Taxonomy and palaeoecology of the Cenomanian-Turonian macro-invertebrates from eastern Sinai, Egypt

(Part A)

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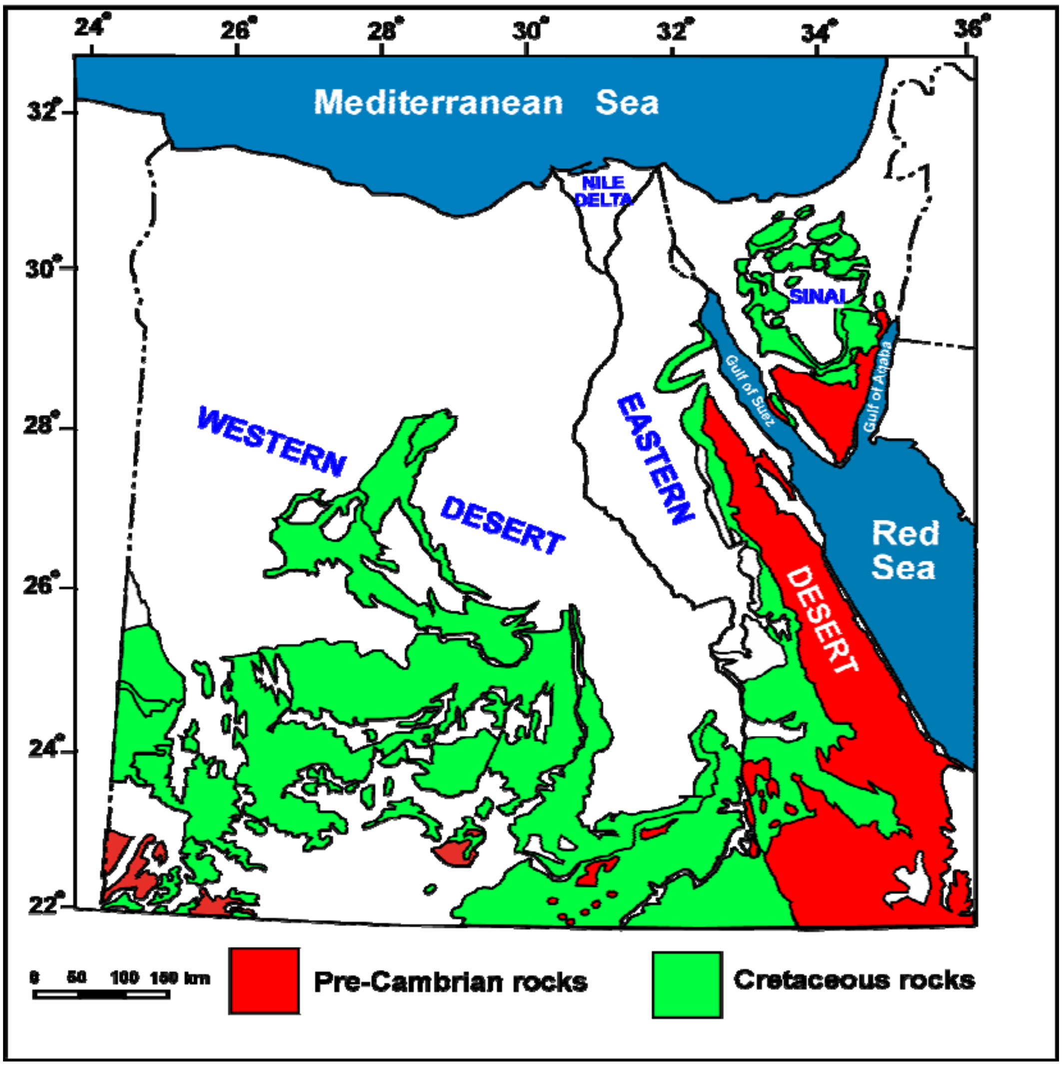
1 INTRODUCTION

Cretaceous sediments cover around 40% of the surface of Egypt. The transgression of the Tethys across Egypt started humbly during the Early Cretaceous but by the Late Cretaceous, the sea covered a huge tract of Egypt extending southwards to the Sudan-Egypt border (ISSAWI et al. 1999: 145). Rocks of Cretaceous age have a wide distribution in Sinai; they occupy about 25% of the total area of the Peninsula, forming a large part of the folded areas of north and central Sinai (Text-fig. 1.1). Many areas of northern Sinai were subjected to transgressive phases during the Late Cretaceous-Tertiary. Therefore, Late Cretaceous-Tertiary marine sediments are widely distributed and well exposed at several localities.



Text-fig. 1.1. Distribution of Cretaceous rocks in Egypt.

In the last years, Cretaceous rocks of Egypt have drawn particular attention from Egyptian geologists. For example, the anticlinal structures of the Syrian Arc System in several regions of northern Sinai play an important role in hydrocarbon exploration (COHEN et al. 1990; ALSHARHAN & SALAH, 1996). In addition, patchy and/or linear carbonate reservoirs in reefal facies developed during Turonian cyclic events especially in northern Sinai and Western Desert provinces (DARWISH, 1994).

2. Aims of the present study

The scopes of the present study are

- the lithostratigraphic classification of the Cenomanian-Turonian successions in north and central East Sinai and their correlation;
- a taxonomic documentation of the macrobenthic fauna, which includes bivalves, gastropods, ammonites, echinoids, and corals;
- the biostratigraphic zonation of these sequences based on their macrofaunal content; and
- a palaeoecological and taphonomic analysis of the statistically sampled macrobenthos and the discussion of the most important environmental parameters governing the distribution of the fauna.

3. Material and methods

To reach the above-mentioned goals of this study, three sections were studied in detail (Gebel Areif El-Naqa, East Themed area, and Wadi Quseib). In this context, the following aspects were studied:

- The literature on the Cenomanian-Turonian successions of the sections was discussed with special references to stratigraphy and palaeontology.
- The field relations of the recognized rock units were studied, stratigraphic sections were measured, and representative samples (rocks and fossils) were collected at every change in lithology. Concerning the macrofauna, all bivalves, gastropods, ammonites, echinoids, and corals were collected (altogether 5880 individuals) and taxonomically described. 402 individuals represent the cephalopods (ammonites and nautilids), while the remaining 5478 individuals, which belong to 132 taxa, were included in the ecological analysis.
- Laboratory investigations included cleaning, washing, and photographing the macrofaunal elements.
- The subsequent analytical work included establishing biostratigraphic zonations and correlating the sections with other areas within and outside Egypt.
- After identification of the fauna, the specimens of each taxon in a sample were counted. Left valves, right valves, and articulated specimens were counted separately. The number of individuals was constructed by adding the larger number of single valves (either right or left valves) to the numbers of articulated specimens. The presence percentage and relative abundances of species was constructed for each quantities sample.
- In order to reconstruct the benthic associations (benthic community relicts), 41 statistical samples were subjected to a cluster analysis after removing samples with less than 30 individuals. The clusters were constructed by using the program PAST (HAMMER et al., 2001; www.//folk.uio.no/ohamer/past). In addition, the diversity (Shannon-index) and evenness values as well as the rarefaction curves were constructed by using the same program.

4. Location of sections

The studied sections are located in Sinai (Text-fig. 1.1). Three localities were studied in north and central East Sinai; they include from north to south:

4.1. Gebel Areif El-Naqa

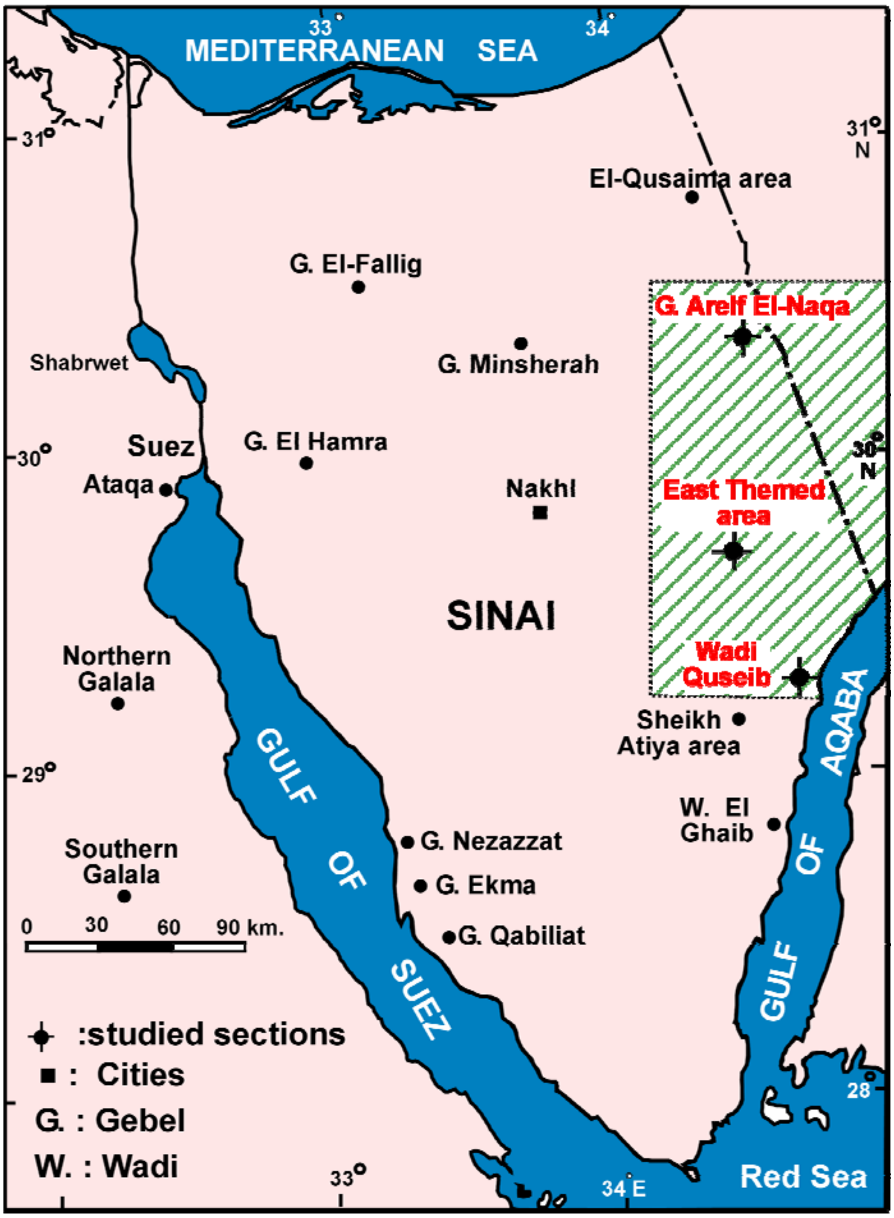
Gebel Areif El-Naqa (co-ordinates: N30°20´ and 30°24´and E34° 24´ and 34° 30´) lies in northeastern Sinai, about 40 km south of El-Qussaima area, 80 km east of El-Minsherah, and 140 km north of Wadi Quseib (Text-fig. 1.2). The area is bounded generally by the Suez Rift to the west and the Aqaba-Dead Sea Rift to the east.

4.2. East Themed area

The East Themed area (co-ordinates: N29°38´-29°42´ and E34°24´-34°26´) is located in southeastern Sinai, east of Themed Village, near the Gulf of Aqaba, about 92 km north of the Sheikh Atiya area, 80 km south of Areif El-Naqa, and about 70 km north of Wadi Quseib (Text-fig. 1.2).

4.3. Wadi Quseib

Wadi Quseib (co-ordinates: N29°16´47" and E34° 43´12") is located in southeastern Sinai, near the Gulf of Aqaba, about 25 km north of Sheikh Atiya area and about 60 km north of Wadi El-Ghaib (Text-fig. 1.2).



Text-fig. 1.2. Locality map of the three sections.

5. Previous studies on the structural and tectonic setting of the study area

HILDEBRAND & SHIRAV (1974) studied the structure of the western margin of Gulf of Elat (Aqaba) in Wadi El Quseib and W. Haimur areas. They concluded that the absence of local facies changes and unconformities in the stratigraphic succession up to the Middle Eocene indicates that along this part of the rift there were no fault movements prior to Late Eocene. They noted that the main structural feature affecting the area is faulting in three direction with, the dominant faults trending about 030°. The local sharp synclines on the eastern side of Wadi Quseib are of similar origin and are a good indicator that movements did not exceed a few meters.

BARTOV et al. (1980a) investigated the stratigraphy, palaeogeography, and structural history of Gebel Arief El-Naqa area. They concluded that Gebel Areif El-Naqa is an anticline with an axis trending N65E, and highly deformed and complex along its southern flank due to faulting and secondary structures.

BARTOV et al. (1980b) studied the sinistral movement along the Gulf of Aqaba and its relation to the opening of the Red Sea. They noted that the first stage of horizontal movements began in the Mesozoic and resulted in a displacement of altogether about 60 km, and that a further movement of about 40-45 km was post-Miocene in age. They used K-Ar dating to determine the age of the dykes in southern Sinai, and of the igneous rock of the Eastern Desert and Saudi Arabia, all of which are considered to be Miocene in age. The largest sinistral displacement recorded in single fault in the study area (Bir Zreir; western side of the Gulf of Aqaba) is 9.8 km and postdates the early Miocene dykes.

ABDEL KHALEK et al. (1992) recognized three main tectonic regimes in the northwestern part of the Gulf of Aqaba; wrenching, gravitational, and extensional. They studied the second type, which is restricted to some stratigraphic levels within the Cretaceous-Eocene sequences and is represented by folds and faults. The tectonic set-up of the Gulf of Aqaba led to the formation of large pull-apart basins and grabens between the wrench faults.

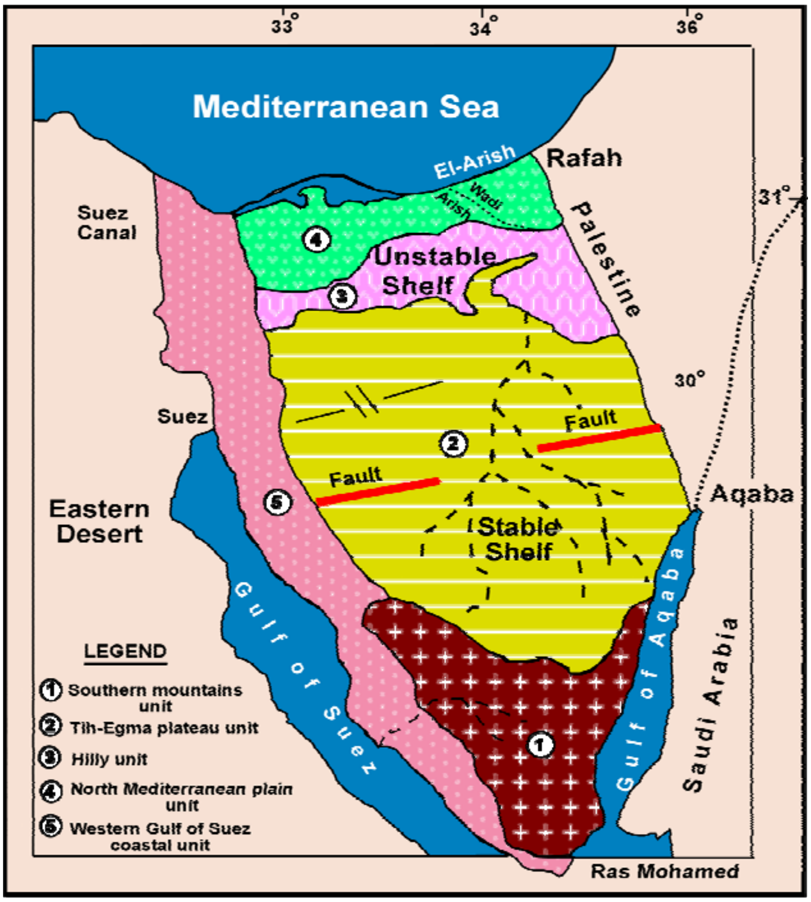
ABDEL KHALEK et al. (1993) analyzed the different structural patterns and the sequence of deformational phases affecting basement rocks and the overlying sediments in five areas (Wadi El Ghaib, W.Haimur, W. Quseib, W. Morakh, W. Taba) along the western side of the Gulf of Aqaba. They distinguished three main tectonic regimes; wrenching, gravitational, and extensional. In addition, four tectonic phases are believed to have occurred during the Aqaba rifting; the Aquitainian-Burdigalian phase, late Middle-Late Miocene phase, Pliocene phase, and post-Pliocene-Late Holocene Phase.

LÜNING et al. (1998a) studied the Mid-Cretaceous to Lower Eocene succession of Gebel Areif El-Naqa, northeast Sinai. According to them, the movements recorded in Sinai reflect tectonic events that affected large parts of northern Afro-Arabian Tethyan margin during the Late Cretaceous-Paleogene. They also reconstructed the depositional history using sequence stratigraphy in connection with facies and microfacies studies.

ISSAWI et al. (1998) studied the geomorphologic characteristics of eastern Sinai and concluded that the fluctuations of wet and dry phases in the area during the Pliocene time contributed to the development of its geomorphic units. The main geomorphic features are (a) landforms related to structural origin (folded landforms, cuesta landforms, fault block landforms, structurally controlled plateaus), (b) landforms related to denudation (bad land mountain zone, sharp narrow ridges, residual hills, kontilla pediplain), (c) landforms related to fluvial origin (drainage lines, alluvial fans, terraces), and (d) aeolian landforms.

6. Geological setting

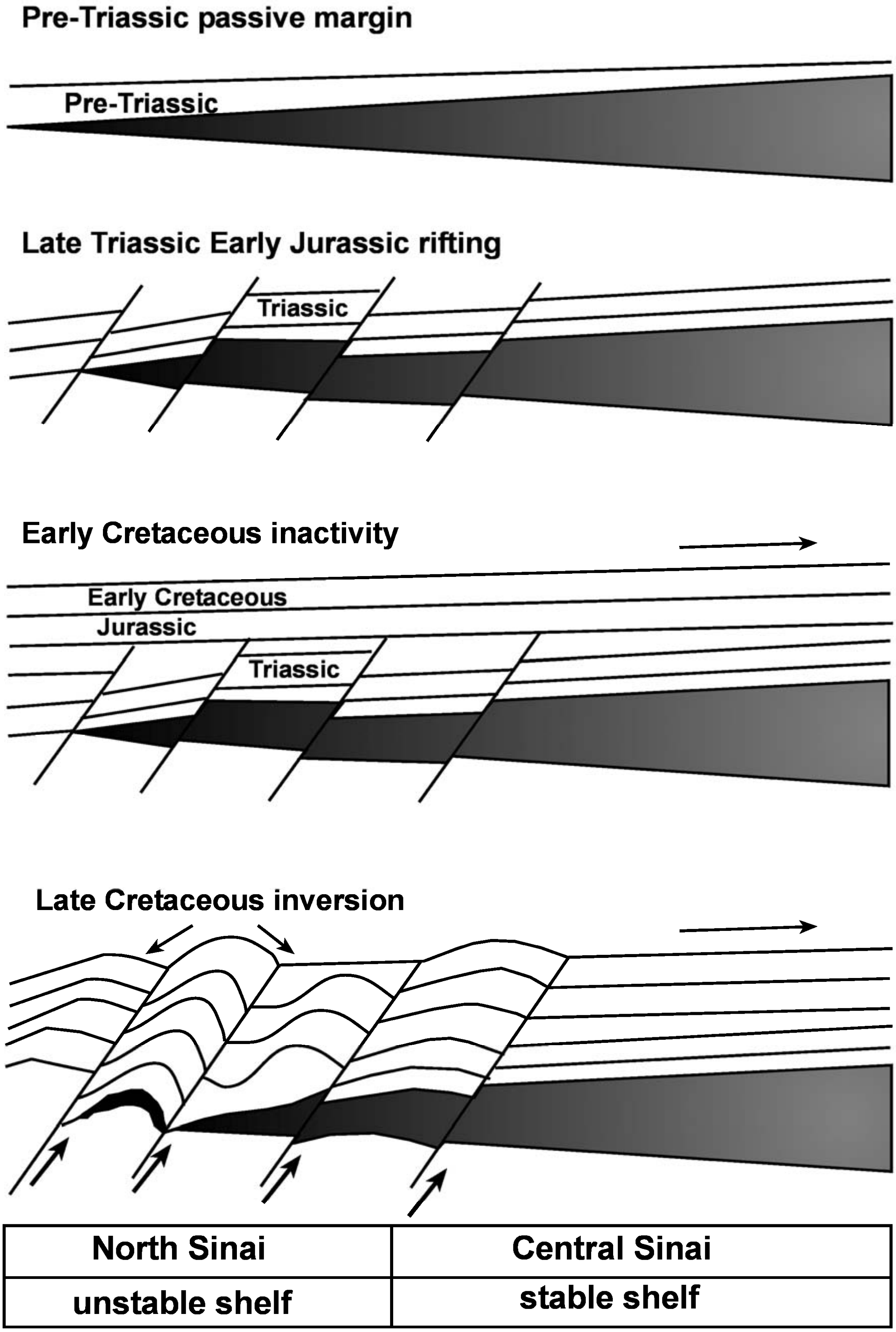
SAID (1962) subdivided the Sinai Peninsula tectonically into the “unstable shelf” of northern Sinai, which is dominated by domal anticlines of the “Syrian Arc Fold Belt” (Gebel Areif El-Naqa lies within this belt) and the “stable shelf” of central and southern Sinai (Text-fig. 1.3), which lacks these features and is characterized by mainly flat-lying strata (East Themed area and Wadi Quseib are located within this belt). The E-W striking Themed Fault in central Sinai is considered to be the boundary between the unstable and stable shelves (Moustafa & Khalil, 1994).



Text-fig. 1.3. Geomorphologic map of Sinai (modified after Abdallah & Abu Khadra, 1977: 512, fig.2).

Abdallah & Abu Khadrah (1977) subdivided the Sinai into five geomorphologic units, which are arranged from south to north as follows: (a) the southern mountain unit; (b) the Tih-Egma plateau unit; (c) the conspicuous hilly unit; (d) the northern Mediterranean plain unit, and (e) the western Gulf of Suez coastal unit (Text-fig.1.3). The Gebel Areif El-Naqa area lies within the third geomorphologic unit, which is characterized by hills area of the compressional folds of the Syrian Arc. The latter is characterized by structural brachy-anticlines and synclines, together with major longitudinal faults. Wadi Quseib and East Themed areas lie within the second geomorphologic unit (Tih-Egma plateau unit), which is characterized by a high topography (up to 1620 m), decreasing in altitude towards the north and dissected by narrow, deep drainage courses.

According to Kuss & Bachmann (1996: 919) and Bauer et al. (2003: 388) the most important Mesozoic–Early Tertiary tectonic events recorded in northeast Africa are: (1) Late Triassic-Early Jurassic E-W directed rifting and opening of the Neo-Tethyan Ocean, which is evident from major subsurface graben and basin structures of the unstable shelf (Text-fig. 1.4). They were proven along the NE-SW trending Trans-Africa Lineament, and were followed by a period of relative tectonic quiescence (Aptian-Turonian). (2) NW-SE convergence of the Afro-Arabian and Eurasian plates resulting in transgressive inversion along the pre-existing ENE-trending half graben structures from the Turonian onwards, and involving several phases of lateral strike-slip faulting and gentle folding (Guiraud, 1998),



Text-fig. 1.4. Sketch of the Mesozoic tectonic evolution of Sinai (redrawn after BAUER et al. 2003).

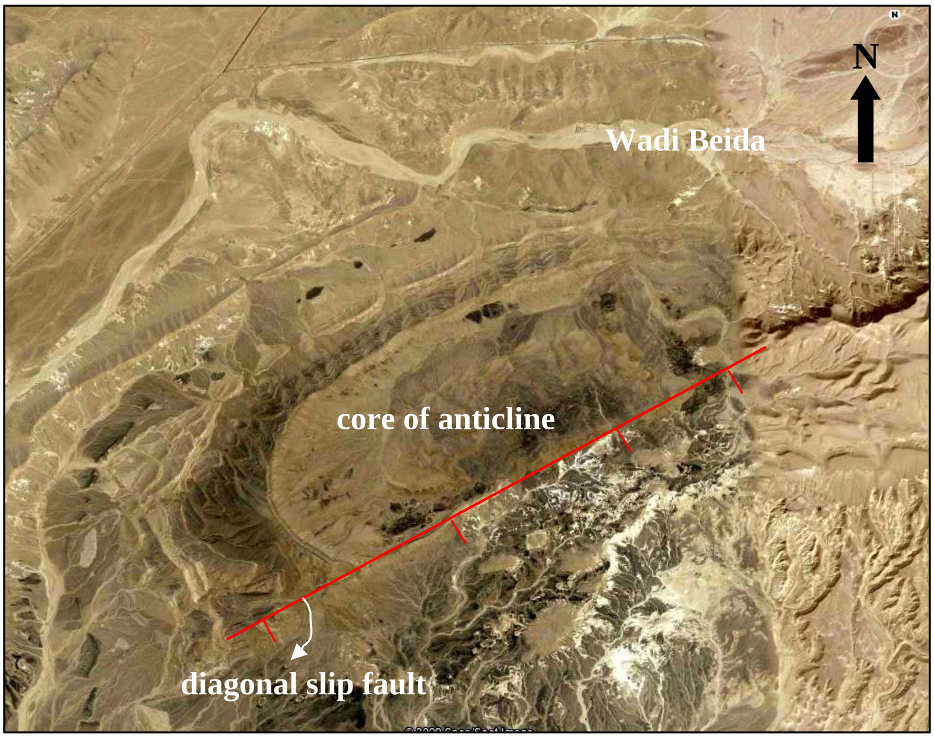
referred to as the Syrian Arc System (KRENKEL, 1924). The ENE-WSW trending domal anticlines in northern Sinai (Text-figs. 1.5 & 1.6A) are part of this intraplate fold belt, which extends from the Sinai Negev Fold Belt in northern Egypt and Israel to the Palmyride Fold Belt of Syria (Text-fig. 1.6B). The sediments in Gebel Areif El-Naqa were deposited during the pre- and syn-inversional phases (LÜNING et al. 1998a).

It is generally accepted that the major period of deformation was the Late Cretaceous, but the timing of first compressional pulses is controversially debated and ranges from the Cenomanian to Campanian. The major episode of reverse faulting probably correlates with compressional deformation in large parts of North Africa and Arabia, referred to as the 'Santonian tectonic event'. Detailed discussions of the Syrian Arc and comparison of this structure with other regions of North Africa are given by MOUSTAFA & KHALIL (1990), SHAHAR (1994), GUIRAUD & BOSWORTH (1997), GUIRAUD (1998), WALLY (1998), BOSWORTH et al. (1999), and ROSENTHAL et al. (2000).

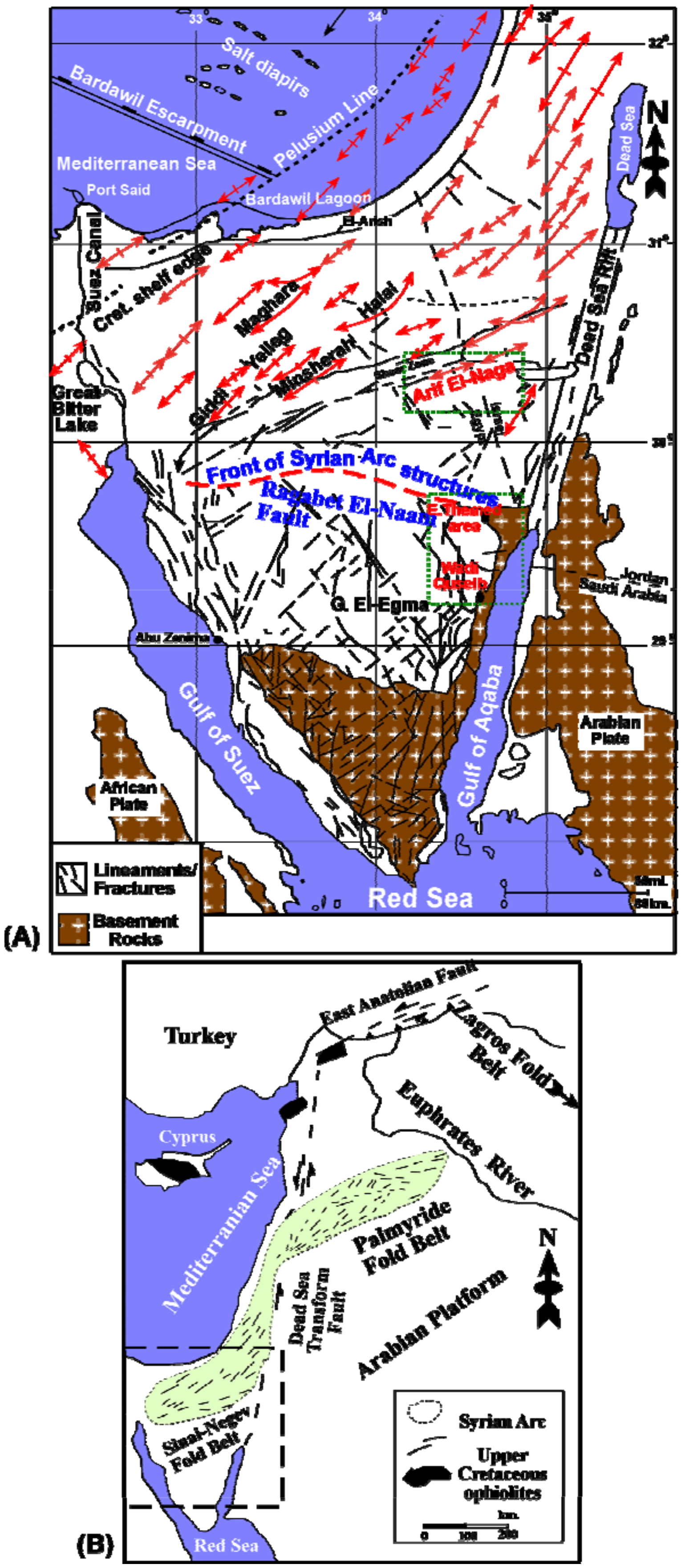
The following is a brief description of the topography and structure of the three sections:

6.1 Gebel Areif El-Naqa

The Areif El-Naqa domal anticline is part of the Syrian Arc. It is an asymmetrically plunging anticline trending ENE-WSW and paralleling the fold axis (Text-fig. 1.5). It is about 21.5 km long and 20.1 km wide and covers an area of about 392.50 km². The northern flank dips 35˚-55˚while the southern flank is steeper (>65˚) and locally vertical or overturned, and bounded by an NE-oriented diagonal-slip (right-lateral thrust) fault that dips steeply towards the SE, parallel to the fold axis (SAID, 1990: 386). According to BARTOV et al. (1980a: 133), the axis of the Areif El-Naqa anticline plunges 25˚-35˚ SW-ward and less than 5˚ NE-wards. The structure is highly deformed and complicated along the southern flank by faulting and by secondary structures (for more discussion about the structural history of the Areif El-Naqa anticline, see BARTOV et al. 1980a).

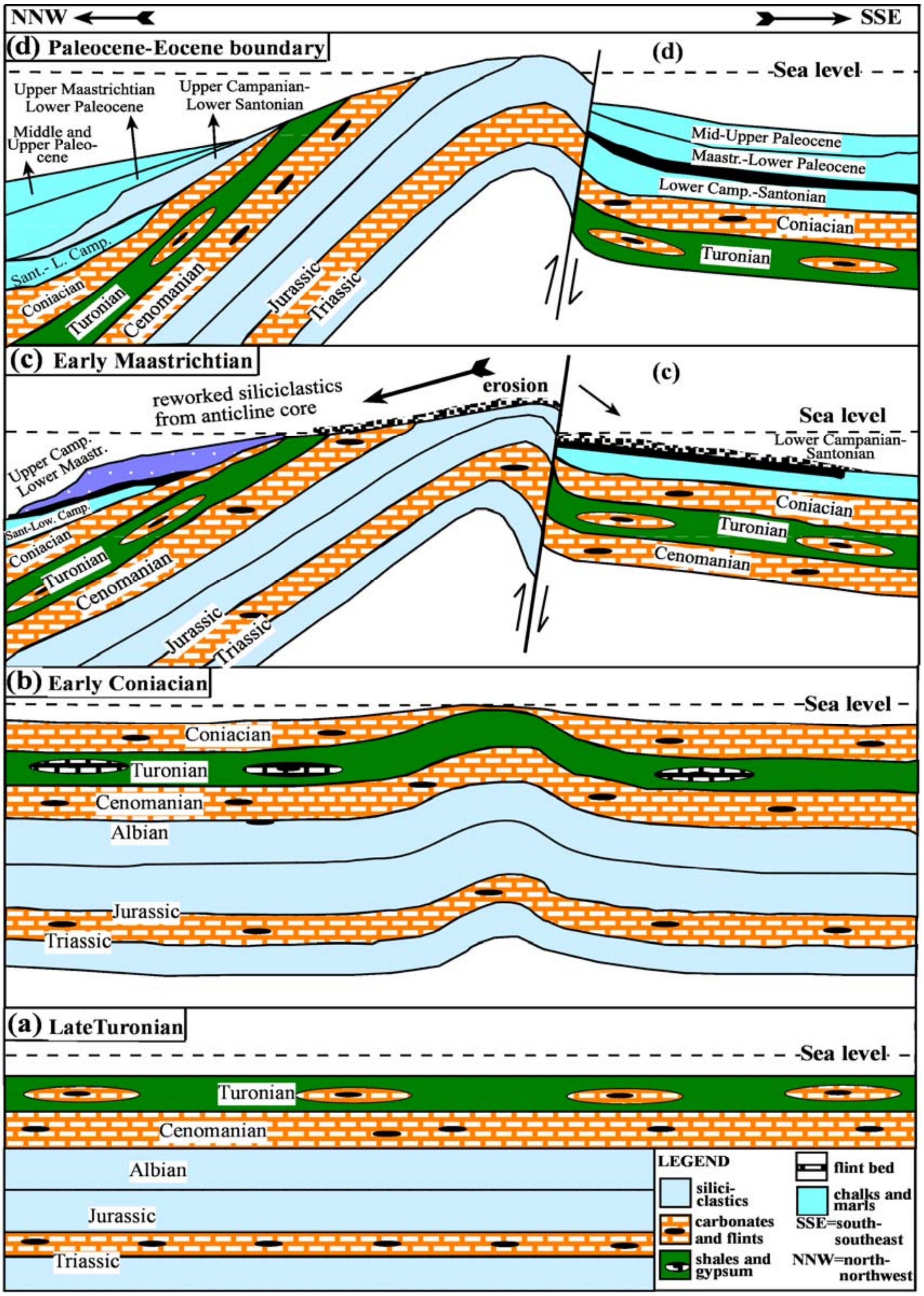


Text-fig. 1.5. Areal photograph of Gebel Areif El-Naqa and the main geological structures. From Earth Google (http://maps.google.com/maps).



Text-fig. 1.6. A. Main direction (NEN-WSW) of the Syrian Arc Fold Belt (redrawn after NEEV, 1975 and AGAH, 1981). B. Tectonic map of the northwestern Arabian Plate (redrawn after CHAIMOV et al. 1992).

Three main phases of uplift have been determined for the Areif El-Naqa anticline by LÜNING et al. (1998a) based on lateral facies and thickness changes, local development of pronounced hiatus, and on comparison with the sequence stratigraphic development in the tectonically quiet region of central-east Sinai. During the Late Turonian, no palaeostructures are known and major tectonic uplift of the area is absent (Text-fig. 1.7A). Based on facies



Text-fig. 1.7. Late Cretaceous-Early Tertiary syn-depositional uplift history of Gebel Areif El-Naqa (modified after LÜNING et al. 1998a).

distributions and thickness variations recorded by BARTOV et al. (1980a) uplift seems to have started during the Early Coniacian (Text-fig. 1.7B). A second compressional pulse during the Late Campanian-Early Maastrichtian led to the exposure of the lower Cretaceous sandstone in the anticlinal core, which was subsequently eroded and redeposited at the flanks of the anticlinal structure (Text-fig. 1.7C). The northern flank is thicker than the southern one as most of the eroded material was deposited along this flank, while the southern flank has a reduced slope and thickness. These differences in thickness are linked to the asymmetric structure of the Arief El-Naqa area. The third compressional pulse is inferred to be of Middle Paleocene to Early Eocene age evidenced by major hiatus, which occurred at the northern flank of the anticline (Text-fig. 1.7D).

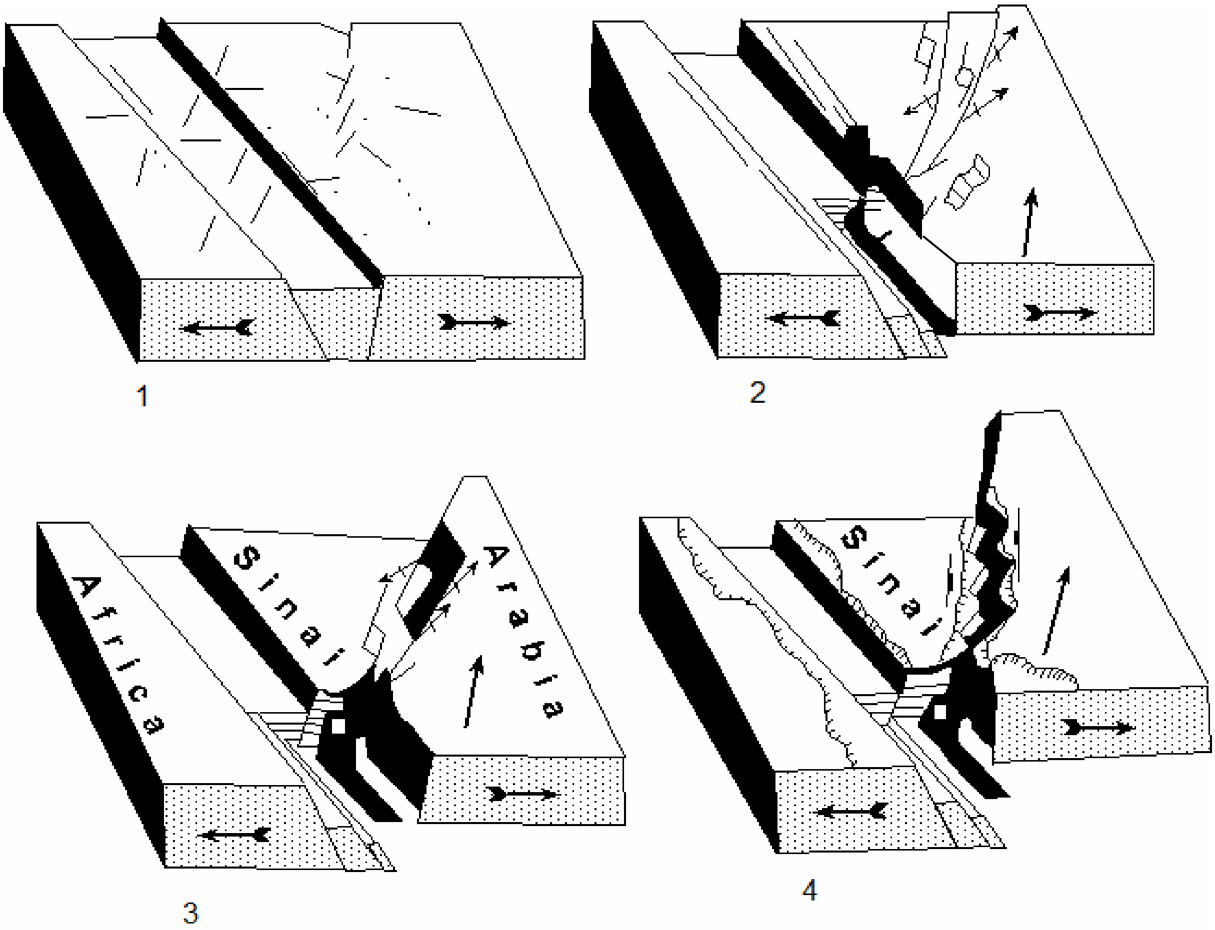
6.2 Wadi Quseib and East Themed area (northwestern Gulf of Aqaba)

The Gulf of Aqaba is the southern extension of a major transform zone, connecting the Red Sea extensional rift and the Zagros-Taurus continental collision belt. The tectonic setting of the Gulf of Aqaba reveals the occurrence of gliding deformation, which is characterized by well-developed pull-apart and prolongated graben blocks. The sedimentary succession in these grabens and pull-aparts nicely exhibit faults and folds of different tectonic regimes. The N-S and NNE-direction faults are usually sinistral whereby displacements may attain 24 km. The same amount of displacement is observed along the NNE faults on the eastern side of the gulf. The E-W to NW faults, in contrast, are of dextral slip. The sinistral and dextral slip-faults are straight or wavy in shape. Folds are one of the compressional structures associated with strike-slip faults, which are recorded in the sedimentary outcrops in the northern part of the western shoulder of the Gulf of Aqaba.

GARFUNKEL (1970) in HILDEBRAND & SHIRAV (1974: 122) suggested that the blocks at the northern part of the Gulf of Aqaba are separated by vertical planar faults, which produced gaps 2-3 km deep and about 200-300 m wide between the blocks as each successive block tilts to the east by 5°-6° more than the one on its western side.

According to ABDEL-KHALEK et al. (1993: 334) four stages are proposed to explain the main phases of formation of the Gulf of Aqaba since the Miocene. In the first stage (Aquitanian-Burdigalian), the NW-directed dikes were intruded concurrently with normal faulting in clysmic direction and NNE- and WNW-directed conjugate wrench faults (Text-fig. 1.8). The second stage (late Middle-Late Miocene) is characterized by horizontal displacement along the Aqaba-trending faults, pull-apart, gliding deformation, and folding. The elaboration of the pull-apart during the Pliocene (third stage) concurred with additional horizontal displacement. During the post-Pliocene to Late Holocene (fourth stage), the shoulder of the Gulf of Aqaba were uplifted and the subsided areas narrowed, while the first deposited Pliocene sediments were raised on either side of the gulf. Latest in this stage, the shoulders of the Gulf of Aqaba were affected by normal faulting parallel to the wrench axis (Text-fig. 1.8) (For more discussion about the structure of the Gulf of Aqaba and surrounding areas, see HILDEBRAND & SHIRAV, 1974; ABDEL-KHALEK et al., 1992, 1993).

The sediments in Wadi Quseib area are confined to an E-W trending, 5 km wide graben. Its northern border is a normal fault in NW-SE direction dipping 30°-50° to 210° with a throw of 480-530 m (e.g. Text-fig.1.9). The southern margin of this graben consists of several square blocks, tilted into the graben from both sides, by 065° in the south and 120° in the north. A fault along Wadi Quseib divides the western part of the graben.

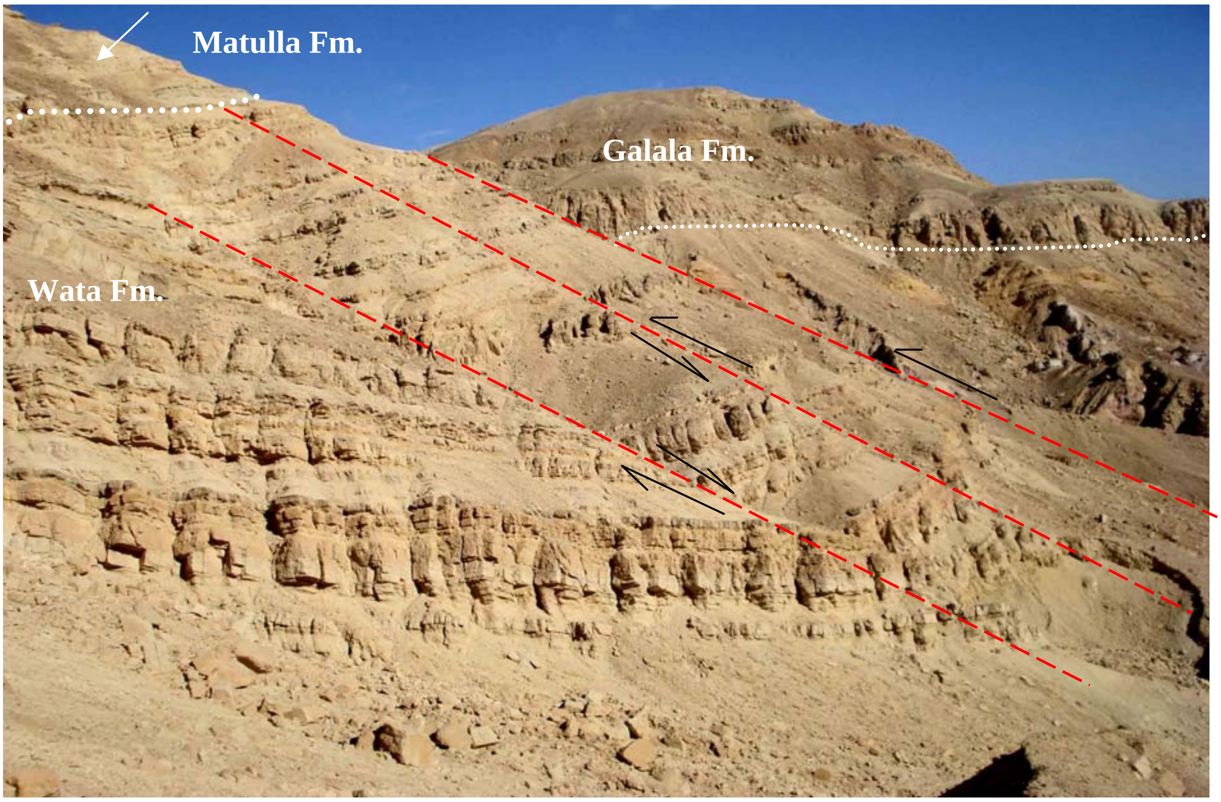


Text-fig. 1.8. Simplified block diagrams showing the structural evolution of the Gulf of Aqaba transform zone (after Abdel Khalek et al. 1993: 435, fig. 19).

North of this fault the sedimentary beds dip from 8°-15° to 90°-140°, while south of this fault, the Malha and Galala formations (equivalent to Nubian Sandstone and Hazera Formation, respectively) dip 25° to the east (Text-fig.1.10). Three narrow folds occur on the eastern side of the Quseib graben; two synclines south of Wadi Quseib plunge 16° to 12°, terminating abruptly at their northern end. The third syncline northeast of Wadi Quseib plunges 14° to 24° (Hildebrand & Shirav 1974: 126).

