

STRATIGRAPHIC STUDIES ON SOME UPPER CRETACEOUS SUCCESSIONS IN SINAI, EGYPT.

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ABSTRACT

Three Upper Cretaceous stratigraphic sections have been measured and studied in detail covering the lateral variation in facies from south to north Sinai; Gebel Ekma (southern Sinai), East Themed area (central Sinai), and Gebel Yelleg (northern Sinai).

Eight lithostratigraphic units are recognised ranging in age from Late Albian to the Maastrichtian and representing the southern and the northern facies. The southern facies includes Raha Formation (Early - Late Cenomanian), Abu Qada Formation (Late Cenomanian - early Middle Turonian), Buttum Formation (Early - early Middle Turonian), Wata Formation (Early - Late Turonian), and Matulla Formation (?Late Turonian - Campanian). While the northern facies is represented by Galala Formation (Late Albian - Late Cenomanian), Wata Formation (Early - Late Turonian), and Themed Formation (Coniacian - Santonian). The Sudr Chalk (Campanian - Maastrichtian) represents the Upper Senonian sequence in both facies.

Biostratigraphically, seven ammonite zones have been recognised from the studied sections; *Neolobites vibrayanus* Total Range Zone, *Vascoceras cauvini* - *Pseudaspidoceras pseudonodosoides* - *Rubroceras alatum* Assemblage Zone, *Choffaticeras quaasi* - *Choffaticeras securiforme* Total Range Zone, *Choffaticeras segne* - *Vascoceras hartii* Total Range Zone, *Choffaticeras sinaiticum* - *Thomasites rollandi* Total Range Zone, *Coilopoceras requienianum* Total Range Zone, and *Metatissotia ewaldi* Total Range Zone.

Twenty zones of bivalves, gastropods, and echinoids are constructed from the studied sections.

Moreover, Two larger foraminiferal zones *Orbitolina conica* Total Range Zone and *Praealveolina cretacea* Total Range Zone are recorded from the Cenomanian of Gebel Yelleg.

The Albian/Cenomanian, Cenomanian/Turonian, Turonian/Coniacian, Coniacian/Santonian, Santonian/Campanian and Campanian/Maastrichtian boundaries are discussed.

INTRODUCTION

Previous work concerning the Upper Cretaceous rocks of Sinai are numerous, but the macrobiostratigraphic studies are few. A few work had been carried out on the stratigraphy of the three measured sections (Gebel Ekma, East Themed area, and Gebel Yelleg) and mostly based on foraminifera; Moon & Sadek (1921), Cherif *et al.* (1989a, b), Ammar & Afifi (1992), Orabi & Ismail (1993), Ziko *et al.* (1993), El-Sheikh (1999), Ismail (2000), and Saber (2002).

Very few work had been carried out using the integrated biostratigraphic scheme of the Upper Cretaceous of Sinai, including Kora & Hamama (1987a, b), El-Sheikh *et al.* (1998), Bauer *et al.* (2001), Kassab & Obaidalla (2001), Obaidalla & Kassab (2002), Zakhera & Kassab (2002), and others.

The present work aims to achieve the following:

- 1) Recognition of the lithostratigraphic units of the Upper Cretaceous succession and considering the lateral facies change from south to the north in Sinai (Fig.

- 1).
- 2) Providing an integrated biostratigraphic scheme based on the identified ammonites and the associated macrofossils as well as the characteristic larger foraminifera. The proposed biozones are to be correlated with their counterparts in the neighbouring countries as well as the standard zones as far as possible.

To achieve the above objectives, three stratigraphic sections representing the

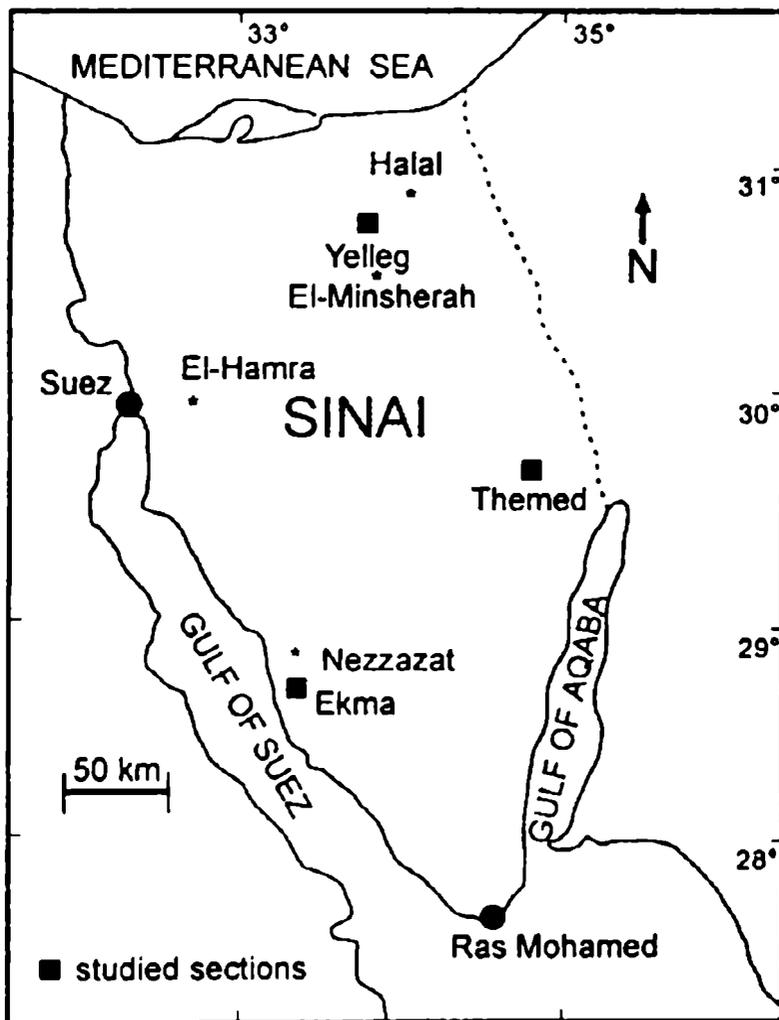


Fig. 1: Location map of the studied sections.

Upper Cretaceous succession in Sinai were measured. These are Gebel Ekma section in southern Sinai, East Themed area in central Sinai, and Gebel Yelleg in northern Sinai (Fig. 1). The macrofaunal assemblages, viz. bivalves, gastropods, cephalopods, and echinoids were collected. Samples for larger foraminifera were collected at Gebel Yelleg. All the studied material is deposited at the Geology Department, Faculty of Science, Zagazig University, Benha Branch, Egypt.

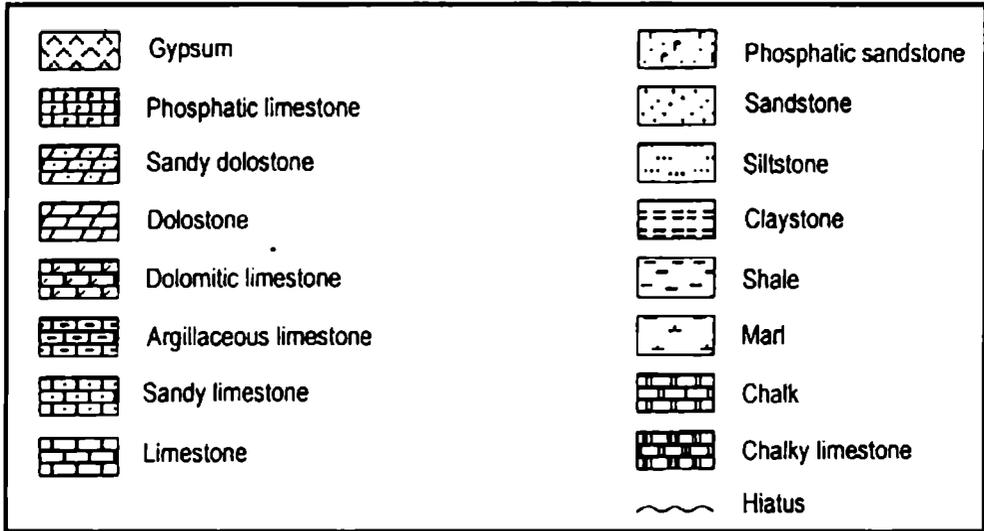


Fig. 2: Lithologic symbols used.

STRATIGRAPHY

Lithostratigraphy

The lateral variation in facies and thickness of the Upper Cretaceous rocks in Sinai led to recognition of the following rock units.

Table 1: The described Upper Cretaceous rock units in the three studied sections.

Gebel Ekma (Southern Sinai)	East Themed area (Central Sinai)	Gebel Yelleg (Northern Sinai)
Sudr Chalk (Campanian - Maastrichtian)	Sudr Chalk (Campanian - Maastrichtian)	Sudr Chalk (Campanian - Maastrichtian)
Matulla Formation (131.5 m) (?Late Turonian-Campanian)	Themed Formation (41 m) (Coniacian - Santonian?)	Themed Formation (15 m) (Coniacian - Santonian?)
Wata Formation (48 m) (late Middle - Late Turonian)	Wata Formation (121 m) (late Middle - Late Turonian)	Wata Formation (102 m) (Early - Late Turonian)
Abu Qada Formation (59 m) (Early - early Middle Turonian)	Buttum Formation (37 m) (Early - early Middle Turonian)	
	Abu Qada Formation (65 m) (Late Cenomanian - Early Turonian)	
Raha Formation (137 m) (Early - Late Cenomanian)	Galala Formation (60 m) (Early Cretaceous - Late Cenomanian)	Galala Formation (422 m) (Late Albian - Late Cenomanian)

The following is a brief description for the recognised rock units from south to north:

The Raha Formation (Ghorab (1961))

The Raha Formation represents the whole Cenomanian sequence of Gebel Ekma, southern Sinai (Fig. 3). It overlies the Malha Formation of Early Cretaceous age and conformably underlies the Abu Qada Formation of Early to early Middle Turonian age. The Raha Formation attains a thickness of 137 m and is composed of a succession of shale, marl, and sandstone intercalations with some limestone interbeds. This succession is topped by a hard, cliff-forming limestone bed (10 m thick) yielded a late Late Cenomanian ammonite association (Fig. 3).

The Raha Formation is relatively rich in macrofossils. The most abundant faunal elements include *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Ilymatogyra africana* (Lamarck), *Ambigostrea pseudovillei* Malchus, *Costagyra olisiponensis* (Sharpe), *Parasea faba faba* (J. de C. Sowerby), *Maghrebella forgemoli* (Coquand), *Tenea delectrei* (Coquand), *Tylostoma cossoni* Thomas & Peron, *Pterodonta deffisi* Thomas & Peron, *Heterodiadema libycum* (Desor), *Coenholectypus cenomanensis* (Gueranger), *Hemiaster (Hemiaster) gabrielis* Peron & Gauthier. The most common ammonites recorded are *Neolobites vibrayeanus* (d'Orbigny), *Vascoceras cauvini* Chudeau, and *Vascoceras cf. durandi* (Thomas & Peron). In addition to *Rubroceras alatum* Cobban, Hook & Kennedy, which is recorded for the first time from outside New Mexico.

The Galala Formation (Abdallah & El Adindani 1963)

The Galala Formation is used herein to describe the Cenomanian sequences of both Gebel Yelleg and the East Themed area, which are characterised by a higher carbonate content than the Raha Formation of Ghorab (1961) but less than that of the Halal Formation as described by Said (1971). The Galala Formation overlies the Lower Cretaceous Malha Formation at Gebel Khashm El-Tarif in the East Themed area (Fig. 4) and is conformably overlain by the Abu Qada Formation of Late Cenomanian-Early Turonian age. It measures 60 m and is composed mainly of dolomitic limestone and argillaceous limestone with marl and a few shale-siltstone interbeds. The upper part of the formation (bed no. 3-6) is highly fossiliferous and yielded *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Ilymatogyra africana* (Lamarck), *Chondrodonta joannae* (Choffat), and *Praeradiolites biskraensis* (Coquand), *Nerinea gemmifera* Coquand, *Pterocera incerta* d'Orbigny, *Pterodonta deffisi* Thomas & Peron, and *Harpagodes heberti* (Thomas & Peron). The only ammonite recorded is *Neolobites vibrayeanus* (d'Orbigny) and *Heterodiadema libycum* (Desor) is the most important echinoid species recorded. The lower part (bed no. 1-2) consists of marl and dolomitic nodular limestone with poorly preserved bivalve and gastropod moulds. This part may represent the ?Early Cretaceous - Early/Middle Cenomanian (transition unit), whereas bed no. 3. yielded *Ilymatogyra africana* (Lamarck) of Middle - Late Cenomanian age (see Malchus 1990, Seeling & Bengtson 1999). Accordingly, the Galala Formation in the East Themed area is ?Early Cretaceous - Late Cenomanian in age.

In Gebel Yelleg section (Fig. 5), the Galala Formation overlies also the Lower Cretaceous Malha Formation and conformably underlies the Turonian Wata Formation. It has a relatively higher carbonate content compared to that of the Themed area and could be equated with the Halal Formation. It measures 422 m

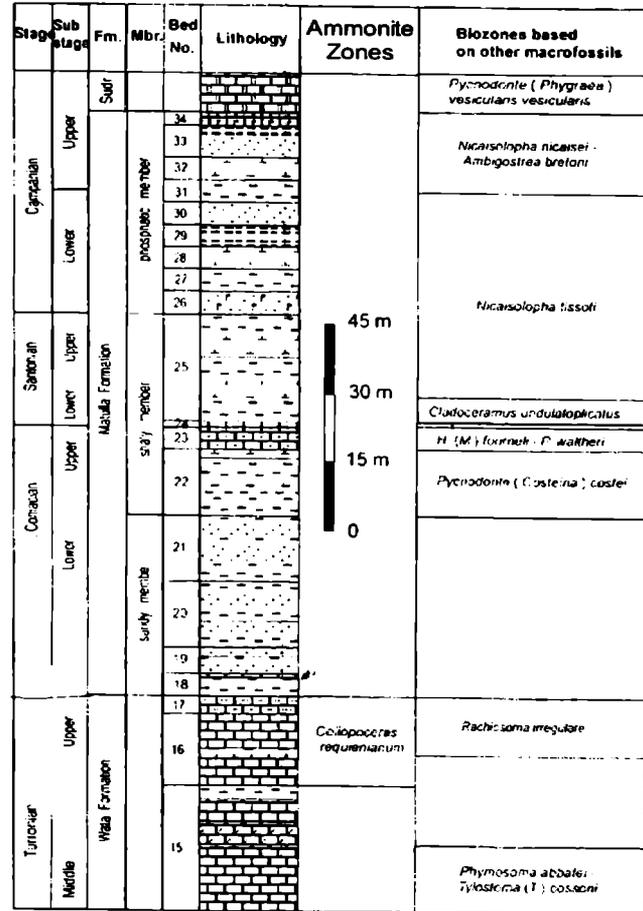
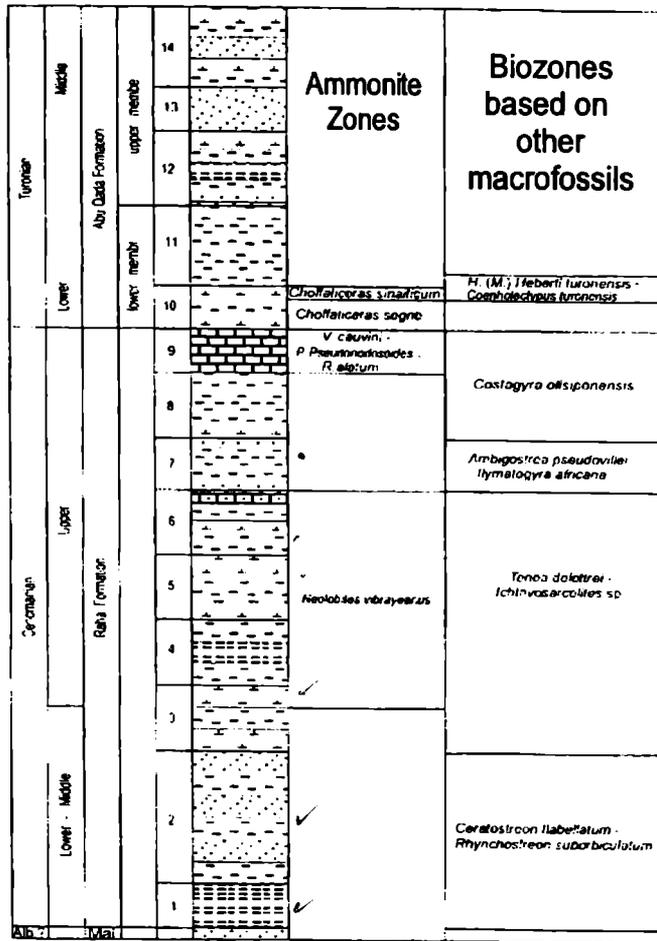


Fig. 3: Stratigraphy of the Upper Cretaceous succession of Gebel Ekma, and the integration between the ammonite zones and biozones based on other macrofossils.

and is composed mainly of dolostone, dolomitic limestone, and argillaceous limestone intercalated with marl and shale. Rudist boundstone and rudstone are very conspicuous of the lower part. The middle part contains four characteristic chert bands. The Galala Formation at Gebel Yelleg is highly fossiliferous, and yielded in addition to the aforementioned fauna *Gyrostrea delettrei* (Coquand), *Ambigostrea pseudovillei* Malchus, *Rastellum carinatum* (Lamarck), *Eoradiolites liratus* (Conrad), *Aptyxiella subaequalis* (d'Orbigny), *Coenholectypus cenomanensis* (Gueranger), *Hemiaster* (*Hemiaster*) *gabrielis* Peron & Gauthier. It yielded also the more diagnostic larger foraminifera *Orbitolina conica* (d'Archiac) of the Lower Cenomanian and *Praealveolina cretacea* (d'Archiac) of the Middle Cenomanian. The lowermost part (33 m of marl, limestone, and shale), form the *Ceratostreon flabellatum* - *Pterocera incerta* Acme Zone assigned to the Upper Albian whereas it underlies the basal Cenomanian *Orbitolina conica* Zone. Therefore, the Galala Formation in Gebel Yelleg belongs to the Late Albian - Late Cenomanian age.

