Stover, 1963. Kahraman-1, Sample 80, 6800 ft., Slide 1, × 500, (late Albian-Cenomanian).

Fig. 5. *Afropollis jardinus* (Brenner) Doyle *et al.*, 1982 (fine reticulation variety). Kahraman-1, Sample 80, 6800 ft., Slide 2, × 1000, (late Albian-Cenomanian).

Fig. 6. *Cretacaeiporites polygonalis* (Jardine and Magloire) Herngreen, 1973. Kahraman-1, Sample 89, 7200 ft., Slide 2, × 1000, (late Albian-Cenomanian).

Fig. 7. *Nyssapollenites albertensis* Singh, 1971. Kahraman-1, Sample 74, 6500 ft., Slide 1, × 1000, (Cenomanian).

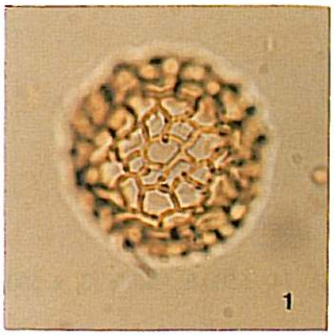
Figs 8, 9. *Stephanocolpites* sp., Kahraman-1, Samples 87 and 96, 7100 and 7500 ft., Slides 3 and 1 respectively, × 1000, (Cenomanian).

Fig. 10. *Classopollis brasiliensis* Herngreen, 1975. Kahraman-1, Sample 68, 6200 ft., Slide 1, × 1000, (Cenomanian).

Fig. 11. *Tetracolpites* sp., Kahraman-1, Sample 91, 7300 ft., Slide 1, × 1000, (Cenomanian).

Fig. 12. *Triporopollenites* sp., Kahraman-1, Sample 29, 4250 ft., Slide 1, × 1000, (late Cenomanian-Maastrichtian).

PLATE 3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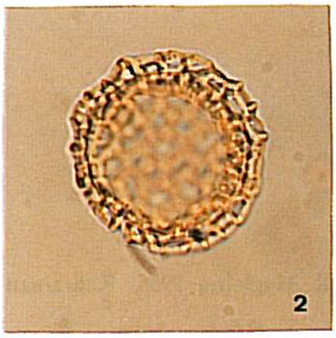
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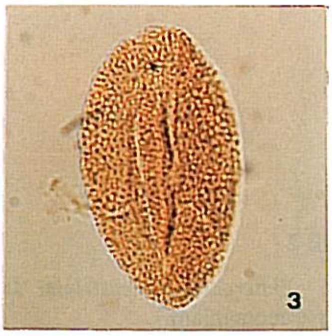
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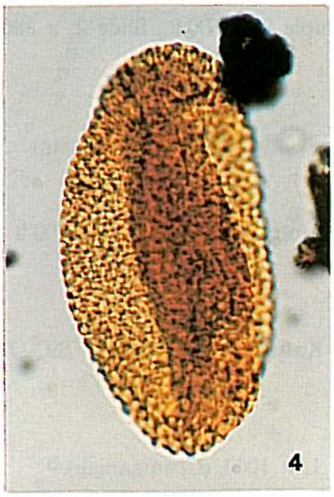
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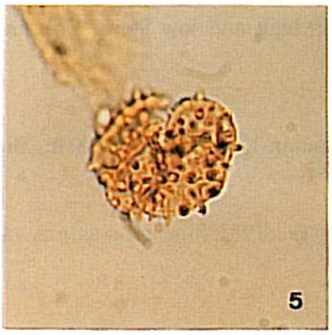
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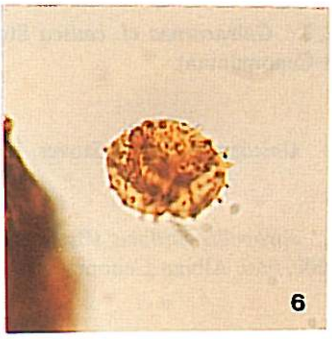
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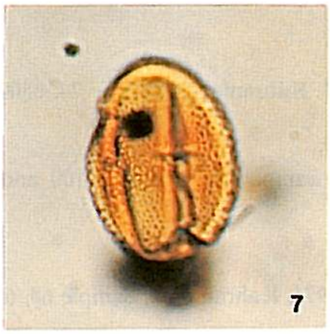
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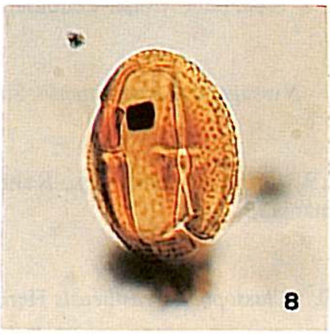
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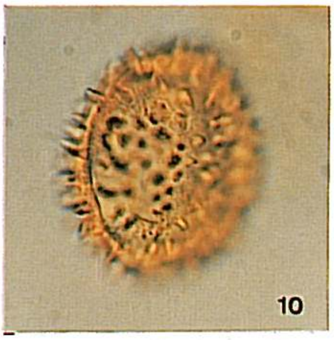
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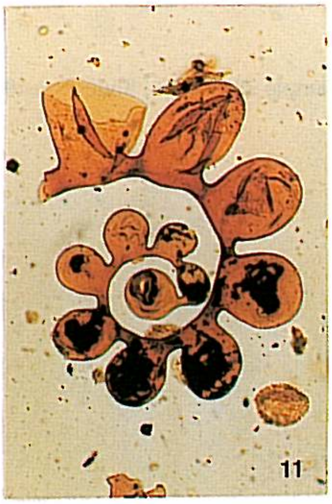
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PLATE 3

Figs. 1, 2. *Dichastopollenites* cf. *dunveganensis* Singh, 1983 (high and low focus). Ghazalat-1, Core 5, 2112–2115 ft., Slide 1, × 1000, (late Cenomanian).

Fig. 3. *Faveotricolpites gigantoreticulatus* (Jardine and Magloire) Schrank, 1987. Kahraman-1, Sample 24, 4000 ft., Slide 1, × 1000, (Turonian-Santonian).

Fig. 4. *Foveotricolpites giganteus* (Jardine and Magloire) Jan Du Chene *et al.*, 1978. Abu Gharadig-18, Sample 15, 8900 ft, Slide 2, × 1000, (Turonian-Santonian).

Figs. 5, 6. *Droseridites senonicus* Jardine and Magloire, 1965. Abu Gharadig-18, Sample 15, 8900 ft., Slide 1, × 1000, (late Turonian-Santonian).

Figs. 7, 8. *Crassitricolporites brasiliensis* Herngreen, 1972. Kahraman-1, Sample 18, 3700 ft., Slide 2, × 1000, (Campanian-Maastrichtian).

Figs. 9, 10. *Spinizonocolpites* cf *echinatus* Muller, 1968. Kahraman-1, Sample 16, 3600 ft., Slide 2, × 1000, (Campanian-Maastrichtian):

Fig. 11. Microforaminiferal lining. Kahraman-1, Sample 32, 4400 ft., × 250.

Fig. 12. Scolecodont. Kahraman-1, Sample 24, 4000 ft., Slide 1, × 500.