7. Palaeogeography of Sinai Peninsula during the Cretaceous

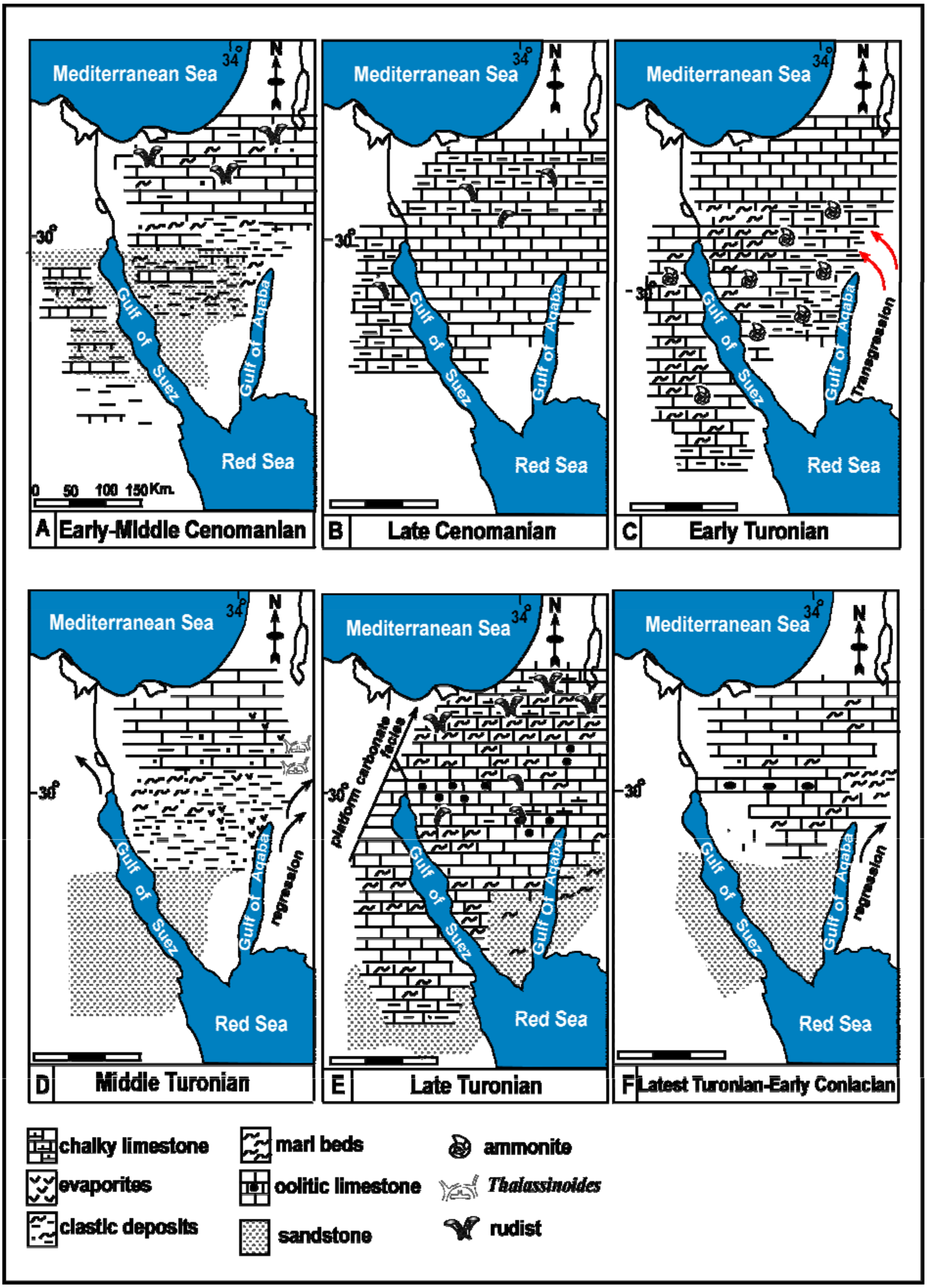
During the Cretaceous, Sinai was part of the broad northern shelf of the Arabian-African carbonate platform, which extended from Morocco to Oman along the southern margin of the Tethyan Ocean (Philip et al., 2000). In Aptian times, a mixed siliciclastic-carbonate ramp was established in north Sinai, but the depositional setting switched to a carbonate-dominate ramp in Albian and Early Cenomanian times (Bachmann & Kuss, 1998; Kunow et al. 1998). The Aptian-Albian limestones formed in shallow-water environments of the carbonate platform. Most of them represent thick, massive oolitic or bioclastic offshore bars, which are often topped by laminated intertidal/supratidal strata indicating small-scale regressive events (Kuss & Schlagintweit, 1989). The distribution of extensive shallow subtidal/peritidal Middle to Late Cenomanian carbonates in Sinai, Eastern Desert, and southern Israel represents peak transgression, followed by a gradual northward retreat during the Early Turonian, when shallow-water carbonates still prevailed (Kuss & Bachmann, 1996).



Text-fig. 1.9. Field photograph of part of the Wadi Quseib section analysed by HILDEBRAND & SHIRAV (1974). Note the NW-SE faults affecting the Turonian Wata Formation at the western side of the Quseib graben.

Text-fig. 1.10. Field photograph of the NE- dip Cenomanian strata of the Galala Formation at Wadi Quseib.

During the Late Cenomanian to Early Turonian, an extensive sea level rise (HAQ et al. 1987; HANCOCK, 1993) led to mainly shallow inner-shelf environments being established on a mixed siliciclastic- carbonate platform. During the Late Cenomanian-Early Turonian, many areas of northeastern Egypt were covered by broad zones represented by fossiliferous limestones, dolomites and marls, intercalated with silt and sandstones (BANDEL et al., 1987). The siliciclastic content increased southwards, while the total thickness of the sediment pile gradually decreased in the same direction (KUSS, 1987, 1989). During the Early Turonian, a shallow sublittoral sea covered the broad Arabian-Nubian shelf in Sinai and the northern Eastern Desert and left deposits of argillaceous limestone, marl and shale with Lower Turonian ammonites (Text-fig. 1.11C) (ABDEL-GAWAD, 1999). A regressive period after the Late Cenomanian-Early Turonian transgression is characterized by siliciclastic deposits, which are again overlain by transgressive Late Turonian strata (carbonate platform facies) composed of glauconitic sand-and siltstones and minor amounts of marly limestones with ammonites (Text-fig. 1.11E) (KUSS, 1989). During the Middle-Turonian, the area emerged and continental "Red Beds" were deposited representing a regressive continental cycle (Text-fig. 1.11.D) (ABDEL-GAWAD, 1999). The sea floaded northern Egypt during early Late Turonian, and another transgressive cycle started, during which platform carbonates were deposited (Text-fig. 1.8E). This transgression was followed by a return to continental sedimentation in Early Coniacian times, paralleling the global drop in sea level at that time (Text-fig. 1.11F). BAUER et al. (2003: 389) noted that in the Coniacian, a basin and swell morphology developed, and siliciclastic input from the southerly exposed hinterland increased markedly. From the Late Coniacian onwards, the inner shelf facies retreated southwards, and deep-water deposits developed in north and central Sinai. Hemipelagic chalk sedimentation dominated during Santonian-Maastrichtian times (KUSS, 1989). (For more discussion about the palaeogeography of Sinai Peninsula and neighbouring areas see KUSS & BACHMANN, 1996).



Text-fig. 1.11. Palaeogeographic maps of the Cenomanian-Turonian interval in Sinai (C, D, E and F modified after ABDEL-GAWAD, 1999).

2 LITHOSTRATIGRAPHY

2.1. Introduction

In this chapter the lithostratigraphy of the Cenomanian and Turonian successions exposed in north and central East Sinai are described.

The Cenomanian-Turonian succession in Sinai exhibits lateral variations in facies and thickness, which originate from local tectonics of the Syrian Arc Event and global sea level changes (SHATA, 1956; KUSS, 1989; SAID, 1990; DARWISH, 1994). In Egypt, the Cenomanian stage is represented by strata of a transgressive sea that progressively extended to the south. In northern Sinai, this succession consists almost entirely of carbonates showing a relatively deep-water pelagic facies correlating with that of the western Mediterranean (SAID & BARAKAT, 1957). Towards the south, siliciclastic rocks increase in abundance at the expense of carbonates (SHATA, 1960), while the total thickness gradually decreases. In central Sinai, the Turonian strata conformably overlie the Cenomanian beds with a thickness ranging from 50 m to more than of 280 m (SAID, 1990: 376). These Turonian sediments were deposited in extended shallow-marine to peritidal environments including a common sabkha-type sedimentation (SAID, 1990). In northern Sinai, a 20 m thick succession of Turonian chalk, chalky limestones, and shales is exposed at Gebel Halal (SHATA, 1960). Moreover, SAID (1962) noted that Turonian rocks of northern Sinai cover large areas, particularly the foot slopes of the large anticlines, which resemble lithologically the Cenomanian strata consisting of dolomitic limestone. BARTOV & STEINITZ (1977) pointed out that the late Turonian sedimentary succession consists of thick carbonates which form prominent dip-slopes of the anticlinal features in Sinai.

2.2. Previous lithostratigraphic studies of the present sections

BARTOV et al. (1980a) investigated the stratigraphy, palaeogeography, and structural history of the Gebel Areif El-Naqa area. They noted that the stratigraphic succession ranges from Triassic and Jurassic rocks in the core of the anticline to rocks of Eocene and Neogene age in the outermost periphery. They concluded that the Gebel Areif El-Naqa is an anticline with an axis trending N65E, with its southern flank being highly deformed and complex by strike-slip faulting (Text-fig. 2.1).

ZIKO et al. (1993) studied the stratigraphy of the Upper Cretaceous-Lower Tertiary sections at Wadi Watir and Themed area, east-central Sinai. They divided the studied sections into four formations; Galala (Cenomanian), Wata (Turonian), Themed (Coniacian-Santonian), and Sudr (Campanian-Maastrichtian) formations. They introduced the Themed Formation for the Coniacian-Santonian succession as a new formation. According to them, the Themed Formation has more carbonates than the Matulla Formation, but both formations have more or less the same faunal content.

ABED et al. (1996) provided a lithostratigraphic classification of Triassic-Cretaceous rocks exposed at Gebel Areif El-Naqa, north-east Sinai. The section is about 1400 m thick, and was divided lithologically into seven formations which are from base to top: Areif El-Naga (Triassic), Malha (Early Cretaceous), Halal (Cenomanian), Abu Qada (Early Turonian), Wata (Late Turonian), Themed (Coniacian-Santonian), and Sudr (Campanian-Maastrichtian) formations. The authors subdivided the Halal Formation (300 m) into five informal members.

LÜNING et al. (1998b) carried out a sequence stratigraphic study of 13 Turonian-Maastrichtian sections of central-East Sinai. Within the Turonian to Maastrichtian interval, six major sequence boundaries were recognized, considering the effect of the Syrian Arc System on the study area, which experienced a major uplift during this period.

OSMAN (1999) subdivided the upper Cretaceous strata of east Sinai into five formations: Galala/Halal (Cenomanian), Abu Qada/Wata (Turonian), and Matulla (Coniacian-Santonian). At Gebel Areif El Naqa, the Cenomanian Halal Formation is about 180 m thick being composed mainly of limestone, marly limestone, and dolostone with shaly and marly interbeds. He studied only the Coniacian-Santonian Matulla Formation in the East Themed area which he divided into two informal members.

AKARISH (1999) subdivided the Cenomanian-Paleocene exposures of the Taba-Nuweiba area, East Sinai, into seven formations. These are from base to top: the Raha Formation (Cenomanian), Abu Qada Formation (Early Turonian), Wata Formation (Late Turonian), Magmar Formation (Coniacian), Rajim Formation (Santonian-Early Campanian), Sudr Chalk (Late Campanian-Early Maastrichtian), and Esna Shale (Late Maastrichtian-late Early Paleocene). He also examined the microfacies and interpreted the depositional environment and the diagenesis of the investigated succession.

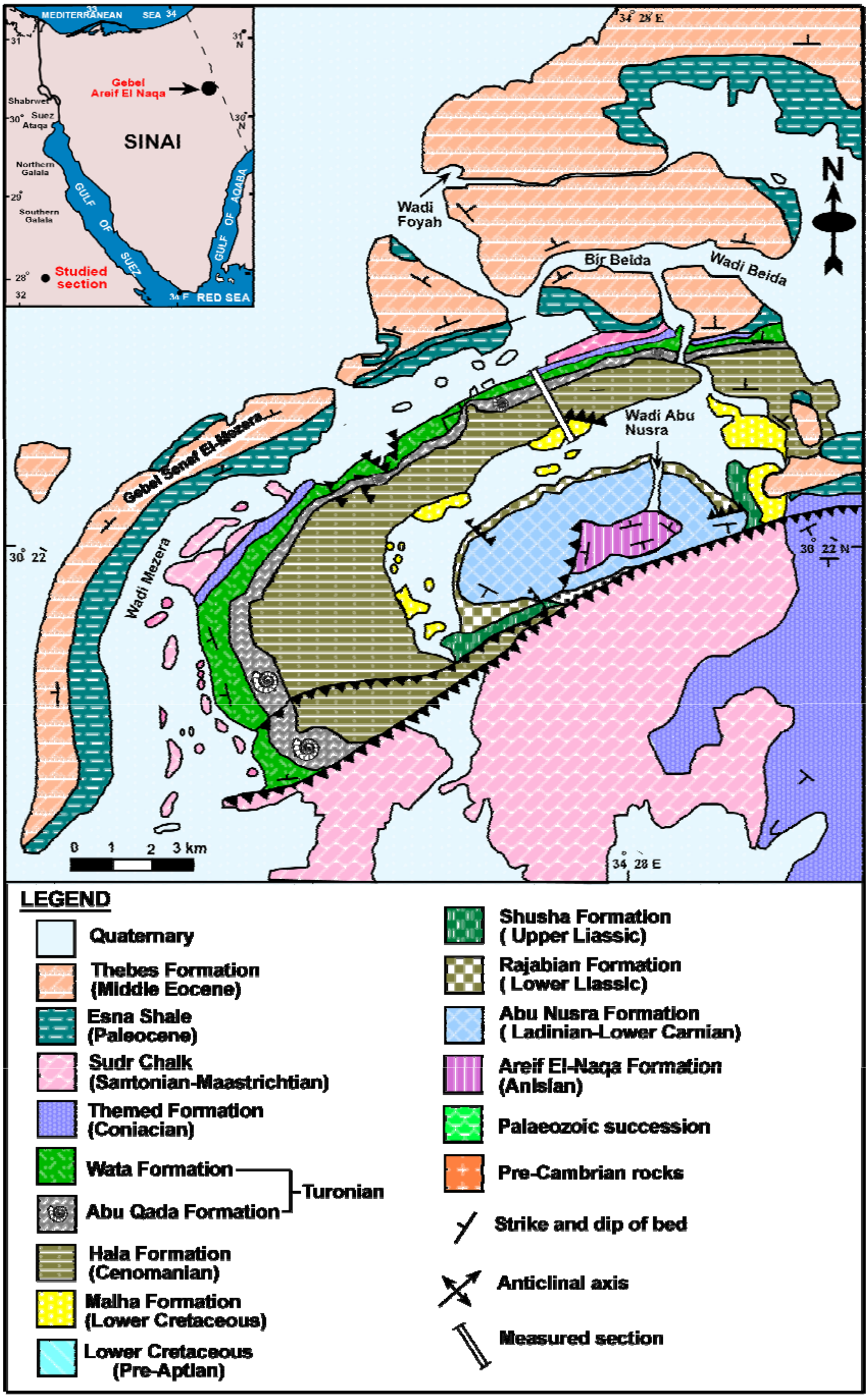
ISMAIL (2000) studied the stratigraphy and micropalaeontology of three sections in eastern Sinai (El-Themed area, Sheikh Attia area, and Taba-Nuweiba area). He recognized five formations; the Raha (Late Cenomanian), Abu Qada (Early Turonian), Wata (Late Turonian), Matulla formations (Coniacian-Santonian), and the Sudr Chalk (Campanian-Maastrichtian). He used benthic foraminifera for age determination and discussed the palaeoenvironments.

BAUER et al. (2001) investigated the lithostratigraphy and biostratigraphy of ten Cenomanian-Santonian sections in Sinai including Gebel Areif El Naqa and Wadi Quseib. Lithostratigraphically, they subdivided the sections into five formations: Raha/Halal (Cenomanian), Abu Qada/Wata (Turonian), and Matulla (Coniacian-Santonian). They suggested the first appearance of late Early Turonian ammonites above the Cenomanian deposits to be a good indicator of a hiatus existing between the Cenomanian and Turonian strata.

ABDEL-GAWAD et al. (2004a) analysed the Upper Cretaceous rocks in Gebel Yelleg (northern Sinai), East Themed area (central Sinai), and Gebel Ekma (southern Sinai). They recognized eight lithostratigraphic units ranging in age from Late Albian to Maastrichtian and representing a southern and northern facies. These formations comprise from base to top: the Early to Late Cenomanian Raha Formation (southern facies), Late Albian to Late Cenomanian Galala Formation (northern facies), Abu Qada Formation (Late Cenomanian to early Middle Turonian), Buttum Formation (Early to early Middle Turonian), Wata Formation (Early to Late Turonian), Matulla Formation (?Late Turonian to Campanian, southern facies), Themed Formation (Coniacian to Santonian, northern facies), and Sudr Formation (Campanian to Maastrichtian).

2.3 Areif El-Naqa section

The sedimentary succession of the Gebel Areif El-Naqa area ranges from Triassic and Jurassic rocks in the core of the anticline to rocks of Eocene and Neogene age at its outermost periphery (BARTOV et al., 1980a). According to ABED et al. (1996), the lithostratigraphic units in Gebel Arief El-Naqa range from Triassic to Cretaceous (with a total thickness of about 1400 m). In course of the present study, the Cenomanian-Turonian succession has been measured, sampled, described in detail and collected for macrofauna. One section through the Cenomanian-Turonian succession was measured on the northern flank of the anticline (Text-fig. 2.1). The Cenomanian-Turonian succession has been subdivided into three formations which are from older to younger: the Halal Formation (Upper Albian-Cenomanian) unconformably overlying the Lower Cretaceous Malha Formation

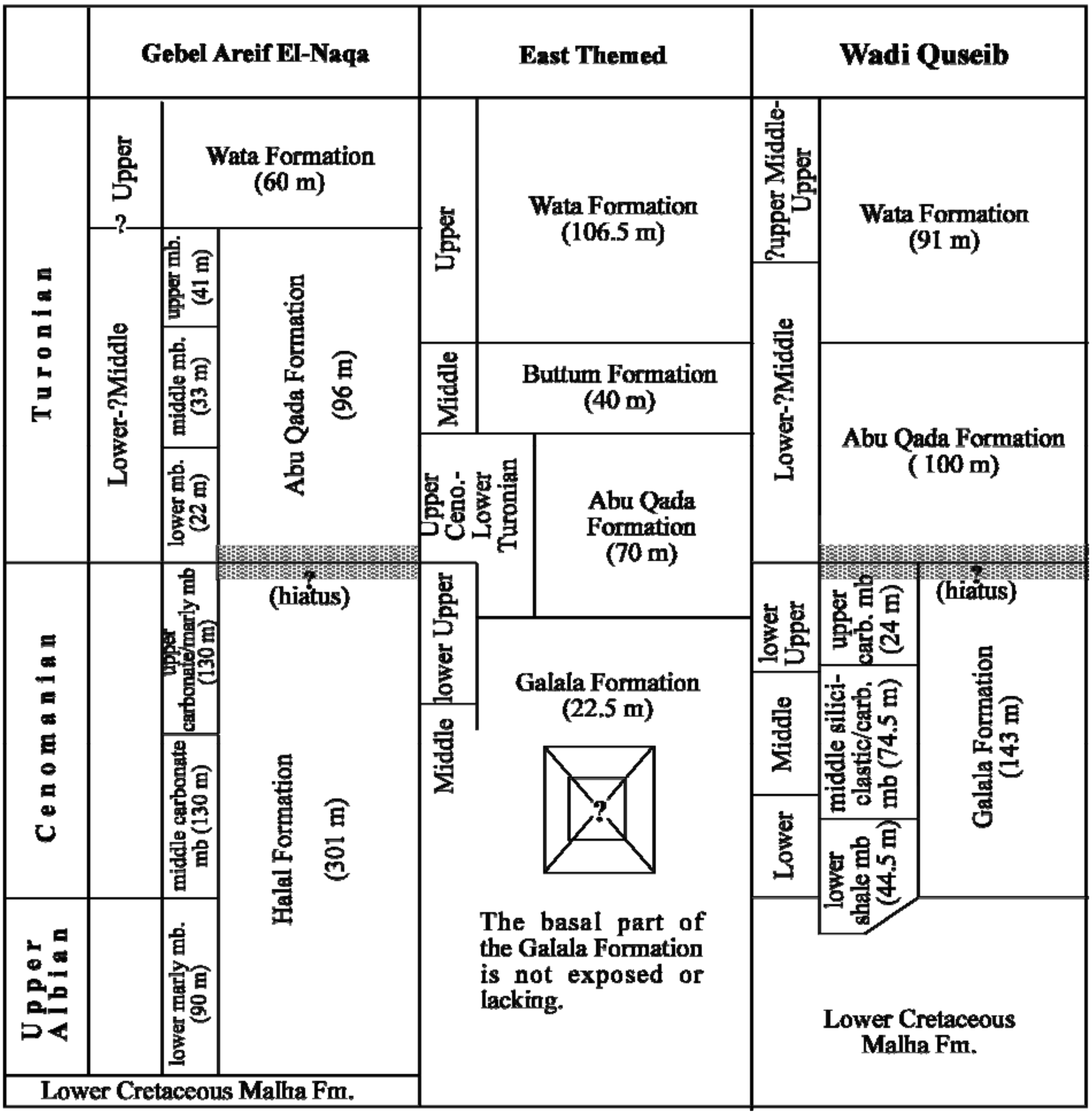


Text-fig. 2.1. Geological map of the Areif El-Naqa anticline (modified after LÜNING et al., 1998a)

(Aptian-?Albian); the Abu Qada Formation (Lower-?Middle Turonian), and the Wata Formation (?Upper Turonian) (Table 1).

The Themed Formation (Coniacian-?Santonian) tops the Wata Formation in the lowland area of Gebel Areif El Naqa (Text-fig. 2.1).

Table. 2.1. Cenomanian-Turonian rock units of the three sections.

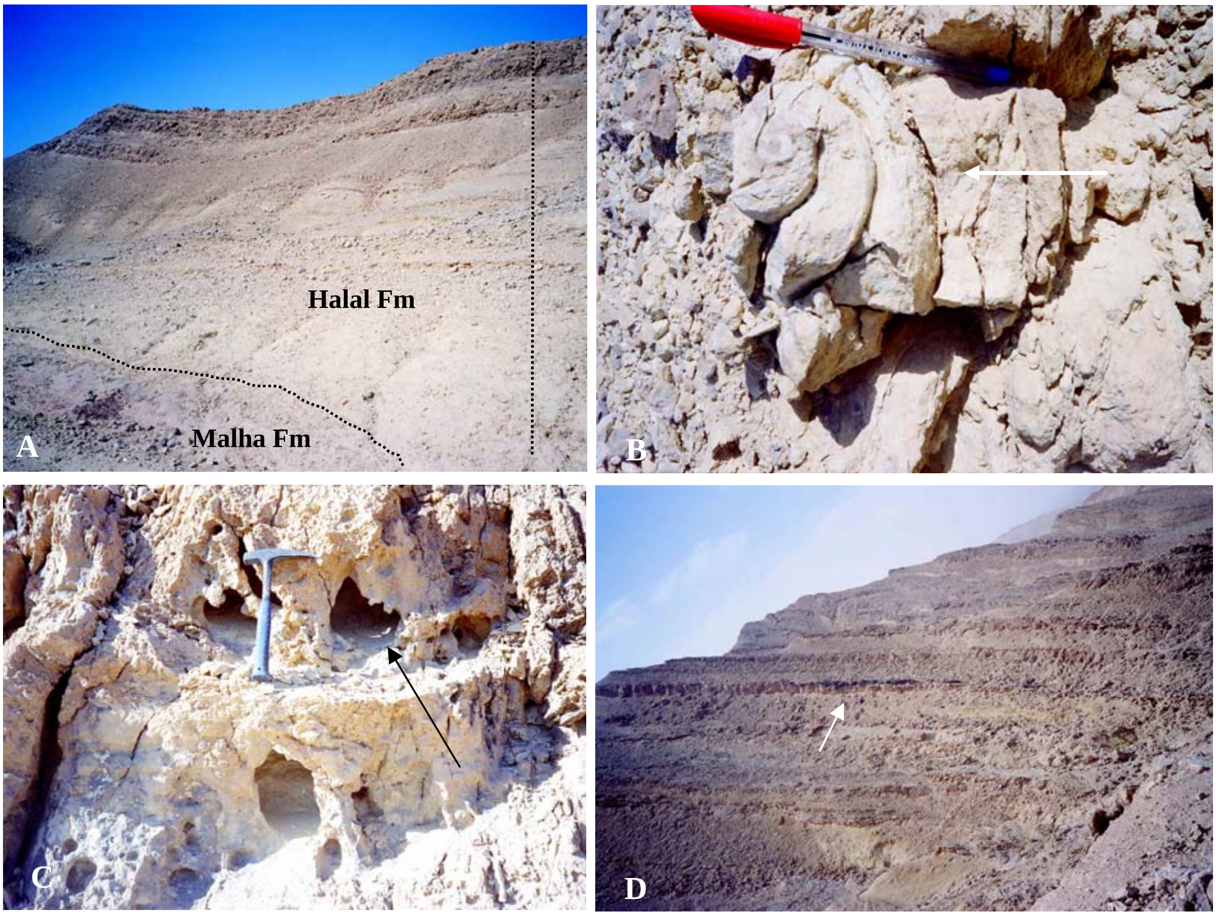


The following stratigraphic subdivisions are based on lithostratigraphic units recognized in the field. The following descriptions include lithologic features, stratigraphic thickness, stratigraphic boundaries, and the macrofaunal content.

Halal Formation

The term Halal Formation was introduced by SAID (1971) for white to grey dolomites with recrystallized limestones and minor marly intercalations, exposed at Gebel Halal, northern Sinai. It directly overlies the Lower Cretaceous Risan Aneiza Formation (Albian) and underlies marine marls of Turonian age (Abu Qada/Wata formations).

In the present study, the Halal Formation unconformably overlies the Lower Cretaceous Malha Formation. The latter is not described in detail, but plays an important role for recognizing the unconformable boundary. In general it is predominantly composed of unfossiliferous, light-violet to reddish loose sands and sandstone units (Text-fig. 2.2A).

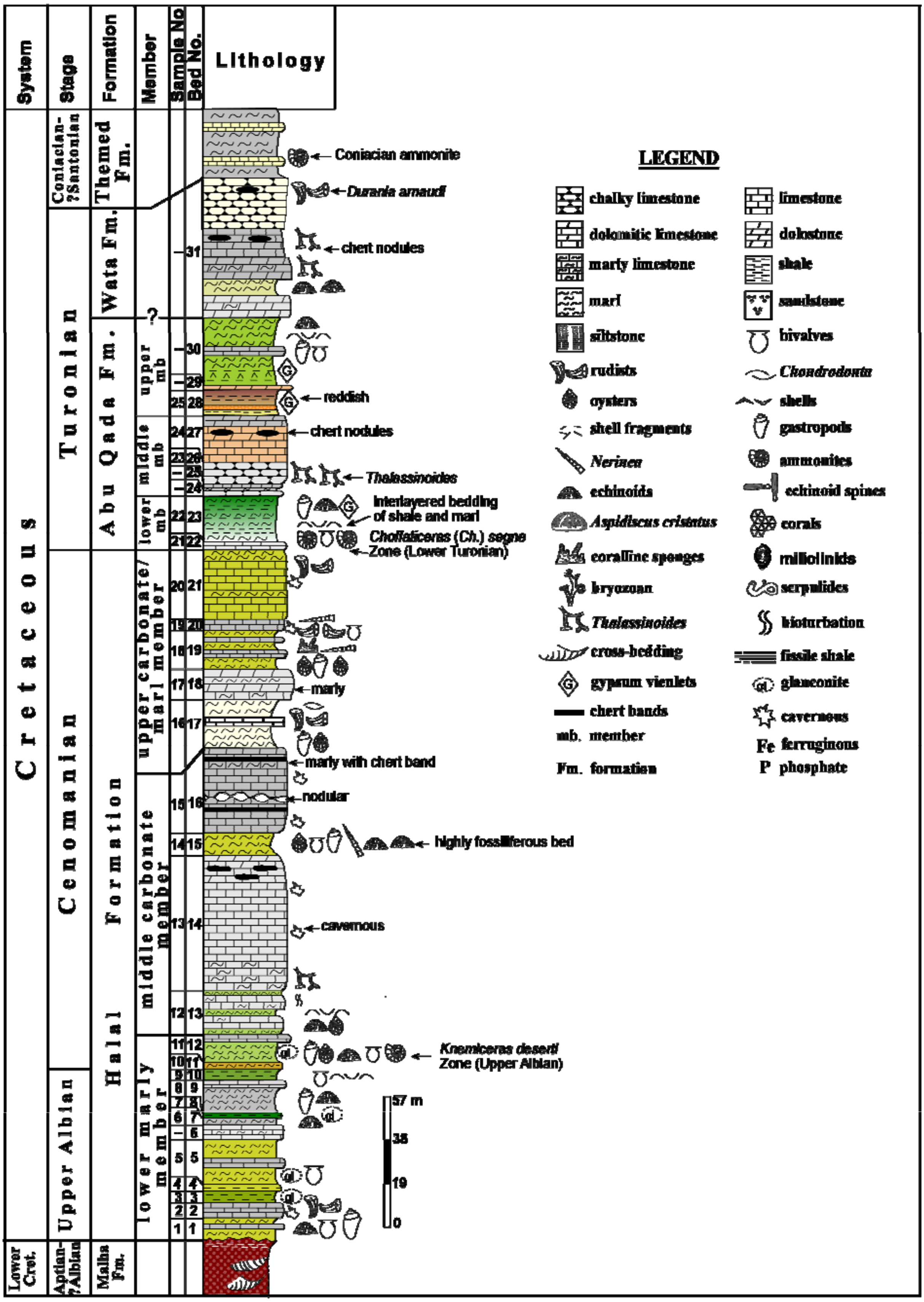


Text-fig. 2.2. Field photographs of the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa. A. Contact with the Lower Cretaceous Malha Formation. B. Large “*Strombus*” *incerta* D’ORBIGNY from the lower member. C. Cavernous limestone in the middle carbonate member. D. Lower chert band from the middle member.

In the study area, the Halal Formation is 301 m thick and is composed mainly of carbonate rocks (about 65% of the total thickness of the formation) which alternate with siliciclastic facies (Text-fig. 2.3). The carbonates are represented by ledge-forming hard limestones, dolostones, and dolomitic limestones, while the terrigenous siliciclastics are represented by marl, shale, and sandy shale. The marly beds contain numerous bivalves, gastropods, and echinoids (see Appendix A for detailed faunal list).

Three informal members based mainly on lithologic features have been recognized in the course of the present investigation (Text-fig. 2.3). These are as follows:

The *lower marly member* attains about 90 m in thickness and is mainly composed of marl and shale (73% of the total thickness of the member). The marly beds are yellow to yellowish-grey, soft, highly fossiliferous, and contain intercalations of hard limestone and dolomitic limestone beds, while the shales are yellowish-green to green, glauconitic, sandy in some parts, and poorly fossiliferous. The limestone and dolomitic limestone interlayers are yellowish-grey in colour, hard – sometimes too hard for breaking up by hammer -, bioturbated with *Thalassinoides* and dissected by vertical fissures. This member starts with highly

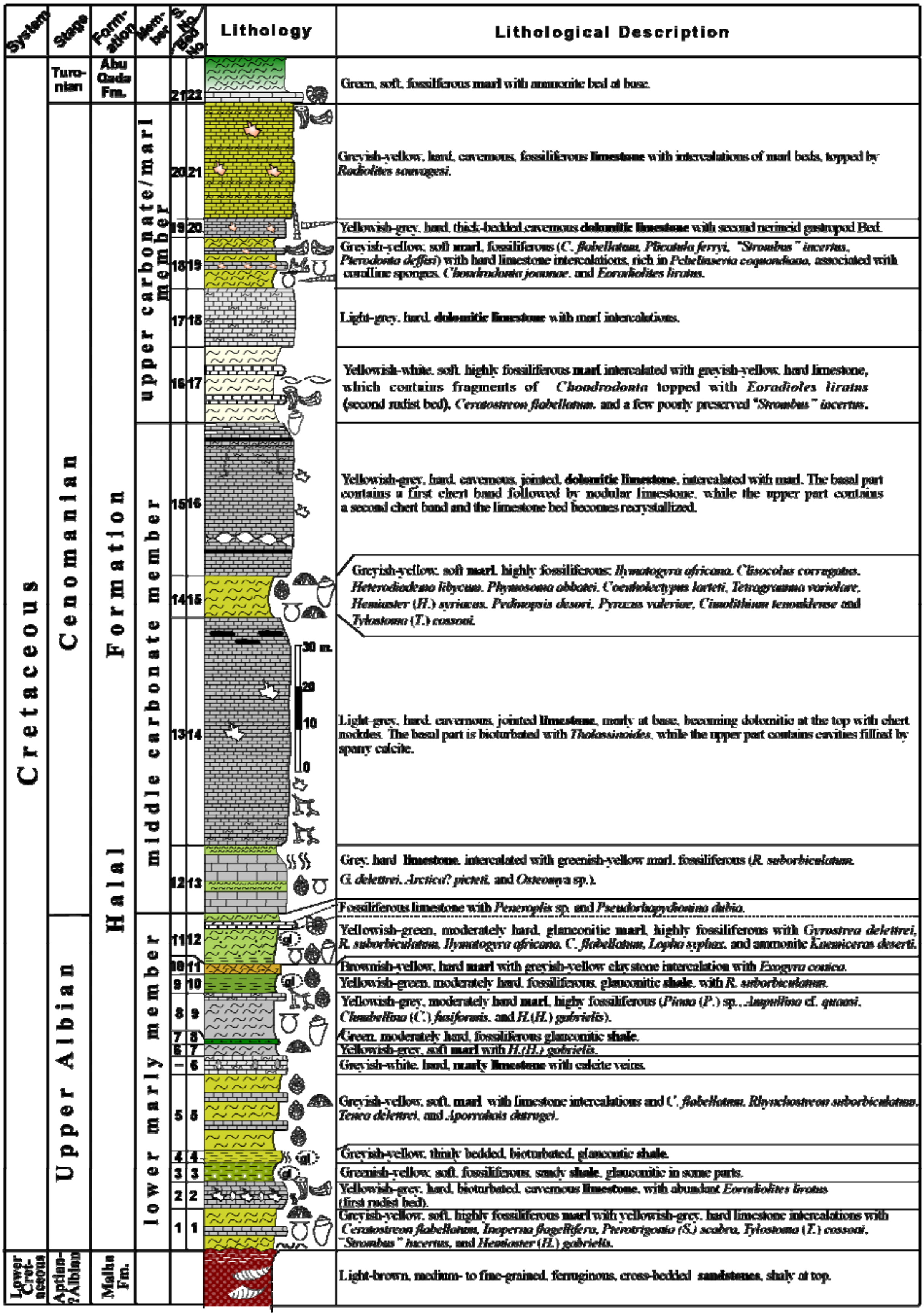


Text-fig. 2.3. Lithostratigraphic section through the Cenomanian-Turonian succession at Gebel Areif El-Naqa area. (all different colours refer to the relatively natural colours in the section).

fossiliferous marl, which contains shell fragments, small-sized and randomly oriented oysters with echinoids and composite moulds of the gastropod "*Strombus*" *incertus* (Text-fig. 2.2B). This oyster horizon is followed by the first rudist horizon (*Eoradiolites liratus*) in yellowish-grey, hard, fossiliferous limestone. The fossiliferous member contains many bivalves such as *Inoperna flagellifera* (FORBES), *Modiolus* (*M.*) *aequalis* (J. SOWERBY), *Mytiloides concentricus* (PARKINSON), the gastropopds e.g., *Cimolithium tenouklense* (COQUAND), *Columbellina* (*C.*) *fusiformis* DOUVILLÉ, and *Pterodonta deffisi* THOMAS & PERON.

The *middle carbonate member* attains a thickness of about 130 m. The member is made up of two carbonate units (accounting for 90 % of the total thickness of the member), separated by greyish-yellow, soft, highly fossiliferous marl (Text-fig. 2.4). These carbonate rocks are represented by limestone and dolomitic limestone, which are partly recrystallized. The lower carbonate unit is characterized by a light-grey, hard, jointed, cliff-forming, cavernous limestone (Text-fig. 2.2C), which is marly and bioturbated by *Thalassinoides* in the lower part of the unit. In contrast, the upper part shows cavities filled with sparry calcite and discontinuous chert nodules. The upper carbonate unit is represented by greyish-yellow, hard, cavernous, jointed limestone, which is dolomitized in the upper part and shows a nodular appearance in the lower part. The unit contains two continuous chert bands, one of them occurring in the lower part and another one in the upper part (Text-fig. 2.2D). The marly bed, which separates the two carbonate units, is fossiliferous containing the bivalves such as *Nayadina gaudryi* THOMAS & PERON, *Ceratostreon flabellatum* (GOLDFUSS), *Rhynchostreon suborbiculatum* (LAMARCK), the echinoids *Pedinopsis desori* (COQUAND), *Tetragramma variolare* (BRONGNIART), *Heterodiadema libycum* (AGASSIZ & DESOR), *Coenholectypus larteti* (COTTEAU) and large internal moulds of gastropods such as *Ampullina* (*Ampullina*) *abeihensis* (HAMLIN), *Aporrhais dutrugei* (COQUAND), and *Harpagodes heberti* (THOMAS & PERON), (see Appendix A for a detailed faunal list).The *upper carbonate/marl member* is 81 m thick and is composed mainly of carbonate rocks, represented by fossiliferous limestone and dolomitic limestone (66% of the total thickness of the member). The rest of the succession is represented by marl (Text-fig. 2.4). The member starts with yellowish-white, soft, highly fossiliferous marl, with two intercalated ledges of greyish-yellow, hard, fossiliferous limestones (second rudist horizon) with *Chondrodonta* fragments. The limestone beds are greyish-yellow, hard, cavernous, fossiliferous, jointed and in some parts marly. The member is characterized by abundant nerineid *Pchelinsevia coquandiana* (D'ORBIGNY, 1842) and coralline sponges associated with *Eoradiolites liratus* (CONRAD), *Pterodonta deffisi* THOMAS & PERON which are especially abundant in the middle part. Three rudist horizons are recognized in the upper carbonate/marl member, one of them occurring in the lower part which is associated with *Chondrodonta joannae* fragments; the second horizon occurs in the middle part and is associated with *P. coquandiana* and coralline sponges; while the third one occurs at the top of the member being characterized by *Radiolites sauvagesi* (D'HOMBRES-FIRMAS) (Text-fig. 2.4).

The Halal Formation is coeval to the Galala Formation as described by ABU KHADRA et al. (1987) from the northern part of the Eastern Desert and by ABDEL-GAWAD & ZALAT (1992), ZIKO et al. (1993), and ISSAWI et al. (1999) from western and central East Sinai. It is also equivalent to the Raha and Abu Qada formations described by GHORAB (1961) from the Gulf of Suez region. The Hazera Formation and the lower part of the Ora Shales from the southern Negev (LEWY, 1996) are mostly equivalent to the Halal Formation (for more information, see Table 2).



Green, soft, fossilferous **marl** with ammonite bed at base.

Greyish-yellow, hard, cavernous, fossiliferous **limestone** with intercalations of marl beds, topped by *Radiolites sauvagesi*.

Yellowish-grey, hard, thick-bedded cavernous **dolomitic limestone** with second nerineid gastropod Bed.

Greyish-yellow, soft **marl**, fossiliferous (*C. flabellatum, Plicatula ferryi, "Strombus" incertus, Pterodonta deffisi*) with hard limestone intercalations, rich in *Pchelinsevia coquandiana*, associated with coralline sponges, *Chondrodonta joannae*, and *Eoradiolites liratus*.

Light-grey, hard, **dolomitic limestone** with marl intercalations.

Yellowish-white, soft, highly fossiliferous **marl** intercalated with greyish-yellow, hard limestone, which contains fragments of *Chondrodonta* topped with *Eoradioles liratus* (second rudist bed), *Ceratostreon flabellatum*, and a few poorly preserved "*Strombus*" *incertus*.

Yellowish-grey, hard, cavernous, jointed, **dolomitic limestone**, intercalated with marl. The basal part contains a first chert band followed by nodular limestone, while the upper part contains a second chert band and the limestone bed becomes recrystallized.

Greyish-yellow, soft **marl**, highly fossiliferous: *Ilymatogyra africana, Clisocolus corrugatus, Heterodiadema libycum, Phymosoma abbatei, Coenholectypus larteti, Tetragramma variolare, Hemiaster (H.) syriacus, Pedinopsis desori, Pyrazus valeriae, Cimolithium tenouklense* and *Tylostoma (T.) cossoni*.

Light-grey, hard, cavernous, jointed **limestone**, marly at base, becoming dolomitic at the top with chert nodules. The basal part is bioturbated with *Thalassinoides*, while the upper part contains cavities filled by spary calcite.

Grey, hard **limestone**, intercalated with greenish-yellow marl, fossiliferous (*R. suborbiculatum, G. delettrei, Arctica? picteti*, and *Osteomya* sp.).

Fossiliferous limestone with *Peneroplis* sp. and *Pseudorhapydionina dubia*.

Yellowish-green, moderately hard, glauconitic **marl**, highly fossiliferous with *Gyrostrea delettrei, R. suborbiculatum, Ilymatogyra africana, C. flabellatum, Lopha syphax*, and ammonite *Knemiceras deserti*.

Brownish-yellow, hard **marl** with greyish-yellow claystone intercalation with *Exogyra conica*.

Yellowish-green, moderately hard, fossiliferous, glauconitic **shale**, with *R. suborbiculatum*.

Yellowish-grey, moderately hard **marl**, highly fossiliferous (*Pinna (P.)* sp., *Ampullina* cf. *quaasi, Cimbellina (C.) fusiformis*, and *H. (H.) gabrielis*).

Green, moderately hard, fossiliferous glauconitic **shale**.

Yellowish-grey, soft **marl** with *H. (H.) gabrielis*.

Greyish-white, hard, marly **limestone** with calcite veins.

Greyish-yellow, soft, **marl** with limestone intercalations and *C. flabellatum, Rhynchostreon suborbiculatum, Tenea delettrei*, and *Aporrhais dutrugei*.

Greyish-yellow, thinly bedded, bioturbated, glauconitic **shale**.

Greenish-yellow, soft, fossiliferous, sandy **shale**, glauconitic in some parts.

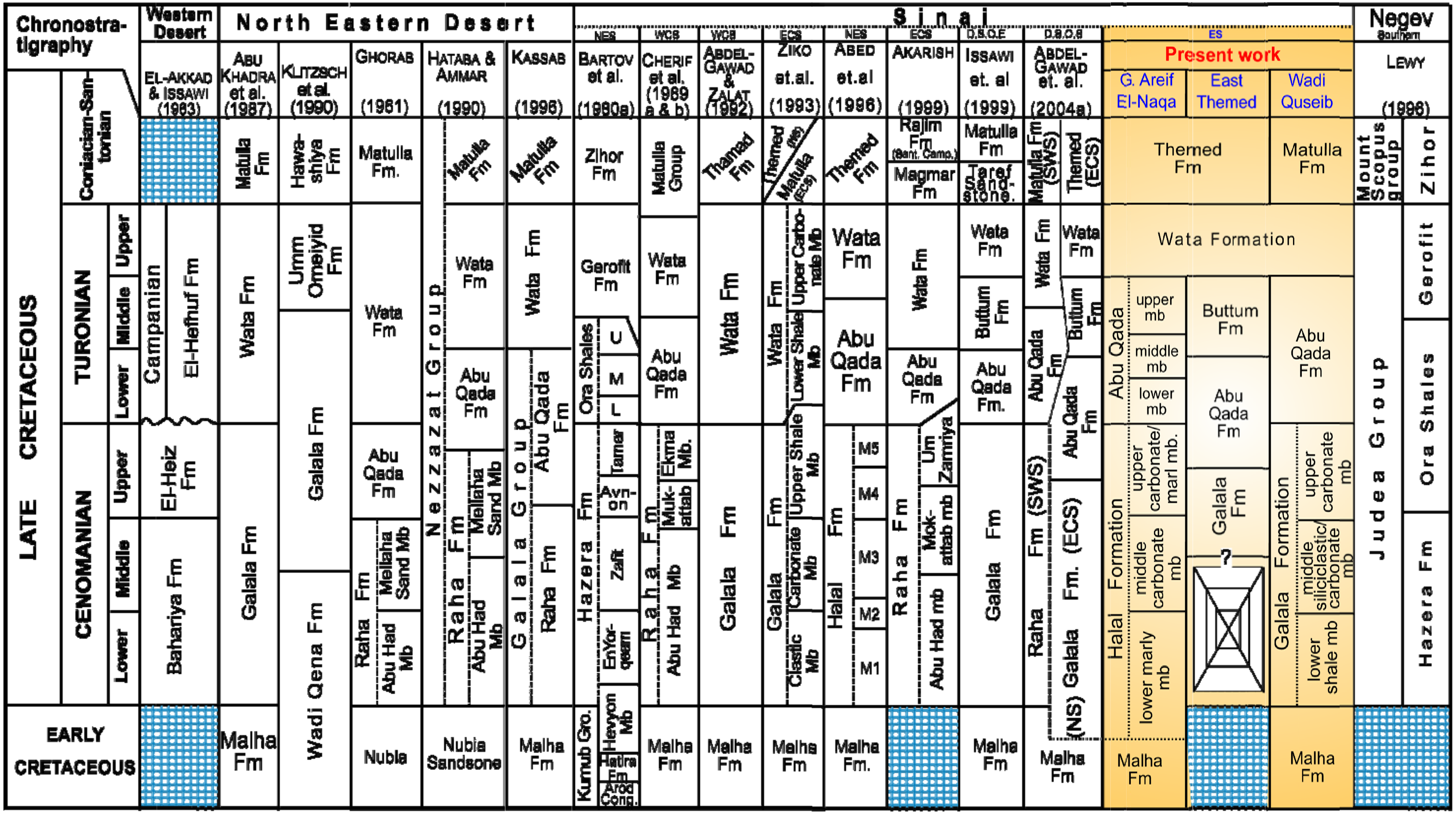
Yellowish-grey, hard, bioturbated, cavernous **limestone**, with abundant *Eoradiolites liratus* (first rudist bed).

Greyish-yellow, soft, highly fossiliferous **marl** with yellowish-grey, hard limestone intercalations with *Ceratostreon flabellatum, Inoperna flagellifera, Pterotrigonia (S.) scabra, Tylostoma (T.) cossoni*, "*Strombus*" *incertus*, and *Hemiaster (H.) gabrielis*.

Light-brown, medium- to fine-grained, ferruginous, cross-bedded **sandstones**, shaly at top.

Text-fig. 2.4. Lithostratigraphy of the Upper Albian-Cenomanian Halal Formation of the Areif El-Naqa section. For symbols see Text-fig. 2.3.

Table 2. Correlation chart of the Cenomanian-Turonian rock units of the study area with those proposed by different authors for various other localities in Egypt.