The Abu Qada Formation (Ghorab 1961)

In the East Themed area, the Abu Qada Formation conformably overlies the Galala Formation and underlies the Buttum Formation. It is composed mainly of marl and shale intercalations with some limestone interbeds, and attains a thickness of 65 m (Fig. 4). The lower part of this unit yielded the oysters; *Ilymatogyra africana* (Lamarck), *Costagyra olisiponensis* (Sharpe), and *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), and the latest Cenomanian ammonite *Vascoceras cauvini* Chudeau. The upper part of the unit is very rich with Early Turonian ammonites *Choffaticeras* spp., *Vascoceras hartii* (Hyatt), and *Thomasites rollandi* (Thomas & Peron). In addition to the echinoids *Hemiaster* (*Mecaster*) *heberti turonensis* Fourtau and *Coenholectypus turonensis* (Desor). Consequently, the age of this formation is Late Cenomanian to Early Turonian.

In Gebel Ekma, the Abu Qada Formation conformably overlies the Raha Formation (Cenomanian), and is overlain by the Wata Formation (late Middle to Late Turonian). It is composed of marl, shale and sandstone intercalations with a few claystone and limestone interbeds and attains a thickness of 59 m (Fig. 5). The Abu Qada Formation at Gebel Ekma can be subdivided into two members, whereby in the lower member grey to yellowish grey shale dominates. The upper member is mainly composed of red and reddish brown sandstone. This upper member is equivalent to the "Red Beds" of Abdel-Gawad (1999a) from west-central Sinai and can be correlated with the clastic middle member of Issawi *et al.* (1981) from West Sinai, and the Buttum Formation of Issawi *et al.* (1999) from East Sinai. The lower member of Abu Qada Formation in Gebel Ekma yielded the Early Turonian ammonites *Choffaticeras segne* (Solger), *Choffaticeras sinaicum* (Douvillé), and *Fagesia catinus* (Mantell). Consequently, the age of this unit is Early to early Middle Turonian.

The Buttum Formation (Issawi *et al.* 1999)

In the East Themed area, the Buttum Formation is composed of vari-coloured shales and gypsum intercalating claystone and siltstone interbeds and attains a thickness of 37 m (Fig. 4). The Buttum Formation indicates very shallow lagoonal or sabkha deposits on tidal flats (Issawi *et al.* 1999). It is equivalent to the upper

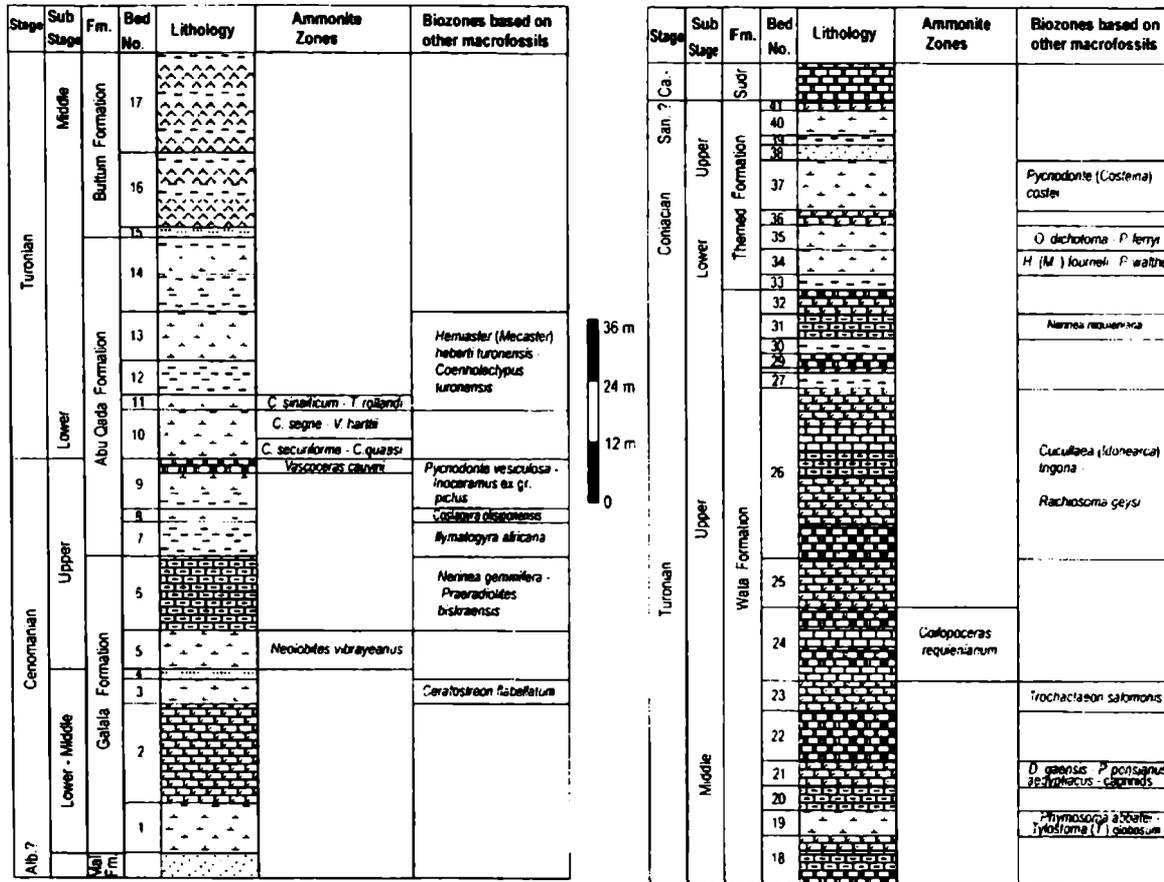


Fig. 4: Stratigraphy of the Upper Cretaceous succession of the East Themed area, and the integration between the ammonite zones and biozones based on other macrofossils.

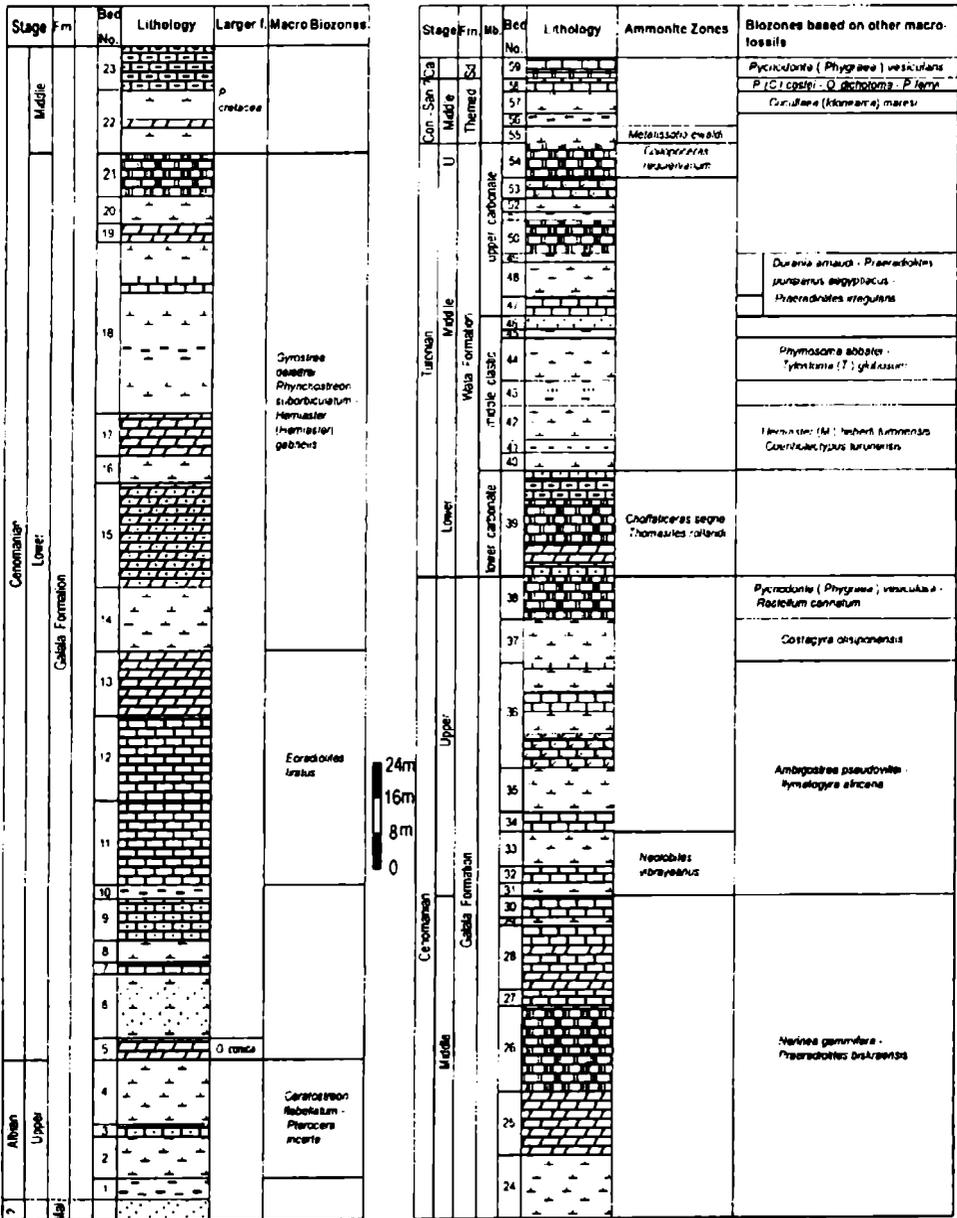


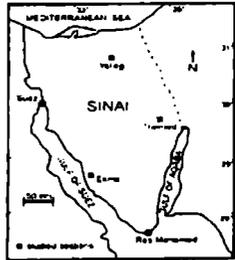
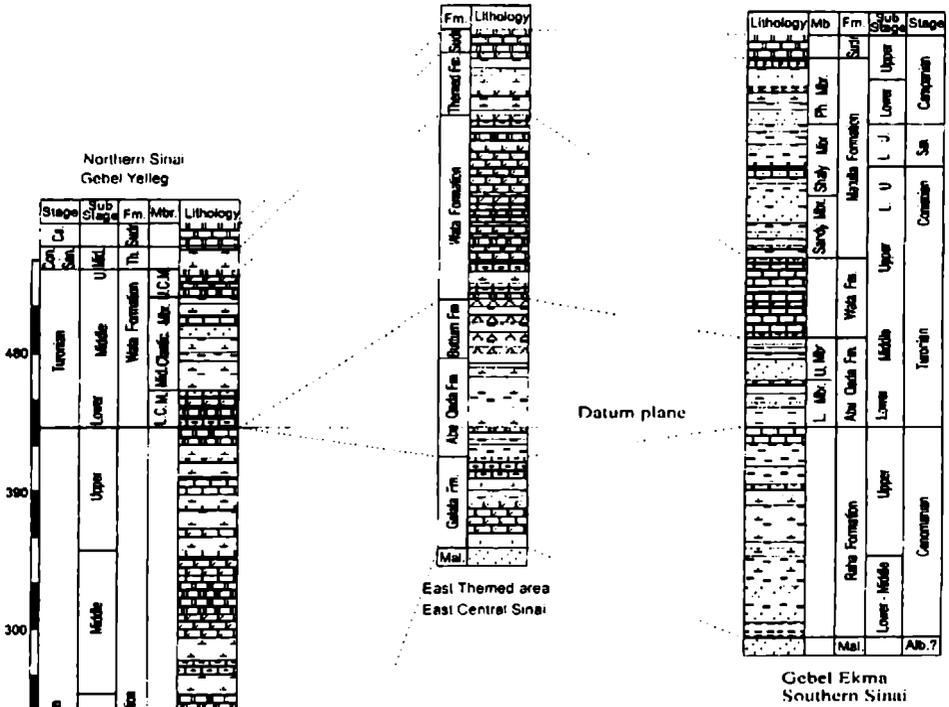
Fig. 5: Stratigraphy of the Upper Cretaceous succession of Gebel Yelleg, and the integration between the ammonite zones and biozones based on other macrofossils and larger foraminifera.

member of the Abu Qada Formation in Gebel Ekma, and it may be coeval with the middle clastic member of the Wata Formation at Gebel Yelleg. The Buttum Formation is barren of macrofauna. The age of this unit is considered Early to early Middle Turonian based on its stratigraphic position.

The Wata Formation (Ghorab 1961)

The Wata Formation conformably overlies the Galala Formation at Gebel Yelleg, the Butum Formation in the East Themed area, and the Abu Qada Formation in Gebel Ekma (Table 1, Fig. 6).

It consists of a sequence of chalky limestone, dolomitic limestone, sandy limestone and argillaceous limestone (Figs. 3-5). Marl, shale, and sandstone interbeds are concentrated in the middle part of the formation at Gebel Yelleg, which led to subdivide it into three members (lower carbonate member, middle



..... Stage boundaries
 - - - - - Lithostratigraphic boundaries

clastic member, and an upper carbonate member). Some chert bands become conspicuous in the middle part of the formation in the East Themed area.

The Wata Formation attains its maximum thickness at the East Themed area, where it measures 121 m. In Gebel Yelleg, it reaches 102 m, while its minimum thickness is recorded at Gebel Ekma, where it attains 48 m (Fig. 6). In all the studied sections the Wata Formation yielded the late Middle - early Late Turonian ammonite *Coilopoceras requienianum* (d'Orbigny). At the East Themed area, the Wata Formation is more fossiliferous than that of Gebel Ekma and Gebel Yelleg, yielding *Tylostoma* (*T.*) *globosum* Sharpe, *Trochactaeon salomonis* (Fraas), *Cucullaea* (*Idonearca*) *trigona* (Seguenza), *Rachiosoma geysi* Abdelhamid & El-Qot, *Nerinea requieniana* d'Orbigny, and "*Amorphospongia*" *tumescens* Thomas & Peron.

In Gebel Yelleg, the middle clastic member of the formation is the most fossiliferous member and yielded *Hemiaster* (*M.*) *heberti* (Coquand) *turonensis* Fourtau, *Coenholectypus turonensis* (Desor), *Durania arnaudi* (Choffat), *Praeradiolites ponsianus* (d'Archiac) *aegyptiacus* Douvillé, and *Praeradiolites irregularis* Douvillé. In Gebel Ekma, the most abundant fauna are *Rachiosoma irregulare* Fourtau and *Phymosoma abbatei* (Gauthier), which was recorded from the three localities.

The age of the Wata Formation is late Middle to Late Turonian at Gebel Ekma and the East Themed area, based on its position overlying the Abu Qada Formation (Early - early Middle Turonian) at Gebel Ekma and The Buttum Formation at the East Themed area and yields *Coilopoceras requienianum* (d'Orbigny) in its upper part. In Gebel Yelleg, it ranges from Early to early Late Turonian age based on the occurrence of *Choffaticeras segne* - *Thomasites rollandi* Zone in the basal part and *Coilopoceras requienianum* Zone in its uppermost part.

The Matulla Formation (Ghorab 1961)

The Matulla Formation is recorded only in Gebel Ekma section in the present study. It overlies the Wata Formation (late Middle to Late Turonian) and underlies conformably the Sudr Chalk of Late Campanian - Maastrichtian age (Cherif *et al.* 1989b, El Sheikh 1999). It is composed mainly of shale with intercalations of sandstone, marl, and limestone and attains a thickness of 131.5 m (Fig. 3). It is sandy at the base, shaly in the middle, while phosphatic limestone characterises the upper part. The present authors prefer the "Formation" rather than the "Group" status for this rock unit and agree with Orabi & Ramadan (1995) in subdividing it into three members (sandy, shaly, and phosphatic members). The sandy mbr. (41 m thick) is barren of both macro- and microfossils. Due to the underlying Wata Formation yielded the late Middle to early Late Turonian *Coilopoceras requienianum* (d'Orbigny) in its uppermost part, and the overlying member (shaly mbr.) yielded a Coniacian fauna. It is clear that, this member is of ?Late Turonian - Coniacian age (Transition Unit). The Matulla Formation (particularly the shaly and phosphatic members) is highly fossiliferous and yielded the following fauna; *Pycnodonte* (*Costeina*) *costei* (Coquand), *Nicaiolopha nicaisei* (Coquand), *Nicaiolopha tissoti* (Thomas & Peron), *Ambigostrea bretoni* (Thomas & Peron), *Plicatula ferryi* Coquand, *Petalobrissus waltheri* (Gauthier), *Hemiaster* (*Mecaster*) *fourneli* Deshayes, and the Lower Santonian *Cladoceramus undulatopticatus* (Roemer). It is worthy to mention that, the shaley member yield poorly preserved

Middle - Upper Coniacian ammonites *Subtissotia africana* (Peron) and *Metatissotia fourneli* (Bayle).

The Themed Formation (Ziko *et al.* 1993)

At Garf El Themed area (type locality), the Themed Formation is composed mainly of marl intercalated with shale, limestone and sandstone and has a thickness of 41 m (Fig. 4). The Themed Formation as defined by Ziko *et al.* (1993) attains a thickness of 115 m, because they included the topmost Turonian rocks consisting of chalky limestone and dolomitic limestone. In the present study, the topmost part of these limestones contain a bed with *Nerinea requieniana* d'Orbigny of Turonian age (Fig. 4). This bed is topped by 5 m thick bed of unfossiliferous dolomitic limestone. The latter is followed by 3 m yellowish grey shale that in turn is topped by yellowish white marl yielding the following Coniacian - Santonian fauna; *Hemiaster* (*Mecaster*) *fourneli* Deshayes, *Petalobrissus waltheri* (Gauthier); *Oscillopho dichotoma* (Bayle), and *Plicatula ferryi* Coquand, corresponding to two zones. These two zones are followed by the *Pycnodonte* (*Costeina*) *costei* Zone. The upper part of the Themed Formation (12 m above the *P. costei* Zone) is unfossiliferous, and according to its stratigraphic position is considered to be Late Coniacian - Santonian? in age.

In Gebel Yelleg, the Themed Formation is much reduced in thickness (15 m) unconformably overlying the Wata Formation. It consists of alternations of marl and shale, which are topped by a cliff-forming sandy limestone bed (Fig. 5). From the ammonite data a hiatus between the Wata and Themed formations (Turonian/Coniacian boundary) can be easily determined. Within 0.5 m above the chalky limestone of the Turonian rocks, that yields *Coilopoceras requienianum* (d'Orbigny) there is a yellowish white marl bed yielding *Metatissotia ewaldi* (von Buch) of the Middle - Late Coniacian. Since *Coilopoceras requienianum* is not the uppermost Turonian zone, a hiatus comprising the latest Turonian to Early Coniacian is suggested. The beds overlying the *M. ewaldi* Zone, which yielded the fauna forming the *Cucullaea* (*Idonearca*) *maresi* Zone and the *Pycnodonte* (*Costeina*) *costei* - *Oscillopho dichotoma* - *Plicatula ferryi* Zone respectively (Fig. 5). This part of the formation did not yield any typical Coniacian or Santonian fauna and is considered to be of Late Coniacian - Santonian ? in age according to its stratigraphic position. Consequently, the age of the Themed Formation is Coniacian - Santonian ? in both G. Yelleg and the East Themed area.

The Sudr Chalk (Ghorab 1961)

This rock unit forms the top of the Cretaceous succession in all the studied sections. It is composed of snow-white, massive chalk with minor marl, shale and limestone interbeds. In the studied sections (Figs. 3-5), it is poorly fossiliferous with respect to macrofossils, yielding only *Pycnodonte* (*Phygraea*) *vesicularis vesicularis* (Lamarck), but it is very rich in microfossils specially planktic foraminifera. The age of this unit is Campanian - Maastrichtian in all studied sections according to its planktonic foraminiferal content (Ziko *et al.* 1993, Cherif *et al.* 1989b, and El Sheikh 1999).

BIOSTRATIGRAPHY

The proposed ammonites zones and the other macroinvertebrate biozones of the three studied sections are given in Tables 2, 3.

Table 2: Correlation of the proposed ammonite zones in the studied sections.

Age		Gebel Ekma	East Themed Area	Gebel Yelleg
Coniacian				<i>Metatissotia ewaldi</i> Total Range Zone
	Mid.- L.	<i>Coilopoceras requienianum</i> Total Range Zone	<i>Coilopoceras requienianum</i> Total Range Zone	<i>Coilopoceras requienianum</i> Total Range Zone
Turonian	Early	<i>Choffaticeras sinaiticum</i> Total Range Zone <i>Choffaticeras segne</i> Total Range Zone	<i>Choffaticeras sinaiticum</i> - <i>Thomasites rollandi</i> Total Range Zone <i>Choffaticeras segne</i> - <i>Vascoceras hartii</i> Total Range Zone <i>Choffaticeras securiforme</i> - <i>Choffaticeras quaasi</i> Total Range Zone	<i>Choffaticeras segne</i> - <i>Thomasites rollandi</i> Total Range Zone
	Late	<i>Vascoceras cauvini</i> - <i>Pseudaspidoceras pseudonodosoides</i> - <i>Rubroceras alatum</i> Assemblage Zone <i>Neolobites vibrayeanus</i> Total Range Zone	<i>Vascoceras cauvini</i> Total Range Zone <i>Neolobites vibrayeanus</i> Total Range Zone	<i>Neolobites vibrayeanus</i> Total Range Zone
Cenomanian	Late	<i>Vascoceras cauvini</i> - <i>Pseudaspidoceras pseudonodosoides</i> - <i>Rubroceras alatum</i> Assemblage Zone <i>Neolobites vibrayeanus</i> Total Range Zone	<i>Vascoceras cauvini</i> Total Range Zone <i>Neolobites vibrayeanus</i> Total Range Zone	<i>Neolobites vibrayeanus</i> Total Range Zone

Ammonite zonation

The stratigraphic distribution of the identified ammonites enabled the subdivision of the Upper Cretaceous succession of the studied sections into seven ammonite zones (Table 2). The proposed zones are to be correlated with the standard ammonite zones and other ammonite zonal schemes of adjacent Tethyan regions. The integration between these ammonite zones and the biozones, which are proposed based on other macrofossils and larger foraminifera are shown in Figs. 3 - 5. Selected ammonite species are illustrated in Pls. 1-4. The following is a brief description of the suggested ammonite zones.

Table 3: Correlation of the proposed zones based on other macrofossils and larger foraminifera in the studied sections.

Age	Gebel Ekma	East Themed Area	Gebel Yelleg
Ma. Campanian	Late <i>Pyxidonte (Phygraea) vesicularis</i> Acme Zone		<i>Pyxidonte (Phygraea) vesicularis</i> Acme Zone
	Early <i>Ambigostrea bretoni</i> - <i>Nicaiolopha nicaissei</i> Total Range Zone		
San. L.	<i>Nicaiolopha trisoti</i> Total Range Zone		
	E. <i>Cladoceramus undulatopectatus</i> Total Range Zone		
Coniacian	L. <i>Hemaster fourneli</i> - <i>Petalobrissus waltheri</i> Acme Zone	<i>Pyxidonte (Casteina) castei</i> Total Range Zone	<i>Pyxidonte (Casteina) castei</i> - <i>Oscillopoda dichotoma</i> - <i>Plicatula ferrys</i> Assemblage Zone
	Mid. <i>Pyxidonte (Casteina) castei</i> Acme Zone		<i>Cucullaea (Idonearca) marexii</i> Acme Zone
	Early <i>Hemaster (Alecaster) fourneli</i> - <i>Petalobrissus waltheri</i> Acme Zone		
Turonian	Late <i>Rachiosoma irregulare</i> Acme Zone	<i>Nerinea reymeniana</i> Total Range Zone	<i>Durania arnaldi</i> - <i>Praeradiolites ponsianus aegyptiacus</i> - <i>Praeradiolites irregularis</i> Assemblage Zone
	Middle <i>Phymosoma abbatei</i> - <i>Tylostoma (T.) costami</i> Acme Zone	<i>Cucullaea (Idonearca) trigona</i> - <i>Rachiosoma geysi</i> Acme Zone <i>Trochactaeon salomonis</i> Total Range Zone	
	Early <i>Hemaster (M.) heberti turonensis</i> - <i>C. turonensis</i> Acme Zone	<i>Durania goensis</i> <i>Praeradiolites ponsianus aegyptiacus</i> - <i>caprinids</i> Assemblage Zone <i>Phymosoma abbatei</i> - <i>Tylostoma (T.) globosum</i> Acme Zone	
Cenomanian	Late <i>Costagyrus ulsiponensis</i> Acme Zone	<i>Hemaster (Mecaster) heberti turonensis</i> - <i>Coenheolcypus turonensis</i> Acme Zone	<i>Phymosoma abbatei</i> - <i>Tylostoma (T.) globosum</i> Acme Zone
	Mid. <i>Ambigostrea pseudovillei</i> - <i>Hymatogyra africana</i> Acme Zone	<i>Pyxidonte (Phygraea) vesiculosa</i> - <i>Inoceramus ex gr. pictus</i> Interval Zone	<i>Pyxidonte (Phygraea) vesiculosa</i> - <i>Rustellum curvatum</i> Total Range Zone
	Early <i>Tenea delectrei</i> - <i>Ichthyosarcollites</i> sp. Acme Zone	<i>Costagyrus ulsiponensis</i> Total Range Zone <i>Hymatogyra africana</i> Acme Zone	<i>Costagyrus ulsiponensis</i> Acme Zone <i>Ambigostrea pseudovillei</i> - <i>Hymatogyra africana</i> Acme Zone
Albian	Mid. <i>Ceratostreon flabellatum</i> - <i>Rhynchostreon suborbiculatum</i> Acme Zone	<i>Nerinea gemmifera</i> - <i>Praeradiolites biskruensis</i> Acme Zone	<i>Nerinea gemmifera</i> - <i>Praeradiolites biskruensis</i> Acme Zone <i>Praculvolmina cretacea</i> Total Range Zone
	Early <i>Ceratostreon flabellatum</i> - <i>Rhynchostreon suborbiculatum</i> Acme Zone	<i>Ceratostreon flabellatum</i> Acme Zone	<i>Gyrostrea delectrei</i> - <i>Rhynchostreon suborbiculatum</i> - <i>Hemaste (H.) gabrielis</i> Acme Zone <i>Foradiolites liratus</i> Total Range Zone <i>Orbitolina conica</i> Total Range Zone
Albian	Late		<i>Ceratostreon flabellatum</i> - <i>Pterocera incerta</i> Acme Zone

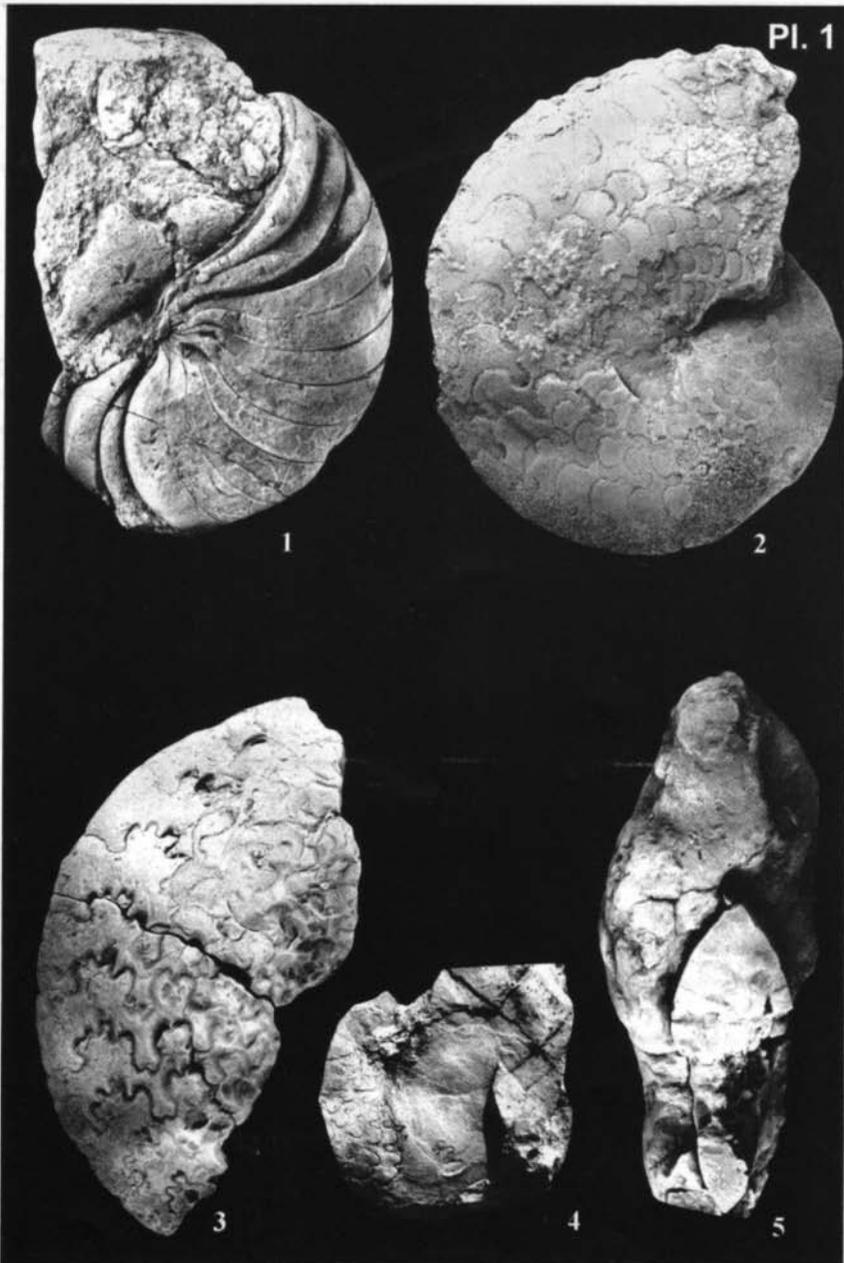


Fig.

1. *Angulithes mermeti* (Coquand, 1862). Side view, lower Upper Cenomanian, Raha Formation, Gebel Ekma, x 0.75.
2. *Neolobites vibrayanus* (d'Orbigny, 1841). Side view, lower Upper Cenomanian, Galata Formation, East Themed area, x 0.75.
- 3, 5. *Collopoceras requienianum* (d'Orbigny, 1841). 3: side view of incomplete specimen, 5: whorl section of incomplete specimen, upper Middle (lower Upper) Turonian, Wata Formation, Gebel Ekma, x 0.75.
4. *Metatissotia ewaldi* (von Buch, 1848). Side view of incomplete specimen, Middle-Upper Coniacian, Themed Formation, Gebel Yelleg, x 0.32.