Region	Author	Units (top to bottom)
Chronostratigraphy		LATE CRETACEOUS: Coniacian-Santonian; TURONIAN (Upper, Middle, Lower); CENOMANIAN (Upper, Middle, Lower) EARLY CRETACEOUS
Western Desert	El-Akkad & Issawi (1963)	Campanian El-Hefhuf Fm El-Heiz Fm Bahariya Fm
North Eastern Desert	Abu Khadra et al. (1987)	Matulla Fm Wata Fm Galala Fm Malha Fm
North Eastern Desert	Klitzsch et al. (1990)	Hawashiya Fm Umm Omeiyid Fm Galala Fm Wadi Qena Fm
North Eastern Desert	Ghorab (1961)	Matulla Fm. Wata Fm Abu Qada Fm Raha Fm: Mellaha Sand Mb, Abu Had Mb Nubia
North Eastern Desert	Hataba & Ammar (1990)	Nezzazat Group: Matulla Fm; Wata Fm; Abu Qada Fm; Raha Fm (Mellaha Sand Mb, Abu Had Mb) Nubia Sandsone
North Eastern Desert	Kassab (1996)	Matulla Fm Wata Fm Galala Group: Abu Qada Fm; Raha Fm Malha Fm
Sinai (NES)	Bartov et al. (1980a)	Zihor Fm Gerofit Fm Ora Shales: U, M, L Hazera Fm: Tamar, Avnon, Zafit, EnYorqeam Kurnub Gro.: Hevyon Mb, Hatira Fm, Arod Cong.
Sinai (WCS)	Cherif et al. (1989 a & b)	Matulla Group Wata Fm Abu Qada Fm Raha Fm: Ekma Mb., Mukattab, Abu Had Mb Malha Fm
Sinai (WCS)	Abdel-Gawad & Zalat (1992)	Thamad Fm Wata Fm Galala Fm Malha Fm
Sinai (ECS)	Ziko et.al. (1993)	Themed (NS) / Matulla (ECS) Wata Fm: Upper Carbonate Mb, Lower Shale Mb Galala Fm: Upper Shale Mb, Carbonate Mb, Clastic Mb Malha Fm
Sinai (NES)	Abed et.al (1996)	Themed Fm Wata Fm Abu Qada Fm Halal Fm: M5, M4, M3, M2, M1 Malha Fm.
Sinai (ECS)	Akarish (1999)	Rajim Fm (Sant. Camp.) Magmar Fm Wata Fm Abu Qada Fm Raha Fm: Um Zamriya, Mokattab mb, Abu Had mb
Sinai (D.S.O.E)	Issawi et. al (1999)	Matulla Fm Taref Sandstone. Wata Fm Buttum Fm Abu Qada Fm. Galala Fm Malha Fm
Sinai (D.S.O.S)	Abdel-Gawad et. al. (2004a)	Matulla Fm (SWS) / Themed (ECS) Wata Fm / Wata Fm Abu Qada Fm / Buttum Fm, Abu Qada Fm Raha Fm (SWS) / (NS) Galala Fm. (ECS) Malha Fm
Present work (ES)	G. Areif El-Naqa	Themed Fm Wata Formation Abu Qada: upper mb, middle mb, lower mb Halal Formation: upper carbonate/marl mb., middle carbonate mb, lower marly mb Malha Fm
Present work (ES)	East Themed	Themed Fm Wata Formation Buttum Fm Abu Qada Fm Galala Fm ?
Present work (ES)	Wadi Quseib	Matulla Fm Wata Formation Abu Qada Fm Galala Formation: upper carbonate mb, middle siliciclastic/carbonate mb, lower shale mb Malha Fm
Negev Southern	Lewy (1996)	Mount Scopus group: Zihor Judea Group: Gerofit; Ora Shales; Hazera Fm

NES= NORTH-EASTERN SINAI WCS= WEST-CENTRAL SINAI SWS= SOUTH-WEST SINAI D.S.O.S= DIFFERENT SECTIONS OF SINAI NED= NORTH-EASTERN DESERT
D.S.O.E= DIFFERENT SECTIONS OF EGYPT ECS= EAST-CENTRAL SINAI NS= NORHT SINAI Fm= Formation mb= Member ☒ not exposed

BARTOV et al. (1980a) described an upper Albian to Cenomanian section of the Hazera Formation (=Halal Formation) overlying the Hatira Formation (=Malha Formation) in the Gebel Areif El-Naqa section. They divided this formation (307 m thick) into five members, which are represented by limestone, dolomite, and fossiliferous marl with minor amounts of chert. They assumed, without evidence, a Late Albian age for the lower member (141 m thick) of the Hazera Formation. The overlying two members were assigned to the early Cenomanian, the upper two members to the late Cenomanian. However, AYYAD et al. (1996) recorded *Rotalipora brotzeni* (SIGAL) from the first member of the Halal Formation at the Gebel Arief El-Naqa section. This species is restricted to the Early Cenomanian (BOLLI, 1966; ROBASZYNSKI & CARON, 1979; CARON, 1985) and is the index species of the *Rotalipora brotzeni* Zone. In the present study, the lower part of the Halal Formation (about 75 m of marl, shale, and limestone) is assigned certainly to the Upper Albian according to the Upper Albian ammonite *Knemiceras deserti* Zone and inoceramid *Mytiloides concentricus* Total Range Zone.

Abu Qada Formation

The Abu Qada Formation was introduced by GHORAB (1961) for the brownish-grey marly succession (24 m thick, Late Cenomanian) exposed above the Mellaha Sand Member of the Raha Formation at Wadi Abu Qada, west-central Sinai. The marine Turonian rocks exposed in northern Egypt are conformably overlying the Cenomanian rocks and are truncated unconformably by Coniacian siliciclastic beds (ABDEL-GAWAD, 1999: 99).

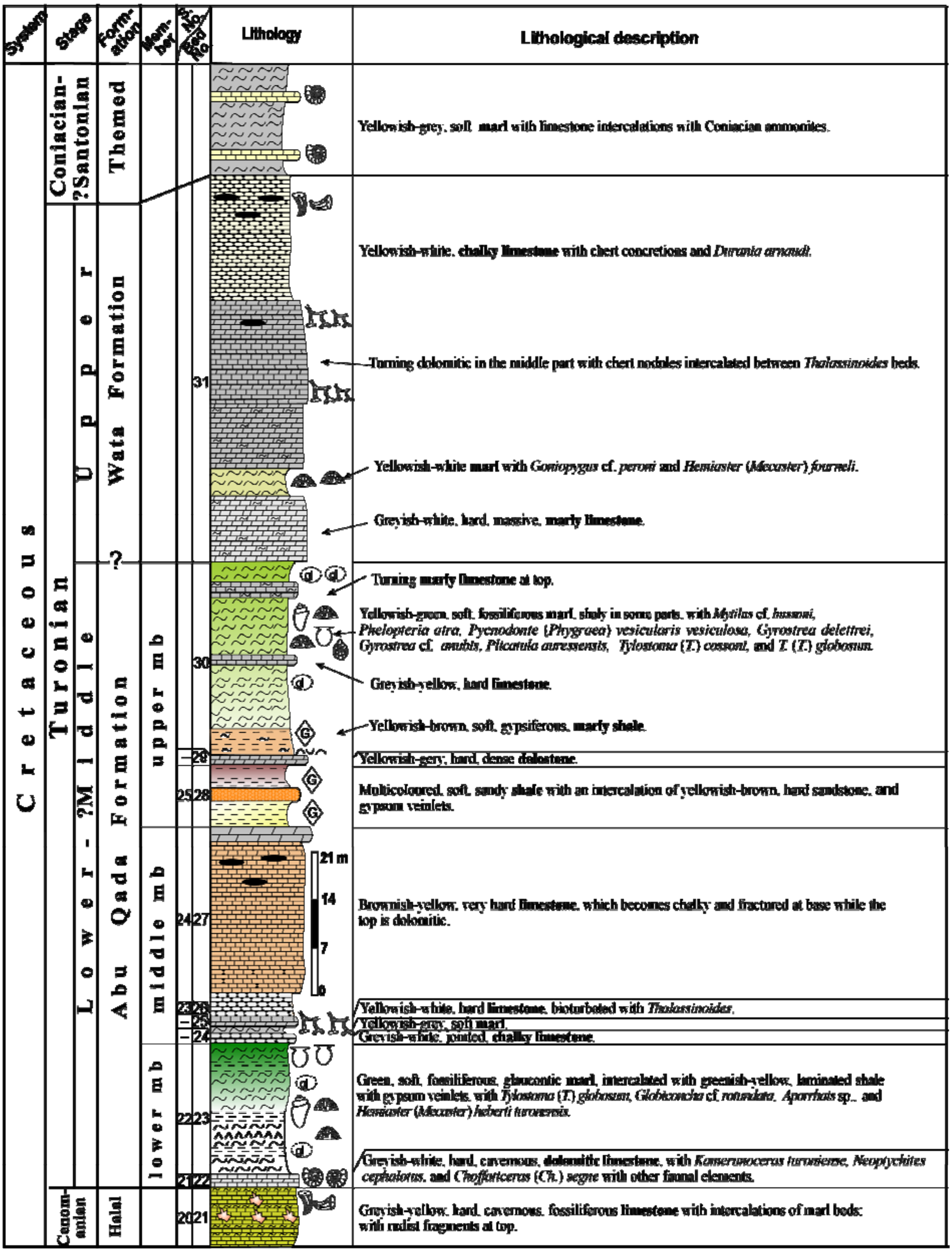
In the study area, the Abu Qada Formation is easily distinguished in the field by its characteristic green fossiliferous marls and shales, which are interbedded with limestone and marly limestone. It is about 96 m thick and can be divided into three informal members. The formation mainly consists of marl and shale (lower and upper members) separated by thick-bedded limestone and chalky limestone (middle member) (Text-fig. 2.5).

The *lower member* is about 22 m thick. The basal part of the member consists mainly of faulted greyish-white, very hard, cavernous, dolomitic limestone which contains densely packed ammonites of lower Turonian age (Ammonite Bed) (Text-figs. 2.6A, D-E). The overlying bed is green, soft, gypsiferous, fossiliferous, glauconitic marl, intercalated with greenish-yellow, laminated shale (Text-fig. 2.6B). The upper part of the member is rich in oysters and contains a few poorly preserved gastropods and echinoids (Appendix A). The lower member is dissected by a conspicuous normal fault (Text-fig. 2.6A).

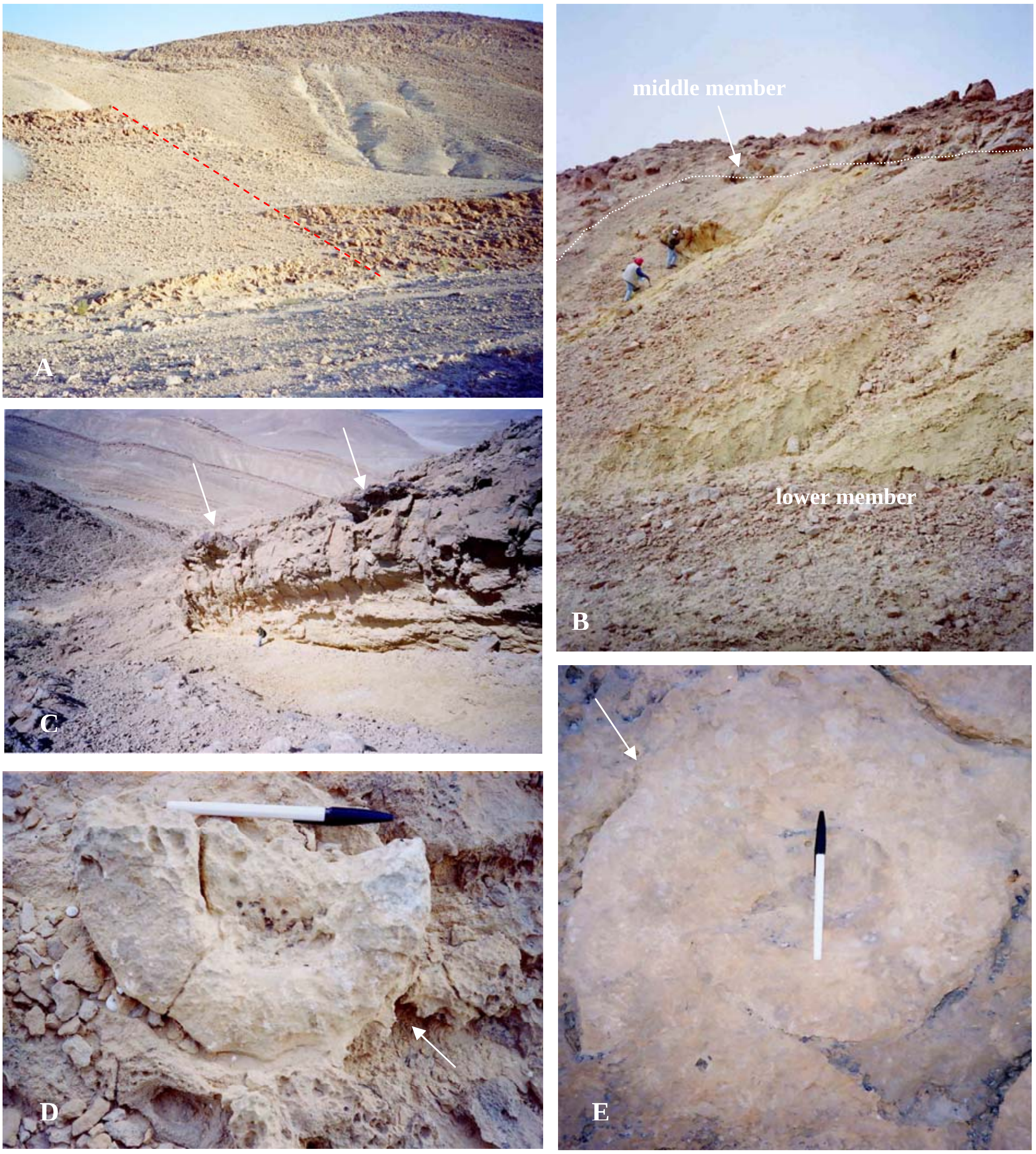
The *middle member* is about 33 m thick and predominantly composed of brownish-yellow, very hard, jointed, cavernous limestone (Text-fig. 2.5). This massive limestone becomes dolomitic in the upper part, showing thin discontinuous chert bands (Text-fig. 2.6C). The lower part of the member in contrast consists of greyish-white chalky limestone, which is followed by hard bioturbated limestone (*Thalassinoides*).

The *upper member* with a thickness of about 41 m is composed mainly of marl and shale with subordinately occurring limestone and dolostone interbeds. The member starts with multicoloured, soft shale, with intercalations of yellowish-brown sandstone with gypsum veinlets, followed by yellowish-grey, hard, dense dolostone. The upper marly beds are yellowish-green in colour, soft, fossiliferous, shaly in the basal part, and exhibit intercalations of greyish-yellow hard limestone. The upper part of the member is rich in clusters of *Gyrostrea* cf. *anubis* MALCHUS.

The macrofauna of the Abu Qada Formation consists of the bivalves *Mytilus* cf. *bussoni* COLLIGNON, *Phelopteria atra* (COQUAND), *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. DE C. SOWERBY), *Gyrostrea delettrei* (COQUAND), the gastropods *Tylostoma* (*T.*) *globosum* SHARPE, *Palaeatractus* cf. *figarii* (GRECO), the ammonites *Kamerunoceras* *turoniense* (D' ORBIGNY), *Choffaticeras* (*Ch.*) *segne* (SOLGER), and the echinoids *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU, 1921 (for detailed faunal list, see Appendix A).



Text-fig. 2.5. Litholog of the Turonian Abu Qada and Wata formations of Gebel Areif El-Naqa.



Text-fig. 2.6. Field photographs of the Abu Qada Formation (Lower-?Middle Turonian). A. The faulted basal part of the formation (normal fault). B. Green, fossiliferous marl of the lower member. C. Discontinuous chert bands (arrowed) in the middle member of the formation. D. Large ammonite *Kamerunoceras turoniense* (d'Orbigny). E. Large internal mould of *Choffaticeras* (*Ch.*) *segne* (Solger).

Some workers considered the Abu Qada Formation to belong to the Late Cenomanian (Ghorab, 1961; Galal & Nafae, 2003), but the majority of workers assigned it to the Early Turonian. However, Abdel-Gawad & Zalat (1992) and Ziko et al. (1993) assigned the Lower and Middle Turonian deposits of west Sinai to the Wata Formation and ignored the Abu Qada Formation (Table 2). The Abu Qada Formation is coeval with the upper part of the Galala Formation and the lower part of the Umm Omeiyid Formation as described by Klitzsch et al. (1990) from the northern Eastern Desert. It can also be correlated with the Lower Shale Member of the Wata Formation described by Ziko et al. (1993) in the Themed area, central-east Sinai. The Ora Shale and the lower part of the Gerofit Formation described by BARTOV et al. (1980a) at Gebel Areif El-Naqa, northeastern Sinai, is also equivalent to the present formation (Table 2).

The Cenomanian-Turonian boundary in Gebel Areif El-Naqa is drawn in the lower part of the Abu Qada Formation between the extinction of Cenomanian oysters and the appearance of early Turonian ammonites. This Ammonite Bed overlies the Cenomanian rudist-bearing beds of the upper part of the Halal Formation. In agreement with BARTOV et al. (1980a), the absence of the earliest Turonian biozones indicates that the study area was a structural high during that time. BAUER et al. (2001) noted that the first appearance of the late Early Turonian ammonites immediately above the Cenomanian deposits is a good indicator of a hiatus between the Cenomanian and Turonian deposits (Table 1).

ABDEL-GAWAD (1999) recorded the “Red Beds” facies in west-central Sinai, which unconformably overlies the Ammonite Marl facies in the Nezzazat section. The “Red Beds” facies is characterized by reddish-brown, yellow and grey sandstones with intercalations of claystone and siltstone. In the Areif El-Naqa section, this red bed succession which contains up to 1m thick gypsiferous beds (BARTOV et al., 1980a: 122, fig. 8a), was deposited in supratidal and lagoonal environments. In the investigated section this unit is only 1 m thick, representing the upper member of the Abu Qada Formation. It is composed mainly of multicoloured, soft, unfossiliferous sandy shales with intercalations of yellowish-brown sandstones with gypsum veinlets.

Wata Formation

The term Wata Formation was first introduced by GHORAB (1961) at the type locality Wadi Wata, Raha Plateau in west Sinai, where it overlies the Abu Qada Formation and underlies the Matulla Formation. In the study area, however, it is conformably overlain by yellowish-grey, fossiliferous marls with ammonites of the Coniacian-Santonian Themed Formation and conformably underlain by the yellowish-green, soft, fossiliferous marls of the Lower Turonian Abu Qada Formation (Text-fig. 2.5).

The Wata Formation is about 60 m thick and can easily be distinguished from the underlying Abu Qada Formation by its thick-bedded (cyclically bedded), cliff-forming chalky limestones with chert nodules, dolomitic limestones, and hard limestones (Text-fig. 2.7). Its lower part is predominately built up of greyish-white, hard, massive, marly limestones intercalated with yellowish-white marls. The limestones are locally dolomitic, bioturbated with *Thalassinoides,* and contain the echinoid *Hemiaster* (*Mecaster*) *fourneli* DESHAYES, concentrated in the middle part of the formation. In contrast, the upper part of the Wata Formation is a bedded, yellowish-white chalky limestone with chert nodules and rudists (Text-fig. 2.5).

Fossils are rare in this formation and are represented by the rudist *Durania arnaudi* (CHOFFAT) and the echinoids *Goniopygus* cf. *peroni* THOMAS & GAUTHIER and *Hemiaster* (*M.*) *fourneli*.

The upper part of the Gerofit Formation as described by BARTOV et al. (1980a) and LEWY (1996) from Gebel Areif El-Naqa and southern Negev respectively is equivalent to the present formation (see Table 2). It is coeval with the upper part of the Umm Omeiyid Formation as described by KLITZSCH et al. (1990) from the northern Eastern Desert. It can also be correlated with the upper part of El-Hefhuf Formation from the Western Desert by El-AKKAD & ISSAWI (1963).

Text-fig. 2.7. Panorama showing the cyclically bedded limestones of the Upper Turonian Wata Formation at Gebel Areif El- Naqa.

2.4 East Themed area

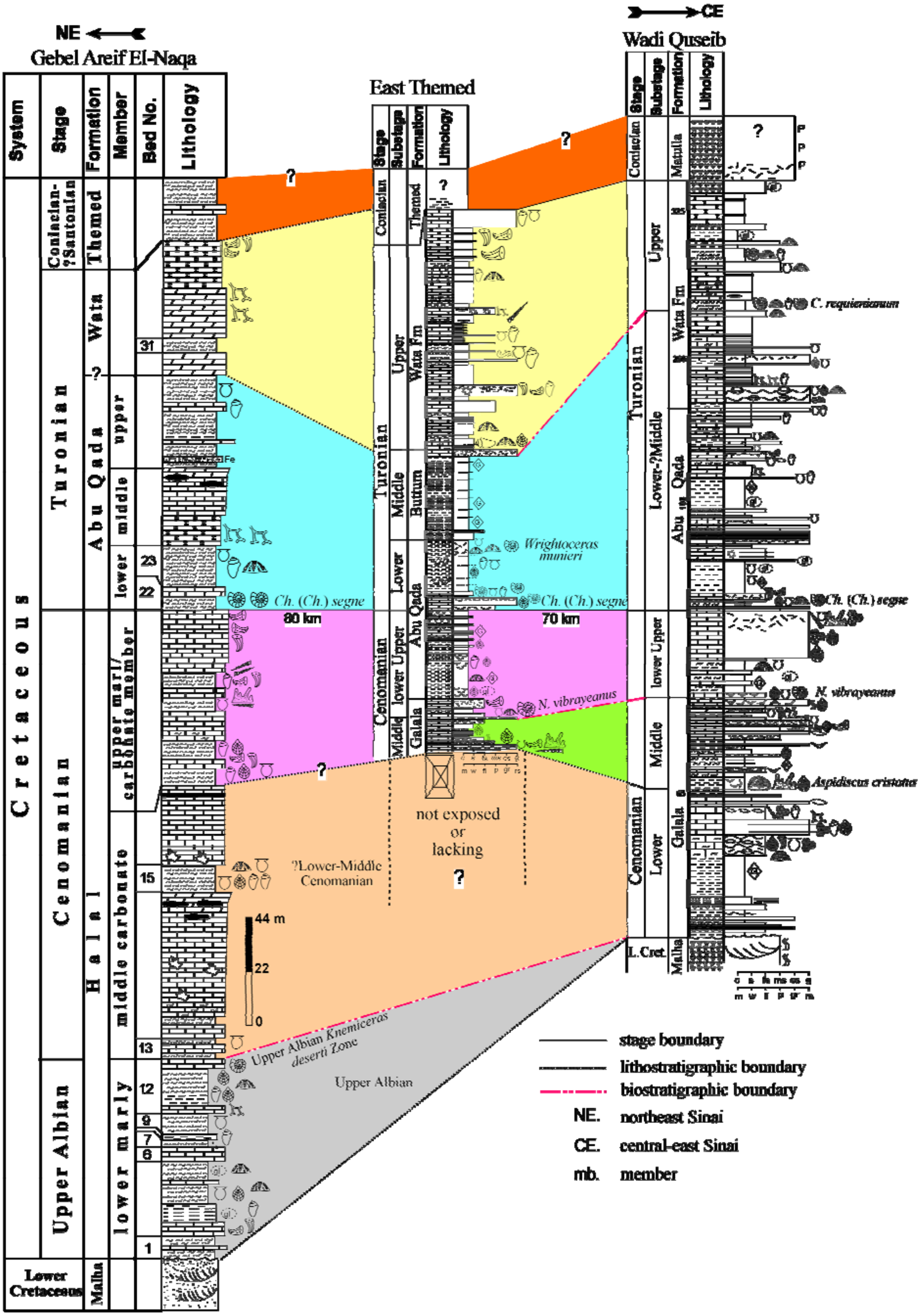
The Cenomanian and Turonian deposits, exposed in the East Themed area, are 239 m thick and subdivided into four formations which are from older to younger: Galala (Middle-lower Upper Cenomanian), Abu Qada (Upper Cenomanian-Lower Turonian), Buttum (Middle Turonian), and Wata formations (Upper Turonian) (Table 1). In the following paragraphs, each rock unit will be discussed in detail starting with the oldest.

Galala Formation

The term Galala Formation was introduced by ABDALLAH & ADINDANI (1963) on the west coast of the Gulf of Suez. The formation is composed mainly of gypsiferous shale, marl, and marly limestone in various colours. It is characterized by a higher carbonate content than the Raha Formation of west-central Sinai as described by GHORAB (1961), but contains less carbonate than the Halal Formation of north Sinai (SAID 1971). The carbonate content of the Halal Formation at Gebel Areif El-Naqa (northern Sinai) is higher than in the Galala Formation of Wadi Quseib and also in the exposed part of the same formation in the East Themed area, central East Sinai (Text-fig. 2.8).

According to ABDEL-GAWAD et al. (2004a: 266) and EL QOT (2006: 11), the Galala Formation overlies the Lower Cretaceous Malha Formation at Gebel Khashm El-Tarif of the East Themed area (about 15 km from the present section) and consists mainly of dolomitic limestone and argillaceous limestone with marl and a few shale-siltstone interbeds. According to them, the lower part is represented by marl and dolomitic nodular limestone with poorly preserved bivalve and gastropod moulds. This part may represent the ?Lower Cretaceous-Early/Middle Cenomanian (transition unit), and the Galala Formation would be then ?Early Cretaceous-Late Cenomanian in age. In the present study, the basal part of the Galala Formation is not exposed and it is questionable, whether the Lower Cenomanian deposits occur.

The exposed part of the Galala Formation is 22.5 m thick and composed mainly of grey to yellowish grey, hard, fossiliferous limestone (floatstone to rudstone) with intercalations of shales and marls. The marly beds are yellowish-green, soft, fossiliferous, topped by thin gypsum layers (5 cm), and followed by thinly-bedded, sandy wackestones (Text-figs. 2.9A-B, 2.10).

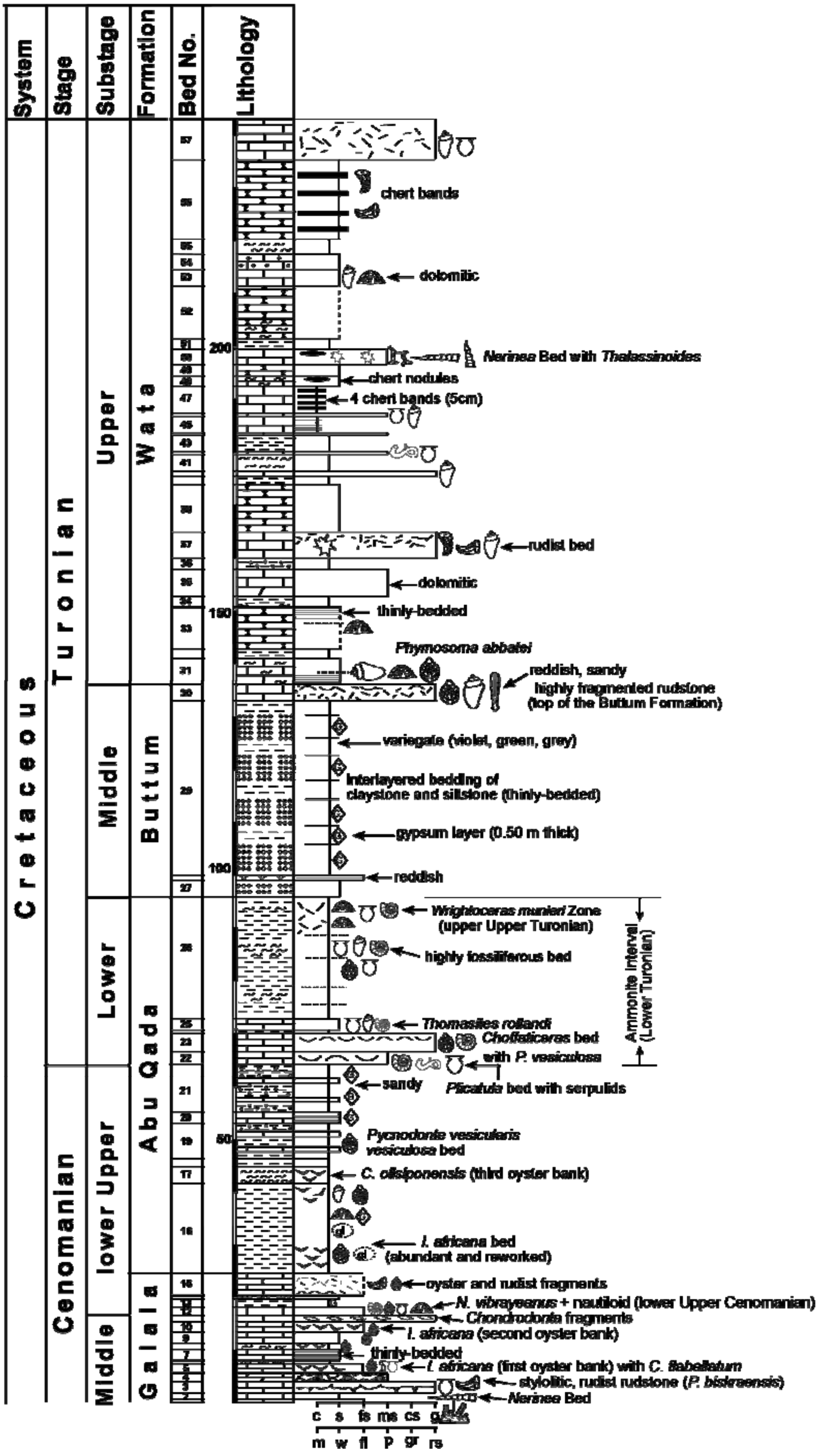


Text-fig. 2.8. Lithostratigraphic and biostratigraphic correlation of the three sections. The lithostratigraphic scale is applied to the East Themed and Wadi Quseib sections only.

The lower 3 m are yellowish-white to grey, hard, weathered, marly wackestone, to be followed with sharp contact by very hard, stylolitic, dolomitic rudist rudstone (Text-figs. 2.9F, 2.10). This part yields globular coralline sponges (*Actinostromarianina* sp.) and *Pchelinsevia coquandiana* (D'ORBIGNY, 1842) at the base (marly wackestone), topped by *Praeradiolites biskraensis* (COQUAND) with *Chondrodonta* fragments (Text-figs. 2.9C-E).

Text-fig. 2.9. Field photographs of the upper part of the Cenomanian Galala Formation at the East Themed area. A. Thin gypsum layer (5 cm) (arrowed) above the oyster bank. B. First oyster bank followed by thinly-bedded limestone. C. Contact between marly limestone with nerineid gastropods at the base and hard dolomitic limestone with rudists at top. D. External moulds of *Pchelinsevia coquandiana* (D'ORBIGNY, 1842). E. *Praeradiolites biskraensis* (COQUAND) (arrowed). F. Rudist fragments and longitudinal section of gastropod (rudist rudstone). G. Clumped oyster *Ilymatogyra africana* (LAMARCK) (second oyster bank) with the ichnogenus *Entobia* BRONN in some left valves. H. Part of the trace fossil *Thalassinoides*. I. *Neolobites vibrayeanus* (D'ORBIGNY) (lower Upper Cenomanian ammonite zone).

The latter nerineid-rudist bed is followed by two oyster banks; with the first one (1.5 m thick) being represented by *Ilymatogyra africana* (LAMARCK) and *Ceratostreon flabellatum* (GOLDFUSS). The basal 0.5 m of the bank contains *C. flabellatum*, followed by 0.5 m of *I. africana* shell fragments with *Thalassinoides* (Text-fig. 2.9H). The upper half meter is rich in *I. africana*. The second oyster bank is also rich in *I. africana* (at 12 m from the section base) in yellowish-grey, moderately hard fossiliferous floatstone (Text-fig. 2.9G). The upper 25 cm of the second bank contains a reddish horizon with thin gypsum layers (5 cm) which is interpreted as paleosoil. Like the first oyster bank, the lower part (1 m) contains also *C. flabellatum*, albeit fragmented. Some of the oyster valves in both banks exhibit borings of the ichnogenus *Entobia* BRONN, 1837 (Text-fig. 2.9G). The upper part of this formation is represented by white,

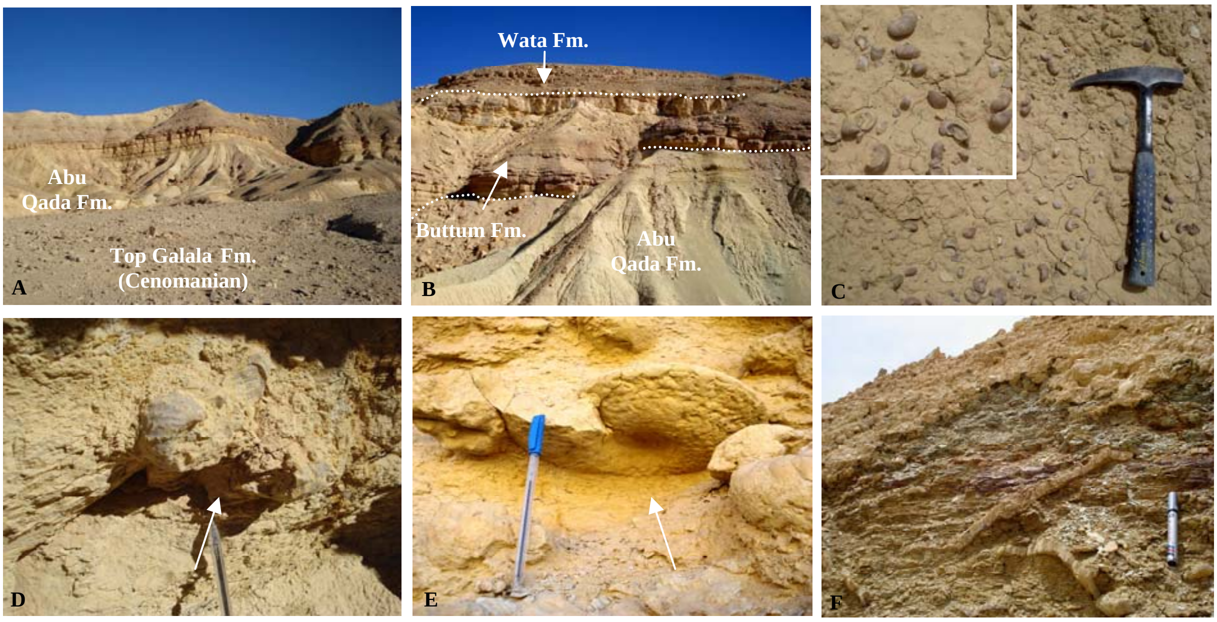


Text-fig. 2.10. Detailed lithology of the Cenomanian and Turonian succession of the East Themed area.

hard, marly floatstone, which contains the ammonite *Neolobites vibrayeanus* (D’ORBIGNY) and the nautiloid *Angulithes mermeti* COQUAND (lower Upper Cenomanian ammonite zone, see the biostratigraphic part, page 277) (Text-fig. 2.9I). This ammonite zone is associated with other faunal elements such as the bivalves *Nuculana* (*Nuculana*) sp., *Pseudolima itieriana* (PICTET & ROUX), and *Granocardium* (*G.*) *productum* (J. DE C SOWERBY), the gastropods *Campanile* (*Campanile*) *ganesha* (NOETLING), *Tylostoma* (*T.*) *pallaryi* (PERON & FOURTAU), and as well as the echinoid *Hemiaster* (*H.*) *syriacus* (CONRAD) (for more faunal elements, see Appendix A).

Abu Qada Formation

The Abu Qada Formation attains a thickness of 70 m which conformably overlies the Cenomanian Galala Formation and underlies the Buttum Formation (Middle Turonian) (Text-figs. 2.11A-B). It is composed mainly of shale with limestone and marly intercalations (Text-fig. 2.10). The formation starts with 17 m of greyish-green, soft, highly fossiliferous, glauconitic shale with thin gypsum veinlets. It contains abundant *Ilymatogyra africana* in the lower 3 m (reworked) which decrease upward in numbers (Text-figs. 2.11C), together with other faunal elements such as *Ceratostreon flabellatum*, *Rhynchostreon suborbiculatum*, and *Granocardium* (*G.*) *productum*. The latter bed is followed by a third oyster bank which is represented by *Costagyra olisiponensis* (SHARPE) with few *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. DE C. SOWERBY), and *Neithea* (*Neithea*) *dutrugei* (COQUAND) in yellowish grey marl (Text-fig. 2.11D). The *olisiponensis* bed is topped by varicoloured shale with thin gypsum bands (Text-fig. 2.11F).



Text-fig. 2.11. A. Contact between the Cenomanian Galala Formation and the Upper Cenomanian-Lower Turonian Abu Qada Formation. B. Contact between the Abu Qada and Buttum formations. C. Abundance of *Ilymatogyra africana* of the lower part of the Abu Qada Formation. D. *Costagyra olisiponensis* (SHARPE) in life position. E. large *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER). F. Varicoloured shale with thin gypsum layers. All photographs are taken from the Abu Qada Formation at the East Themed section.

The middle part of the Abu Qada Formation consists of yellowish-white, moderately hard, fossiliferous limestone rich in ammonites (e.g., *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK) and *Choffaticeras* (*Ch.*) *segne* (SOLGER); Text-fig. 2.11E). Other faunal elements include *Plicatula* (*P.*) *auressensis* COQUAND, *Hemiaster* (*Mecaster*) *heberti turonensis* FOURTAU, and *Thalassinoides*. The upper 23 m are yellowish-grey, moderately hard shale/marl alternations which interfinger with thin gypsum layers. The marly beds are highly fossiliferous, the diverse fauna consisting of bivalves, gastropods, ammonites, and echinoids (see Appendix A for a detailed faunal list). The topmost part of the Abu Qada Formation contains the upper Lower Turonian ammonite zone, indicated by *Wrightoceras munieri* (PERVINQUIÈRE).

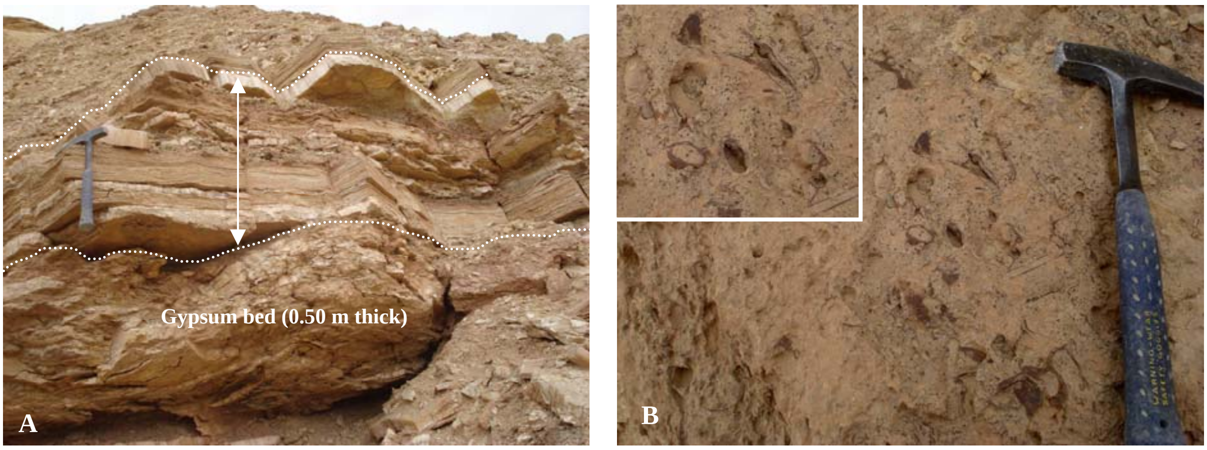
The Cenomanian-Turonian boundary in the East Themed area is detected by the first appearance of Lower Turonian ammonites such as *Choffaticeras* (*Ch.*) *securiforme*, *Ch.* (*Ch.*) *segne*, and *Vascoceras durandi*.

In the East Themed and Wadi Quseib sections, the siliciclastic content (shale and marl) of the Abu Qada Formation remarkably increases, whereas the carbonate content increases towards northern Sinai (platform carbonates) as can be observed in the Gebel Areif El-Naqa section (Text-fig. 2.8).

Buttum Formation

The term Buttum Formation was introduced by ISSAWI et al. (1999) for the strata at Wadi El-Buttum of eastern Sinai. According to these authors, it is composed mainly of 15 m of crystalline gypsum alternating with shale and sandy silt beds and belongs to the middle part of the Turonian. ISSAWI et al. (1999) noted that the Buttum Formation indicates very shallow lagoonal or sabkha deposits of a tidal flat (regressive phase linked with a climate change to arid conditions). The overlying Wata and underlying Abu Qada formations completely differ in lithology from the Buttum Formation. For this reason, ISSAWI et al. (1999) separated this unit as a new formation. In the present study, the formation was found to be 40 m thick, consisting mainly of variegated gypsum/claystone intercalations (Text-figs. 2.10).

The Buttum Formation starts with a massive siltstone, which is followed by reddish, thinly-bedded, hard, ferruginous, fine-grained sandstone (about 1 m). The upper 33 m of this formation contain shale and massive gypsum layers of 0.5 m thickness (Text-fig. 2.12A) with intercalations of claystone and siltstone. The fibrous gypsum layers are avoid of a nodular and chicken wire structure typical of a sabkha facies, but show instead a laminated fabric. They are therefore interpreted to have precipitated subaqueously in a lagoonal environment. The topmost part of the formation (3 m thick) is a brownish, ferruginous, highly fragmented oyster rudstone (Text-fig. 2.12B). It is equivalent to the upper member of the Abu Qada Formation at Gebel Areif El-Naqa. The red bed facies of the upper member of the Abu Qada Formation at Gebel Nezzazat described by ABDEL-GAWAD (1999: 104, fig. 2) is also equivalent to the present formation. The Buttum Formation lacks any macrofauna and is considered to be Middle Turonian in age based on its stratigraphic position.

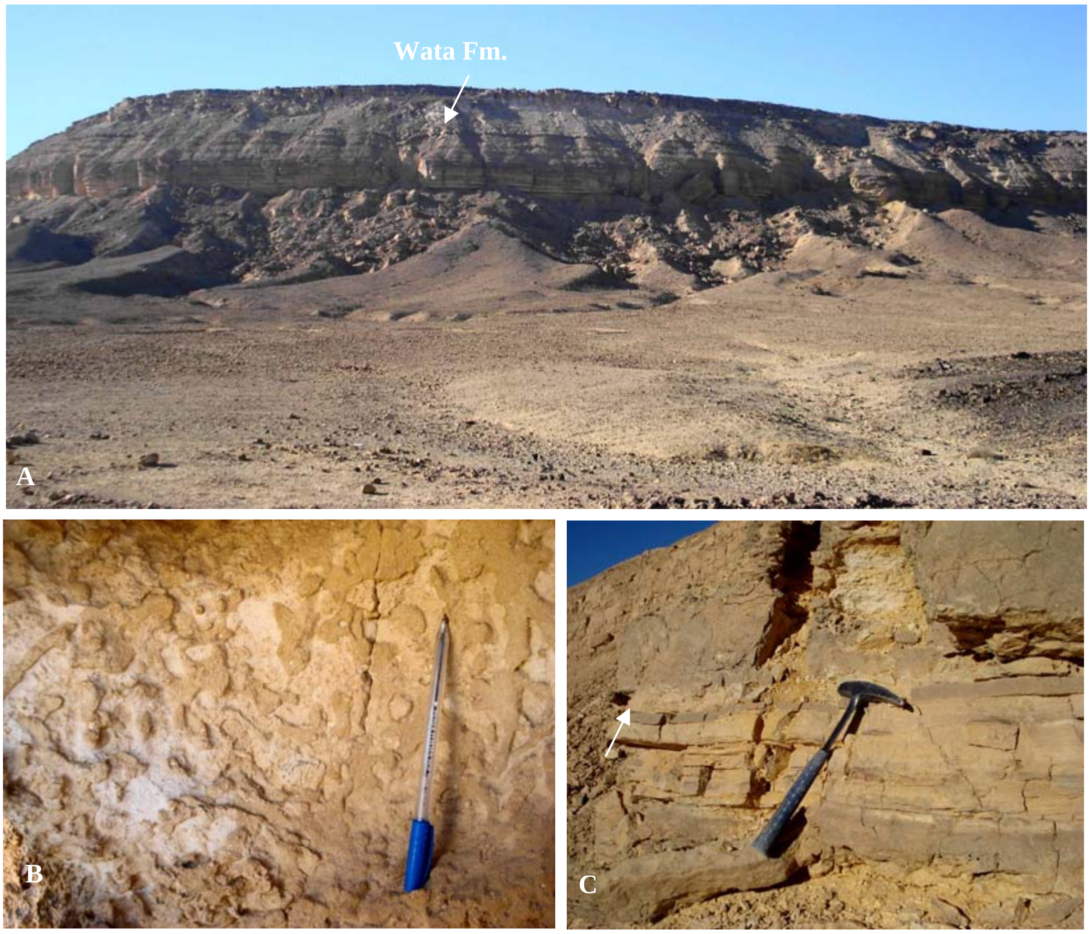


Text-fig. 2.12. Buttum Formation in the East Themed area. A. Fibrous gypsum bed (0.5 m thick). B. Reddish, highly fragmented oyster rudstone (topmost part of the formation).

Wata Formation

In the present study, the Wata Formation conformably overlies the Buttum Formation and is 106.5 m thick (Text-fig. 2.10). It is composed mainly of thick-bedded carbonate rocks with minor intercalations of shale and marl. The carbonate rocks are represented by chalky limestone (most common) (Text-fig. 2.13A) and hard, dolomitic, partially argillaceous limestone (e.g. rudist rudstone). Some conspicuous chert bands occur in the middle and upper parts (Text-fig. 2.13C). The marl and shale content of the Wata Formation in the East Themed section as well as in the Wadi Quseib section decreases towards the north as seen in the Gebel Areif El-Naqa section, north-east Sinai (Text-fig. 2.8). The most common faunal elements include the bivalve *Cucullaea* (*Idonearca*) *trigona* (SEGUANZA), the gastropods *Tylostoma (T.) globosum* and nerineid gastropods, and the echinoids *Phymosoma abbatei* (GAUTHIER), and *Hemiaster* (*Mecaster*) *heberti turonensis*, together with *Thalassinodes* (Text-fig. 2.13B).

The age of the formation is Late Turonian, based on its position overlying the Middle Turonian Buttum Formation. ABDEL-GAWAD et al. (2004a: 298) and EL QOT (2006: 13) recorded the ammonite *Coilopoceras requienianum* (D'ORBIGNY) from the upper part of the Wata Formation at the East Themed area. They established two other Turonian zones overlying the *Coilopoceras requienianum* Zone; the *Cucullaea* (*Idonearca*) *trigona*-*Rachiosoma geysi* Zone and the *Nerinea requieniana* Total Range Zone. This indicates that



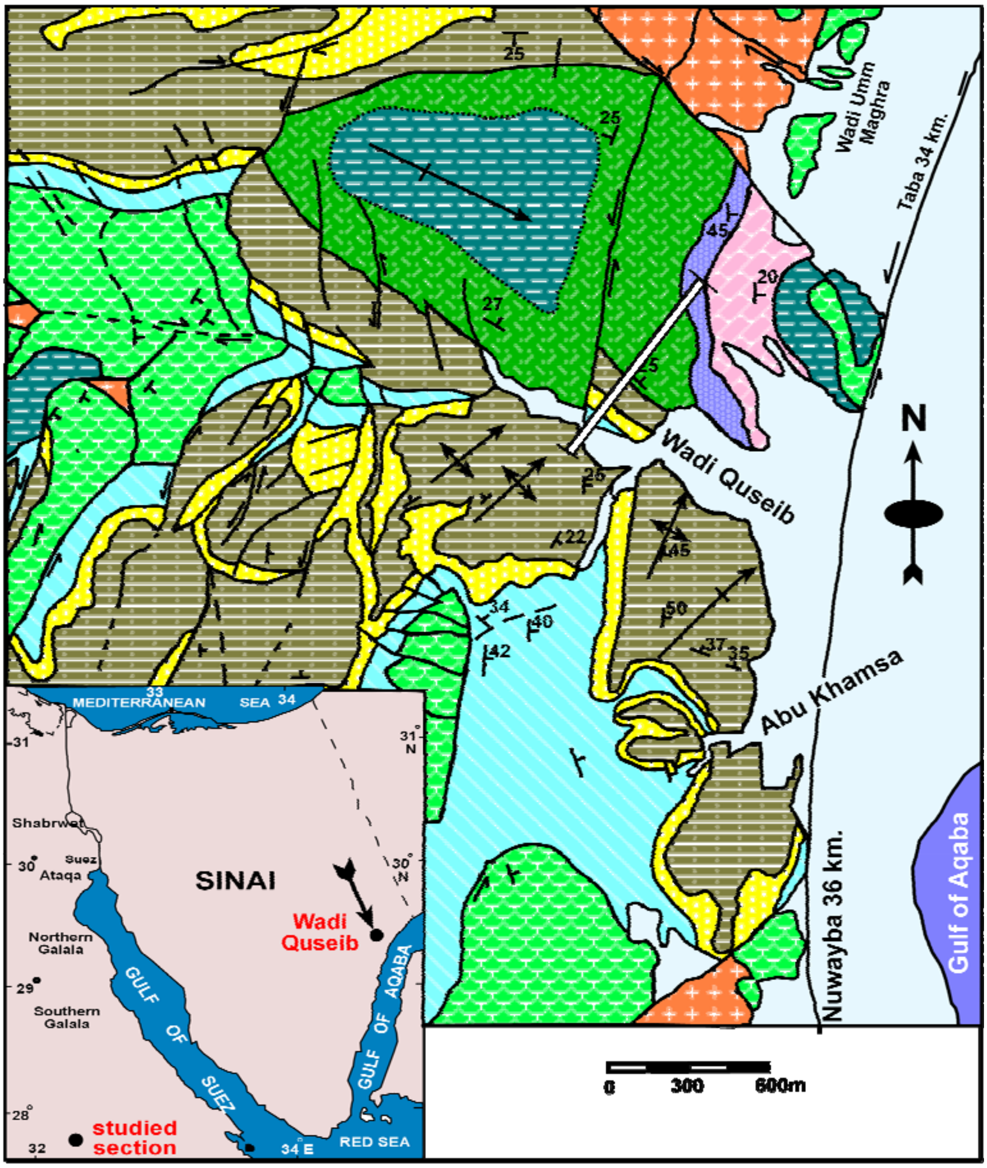
Text-fig. 2.13. Field photographs of the Upper Turonian Wata Formation at the East Themed area. A. Thick-bedded chalky limestone of the Wata Formation. B. The trace fossil *Thalassinoides*. C. Chert bands and dolomitic limestone in the upper part of the formation.

the *C. requienianum* Zone does not correspond to the topmost Turonian as mentioned by many earlier authors (e.g. KASSAB, 1991, 1994, 1999; EL-HEDENY, 2002). Furthermore they were unable to determine the Turonian-Coniacian boundary, due to the absence of typical Early Coniacian macro-and microfaunal elements.

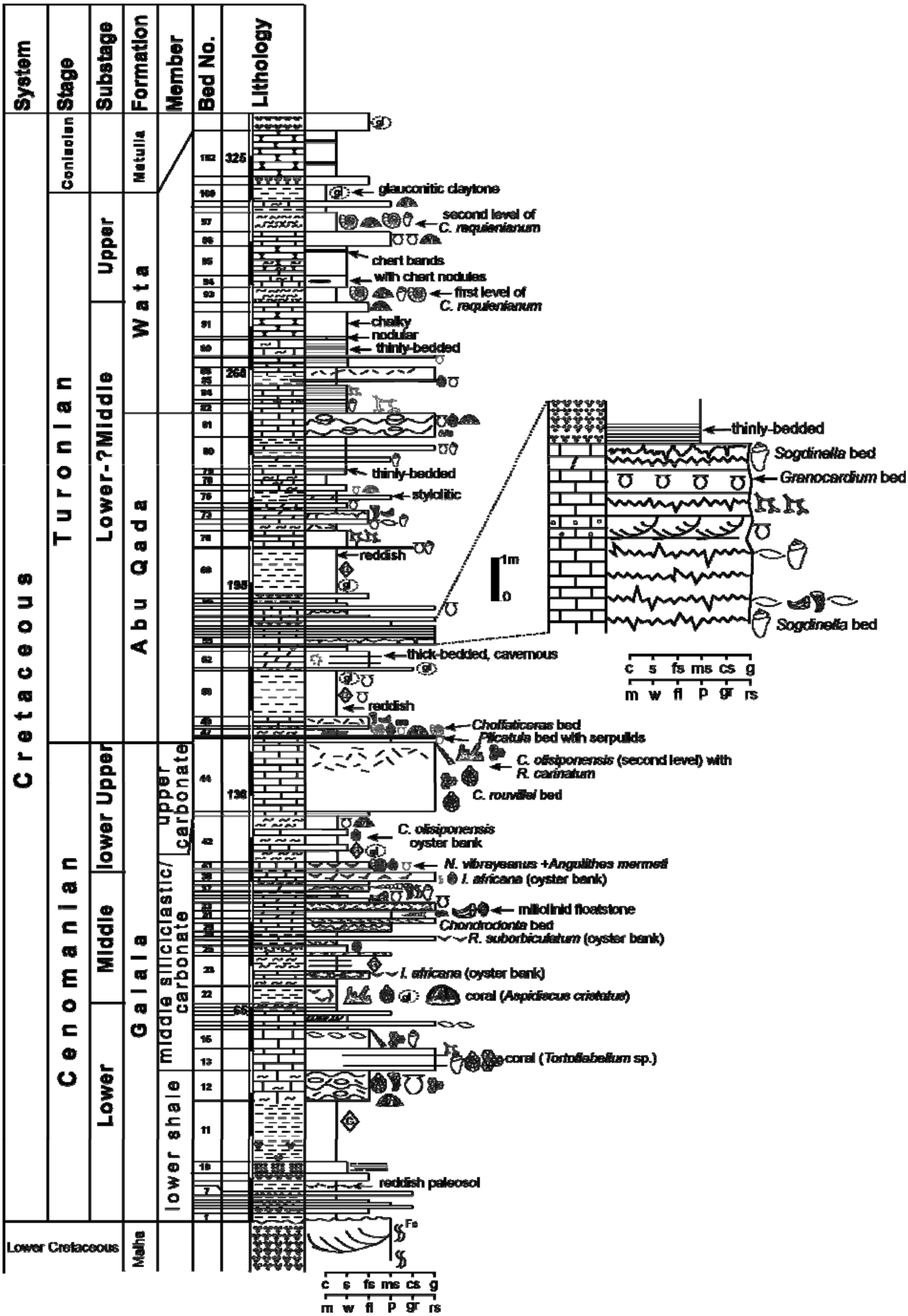
2.5 Wadi Quseib

The sedimentary rocks, cropping out the northwestern side of the Gulf of Aqaba, show a very limited extent and are restricted to grabens and pull-apart basins (ABDEL-KHALEK et al. 1993). According to HILDEBRAND & SCHIRAV (1974), the Precambrian igneous and metamorphic rocks are covered by a widespread Palaeozoic succession, which is unconformably overlain by Cenomanian to Eocene marine carbonates and shales. Upper Palaeozoic, Tirassic, Jurassic, and Miocene sediments are absent. Oligocene rocks are represented by basaltic dykes.

A section through the Cenomanian and Turonian succession was measured, sampled, and described on the north side of Quseib graben (Text-fig. 2.14).



Text-fig. 2.14. Geological map of Wadi Quseib (modified after ABDEL-KHALEK et al., 1993). The colours and symbols are the same of geological map at the Gebel Areif El-Naqa section, Text-fig. 2.1, page 3.



Text-fig. 2.15. Litholog of the Cenomanian and Turonian succession at Wadi Quseib.

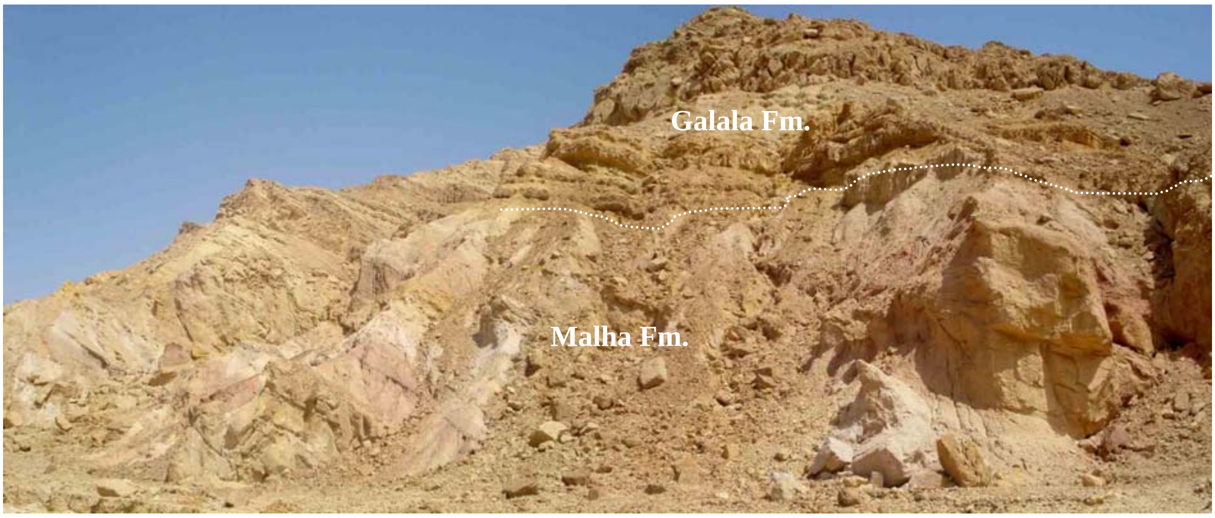
The Cenomanian and Turonian successions are 334 m thick and have been subdivided into three formations, arranged from base to top: The Galala (Cenomanian), Abu Qada (Lower-?Middle Turonian), and Wata formations (upper Middle-Upper Turonian) (Table 1). The Galala Formation has been subdivided into three informal members. The Matulla Formation (Coniacian-?Santonian) tops the Wata Formation, while the Malha Formation (Early Cretaceous) unconformably underlies the Cenomanian Galala Formation (Text-fig. 2.15).

The characteristics of the rock units from base to top are summarized in the following:

Galala Formation

The Galala Formation unconformably overlies multicoloured, kaolinitic, ferruginous sandstone of the Lower Cretaceous Malha Formation (Text-fig. 2.16) and is conformably underlain by fossiliferous shale and limestone of the Abu Qada Formation (Lower Turonian) (Text-fig.2.15).

The Galala Formation differs from the underlying, multicoloured Malha beds by the lower green shale and claystone beds, which form a distinctive lithologic boundary. HILDEBRAND & SCHIRAV (1974:129) measured 80.50 m for the Cenomanian Hazera Formation (equivalent to the Cenomanian Galala Formation) at Quseib graben and divided it into four informal members.

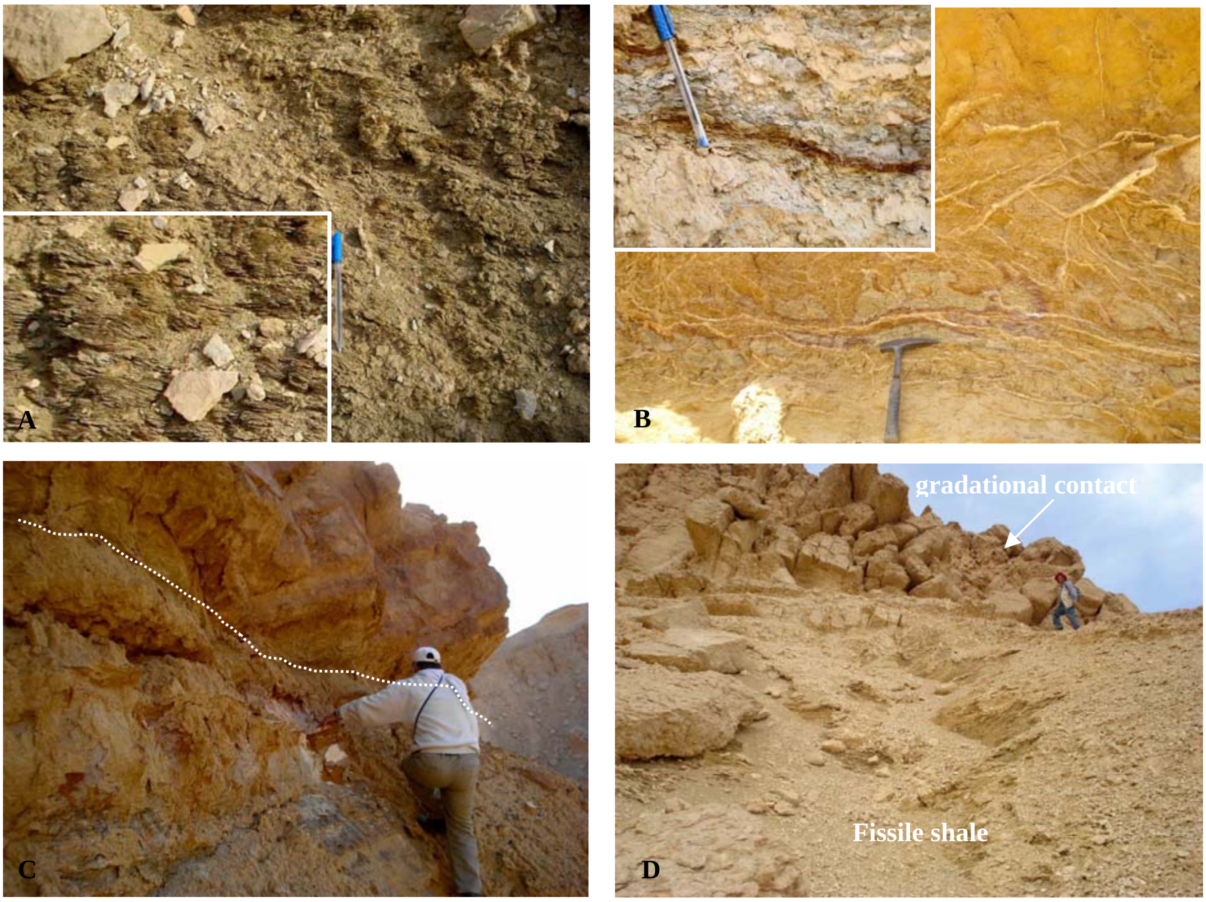


Text-fig. 2.16. Unconformity between the Lower Cretaceous Malha Formation and the Cenomanian Galala Formation of the Wadi Quseib section.

In the present study, the Galala Formation attains a thickness of 143 m and is subdivided into three informal members (Text-fig. 2.15).

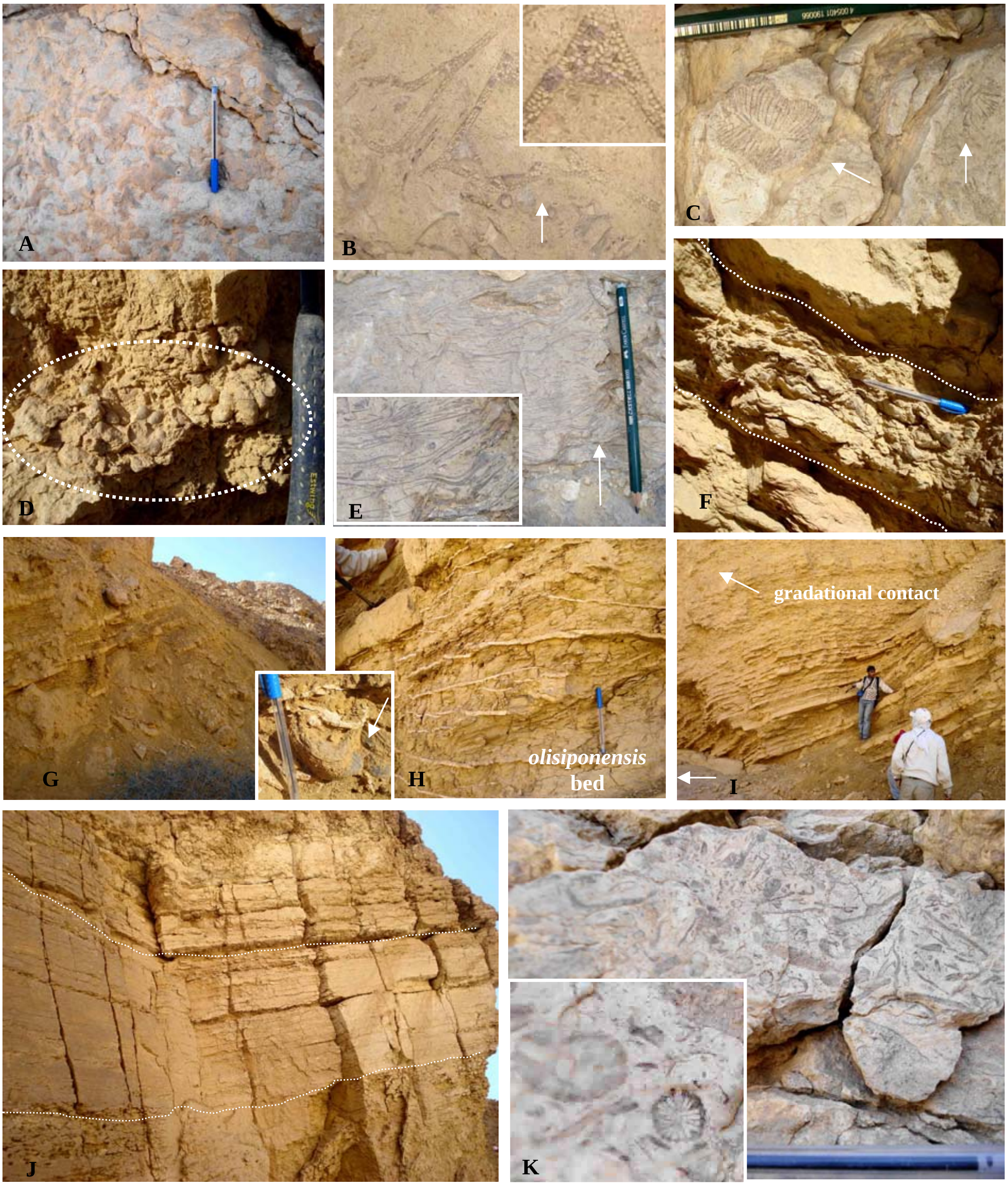
The formation is predominantly siliciclastic (gypsiferous shales and sandstones) at the base, more calcareous in the middle part (floatstone to rudstone), and dolomitic at the top (*Cladocora* /*Chondrodonta* rudstone).

The *lower shale member* (44.5 m thick) consists mainly of shale (61% of the total thickness of the member) with intercalations of sandstone (fine- to coarse-grained, thin-bedded) and siltstone. The shale beds are varicoloured (greyish-green to reddish), glauconitic, gypsiferous (network veinlets), and highly fissile with thin reddish paleosoil interbeds (5 cm) (Text-fig. 2.17A-B). The contact between the sandstone bed and the underlying shale bed is sharp (Text-fig. 2.17C). In the upper part of the member, the fissile shale grades upwards into nodular, highly fossiliferous marly limestone that forms a gradational contact with the middle siliciclastic/carbonate member above (Text-fig. 2.17D). The upper 10 m (nodular marly limestone) contain abundant echinoids, e.g. *Sinaecidaris* cf. *gauthieri* FOURTAU, *Heterodiadema libycum* (AGASSIZ & DESOR), *Anorthopygus orbicularis* (GRATELOUP), *Hemiaster* (*Mecaster*) *pseudofourneli* PÉRON & GAUTHIER, bivalves such as *Pseudolima itieriana* (PICTET & ROUX) and *Chondrodonta joannae* (CHOFFAT), gastropods such as *Pterodonta deffisi* THOMAS & PERON, *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON, and coralline sponges (*Actinostromarianina* sp. 2) (For detailed faunal list, see Appendix A.).



Text-fig. 2.17. Field photographs of the lower shale member of the Cenomanian Galala Formation at Wadi Quseib. A. Green, glauconitic, highly fissile shale. B. Reddish paleosoil within grey shale bed and gypsum veinlets (network) in the lower part of the member. C. Sharp contact between the lower grey shale and sandstone ledge above in the middle part of the member. D. Gradational contact (nodular marly limestone) between basal fissile, green shale and the middle siliciclastic/carbonate member at top.

The *middle siliciclastic/carbonate member* is 74.5 m thick and is composed of carbonate rocks with intercalations of highly fossiliferous shale and marly beds. The basal part of the member is represented by 28.5 m of grey to greyish-yellow, very hard, occasionally cross-bedded fossiliferous floatstone to rudstone containing *Chondrodonta* fragments, oysters, rudists, corals (*Tortoflabellum* sp.), coralline sponges (*Actinostromarianina* sp. 2), bryozoans, and *Thalassinoides* isp. (Text-figs. 2.18A-C). This bed is followed by 24 m of greenish yellow to grey, glauconitic, gypsiferous, highly fossiliferous shale and marl with intercalations of oyster floatstone and rudstone. The shale beds are fossiliferous containing e.g. the coral *Aspidiscus cristatus* (LAMARCK), the rudist *Toucasia*? *matheroni* (COQUAND), and the gastropod *Pchelinsevia coquandiana* (D'ORBIGNY). In the latter interval, two oyster banks have also been recorded: the basal one is rich in *Ilymatogyra africana* (LAMARCK) and the second bank contains *Rhynchostreon suborbiculatum* (LAMARCK) (see Appendix A for detailed faunal list) (Text-fig. 2.18D). The upper part of the middle siliciclastic/carbonate member is a 17 m thick, mostly grey, dolomitic *Chondrodonta* rudstone (Text-fig. 2.18E). It contains the third and fourth oyster bank (*I. africana*) and a 0.30-0.50 m thick *Chondrodonta* bed (Text-fig. 18F), associated with other faunal elements such as gastropods, rudists, a few corals, foraminifera (miliolinids), and serpulids.



Text-fig. 2.18. Field photographs of the middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation at the Wadi Quseib section. A. *Thalassinoides* network. B. Bryozoans rudstone. C. The coral *Tortoflabellum* sp. D. Oyster concentration. E. *Chondrodonta* rudstone. F. *Chondrodonta* bed (20 cm). G. Upper glauconitic shale with thin limestone interbeds. H. Gypsum veinlets with *C. olisiponensis* in life position. I. Thinly-bedded limestone followed by gradational zone with the overlying carbonate member. J. Thick-bedded, jointed dolomitic limestone (*Cladocora*/*Chondrodonta* rudstone) in the middle, weathered at base and turning thin-bedded at top. K. The coral *Cladocora* sp., *Chondrodonta* fragments, and recrystallized coralline sponges (topmost part of the formation).

Beds overlying the fourth oyster bank belong to the lower Upper Cenomanian, represented by the ammonite *Neolobites vibrayeanus* (D'ORBIGNY) and the nautiloid *Angulithes mermeti* COQUAND with few *I. africana*. The topmost part of the member (15 m thick) is a yellowish-green, moderately hard, highly fossiliferous, glauconitic marl with thin gypsum veinlets in the basal 3 m (Text-fig. 2.18G-H), which contains hard, thinly-bedded limestone intercalations at top (about 12 m). This basal part contains a fifth oyster bank which is represented by *Costagyra olisiponensis* (SHARPE), associated with *I. africana*, *P.* (*Ph.*) *vesicularis vesiculosa*, and the gastropod *P. deffisi*. The topmost part of the member grades into nodular, highly fossiliferous, marly limestone with a gradational contact to the overlying thick-bedded, dolomitic rudstone of the upper carbonate member (Text-fig. 2.18I). The nodular marly limestone bed starts with a high concentration of the oyster *Curvostrea rouvillei* (COQUAND), followed again by *C. olisiponensis* and *Rastellum carinatum* (LAMARCK) which are associated with the echinoid *Micropedina olisiponensis* (FORBES) (see Appendix A for detail faunal list).

The *upper carbonate member* is 24 m thick and is composed mainly of greyish-yellow, hard, thick-bedded, jointed, fossiliferous dolomitic rudstone. The basal 3 m consist of nodular, cavernous, bioturbated limestone, whereas the upper dolomitic limestone bed (15 m) is weathered at the base, thick-bedded, jointed, cliff-forming in the middle part, and thin-bedded, fossiliferous at the top (Text-fig. 2.18J). The topmost part of this member is rich in corals (*Cladocora* sp.), rudist fragments (*Praeradiolites biskraensis*), recrystallized coralline sponges, and *Chondrodonta* fragments (Text-fig. 2.18K).

The Galala Formation, used here to describe the Cenomanian deposits exposed in Wadi Quseib, is equivalent to the Hazera Formation described by HILDEBRAND & SHIRAV (1974) from the same area and by BARTOV et al. (1980a) from Gebel Areif EL-Naqa. It is also equivalent to the Raha Formation described by CHERIF et al. (1989 a, b), AKARISH (1999), and ABDEL-GAWAD et al. (2004a) from Sinai. Moreover, the Halal Formation, which has been described by ABDE et al. (1996) from Gebel Areif El-Naqa, is also an equivalent of the present formation (Table 2).

Abu Qada Formation

The Abu Qada Formation (Lower-?Middle Turonian) in the study area is 100 m thick and is made up of yellowish-green, moderately hard, gypsiferous shale (about 53% of the total thickness of the formation). The carbonate rocks are represented by greyish-yellow to grey, dolomitic, hard to very hard, fossiliferous, stylolitic limestone (wackestone to rudstone) and fine-grained dolostone in the middle and upper parts (42% of the total thickness). The rest of the Abu Qada Formation consists of moderately hard, fossiliferous marl and fine- to medium-grained, ferruginous thinly-bedded sandstone (Text-fig. 2.15).

The Abu Qada Formation can be subdivided into three parts: the lower part (from bed 45 to 51), is 23.5 m thick and consists mainly of varicoloured, fossiliferous, gypsiferous shale with dolomitic *Chondrodonta*/rudist rudstone to floatstone interbeds in the lower part. This part starts with a *Plicatula* bed (*Plicatula auressensis*), followed by an ammonite bed in green, glauconitic, moderately hard marlstone with fossiliferous limestone (wackestone) intercalations (Text-figs. 2.19A-B). This ammonite bed yielded *Neoptychites cephalotus* (COURTILLER), *Choffaticeras* (*Ch.*) *securiforme* (ECK), and *Choffaticeras* (*Ch.*) *segne* (SOLGER), together with other faunal elements such as the bivalves *P. auressensis* and *Paraesea faba* (J. DE C. SOWERBY), the gastropod *Campanile* (*Campanile*) *ganesha* (NOETLING) (Text-fig. 2.19C), the echinoid *Hemiaster* (*Mecaster*) *heberti turonensis* FOURTAU, and the trace fossil *Thalassinoides* (see Appendix A for a detailed faunal list).

The middle part (from bed 52 to 65) of 16 m thickness starts with grey, very hard, thick-bedded, cavernous, fine-grained dolostone, followed by 4 m of hard, stylolitic, molluscan calcareous rudstone (Text-fig. 2.19D-E) with intercalations of thinly-bedded, hard, fine to medium-grained sandstone. The latter 4 m which are bioturbated by *Thalassinoides* yield the gastropods *Sogdianella*? *laevis laevis* (SOWERBY) (two *Sogdianella* beds) and *Neoptyxis olisiponensis* (SHARPE), furthermore two bivalve beds with *Granocardium* and other heterodont bivalves as well as rudists (Text-figs. 2.19F-H). The carbonate rocks form the top of the middle part, turn into nodular, reddish, sandy wackestone.

The upper part (from bed 66 to 81) is 60.5 m thick and is made up of siliciclastic rocks (65%; shale and marl) with hard limestone, dolomitic limestone, and dolostone interbeds. This part starts with 17.5 m of greenish-grey, highly fissile, gypsiferous, glauconitic shale with thin, reddish, ferruginous, thinly-bedded, fine-grained sandstone intercalations. Shales also occur in the topmost part (10 m thick) with two hard ledges of medium-grained dolostone and bivalve rudstone. Most of the carbonate rocks in this part are thin-bedded to nodular (Text-fig. 2.19J), marly, fossiliferous wackestone with 3 m of fine-grained, fossiliferous (*Thalassinoides*), stylolitic dolostone, topped by a 0.5 m thick rudist bed (Text-figs. 2.19I, L). The upper 8 m of this part are a grey, hard, bioturbated, molluscan rudstones with echinoid debris and shell fragments.

The upper part contains gastropods *Sogdianella*? *laevis laevis* (third *Sogdianella* bed), rudists (*Praeradiolites* sp.), *Chondrodonta* sp., and *Gyrostrea anubis* MALCHUS.

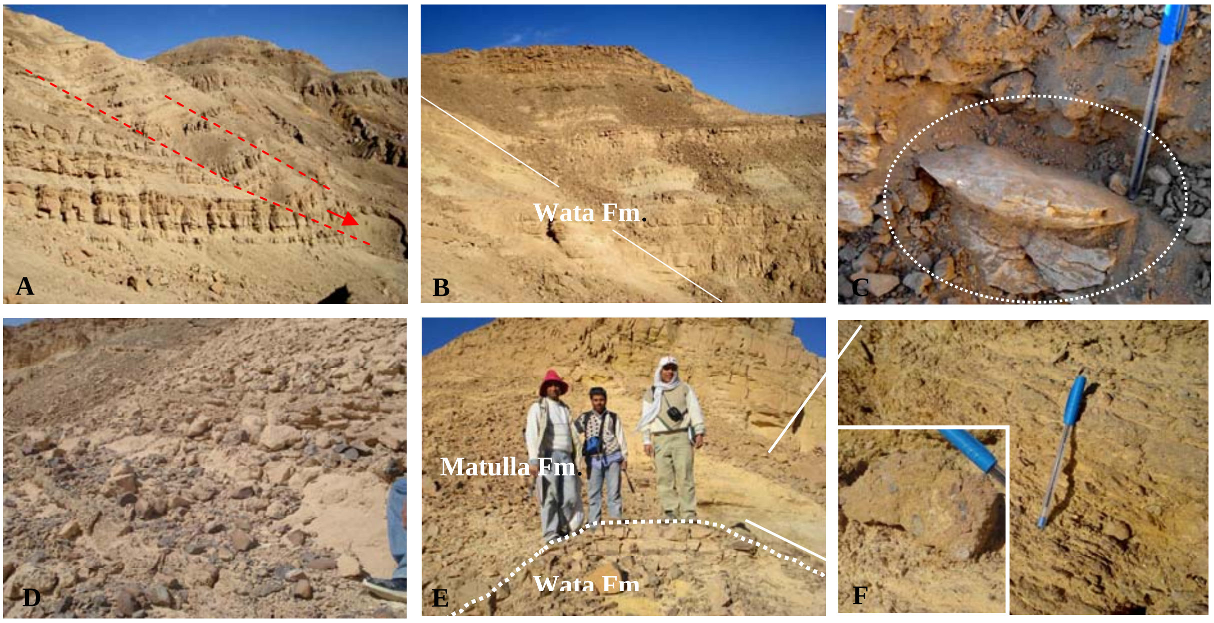
The Cenomanian-Turonian boundary in Wadi Quseib is defined with the first appearance of *Choffaticeras* (*Choffaticer*as) *securiforme* (ECK) and *Choffaticeras* (*Ch.*) *segne* (SOLGER), located within the basal part of the Abu Qada Formation, which lies just above the topmost coralline sponge and rudist horizon (*Cladocora*/*Chondrodonta* rudstone) of the Upper Cenomanian Galala Formation. The boundary also coincides with the extinction of oyster *Costagyra olisiponensis* (SHARPE) and *Rastellum carinatum* (LAMARCK).

Wata Formation

The Wata Formation can be recognized in the field by the disappearance or reduction of green siliciclastic facies and the beginning of light-coloured carbonates. Palaeontologically, this formation is not as rich in macrofauna as the underlying Abu Qada and Galala formations. In the study area, the Wata Formation overlies the Abu Qada Formation and underlies the Coniacian-?Santonian Matulla Formation (Text-fig. 2.15). The lower Upper Turonian ammonite *Coilipoceras requienianum* (D'ORBIGNY) was found at two levels (Text-fig. 2.20C). The formation is 91 m thick and is composed mainly of thick-bedded, hard, massive limestone, chalky limestone with chert layers with intercalations of marl and shale (Text-figs.2.20A-B). It starts with 9 m of thinly-bedded wackestone bioturbated by *Thalassinoides*. The latter bed is topped by a sandy, fossiliferous shale, which contains a hard ridge of molluscan rudstone (*Cerithium*? sp., bed). The middle and upper parts of the formation consist mainly of chalky limestone with thin intercalations of marl. The chalky limestone beds are white to greyish-white, moderately hard, thick-bedded, and contain thin chert bands (Text-fig. 2.20D). The marly beds are greenish-yellow, moderately hard, highly fossiliferous. They included the first and second *Coilipoceras requienianum* levels associated with other faunal elements such as the bivalves *Phelopteria gravida* (COQUAND), *Paraesa faba* and *Pholadomya pedernalis* ROEMER, the gastropod *Tylostoma* (*Tylostoma*) *globosum* SHARPE, and the echinoids *Hemiaster* (*Mecaster*) *fourneli* DESHAYES and *H.*(*M.*) *heberti turonensis* (see Appendix A).

Text-fig. 2.19. Field photographs of the Abu Qada Formation (Lower-?Middle Turonian). A. Randomly oriented and fragmented *Plicaulta auressensis* shells. B. *Choffaticeras* (*Ch.*) *segne* (SOLGER) (Lower Turonian ammonite zone). C. *Campanile* (*Campanile*) *ganesha* (NOETLING). D-E. Thick-bedded, stylolitic limestone. F: Molluscan rudstone. G. Recrystallized *Sogdianella*? *laevis laevis* (SOWERBY) (*Sogdianella*? bed). H. Longitudinal section of *Neoptyxis olisiponensis* (SHARPE, 1850) and other gastropods. I. Stylolitic, fine-grained dolostone with *Thalassinoides*. J. Thin-bedded limestone (marly wackestone). K. *Granocardium* with other heterdont bivalves (?*Meretrix* sp.). L. The rudist *Praeradiolites* sp. in very hard, fine-grained dolostone.

The chalky limestone of the topmost part of the Wata Formation is followed by green, fossiliferous, glauconitic sandstone with interbeds of yellow phosphatic limestone. It ends with 5 m of greyish-yellow, highly fossiliferous shale (shell fragments). These beds may belong to the Coniacian-?Santonian Matulla Formation (Text-figs. 2.20E-F).



Text-figs. 2.20. Field photographs of the Upper Turonian Wata Formation at Wadi Quseib. A-B. Thick-bedded and faulted (graben fault) limestone and chalky limestone. C. *Coilipoceras requienianum* (D'ORBIGNY). D. Chert bands in the upper part of the formation. E. Topmost part of the Wata Formation (with chert bands) overlain by the Matulla Formation (Coniacian-?Santonian). F. Greyish-yellow, rich in shell fragments, Matulla Formation.

3 SYSTEMATIC PALAEONTOLOGY

This chapter deals with the systematic classification of more than 5880 individuals, which have been collected from the Cenomanian-Turonian of eastern Sinai. 145 taxa, which are distributed among the bivalves, gastropods, ammonites, echinoids, and corals, are revised and discussed in details. The description of the coralline sponges are not described in this chapter. Due to the lack of a spicular framework in the coralline sponge's materials and their superficial resemblance to corals, the coralline sponges could not be determined accurately. The material has been deposited in the Museum of Geology Department, Menoufiya University under collection numbers MGDMU.

3.1. Coral

Abbreviations: D: diameter of corallum;
H: height of corallum;
c-c: distance between two adjacent corallite centers;
ds: density of septa per 1mm;
dt: density of trabeculae per 1 mm;
Ls: maximum length of series;
Ws: maximum width of series;
Dd: maximum density of dissepiments.
MGDMU:WQ.C.: WQ=Wadi Quseib, C=coral

Suborder Microsolenina MORYCOWA & RONIEWICZ, 1995
Family Latomeandridae ALLOITEAU, 1952

Remarks. The genus *Aspidiscus* KÖNIG, 1825 has been assigned to different families from time to time. VAUGHAN & WELLS (1943: 134) and (WELLS, 1956: F 387) assigned the genus to the family Cyclolitidae D' ORBIGNY 1851. ALLOITEAU (1952: 663, pl. 9, fig. 12), CHEVALIER (1987), and ABDEL-GAWAD & GAMEIL (1995: 22) grouped the genus with the family Funginellidae ALLOITEAU, 1952. Subsequently, MORYCOWA & RONIEWICZ (1995: 378, table 1), based on having upward directed pennulae and proximally diminishing septal perforations, assigned it to the family Latomeandridae.

Lately, BARON-SZABO (2002: 142) assigned it to the family Cunnolitidae ALLOITEAU, 1952. The obvious reason for the assignment to different families was either its shape or free living mode of life, meandroid/subthamnasterioid growth structure, or septal microstructure.

The septa in the distal part show all essential characters of the family Microsolenidae. The internal characters in the lower part of the corallum are not preserved due to re-crystallization. Thus we do not see the proximally diminishing pores as illustrated by GILL & LAFUSTE (1987: 928) and mentioned by MORYCOWA & RONIEWICZ (1995: 378). The proximally diminishing pores of septa were used by MORYCOWA & RONIEWICZ (1995: 378) to assign the genus to the family Latomeandridae ALLOITEAU, 1952, a view which is followed here.

Genus *Aspidiscus* KÖNIG, 1825

Type species. *Aspidiscus shawi* (= *Cyclolites cristata* LAMARK, 1801) (*Cyclophyllia* MILNE EDWARD & HAIME, 1848; Hilladastraea AVNIMELECH, 1947); Cenomanian of Tingitano, Algeria.

Remarks. GILL & LAFUSTE (1987: 921) rightly pointed out that this Cenomanian genus is very attractive in shape and can be easily identified in the field.

Aspidiscus cristatus (LAMARCK, 1801)
Pl. 1, Figs.1-6; Pl. 2, Fig. 1

1801 *Cyclolites cristata* sp. nov. – LAMARCK: 369.
1914 *Aspidiscus cristatus* (LAMARCK) – FELIX: 107 (see for extensive synonymy).
1930 *Aspidiscus cristatus* (LAMARCK) – RENZ: 8, pl. 2, fig. 1.
1932 *Aspidiscus cristatus* (LAMARCK) – LLUECA: 347, pl. 1, fig. 5-6.
1952 *Aspidiscus cristatus* (LAMARCK) – ALLOITEAU: 663, pl. 9, fig. 12.
1957 *Aspidiscus cristatus* (LAMARCK) – THOMAS & OMARA: 152, pls. 4-5.
1987 *Aspidiscus cristatus* (LAMARCK) – GILL & LAFUSTE: 926, pl. 1, figs. 1-9 (non. fig. 10), 11-14; pl. 2, figs. 1-10; text-figs. 1- 3a, 5.
1991 *Aspidiscus cristatus* (LAMARCK) – GILL & CHIKHI: 349, fig. 1-2.
1995 *Aspidiscus cristatus* (LAMARCK) – ABDEL-GAWAD & GAMEIL: 23, pl. 9, fig. 6.
2002 *Aspidiscus cristatus* (LAMARCK) – BARON-SZABO: 144, text-fig. 53A.

Material. 15 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 22 of Wadi Quseib (MGDMU:WQ.C.**22**.1-15).

Description. Corallum colonial, cupolate with a concave lower surface and a convex upper surface, circular in outline, hydnophoroid. Peripheral crown distinct, margin sharp, covered with septa running at right angle to the margin and continuing over the lower surface for a narrow zone as costae. Lower surface covered with thin holotheca with concentric growth rugae and folds (a concentric fold is seen in specimen MGDMU: WQ.C.1-10 without any attachment area. Upper surface covered with a curved or sinuous median crest that divides the surface into two sub-equal halves. Radial crests more or less bilaterally symmetrical on both sides of the median crest. Radially arranged monticules occurring between the crests and calice centers, which are arranged in series along valleys, limited by either monticules on one side and crest (colline) on the other side or by crests on both sides. Crests or collines distinct, tectiform, successively increasing in number towards periphery. Monticules circular to oval in

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EXPLANATION OF PLATE 1

1-6. *Aspidiscus cristatus* (LAMARCK, 1801) from the middle siliciclastic/carbonate member of the Galala Formation (Cenomanian) of Wadi Quseib, East Sinai, Egypt.

1. MGDMU:WQ.C.**22**.1. **a**: Upper surface view showing sinuous median crest. Scale bar 10 mm. **b**: Side view showing symmetrical convexity and distinct peripheral crown. Scale bar 10 mm. **c**: Lower surface with concentric rugae. Scale bar 10 mm. **d**: Magnified view of upper surface showing calicular centers arranged between crest and row of oval monticules and pennular septa. Note beaded distal margin of septa and outline of pennular structures in plan view. Scale bar 5 mm.

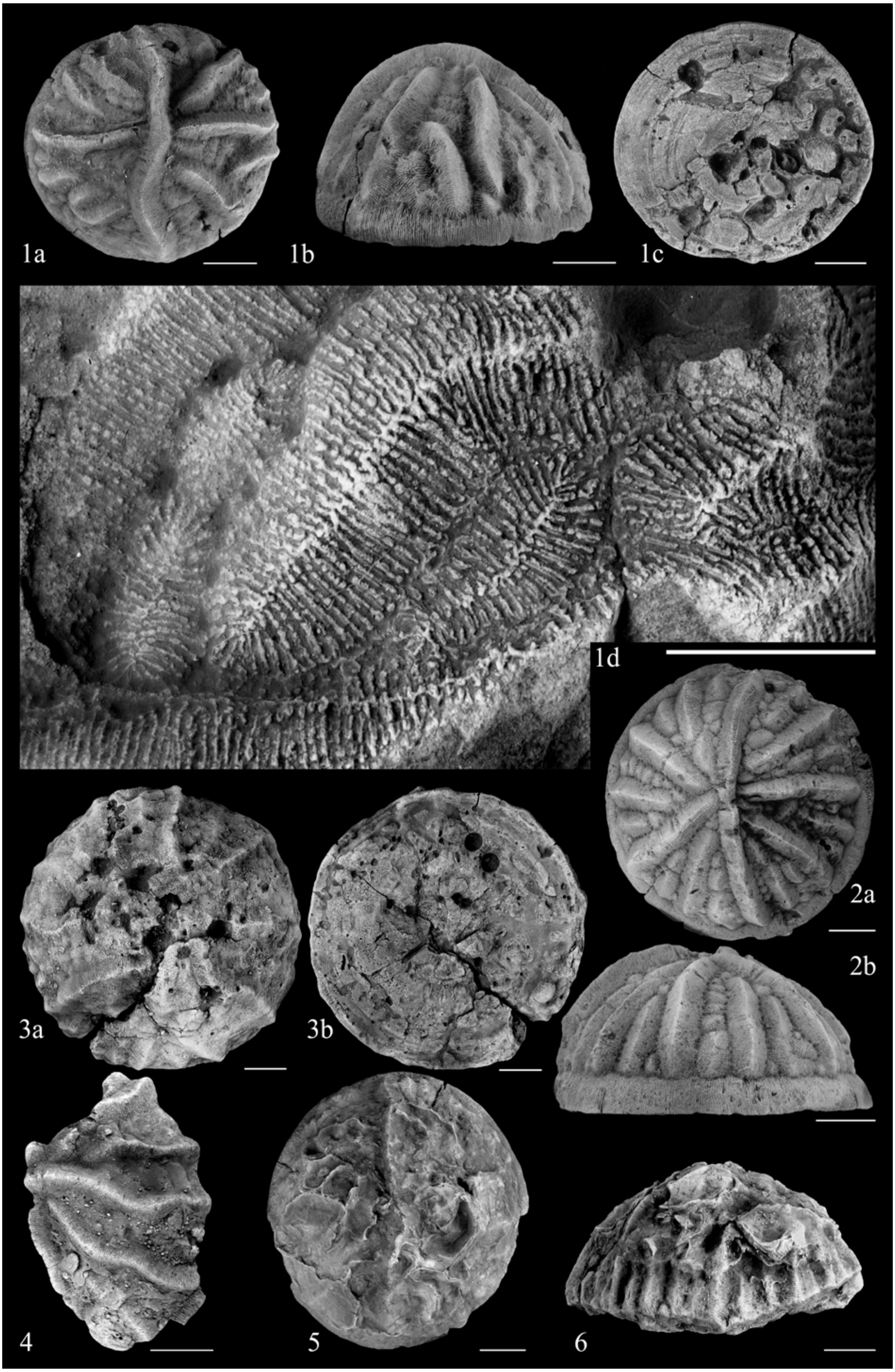
2. MGDMU:WQ.C.**22**.2. Scale bar 10 mm. a: Upper surface view showing arched median crest. Note arrangement of crests in hexameral system. The monticules are of early ontogenetic origin and the formation of crests is of later ontogenetic origin. **b**: Side view showing distinct peripheral crown. Note asymmetric convexity of the upper surface.

3. MGDMU:WQ.C.**22**.3. Scale bar 10 mm. **a**: Upper surface view. b: Lower surface view. Note paired borings.

4. Upper surface of a fragmented colony. Note that in this colony the monticule stage is not represented. The calicular centers are arranged between two crests. MGDMU: WQ.C.**22**.4. Scale bar 10 mm.

5. Upper surface view. Note upper surface encrusted with oysters. MGDMU:WQ.C.9. Scale bar 10 mm.

6. Side view showing encrustation by oysters. MGDMU:WQ.C.**22**.5. Scale bar 10 mm.


1a
1b
1c
1d
2a
2b
3a
3b
4
5
6

outline. Median crests and other radial crests together with monticules hexamerally arranged. Calice centers moderately distinct. Septa thin, few (4-8), pennular, fenestrate distally, running at right angle to the crest and limited by a synapticulothecal wall. Both symmetrical and mi-pennulae conspicuous, concave upward, with arch-shaped to straight margin, continuing around the innermost trabecula. Menianae continuous to discontinuous, margin with very fine denticles (9 per 0.5 mm). Dissepiments present, vesicular. Synapticulae occurring along the wall, which coincides with the peak of crests (collines). Columella indistinct, columellar fossa slightly elongated in the direction of valley.

Remarks. The lower surface of the specimens is bored and the holotheca is eroded in a few places exposing the costae underneath. In specimen MGDMU: WQ.C.1-10, due to erosion of the concentric fold of the lower surface, apparently an oval-shaped monticule-like structure has formed (Fig. 3.1c). Monticules on the upper surface represent initial ontogenic stage of crests (collines). We do not find any difference between collines in latomeandrids and in this genus. GILL & LAFUSTE (1987: 926, figs. 1-3) studied the variability in the position of crests, monticules and calices in specimens of *Aspidiscus cristatus* LAMARCK, from different localities. The different species of the genus *Apidiscus* have been distinguished on the basis of position of crests and monticules. The three specimens described herein show a long median crest, which divides the central dome into two equal halves. In this respect the specimens match well with this species. GILL & LAFUSTE (1987) excellently illustrated the micro-architecture, particularly the pennular structures. The morphology of the pennular structures corresponds to that of the present specimens. However, the “spoon-like terminal pennula” GILL & LAFUSTE (1987: 928, fig. 8) is not always seen. The outline of that pennula varies from one septum to another and its size may be reduced to a finely denticulated line at the margin.

Discussion. The crest-monticule ratio has been used to distinguish different species of the genus *Aspidiscus*. For instance, *Aspidiscus cristatus* is dominated by crests with a few monticules. In contrast, *Aspidiscus felixi* RENZ (1930; VAUGHAN & WELLS, 1943: 309, pl. 17, figs. 7, 7a; BARON-SZABO, 2002: 145, text-fig. 53B) has densely packed monticules with no crests. *Aspidiscus montgrinensis* SOLÉ (in BATALLER 1937) has short crests and scattered monticules, which increase in *Aspidiscus franchii* ZUFFARDI-COMERCI (1921) and become elongated at the expense of crests.