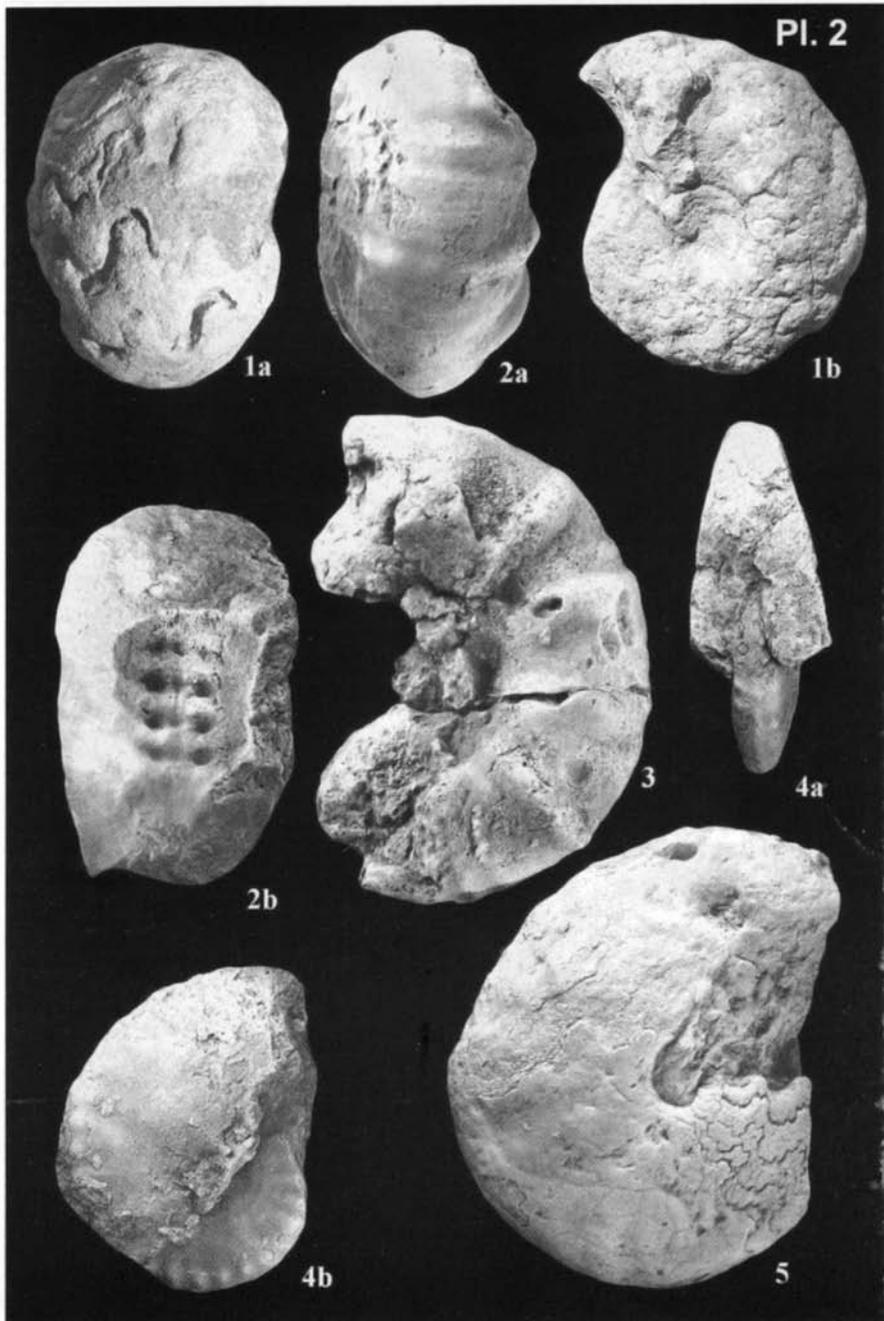


Fig.
 1a-b. *Vascoceras hartii* (Hyatt, 1870). a: venter view, b: side view, Lower Turonian, Abu Qada Formation, East Themed area, x 0.5.
 2a-b, 3. *Rubroceras alatum* Cobban, Hook & Kennedy, 1989. Incomplete specimens; 2a: venter view, 2b: ventral view of 2a, 3: side view, upper Upper Cenomanian, Raha Formation, Gebel Ekma, x 0.75.
 4a-b, 5. *Thomasites rollandi* (Thomas & Peron, 1889). 4a: apertural view, 4b, 5: side views, Lower Turonian, Abu Qada Formation, East Themed area, x 0.75.

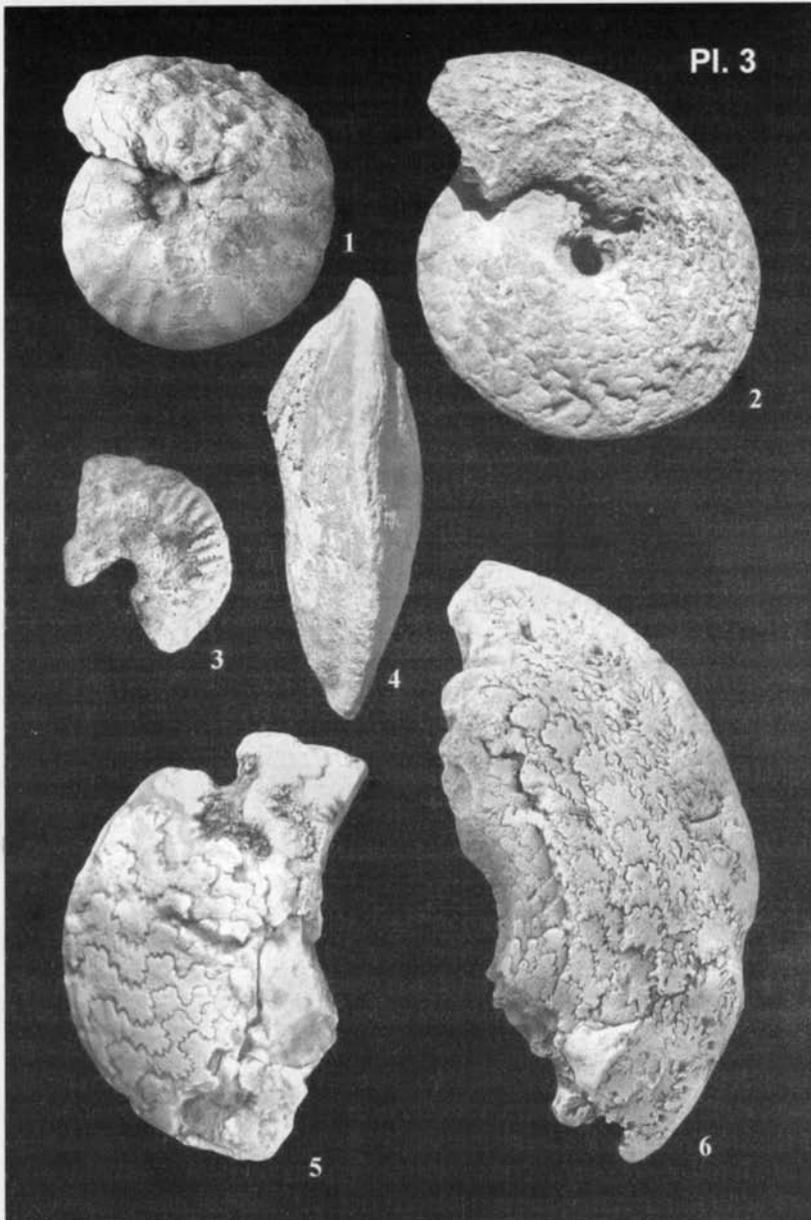


Fig.

1. *Thomasites rollandi* (Thomas & Peron, 1889). Side view, Lower Turonian, Abu Qada Formation, East Themed area, x 0.75.
- 2, 6. *Choffaticeras segne* (Solger, 1903). 2: side view of complete specimen, x 0.3; 6: side view of incomplete specimen, x 0.75, Lower Turonian, Abu Qada Formation, East Themed area.
3. *Choffaticeras quaasi* (Peron, 1904). Side view of incomplete specimen, Lower Turonian, Abu Qada Formation, East Themed area, x 1.1.
4. *Choffaticeras securiforme* (Eck, 1909). Venter view, Lower Turonian, Abu Qada Formation, East Themed area, x 0.33.
5. *Choffaticeras sinaticum* (Douvill  , 1928). Side view of incomplete specimen. Lower Turonian, Abu Qada Formation. East Themed area. x 0.75.

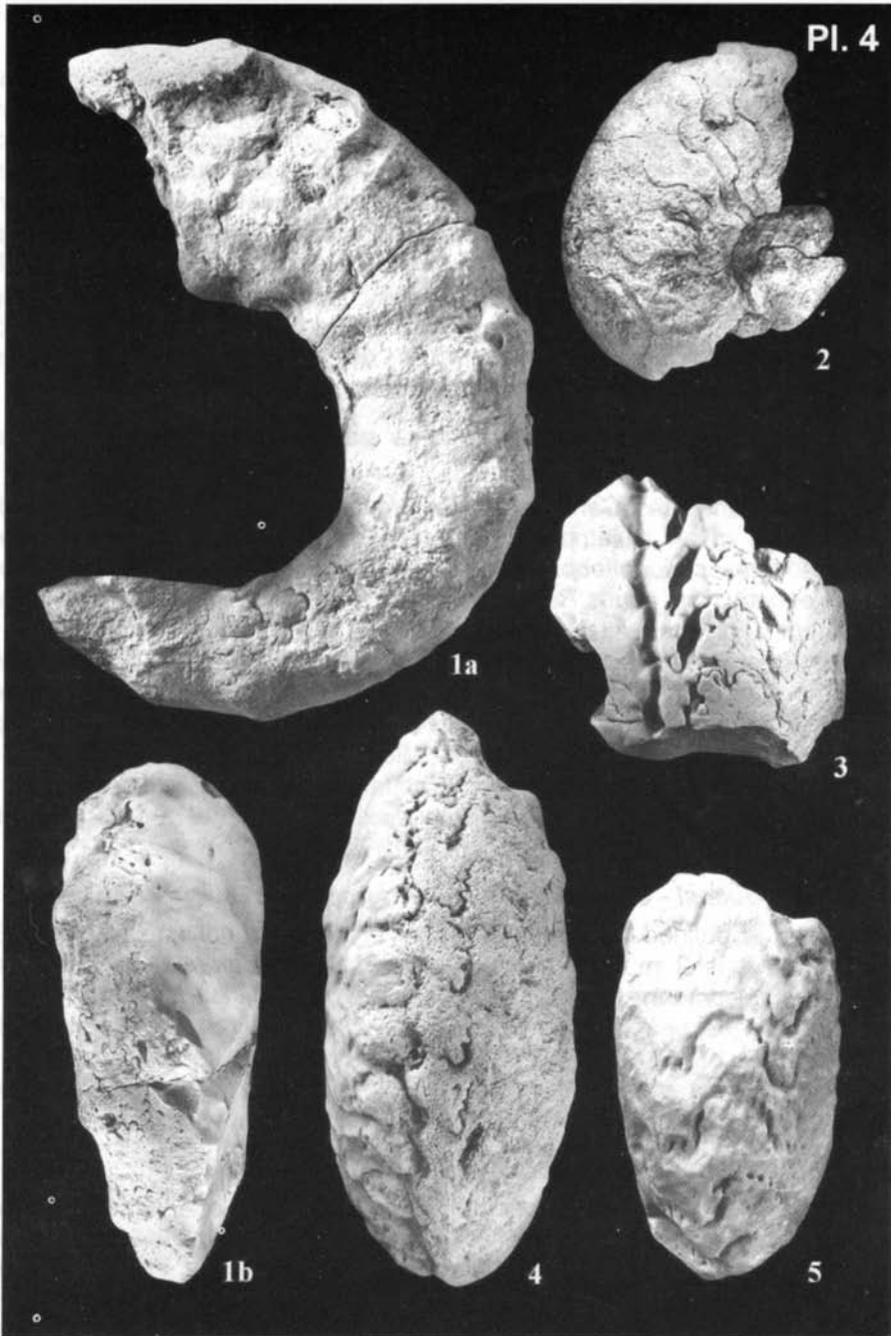


Fig.
 1a-b. *Pseudaspidoceras pseudonodosoides* (Choffat, 1899). Incomplete specimen; a: side view, b: venter view, upper Upper Cenomanian, Raha Formation, Gebel Ekma, x 0.75.
 2-3, 5. *Vascoceras cauvini* Chudeau, 1909. Incomplete specimens, 2: side view, 3, 5: venter views, upper Upper Cenomanian, Raha Formation, Gebel Ekma, 2: x 1.1; 3, 5: x 0.75.
 4. *Vascoceras cf. durandi* (Thomas & Peron, 1890). Venter view, Lower Turonian, Abu Qada Formation, Gebel Ekma, x 0.75.

***Neolobites vibrayeanus* Total Range Zone**

The zone is defined by the total range of the zonal species. It ranges in thickness from 8 m in the East Themed area to 15 m in Gebel Yelleg, and 50 m at Gebel Ekma. The associated faunal elements are *Ilymatogyra africana* (Lamarck), *Ceratostreon flabellatum* (Goldfuss), *Barbatia aegyptiaca* (Fourtau), *Parasea faba faba* (J. de C. Sowerby), *Maghrebella forgemoli* (Coquand), *Arctica* spp., *Tenea delettrei* (Coquand), *Heterodiadema libycum* (Desor), *Coenholectypus cenomanensis* (Gueranger), and the nautiloid *Angulithes mermeti* (Coquand). The *Neolobites vibrayeanus* (d'Orbigny) is widely known from the lower Upper Cenomanian (western Europe, North Africa, the Middle East, and South America), just below the *Metoicoceras geslinianum* Zone (Kennedy & Juignet 1981) and is in part equivalent to the standard *Calycoceras guerangeri* Zone.

***Vascoceras cauvini* - *Pseudaspidoceras pseudonodosoides* - *Rubroceras alatum* Assemblage Zone**

This zone is the latest Cenomanian zone recorded in this study. It is defined by the total range of an assemblage consisting of *Vascoceras cauvini* Chudeau, *Pseudaspidoceras pseudonodosoides* (Choffat), and *Rubroceras alatum* Cobban, Hook & Kennedy. The genus *Rubroceras* is recorded for the first time from outside New Mexico. This zone attains a thickness of 10 m in Gebel Ekma and 3 m in the East Themed area. It is represented by the whole assemblage in Gebel Ekma, while in the East Themed area it is represented by *Vascoceras cauvini* Chudeau. This zone is equivalent to the *Vascoceras cauvini* Zone, which has been recorded by many authors in Egypt and the Middle East. The co-occurrence of *Pseudaspidoceras pseudonodosoides* (Choffat), *Rubroceras alatum* with the standard *Neocardioceras juddii* Zone in New Mexico (Cobban et al. 1989), indicates that this zone is equivalent to the standard *juddii* Zone.

***Choffaticeras quaasi* - *Choffaticeras securiforme* Total Range Zone**

This zone is defined by the total range of the two zonal species. In the East Themed area, it is 3 m thick and very rich in *Choffaticeras quaasi* (Peron) and *Choffaticeras securiforme* (Eck). This zone is equivalent to the two zones of *Ch. quaasi* and *Ch. securiforme* from Israel (Lewy 1989, Lewy et al. 1984). In the first section of Lewy et al. (1984), *Ch. quaasi* is followed by *Ch. securiforme* and in the second section the reverse is the case. Moreover, in the present study, specimens of *Ch. securiforme* contains juvenile *Ch. quaasi* inside their shells.

***Choffaticeras segne* - *Vascoceras harttii* Total Range Zone**

This zone is very diagnostic zone of the Lower Turonian due to the presence of large, lanceolate, compressed *Choffaticeras*. It is defined by the total range of *Choffaticeras segne* (Solger) and *Vascoceras harttii* (Hyatt). The zone is well traceable in the East Themed area, where it measures 5 m thick, very rich in *Ch. segne*, usually occurs parallel to the bedding planes and the globose *Vascoceras harttii* (Hyatt) occurs in the middle part of this zone. In Gebel Ekma, the zone reaches a thickness of 4 m but is less fossiliferous than in the East Themed area and is represented only by the first zonal species (*Ch. segne*) comparable to the *Ch. segne* Zone recorded from southeastern Sinai by Kora & Hamama (1987a). *V. harttii* has been regarded as of Early Turonian age in Mexico (Chancellor 1982), Brazil (Bengtson 1983), Angola (Howarth 1985), and Nigeria (Zaborski 1996).