The most important diagnostic feature of the genus is the position of the monticules in the valleys. In some cases, the monticules dominate the entire central dome with no crests present. In these forms the monticules are elevated with the calicular pits located at the summit of the monticules. These monticules show a crater-like appearance which is completely different from the normal form of *Aspidiscus*. For this reason, GILL & LAFUSTE (1987) excluded *Aspidiscus semhae* KOSSMAT from the Cenomanian of Semhae Island, Socotra Archipelago, and *Aspidiscus orientalis* KÜHN, 1933 from the Senonian of Iran from the genus *Aspidiscus*. Also, AVNIMELECH (1947) excluded *Aspidiscus labyrinthicus* HOPPE, 1922 from the Upper Jurassic of Egypt from the genus *Aspidiscus* and assigned it to a new genus *Sinaiastraea* for the same reason.

Aspidiscus sinaiticus AVNIMELECH (1947: 296, pl. 5, figs. 1-3) is composed entirely of monticules reaching 2-3 mm in height with the crateriform calicular pit at the summit of each monticule. The present authors suggest that AVNIMELECH’s species should be assigned to another genus rather than to *Aspidiscus* for the same reason *Aspidiscus semhae* has been excluded by GILL & LAFUSTE (1987).

Temporal and spatial distribution. *Aspidiscus cristatus* has been recorded from the Cenomanian (Upper Cretaceous) of Algeria (ALLOITEAU, 1952: 663; Gill & Chikhi, 1991), Afghanistan (GILL & LAFUSTE, 1987), Greece (RENZ, 1930), Tunisia (ALLOITEAU, 1952: 664) and Spain (BARON-SZABO, 2002). In Egypt, it is also known from the Cenomanian of Sinai and the western side of the Gulf of Suez. In Sinai, *Aspidiscus cristatus* has been recorded from the Nezzazt Mountain in the southwestern part (THOMAS & OMARA, 1957; ABDEL-GAWAD & GAMEIL, 1995), from Risan Aneiza in the central part (AVNIMELECH, 1947), from the El-Themed area in the central-eastern part, and from El-Minsherah Mountain in the northern part (ABDEL-GAWAD & GAMEIL, 1995). *Aspidiscus* sp., recorded from the Albian of northern Sinai by ABDEL-GAWAD & GAMEIL (1995), is poorly preserved and it is clearly not similar to *Aspidiscus cristatus*. On the western side of the Gulf of Suez, the species has been recorded from the Middle Cenomanian of Wadi Araba by AWAD (1961).

The specimens described in the present paper have been collected from Wadi Quseib in the eastern part of Sinai from a horizon 20 m below the early Late Cenomanian ammonite *Neolobites vibrayeanus* Zone. In contrast, ABDEL-GAWAD & GAMEIL (1995) recorded *Aspidiscus cristatus*, which occurs in abundance in the Nezzazt Mountain section, within the early Late Cenomanian *Neolobites vibrayeanus* Zone. The stratigraphic range of *Aspidiscus cristatus* has been considered to be restricted to the Middle Cenomanian (GILL & CHIKHI, 1991: 349). However, the record of *Aspidiscus cristatus* by ABDEL-GAWAD & GAMEIL (1995) suggests that it ranges stratigraphically from the Middle to the early Late Cenomanian. The geographic distribution of *Aspidiscus cristatus* around the Mediterranean (GILL & CHIKHI, 1991: 349) may also corroborate to the data on palaeogeographic settings of the sedimentary basins yielding this taxa during the Cretaceous period.

Suborder Faviina VAUGHAN & WELLS, 1943
Family Meandrinidae GRAY, 1847
Subfamily Eusmiliinae MILNE EDWARDS & HAIME, 1857
Genus *Tortoflabellum* SQUIRES, 1958
Type species *Tortoflabellum flemingi* SQUIRES, 1858, Miocene of New Zealand

Remarks. The genus *Tortoflabellum* SQUIRES, 1958 has been associated with the family Caryophylliidae (SQUIRES, 1958). However, based on the compact nature of septa, presence of costae, parathecal or septoparathecal wall and abundant thin dissepiments, the genus has been transferred to the subfamily Eusmiliinae MILNE EDWARDS & HAIME, 1857 of the family Meandrinidae GRAY, 1847 (BARON-SZABO, 2002: 65). The genus is rare in Cretaceous. It is doubtfully known from the Aptian of Bulgaria and Maastrichtian of Jamaica (BARON-SZABO, 2002: 72). The present record from the Galala Formation (Cenomanian) of Wadi Quseib, East Sinai, Egypt, is thus significant.

Tortoflabellum sp.
Pl. 2, Figs. 2-4

Material. 38 specimens from the lower shale and middle siliciclastic/carbonate members of the Galala Formation (Cenomanian), beds 12, 14, 15, 31, and 34 at Wadi Quseib, (MGDMU:WQ.C.**12**.1-15; **14**.1-8; **15**.1-5; **31**.1-7; **34**.1-3).

Description. Corallum colonial, flabello-meandroid, consisting of polystomodaeal series, with intracalicular linear budding. Septa compact, laterally covered with spinules, arranged in at least four cycles. Primary septa long, thickest, maximum thickness near the wall, thinning towards the columellar area, and may bending uniformly in one direction, occasionally anastomosing. Secondary septa thinner, correspondingly shorter and straight or curved. Inner edge of septa rarely auriculate or swollen. Dissepiments thin, sub-tabular, vesicular, dense, abundant. Costae thin with abundant thin closely spaced dissepiments. Wall parathecal, occasionally septo-parathecal. Columellar area elongated to linear, occupied by bend part of inner end of septa or dissepiments.

Remarks. All specimens are fragmentary and embedded in marly matrix; therefore only the polished section of the broken surface could be studied. The morphological features of the specimens compare well with the genus *Strotogyra* WELLS, 1937 and *Tortoflabellum* SQUIRES, 1958 (BARON-SZABO, 2002: 69, 72). Both genera are very close morphologically except for the nature of the columella. In the former, the columella is lamellar, attached to the processes of the inner edges of the septa, and in the latter the columella is formed by fusion of the inner edges of septa. In the present specimens, columella if at all is considered it fall near to second category. Due to the fragmentary nature of the corallum, a more detailed identification is not possible.

Suborder Faviina VAUGHAN & WELLS, 1943
(nom. corr. ex Faviida VAUGHAN & WELLS, 1943; after WELLS, 1956)
Family Faviidae GREGORY, 1900
Genus *Cladocora* EHRENBERG, 1834

Type species. *Madrepora flexuosa* PALLAS, 1766, Recent, Mediterranean Sea.

Cladocora sp.
Pl. 2, Fig. 5

Material. Five specimen from the upper carbonate member of the Galala Formation (Cenomanian), bed 44 at Wadi Quseib (MGDMU: WQ.C.**44**.1-5).

Description. Corallum ?colonial Corallites circular in outline. Costosepta moderately thick, compact, lateral surface ornamented with spinules. Septa arranged in three cycles of six

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EXPLANATION OF PLATE 2

1. *Aspidiscus cristatus* (LAMARCK, 1801) from the middle siliciclastic/carbonate member of the Galala Formation (Cenomanian) of Wadi Quseib, East Sinai, Egypt. MGDMU:WQ.C. Scale - width of photographs 2.5 mm. **a**: Magnified longitudinal thin-section showing mi-pennulae. **b**: Magnified longitudinal thin-section parallel to septal plane showing rows of concave upward oriented pennular structures. **c**: Magnified transverse thin-section showing mi-pennulae, MGDMU:WQ.C.**22**.1. Note the change in the upward direction of the pennular structures on the two sides of the crest or monticule.

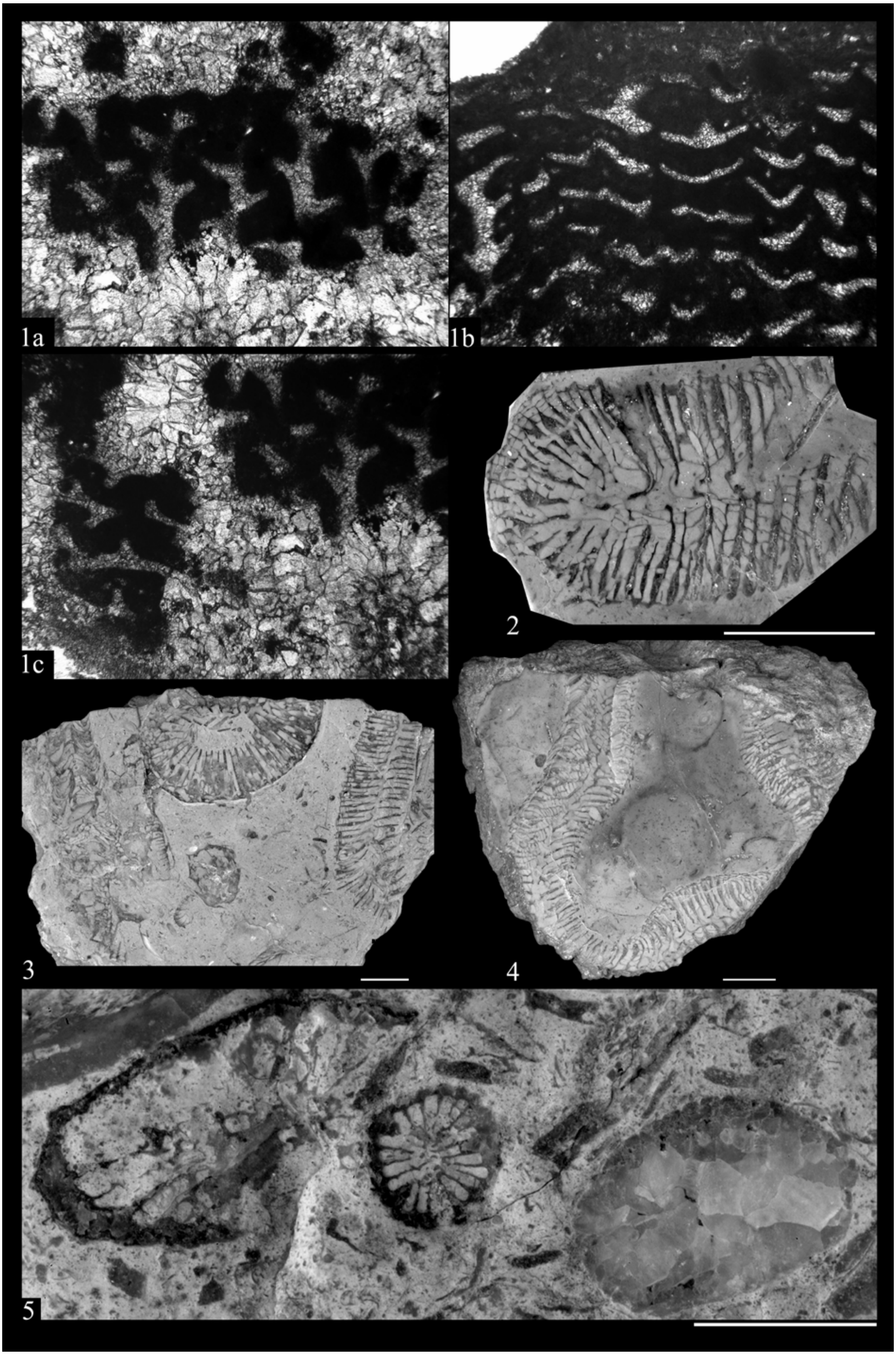
2-4. *Tortoflabellum* sp. from the middle siliciclastic/carbonate member of the Galala Formation (Cenomanian) of Wadi Quseib, East Sinai. Scale bar 10mm.

2. MGDMU:WQ.C.**12**.1. Magnified view of the transverse polished-section showing compact nature of septa and abundance of closely spaced dissepiments. Note the bending of septa at the inner edge, the columnar area covered with dissepiments, and the costae on the top left of the photograph.

3. MGDMU: WQ.C.**12**.2. Transverse polished-section showing parts of flabello-meandroid colony consisting of polystomodaeal series. Note that the series are laterally free.

4. MGDMU: WQ.C.**12**.3. Transverse polished-section showing flabello-meandroid colony.

5. *Cladocora* sp. from the upper carbonate member of the Galala Formation (Cenomanian) at Wadi Quseib, East Sinai, Egypt. Scale bar 5 mm. MGDMU:WQ.C.**44**.1. Magnified view of transverse to oblique polished section showing recrystallized and poorly preserved colony with circular outline of corallites, septoparathecal wall and septal position. Note the presence of pali against each septa.


1a
1b
1c
2
3
4
5

systems. Septa of first cycle nearly reach the center. Septa of second and third cycles correspondingly shorter but of the same thickness. Pali present opposite all cycles. Costae short, equal to number of septa. Dissepiments present. Columella sublamellar. Wall septoparathecal.

Remarks. The specimen in the present collection is represented by a transverse-section of a single corallite and some incomplete small fragments cut at different angles embedded in the same rock, which gives the appearance of a branching colony. The internal microstructure is not preserved. The dimensions of the single corallite match *Cladocora gracilis* (D'ORBIGNY, 1850) (e.g. BARAON-SZABO, 2002: 33, pl. 17, figs. 1, 3; 2006: 39, pl. 4, figs. 4, 6; BARAON-SZABO et al., 2006: 1035, fig. 4.6). However, due to the limited information available a specific identification has not been attempted.

3.2. Class Bivalvia LINNÉ, 1758

The systematic classification of the bivalves follows that of AMLER et al. (2000). The terminology of the bivalves follows the glossary presented by COX (1969) in the Treatise on Invertebrate Paleontology. The terminology for the morphological features of oysters follows that of STENZEL (1971).

All linear measurements (taken with a Vernier Caliper) are given in millimeters. Abbreviations used are as follows:

n= number of measured specimens;
L= shell length;
H= shell height;
C= thickness of articulated shell;
nr= number of ribs.

Phylum Mollusca CUVIER, 1795
Class Bivalvia LINNÉ, 1758
Subclass Palaeotaxodonta KOROBKOV, 1954 (NEWELL, 1965)
Order Nuculoida DALL, 1889
Superfamily Nuculacea GRAY, 1824
Family Nuculidae GRAY, 1824
Genus *Nucula* LAMARCK, 1799
Subgenus *Nucula* LAMARCK, 1799
Nucula (*Nucula*) *margaritifera* DOUVILLÉ, 1916
Pl. 3, Fig. 1

1916 *Nucula margaritifera* sp. nov. – DOUVILLÉ: 177, pl. 21, figs. 19-21.
1916 *Nucula simplex* DESHAYES - DOUVILLÉ: 177, pl. 21, fig. 22 (non DESHAYES).
1955 *Nucula margaritifera* DOUVILLÉ – MAHMOUD: 108, pl. 9, figs. 10-13.
1962 *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ - ABBASS: 7, pl. 1, figs. 1-7.
1963 *Nucula awadensis* sp. nov. – FAWZI: 19, pl. 1, figs. 8-10.
1992 *Nucula margaritifera* DOUVILLÉ – ABDEL-GAWAD & ZALAT: pl. 2, fig. 1.
2002 *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ – ABDEL-GAWAD & GAMEIL: 77, pl. 1, fig. 1.
2006 *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ – EL QOT: 16, pl. 1, figs. 1-2, 5-6.
2007b *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ – MEKAWY: 201, pl. 1, fig. 1.
2008 *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ – MEKAWY & ABU-ZIED: 294, pl. 1, fig. 1.

Material and occurrence. Two composite moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation, beds 1 and 5 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.1,.**5**.1), and 10 specimens from the Cenomanian Galala Formation, beds 3 and 12 of the East Themed area (MGDMU:ET.Bi.**3**.1-8, **12**.1-2).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	22-26	11-15	8-10	0.50-0.57	0.36-0.38	0.66-0.73
Mean	24	13	9	0.53	0.37	0.69

Description. Valves elongated-ovate, small-sized, equivalved, moderately inflated, and inequilateral. Anterior flank nearly straight, gently inclined and longer than the posterior one. Posterior flank, in contrast, shorter, steeper, and slightly concave. Ventral margin broadly rounded meeting the anterior and posterior margins in rounded angles. Umbo opisthogyrate, prominent, situated nearly one-third of the shell-length from the posterior end. Ornamentation consisting of faint commarginal ribs with traces of radial ribs, which are well developed near the dorsal side.

Temporal and spatial distribution. *Nucula* (*Nucula*) *margaritifera* has been recorded from the Albian of Gebel Manzour (DOUVILLÉ 1916; ABBASS, 1962), Cenomanian of G. El-Minsherah (FAWZI, 1963), G. El-Hamra (ABDEL-GAWAD & ZALAT, 1992), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), from the Upper Albian-Cenomanian of G. Ekma, East Themed, and G. Yelleg (EL QOT, 2006), and from the Upper Barremian-Lower Albian of northern Sinai (MEKAWY & ABU ZEID, 2008). The species has been also recorded from the Cenomanian of the Eastern Desert (Wadi El Deir and Abu Darag) by MEKAWY (2007b). Thus, *N.* (*N.*) *margaritifera* ranges from the Barremian to the Cenomanian.

EXPLANATION OF PLATE 3

Fig. 1. *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ, 1916. Composite mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa area, x2. **a**: Side view of left valve, **b**: dorsal view; MGDMU:AEN.Bi.**1**.1.

Fig. 2. *Nuculana* (*Nuculana*) sp. Internal mould from the Upper Cenomanian Galala Formation of the East Themed area, x1. **a**: Side view of right valve, **b**: dorsal view; MGDMU:ET.Bi.**12**.3.

Fig. 3. *Mytilus* cf. *bussoni* COLLIGNON, 1971 from the upper member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x1.5. **a**: Side view of left valve, **b**: postero-dorsal view; MGDMU:AEN.Bi.30.**1**.

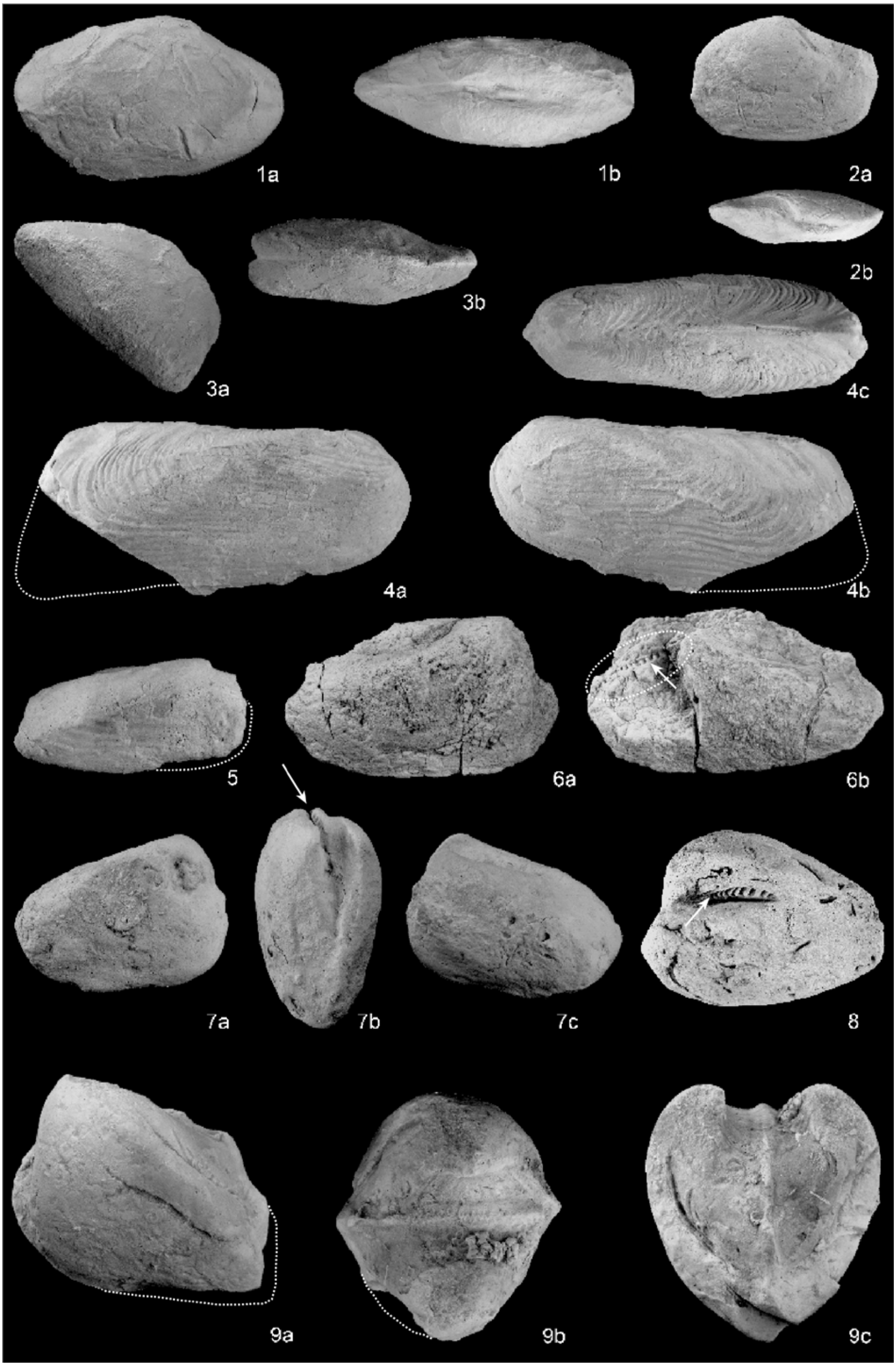
Fig. 4. *Inoperna flagellifera* (FORBES, 1846). Composite mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. **a**: External view of right valve, **b**: side view of left valve, **c**: dorsal view; MGDMU:AEN.Bi.**1**.2.

Fig. 5. *Modiolus* (*Modiolus*) *aequalis* (J. SOWERBY, 1818). Composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. Side view of right valve; MGDMU:AEN.Bi.**1**.7.

Fig. 6. *Arca* (*Idonearca*) *diceras* (SEGUENZA, 1882). Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. **a**: External view of right valve, **b**: side view of left valve; MGDMU:WQ.Bi.**39**.1.

Figs. 7-8. *Cucullaea* (*Idonearca*) *trigona* (SEGUENZA, 1882). **7**. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. **a**: Side view of right valve, b: dorsal view with dentition (arrowed), c: side view of left valve; MGDMU:WQ.Bi.**47**.3. - **8**. Internal mould from the Lower Turonian Abu Qada Formation of the East Themed area, x1. Dorsal view with dentition (arrowed); MGDMU:ET.Bi.**25**.1.

Fig. 9. *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND, 1862). Internal mould from the Upper Turonian Wata Formation at Wadi Quseib, x1. **a**: Side view of left valve, **b**: dorsal view, **c**: postero-dorsal view; MGDMU:WQ.Bi.**97**.1.


1a
1b
2a
2b
3a
3b
4a
4b
4c
5
6a
6b
7a
7b
7c
8
9a
9b
9c

Discussion. The present material closely resembles *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ, as described and figured by DOUVILLÉ (1916) and ABBASS (1962) in general shape and ornamentation but differs in being less inflated (C/L=0.37 mm).

DOUVILLÉ (1916) described two species of the genus *Nucula*; *N. margaritifera* (the present species) and *N. simplex* DESHAYES, 1842. In agreement with ABBASS (1962), *N. simplex* closely resembles the present species and is considered herein as a junior synonym of *N.* (*N.*) *margaritifera*. Also, the present species is very similar to *N. awadensis* FAWZI, 1963 in general shape and outline. However, FAWZI pointed out that his new species had descended from *N. margaritifera* without explaining the difference between the two species. Therefore, FAWZI'S species is considered herein as a junior synonym of *N.* (*N.*) *margaritifera.*

N. (*N.*) *tarfayensis* FRENEIX (1972: 62, pl. 1, figs. 1, 3) from the Albian of Morocco differs in having a much higher and oval shell (H/L= 0.86-0.97 mm) with strongly inclined posterior margin.

FOURTAU (1917) and ABBASS (1962) discussed the differences between *N.* (*N.*) *margaritifera* and some other *Nucula* species e.g. *N. desvauxi* COQUAND, *N. cretacea* COQUAND, *N. edwardsi* MAYER-EYMAR, *N. stantoni* STEPHENSON, and *N. ovata* MANTELL (in WOODS, 1899). (For more detailed discussion, see FOURTAU, 1917: 1-4 and ABBASS, 1962: 8).

Superfamily Nuculanacea (ADAMS & ADAMS, 1858)
Family Nuculanidae ADAMS & ADAMS, 1858
Genus *Nuculana* LINK, 1807
Subgenus *Nuculana* LINK, 1807
Nuculana (*Nuculana*) sp.
Pl. 3, Fig. 2

Material and occurrence. One articulate specimen from the Galala Formation (Upper Cenomanian), bed 12 of the East Themed area (MGDMU:ET.Bi.**12**.3), and one specimen from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian), bed 15 at Gebel Areif El Naqa (MGDMU:AEN.Bi.**15**.1).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	35	25	10	0.71	0.28	0.40

Description. Specimen elongated-ovate (H/L=0.71), inequilateral, equivalved, and less inflated (C/L=28% of the total shell length). Anterior margin broadly rounded, meeting the ventral margin in an even curve. Posterior margin longer than the anterior one. Postero-dorsal margin slightly concave, antero-dorsal margin nearly straight. Ventral margin regularly convex. Umbones less prominent and situated posteriorly. Ornamentation consisting of commarginal ribs separated by wide interspaces. Dentition partly preserved on the antero-dorsal margin.

Discussion. The present material shows some similarity with *Leda perdita* CONRAD as figured by FOURTAU (1917: 5, pl. 2, figs. 7-8) from the Campanian of Sinai, but the latter species differs in being smaller with a sharp posterior end. *Nuculana mariae* D'ORBIGNY as figured by WOODS (1904: 6, pl. 1, figs. 25-27) from the Albian of England differs in having a more concave antero-dorsal margin, more prominent umbones, numerous commarginal ribs, and in being smaller. *Leda leia* WANNER as figured by PERVINQUIÈRE (1912: 96, pl. 7, figs. 15-19) from Tunisia resembles also the present material in general shape and outline but differs in having nearly centrally placed umbones, which are less high than the present material, and in being smaller.

Subclass Pteriomorphia BEURLEN, 1944
Superorder Isofilibranchia (IREDALE, 1939) POJETA, 1971
Order Mytiloida FÉRUSSAC, 1822
Superfamily Mytilacea RAFINESQUE, 1815
Family Mytilidae RAFINESQUE, 1815
Genus *Mytilus* LINNÉ, 1758
Mytilus cf. *bussoni* COLLIGNON, 1971
Pl. 3, Fig. 3

cf.1971 *Mytilus bussoni* sp. nov. – COLLIGNON: 24 (166), pl. 4, figs. 8-9.
cf.2006 *Mytilus* cf. *bussoni* COLLIGNON – EL QOT: 17, pl. 1, fig. 7a-b.
cf.2007b *Mytilus* cf. *bussoni* COLLIGNON – MEKAWY: 203, pl. 1, fig. 2.

Material and occurrence. One articulate specimen from the upper member of the Lower Turonian Abu Qada Formation, bed 30 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**30**.1).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	28	15	10	0.53	0.36	0.66

Description. Outline mytiliform, medium-sized, strongly inequilateral, moderately inflated, and slightly equivalved. Anterior margin straight and forming a flat and wide area. Posterior margin strongly convex, pointed. Maximum thickness near the umbonal area, becoming less towards the postero-ventral margin. Umbones small, terminal, little prominent, and situated near the anterior end. Surface with a moderately well-developed keel, extending from the umbonal area and dying out ventrally. Ornamentation not well preserved but the middle part shows faint commarginal lamellae separated by wide interspaces.

Temporal and spatial distribution. *Mytilus bussoni* has been recorded from the Maastrichtian of Sahara, Algeria (COLLIGNON, 1971). In Egypt, it occurs in the Coniacian-Santonian of the East Themed area (Sinai) and Wadi El Deir (Eastern Desert) by EL QOT (2006) and MEKAWY (2007b), respectively. Stratigraphically, the species has a wide stratigraphic range, from the Turonian to the Maastrichtian.

Discussion. The present material closely resembles *Mytilus bussoni* COLLIGNON, 1971 in general shape and outline but differs in being smaller with a longer hinge margin. According to COLLIGNON (1971), *M. indifferens* COQUAND, 1862 from the Turonian of Algeria differs in having strongly curved and strongly pointed umbones with a more prominent postero-ventral keel. *M. simplex* D'ORBIGNY (1844: 269, pl. 337, figs. 1-4) differs from the present species in being less arched.

Subfamily Lithophaginae ADAMS & ADAMS, 1857
Genus *Inoperna* CONRAD in KERR, 1875
Inoperna flagellifera (FORBES, 1846)
Pl. 3, Fig. 4

1846 *Mytilus* (*Modiolus*) *flagelliferus* sp. nov. – FORBES: 152, pl. 16, fig. 9.
1871 *Modiola flagellifera* FORBES – STOLICZKA: 379, pl. 24, figs. 1-2.
1900 *Modiola flagellifera* FORBES – WOODS: 99, pl. 17, figs. 1-2.
1986 *Inoperna flagellifera* (FORBES) – ABDEL-GAWAD: 138, pl. 27, fig. 4.
2002 *Panopea* sp. – ABDELHAMID & EL QOT: 284, pl. 7, figs. 4-5.
2006 *Inoperna flagellifera* (FORBES) – EL QOT: 20, pl. 1, figs. 11a-c, 13-14.

Material and occurrence. Five incomplete composite moulds from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), bed 1 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.2-6).

Measurements (in mm).

n=4	L	H	C	H/L	C/L	C/H
Range	38-41	17-20	13-16	0.45-0.49	0.34- 0.39	0.76-0.80
Mean	39.50	18.50	14.50	0.47	0.36	0.78

Description. Specimens medium-sized, elongated to modioliform, equivalved, strongly inequilateral, moderately inflated, and somewhat enlarged posteriorly. Dorsal margin almost straight and running nearly parallel to the nearly straight ventral margin. Both anterior and posterior margins strongly convex and meeting the ventral margin in even curve. Umbo relatively broad, sub-terminal, slightly incurved anteriorly, and situated at about one-fifth of shell length from the anterior end. Surface with oblique dorso-ventral keel, which is less developed near the postero-ventral margin and divides the shell surface into two parts. The part ventral to the ridge is ornamented with faint commarginal growth lines, which run subparallel to the ventral margin. These commarginal ribs are flagelliform, strong posteriorly and across the umbonal ridge, bifurcated dorsally, weakly developed on the anterior part of the ridge, and separated by wide interspaces which are smooth and occasionally occupied by secondary ribs.

Temporal and spatial distribution. *Inoperna flagellifera* has been recorded from the Upper Cretaceous of South India (FORBES, 1846; STOLICZKA, 1871), Albian of England (WOODS, 1900), and topmost Maastrichtian of the Middle Vistula Valley, Poland (ABDEL-GAWAD, 1986). In Egypt, it is known from the Early Cenomanian of Gebel Yelleg and G. El-Hamra, Sinai (ABDELHAMID & EL QOT, 2002; EL QOT, 2006). Therefore, *I. flagellifera* has a wide stratigraphic range, occurring from the Albian to the Maastrichtian (EL QOT, 2006: 21).

Discussion. *Inoperna flagellifera* differs from other species of the genus *Inoperna* by its more developed dorso-ventral keel and ornamentation (well developed flagelliform commarginal ribs).

Inoperna transjordanica BLANCKENHORN (1934: 206, pl. 10, figs. 48-50) from the Cenomanian-Turonian of Jordan is similar to the present species in general shape and outline but differs in having a higher postero-dorsal flank (arched form), less developed keel, and poorly preserved commarginal ribs. *I. gillieroni* (PICTET & CAMPICHE, 1864) differs by having fewer ribs dorsally and by the general absence of bifurcation (WOODS, 1900).

I. bellarugosa POPENOE (1937: 382, pl. 45, figs. 6-7) from the Cretaceous of southern California differs in lacking a carina, in having shorter, fine commarginal ribs, and in being less slender than *I. flagellifera*. *Volsella flichei* (PERON, 1889) of BARBER (1958: 15, pl. 6, figs. 4-5) from the Lower Turonian of Nigeria has numerous fine concentric lamellae and a more elongated and inflated shell with a highly arched postero-dorsal flank.

Subfamily Modiolinae KEEN, 1958
Genus *Modiolus* LAMARCK, 1799
Subgenus *Modiolus* LAMARCK, 1799
Modiolus (*Modiolus*) *aequalis* (J. SOWERBY, 1818)
Pl. 3, Fig. 5

1818 *Modiola aequalis* sp. nov. – J. SOWERBY: 18, pl. 210, fig. 2.
1866 *Modiola capitata* sp. nov. – ZITTEL: 80, pl. 12, fig. 1a-d.
1900 *Modiola aequalis* J. SOWERBY – WOODS: 92, pl. 15, figs. 8-14.
1912 *Modiola aequalis* J. SOWERBY – PERVINQUIÈRE: 124.
1912 *Modiola capitata* ZITTEL – PERVINQUIÈRE: 124, pl. 8, fig. 10a-b.
1941 *Volsella capitata* (ZITTEL) – VOKES: 8 (1145), fig. 8.
?1962 *Modiolus* (*Modiolus*) *farisi* sp. nov. – ABBASS: 28, pl. 3, fig. 6.
1963 *Modiola capitata* ZITTEL – FAWZI: 27.
1971 *Modiolus capitatus* ZITTEL – COLLIGNON: 25 (167), pl. D, fig. 10.
1981 *Modiolus capitatus* ZITTEL – AMARD et al.: 71, pl. 2, fig. 1a-b; pl. 8, fig. 6a-b.
2006 *Modiolus* (*Modiolus*) *aequalis* (J. SOWERBY) – EL QOT: 21, pl. 1, fig. 12.

Material and occurrence. Seven articulated specimens (composite moulds) from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 1 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.7-9,**15**.2-5), one specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 41, and two specimens from the Abu Qada (Lower Turonian) Formation, bed 47 (the *Choffaticeras* (*Ch.*) *segne* Zone) at Wadi Quseib (MGDMU:WQ.Bi.**41**.1,**47**.1-2), and Six internal moulds from the Upper Cenomanian Galala Formation (*Neolobites vibrayeanus* Zone), bed 12 at the East Themed area, and one specimen from the Abu Qada Formation (Upper Cenomanian-Lower Turonian), bed 26 from the same section (MGDMU:ET.Bi.**12**.4-9,**26**.1).

Measurements (in mm).

n=7	L	H	C	H/L	C/L	C/H
Range	20-38	9-15	7-12	0.37-0.46	0.31-0.42	0.69-1.00
Mean	27	11.57	9.57	0.43	0.36	0.83

Description. Small- to medium-sized, modiliform, strongly inequilateral, equivalved, and moderately inflated. Antero-dorsal margin short and rounded. Postero-dorsal margin long, broad, and nearly straight. Ventral margin slightly convex to straight, meeting the anterior and posterior margins in obtuse angles. Umbo sub-terminal, prosogyrate, situated distinctly behind the anterior end. Both valves have a strong diagonal keel, extending from the umbonal area towards the postero-ventral margin. This keel separates a small postero-dorsal area from the flank. Ornamentation consisting of strong, commarginal ribs, separated by wide and smooth interspaces. These interspaces become narrower dorsally.

Temporal and spatial distribution. *Modiolus* (*Modiolus*) *aequalis* has been recorded from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Lebanon (VOKES, 1941), Cenomanian-Paleocene of Algeria (AMARD et al., 1981) and from the Campanian-Maastrichtian of the same locality by COLLIGNON (1971). In Egypt, it is known from the Cenomanian of Gebel Shabrawit (FAWZI, 1963) and G. Ekma (EL QOT, 2006).

According to EL QOT (2006: 21), *M.* (*M.*) *aequalis* has a broad stratigraphic range, from the "Néocomian" (PERVINQUIÈRE, 1912) to the Paleocene (AMARD et al., 1981).

Discussion. The present species closely resembles *Modiola capitata* ZITTEL as figured by PERVINQUIÈRE (1912) and COLLIGNON (1971) in general shape, outline, and ornamentation and differs only in having a higher postero-dorsal side. According to EL QOT (2006: 21), *M.* (*M.*) *aequalis* is a highly variable species. Therefore, ZITTEL'S species is considered herein as a junior synonym of *M.* (*M.*) *aequalis* according to the law of priority.

M. (*M.*) *magharensis* of ABBASS (1962) from the Albian of El-Maghara closely resembles the present species in general outline and ornamentation but differs in having a less prominent keel and an ornamentation of finer commarginal striations separated by wide interspaces. The latter author erected another new species, *M.* (*M.*) *farisi*, from the Albian of Gebel Manzour (Sinai) which closely resembles the present species. His material is an internal mould and only the right valve has been photographed. ABBASS distinguished *M.* (*M.*) *farisi* from other *Modiolus* species by having a diagonal keel which dies out before reaching the postero-ventral margin. However, *M.* (*M.*) *aequalis* as figured by other authors e.g., EL QOT (2006: pl. 1, fig. 12b) has a keel which also dies out before the postero-ventral margin. Therefore, ABBASS's species is considered herein as a junior synonym of *M.* (*M.*) *aequalis.*

Order Arcoida STOLICZKA**, 1871**
Superfamily Arcacea LAMARCK**, 1809**
Family Arcidae LAMARCK**, 1809**
Genus *Arca* LINNÈ, 1758
Subgenus *Idonearca* CONRAD, 1862
Arca (*Idonearca*) *diceras* SEGUENZA, 1882
Pl. 3, Fig. 6

1882 *Arca diceras* sp. nov. – SEGUENZA: 96, pl. 14, fig. 1a-b.
1912 *Arca* (*Trigonoarca*?) *diceras* SEGUENZA – PERVINQUIÈRE: 102, pl. 7, figs. 23a-b, 25-26.
1917 *Arca diceras* SEGUENZA – FOURTAU: 8.
1918 *Arca* (*Trigonoarca*) *diceras* SEGUENZA – GRECO: 29 (211), pl. 3 (19), figs. 14-15.
1937 *Arca* (*Trigonoarca*) *diceras* SEGUENZA – TREVISAN: 48, pl. 2, figs. 12-13.
1962 *Arca* (*Idonearca*) *diceras* (SEGUENZA) – ABBASS: 23, pl. 2, fig. 10.
1963 *Arca* (*Idonearca*) *diceras* (SEGUENZA) – FAWZI: 22.
2002 *Trigonaraca diceras* (SEGUENZA) – ABDEL-GAWAD-GAMEIL: 81, pl. 1, fig. 10.
2004b *Trigonaraca diceras* (SEGUENZA) – ABDEL-GAWAD et al.: pl. 1, fig. 7.
2006 *Cucullaea* (*Idonearca*) *diceras* (SEGUENZA) – EL QOT: 24, pl. 2, figs. 6-8.
?2007b *Cucullaea* (*Idonearca*) *diceras* (SEGUENZA) – MEKAWY: 205, pl.1 ,fig. 7.

Material and occurrence. Two internal moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 39 at Wadi Quseib (MGDMU:WQ.Bi.**39**.1-2).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
Range	41-50	23-28	19-21	0.56-0.57	0.42-0.46	0.75-0.82
Mean	45.5	25.5	20	0.56	0.44	0.78

Description. Specimen large, elongated posteriorly, moderately inflated (C/H=0.78), strongly inequilateral, and equivalved. Anterior part shorter than the posterior one. Both antero- and postero-dorsal margins slightly concave. Ventral margin slightly convex and meeting the anterior and posterior margins in an even curve. Posterior umbonal keel well developed and separating a depressed postero-dorsal area from the flank. Umbo broad, anteriorly incurved, and situated one-forth of shell length from the anterior end. Below the umbo numerous, small, teeth imprints are partially preserved (Pl. 3 Fig. 6b). Hinge nearly straight and converging slightly towards the ventral margin anteriorly. The studied material consists of internal moulds without elements of ornamentation except for a few faint radial ribs near the ventral margin.

Temporal and spatial distribution. *Arca* (*Idonearca*) *diceras* has been recorded from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912) and Italy (TREVISAN, 1937). In Egypt, it is known from the Cenomanian of Gebel Gunna (FOURTAU, 1917; ABBASS, 1962), the Eastern Desert (GRECO, 1918; FAWZI, 1963; MEKAWY, 2007b), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al, 2004b), and G. Ekma (EL QOT, 2006).

Discussion. The dentition of the present material is very similar to that of the genus *Arca* (nearly straight, numerous teeth). Outline, width, and height of the cardinal area are closely similar to that of the subgenus *Idonearca*.

Arca (*Idonearca*) *diceras* can be easily distinguished by having a comparatively elongated shell (H/L=0.56) and prominent umbones. The outline of *Cucullaea* (*I.*) *diceras*, as figured by MEKAWY (2007b), is less elongated (H/L=0.70) and her specimen is shown in only one view without obvious hinge structures.

Trigonoarca passyana (WOODS, 1904) from the Upper Greensand of England is very similar to the present species in general outline but shows faint radial ribs crossed by commarginal growth lines. According to ABBASS (1962: 23), *A.* (*I.*) *diceras* differs from *Cucullaea ligeriensis* D'ORBIGNY in having a higher shell.

A. olisiponensis SHARPE (1850: 176, pl. 14, fig. 1a-c) from the Upper Cretaceous of Portugal differs in having a higher and truncated posterior margin, shorter hinge, and in being higher (H/L=0.75) and more inflated (C/L=0.66) than the present specimens.

A. tinrhertensis COLLIGNON (1971: 20 (162), pl. D, fig. 1) from the Maastrichtian of Algeria also closely resembles the present species in general outline and size but it has been collected from a higher stratigraphic level (Maastrichtian). Moreover, COLLIGNON'S material is an internal mould any traces of ornamentation. The hinge characters are also not seen. *A. tinrhertensis* belongs to the present species.

Family Cucullaeidae STEWART, 1930

Genus *Cucullaea* LAMARCK, 1801
Subgenus *Idonearca* CONRAD, 1862
Cucullaea (*Idonearca*) *trigona* (SEGUENZA, 1882)
Pl. 3, Figs. 7-8

1882 *Arca trigona* sp. nov. – SEGUENZA: 98, pl. 13, figs. 6, 6a.
1912 *Arca* (*Trigonoarca*?) *trigona* SEGUENZA – PERVINQUIÈRE: 103, pl. 7, figs. 20-21.
1918 *Arca* (*Trigonoarca*) *trigona* SEGUENZA – GRECO: 28 (210), pl. 3 (19), figs. 12-13.
1937 *Arca* (*Trigonoarca*) *trigona* SEGUENZA – TREVISAN: 47, pl. 2, fig. 10.
1963 *Arca* (*Idonearca*) *trigona* (SEGUENZA) – FAWZI: 21.
2001 *Trigonarca trigona* (SEGUENZA) – ABDALLAH et al.: pl. 2, fig. 1.
2004a *Cucullaea* (*Idonearca*) *trigona* (SEGUENZA) – ABDEL-GAWAD et al.: pl. 5, fig. 2a-b.
2006 *Cucullaea* (*Idonearca*) *trigona* (SEGUENZA) – EL QOT: 25, pl. 3, fig. 2a-b.
?2007b *Cucullaea* (*Idonearca*) *trigona* (SEGUENZA) – MEKAWY: 208, pl. 1, fig. 11.

Material and occurrence. 45 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada and Upper Turonian Wata formations, beds 19, 25, 31, 57 of the East Themed area (MGDMU:ET.Bi.**19**.1, **25**.1-5,**31**.1-35,**57**.1-4), and seven internal moulds from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.Bi.**47**.3-9).

Measurements (in mm).

n=6	L	H	C	H/L	C/L	C/H
Range	39-43	25-33	18-23	0.58-0.76	0.45-0.57	0.66-0.76
Mean	41.5	28.17	21	0.67	0.50	0.74

Description. Specimen medium-sized, trapezoidal to subtriangular, moderately inflated, strongly inequilateral, and equivalved. The anterior margin shorter than the posterior one and forming an approximately right angle with the hinge line. Posterior margin slightly convex, strongly inclined, and forming a rounded obtuse angle with the ventral margin. Ventral margin slightly convex, meeting the anterior margin in a rounded angle. Hinge line nearly straight mesially, and inclined towards the ventral margin at the two extremities. Umbones less prominent, broad, anteriorly incurved, widely separated, and situated about one-third to one-fourth of shell length from the anterior end. Posterior umbonal keel well developed and separating a depressed postero-dorsal area from the flank. Posterior teeth well preserved, few and large (Pl. 3, Fig. 8). The studied material is an internal mould without elements of ornamentation exceot a few faint radial ribs near the ventral margin.

Temporal and spatial distribution. *Cucullaea* (*Idonearca*) *trigona* has been recorded from the Turonian of Tunisia (PERVINQUIÈRE, 1912) and Italy (TREVISAN, 1937). In Egypt, it is known from the Cenomanian of the Eastern Desert (GRECO, 1918; FAWZI, 1963), Turonian of El-Giddi Pass (ABDALLAH et al., 2001), and from the Upper Cenomanian-Upper Turonian of G. Ekma and East Themed (ABDEL-GAWAD et al., 2004a; EL QOT, 2006). MEKAWY (2007b: 208) recorded the species from the Coniacian-Santonian Matulla Formation of the Eastern Desert. Therefore, *C.* (*I.*) *trigona* ranges from the Cenomanian to the Santonian.

Discussion. *Cucullaea* (*Idonearca*) *trigona* resembles *Arca* (*Idonearca*) *diceras* (SEGUENZA, 1882) in general shape and outline but differs in being smaller, less elongated, less inflated, and also in having less prominent umbones.

A. (*Trigonoarca*) *navis* SEGUENZA as figured by TREVISAN (1937: 50, pl. 2, fig. 11) from Italy differs in having wide umbones, a sharp posterior end, and in being more inflated than the present species.

Cucullaea (*Idonearca*) *thevestensis* (COQUAND, 1862)
Pl. 3, Fig. 9; Pl. 4, Figs. 1-2

1862 *Arca Tevesthensis* sp. nov. – COQUAND: 212, pl. 15, figs. 9-10.
1891 *Arca Thevestensis* COQUAND – PERON: 257.
1912 *Arca* (*Trigonarca*?) *Thevestensis* COQUAND – PERVINQUIÈRE: 104, pl. 7, figs. 22, 27a, b.
1917 *Arca Thevestensis* COQUAND – FOURTAU: 12.
1934 *Arca* (*Trigonarca*?) *Thevestensis* COQUAND – BLANCKENHORN: 211.
2006 *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND) – EL QOT: 25, pl. 2, figs. 14-15; pl. 3, fig. 1.
?2007b *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND) – MEKAWY: 207, pl. 1, fig. 10.

Material and occurrence. Five specimens from the Upper Turonian Wata Formation, bed 97 at Wadi Quseib (from the ammonite *Coilopoceras requienianum* Zone) (MGDMU:WQ.Bi.**97**.1-5), and 14 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 23, 26 of the East Themed area (MGDMU:ET.Bi.**23**.1-4, **26**.2-11).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	45-47	33-38	30-43	0.73-0.81	0.66-0.91	0.90-1.13
Mean	46	35	36.5	0.77	0.78	1.00

Description. Specimen large-sized, trapezoidal, equivalved, strongly inequilateral, and strongly inflated (C/H=1.00). Umbones broad, anteriorly incurved, widely separated, not strongly prominent, and situated about one-fourth of shell length from the anterior end. Antero-dorsal margin slightly concave, postero-dorsal margin slightly convex. Ventral margin slightly curved, broad, and meeting the anterior margin in an even curve. Anterior margin shorter than the posterior one. Posterior umbonal keel well developed. Hinge nearly straight mesially, inclined towards the ventral margin at the two extremities, and forming an obtuse angle with the posterior margin. Adductor scars are ovate and nearly isomyarian, pallial line without sinus (Pl. 4, Fig. 2). Teeth preserved, apparently small and numerous in the cardinal part. Ornamentation consisting of fine radial ribs, which are well preserved near the ventral margin and separated by narrower interspaces (Pl. 4, Fig. 1b).

Temporal and spatial distribution. *Cucullaea* (*Idonearca*) *thevestensis* has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862), Lower Turonian of Tunisia (PERVINQUIÈRE, 1912), and Syria (BLANCKENHORN, 1934). In Egypt, it is known from the Cenomanian of West Wadi Gharamul (FOURTAU, 1917), Lower Turonian of the East Themed area, Sinai (EL QOT, 2006) and Abu Darag, Eastern Desert (MEKAWY, 2007b). Stratigraphically, the species ranges from the Cenomanian to the Turonian.

EXPLANATION OF PLATE 4

Figs. 1-2. *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND, 1862). **1**. Internal mould from the Upper Cenomanian-Lower Turonian Galala Formation of the East Themed area, x1. **a**: External view of right valve, **b**: side view of left valve; MGDMU:ET.Bi.**23**.1: - **2**. Internal mould from the Upper Turonian Wata Formation at Wadi Quseib, x1. Side view of left valve with adductor muscle scars (arrowed); MGDMU:WQ.Bi.**97**.1.

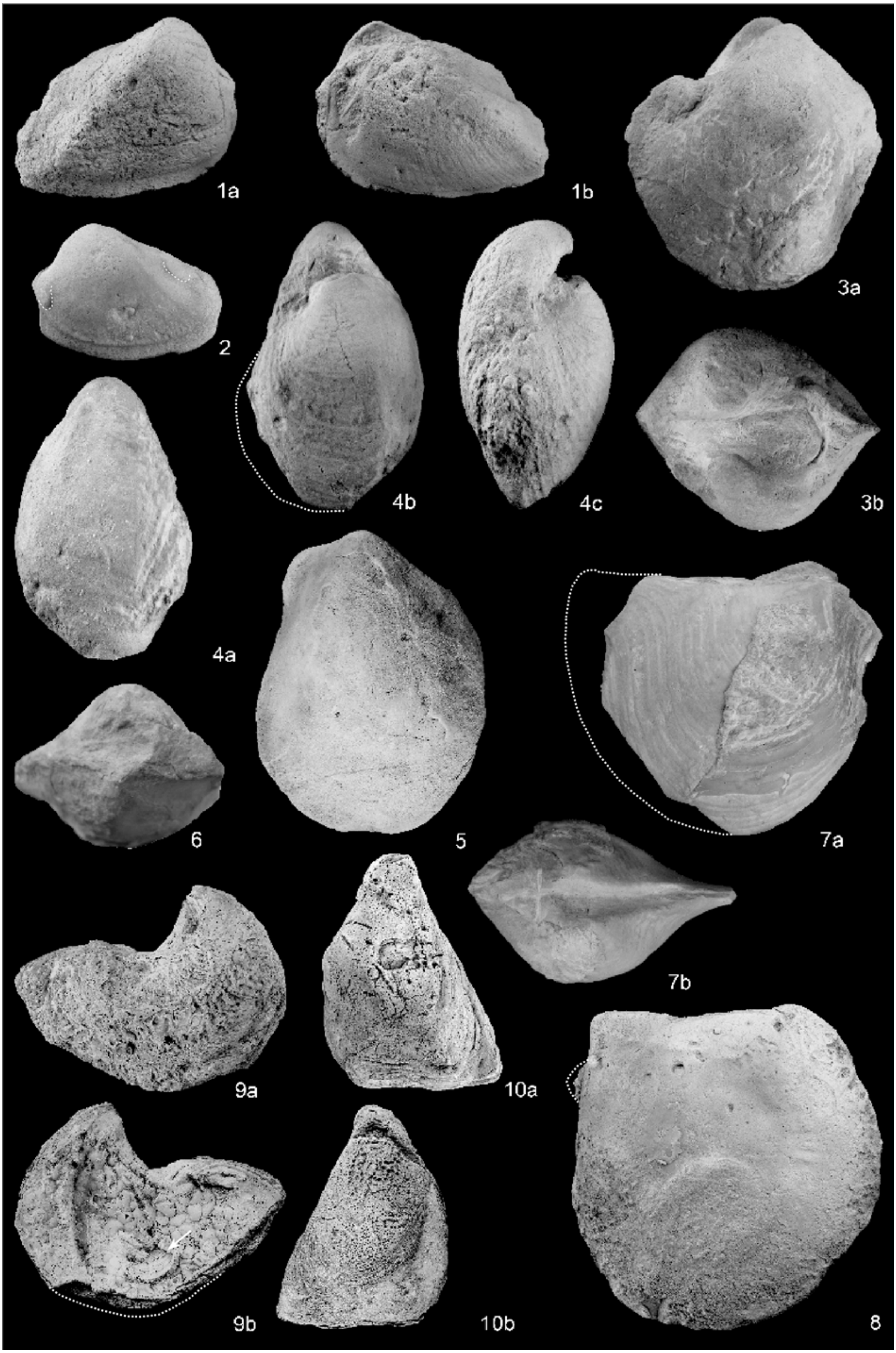
Fig. 3. *Cucullaea*? cf. *favrei* (COQUAND, 1862). Internal mould from the upper carbonate/marl member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: Side view of right valve, **b**: dorsal view; MGDMU:AEN.**Bi**.19.2.

Fig. 4. *Mytiloides concentricus* (PARKINSON, 1819). Composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation (Upper Albian *Mytiloides concentricus* Zone) at Gebel Areif El-Naqa, x1.5. **a**: External view of left valve, **b**: side view of right valve, **c**: posterior view; MGDMU:AEN.Bi.**12**.1.

Figs. 5-6. *Phelopteria atra* (COQUAND, 1862). **5**. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib. Side view of right valve, x1.5; MGDMU:WQ.Bi.**47**.4. - **6**. Internal mould from the Upper Turonian Wata Formationat Wadi Quseib. Dorsal view, x1; MGDMU:WQ.Bi.**93**.1.

Figs. 7-8. *Phelopteria gravida* (COQUAND, 1862). **7**. Specimen with partially preserved shell from the upper member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x1. **a**: Side view of right valve, **b**: dorsal view; MGDMU:AEN.Bi.**30**.2. - **8**. Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of East Themed. Side view of left valve, x1; MGDMU:ET.Bi.**19**.2.

Figs. 9-10. *Nayadina* (*Nayadina*) *gaudryi* THOMAS & PERON, 1891 from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. **9a**: Side view of right valve, b: internal view of right valve; MGDMU:WQ.Bi.**44**.6. - **10a**: Side view of left valve, b: side view of right valve; MGDMU:WQ.Bi.**44**.7.


1a
1b
3a
2
4b
4c
3b
4a
6
5
7a
7b
9a
10a
9b
10b
8

Discussion. The present specimen has been identified based on its close similarity in general shape, outline, and size with *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND) as figured and described by PERVINQUIÈRE (1912) from the Lower Turonian of Tunisia.

PERON (1891: 257) mentioned that the correct name for *tevesthensis* is *thevestensis. C.* (*I.*) *maresi* (COQUAND, 1880) and *C.* (*I.*) *teutobochus* (COQUAND, 1880) as figured and described by PERON (1891: 257-259: pl. 27, figs. 24-27) from the Santonian of Tunisia differ in having a wider umbonal area, less inflated shell, and truncated posterior margin.

Arca (*Trigonarca*) *tumida* D'ORBIGNY, which has been recorded from the Santonian of Abu Roash (Egypt) by ABBASS (1962: 24, pl. 2, fig. 6), closely resembles the present species in general outline but differs in being smaller and less inflated than the present material (L=42 mm, H=33 mm, C=11 mm, C/L= 0.26).

Cucullaea? cf. *favrei* (COQUAND, 1862)
Pl. 4, Fig. 3

cf. 1862 *Arca Favrei* sp. nov. - COQUAND: 212, pl. 15, figs. 11-12.
cf. 1918 *Arca* (*Cucullaea*) *favrei* COQUAND – GRECO: 209, pl. 3, fig. 11.
cf. 2002 *Cucullaea* (*Idonearca*) cf. *favrei* (COQUAND) – ABDEL-GAWAD & GAMEIL: 79, pl. 1, fig. 7.

Material and occurrence. Two internal moulds from the upper carbonate/marl member of the Upper Albian-Cenomanian Halal Formation, bed 19 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**19**.1-2).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	47-60	47-60	36-50	1	0.76-0.83	0.76-0.83
Mean	53.5	53.5	43	1	0.79	0.79

Description. Specimen trapezoidal, large-sized, equivalved, strongly inequilateral, and strongly inflated (C/L=0.79). Anterior margin regularly rounded, higher than the posterior one, and forming an approximately right angle with the hinge line. Postero-dorsal margin strongly concave. Ventral margin strongly convex, meeting the anterior and posterior margins in rounded curves. Umbones prominent, sharply pointed, widely separated, anteriorly incurved, and situated about one-fourth of shell length from the anterior end. Hinge line nearly straight and inclined towards the posterior side. Dentition not preserved. The present material are internal moulds which carry traces of faint radial ribs near the anterior side.

Temporal and spatial distribution. *Cucullaea favrei* has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862). In Egypt, it is known from the Cenomanian of Wadi Araba, Eastern Desert (GRECO, 1918) and Gebel Nezzazat (ABDEL-GAWAD & GAMEIL, 2001).

Discussion. The classification as *Cucullaea* was mainly based on the outline, ornamentation, and dentition. As the present material is articulated, the hinge and other internal characters are not seen. Therefore, it is attributed herein to the genus *Cucullaea* with some doubts.

The material closely resembles *Arca favrei* COQUAND from Algeria in general outline and size but COQUAND'S species differs in having a narrower umbonal area, shorter hinge, and well-developed ribs. *Arca delettrei* COQUAND (1862: pl. 15, figs. 5-6) from the same locality differs in having a well developed postero-dorsal keel and less prominent umbones.

Arcullaea olea VOKES (1946: 151, pl. 1, figs. 15-22) from the Albian of Lebanon is also similar to the present material with respect to most external features e.g., ornamentation and general outline but differs in being smaller (max. L=33.3 mm, H=26.4 mm, C=22.3 mm) and more elongated than the present material (H/L=0.75).

A. (*C.*) *schweinfurthi* QUAAS as figured by PERVINQUIÈRE (1912: pl. 7, figs. 28-31) from the Maastrichtian of Tunisia differs in having a nearly rounded shell and faint commarginal growth lines.

Superorder Eupteriomorphia BOSS, 1982
(Anisomyaria NEUMAYR, 1883)
Order Pterioida NEWELL, 1965
Suborder Pteriina NEWELL, 1965
Superfamily Ambonychiacea MILLER, 1877
Family Inoceramidae (GIEBEL, 1852) ZITTEL, 1881
Genus *Mytiloides* BRONGNIART, 1832
Mytiloides concentricus (PARKINSON, 1819)
Pl. 4, Fig. 4; Text-fig. 3.1

1819 *Inoceramus concentricus* sp. nov. – PARKINSON: 58, pl. 1, fig. 4.
1910 *Inoceramus concentricus* PARKINSON – WOODS: 265, pl. 65, fig. 11; pl. 66, figs. 8-10; pl. 67, figs. 1-2.
?1972 *Inoceramus* aff. *concentricus* PARKINSON – THOMSON & WILLEY: 13, figs. 6e, 9a-b, 10.
1979 *Inoceramus concentricus* PARKINSON – CRAME: 283, fig. 2,

Material and occurrence. One composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation (Upper Albian *Mytiloides concentricus* Zone), bed 12 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**12**.1).

Measurements (in mm).

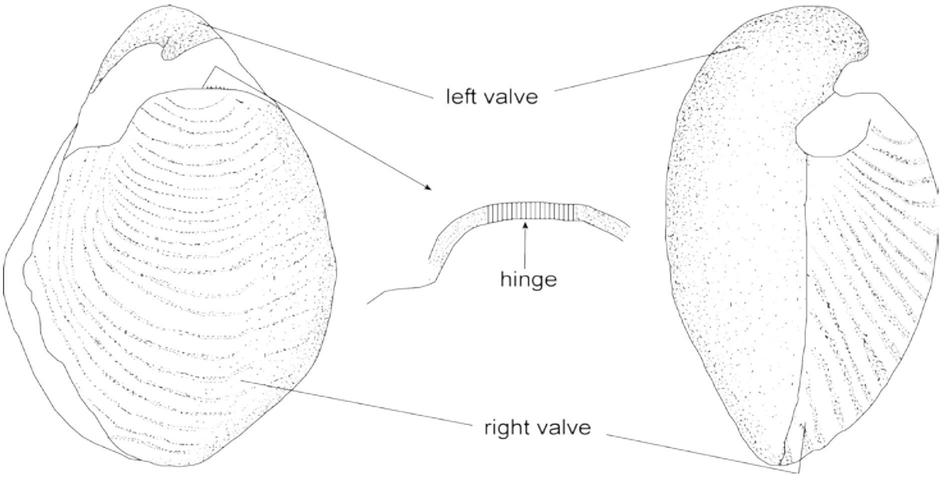
n=1	L	H	C	H/L	C/L	C/H
	21	34	20	1.62	0.95	0.59

Description. Medium-sized, ovate, much higher than long (H/L=1.62), strongly inequivalved, inequilateral, and strongly inflated. Left valve higher than right one, drop-shaped, possessing an umbo which is sharply pointed, narrow, and slightly incurved posteriorly (opisthogyrate). Right valve ovate and slightly more convex than the left one (Pl. 4, Fig. 4c). Anterior margin convex, posterior margin more expanded but less convex than the anterior one. Ventral margin rounded, meeting the anterior and posterior margins in even curves. Hinge short and straight behind the umbo with fine striations (teeth imprints) arranged perpendicular to the hinge line (Text-fig. 3.1). Ornamentation consisting of commarginal ribs, separated by wide, asymmetrical, and smooth interspaces. These ribs are well developed near the ventral margin of the right valve.

Temporal and spatial distribution. *Mytiloides concentricus* (PARKINSON) has been recorded from the Middle-Upper Albian of England (WOODS, 1910), Alexander Island, North America (THOMSON & WILLEY, 1972), Middle-Upper Albian to ?Cenomanian of Dundee Island, North America (CRAME, 979).

According CRAME (1979: 285), the stratigraphic level of *M. concentricus* in Western Europe is Middle to Upper Albian. However, there is some evidence to suggest that outside Europe this range extends upward. For instance, in New Zealand, the species has been recorded from the base of the Cenomanian.

Discussion. THOMSON & WILLEY (1972) described five poorly preserved specimens as *Inoceramus* aff. *concentricus* but their specimens are larger (height ranging from 100 to 120 mm) than typical *I. concentricus* as figured WOODS (1911). According to CRAME (1979), *I. concentricus* can be confused with *I. salomoni* D'ORBIGNY and *I. tenuis* MANTELL. He pointed out that *I. salomoni* generally has prominent radial ribs on the left valve, while in *I. tenuis* the umbo of the left valve is less prominent (for more detailed discussion, see CRAME: 1979: 284-286).



Text-fig. 3.1. Hinge, outline, and ornamentation of *Mytiloides concentricus* (PARKINSON, 1819) from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

Superfamily Pteriacea GRAY (1820) 1847
Family Bakevelliidae KING, 1850
Genus *Phelopteria* STEPHENSON, 1952
Phelopteria atra (COQUAND, 1862)
Pl. 4, Figs. 5-6; Text-fig. 3.2A

1862 *Avicula atra* sp. nov. – COQUAND: 217, pl. 14, figs. 5-6.
1882 *Avicula atra* COQUAND – SEGUENZA: 164.
1903 *Avicula atra* COQUAND – PERVINQUIÈRE: 97, 112.
1912 *Avicula atra* COQUAND – PERVINQUIÈRE: 110.
1918 *Avicula atra* COQUAND – GRECO: 1 (183), pl. 1(17), fig. 3a-b.

Material and occurrence. Nine articulated internal moulds from the Upper Cenomanian Galala Formation (*Neolobites vibrayeanus* Zone), Lower Turonian Abu Qada Formation (*Choffaticeras segne* Zone), and from the Upper Turonian Wata Formation (*Coilopoceras requienianum* Zone), beds 41, 47, and 93 at Wadi Quseib (MGDMU:WQ.Bi.**41**.2-3, **47**.4-14, **93**.1-2).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	29-43	36-50	17-27	1.16-1.24	0.58-0.62	0.47-0.54
Mean	36	43	22	1.20	0.60	0.50

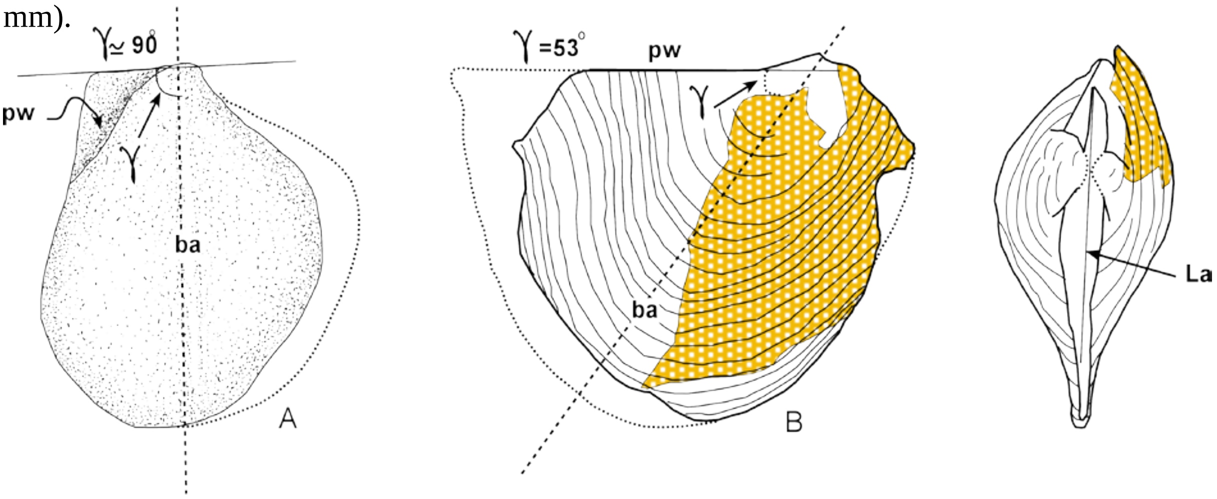
Description. Outline pear-shaped, medium-sized, elongated in a postero-ventral direction, nearly equivalved, strongly inequilateral, and moderately inflated along the umbonal area. Left valve more convex than right one. Both anterior and posterior margins convex, meeting the ventral margin in even an curve. Ligamental area (La) straight. Posterior wing (hF) small, higher than the anterior one, and forming a nearly right angle with the main body axis (Text-fig. 3.2A). Umbones broad, slightly prominent, and situated anteriorly. Ornamentation not preserved.

Temporal and spatial distribution. *Phelopteria atra* has been recorded from the Lower Turonian (Mornasien) of Algeria (Coquand, 1862) and Tunisia (Pervinquière, 1912). In Egypt, it is known from the Turonian of the Eastern Desert (Greco, 1918).

According to Pervinquière (1912), *Ph. atra* (Coquand) has a broad stratigraphic range, from the Cenomanian to the Coniacian.

Discussion. Many species of the genus *Phelopteria* can be distinguish on the basis of the angle between the hinge and the body axis (Text-fig. 3.2).

The present species is distinguished from *Phelopteria gravida* (Coquand, 1862) by its elongated outline, shorter hinge (with nearly right angle with the main body axis), and narrower umbonal area. *Pteria* (*Electroma*) *hadhirensis* Abbass (1962: 39, pl. 5, fig. 6) from the Cenomanian of El Hadhira, Egypt differs in being smaller (L=17 mm, H= 16 mm, C=8 mm).



Text-fig. 3.2. Angle between the posterior wing and the main body axis of *Phelopteria* Stephenson, 1952. A. *Phelopteria atra* (Coquand, 1862) from the Lower Turonian Abu Qada Formation at Wadi Quseib. B. *Phelopteria gravida* (Coquand) from the Upper Turonian Wata Formation of the Wadi Quseib area. The yellow part of the figure refers to the shell part. pw= posterior wing, La= ligamental area, ba=diagonal (body axis), γ=angle between the body axis and posterior wing.

Phelopteria gravida (Coquand, 1862)
Pl. 4, Figs. 7-8; Text-fig. 3.2B

1862 *Avicula gravida* sp. nov. – Coquand: 216, pl. 13, figs. 17-18.
1912 *Avicula gravida* Coquand – Pervinquière: 109.
1917 *Avicula* cf. *gravida* Coquand – Fourtau: 16.
1934 *Avicula gravida* Coquand – Blanckenhorn: 178, pl. 7, fig. 2.
1962 *Pteria* (*Electroma*) *tihensis* sp. nov. - Abbass: 38, pl. 5, fig. 5.
2002 *Phelopteria tihensis* (Abbass) – Abdel-Gawad & Gameil: 83, pl. 1, fig. 18.
2002 *Pteria tihensis* Abbass – Abdelhamid & El Qot: 262 pl. 1, figs. 7-8.

2006 *Phelopteria gravida* (COQUAND) – EL QOT: 30, pl. 4, figs. 1-2.
2007b *Phelopteria gravida* (COQUAND) – MEKAWY: 210, pl. 2, fig. 2.

Material and occurrence. 45 specimens from the Upper Cenomanian Galala and Lower Turonian Abu Qada formations, beds 12, 16, 19, 23, 25, and 26 of the East Themed area (MGDMU:ET.Bi.**12**.10-13,**16**.1-2,**19**.2-19,**23**.5-8,**25**.6-17,**26**.12-16), and one specimen from the upper member of the Lower Turonian Abu Qada Formation, bed 30 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**30**.2).

Measurements (in mm).

n=5	L	H	C	H/L	C/L	C/H
Range	44-65	44-73	25-34	0.89-1.10	0.50-0.61	0.46-0.61
Mean	54.8	58	30	1	0.55	0.52

Description. Medium-to large-sized, sub-quadrangular to nearly rounded, moderately inflated, slightly equivalved, and inequilateral. Left valve slightly more convex than right one. Ventral margin curved and meeting the anterior and posterior margins in rounded curve. Postero-dorsal margin and ligamental area (La) straight, long, forming an acute angle (about 53°) with the main body axis (Text-fig. 3.2B). Umbones broad, less prominent, and slightly incurved anteriorly. Ornamentation consisting of commarginal growth lines, separated by wide interspaces.

Temporal and spatial distribution. *Phelopteria gravida* has been recorded from the Lower Turonian (Mornasien) of Algeria (COQUAND, 1862) and Tunisia (PERVINQUIÈRE, 1912). In Egypt, it is known from the Upper Cenomanian of Gebel Tih (FOURTAU, 1917; ABBASS, 1962), Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Hamra (ABDELHAMID & EL QOT, 2002), and from the Upper Cenomanian-Middle Turonian of the East Themed area and G. Ekma (EL QOT, 2006). The species has been also recorded from the Upper Cenomanian-Lower Turonian of the Eastern Desert by MEKAWY (2007b).

Discussion. *Pteria* (*Electroma*) *tihensis* ABBASS, 1962, from the Cenomanian of Gebel Tih, Sinai, closely resembles *Avicula gravida* COQUAND, 1862 in general shape, outline, size, and the angle between the posterior wing and body axis. FOURTAU (1917) recorded *Phelopteria gravida* from the same stratigraphic level and the same locality of ABBASS's species. ABBASS (1962: 39) distinguished his new species from COQUAND's species by its subcircular outline and hinge line that is inclined with respect to the main body axis. PERVINQUIÈRE (1912) and BLANCKENHORN (1934) in their discussions of *Ph. gravida* mentioned that the hinge line forms an angle of 50° -60° with the main body axis. Therefore, *Ph. tihensis* (ABBASS) is a junior synonym of *Ph. gravida*. *Ph. caudigera* (ZITTEL, 1866: 89, pl. 12, figs. 12a-c) as described and figured by EL QOT (2006: 28, pl. 3, figs. 12-13) differs in having a deep byssal concavity, higher shell, and a main body axis that is more strongly inclined with respect to the hinge line (for more detailed discussion, see EL QOT, 2006: 30-31).

Avicula delettrei COQUAND (1862: 216, pl. 14, figs. 1-2) from the Upper Cretaceous of Algeria differs in having a postero-ventral keel, narrower umbonal area, and a hinge which is more inclined with respect to the main body axis. The latter author also erected *Avicula producta* (1862: 217, pl. 14, figs. 3-4) from the Upper Cretaceous of Algeria, which differs in having a more prolongated (obliquely extended) postero-ventral part and a strong postero-dorsal keel.

Family Malleidae LAMARCK, 1818

Genus *Nayadina* MUNIER-CHALMAS, 1864
Subgenus *Nayadina* MUNIER-CHALMAS, 1864
Nayadina (*Nayadina*) *gaudryi* THOMAS & PERON, 1891
Pl. 4, Figs. 9-10; Text-fig. 3.3

1891 *Nayadina Gaudryi* sp. nov. – THOMAS & PERON in PERON: 200, pl. 26, figs. 4-15.
1917 *Nayadina Gaudryi* THOMAS & PERON – FOURTAU: 58.
1918 *Nayadina Gaudryi* THOMAS & PERON – GRECO: 17 (199), pl. 3 (19), fig. 2.
1962 *Nayadina gaudryi* THOMAS & PERON – ABBASS: 84, pl. 12, fig. 7.
1963 *Nayadina gaudryi* THOMAS & PERON – FAWZI: 26, pl. 2, fig. 2.
2002 *Nayadina* (*Nayadina*) *gaudryi* THOMAS & PERON – ABDELHAMID & EL QOT: 263, pl. 1, figs. 9-10.
2004b *Nayadina* (*Nayadina*) *gaudryi* THOMAS & PERON – ABDEL-GAWAD et al.: pl. 1, fig. 10.
2006 *Nayadina* (*Nayadina*) *gaudryi* THOMAS & PERON – EL QOT: 32, pl. 4, figs. 6, 9.
2007b *Nayadina* (*Nayadina*) *gaudryi* THOMAS & PERON – MEKAWY: 211, pl. 2, fig. 3.

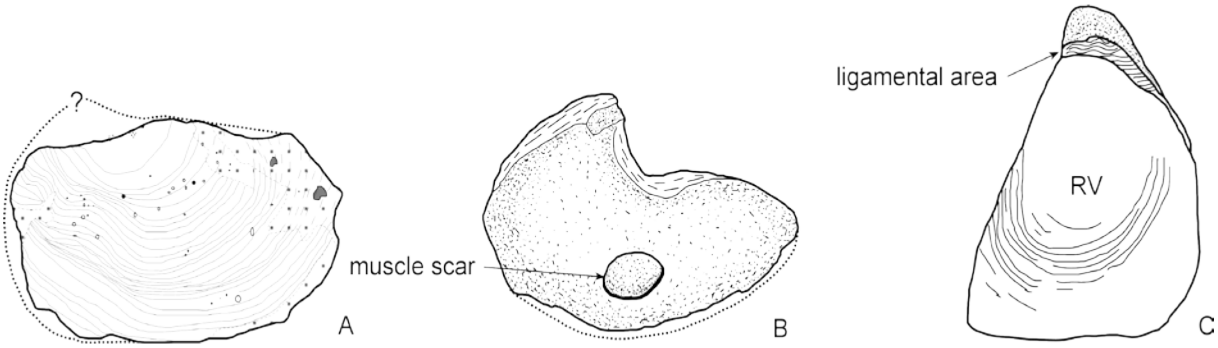
Material and occurrence. Three specimens from the upper carbonate member of the Galala Formation (Upper Cenomanian), bed 44 at Wadi Quseib (MGDMU:WQ.Bi.**44**.6-8), three specimens from the same formation, bed 12 of the East Themed section (MGDMU:ET.Bi.**12**.14-16), and one articulated specimen (in shell preservation) from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian), bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.6).

Measurements (in mm).

n=4	L	H	C	H/L	C/L	C/H
A	46	26	15	0.56	0.33	0.58
B	47	33	--	0.70	--	--
C	33	43	23	1.30	0.69	0.53
D	37	41	17	1.20	0.45	0.41

Description. Shell medium-sized, variable in outline, ovate, subtriangular, lunate (Text-fig. 3.3), slightly equivalved, strongly inequilateral, moderately inflated, and usually higher than long. Umbones terminal and only little prominent. Ligamental area well exposed to the exterior, with broad, deeply concave ligamental pit occupying most of its width. Adductor muscle scar small, ovate to semi-circular and placed near the ventral margin or subcentrally (Text-fig. 3.3B). Ventral margin broadly rounded and meets the anterior and posterior margins in even curves. Ornamentation consisting of irregular commarginal growth lines separated by wide interspaces.

Temporal and spatial distribution. *Nayadina* (*Nayadina*) *gaudryi* has been recorded from the Cenomanian of Tunisia (PERON, 1891). In Egypt, it occurs in the Cenomanian of Wadi Abu Qada (FOURTAU, 1917), Eastern Desert (GRECO, 1918; MEKAWY, 2007b), G. Dhalfa (ABBASS, 1962), Gebel El-Minsherah and G. El-Hamra (FAWZI, 1963; ABDELHAMID & EL QOT, 2002), East Themed and G. Yelleg (EL QOT, 2006), and G. El-Fallig (ABDEL-GAWAD et al., 2004b).



Text-fig. 3.3. Variation in outline of *Nayadina* (*Nayadina*) *gaudryi* Thomas & Peron, 1891 from the Galala Formation (Upper Cenomanian) at Wadi Quseib. For dimensions see the measurements above (A, B, and C).

Suborder Pinnina Waller, 1978
Superfamily Pinnacea Leach, 1819
Family Pinnidae Leach, 1819

Genus *Pinna* Linné, 1758
Subgenus *Pinna* Linné, 1758
Pinna (*Pinna*) sp.
Pl. 5, Fig. 1

Material and occurrence. One incomplete specimen, with some shell parts, from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 9 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**9**.1).

Description. Valves wedge-shaped or like the head of a spear, incomplete, most probably equivalved, strongly inequilateral, shell expanding towards the posterior end, rhombic in cross-section, and slightly asymmetrical. Ventral margin straight. Anterior margin rounded. Both valves convex with faint median carina running from the umbones towards the posterior margin and dividing the valves into two unequal parts. Umbones eroded. Ornamentation consisting of strong radial ribs, separated by broad and concave interspaces. These radial ribs are crossed by concentric commarginal lines near the dorsal side.

EXPLANATION OF PLATE 5

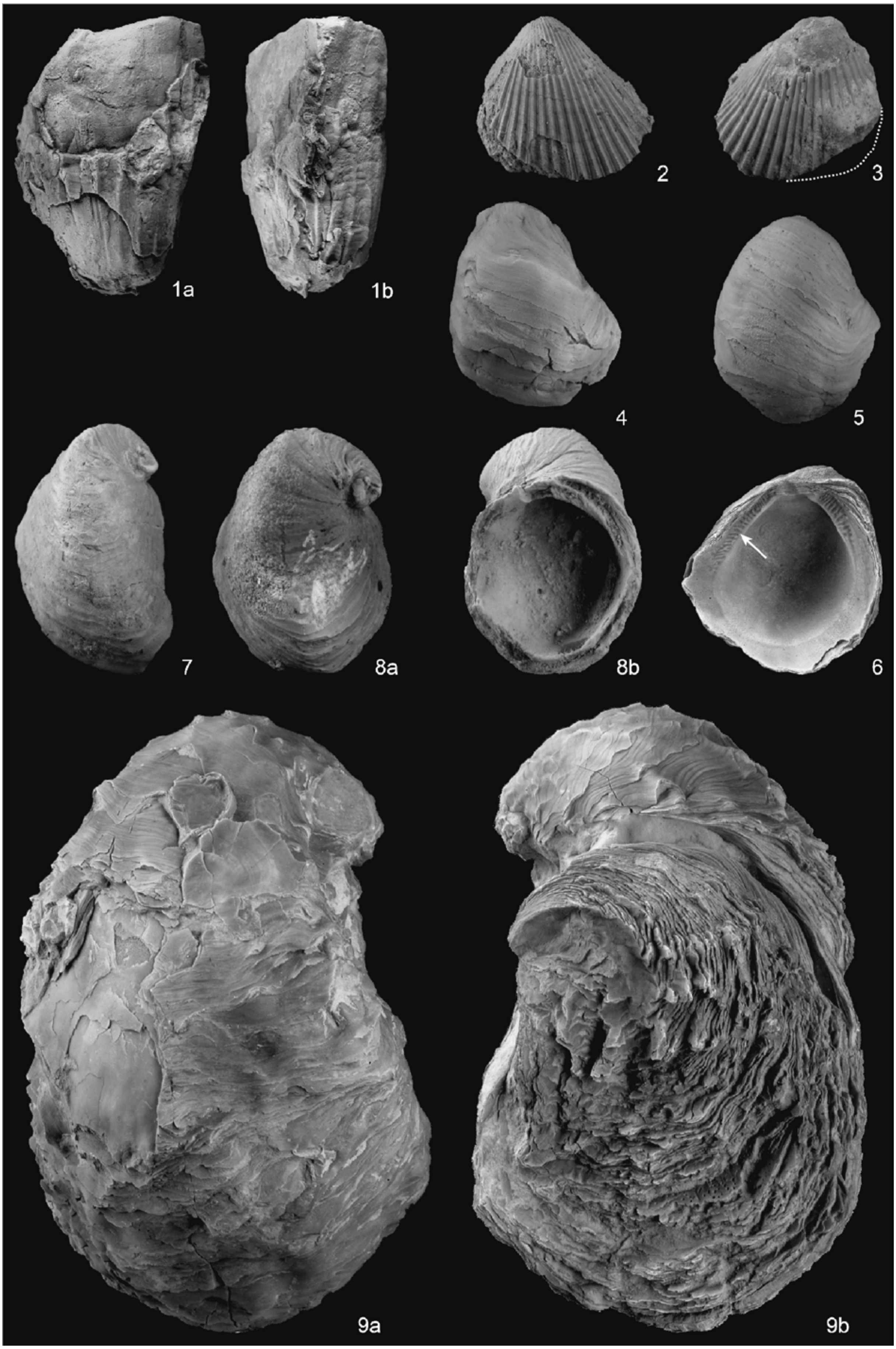
Fig. 1. *Pinna* (*Pinna*) sp., lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: Side view of right valve, **b**: dorsal view; MGDMU:AEN.Bi.**9**.1.

Figs. 2-3. *Pseudolima itieriana* (Pictet & Roux, 1852). **2**. Specimen from the Upper Cenomanian Galala Formation at the East Themed area, x2. Side view of left valve; MGDMU:ET.Bi.5.**1**. - **3**. Middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x2. Side view of right valve; MGDMU:WQ.Bi.**12**.16.

Figs. 4-6. *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. de C. Sowerby, 1823). Upper Cenomanian-Lower Turonian Abu Qada Formation at the East Themed area, x1.5. **4**. Side view of left valve; MGDMU:ET.Bi.**19**.20. - **5**. External view of left valve; MGDMU:ET.Bi.23. - **6**. Internal view with well-developed catachomata (arrowed) of left valve; MGDMU:ET.Bi.**23**.9.

Figs. 7-8. *Exogyra conica* (J. de C. Sowerby, 1813) from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa. **7**. Side view of left valve, x2; MGDMU:AEN.Bi.**15**.7. - **8a**. Side view of left valve, x3, **b**: internal view of left valve, x3; MGDMU:AEN.Bi.**1**.10.

Fig. 9. *Costagyra olisiponensis* (Sharpe, 1850). Large articulated valves from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **a**: Side view of left valve, **b**: side view of right valve; MGDMU:ET.Bi.**17**.1.


1a
1b
2
3
4
5
7
8a
8b
6
9a
9b

Discussion. The principal distinguishing character of the genus *Pinna* is the presence of a median carina in the two valves. According to SEELING & BENGTSON (2003: 497), most of the European Upper Cretaceous pinnids have been assigned to *Pinna cretacea* (SCHLOTHEIM, 1813) or *P. decussata* GOLDFUSS, 1837. The present material resembles *P. cretacea* as figured and described by SEELING & BENGTSON (2003: fig. 4D) in the general outline and ornamentation but a precise identification is not possible because of the fragmented nature of the specimen.

P. cretacea differs from *P. decussata* in being more elongated and in having less distinctly curved ridges on the ventral part of shell. These differences are minor and have never been clearly defined (DHONDT, 1987). In addition, ABDEL-GAWAD (1986) pointed out that the main difference between *P. cretacea* and *P. decussata* lies only in the strength of longitudinal ribs and cross-section and that these differences are probably of ecological significance and substrate-controlled (for more detailed discussion, see SEELING & BENGTSON, 2003: 475-480). *P. robinaldina* D'ORBIGNY, 1844 as figured by WOODS (1905: 96, pl. 12, figs. 11-15; pl. 13, fig. 1) from the Lower Greensand of England and *P. rugosa* ROEMER (1839: 32, pl. 18, fig. 37) differ from the present material in the style of ornamentation.

Order Limoida (RAFINESQUE, 1815) WALLER, 1978
Superfamily Limacea RAFINESQUE, 1815
Family Limidae RAFINESQUE, 1815
Genus *Pseudolimea* ARKELL, 1932
Pseudolimea itieriana (PICTET & ROUX, 1852)
Pl. 5, Figs. 2-3

1852 *Lima Itieriana* sp. nov. – PICTET & ROUX: 484, pl. 40, fig. 5a-f.
1912 *Lima Itieriana* PICTET & ROUX – PERVINQUIÈRE: 146, pl. 9, figs. 8-9.
1937 *Lima Itieriana* PICTET & ROUX – TREVISAN: 59, pl. 2, fig. 14a-b.
1962 *Lima* (*Radula*) *cenomanensis* sp. nov. – ABBASS: 48, pl. 8, figs. 6-7.
2006 *Pseudolimea itieriana* (PICTET & ROUX) – EL QOT: 35, pl. 5, figs. 5-6.

Material and occurrence. 14 specimens from the lower shale and middle siliciclastic/carbonate members of the Cenomanian Galala Formation and two specimens from the Lower Turonian Abu Qada Formation, beds 12, 41, 47 at Wadi Quseib (MGDMU:WQ.Bi.**12**.16-25,**41**.4-5,**47**.15-16), and 16 specimens from the Upper Cenomanian Galala and Lower Turonian Abu Qada Formation, beds 5, 22, 25, and 26 at the East Themed area (MGDMU:ET.Bi.**5**.1-2,**22**.1-7,**25**.18-22, **26**.17-18).

Measurements (in mm).

n=2	L	H	H/L
Range	14-15	13-15	0.93-1
Mean	14.5	14	0.96

Description. Small- to medium-sized, subtrigonal to ovate, moderately convex, and inequilateral. Both anterior and posterior margins convex, meeting the ventral margin in an even curve. Antero-dorsal margin straight, long, and oblique towards the ventral side, postero-dorsal margin slightly convex and relatively short. Umbones pointed and situated nearly in the middle. Ears small. Shell margin crenulated. Ornamentation consisting of strong radial ribs (with sharp crests), separated by deep interspaces. The interspaces are nearly the same width as radial ribs and carry fine radial riblets.

Temporal and spatial distribution. *Pseudolimea itieriana* has been recorded from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912) and Italy (TREVISAN, 1937). In Egypt, it is known from the Cenomanian of El Hadhira, North Sinai (ABBASS, 1962) and from the Upper Cenomanian-Middle Turonian of Gebel Ekma and East Themed by EL QOT (2006).

Discussion. *Lima* (*Radula) cenomanensis* ABBASS (1962) from Sinai closely resembles the present species in general outline, size, and ornamentation. Therefore and in agreement with EL QOT (2006), ABBASS's species is regarded as a junior synonym of *Pseudolimea itieriana*.

L. numidica THOMAS & PERON in PERON (1890: 217, pl. 27, fig. 2) from the Cenomanian of Tunisia also closely resembles the present species but differs in having a more prolongated antero-ventral margin.

L. (*Mantellum*) *parallela* (J. SOWERBY, 1812) as figured and described by WOODS (1904: 28, pl. 5, figs. 14-15) from the Lower Greensand of England resembles the present species in general outline and ornamentation but differs in being less compressed and in having finer radial ribs on the posterior part. The latter author erected a new species *L.* (*Mantellum*) *gaultina* (1904: 31, pl. 5, figs. 16-20) from the same locality. It is very similar to *Pseudolimea itieriana* in general outline but differs in having strong radial ribs, wider interspaces and in being higher than the present species.

Order Ostreoida FÉRUSSAC, 1822
(=Ostreina WALLER, 1978)
Superfamily Ostreacea WILKES, 1810
Family Gryphaeidae VIALOV, 1936

Genus *Pycnodonte* FISCHER DE WALDHEIM, 1835
Subgenus *Phygraea* VYALOV, 1936
Pycnodonte (*Phygraea*) *vesicularis vesiculosa* (J. DE C. SOWERBY, 1823)
Pl. 5, Figs. 4-6

1823 *Gryphea vesiculosa* sp. nov. – J. DE C. SOWERBY: 93, pl. 369.
1871 *Gryphea vesiculosa* SOWERBY - STOLICZKA: 466, pl. 39, figs. 1-2.
1890 *Ostrea vesiculosa* SOWERBY – PERON: 126.
1912 *Pycnodonta vesiculosa* SOWERBY – PERVINQUIÈRE: 195.
1913 *Ostrea vesiculosa* (SOWERBY) – WOODS: 374, pl. 55, figs. 10-14; pl. 56, fig. 1.
1917 *Ostrea vesicularis* LAMARCK race *vesiculosa* SOWERBY – FOURTAU: 56.
1918 *Pycnodonta vesicularis* LAMARCK var. *vesiculosa* SOWERBY – GRECO: 13 (195), pl. 2 (18), fig. 12.
1937 *Pycnodonta vesicularis* LAMARCK mut. *vesiculosa* SOWERBY – TREVISAN: 79, pl. 2, figs. 15-16.
1963 *Pycnodonta vesiculosa* SOWERBY – FAWZI: 49, pl. 5, figs. 1-2.
1972 *Pycnodonte* (*Pycnodonte*) *vesicularis* (LAMARCK) *vesiculosa* (SOWERBY) – FRENEIX: 102, pl. 10, figs. 1-3; text-figs. 11-12.
1972 *Pycnodonte* (*Pycnodonte*) *vesicularis* (LAMARCK) *subvesiculosa* RENNGARTEN – FRENEIX: 104, pl. 10, fig. 4; text-figs. 11-12.
1982 *Pycnodonte vesiculosa* (SOWERBY) – DHONDT: 859.
1990 *Pycnodonte* (*Phygraea*) *vesiculosum* (SOWERBY) – MALCHUS: 145, pl. 2, figs. 2-7.
1995 *Pycnodonte* (*Phygraea*) *vesiculosum* (SOWERBY) – ABDEL-GAWAD: 170, pl. 3, fig. 1.

1999 *Pycnodonte* (*Phygraea*) *vesiculosa* (Sowerby) – Seeling & Bengtson: 761, fig. 11a-b.
2002 *Pycnodonte* (*Phygraea*) *vesiculosum* (Sowerby) – Ahmad & Al-Hammad: 458, fig. 4/3-6.
2002 *Pycnodonte* (*Phygraea*) *vesiculosum* (Sowerby) – Kassab & Zakhera: 14, fig. 4/11-12.
2004a *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (Sowerby) – Abdel-Gawad et al.: pl. 6, figs. 6-7.
2006 *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (Sowerby) – El Qot: 38, pl. 5, figs. 10-11; text-fig. 7.
2006 *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (Sowerby) – Wilmsen & Voigt: 22, pl. 4C-G.
2007 *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (Sowerby) – Abdel-Gawad et al.: pl. 4, fig. 4.
2007b *Pycnodonte* (*Phygraea*) *vesiculosa* (Sowerby) – Mekawy: 213, pl. 2, figs. 7-8.

Material and occurrence. 92 left valves from the Abu Qada Formation (Upper Cenomanian-Lower Turonian), beds 19, 23, 25, 26 of the East Themed area (MGDMU:ET.Bi.**19**.20-66,**23**.9-12,**25**.19-52,**26**.18-29), two specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 39 at Wadi Quseib (MGDMU:WQ.Bi.**39**.3-4), and three left valves from the upper member of the Lower Turonian Abu Qada Formation, bed 30 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**30**.3-5).

Measurements (in mm).

n=22	L	H	H/L
Range	12-27	14-30	0.9-1.36
Mean	18.77	20.95	1.12

Description. Small- to medium-sized, high-ovate to subrounded shell with a short and relatively broad rostrum at the posterior end. Some specimens longer than high, but most higher than long (H/L=1.12 mm). Anterior and ventral margins convex with shallow sulcus along the posterior margin. Left valves strongly convex. Catachomata well developed (Pl. 5, Fig. 6b). Umbo small, pointed, and slightly opisthogyrate to orthogyrate. Adductor muscle scar small, oval to rounded, and situated near the posterior margin. Attachment areas small to medium-sized and not visible in some individuals. Left valves ornamented with closely-spaced growth lamellae.

Temporal and spatial distribution. *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* is a very widespread Cretaceous oyster. It has been recorded from the Upper Cenomanian of Jordan (Ahmad & Al-Hammad, 2002), India (Stoliczka, 1871), Tunisia (Pervinquière, 1912), Libya (Abdel-Gawad, 1995), Morocco (Freneix, 1972), Italy (Trevisan, 1937), England (Woods, 1913), and Brazil (Seeling & Bengtson, 1999). In Egypt, it occurs in the Cenomanian-Santonian of the East Themed area and Gebel Ekma (Abdel-Gawad et al., 2004a; El Qot, 2006), Eastern Desert (Greco, 1918; Fawzi, 1963; Malchus, 1990; Kassab & Zakhera, 2002; Abdel-Gawad et al., 2007; Mekawy, 2007b).

Discussion. The great similarity between *Pycnodonte* (*Phygraea*) *vesicularis* and *P.* (*Ph.*) *vesiculosa* caused much confusion among authors. Stoliczka (1871), Woods (1913), Dhondt (1984), Malchus (1990), Abdel-Gawad (1995), and Seeling & Bengtson, 1999) separated them as two different species. In contrast, Greco (1918) regarded *P. vesiculosa* as a variety of *P. vesicularis*. TREVISAN (1937) regarded *P. vesiculosa* as a “mutation” of *P. vesicularis*. FRENEIX (1972) differentiated *P. vesicularis* from the Tarfaya Basin of Morocco into three subspecies i.e., *P.* (*Ph.*) *vesicularis vesiculosa* (Late Albian-Cenomanian), *P* (*Ph.*). *vesicularis subvesiculosa* (?Turonian-Coniacian), and *P.* (*Ph.*) *vesicularis vesicularis* (Santonian-Danian). In agreement with EL QOT (2006), the first two subspecies of FRENEIX are considered synonyms of the present species. EL QOT identified as *P. vesicularis vesiculosa* relatively thin and small-sized shells, ranging in age from the Cenomanian to the Santonian. *P. vesicularis vesicularis*, in contrast, is characterized by thick and large-sized shells and is Campanian-Danian in age. All specimens of *P.* (*Ph.*) *vesicularis vesiculosa* from the East Themed area (present study) are small and have been collected from Upper Cenomanian rocks (for more detailed discussions see MALCHUS, 1990; EL QOT, 2006; WILMSEN & VOIGT, 2006).