***Choffaticeras sinaiticum* - *Thomasites rollandi* Total Range Zone**

This zone attains a thickness of about 3 m in both Gebel Ekma and in the East Themed area. It is represented by the two zonal species in the East Themed area while in Gebel Ekma it is represented only by *Choffaticeras sinaiticum* (Douvillé). In Gebel Yelleg the second zonal species *Thomasites rollandi* (Thomas & Peron) is associated with *Choffaticeras segne* (Solger), and attains a thickness of 25 m. It is equivalent to the three *Choffaticeras* zones of the East Themed area, and the two *Choffaticeras* zones of Gebel Ekma. Other associated faunal elements are *Plicatula auressensis* (Coquand), *Lima itieriana* Pictet & Roux, *Pholadomya pedernalis* Roemer, and the echinoids *Hemiaster (Mecaster) heberti turonensis* Fourtau and *Coenholectypus turonensis* (Desor). The *Choffaticeras sinaiticum* - *Thomasites rollandi* Zone is equivalent to the *Thomasites rollandi* Zone of Chancellor *et al.* (1994) from the Lower Turonian of Tunisia.

The three *Choffaticeras* zones of the present study have been recorded by many authors from different localities of Egypt as *Choffaticeras segne* Zone (e.g. Kassab 1991, 1994, Aly & Abdel-Gawad 2001). The genera *Choffaticeras* and *Thomasites* are restricted to the Lower Turonian (Wright *et al.* 1996). Consequently, these three *Choffaticeras* zones are of Early Turonian age.

***Coilopoceras requienianum* Total Range Zone**

This zone is defined by the total range of *Coilopoceras requienianum* (d'Orbigny), which is the only ammonite recorded from this interval. It attains a maximum thickness of 20 m at Gebel Ekma and a minimum thickness of 8 m at Gebel Yelleg. In the East Themed area, the thickness is 15 m. This zone was correlated by many authors with the European *Romaniceras devrianum* Zone on the basis of the common occurrence of *C. requienianum* (d'Orbigny). Lewy (1989) recorded this species from a level above the *R. devrianum* Zone. Therefore, the *C. requienianum* Zone is considered to be late Middle - early Late Turonian in age, based on the fact that the *R. devrianum* Zone is of late Middle Turonian age (Hardenbol *et al.* 1998). The *requienianum* Zone is considered the Latest Turonian ammonite zone recorded from Egypt till now. In the East Themed area, the two biozones [*Cucullaea (Idonearca) trigona* - *Rachiosoma geysi* Acme Zone and *Nerinea requieniana* Total Range Zone] recognised in the present study, overlying the *requienianum* Zone confirm that the *requienianum* Zone is not the uppermost Turonian interval.

***Metatissotia ewaldi* Total Range Zone**

It is defined by the total range of *Metatissotia ewaldi* (von Buch). The zone is considered equivalent to the European *Peroniceras (Peroniceras) tridorsatum* Zone based on the common occurrence of *Metatissotia ewaldi* (von Buch). It is worth to mention that *M. ewaldi* was recorded together with *P. (P.) tridorsatum* from the *Metatissotiaourneli* Zone of Kora *et al.* (2002) from west-central Sinai. *M. ewaldi* has been recorded from the Middle Coniacian of France, northern Spain and Austria (Luger & Gröschke 1989). It has been recorded at the same level in the *Metatissotiaourneli* Zone from the Eastern Desert of Egypt (Kassab 1991) and from west-central Sinai (Abdel-Gawad 1999b, El-Hedeny 2002, and Kora *et al.* 2002). Lewy & Raab (1976) recorded *M. ewaldi* from the Upper Coniacian. Consequently, the zone is considered to be Middle - Late Coniacian in age.

***Orbitolina conica* Total Range Zone**

The *Orbitolina conica* Zone is the second biozone recorded from Gebel Yelleg and it is considered herein the first Cenomanian zone. It is defined by the total range of *Orbitolina conica* (d'Archiac). This zone can be correlated with the *Orbitolina* cf. *concava* Zone which was recorded by El Sheikh *et al.* (1998) and *Orbitolina concava* Zone of El-Sheikh & Hewaidy (1998). It can be correlated also with the lower part of the Rudists - *Orbitolina* Horizon of Hamza *et al.* (1994). It measures 5 m thick in Gebel Yelleg, where the zonal species is very abundant in a limestone bed forming *Orbitolina* limestone bed. Tröger & Kennedy in Rawson *et al.* (1996) mentioned that the FO (first occurrence) of *O. (Orbitolina) concava concava* and *O. (O.) conica* indicate Albian/Cenomanian boundary in the Tethyan shelf carbonate successions. Therefore, this zone is of early Early Cenomanian age and its lower limit marks the Albian/Cenomanian boundary.

***Eoradiolites liratus* Total Range Zone**

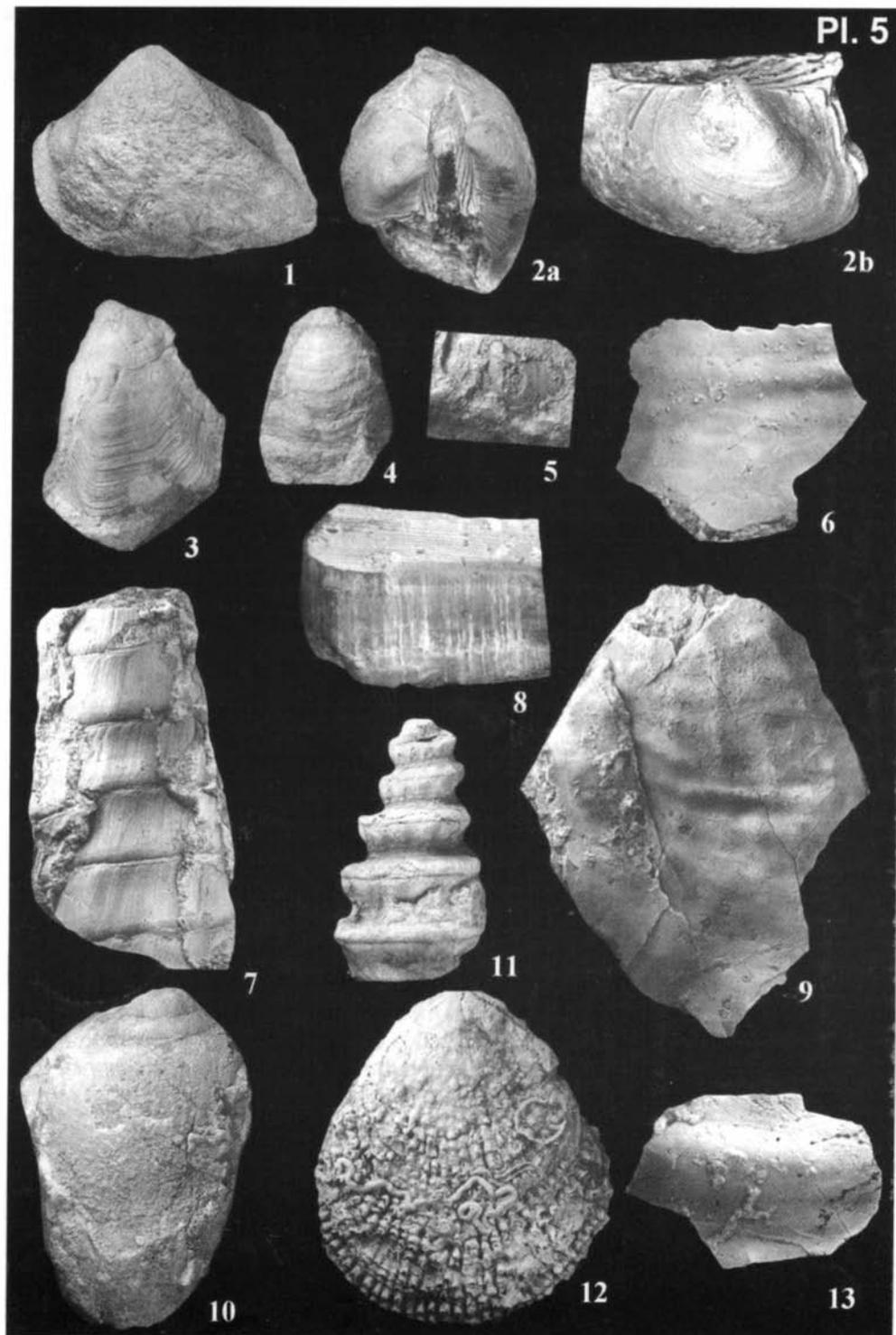
This zone is defined by the total range of the index species *Eoradiolites liratus* Conrad and measures 55 m. The zonal species is very abundant forming rudist boundstone and rudstone. This zone is very characteristic for the Lower Cenomanian specially in the northern part of Sinai. The zone is very well developed in G. Yelleg, where the rudist buildups are located (Ammar & Afifi, 1992). The associated fauna are *Praeradiolites biskraensis* Coquand, *Neithea dutrugi* (Coquand), *Arctica picteti* (Coquand), *Plectomya? humei* Fourtau. This zone is equivalent to the Rudists Zone of Ziko *et al.* (1993). It is equivalent to the upper part of the rudists - *Orbitolia* horizon of Hamza *et al.* (1994), and the lower part of the rudists - *Hemiaster gabrielis* horizon of El - Sheikh *et al.* (1998) from Gebel El-Minsherah.

***Gyrostrea delettrei* - *Rhynchostreon suborbiculatum* - *Hemiaster gabrielis* Acme Zone**

This zone is characterised by the presence of numerous individuals of the three zonal species. It is the highest fossiliferous zone in Gebel Yelleg and attains a thickness of 117 m. The most dominant associated fossils are *Barbatia aegyptiaca* (Fourtau), *Granocardium productum* (Sowerby), *Tenea delettrei* (Coquand), *Maghrebella forgemoli* (Coquand), *Pterodonta deffisi* Thomas & Peron, *Coenholectypus excisus* (Desor), and "*Globulipora*" *africana* Thomas & Peron. This zone is equivalent to the *Rhynchostreon mermeti* - *Hemiaster gabrielis* horizon of El-Sheikh *et al.* (1998) at Gebel El-Hamra. It is equivalent also to the upper part of the rudists - *Hemiaster gabrielis* horizon and the lower part of the *Rhynchostreon mermeti* - *Neolobites fourtaui* Zone that was recorded by the same authors from Gebel El-Minsherah.

***Praealveolina cretacea* Total Range Zone**

The zone is defined by the total range of *Praealveolina cretacea* (d'Archiac), and it attains a thickness of 25 m. Within this zone there is a 2 m thick argillaceous limestone bed flooded with large *Chondrodonta joannae* (Choffat) (*Chondrodonta* Bed). This zone is equivalent to the *Praealveolina cretacea tenuis* Zone of El-Sheikh & Hewaidy (1998). The zonal species *P. cretacea* belongs to the Middle - Upper Cenomanian (Schörder & Neumann 1985, Hardenbol *et al.* 1998). This zone



underlies the *Nerinea gemmifera* - *Praeradiolites biskraensis* Acme Zone, which is overlain by the *Neolobites vibrayeanus* Zone of early Late Cenomanian age. Thus, this zone is of Middle Cenomanian age in Gebel Yelleg.

***Nerinea gemmifera* - *Praeradiolites biskraensis* Acme Zone**

This zone is highly fossiliferous, being very rich in gastropods, specially *Nerinea gemmifera* Coquand, rudists (mostly of *Praeradiolites biskraensis* Coquand), corals, and coralline sponge. In Gebel Ekma, it is represented by *Tenea delettrei* - *Ichthyosarcolithes* sp. Acme Zone, being associated with the *Neolobites vibrayeanus* Zone of the early Late Cenomanian. It overlies the *Praealveolina cretacea* Zone and underlies the *Neolobites vibrayeanus* Zone in Gebel Yelleg. In the East Themed area, in contrast, it overlies the *Neolobites vibrayeanus* Zone. Therefore, this zone is of late Middle - early Late Cenomanian age. It varies in thickness from 15 m in the East Themed area, about 60 m in Gebel Ekma and 75 m in Gebel Yelleg. The most dominant taxa are *Aptyxiella subaequalis* (d'Orbigny), *Tylostoma cossoni* Thomas & Peron, *Aporrhais dutrugi* (Coquand); *Nayadina* (N.) *gaudryi* Thomas & Peron; *Heterodiadema libycum* (Desor), *Coenholectypus cenomanensis* (Gueranger), *Hemiaster* (H.) *syriacus* (Conrad); *Thecosmilia tommasii* Prever, *Aspidiscus cristatus* (Lamarck), and "*Ceriopora*" *letourneuxi* Thomas & Peron. The zone is equivalent to the gastropod horizon of Awad & Fawzi (1956) from Gebel El-Minsherah and to the *Strombus incertus* Zone and the *Nerinea gemmifera* Acme Zone of Ziko *et al.* (1993).

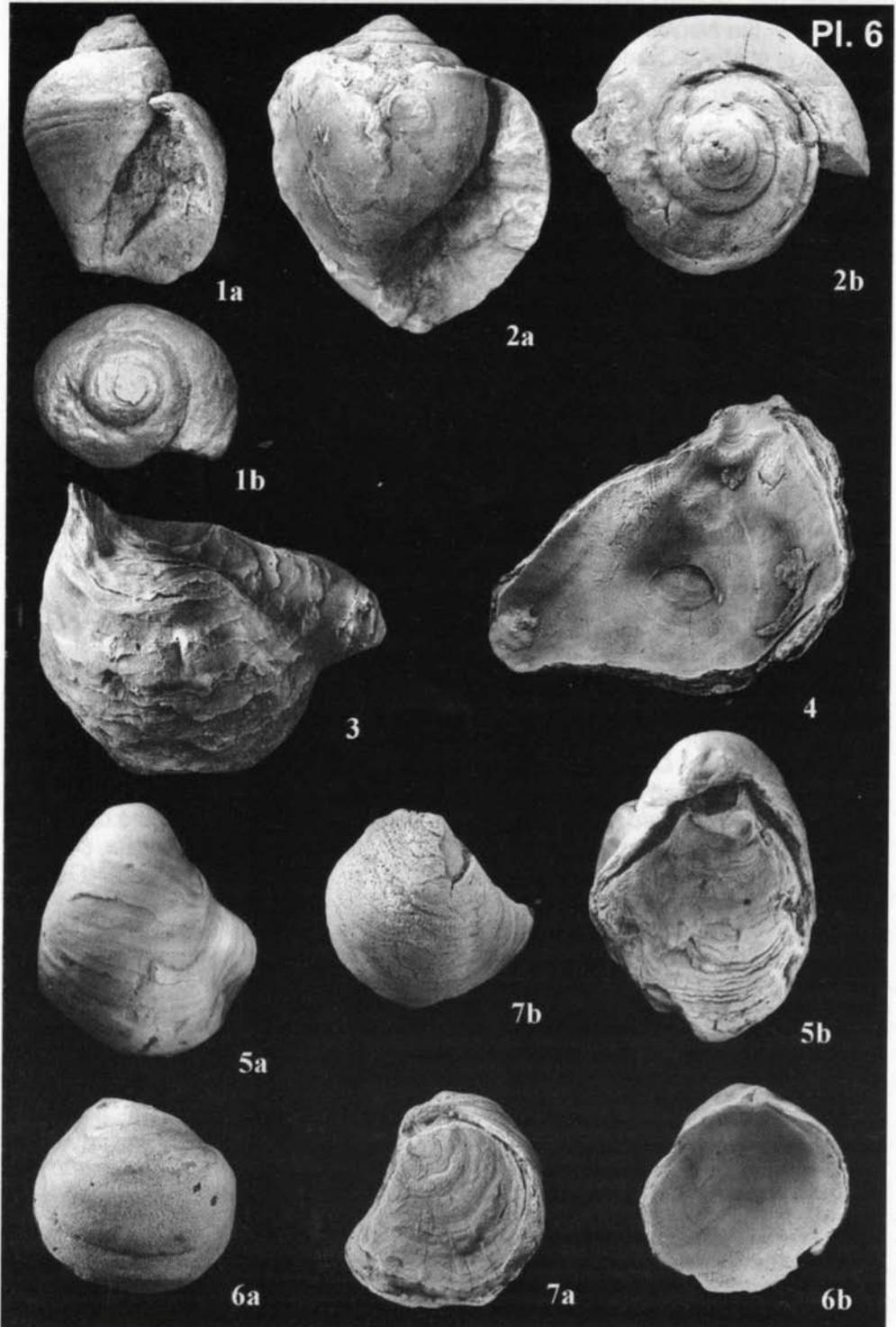
***Ambigostrea pseudovillei* - *Ilymatogyra africana* Acme Zone**

This zone is very characteristic for the Upper Cenomanian and can be easily traced in the field, being a 7 - 15 m thick shale bed full of *Ilymatogyra africana* (Lamarck), which is mostly associated with *Ambigostrea pseudovillei* Malchus. This zone is equivalent to the *Exogyra africana* - *Neolobites fourtaui* Zone of Awad & Isswai (1975), the *Ceratostreon flabellatum* - *Ilymatogyra africana* Acme Zone of Ziko *et al.* (1993), and the *Ceratostreon flabellatum* - *Ilymatogyra africana* of Abdel-Gawad (1999a), *Ilymatogyra* (A.) *africana* - *Neolobites vibrayeanus* Zone of Kora *et al.* (2001). It is also equivalent to the *Ostrea africana*, *Ostrea flabellata*, *Dosinia*, *Venus* and *Neolobites* horizon that was noted by Awad & Fawzi (1956). It is also

Explanation of Plate 5

Fig.

1. *Cucullaea (Idonearca) maresi* (Coquand, 1880). Internal mould of articulated specimen; side view, Coniacian-Santonian, Themed Formation, Gebel Yelleg, x 0.75.
- 2a-b. *Cucullaea (Idonearca) trigona* (Seguanza, 1882). Articulated specimen; a: dorsal view, b: side view of right valve, Upper Turonian, Wata Formation, East Themed area, x 0.75.
- 3-5. *Inoceramus* ex gr. *Inoceramus pictus* J. de C. Sowerby, 1829. Side views, Upper Cenomanian, Abu Qada Formation, East Themed area, figure 3: x 0.75, figures 4, 5: x1.1.
- 6, 8-9, 13. *Cladoceramus undulatoaplicatus* (Roemer). 6, 13: fragments of a large left valve, internal views, x 0.75, 8: shell microstructure, x 3, 9: incomplete left valve, external view, x 0.75, Lower Santonian, shaly member, Matulla Formation, Gebel Ekma.
7. *Nerinea requieniana* d'Orbigny, 1842. Side view of incomplete specimen, Upper Turonian, Wata Formation, East Themed area, x 1.
10. *Trochactaeon salomonis* (Fraas, 1867). Side view, Middle Turonian, Wata Formation, East Themed area, x 0.75.
11. *Nerinea gemmifera* Coquand, 1862. Side view, Middle Cenomanian, Galala Formation, Gebel Yelleg, x 0.75.
12. *Plicatula ferryi* Coquand, 1862. Articulated specimen; left valve, external view, Coniacian-Santonian?. Themed Formation, East Themed area, x 0.75.



equivalent to the lower part of the *Exogyra (C.) olisiponensis - Ilymatogyra africana* Zone of Kora & Hamama (1987a), and the *Costagyra olisiponensis - Ilymatogyra africana* horizon of El-Sheikh *et al.* (1998). The zone is mostly present above the lower Upper Cenomanian *Neolobites vibrayeanus* Zone. Occasionally, as in Gebel Yelleg, the upper part of the *vibrayeanus* Zone is associated with this zone. Thus, it is considered to be of Late Cenomanian age.

***Costagyra olisiponensis* Acme Zone**

The zone varies in thickness from 3-10 m and is very rich in *Costagyra olisiponensis* (Sharpe), which is usually present in a marl or an argillaceous limestone bed. It is defined by the acme of the zonal species in both Gebel Ekma and Gebel Yelleg, whereas it is defined by the total range of its index species in the East Themed area. The zone is equivalent to the *Exogyra (C.) olisiponensis* Zone of Kora *et al.* (2001). It is equivalent to the lower part of the *Exogyra olisiponensis - Pycnodonte vesiculosa* Zone of Ziko *et al.* (1993), and the *Pycnodonte vesiculosa - Exogyra olisiponensis* of Abdel-Gawad (1999a). It is equivalent to the upper part of *Exogyra (C.) olisiponensis - Ilymatogyra africana* Zone of Kora & Hamama (1987a), and the *Costagyra olisiponensis - Ilymatogyra africana* horizon of El-Sheikh *et al.* (1998). It can also be correlated with the second *Ostrea* and lamellibranch horizon of Awad & Fawzi (1956).

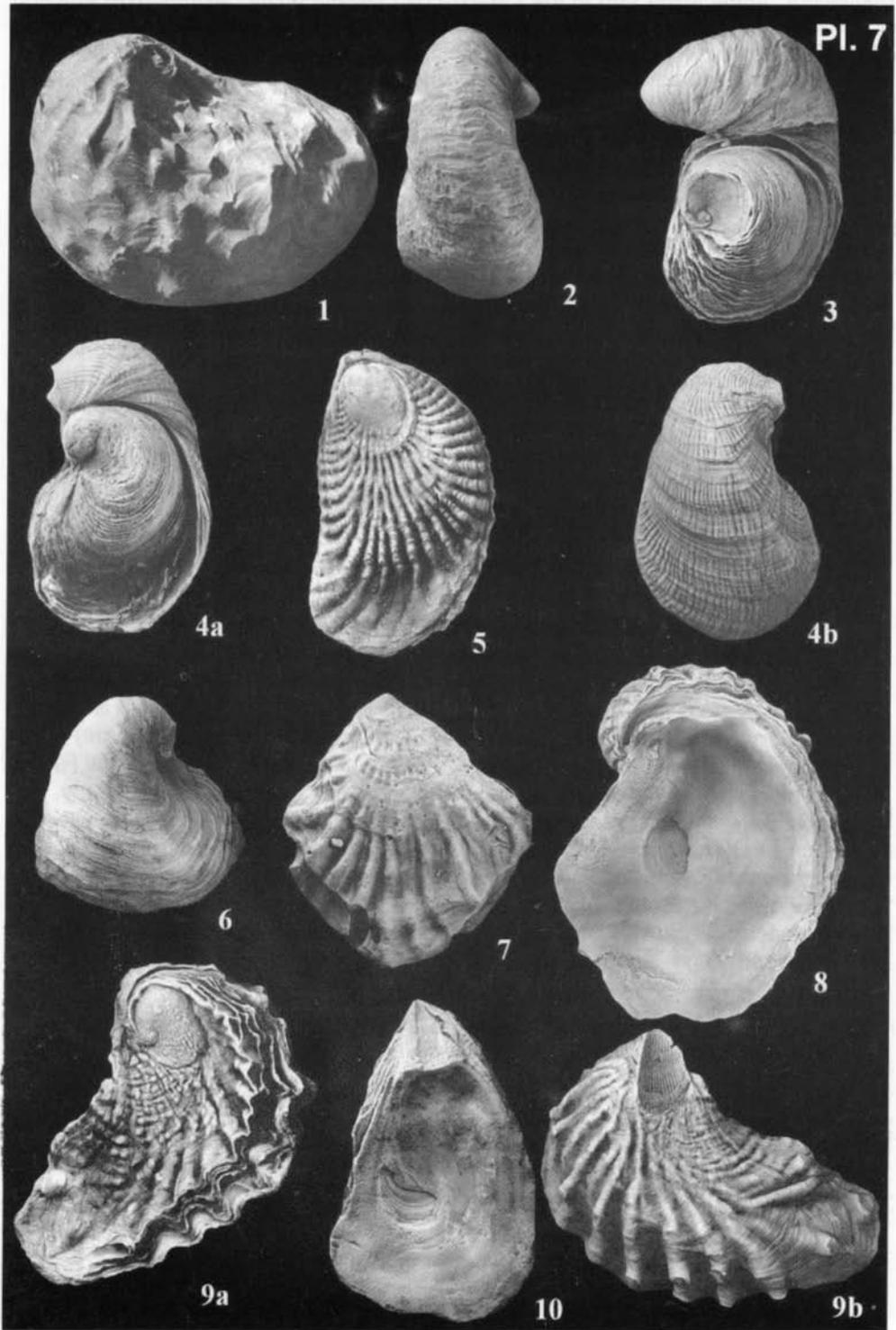
***Pycnodonte (Phygraea) vesiculosa - Rastellum carinatum - Inoceramus ex gr. pictus* Assemblage Zone**

This is the latest Cenomanian zone based on macrofossils other than ammonites recorded in the present study. The zone ranges from 3 to 10 m in thickness. In the East Themed area, it is represented by the *Pycnodonte (Phygraea) vesiculosa - Inoceramus ex gr. pictus* Interval Zone, where it is defined by the interval from the last appearance of *Costagyra olisiponensis* (Sharpe) to the first appearance of *Choffaticeras quaasi - Choffaticeras securiforme* Total Range Zone. This zone includes the acme of *Pycnodonte vesiculosa* J. Sowerby, that coincides with the total range of *Inoceramus ex gr. pictus* J. de C. Sowerby, which is recognised here for the first time from Egypt. In Gebel Yelleg, it is represented by the *Pycnodonte vesiculosa - Rastellum carinatum* Total Range Zone. This zone is not recognised at Gebel Ekma, as the *Costagyra olisiponensis* Zone continues till the *Vascoceras cauvini - Pseudaspidoceras pseudonodosoides - Rubroceras alatum* Assemblage Zone. This assemblage zone (*P. vesiculosa - R. carinatum - I.*

Explanation of Plate 6

Fig.

- 1a-b. *Pterocera incerta* d'Orbigny, 1842. a: apertural view, b: apical view, Upper Albian, Galala Formation, Gebel Yelleg, x 1.1.
- 2a-b. *Tylostoma (Tylostoma) globosum* Sharpe, 1849. a: apertural view, b: apical view, Middle Turonian, Wata Formation, East Themed area, x 0.75.
- 3-4. *Pycnodonte (Costeina) costei* (Coquand, 1869). 3: left valve, external view, 4: left valve, internal view, Coniacian- Santonian, Themed Formation, East Themed area, x 0.75.
- 5a-b. *Pycnodonte (Phygraea) vesicularis vesicularis* (Lamarck, 1806). Articulated specimen; a: left valve, external view, b: right valve, external view, Upper Campanian, Sudr Chalk, Gebel Ekma, x 0.75.
- 6a-b, 7a-b. *Pycnodonte (Phygraea) vesicularis* (Lamarck, 1806) *vesiculosa* (J. Sowerby, 1813). 6: left valve; a: external view, b: internal view, 7: articulated specimen; a: right valve, external view, b: left valve, external view, Upper Cenomanian, Abu Gada Formation, East Themed area. x 1.5.



pictus) is equivalent to the upper part of *Pycnodonte vesiculosum* - *Exogyra olisiponensis* Zone of Abdel-Gawad (1999a), and *Exogyra olisiponensis* - *Pycnodonte vesiculosa* Zone of Ziko *et al.* (1993).

***Hemiaster (Mecaster) heberti turonensis* - *Coenholectypus turonensis* Acme Zone**

This zone ranges in thickness from 10 to 20 m and yields, besides the two index species, *Plicatula auressensis* (Coquand), *Lima itieriana* Pictet & Roux, *Phelopteria grvida* (Coquand), *Phymosoma major* Faurtau, and *Orthopsus ovata* (Coquand). The zone is equivalent to the *Hemiaster heberti turonensis* horizon at Gebel El-Hamra and the lower part of the *Phymosoma abbatei* - *Hemiaster heberti turonensis* horizon from Gebel El-Minsherah (El-Sheikh *et al.* 1998). It can be correlated with the lower part of the *Cyphosoma abbatei* - *Holectypus turonensis* Zone of Awad & Issawi (1975). The lower part of the zone coincides with the *Hoffaticeras sinaiticum* Zone. This zone is therefore of Early Turonian age.

***Phymosoma abbatei* - *Tylostoma* (T.) spp. Acme Zone**

The zone is characterised by numerous individuals of *Phymosoma abbatei* (Gauthier), *Tylostoma* (T.) *globosum* Sharpe in Gebel Yelleg and the East Themed area. In Gebel Ekma, *Tylostoma* (T.) *globosum* is replaced by *T. (T.) cossoni* Thomas & Peron. The zone ranges in thickness from 5 to 15 m and yields also *Pholadomya pedernalis* Roemer. This zone is equivalent to the *Phymosoma abbatei* horizon at Gebel El-Hamra and the upper part of the *Phymosoma abbatei* - *Hemiaster heberti turonensis* horizon at Gebel El-Minsherah (El-Sheikh *et al.* 1998). It can be correlated with the upper part of the *Cyphosoma abbatei* - *Holectypus turonensis* Zone of Awad & Issawi (1975). Its age is assigned to be Middle Turonian, as it overlies an Early Turonian interval.

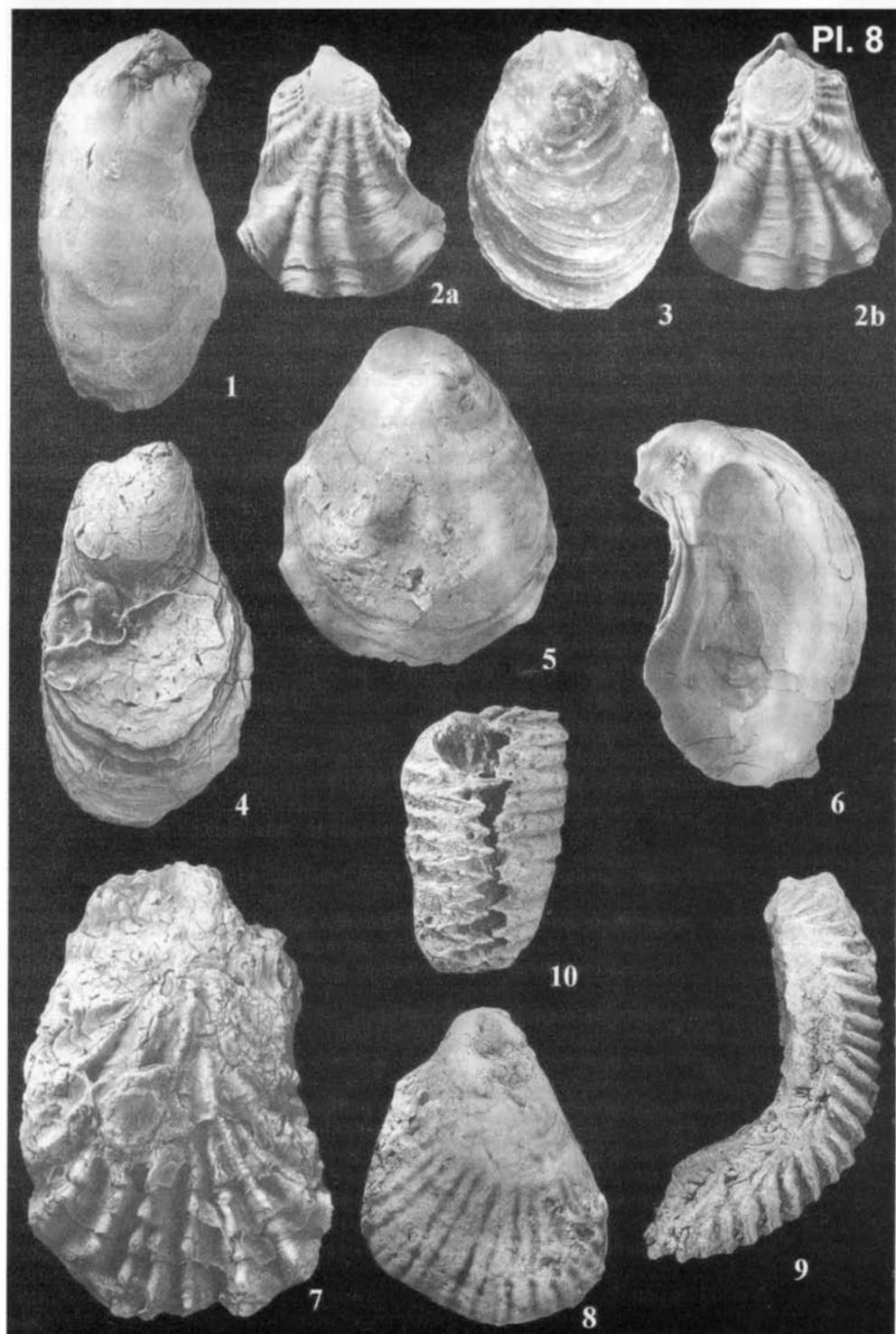
***Durania* spp.- *Praeradiolites* spp. Assemblage Zone**

This zone is characterised by the abundance of rudists, which are represented in some localities by *Durania*, in others by *Praeradiolites* and in yet others by both, associated with or without caprinids. The most abundant species recorded from this zone are *Durania arnaudi* Choffat, *D. gaensis* Dacqué and *Praeradiolites ponsianus* (d'Archiac) *aegyptiacus* Douvillé. In the East Themed area, it is represented by the total range of the assemblage *Durania gaensis* - *Praeradiolites ponsianus aegyptiacus* - caprinids, while in Gebel Yelleg it is represented by the *Durania*

Explanation of Plate 7

Fig.