Subfamily Exogyrinae VYALOV, 1936
Tribe Exogyrini VYALOV, 1936
Genus *Exogyra* SAY, 1820
Exogyra conica (J. SOWERBY, 1813)
Pl. 5, Figs.7-8; Text-fig. 3.4

1813 *Chama conica* sp. nov. – J. DE C. SOWERBY: 69, pl. 26, fig. 3.
1813 *Chama obliquata* sp. nov. – PULTENEY: 108, fig. 8, in COX, 1940.
1869 *Ostrea Conica* SOWERBY – COQUAND: pl. 53, figs. 1-7.
1912 *Exogyra conica* SOWERBY – PERVINQUIÈRE: 182.
1913 *Exogyra conica* (SOWERBY) – WOODS: 407, text-figs. 215-242 (with extensive synonymy).
1917 *Ostrea conica* SOWERBY – FOURTAU: 32.
1934 *Exogyra conica* SOWERBY – BLANCKENHORN: 202, pl. 9, fig. 44.
1959 *Exogyra* cf. *conica* (SOWERBY) – BOREHAM: 121, pl. 11, figs. 1-3.
1962 *Exogyra conica* SOWERBY – ABBASS: 67, pl. 9, fig. 12.
1963 *Exogyra conica* SOWERBY – FAWZI: 39, pl. 4, figs. 1-3.
1972 *Amphidonte conica* (SOWERBY) – FRENEIX: 85, pl. 5, figs. 1a-b, 2a-b.
1981 *Amphidonte conicum* (SOWERBY) – AMARD et al.: 83, pl. 4, figs. 12-13.
1982 *Amphidonte obliquatum* (SOWERBY) – DHONDT: 856.
?1990 *Rhynchostreon mermeti* (SOWERBY) – MALCHUS: pl. 9, figs. 5-7, 10 (= forma minor).
1994 *Amphidonte obliquatum* (SOWERBY) – KASSAB & ISMAEL: 232, fig. 4/8.
2002 *Exogyra conica* (SOWERBY) – ABDEL-GAWAD & GAMEIL: 85, pl. 2, figs. 3-4.
2004b *Exogyra conica* (SOWERBY) – ABDEL-GAWAD et al.: pl. 1, fig. 14.

Material and occurrence. Five left valves from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 1 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.10-13,**15**.7), four specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 39 at Wadi Quseib (MGDMU:WQ.Bi.**39**.5-8), and two specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 at the East Themed area (MGDMU:ET.Bi.**26**.30-31).

Measurements (in mm).

n=5	L	H	H/L
Range	10-16	14-22	1.31-1.81
Mean	12.50	19.25	1.55

Description. Shell small- to medium-sized, oval to exogyriform, and strongly inequilateral. Left valve strongly convex. Umbones little spirally incurved posteriorly. Anterior and ventral margins convex. Posterior margin oblique, either straight or slightly concave. Attachment area small to absent. Ligamental area relatively small and narrow. Chomata not seen. Ornamentation consisting of highly undulating concentric laminae. With sharp keel extending in a curve from the umbo towards the postero-ventral margin where it is pronounced (Text-fig. 3.4). This keel divides the shell surface into two parts, a small steeply sloping, and flat anterior part and a wide and slightly convex posterior part.

Temporal and spatial distribution. *Exogyra conica* has been recorded from the Cenomanian of Morocco (FRENEIX, 1972), Algeria (COQUAND, 1869; AMARD et al., 1981), Tunisia (PERVINQUIÈRE, 1912), Syria (BLANCKENHORN, 1937), Pitt Island and Chatham Island (near New Zealand, BOREHAM, 1959), Spain (DHONDT, 1982), and England (WOODS, 1913). In Egypt, it is known from the Cenomanian of El Baharyia Oasis (Western Desert) and Gebel Shabrawit (Eastern Desert) (FOURTAU, 1917), G. El-Halal (FAWZI, 1963), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. Musabaa Salama (KASSB & ISMAEL, 1994), and G. Tih (ABBASS, 1962). According to FRENEIX (1972: 87), the species ranges from the Albian to the Cenomanian.

Discussion. The present material morphologically resembles *Exogyra conica* described by WOODS (1913) from the Upper Greensand of England. His figures of this species exhibit a great variation in size of shell and attachment area.

J. SOWERBY (1813) figured small specimens with a small attachment area as *E. conica* and a small shell with a relatively large attachment area as *E. haliotoidea* (1813: 67, pl. 25f, 1-5). According to WOODS (1913: 410), *E. haliotoidea* is a small form of *E. conica* with a large attachment area. As there are intermediate forms between the two taxa, he considered *E. haliotoidea* as a synonym to *E. conica.*

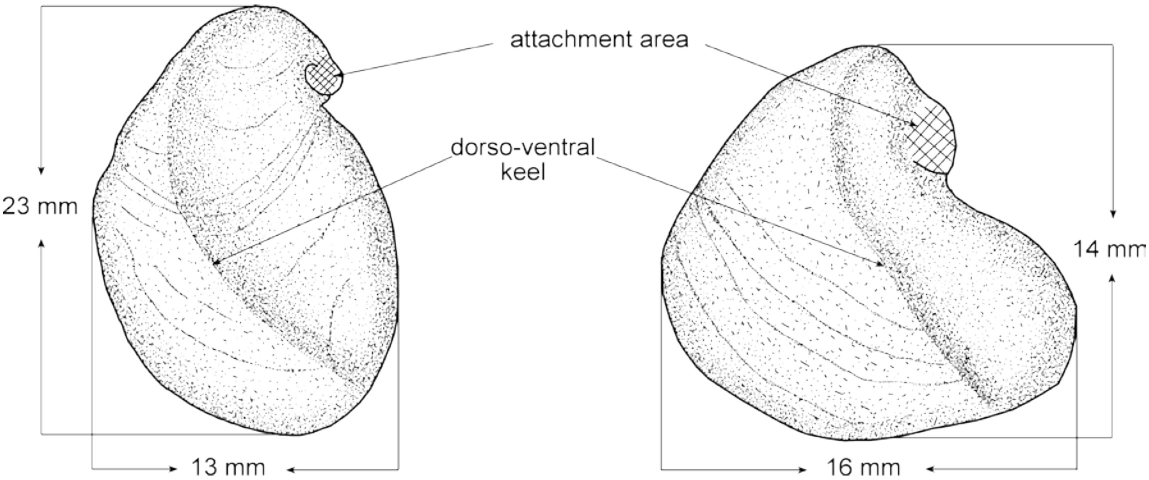
ABBASS (1962) found *E. flabellata* and *E. conica* to occur in the same bed at Gebel Shabrawit and suggested that *E. conica* is a variety of *A. flabellatum* (GOLDFUSS). However, *C. flabellatum* differs from the present species by having thick ribs radiating from a medium keel and occasionally bifurcating forming V-shaped ridges. These characters are not found in *E. conica.*

According to ABDEL-GAWAD & GAMEIL (2002), *E. conica* differs also from *E. suborbiculata* LAMARCK in having a strong and salient keel, which is less pronounced near the ventral margin and lies centrally or slightly posteriorly; in the latter species the carina lies centrally to anteriorly. In addition, *E. suborbiculata* is ornamented with radial ribs which extend from the umbo to the ventral margin or are restricted to the umbonal area, whereas *E. conica* is commonly ornamented with undulating concentric laminae. WOODS (1913: 416) noted that *E. columba* (=*E. suborbiculata*) resembles *E. conica* but differs in having a less distinct and more rounded keel and a less flattened posterior part of the left valve with a more strongly curved umbo.

Rhynchostreon mermeti (COQUAND), described and figured by MALCHUS (1990: pl. 9, figs. 5-7, 10, forma minor), is similar to *E. conica* in having a dorso-ventral keel and concentric laminae. In his discussion, MALCHUS ignored SOWERBY'S species. As his material more closely resembles *E. conica* than *R. memeti* it has been included in the present species.

KASSAB & ISMAEL (1994) considered *E. conica* as a synonym of *Amphidonte obliquatum* (PULTENEY, 1813) without discussing the differences between the two species. In contrast, FRENEIX (1972) considered *A. obliquatum* as a synonym of *E. conica*. She argued that *A. obliquatum* is an old name for *E. conica* and that many authors have not used this species since 1813 (see Freneix, 1972: 85). Dhondt (1982) noted that *A. obliquatum* from the Late Aptian to Late Cenomanian is generally known as *E. conica* (Sowerby).

Freneix (1972) discussed several subspecies of *A. conica*, e.g. *A. conica conica* (J. Sowerby, 1813) (d'Orbigny, 1847: pl. 479, fig. 3; Woods, 1913: 411, Figs. 215-218, 220-225), *A. conica undata* (Goldfuss, 1833) (d'Orbigny, 1847: pl. 478, figs. 5-7; Woods, 1913: 411, fig. 219), *A. conica haliotidea* (Sowerby, 1813) (d'Orbigny, 1847: pl. 478, fig. 4; Woods 1913: 412, figs. 240-242), and *A. conica gigantea* (Marlière, 1939) (d'Orbigny, 1847: pl. 479, figs. 1-2; Woods, 1913: 411, figs. 228-231) (for differentiation among these subspecies see Freneix, 1972: 86-87).



Text-fig. 3.4. Variation in outline and dorso-ventral keel of *Exogyra conica* (J. Sowerby, 1813) from the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

Genus *Costagyra* Vyalov, 1936
Costagyra olisiponensis (Sharpe, 1850)
Pl. 5, Fig. 9; Pl. 6, Figs. 1-2; Text-fig. 3.5

1850 *Exogyra Olisiponensis* sp. nov. – Sharpe: 185, pl. 19, figs. 1-2.
1891 *Ostrea Olisiponensis* Sharpe – Peron: pl. 23, figs. 14-18.
1912 *Exogyra Olisiponensis* Sharpe – Pervinquière: 174, pl. 13, figs. 4-5, 9.
1917 *Ostrea olisiponensis* Sharpe – Fourtau: 44.
1918 *Exogyra Olisiponensis* Sharpe – Greco: 187, pl. 1 (17), figs. 12-14.
1937 *Exogyra olisiponensis* Sharpe var. *oxyntas* Coquand, var. *ecostata* Seguanz – Trevisan: 67, pl. 4, figs. 2-6.
1958 *Exogyra olisiponensis* Sharpe – Barber: 21, pl. 8, figs. 3-4.
1962 *Exogyra olisiponensis* Sharpe – Abbass: 69, pl. 9, fig. 10.
1963 *Exogyra olisiponensis* Sharpe – Fawzi: 45, pl. 4, figs. 6-7.
1971 *Exogyra olisiponensis* Sharpe – Collignon: 174 (32), pl. F, fig. 5.
1972 *Exogyra olisiponensis* Sharpe – Freneix: 89, pl. 5, fig. 6.
1981 *Exogyra* (*Costagyra*) *olisiponensis* (Sharpe) – Amard et al.: 83, pl. 3, figs. 1-2; pl. 4, figs. 1-2.
1981 *Freneixostrea* aff. *digitata* Sowerby - Amard et al.: 85, pl. 4, figs. 3-7.
1985 *Exogyra olisiponensis* Sharpe – Dominik: pl. 13, fig. 1.
1987 *Exogyra* (*Costagyra*) *olisiponensis* (Sharpe) – Kora & Hamama: pl. 1, figs. 1-2.
1990 *Exogyra* (*Costagyra*) *olisiponensis* Sharpe – Malchus: 134, pl. 10, figs. 1-6 (with full synonymy)
1993 *Exogyra* (*Costagyra*) *olisiponensis* (Sharpe) – Orabi: pl. 2, fig. 7.

1994 *Exogyra* (*Costagyra*) *olisiponensis* (SHARPE) – KASSAB & ISMAEL: 231, fig. 4/15.
1995 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – ABDEL-GAWAD: 168, fig. 3/2-6.
1998 *Costagyra olisiponensis* (SHARPE) – EL-SHEIKH et al.: pl. 1, fig. I.
1999 *Costagyra olisiponensis* (SHARPE) – DHONDT et al.: pl. 1, fig. 7.
1999 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – SEELING & BENGTSON: 756, fig. 9a-c.
2001 *Costagyra olisiponensis* (SHARPE) – ABDALLAH et al.: pl. 2, fig. 7.
2001 *Exogyra* (*Costagyra*) *olisiponensis* (SHARPE) – KORA et al.: pl. 1, fig. 4.
2002 *Exogyra* (*Costagyra*) *olisiponensis* (SHARPE) – ABDEL-GAWAD & GAMEIL: 85, pl. 2, figs. 3-4.
2002 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – ABDELHAMID & EL QOT: 268, pl. 3, fig. 1.
2002 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – BERNDT: 112, pl. 3, figs. 12-13.
2002 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – KASSAB & ZAKHERA: 9, fig. 3/12.
2004 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – KHALIL & MASHALY: pl. 1, figs. 9-10.
2004a *Costagyra olisiponensis* (SHARPE) – ABDEL-GAWAD et al.: pl. 7, fig. 1.
2004b *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – ABDEL-GAWAD et al.: pl. 2, fig. 1.
2006 *Costagyra olisiponensis* (SHARPE) – EL QOT: 39, pl. 6, figs. 1-4; text-fig. 7c.
2006 *Exogyra* (*Costagyra*) *olisiponensis* SHARPE – PERRILLIAT et al.: 99, figs. 10-11.
2007b *Exogyra olisiponensis* SHARPE – MEKAWY: 215, pl. 2, fig, 10.

Material and occurrence. 66 specimens (43 left, 7 right, and 16 articulated valves) from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 17 of the East Themed area (MGDMU:ET.Bi.**17**.1-66) and 93 specimens from the middle siliciclastic/carbonate and upper carbonate member of the Cenomanian Galala Formation, beds 42, 43, 44 at Wadi Quseib MU:WQ.Bi.**42**.1-60,**43**.1-3,**44**.9-38).

Measurements (in mm).

n=56	L	H	C	H/L	C/L	C/H
Range	25-104	33-130	33-75	0.65-1.85	0.46-0.97	0.37-0.78
Mean	65.50	84.8	49	1.31	0.69	0.56

Description. Shell small- to large-sized, very thick, varying in outline from high-oval, subrounded to exogyriform, strongly inequivalved, inequilateral, and slightly higher than long (H/L=1.31; Text-fig. 3.5). Left valve strongly convex and very thick. Ventral margin rounded, anterior margin convex, posterior margin close to umbo slightly concave. In some individuals, the posterior margin is expanded. Right valve flat to slightly concave and relatively thin. Umbo strongly curved to helicoidal. Attachment area variable in size from small to very large and occasionally absent, especially in small individuals (Pl. 6, Fig. 6). Ligamental area

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EXPLANATION OF PLATE 6

Figs. 1-2. *Costagyra olisiponensis* (SHARPE, 1850). Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **1a**: External view of left valve with large attachment area (AA, arrowed), **b**: internal view of right valve; MGDMU:ET.Bi.**17**.2. - **2**. Middle siliciclastic/carbonate member of the Cenomanian Galala Formation, x1. Side view of left valve; MGDMU:WQ.Bi.**44**.9.

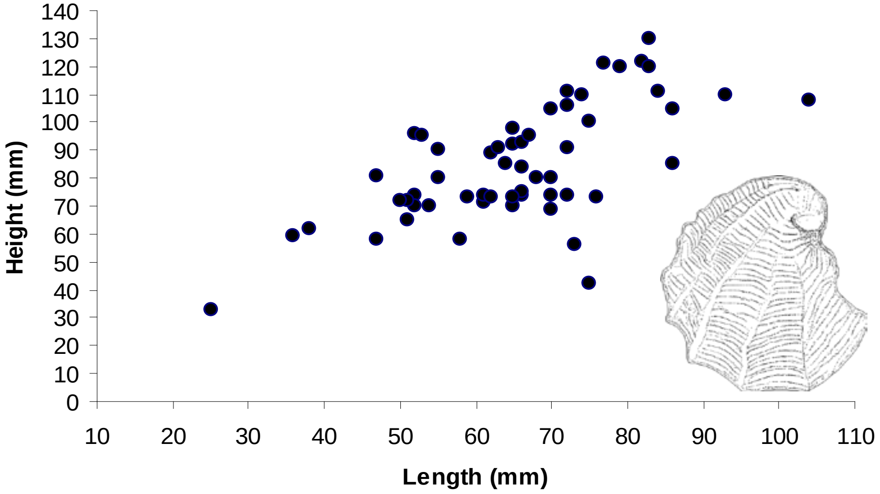
Figs. 3-5. *Ceratostreon flabellatum* (GOLDFUSS, 1833) from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa x1.5. **3a**: Side view of left valve, **b**: internal view of left valve; MGDMU:AEN.Bi.**5**.2. - **4a**: Side view of left valve with attachment area (AA), **b**: internal view of left valve; MGDMU:AEN.Bi.**5**.3. - **5**. Side view of left valve; MGDMU:AEN.Bi.**5**.4.


AA
1a
1b
3a
3b
AA
4a
2
5
4b

medium to large. Adductor muscle scar relatively large, pear-shaped with a slightly concavity dorsally, and situated postero-dorsally. Left valve ornamented with sharp radial ribs; these radials are crossed by scaly growth lamellae. Right valve ornamented with concentric, scaly growth lamellae, partly traversed by short radial ribs (Pl. 5, Fig. 9b).

Temporal and spatial distribution. *Costagyra olisiponensis* has been recorded from the Cenomanian of Tunisia (PERON, 1891; PERVINQUIÈRE, 1912), Algeria (COLLIGNON, 1971; AMARD et al., 1981), Morocco (FRENEIX, 1972), Jordan (PERRILLIAT et al., 2006), Libya (ABDEL-GAWAD, 1995), Middle and Upper Cenomanian of Brazil (SEELING & BENGTSON, 1999), and the Lower Turonian of Nigeria (BARBER, 1958). In Egypt, it is known from the Upper Cenomanian of the Eastern Desert (GRECO, 1918; MEKAWAY, 2007b), Bahariya Oasis (DOMINIK, 1985), Gebel Ekma, East Themed, and G. Yelleg (ABBASS, 1962; ABDEL-GAWAD et al., 2004a; EL QOT, 2006), G. El-Fallig (ABDEL-GAWAD et al., 2004b), Wadi Taba (ORABI, 1993), W. Araba (FAWZI, 1963), G. Mukattab (KORA et al., 2001), W. Mor (MALCHUS, 1990), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Hamra (ABDELHAMID & EL QOT, 2002), El Giddi Pass (ABDALLAH et al., 2001), G. Gunna (KORA & HAMAMA, 1987), W. Dakhal (KASSAB & ZAKHERA, 2002), G. El-Minsherah (EL-SHEIKH et al., 1998), and from the Lower Turonian of G. Musaba Salama (KHALIL & MASHALY, 2004; KASSAB & ISMAEL, 1994).

According to MALCHUS (1990), the main occurrence of *C. olisiponensis* is in the Upper Cenomanian. The total range of the species is from the Albian to the Turonian in North Africa and, from the Upper Cenomanian to the Turonian in Central Asia (DHONDT et al., 1999: 74).



Text-fig. 3.5. Biometric data of *Costagyra olisiponensis* (SHARPE, 1850) from the Cenomanian Galala Formation at Wadi Quseib and East Themed.

Discussion. Due to the great variability of *Costagyra olisiponensis* many authors split the taxon into different species and varieties. For instance, TREVISAN (1937) differentiated the species into two different varieties (var. *oxyntas* COQUAND and var. *ecostata* SEGUANZA). Others erected new species (see the synonymy list of MALCHUS, 1990). AMARD et al. (1981) erected the new genus *Freneixostrea* based on some right valves of *C. olisiponensis.* All these varieties are based on the different development of ribs, spines, and scales of growth lamellae. However, SEELING & BENGTSON (1999: 758) suggested that the variation in thickness and ornamentation is possibly related to water energy. Spines may have protected the bivalve from sinking into unstable sediment and aided in maintaining its position in a soft substrate.

Therefore, all varieties and subspecies of *C. olisiponensis* are related to palaeoecological factors.

MALCHUS (1990) observed that nearly all long and narrow specimens have small or no attachment areas, whereas the wider and shorter forms have large to very large attachment areas. The latter observation is confirmed by the present material from the East Themed section.

FAWZI (1963) considered *Exogyra overwegi* of COQUAND (1862-1869) as a synonym of *C. olisiponensis*. COQUAND's species differs in lacking the spinose radial ribs, in possessing numerous radial ribs, and in being restricted to the Campanian-Maastrichtian of the Eastern Desert (for more detailed discussion see MALCHUS, 1990: 137-138).

Genus *Ceratostreon* BAYLE, 1878
Ceratostreon flabellatum (GOLDFUSS, 1833)
Pl. 6, Figs. 3-5; Pl. 7, Figs.1-3; Text-fig. 3.6

1833 *Exogyra flabellata* sp. nov. – GOLDFUSS: 38, pl. 87, fig. 6.
1912 *Exogyra flabellata* GOLDFUSS – PERVINQUIÈRE: 189, pl. 13, figs. 6a-b, 7a-b, 8.
1917 *Ostrea flabellata* GOLDFUSS - FOURTAU: 37.
1918 *Exogyra flabellata* GOLDFUSS – GRECO: 11 (193), pl. 2 (18), figs. 9-11.
1937 *Exogyra flabellata* GOLDFUSS – TREVISAN: 37, pl. 5, figs. 11-12.
1955 *Exogyra complicata* sp. nov. – MAHMOUD: 111, pl. 7, figs. 1-10; pl. 8, figs. 1-12; text-fig. 52-54.
1962 *Exogyra flabellata* GOLDFUSS – ABBASS: 66, pl. 9, figs. 4-6.
1963 *Exogyra flabellata* GOLDFUSS – FAWZI: 43, pl. 4, figs. 10-12.
1972 *Ceratostreon flabellatum* (GOLDFUSS) – FRENEIX: 91, pl. 5, figs. 8-9.
1981 *Ceratostreon flabellatum* (GOLDFUSS) – AMARD et al.: 84, pl. 3, figs. 4-7a-b.
1985 *Exogyra flabellata* GOLDFUSS – DOMINIK: pl. 13, fig. 10a-b.
1990 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – MALCHUS: 111, pl. 4, figs. 4-11; pl. 5, figs. 1-7 (with extensive synonymy).
1992 *Ceratostreon flabellatum* (GOLDFUSS) – ABDEL-GAWAD & ZALAT: pl. 2, figs. 9-11.
1993 *Ceratostreon flabellatum* (GOLDFUSS) – KORA et al.: pl. 2, figs. 6-7.
1993 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – ORABI: pl. 2, fig. 2.
1994 *Ceratostreon flabellatum* (GOLDFUSS) – KASSAB & ISMAEL: 231, fig.4/7.
1998 *Ceratostreon flabellatum* (GOLDFUSS) – EL-SHEIKH et al.: pl. 1, fig. A.
1999 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – SEELING & BENGTSON: 755, fig. 8a-d.
2001a *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – KORA et al.: pl. 1, fig. 2.
2001 *Ceratostreon flabellatum* (GOLDFUSS) – ABDALLAH et al.: pl. 2, figs. 8-9.
2002 *Ceratostreon flabellatum* (GOLDFUSS) – ABDEL-GAWAD & GAMEIL: 86, pl. 2, fig. 8.
2002 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – AHMAD & AL-HAMMAD: 450, fig. 2/1, 3, 4, 6.
2002 *Ceratostreon flabellatum* (GOLDFUSS) – ABDELHAMID & EL QOT: 269, pl. 3, fig. 2.
2002 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – BERNDT: 109, pl. 3, fig. 8a-b.
2002 *Ceratostreon flabellatum* (GOLDFUSS) – KASSAB & ZAKHERA: 8, fig. 3/13-15.
2004 *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – KHALIL & MASHALY: pl. 2, fig. 7.
2004a *Ceratostreon flabellatum* (GOLDFUSS) – ABDEL-GAWAD et al.: pl. 7, figs. 8, 9a- b.
2004b *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS) – ABDEL-GAWAD et al.: pl. 2, fig. 2a-b.
2006 *Ceratostreon flabellatum* (GOLDFUSS) – EL QOT: 40, pl. 6, figs. 5-8; text-fig. 8.

2007b *Ceratostreon flabellatum* (GOLDFUSS) – MEKAWY: 215, pl, 2, fig. 11; pl. 3, fig. 6.
2008 *Ceratostreon flabellatum* (GOLDFUSS) – MEKAWY & ABU-ZIED: 301, pl. 2, fig. 1.

Material and occurrence. 180 mostly disarticulated valves from the lower marly, middle carbonate, and carbonate/marl member of the Halal Formation (Upper Albian- Cenomanian), beds 1, 5, 9, 12-13 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.19-88,**5**.2-19,**9**.2-41,**12**.2-5,**13**.1), 44 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 13, 22, 24, 29, and 39 at Wadi Quseib (MGDMU:WQ.Bi.**13**.1-21,**22**.16-25,**24**.1-5,**29**.1-4,**39**.9-12), and 90 left valves from the Cenomanian Galala and Upper Cenomanian-Lower Turonian Abu Qada formations, beds 3, 5, 8, 9, 10, and 16 of the East Themed area (MGDMU:ET.Bi.**3**.9-11, **5**.3-40, **8.**1-5, **9.**1-5, **10.**1-15, **16**.3-6).

Measurements (in mm).

n=66	L	H	C	nr	H/L	C/L	C/H
Range	9-33	16-51	7-25	7-33	1.16-2.66	0.50- 0.83	0.41-0.64
Mean	19.03	31.77	14.8	14	1.73	0.70	0.48

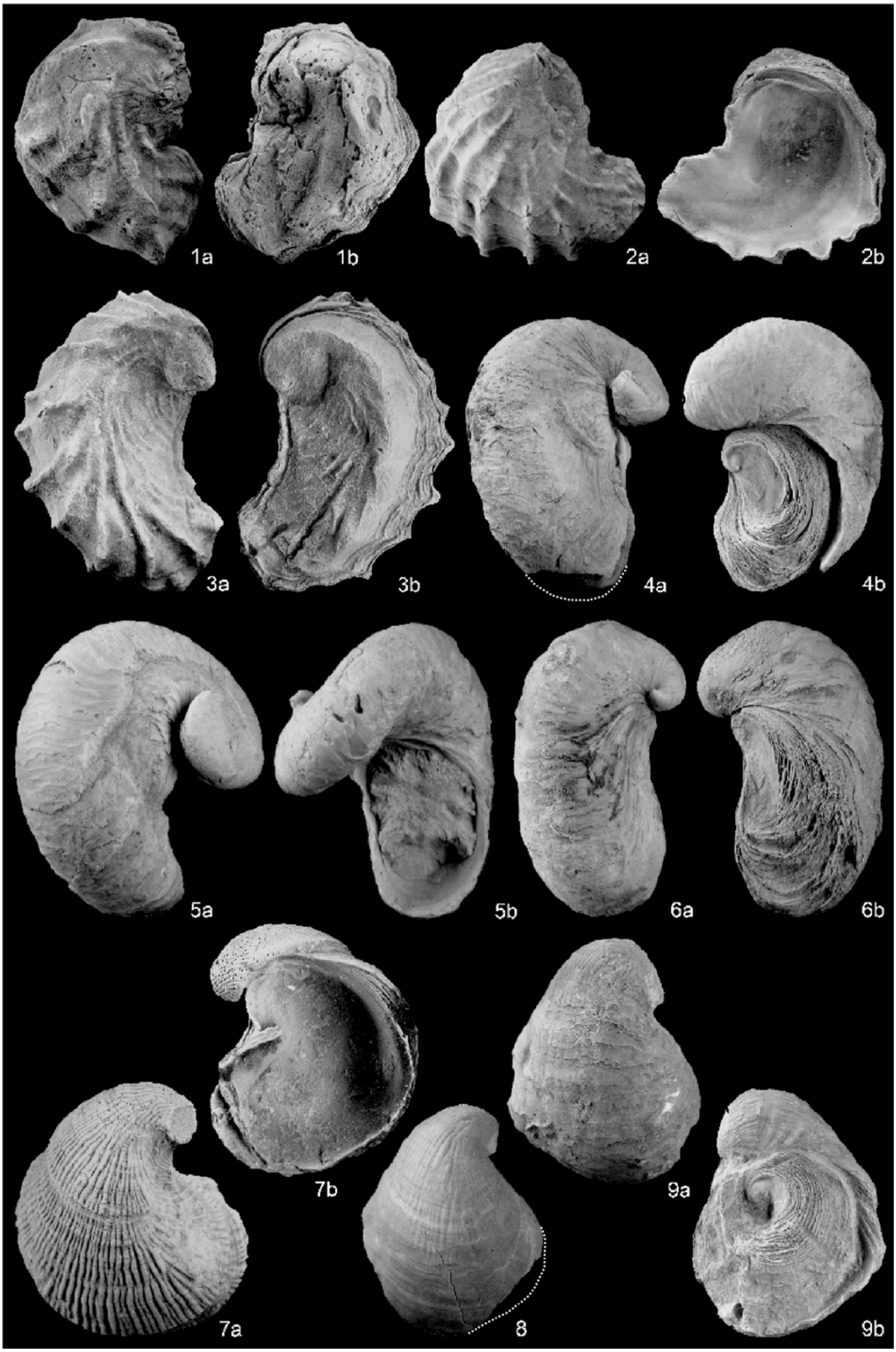
Description. Shell variable in size, small to relatively large, height greater than length (average H/L ratio 1.73; Text-fig. 3.6), highly variable in outline, crescentic, high-ovate to rounded, strongly inequivalved, and inequilateral. Left valve more convex and larger than the right one, with median curved keel. This keel divides the shell surface into two different slopes. Anterior slope narrower, slightly convex, descending steeply to the anterior valve margin, while the posterior slope is larger, descending more gently to the posterior valve margin, which is flat or concave in the left valve and strongly convex in the right valve. Ligamental area narrow and moderately wide. Chomata straight, well developed along the periphery of the valve. Umbo twisted and posteriorly incurved. Adductor muscle scar nearly sub-rounded and located posteriorly. Attachment area clearly visible, round, and covering a large part of the umbonal area (Pl. 6, Fig. 4a). Ornamentation consisting of thick and occasionally dichotomizing ribs (Pl. 6, Fig. 3a; Pl. 7, Fig. 3a), which are reversed V-shaped in cross-section and radiate from the middle keel. These ribs are closer to each other dorsally and posteriorly and relatively decrease in number with shell length (Text-fig. 3.6).

EXPLANATION OF PLATE 7

Figs. 1-3. *Ceratostreon flabellatum* (GOLDFUSS, 1833). **1-2**. Lower marly and middle carbonate members of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **1a**: Side view of left valve, **b**: side view of right valve; MGDMU:AEN.Bi.**5**.4. - **2a**: External view of left valve, **b**: internal view of left valve, x1; MGDMU:AEN.Bi.**15**.8 - **3**. Articulated valves from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **a**: External view of left valve, **b**: side view of right valve; MGDMU:WQ.Bi.**39**.9.

Figs. 4-6. *Ilymatogyra africana* (LAMARCK, 1801). Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area. **4a**: Side view of left valve, x1.5, **b**: side view of right valve x1.5; MGDMU:ET.Bi.**16**.7. - **5a**: Side view of left valve, x2, **b**: internal view of left valve with helicoidally twisted umbo, x2; MGDMU:ET.Bi.**12**.17. - **6a**: Side view of left valve, x1.5, **b**: side view of right valve, x1.5; MGDMU:ET.Bi.**12**.18.

Figs. 7-9. *Rhynchostreon suborbiculatum* (LAMARCK, 1801). **7-8**. Lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x2. **7a**: Side view of left valve, **b**: internal view of left valve; MGDMU:AEN.Bi.**11**.1. - **8**. Side view of left valve; MGDMU:AEN.Bi.**15**.49 - **9**. Articulated valves from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **a**: Side view of left valve, **b**: side view of right valve; MGDMU:WQ.Bi.**23**.41.


1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
7b
9a
7a
8
9b

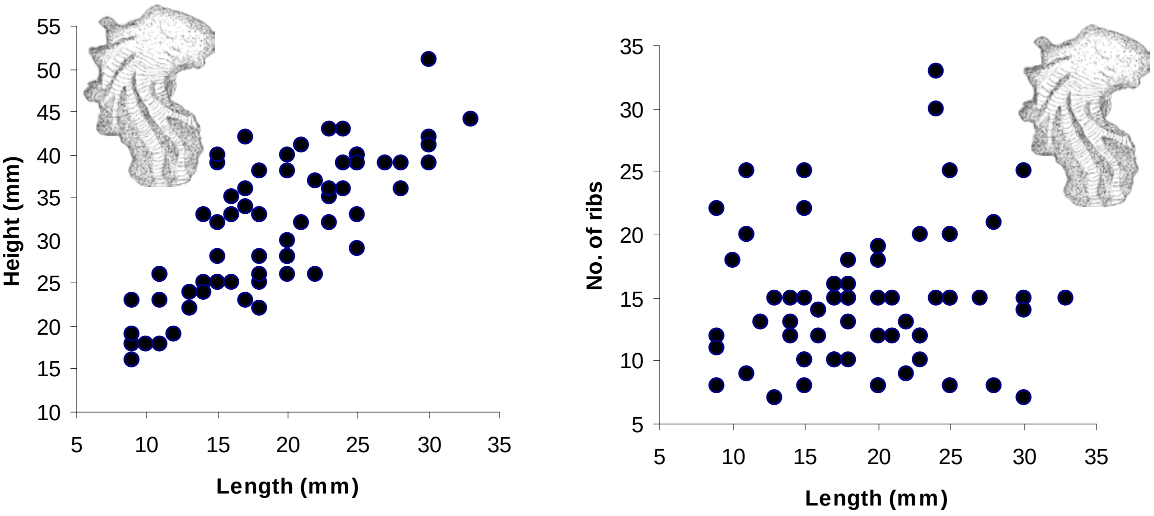
Small spines may be irregularly developed towards the anterior margin. Right valves smaller, nearly flat to slightly concave, with radial ribs that partly exhibit tubercles and commarginal growth lamellae (Pl. 7, Fig. 3b).

Temporal and spatial distribution. *Ceratostreon flabellatum* has been recorded from the Cenomanian of Italy (TREVISAN, 1938), Tunisia (PERVINQUIÈRE, 1912), Algeria (AMARD et al., 1981), Morocco (FRENEIX, 1972), Upper Aptian-Lower Cenomanian of Jordan (AHMAD & AL-HAMMAD, 2002; BERNDT, 2002), and Brazil (SEELING & BENGTSON, 1999). In Egypt, it is known from the Upper Cenomanian of the Eastern Desert (MALCHUS, 1990; KASSAB & ZAKHERA, 2002; MEKAWY, 2007b), G. Halal and G. Nezzazat (FAWZI, 1963; ABDEL-GAWAD & GAMEIL, 2002), G. Ekma, East Themed, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), Bahariya Oasis, Western Desert (DOMINIK, 1985), W. Abu Qada (KORA et al., 2001), El Giddi Pass (ABDALLAH et al., 2001), G. Musabaa Salamaa (KASSAB & ISMAEL, 1994; KHALIL & MASHALY, 2004), G. Tih (ABBASS, 1962), W. Taba (ORABI, 1993), G. El-Minsherah (EL-SHEIKH, 1998), G. El-Hamra (ABDELHAMID & EL QOT, 2002), El-Fallig (ABDEL-GAWAD et al., 2004b), and from the Maghara area (MEKAWY & ABU-ZEID, 2008).

According to SEELING & BENGTSON (1999: 756), *C. flabellatum* ranges from the Aptian?, Albian to the Cenomanian.

Discussion. The great morphological variability of *Ceratostreon flabellatum* led many authors to divide it into several varieties and forms. For instance, SEGUANZA (1882) divided the species into five varieties; var. *dilatata*, var. *trigona*, var. *ecostata*, var. *crassiplicata*, and var. *semilunata*. In addition, FAWZI (1963) recognized two varieties, "form typique" and the new variety *excavata*. In fact, it is very difficult to distinguish between these different varieties and forms, because in very large populations, the different forms are linked by transitional ones to make it impossible to recognize different species (see EL QOT, 2006: 42).

The present species is very similar to some varieties of *Exogyra complicata* erected by MAHMOUD (1955) based on material from the Albian of Gebel El-Maghara (Sinai, Egypt). He considered *Ceratostreon flabellatum* as a descendant of his newly described species. According to MALCHUS (1990: 112) there is no need to separate *C. flabellatum* and *E. complicata*, and the latter species is just as a variety of *C. flabellatum* (For more discussion, see MALCHUS, 1990).



Text-fig. 3.6. Biometric data of *Ceratostreon flabellatum* (GOLDFUSS, 1833) from the Cenomanian Halal and Galala formations of the studied sections.

Genus *Ilymatogyra* STENZEL, 1971
Ilymatogyra africana (LAMARCK, 1801)
Pl. 7, Figs. 4-6; Text-fig. 3.7

1801 *Gryphaea africana* sp. nov. - LAMARCK: 399, pl. 139, figs. 5-6.
1862 *Ostrea auressensis* sp. nov. – COQUAND: 233, pl. 22, figs. 12-13.
1912 *Exogyra Africana* LAMARCK - PERVINQUIÈRE: 184.
1917 *Ostrea africana* LAMARCK - FOURTAU: 27.
1918 *Exogyra Africana* LAMARCK – GRECO: 9 (191), pl. 2 (17), figs. 5-6.
1937 *Exogyra africana* LAMARCK – TREVISAN: 72, pl. 3, fig. 18; pl. 5, figs. 1-4.
1962 *Exogyra africana* LAMARCK – ABBASS: 65, pl. 9, figs. 2-3.
1963 *Exogyra africana* LAMARCK – FAWZI: 37, pl. 2, figs. 8-9.
1987 *Ilymatogyra africana* (LAMARCK) – KORA & HAMAMA: pl. 1, fig. 3.
1990 *Ilymatogyra (Afrogyra) africana* (LAMARCK) “forma typica” – MALCHUS: 121, pl. 6, figs. 6-16; pl. 7, figs. 1-5, 7, 10, 13, 21; pl. 8, fig. 4.
1990 *Ilymatogyra (Afrogyra) africana* (LAMARCK) “forma crassa” – MALCHUS: 121, pl. 7, figs. 6, 8-9, 11-12, 14-20; pl. 8, figs. 1-3.
1992 *Ilymatogyra africana* (LAMARCK) – ABDEL-GAWAD & ZALAT: pl. 2, figs. 12-13.
1993 *Ilymatogyra africana* (LAMARCK) – KORA et al.: pl. 2, fig. 1.
?1993 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – ORABI: pl. 2, fig. 1.
1994 *Ilymatogyra africana* (LAMARCK) – KASSAB & ISMAEL: 230, fig. 4/ 4-6.
1999 *Ilymatogyra africana* (LAMARCK) – DHONDT et al.: pl. 1, figs. 1a-b, 2a-b.
1999 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – SEELING & BENGTSON: 758, fig. 9d-g.
2001 *Ilymatogyra africana* (LAMARCK) – ABDALLAH et al.: pl. 2, fig. 10.
2001 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – KORA et al.: pl. 1, fig. 1.
2002 *Ilymatogyra africana* (LAMARCK) – ABDEL-GAWAD & GAMEIL: 86, pl. 2, fig. 9.
2002 *Ilymatogyra africana* (LAMARCK) – ABDELHAMID & EL QOT: 269, pl. 3, fig. 3.
2002 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – BERNDT: 110, pl. 3, figs. 5-7 (forma typica and forma crassa).
2002 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – AHMAD & AL-HAMMAD: 452, fig. 2/7-10, non fig. 2.
2002b *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – ZAKHERA & KASSAB: pl. 3, figs. 1-12.
2002 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – KASSAB & ZAKHERA: 10, fig. 4/1-3.
2004 *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK) – KHALIL & MASHALY: pl. 2, figs. 1-2.
2004a *Ilymatogyra africana* (LAMARCK) – ABDEL-GAWAD et al.: pl. 7, figs. 2-3.
2004b *Ilymatogyra africana* (LAMARCK) – ABDEL-GAWAD et al.: pl. 1, fig. 15.
2006 *Ilymatogyra africana* (LAMARCK) – EL QOT: 42, pl. 7, figs. 1-7, 8a-b; text-fig. 7b.
2007 *Ilymatogyra africana* (LAMARCK) – ABDEL-GAWAD et al.: pl. 5, fig. 8.
2007b *Ilymatogyra africana* (LAMARCK) – MEKAWY: 216, pl. 3, fig. 2.

Material and occurrence. 765 specimens (mostly disarticulated valves) from the Upper Cenomanian Galala Formation and Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 5, 10, 12, 15, 16, and 19 at East Themed (MGDMU:ET.Bi.**5**.41-155,**10**.16-186,**12**.17-61,**15**.1-10,**16**.7-421,**19**.21-76), 248 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 21, 22, 23, 39 and 41 at Wadi Quseib (MGDMU:WQ.Bi.**21**.1-11,**22**.26-45,**23**.1-10,**39**.13-167,**41**.5-15), and seven disarticulated valves from the lower marly and middle carbonate members of the Cenomanian Halal Formation, beds 13 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**13**.2,**15**.43-48).

Measurements (in mm).

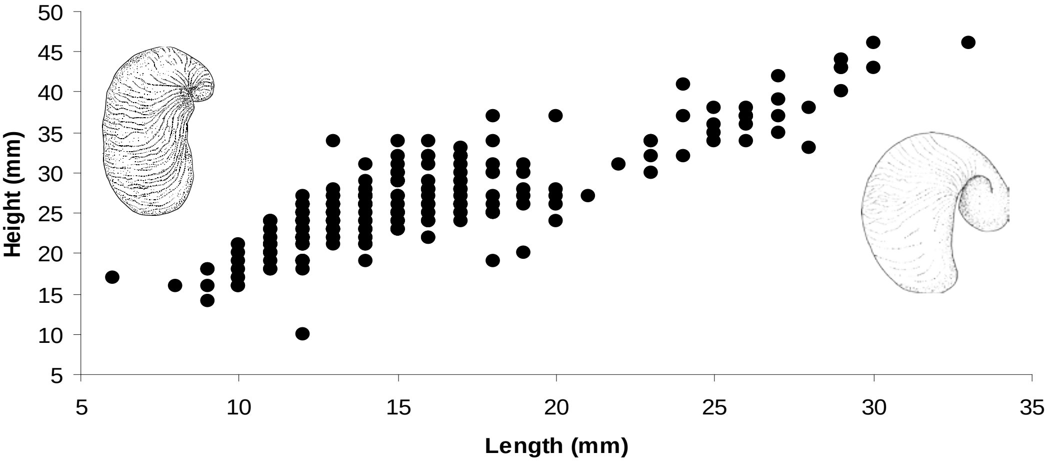
n=250	L	H	C	H/L	C/L	C/H
Range	6-33	10-46	6-29	1.05-2.83	0.66-1.38	0.35-0.73
Mean	15.60	26.36	15.13	1.74	0.90	0.52

Description. Small- to medium-sized, oval to elongated-oval, partly obliquely tear-shaped, height greater than length (H/L=1.74; Text-fig. 3.7), inequivalved, and inequilateral. Left valve commonly strongly convex, right valve flat to slightly convex. Anterior margin strongly convex and meeting the ventral margin in rounded curve. Posterior margin concave. Umbo small and strongly helicoidally twisted in most individuals (without attachment area) and slightly twisted in others (Pl. 7, Figs 5, 6). Ligamental area variable in size but often large (longer than high). Adductor muscle scar small, rounded to kidney-shaped, and situated postero-centrally. Left valve ornamented with regular scaly or smooth growth lamellae. Right valve covered with closely spaced growth lamellae (Pl. 7, Fig. 6b).

Temporal and spatial distribution. *Ilymatogyra africana* has been recorded from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Algeria (COQUAND, 1862), Jordan (AHMAD & AL-HAMMAD, 2002; BERNDT, 2002), Italy (TREVISAN, 1937), and Brazil (SEELING & BENGTSON, 1999). In Egypt, it is known from the Cenomanian of Gebel Ekma, East Themed, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), G. El-Fallig (ABDEL-GAWAD et al., 2004b), Wadi Abu Qada and G. Musaba Salama (KORA et al., 1993; KASSAB & ISMAEL, 1994; KHALIL & MASHALY, 2004), G. Tih (ABBASS, 1962), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Halal (FAWZI, 1963), Eastern Desert (GRECO, 1918; MALCHUS, 1990; ZAKHERA & KASSAB, 2002b; KASSAB & ZAKHERA, 2002), G. El-Minsherah (ABDELHAMID & EL QOT, 2002), and El Giddi Pass (ABDALLAH et al., 2001).

According to EL QOT (2006), *I. africana* is a geographically very widely distributed species and considered diagnostic of the Middle and Upper Cenomanian.

Discussion. MALCHUS (1990) erected two varieties of *Ilymatogyra africana*, forma typica and forma crassa. The latter variety is larger, with a less twisted umbo, less convex, and is covered with very scaly growth lamellae. According to him, the two forms in Egypt are tied to different facies. Forma typica occurs in clay- and silt-rich marl, whereas forma crassa occurs in sandy marl and marly limestone. Most of the present material belongs to *I. africana* forma typica (about 415 specimens) and has been collected from soft substrate (greyish-green, soft, glauconitic shale) at the East Themed section, bed 16. A few other specimens (belonging to forma crassa) have been collected from firm substrate (marly limestone) at Gebel Areif El-Naqa, bed 13. The wide variability of *I. africana* is related to ecological factors (MALCHUS, 1990). Also the morphological variability within populations is very high (KASSAB, 1991a). *I. africana* belongs to the cup-shaped recliners, which are adapted to life on soft substrates (SEILACHER, 1984). According to EL QOT (2006: 43), the differentiation of this species into two forms is very difficult when very large populations are studied as there are many intermediate forms (Text-fig. 3.7). Therefore and in agreement with the latter author, the two forms of *I. africana*, erected by MALCHUS, are considered herein as synonyms to *I. africana*.
COQUAND (1862) identified *Ostrea auressensis* as new species but many authors (e.g. COQUAND 1869; PERVINQUIÈRE 1912, GRECO 1918; ABBASS 1962, EL QOT, 2006) considered his new species as a synonym of *I. africana* (for more detailed discussion see MALCHUS, 1990: 123-124).



Text-fig. 3.7. Biometric data of *Ilymatogyra africana* (LAMARCK, 1801) from the Abu Qada Formation (Upper Cenomanian-Lower Turonian) of East Themed.