1. *Costagyra olisiponensis* (Sharpe, 1850). Left valve, external view, Upper Cenomanian, Galala Formation, Gebel Yelleg, x 0.75.
- 2-3. *Ilymatogyra africana* (Lamarck). Articulated specimens; 2: left valve, external view, 3: right valve, external view, Upper Cenomanian, Galala Formation, East Themed area, x 1.5.
- 4a-b, 6. *Rhynchostreon suborbiculatum* (Lamarck, 1801). Articulated specimens; 4a: right valve, external view, 4b: left valve, external view, Lower Cenomanian, Galala Formation, Gebel Yelleg, x 1.5, 6: left valve, external view, Upper Cenomanian, Galala Formation, East Themed area, x 0.75.
- 5, 7, 10. *Ambigostrea pseudovillei* Malchus, 1990. 5, 7: articulated specimens; 5: right valve, external view; 7: left valve, external view, 10: left valve, internal view, Upper Cenomanian, Raha Formation, Gebel Ekma, 5: x 1.5; 7, 10: x 1.1.
- 8, 9a-b. *Ceratostreon flabellatum* (Goldfuss, 1833). 8: Left valve, internal view, 9: articulated specimen; a: right valve, external view, b: left valve, external view, Lower Cenomanian. Galala Formation. Gebel Yelleg. x 1.1.



arnaudi - *Praeradiolites ponsianus aegyptiacus* - *Praeradiolites irregularis* Assemblage Zone. The zone attains a thickness of 5 m in both localities. This zone has been recorded in Egypt by many authors either as the *Durania humei* Zone (Awad & Issawi 1975, Kora & Hamama 1987a) as the *Durania* sp. Zone (Ziko *et al.* 1993) or as the large rudists horizon (El-Sheikh *et al.* 1998). Awad & Issawi (1975) considered this zone to be Early Turonian in age. Kora & Hamama (1987a) in contrast recognised that this zone overlies the *Coilopoceras requienianum* Zone and considered it to be Late Turonian. Parnes (1987) recorded and erected some *Radiolites* species from the basal Upper Turonian of Gebel El-Risha, north-East Sinai. In Israel this zone is considered to be Middle Turonian in age (Lewy 1989). In all studied sections the zone underlies the *Coilopoceras requienianum* Zone. Aly & Abdel-Gawad (2001) reached to the same conclusion, but they considered it to be Late Turonian in age. Based on the *requienianum* Zone is of late Middle - early Late Turonian in age. This rudists assemblage zone is considered here to be of Middle Turonian age.

***Trochactaeon salomonis* Total Range Zone**

The zone is defined by the total range of the index species, *Trochactaeon salomonis* Fraas and measures 5 m in the East Themed area. It is equivalent to the *Acteonella salomonis* Zone of Awad & Issawi (1975). These authors considered it to be Late Turonian in age, whereas in the present study, its age is to be late Middle Turonian, because it underlies the late Middle - early Late Turonian *Coilopoceras requienianum* Zone and overlies the rudists zone in the East Themed area.

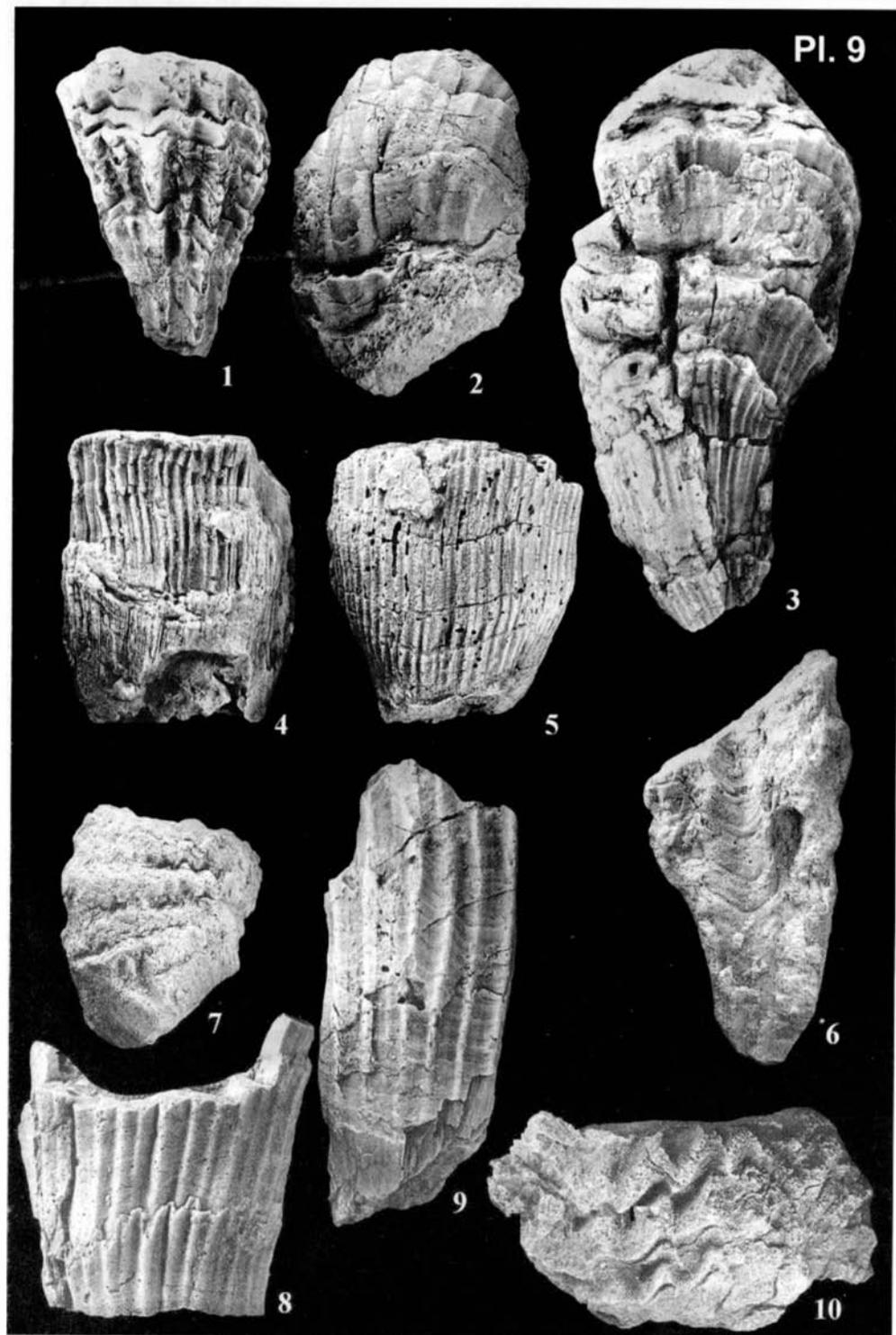
***Cucullaea (Idonearca) trigona* - *Rachiosoma irregulare* - *Rachiosoma geysi* Acme Zone**

This zone yields, besides numerous individuals of the three index species [*Cucullaea (Idonearca) trigona* (Seguanza), *Rachiosoma irregulare* Fourtau, and *Rachiosoma geysi* Abdelhamid & El-Qot], *Petalobrissus pygmaeus* Fourtau, and *Goniopygus peroni* (Thomas & Gauthier). It attains a thickness of 35 m in the East Themed area and is represented by *Cucullaea (Idonearca) trigona* - *Rachiosoma geysi* Acme Zone. In Gebel Ekma, it measures 15 m and is represented by *Rachiosoma irregulare* Zone. The zone is equivalent to the *Trigonarca* sp. Zone of

Explanation of Plate 8

Fig.

- 1, 3. *Gyrostrea thevestensis* (Coquand, 1862). 1: Articulated specimen, left valve, external view, Coniacian-Santonian, Themed Formation, East Themed area, x 1.1; 3: right valve, external view, Coniacian, shaly member, Matulla Formation, Gebel Ekma, x 0.75.
- 2a-b. *Nicaisolopha tissetti* (Thomas & Peron, 1891). Articulated specimen; a: left valve, external view; b: right valve, external view, Upper Santonian, shaly member, Matulla Formation, Gebel Ekma, x 1.1.
- 4, 6. *Gyrostrea delettrei* (Coquand, 1862). 4: right valve, external view; 6: left valve, internal view, Lower Cenomanian, Galala Formation, Gebel Yelleg, x 0.75.
5. *Nicaisolopha nicaisei* (Coquand, 1862). Left valve, external view, Upper Campanian, phosphatic member, Matulla Formation, Gebel Ekma, x 1.1.
7. *Oscillopoda dichotoma* (Bayle, 1849). Left valve, external view, Coniacian-Santonian?, Themed Formation, East Themed area, x 0.75.
8. *Ambigostrea bretoni* (Thomas & Peron, 1891). Left valves, external view, Upper Campanian, phosphatic member, Matulla Formation, Gebel Ekma, x 1.5.
- 9-10. *Rastellum carinatum* (Lamarck, 1806). 9: left valve, external view; 10: incomplete articulated specimen, Upper Cenomanian, Galala Formation, Gebel Yelleg, x 0.75.



Ziko *et al.* (1993) from the Themed area, which is regarded to be of Coniacian age. It is considered herein to be Late Turonian in age, because it overlies the *Coilopoceras requienianum* Zone of the late Middle - early Late Turonian and underlies the Turonian *Nerinea requieniana* Total Range Zone.

***Nerinea requieniana* Total Range Zone**

This is the uppermost Turonian zone recognised in the present study, overlying the *Cucullaea (Idonearca) trigona - Rachiosoma irregulare - Rachiosoma geysi* Acme Zone and underlying the Lower Coniacian *Hemiaster (Mecaster)ourneli - Petalobrissus waltheri* Zone in the East Themed area. It is defined by the total range of *Nerinea requieniana* d'Orbigny. The zone attains a thickness of 5 m, where "*Amorphospongia tumescens* Thomas & Peron is present associated with *N. requieniana* in the upper part of the zone.

***Hemiaster (Mecaster)ourneli - Petalobrissus waltheri* Acme Zone**

The zone is about 5 m thick, being very rich in the two index species. In addition, *Cucullaea (Idonearca) maresi* (Coquand), *Mytilus cf. bussoni* Collignon, *Aporrhaisourneli* (Coquand), *Helicaulax themedensis* (Abbass), and *Goniopygus innesi* Gauthier. It is equivalent to the *Hemiasterourneli Petalobrissus waltheri* horizon of El-Sheikh *et al.* (1998), and *Echinobrissus waltheri* Zone of Ziko *et al.* (1993). It can be correlated with the horizons DEH4 (from Wadi Dakhl); QEH8 (from Wadi Abu Qada); REH6 (from Abu Roash) of Abdelhamid (1995) and with the SEH3 (from Wadi Sudr); MEH1 (from Wadi Matulla) horizons of Abdelhamid (1997). In the East Themed area, the age of this zone is considered Coniacian-Santonian?, based on its stratigraphic position. In Gebel Ekma, it is of Coniacian age, as it underlies the standard Lower Santonian *Cladoceramus undulatopticatus* Zone. In Gebel Yelleg, the zone is represented by the *Cucullaea (Idonearca) maresi* Zone, and is considered to be Late Coniacian - Santonian? in age, as it overlies the Middle -Late Coniacian *Metatissotia ewaldi* Zone.

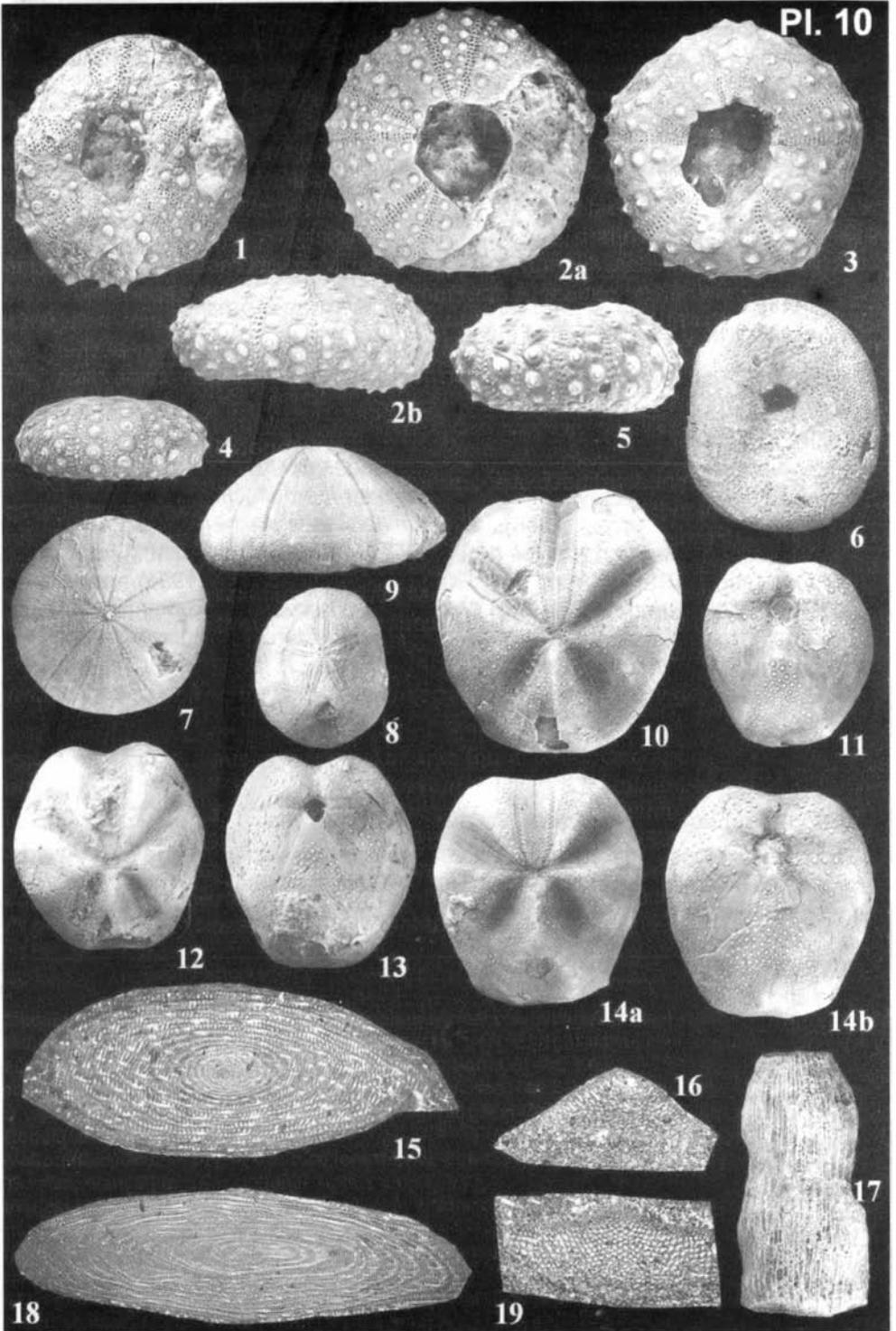
***Oscillopha dichotoma - Plicatula ferryi* Acme Zone**

This zone is considered by many authors to be Santonian in age (e.g. Awad & Issawi 1975, Kora & Hamama 1987b). The first zonal species *Oscillopha dichotoma* (Bayle) ranges from the Coniacian to the Campanian (Malchus 1990). In Gebel Ekma, *Plicatula ferryi* ranges from the Late Cenomanian to the Early Campanian age, being associated with the *Nicaiolopha tissoti* Zone. It measures 5 m in Gebel Yelleg and the East Themed area. In the East Themed area, the zone is considered

Explanation of Plate 9

Fig.

- 1, 3. *Praeradiolites biskraensis* Coquand, 1880. Attached valve (AV), Upper Cenomanian, Galala Formation, East Themed area, x 0.75.
2. *Praeradiolites irregularis* Douvillé, 1910. Incomplete attached valve, Middle Turonian, Wata Formation, Gebel Yelleg, x 1.1.
- 4-5. *Durania arnaudi* (Choffat, 1891). Incomplete attached valves, Middle Turonian, Gebel Yelleg, side view, 4: x 1.1, 5: x 1.5.
6. *Durania gaensis* (Dacqué, 1903). Incomplete attached valve, Middle Turonian, East Themed area, x 1.1.
- 7, 10. *Praeradiolites ponsianus* (d'Archiac, 1835) *aegyptiacus* Douvillé 1910. Side view of incomplete left valves, Middle Turonian, Wata Formation, Gebel Yelleg, x 1.1.
- 8-9. *Eoradiolites liratus* (Conrad, 1852). Side view of incomplete left valves, Lower Cenomanian, Galala Formation, Gebel Yelleg, 8: x 0.75, 9: x 1.1.



to be Coniacian - Santonian? in age. In Gebel Yelleg, it is considered to be Late Coniacian - Santonian? in age, because it overlies the above zone *Metatissotia ewaldi* Zone of the Middle Coniacian. Consequently, the age of this zone ranges from the Coniacian to Santonian.

***Pycnodonte (Costeina) costei* Total Range Zone**

The zone is defined by the total range of *Pycnodonte (Costeina) costei* (Coquand) and ranges in thickness from 5 m at Gebel Yelleg, 10 m in the East Themed area to 15 m at Gebel Ekma. It is considered to be Coniacian in age at Gebel Ekma, where it underlies the *Hemiaster (Mecaster) fourneli - Petalobrissus waltheri* Zone which underlies the basal Santonian *Cladoceramus undulatoplicatus* Zone. In the East Themed area, it is considered to be Coniacian - Santonian? in age. In Gebel Yelleg, the zone is considered to be Late Coniacian - Santonian? in age, because it underlies the Sudr Chalk and overlies the *Cucullaea (Idonearca) maresi* Zone. The latter overlies the Middle -Late Coniacian *Metatissotia ewaldi* Zone.

***Cladoceramus undulatoplicatus* Total Range Zone**

This standard, world-wide, Lower Santonian zone is recorded in the present study for the first time from the Middle East and North Africa. It is defined by the total range of the index species *Cladoceramus undulatoplicatus* Roemer and attains a thickness of 1.5 m. The most common associated faunal elements are *Spondylus fimbriatus* Goldfuss, *Caricella stromboides* (Munier- Chalmas), and *Parapygyus casiduloides* (Thomas & Gauthier). *Spondylus fimbriatus* Goldfuss is present cementing to the shell of the index species. Dhondt & Dieni (1990) have been recorded and discussed in detail this association. These authors mentioned that complete specimens, specially in the groups with large shells such as *Platyceramus* and *Cladoceramus* are very rare, and argued this to preservational problems and preparation difficulties. Lamolda & Hancock in Rawson *et al.* (1996)

Explanation of Plate 10

Fig.

- 1, 4. *Phymosoma abbatei* (Gauthier, 1898). 1: adapical view, 4: side view, Middle Turonian, Wata Formation, East Themed area, x 1.5.
- 2a-b. *Rachiosoma geysi* Abdelhamid & El Qot, 2001. 2a: adapical view, 2b: side view, Upper Turonian, Wata Formation, East Themed area, x 1.1.
- 3, 5. *Rachiosoma irregulare* Fourtau, 1921. a: adapical view, b: adoral view, Upper Turonian, Wata Formation, Gebel Ekma, x 0.9.
- 6, 8. *Petalobrissus waltheri* (Gauthier, 1900). 6: adoral view, 8: adapical view, Santonian, shaly member, Matulla Formation, Gebel Ekma, 6: x 1.5; 8: x 2.3.
- 7, 9. *Coenholectypus turonensis* (Desor, 1847). 7: adapical view; 9: side view, Lower Turonian, Abu Qada Formation, East Themed area, x 1.1.
- 10-11. *Hemiaster (Hemiaster) gabrielis* Peron & Gauthier, 1878. 10: adapical view, 11: adoral view, Lower Cenomanian, Galala Formation, Gebel Yelleg, x 1.5.
- 12-13. *Hemiaster (Mecaster) fourneli* Deshayes, 1847. 12: adapical view, 13: adoral view, Coniacian-Santonian, Themed Formation, East Themed area, x 0.75.
- 14a-b. *Hemiaster (Mecaster) heberti* (Coquand, 1862) *turonensis* Fourtau, 1921. a: adapical view, b: adoral view, Lower Turonian, Abu Qada Formation, East Themed area, x 1.5.
- 15, 18 *Praealveolina cretacea* (d'Archiac, 1837). Subaxial sections, Middle Cenomanian, Galala Formation, Gebel Yelleg, 15: x 11, 18: x 8.
- 16, 19. *Orbitolina conica* (d'Archiac, 1837). 16: axial section, 19: tangential section, basal part of the Lower Cenomanian, Galala Formation, Gebel Yelleg, x 11.
17. *Thecosmilla tommasii* Prever, 1909. Side view, Upper Cenomanian, Galala Formation, East Themed area, x 0.75.

indicated that three inoceramid species have been used to define the Coniacian/Santonian boundary, the widespread species, *Cladoceramus undulatoplicatus* Roemer, the North Temperate *Sphenoceramus pachticardissoides* group and the North African species *Platyceramus siccensis*. They added that, the North African species, is not known outside North Africa. It is worth to mention that Abdel-Gawad (1999b) recorded *Pl. siccensis* from the Lower Santonian of Gebel Nezzazat.

***Nicaiolopha tissoti* Total Range Zone**

This zone is characterised by the total range of its index species *Nicaiolopha tissoti* (Thomas & Peron). This index species ranges from the Coniacian to the Campanian (Malchus 1990). In Gebel Ekma, the zone is 40 m thick and is considered to be Late Santonian - Early Campanian in age because it is enclosed between the Lower Santonian *Cladoceramus undulatoplicatus* Zone and the Upper Campanian *Nicaiolopha nicaisei* - *Ambigostrea bretoni* Zone. In the present study, the lower part of this zone coincides with the *Dicarinella concavata* Zone of El-Sheikh (1999). Rawson et al. (1996) and Hardenbol et al. (1998) indicated that the highest occurrence of *Dicarinella concavata* marks the Santonian/Campanian boundary. This suggests a Late Santonian - Early Campanian age for this zone.

***Nicaiolopha nicaisei* - *Ambigostrea bretoni* Total Range Zone**

The zone is defined by the total range of the two index species, *Nicaiolopha nicaisei* (Coquand) and *Ambigostrea bretoni* (Thomas & Peron), which attains thickness of 18 m at Gebel Ekma. Malchus (1990) recorded *A. bretoni* (Thomas & Peron) from the Upper Campanian rocks of Wadi Qena, Eastern Desert of Egypt. He indicated that, it has a long stratigraphic range (Coniacian - Maastrichtian). Moreover, *N. nicaisei* (Coquand) ranges from the Late Campanian to the Early Maastrichtian (Malchus 1990 and Aqrabawi 1993). Consequently, this zone is considered of Late Campanian in age in Gebel Ekma. The planktonic foraminifera identified from Gebel Ekma confirmed the Late Campanian age of this zone, because it coincides with the Late Campanian *Globotruncana rosetta* Zone of EL-Sheikh (1999).

***Pycnodonte (Phygraea) vesicularis vesicularis* Acme Zone**

The *Pycnodonte (Phygraea) vesicularis vesicularis* Zone is the youngest zone recorded in the present study. It is defined by the abundance of the index species. The zone is considered by some authors to be Campanian in age (Issawi et al. 1981, Kora & Hamama 1987b), but it has also been considered Maastrichtian in age and equivalent to the *Exogyra overwegi* Zone, which prevails in the central and southern parts of the Western Desert of Egypt (Awad & Issawi 1975). In particular in Gebel Ekma, this zone is considered Campanian - Maastrichtian in age, being recorded from the Upper Campanian rocks of the Matulla Formation and from the lower part of the massive, snow-white chalk of the Sudr Chalk of the Upper Campanian - Maastrichtian age based on planktonic foraminifera (Cherif et al. 1989b).

The stage boundaries

Albian/Cenomanian boundary

In Gebel Ekma, the contact between the Lower Cretaceous Malha Formation

and the Cenomanian is marked by the Cenomanian transgression, which is indicated by the oysters forming the *Ceratostreon flabellatum* - *Rhynchostreon suborbiculatum* Zone. *C. flabellatum* (Goldfuss) has a long stratigraphic range, as it is originally described from the Cenomanian of Germany; and distributed in the Albian - Cenomanian (Dhondt 1982). It ranges from the Albian to the Senonian, but is widely distributed in the Cenomanian - Turonian (Freneix 1972). It is considered to be Aptian ?, Albian - Cenomanian in age (Malchus 1990, Aqrabawi 1993, Seeling & Bengtson 1999). While *R. suborbiculatum* (Lamarck) has not been recorded elsewhere from levels below the Cenomanian. Therefore, the Early Cretaceous/Cenomanian boundary is located at the base of bed no. 1 (glauconitic claystone and shale), which coincides with the base of the *C. flabellatum* - *R. suborbiculatum* Acme Zone. This zone has been assigned an Early - Middle Cenomanian age because it is overlain by the lower Upper Cenomanian *Neolobites vibrayeanus* Zone.

In the East Themed area, the typical Cenomanian fauna recorded from bed no. 3 (yellowish white marl of 5 m thickness), at the base of which there is the *Ceratostreon flabellatum* Zone. Within 1 m above this zone there are two oyster banks with *Ilymatogyra africana* (Lamarck), which is considered belong to the Middle - Upper Cenomanian (Malchus 1990, Aqrabawi 1993, and Seeling & Bengtson 1999). Accordingly the lowermost part of the Galala Formation (30 m of marl and dolomitic nodular limestone with poorly preserved bivalves and gastropod moulds) is attributed to the Early Cretaceous - Early Cenomanian (transition unit).

The Albian/Cenomanian boundary in Gebel Yelleg is determined at the base of the *Orbitolina conica* Total Range Zone, which overlies the *Ceratostreon flabellatum* - *Pterocera incerta* Acme Zone. The base of the latter zone occurs above the Lower Cretaceous sandstone with 5 m of vari-coloured shale. This zone measures 28 m of marl with an intercalation of cliff-forming sandy limestone in the middle and is overlain by 5 m of *Orbitolina* limestone, which forms the second zone. The first zone has a long stratigraphic range (Albian - Cenomanian). According to Tröger & Kennedy (in Rawson *et al.* 1996) the FO (first occurrence) of *O. (Orbitolina) concava concava* and *O. (O.) conica* indicate the Albian/Cenomanian boundary in Tethyan shelf carbonate successions. Therefore, the Albian/Cenomanian boundary is located at the base of the *Orbitolina* limestone bed constitutes the *O. (O.) conica* Zone and the lower 33 m (*Ceratostreon flabellatum* - *Pterocera incerta* Acme Zone) is assigned to the Upper Albian. This lower zone contains no definite Albian fauna except one poorly preserved *Kneimeceras?* sp.

The integration between the two larger foraminiferal zones; *O. (O.) conica* Zone (basal Cenomanian), *Praealveolina cretacea* Zone of the Middle - Upper Cenomanian (Schörder & Neumann 1985, Hardenbol *et al.* 1998), and the *Neolobites vibrayeanus* Zone of the early Late Cenomanian age led to subdivide the Cenomanian sequence of Gebel Yelleg into a Lower, Middle and Upper substages.

Cenomanian/Turonian boundary

The Cenomanian/Turonian boundary is placed at the top of the *Vascoceras cauvini* - *Pseudaspidoceras pseudonodosoides* - *Rubroceras alatum* Assemblage Zone and the base of the *Choffaticeras segne* Total Range Zone and *Choffaticeras quaasi* - *Choffaticeras securiforme* Total Range Zone in Gebel Ekma and the East

Themed area, respectively. In Gebel Yelleg, the Cenomanian/Turonian boundary is located at the base of the *Choffaticeras segne* - *Thomasites rollandi* Zone. Based on the *Vascoceras cauvini* - *Pseudaspidoceceras pseudonodosoides* - *Rubroceras alatum* Assemblage Zone is equivalent to the *Neocardioceras juddii* Zone as discussed before. In addition to, the genera *Choffaticeras* and *Thomasites* are restricted to the Lower Turonian (Wright et al. 1996).

Turonian/Coniacian boundary

Coilopoceras requienianum Zone is considered to constitute the latest Turonian zone in Israel (Lewy 1989, Lewy et al. 1984) and in Egypt (Table 4). Based on the common occurrence of *C. requienianum* (d'Orbigny) in the European *Romaniceras devrianum* Zone, the species is considered to be indicative of the late Middle Turonian. Lewy (1989) recorded *C. requienianum* from level above this zone in Israel, and after Kennedy (pers. comm. 2002) the species is indicative of the late Middle - early Late Turonian. For the East Themed section, in the present study, demonstrates two Turonian zones overlying the *Coilopoceras requienianum* Zone; *Cucullaea (Idonearca) trigona* - *Rachiosoma geysi* Zone and *Nerinea requieniana* Total Range Zone. The lower zone, *Cucullaea (Idonearca) trigona* - *Rachiosoma geysi* Zone can be correlated with the *Rachiosoma irregulare* Acme Zone in Gebel Ekma. This indicates that the *C. requienianum* Zone does not correspond to the topmost Turonian. Due to the absence of typical Early Coniacian of both macro and microfauna in the present study the Turonian/Coniacian boundary can not be determined.

Coniacian/Santonian boundary

According to Lamolda & Hancock (in Rawson et al. 1996) six criteria are proposed for the Coniacian/Santonian boundary; FO of *Texanites (Texanites)*, FO of *Sigalia carpathica*, FO of *Dicarinella asymerica*, FO of *Platyceramus siccensis*, FO of *Cladoceramus undulatoapplicatus*, and FO of *Sphenoceramus pachti*. They selected the lowest occurrence of *Cladoceramus undulatoapplicatus* as a primary marker for the Coniacian/Santonian boundary and *Sigalia carpathica* as a secondary marker.

Consequently, the Coniacian/Santonian boundary is located at the base of the bed no. 24 within the shaly member of the Matulla Formation in Gebel Ekma, at the level of the FO of *Cladoceramus undulatoapplicatus* (Roemer), while in both Gebel Yelleg and the East Themed area the Coniacian/Santonian boundary can not be determined due to the absence of typical Early Santonian fauna.

Santonian/Campanian boundary

The Santonian/Campanian boundary is defined based on the integration between the oysters and planktonic foraminifera. El-Sheikh (1999) recorded the *Dicarinella concavata* Zone from the sequence of shale and marl (lower part of the *Nicaiolopha tissoti* Zone), which underlies the phosphatic sandstone (base of the phosphatic member of the Matulla Formation at Gebel Ekma) and attributed it to the Lower Santonian. He suggested a hiatus corresponding to most of the Santonian and to the Lower Campanian. This conclusion is adopted herein, because Hancock & Gale (in Rawson et al. 1996) considered the LO (last occurrence) of *Dicarinella asymerica* (Sigal) and *D. concavata* (Brotzen) to be the most used foraminiferal criteria for the Santonian/Campanian boundary. A Late Campanian age is assigned

to the base of the *Nicaiolopha nicaisei* - *Ambigostrea bretoni* Total Range Zone, which coincides with the Late Campanian *Globotruncana rosetta* Zone of El-Sheikh (1999). The second zonal species, *A. bretoni* (Thomas & Peron), has a long stratigraphic range (Coniacian - Maastrichtian), but it is recorded from Upper Campanian rocks in Wadi Qena (Malchus 1990). Moreover, *N. nicaisei* (Coquand) is restricted to the Upper Campanian - Lower Maastrichtian (Malchus 1990, Aqrabawi 1993). The first occurrence of *N. nicaisei* is in the shale bed, which is 32 m above the top of the *concovata* Zone. This indicates that the lower 32 m of the phosphatic member are of Early Campanian age, while the upper 13 m are of Late Campanian in age. Therefore, the Santonian/Campanian boundary is located at the base of the phosphatic sandstone bed (base of the phosphatic member), which yields numerous shark teeth. This contact coincides with the LO of *Dicarinella concavata*. In the other two localities the boundary can not be determined due to the absence of typical Late Santonian fauna.

Campanian/Maastrichtian boundary

The Sudr Chalk is considered to be Campanian - Maastrichtian in age at different localities in Egypt (Kora & Hamama 1987b, Cherif *et al.* 1989b, Ziko *et al.* 1993, and Ismail 2000). Abdel-Gawad (1990) introduced the heteromorph ammonite *Solenoceras (Oxybeloceras) humei* - *Nostoceras* spp. Zone for the topmost Campanian rocks of Egypt. Where this zone is restricted to a phosphate bed in the upper member of the Sudr Chalk in Sinai. In the present study except for *Pycnodonte (Phygraea) vesicularis vesicularis* (Lamarck) no macrofossils were collected from the chalk of the Sudr Chalk.

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