Genus *Rhynchostreon* BAYLE, 1878
Rhynchostreon suborbiculatum (LAMARCK, 1801)
Pl. 7, Figs. 7-9; Text-fig. 3.8

1801 *Gryphaea suborbiculata* sp. nov. – LAMARCK: 398, pl. 23, figs. 11-13.
1819 *Gryphaea columba* sp. nov. – LAMARCK: 198.
1862 *Ostrea Mermeti* sp. nov. – COQUAND: 234, pl. 23, figs. 3-5.
1871 *Exogyra suborbiculata* LAMARCK – STOLICZKA: 462, pl. 35, figs. 1-4.
1912 *Exogyra columba* LAMARCK – PERVINQUIÈRE: 180.
1917 *Ostrea Mermeti* COQUAND – FOURTAU: 40.
1918 *Exogyra columba* LAMARCK – GRECO: 7 (189), pl. 1 (17), figs. 15-18; pl. 2 (18), figs. 1-4.
1962 *Exogyra suborbiculata* (LAMARCK) – ABBASS: 68, pl. 9, figs. 7-8.
1963 *Exogyra columba* LAMARCK – FAWZI: 40, pl. 3, figs. 1-10.
1971 *Exogyra columba* LAMARCK – COLLIGNON: 33 (175), pl. F, fig. 7.
1972 *Rhynchostreon columbum columbum* (LAMARCK) - FRENEIX: 88, pl. 5, fig. 3a-b.
1972 *Rhynchostreon columbum* (LAMARCK) *mermeti* (COQUAND) - FRENEIX: 89, pl. 5, figs. 4, 5.
1985 *Exogyra* cf. *suborbiculata* (LAMARCK) – DOMINIK: pl. 13, fig. 3.
1985 *Exogyra columba* LAMARCK – DOMINIK: pl. 13, figs. 4-5.
1985 *Rhynchostreon suborbiculatum* (LAMARCK) – DHONDT: 61, fig.3a.
1990 *Rhynchostreon mermeti* (COQUAND) – MALCHUS: 128, pl. 8, figs. 15-17; pl. 9, figs.1-4 (=forma typica); pl. 9, figs. 8, 9-12 (= forma minor) (with extended synonymy).
1991a *Ilymatogyra africana* (LAMARCK) – KASSAB: 251, fig. 7/2-5, 9-11, 17-18.
1992 *Rhynchostreon mermeti* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 2, figs. 4-8.
1993 *Rhynchostreon suborbiculatum* (LAMARCK) – KORA et al.: pl. 2, fig. 2.
1993 *Rhynchostreon mermeti* (COQUAND) – ORABI: pl. 1, figs. 21-23.
?1998 *Rhynchostreon mermeti* (COQUAND) – EL-SHEIKH et al.: pl. 1, fig. D.
1999 *Rhynchostreon mermeti* (COQUAND) – DHONDT et al.: pl. 1, fig. 4.
1999 *Rhynchostreon* (*Rhynchostreon*) *mermeti* (COQUAND) – SEELING & BENGTSON: 759, fig. 10a, b.
2001 *Rhynchostreon suborbiculatum* (LAMARCK) – KORA et al.: pl. 1, fig. 6a-b.
2001 *Rhynchostreon mermeti* (COQUAND) – KORA et al.: pl. 1, fig. 3.

2001 *Rhynchostreon mermeti* (COQUAND) – ABDALLAH et al.: pl. 2, figs. 11-12.
2002 *Rhynchostreon suborbiculatum* (LAMARCK) – ABDEL-GAWAD & GAMEIL: 87, pl. 2, fig. 10.
2002 *Rhynchostreon mermeti* (COQUAND) – BERNDT: 111, pl. 3, figs. 9-10.
2002 *Rhynchostreon mermeti* (COQUAND) – AHMAD & AL-HAMMAD: 456, fig. 3/4-11; fig. 4/1-2.
2002 *Rhynchostreon serrulatum* sp. nov. - KASSAB & ZAKHERA: 12, fig. 4/6-8.
2002 *Rhynchostreon mermeti* (COQUAND) – KASSAB & ZAKHERA: 12, fig. 4/4-5.
2002b *Rhynchostreon mermeti* (COQUAND) – ZAKHERA & KASSAB: pl. 4, figs. 1-12.
2004 *Rhynchostreon suborbiculatum* (LAMARCK) – KHALIL & MASHALY: pl. 2, figs. 3-4.
2004a *Rhynchostreon suborbiculatum* (LAMARCK) – ABDEL-GAWAD et al.: pl. 7, figs. 4a-b, 6.
2004b *Rhynchostreon mermeti* (COQUAND) – ABDEL-GAWAD et al.: pl. 1, fig. 16.
2006 *Rhynchostreon suborbiculatum* (LAMARCK) – EL QOT: 43, pl. 7, figs. 9a-11; pl. 8, figs. 1-4, text-fig. 8B.
2007b *Rhynchostreon suborbiculatum* (LAMARCK) – MEKAWY: 217, pl. 3, figs. 3, 4.

Material and occurrence. 75 specimens, mostly disarticulated valves, from the lower marly, middle carbonate, and upper carbonate/marl members of the Upper Albian-Cenomanain Halal Formation, beds 1, 5, 11-13, 15, and 17 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.89-91,**5**.20-29,**11**.1-6,**12**.6-20,**13**.3-27,**15**.49-63,**17**.1), 415 specimens from the lower shale and middle siliciclastic/carbonate members of the Cenomanian Galala Formation, beds 12, 13, 21-23, 26-29, 37, and 39 at Wadi Quseib (MGDMU:WQ.Bi.**12**.28-30,**13**.22-27,**21**.12-14,**22**.27-65,**23**.41-48,**26**.1-4,**27**.1-297,**28**.1-60,**29**.5-12,**37**.1-3,**39**.168-170), and 44 left valves from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 16, 19 and 26 at East Themed area (MGDMU:ET.Bi.**16**.422-427,**19**.77-79,**26**.32-66).

Measurements (in mm).

n=53	L	H	C	nr	H/L	C/L	C/H
Range	8-32	11-42	7-13	10-98	0.75-1.66	0.39- 0.71	0.29-0.62
Mean	17.43	22.75	9.66	35	1.32	0.61	0.48

Description. Shell varying in size from small to medium, elongated-oval to exogyriform, strongly ineqivalved, inequilateral, mostly higher than long (average H/L=1.32; Text-fig. 3.8). Left valve broad and strongly convex. Right valve flat to slightly convex, subrounded, smaller than left one, and ornamented with commarginal growth lamellae. In most individuals, anterior and posterior margins strongly convex, in others postero-ventral margin slightly prolongated. Umbo moderately twisted and opisthogyrate but low, relatively small, slightly posteriorly coiled and occasionally hidden behind the postero-dorsal margin in young individuals. Attachment area small to medium-sized, semi-circular to elongated, and present only in younger individuals. Ligamental area variable in size and shape, mostly small and narrow. Chomata not visible. Adductor muscle scar large, subrounded, and situated postero-ventrally. Left valve ornamented with radial ribs, which vary in shape, size, and number. Some valves with radial ribs, which either extend from the umbo to the ventral margin (Pl. 7, Fig. 7a) and are crossed by wide growth laminae or are restricted to the umbonal area (Pl. 7, Fig. 8), the rest of the shell being smooth or carrying just growth lines. Number of ribs decreasing with shell height (Text-fig. 3.8B).

Temporal and spatial distribution. *Rhynchostreon suborbiculatum* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862; COLLIIGNON, 1971), Cenomanian of

Tunisia (PERVINQUIÈRE, 1912), Jordan (AHMAD & AL-HAMMAD, 2002), Morocco (FRENEIX, 1972), France (DHONDT, 1985), India (STOLICZKA, 1871), and Brazil (SEELING & BENGTSON, 1999). In Egypt, it occurs in the Cenomanian of East Themed, Gebel Ekma, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. Musaba Salamaa (KHALIL & MASHALY, 2004), Eastern Desert (GRECO, 1918; MALCHUS, 1990; KASSAB, 1991a; ZAKHERA & KASSAB, 2002b; MEKAWY, 2007b), El-Giddi Pass (ABDALLAH et al., 2001), W. Abu Qada and W. Abu Had (ABBASS, 1962; KORA et al., 2001), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Hamra (ABDEL-GAWAD & ZALAT, 1992; EL-SHEIKH et al., 1998), W. Taba (ORABI, 1993), G. El-Halal (FAWZI, 1963), and Bahariya Oasis, Western Desert (DOMINIK, 1985).

According to SEELING & BENGTSON (1999: 760), *R. suborbiculatum* is widely distributed in the Cenomanian-Turonian of the southern Tethys. In Africa and Central Asia, the species extends from the Cenomanian to the Turonian, while in northern Europe it often extends to the Turonian, in northern Ireland even to the Coniacian (DHONDT et al., 1999: 74).

Discussion. The great similarity between *Rhynchostreon mermeti* (COQUAND), *R. suborbiculatum* (LAMARCK), and *R. columbum* (LAMARCK) with respect to ribbing, degree of umbo coiling, and shell outline makes it difficult to separate these species (Text-fig. 3.8A). Therefore, many discussions centred around the diagnostic features of these species. Many authors divided them into different forms and varieties according to the presence or absence of ornamentation and general outline. For instance, ABDEL-GAWAG & GAMEIL (2002) and EL QOT (2006) noted that individuals with radial ribs all over the surface appeared first and that this radial ribbing gradually disappeared stratigraphically upwards. GRECO (1918) applied the name *Exogyra columba* to three varieties; a variety characterized by radial ribs extending from the umbo to the ventral margin, a second variety with a long and triangular valve which narrows towards the umbo and has a wide ligament area, and a third variety with a short, slightly twisted beak and with an elongated and narrow ligament area. SEELING & BENGSTON (1999: 760) argued that the presence or absence of this ornamentation may be result from abrasion during transport or represent natural variability. According to the latter authors, it is also difficult to separate between *R. mermeti* and *R. suborbiculatum*, especially when dealing with small specimens.

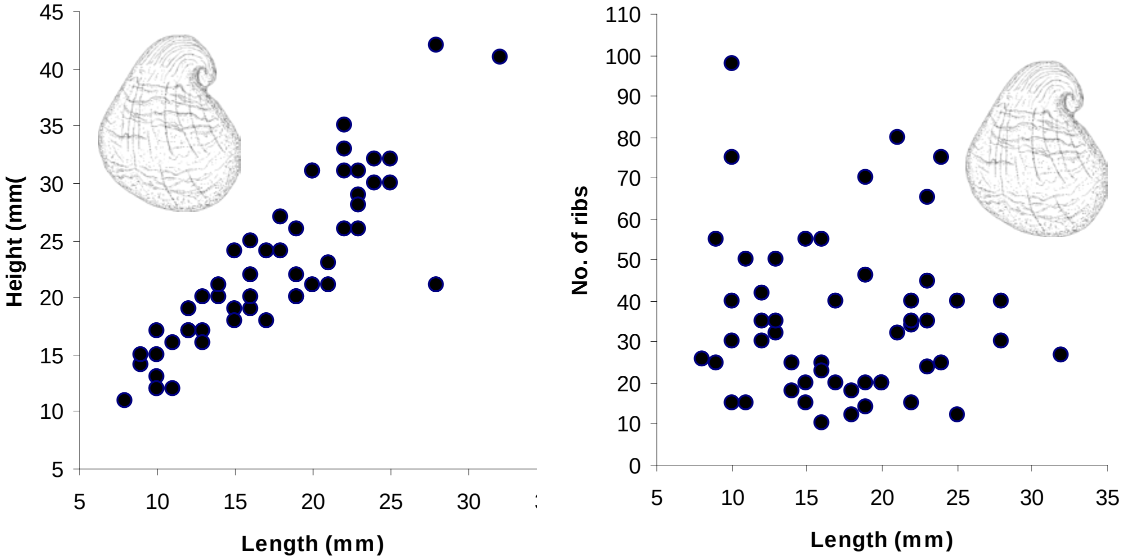
PERVINQUIÈRE (1912) and FAWZI (1963) considered the three species to be synonyms and placed them under *R. columbum*. According to TREVISAN (1937) *R. columbum* and *R. mermeti* as conspecific, whereas WOODS (1913) and MALCHUS (1990) regarded *R. mermeti* as related to North Africa and the other two species to Europe. MALCHUS (1990) classified *R. mermeti* into two forms; forma typica and forma minor, the latter being characterized by small size and a variable L/H ratio (for differentiation among these varieties, see MALCHUS, 1990: 130). LARTET (1873) divided *R. mermeti* into six varieties while FAWZI (1963) classified *R. columbum* into four varieties (for more detailed discussion see EL QOT, 2006: 44, 46).

In the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, the individuals are small-to medium-sized, oval, and completely ribbed (beds, 1, 5, and 10). In contrast, the shells in the middle carbonate member of the same formation become larger, variable in outline, and the radial ribs are restricted to the umbonal area and crossed by commarginal growth laminae (beds 15, and 17). In the lower part of the Cenomanian Galala Formation at Wadi Quseib some specimens have radial ribs all over the surface and others have radial ribs restricted to the umbonal area. Therefore, it is very difficult to separate the species into two or more varieties.

In agreement with FOURTAU (1904) and EL QOT (2006), regarded as *R. mermeti* (COQUAND) and *R. columbum* (LAMARCK) are synonyms of *R. suborbiculatum* according to the law of priority. Moreover, the present author suggests that all the varieties of *R. suborbiculatum* may be related to the nature of the substrate and to other environmental factors.

R. serrulatum, from the Turonian of Wadi El-Dakhl (Eastern Desert) described and figured as new species by Kassab & Zakhera (2002), is identical to *R. mermeti* in the style of ornamentation, umbo coiling, and general outline. The authors suggested that their species is probably a descendant of the Cenomanian *R. mermeti*. Therefore, *R. serrulatum* is considered herein as a junior synonym of the present species.

The specimens described as *Ilymatogyra africana* by Kassab (1991a) are identical to the large form of *R. suborbiculatum* in having a ribbed surface and therefore are considered herein as a synonym of *R. suborbiculatum.*



Text-fig. 3.8. Biometric data of *Rhynchostreon suborbiculatum* (Lamarck, 1801) from the Cenomanian Galala Formation of the Wadi Quseib section.

Family Ostreidae Wilkes, 1810
Subfamily Liostreinae Malchus, 1990
Tribe Curvostreini Malchus, 1990
Genus *Curvostrea* Vyalov, 1936
Curvostrea rouvillei (Coquand, 1862)
Pl. 8, Figs. 1-2

1862 *Ostrea Rouvillei* sp. nov. - Coquand: 232, pl. 22, figs. 8-10.
1869 *Ostrea Rouvillei* Coquand – Coquand: 89, pl. 21, figs. 3-6; pl. 24, figs. 7-11.
?1869 *Ostrea Rediviva* sp. nov. - Coquand: 154, pl. 42, figs. 8-11; pl. 54, figs. 18-30.
1912 *Liostrea Rouvillei* Coquand – Pervinquière: 168.
1917 *Ostrea Rouvillei* Coquand – Fourtau: 50.
1918 *Liostrea Rouvillei* Coquand – Greco: 4 (186), pl. 1 (17), figs. 6-11.
1962 *Ostrea* (*Crassostrea*) *rouvillei* (Coquand) – Abbass: 74, pl. 11, fig. 8.
1963 *Liostrea rouvillei* Coquand – Fawzi: 36, pl. 2, fig. 7.
1972 *Liostrea rouvillei* (Coquand) – Freneix: 97; text-fig. 10A-D.
?1985 *Ostrea* cf. *rediviva* Coquand – Dominik: pl. 13, fig. 7.
1990 *Curvostrea rouvillei* (Coquand) – Malchus: 154, pl. 14, figs. 1-7, 16.

1993 *Curvostrea rouvillei* (COQUAND) – ORABI: pl. 2, figs. 16-17.
1999 *Curvostrea rouvillei* (COQUAND) – SEELING & BENGTSON: 761, fig. 12a-d.
2002 *Curvostrea rouvillei* (COQUAND) – ABDELHAMID & EL QOT: 273, pl. 3, fig. 8; pl. 4, fig. 1.
2002 *Liostrea rouvillei* (COQUAND) – ABDEL-GAWAD & GAMEIL: 88, pl. 2, fig. 11.
2006 *Curvostrea rouvillei* (COQUAND) – EL QOT: 47, pl. 8, figs. 5-6.
2007b *Curvostrea rouvillei* (COQUAND) – MEKAWY: 218, pl. 3, fig. 5.

Material and occurrence. 59 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 22, 39, 42, and 44 at Wadi Quseib (MGDMU:WQ.Bi.**22**.66-70,**39**.169-175,**42**.61-63,**44**.39-84), eigth specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 25, 31 of the East Themed area (MGDMU:ET.Bi.**25**.53-55,**31**.36-40), and a single right valve from the lower marly member of the Upper Albian Halal Formation, bed 9 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**9**.42).

Measurements (in mm).

n=4	L	H	C	H/L	C/L	C/H
Range	16-26	30-35	8-12	1.15-1.94	0.47-0.63	0.25-0.34
Mean	20	32	9.66	1.70	0.53	0.29

Description. Shell medium-sized, flat, varying in shape from hook- to tongue-shaped or elongated-oval, and depressed (C/H=0.29). Shell thin, slightly curved dorsally, inequilateral, and slightly inequivalved. Left valve slightly convex, smooth, and partly with weak commarginal growth lines. Dorso-ventral keel extending from the umbonal area, being less developed ventrally (Pl. 8, Fig. 1a). Right valve less convex to slightly concave ventrally with faintly developed growth lines. Umbo small and not very prominent. Ligamental area narrow, elongated, and relatively small. Adductor muscle scar not seen.

Temporal and spatial distribution. *Curvostrea rouvillei* has been recorded from the Santonian of Algeria (COQUAND, 1862), Upper Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Morocco (FRENEIX, 1972), and Brazil (SEELING & BENGTSON, 1999).

EXPLANATION OF PLATE 8

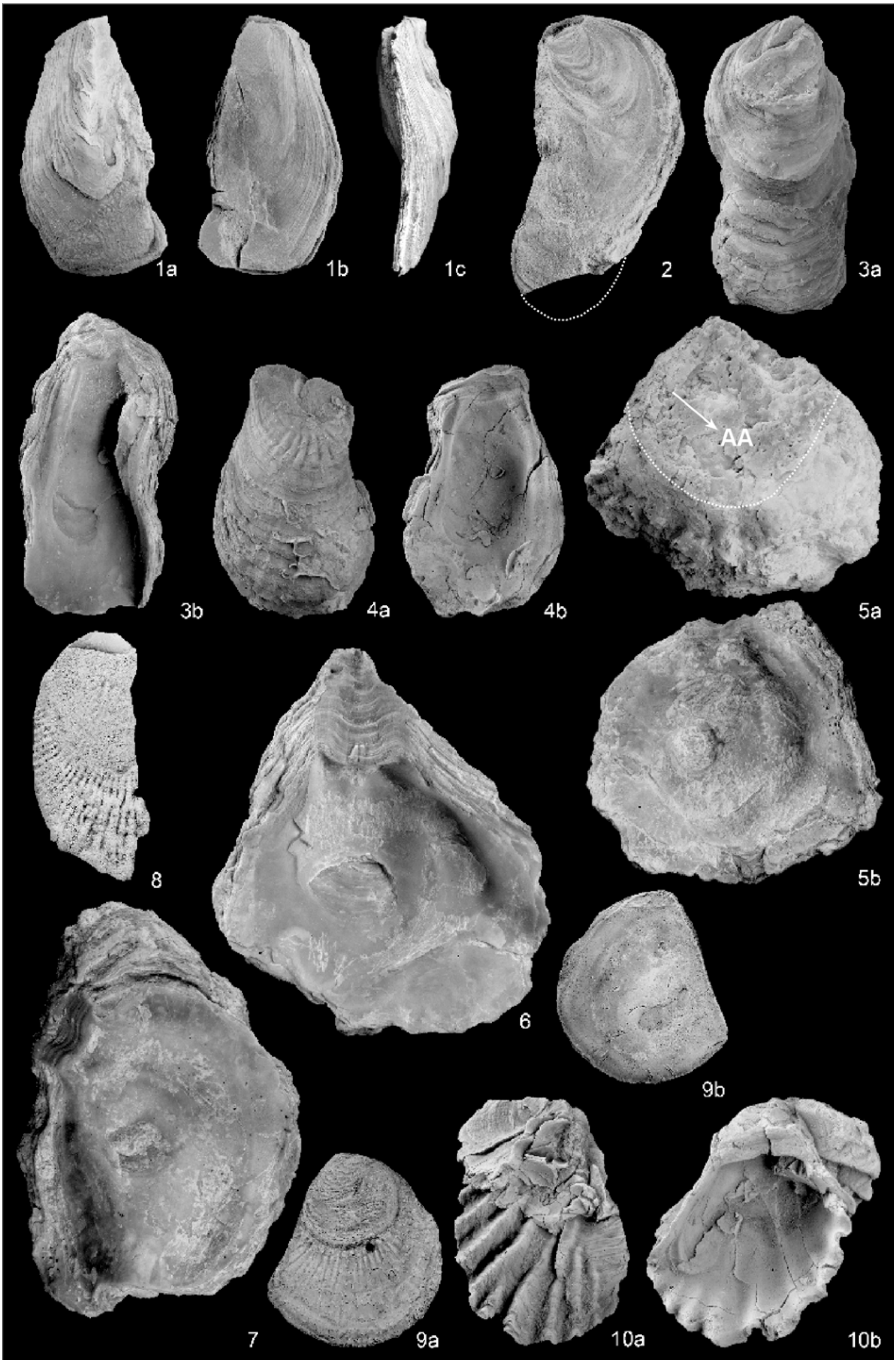
Figs. 1-2. *Curvostrea rouvillei* (COQUAND, 1862). Articulated valves from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **1a**: View of left valve, b: view of right valve, **c**: anterior view; MGDMU:WQ.Bi.44. - **2**. View of right valve; MGDMU:WQ.Bi.**44**.39.

Figs. 3-4. *Gyrostrea delettrei* (COQUAND, 1862) from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **3a**: External view of left valve, b: internal view of left valve; MGDMU:AEN.Bi.**13**.28. - **4a**: View of left valve, **b**: internal view of left valve; MGDMU:AEN.Bi.**13**.29.

Figs. 5-7. *Gyrostrea* cf. *anubis* MALCHUS, 1990 from the upper member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x1. **5a**: View of left valve with large attachment area (AA), **b**: internal view of left valve; MGDMU:AEN.Bi.**30**.9. - **6**. Internal side view of left valve; MGDMU:AEN.Bi.30. - **7**. Internal view of left valve; MGDMU:AEN.Bi.**30**.10.

Figs. 8-9. *Ambigostrea pseudovillei* MALCHUS, 1990 from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **8**. Side view of fragmented right valve; MGDMU:WQ.Bi.39. - **9a**: Side view of right valve, **b**: internal view of right valve; MGDMU:WQ.Bi.**39**.178.

Fig. 10. *Lopha syphax* (COQUAND, 1854) from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. **a**: External view of left valve, **b**: internal view of left valve; MGDMU:AEN.Bi.**12**.36.


1a
1b
1c
2
3a
3b
4a
4b
AA
5a
8
6
5b
9b
7
9a
10a
10b

In Egypt, it is known from the Upper Cenomanian-Turonian of Gebel Ekma, East Themed, and G. Yelleg (EL QOT, 2006), G. Um Raiying (ABBASS, 1962), Eastern Desert (GRECO, 1916; FAWZI, 1963; MALCHUS, 1990; MEKAWY, 2007b), W. Watir (ORABI, 1993), and G. El-Minsherah (ABDELHAMID & EL QOT, 2002). Stratigraphically, the species ranges from the Cenomanian to the Senonian.

Discussion. STENZEL (1971: N1168) placed *Curvostrea* VYALOV (1936) in his group of genera of uncertain systematic position, because the internal characters of the shell were not known. Recently, MALCHUS (1990) assigned the genus to his new subfamily Liostreinae within the Family Ostreidae RAFINESQUE, 1815.

Many authors (e.g. FAWZI, 1963; MALCHUS, 1990; EL QOT, 2006) considered *Ostrea rediviva* COQUAND from the Cenomanian of Algeria as a synonym of *Curvostrea rouvillei*. However, *O. rediviva* has a more curved shell (falciform) and more strongly resembles *C. isidis* (FOURTAU, 1917: 39, pl. 2, figs. 1-6) from the Cenomanian of Egypt than the present species. Therefore, *O. rediviva* is considered herein with some doubt as a synonym of *C. rouvillei.*

O. biskarensis COQUAND (1862-1869) from the Upper Cretaceous of Algeria differs from the present species in having a trigonal and shorter shell with a more convex left valve.

Tribe Flemingostreini STENZEL, 1971
Genus *Gyrostrea* MIRKAMALOV, 1963
Gyrostrea delettrei (COQUAND, 1862)
Pl. 8, Figs. 3-4; Text-fig. 3.9A

1862 *Ostrea Delettrei* sp. nov. - COQUAND: 224, pl. 18, figs. 1-7.
1869 *Ostrea Delettrei* COQUAND – COQUAND: 143, pl. 46, figs. 16-18; pl. 47, figs. 1-6; pl. 48, figs. 1-5.
?1869 *Ostrea Canaliculata* sp. nov. - COQUAND: pl. 47, figs. 7-10.
1912 *Exogyra Delettrei* COQUAND – PERVINQUIÈRE: 186, pl. 12, figs. 18-?19.
1917 *Ostrea Delettrei* COQUAND – FOURTAU: 34, pl. 1, figs. 1-4.
1918 *Exogyra Delettrei* COQUAND – GRECO: 10 (192), pl. 2 (18), figs. 7-8.
1937 *Exogyra Delettrei* COQUAND – TREVISAN: 74, pl. 5, figs. 5-10.
1962 *Ostrea* (*Crassostrea*) *delettrei* (COQUAND) - ABBASS: 75, pl. 10, figs. 4-5; pl. 12, fig. 4.
1963 *Exogyra delettrei* COQUAND – FAWZI: 47, pl. 4, figs. 4-5.
1971 *Exogyra delettrei* COQUAND – COLLIGNON:172 (30); pl. E, figs. 7-8; pl. F, fig. 1.
1971 *Exogyra africana* LAMARCK - COLLIGNON:173 (31); pl. F, figs. 2-4.
1972 *Crassostrea* (*Gyrostrea*) *delettrei* (COQUAND) *tarfayensis* subsp. nov. – FRENEIX: 98, pl. 8, figs. 5-8; pl. 9, figs. 1-7.
1972 *Crassostrea* (*Gyrostrea*) *delettrei* (COQUAND) - FRENEIX: 99.
1982 *Gyrostrea delettrei* (COQUAND) – FRENEIX: 9, pl. 4, figs. 1-2 (shell microstructure).
1987 *Gyrostrea delettrei* (COQUAND) – BANDEL et al.: pl. 2, fig. 10a-b
1992 “*Ilymatogyra*” *delettrei* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 2, fig. 14.
1993 *Gyrostrea delettrei* (COQUAND) – KORA et al.: pl. 2, fig. 3.
1998 *Gyrostrea delettrei* (COQUAND) – EL-SHEIKH et al.: pl. 1, fig. B.
1999 *Crassostrea canaliculata* sp. nov. - ZAKHERA & KASSAB: 387, figs. 2, 4/10-12.
2001 *Gyrostrea delettrei* (COQUAND) – ABDALLAH et al.: pl. 2, figs. 13-14.
2002 *Gyrostrea delettrei* (COQUAND) – ABDELHAMID & EL QOT: 271, pl. 3, fig. 5.
2002 *Crassostrea canaliculata* ZAKHERA & KASSAB – KASSAB & ZAKHERA: 20, fig. 6/1, 4.
2004a *Gyrostrea delettrei* (COQUAND) – ABDEL-GAWAD et al.: pl. 8, figs. 4, 6.

2004b *Gyrostrea delettrei* (COQUAND) – ABDEL-GAWAD et al.: pl. 2, fig. 3 a-b.
2006 *Gyrostrea delettrei* (COQUAND) – EL QOT: 47, pl. 8, figs. 7-10.
2007b *Gyrostrea delettrei* (COQUAND) – MEKAWY: 220, pl. 3, fig. 7.
2008 *Gyrostrea delettrei* (COQUAND) – MEKAWY & ABU-ZIED: 303, pl. 2, fig. 3.

Material and occurrence. 21 disarticulated valves from the lower marly member of the Upper Albian Halal Formation, beds 12 and 13 at Gebel Areif El-Naqa and the upper member of the Lower Turonian Abu Qada Formation, bed 30 from the same section (MGDMU:AEN.Bi.**12**.21-35,**13**.28-30,**30**.6-8), and two specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 39 at Wadi Quseib (MGDMU:WQ.C.**39**.176-177).

Measurements (in mm).

n=13	L	H	H/L
Range	19-55	29-110	1.28-2.08
Mean	28.23	47.77	1.66

Description. Shell varying in size from small to large, elongated-oval to nearly rectangular, moderately thick, ineqivalved, and strongly inequilateral. Left valve slightly to strongly convex with auricle-like projection in some forms. Ventral margin rounded with subparallel anterior and posterior margins. Umbo pointed, nearly central in position, posteriorly incurved in some individuals and orthogyrate in others. Ligamental area medium to large and subrectangular. Resilifer pit long and deep with well developed bourrelets on either side. Adductor muscle scar kidney-shaped, close to the posterior margin and closer to the ventral margin than to the hinge. Attachment area large, smooth and rounded to oval. Chomata weak and hardly visible in most specimens. Ornamentation consisting of widely spaced imbricating commarginal lamellae separated by wide interspaces. Some specimens ornamented with radial ribs along the umbonal area (Pl. 8, Fig. 4).

Temporal and spatial distribution. *Gyrostrea delettrei* has been recorded from the Upper Cretaceous (?Rhotomagiennes) of Algeria (COQUAND, 1862; COLLIGNON, 1971), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Italy (TREVISAN, 1937), and Morocco (FRENEIX, 1972). In Egypt, it occurs in the Cenomanian of the Eastern Desert (GRECO, 1918; ABBASS, 1962; MEKAWY, 2007b), Gebel El-Hamra and G. El-Minsherah (EL-SHEIKH et al., 1998; ABDEL-GAWAD & ZALAT, 1992; ABDELHAMID & EL QOT, 2002), G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. Nezzazat (FAWZI, 1963), El Giddi Pass (ABDALLAH et al., 2001), W. Feiran and W. Abu Qada (KORA et al., 1993), and from the Lower Turonian of Abu Zuneima (KASSAB & ISMAEL, 1994).

According to FRENEIX (1972) noted that *G. delettrei* predominates in North Africa from Morocco to Egypt, but occurs also in the Cenomanian of Niger, the Turonian of Nigeria, and Turonian-Senonian of Congo.

Discussion. According to MALCHUS (1990: 165) most varieties of the genus *Gyrostrea* have a compact shell microstructure but he provided no figures to substantiate his opinion. In contrast, FRENEIX (1982) recorded a lens-foliated microstructure as the main characteristic feature of the genus *Gyrostrea*. Here, the view of FRENEIX (1982) is followed and the microstructure is illustrated in Text-fig. 3.9A-B.

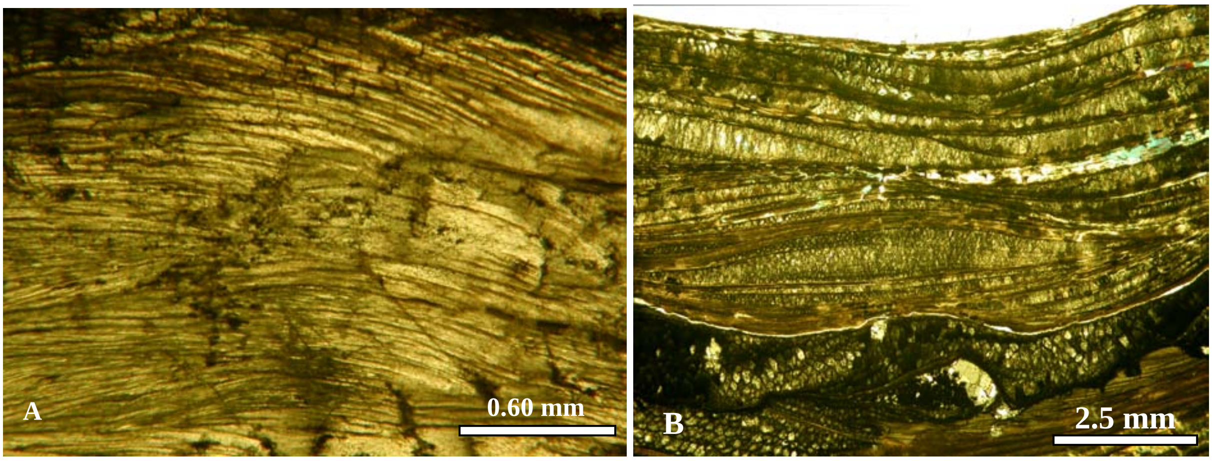
Gyrostrea roachensis (FOURTAU 1917: 50, pl. 3, fig. 1) from the Santonian of Abu Roash and *G. antwani* MALCHUS (1990:169, pl. 17, figs. 14-13; pl. 18, figs. 1-3) from the

Coniacian of Wadi Tarfa (Egypt) exhibit some similarity to *G. delettrei* (COQUAND, 1862: pl. 18, fig. 3; 1869: pl. 46, figs. 16-17; pl. 47, fig. 6) with respect to ornamentation style, ligamental area, and resilifer. According to FOURTAU (1917) and MALCHUS (1990), their species have a regular oval shell, large attachment area, and come from a higher stratigraphic level (Coniacian-Santonian). However, *G. delettrei* is quite variable with respect to size, shape, size of the attachment area, and ribbing (COQUAND, 1862, 1869). *G. delettrei* has also been recorded from the Upper Cretaceous of Algeria (COLLIGNON, 1971), and the Turonian-Senonian of Congo (FRENEIX, 1972). MALCHUS (1990) regarded *Ostrea delettrei* COQUAND of FOURTAU (1917), *O.* (*Crassostrea*) *delettrei* (COQUAND) of ABBASS (1962) from the Cenomanian of Wadi Araba, and *G. delettrei* (COQUAND) of BANDEL et al. (1987) from Wadi Qena as synonyms of his new species *antwani*. EL QOT (2006) regarded *G. antwani* as a possible junior synonym of *G. delettrei*. Therefore, FOURTAU' and MALCHUS's species may belong to *G. delettrei* and constitute ecophenotypic varieties.

Crassostrea canaliculata, from the Santonian of Saint Anthony (Eastern Desert), erected by ZAKHERA & KASSAB (1999), is not a valid species according to the International Code of Zoological Nomenclature (ICZN, 1895) as COQUAND (1869) has already figured and described *Ostrea canaliculata*. Moreover, KASSAB & ZAKHERA (2002) suggested that *O.* (*C.*) *delettrei* COQUAND described and figured by ABBASS (1962) is similar, if not identical, to their new species. Therefore, their species is considered herein as a junior synonym of *G. delettrei*.

Ilymatogyra africana (LAMARCK) differs from the present species in having a strongly twisted umbo, more convex shell, and narrow concentric growth laminae. *G. delettrei* (COQUAND), figured by KASSAB & ISMAEL (1994: 233, pl. 4, figs. 9, 14) from the Lower Turonian Abu Qada Formation at Gebel Musabaa Salama, differs in outline (exogyriform), a more twisted umbo, and is therefore more similar to *I. africana* than to *G. delettrei*. In contrast, *I. africana* as figured by COLLIGNON (1971) from the Senonian of Algeria is closer *G. delettrei* than to *I. africana* and this confusion is due to the high variability of *I. africana* (see discussion of *I. africana*).

According to MALCHUS (1990) *Gyrostrea delettrei* (COQUAND) does not occur in Egypt. He suggested a transition between *I.* (*Afrogyra*) *africana* "forma crassa" and *G. delettrei* (COQUAND) in Algeria and Tunisia, with the possibility that *G. delettrei* might be a later ecomorph of *I.* (*A.*) *africana* (EL QOT, 2006: 48). Therefore, MALCHUS considered *Exogyra delettrei* (COQUAND) figured by PERVINQUIÈRE (1912) from the Cenomanian of Tunisia and of GRECO (1918) from the Cenomanian of the Eastern Desert as synonyms of



Text-fig. 3.9. Cross-section of *Gyrostrea* MIRKAMALOV, 1963 showing the lens-foliated microstructure. A. *Gyrostrea delettrei* (COQUAND, 1862). B. *Gyrostrea* cf. *anubis* MALCHUS, 1990.

I. (*A.*) *africana* forma crassa. In fact, *G. delettrei* figured by GRECO (semi-rounded) and by PERVINQUIÈRE (an elongated-form) are different varieties of *G. delettrei* (COQUAND 1862-1869) as mentioned above.

Gyrostrea cf. *anubis* MALCHUS, 1990
Pl. 8, Figs.5-7; Text-figs. 3.9B, 3.10

cf. 1990 *Gyrostrea anubis* sp. nov. – MALCHUS: 170, pl. 18, figs. 6, 7, 11, 12.

Material and occurrence. 20 disarticulated valves from the upper member of the Lower Turonian Abu Qada Formation, bed 30 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**30**.9-25), 23 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation (Lower Turonian *Choffaticeras segne* Zone), beds 25 and 26 at East Themed (MGDMU:ET.Bi.**25**.56-61,**26**.67-83), and 17 specimens from the Upper Turonian Wata Formation (Upper Turonian ammonite *Coilopoceras requienianum* Zone), beds.71, 78, and 97 at Wadi Quseib (MGDMU:WQ.Bi.**71**.1-3,**78**.1-4,**97**.6-15).

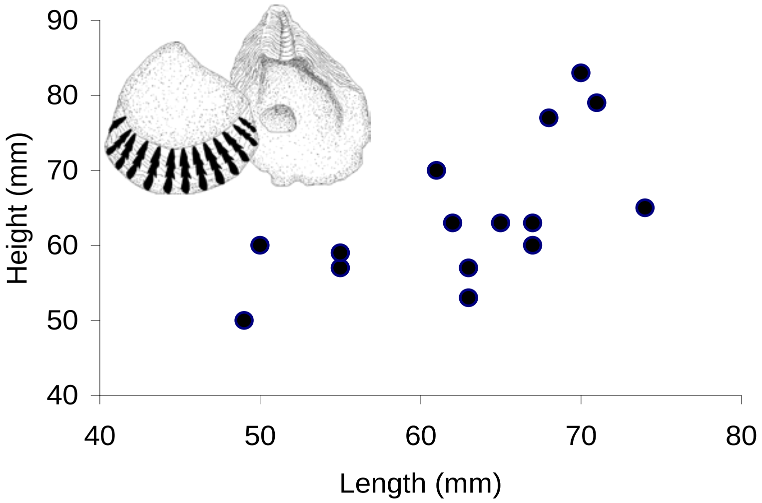
Measurements (in mm).

n=15	L	H	H/L
Range	49-74	50-83	0.87-1.18
Mean	62.66	63.93	1.02

Description. Shell large-sized, varying in outline from oval, subtriangular to rounded. Slightly higher than long (Text-fig. 3.10), and inequilateral. Anterior and posterior margins nearly straight to convex and grading into the convex ventral margin. Umbo slightly to moderately twisted posteriorly. Ligamental area variable in size but commonly large, triangular, high in some specimens (ranging from 11 to 20 mm), and broad with deep resilifer, flanked by narrow, flat bourrelets on either side. Adductor muscle scar rounded to kidney-shaped, deeply concave, and situated postero-ventrally to sub-centrally. Umbonal cavities absent to shallow in left valve with very deep anterior groove along the interior side of the left valve (Pl. 8, Fig. 6). Attachment area medium to large (Pl. 8, Fig. 5a). Ornamentation consisting of imbricated commarginal lamellae of nearly equal width with poorly preserved radial ribs. Shell microstructure with lens-foliated fabric (Text-fig. 3.9B).

Temporal and spatial distribution. *Gyrostrea anubis* has been recorded from the Coniacian of Wadi Qena, Eastern Desert by MALCHUS (1990).

Discussion. MALCHUS (1990) named his new species *Gyrostrea anubis* after the Egyptian God Anubis and noted the resemblance of his new species to *G. roachensis* (FOURTAU, 1917) and *G. antwani* MALCHUS, 1990 (a drop-shaped shell with weak radial ribs and concentric lamellae). He pointed out that *G. anubis* differs in having a small ligamental area, a comparatively strong anterior groove and lacking an umbonal cavity. The present specimens are closely similar to some *G. anubis* figured by MALCHUS (1990: pl. 18, figs. 6-7, 11-12) in general outline, position of the adductor muscle scar, and ornamentation, but differ in having a wider ligamental area and shallower umbonal cavity in some specimens. *G. antwani* differs in having a regular oval shell, wider ligamental area, very deep umbonal cavity, and ribs extending from the umbo to the ventral margin.



Text-fig. 3.10. Biometric data of *Gyrostrea* cf. *anubis* MALCHUS, 1990 from the upper member of the Lower Turonian Abu Qada Formation of Gebel Areif El-Naqa.

Tribe Ambigostreini MALCHUS, 1990
Genus *Ambigostrea* MALCHUS, 1990
Ambigostrea pseudovillei MALCHUS, 1990
Pl. 8, Figs. 8-9

1990 *Ambigostrea pseudovillei* sp. nov. – MALCHUS: 178, pl. 21, figs. 4-12.
1990 *Ambigostrea dominici* sp. nov. – MALCHUS: 179, pl. 21, figs. 1-3.
?1999 *Ambigostrea* sp. – SEELING & BENGTSON: 762, fig. 11d.
2004a *Ambigostrea pseudovillei* MALCHUS – ABEL-GAWAD et al.: pl. 7, figs. 5, 7, 10.
2006 *Ambigostrea pseudovillei* MALCHUS – EL QOT: 56, pl. 10, figs. 5-10; pl. 11, figs. 1-2.

Material and occurrence. Seven specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 21 and 39 at Wadi Quseib (MGDMU:WQ.Bi.**21**.15-16,**39**.178-182).

Measurements (in mm).

n=2	L	H	nr	.H/L
Range	22-30	24-31	40-60	1.03-1.10
Mean	28.5	27.5	50	1.06

Description. Small-sized, ovate, higher than long (H/L=1.06), inequilateral, and feebly inflated. Posterior margin truncated while anterior one strongly rounded and meeting the ventral margin in a rounded curve. Shell thin, right valve flat, left valve slightly convex. Umbo only little prominent and opisthogyrate. Attachment area large. Ligamental area wide and longer than high. Adductor muscle scar kidney-shaped and situated postero-ventrally. Anachomata well developed postero-dorsally and less developed antero-dorsally. Ornamentation consisting of fine and numerous radial ribs (40-60). These radials are crossed by wide and fine commarginal striations and becoming less conspicuous dorsally.

Temporal and spatial distribution. *Ambigostrea pseudovillei* has been recorded from the Upper Cenomanian of Wadi Qena (Eastern Desert) as the type species and El Bahariya Oasis, (Western Desert) by MALCHUS (1990) and from the Cenomanian of Gebel Ekma, G. Yelleg

(ABDEL-GAWAD et al., 2004a; EL QOT, 2006). *A. pseudovillei* has been also recorded from the Middle-lower Upper Cenomanian of Brazil by SEELING & BENGTSON (1999).

Discussion. The features described above, place this material in the genus *Ambigostrea*, which was introduced by MALCHUS (1990). The latter author erected two new species belonging to his new genus *Ambigostrea*, *A. pseudovillei* (present species) and *A. dominici*. The latter species has been recorded from the Upper Cenomanian of El Bahariya Oasis, Western Desert. According to him, *A. dominici* differs from the present species mainly in having many finer radial ribs. EL QOT (2006) considered *A. dominici* as a junior synonym to *A. pseudovillei* based on his large population collected from Gebel Ekma. He collected 10 specimens belonging to *dominici*, 41 specimens to *pseudovillei*, and 15 intermediate specimens from a single bed in the lower Upper Cenomanian (lower Upper Cenomanian ammonite *Neolobites vibrayeanus* Zone) and found it very difficult to distinguish between these two forms. Therefore and in agreement with EL QOT, *A. dominici* is considered herein as a junior synonym of *A. pseudovillei*.

Ambigostrea sp., described by SEELING & BENGTSON (1999), is poorly preserved and all the internal characters are lacking but the ribs pattern shows some affinity with *A. dominici*. Therefore, their specimen is considered with some doubt as a synonym of *A. pseudovillei*.

Subfamily Lophinae VYALOV, 1936
Genus *Lopha* RÖEDING, 1798
Lopha syphax (COQUAND, 1854)
Pl. 8, Fig. 10

1854 *Ostrea syphax* sp. nov. – COQUAND: 143, pl. 4, figs. 1-4.
1862 *Ostrea syphax* COQUAND – COQUAND: 228, pl. 20, figs. 1-4
1869 *Ostrea syphax* COQUAND: 138, pl. 55, fig. 13; pl. 56; pl. 58, figs. 1-5.
1912 *Alectryonia Syphax* COQUAND – PERVINQUIÈRE: 203, pl. 14, figs. 15-18.
1917 *Ostrea Syphax* COQUAND – FOURTAU: 53.
1937 *Alectryonia Syphax* COQUAND – TREVISAN: 80, pl. 4, fig. 7.
1954 *Lopha scyphax* (COQUAND) – RUTSCH & SALVADOR: 422, pl. 40, figs. 4-5.
1963 *Lopha syphax* COQUAND – FAWZI: 51, pl. 5, fig. 5.
1972 *Lopha syphax* (COQUAND) – FRENEIX: 93, pl. 6, figs. 1-5; pl. 7, fig. 1a-b; pl. 8, figs. 1-4; text-fig. 9.
2002 *Lopha syphax* (COQUAND) – ABEDL-GAWAD & GAMEIL: 88, pl. 2, fig. 12.
2004b *Lopha syphax* (COQUAND) – ABEDL-GAWAD et al.: pl 2, fig. 4a-b.

Material and occurrence. One left valve from the lower marly member of the Halal Formation (Upper Albian), bed 12 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**12**.36).

Measurements (in mm).

n=1	L	H	nr.	H/L
	20	27	12	1.35

Description. Shell medium-sized, oval in outline, and inequilateral. Left valve strongly convex. Posterior margin nearly straight, with strongly convex antero-ventral margin. Ventral margin plicated, rounded, and meeting the anterior margin in a continuous curve. Umbones small, terminal, and little pointed. Ligamental area wide, rectangular, and slightly depressed.

Resilifer shallow, narrow with small bourrelets on either side. Adductor muscle scar tear-shaped and located close the postero-central side. Attachment area large. Ornamentation consisting of regular, subequal, sharp-crested ribs, separated by deep V-shaped furrows nearly as wide as the ribs themselves. These ribs are crossed by imbricated commarginal lamellae. Dichotomizing ribs occur near the ventral margin.

Temporal and spatial distribution. *Lopha syphax* has been recorded from the Cenomanain of Morocco (FRENEIX, 1972), Tunisia (PERVINQUIÈRE, 1912), Algeria (COQUAND, 1862), Italy (TREVISAN, 1937), and Western Venezuela (RUTSCH & SALVADOR, 1954). In Egypt, it is known from the Cenomanian of Gebel Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. El-Minsherah (FAWZI, 1963), and Wadi Araba (FOURTAU, 1917).

L. syphax is of Cenomanian age and is most common in the lower part of this stage (for more details about the stratigraphic significance see RUTSCH & SALVADOR, 1954: 423).

Discussion. The great similarity between *Lopha syphax* and *L. dichotoma* (BAYLE, 1849) caused much confusion among authors. For instance, FOURTAU (1917) considered the Cenomanian *L. syphax* as ancestral form of the Santonian *L. dichotoma*. ABBASS (1962: 82) noted that the dorsal side of *L. syphax* is wider than that of *L. dichotoma.* However, some specimens of FRENEIX (1972: pl. 6, fig. 5a-b; pl. 8, fig. 1) from the Cenomanain of Morocco have a shorter dorsal side (the greatest elongation near the ventral margin), which contradicts ABBASS's opinion. Thus, based on the great variability of the shape, ABDEL-GAWAD & GAMEIL (2002) distinguished three forms of *L. syphax* (COQUAND), one type with a trigonal shell, a second with an elongated and curved shell, and a third type, which is similar to the second except that the postero-ventral margin is much longer.

In agreement with FRENEIX (1972: 96), *L. dichotoma* is characterized by having dense ribs which are uniformly distributed. In addition, the internal structure of the latter species differs from *L. syphax* in the ligament having a median position and its muscle scars being transverse and lying near the median line. Moreover, the stratigraphic range of *L. dichotoma* is much younger (Coniacian-Campanian) than that of the present species.

Genus *Rastellum* FAUJAS-SAINT-FOND, 1799
Rastellum carinatum (LAMARCK, 1806)
Pl. 9, Figs. 1-2

1806 *Ostrea carinata* sp. nov. – LAMARCK: 166.
1871 *Ostrea* (*Alectryonia*) *carinata* LAMARCK – STOLICZKA: 468, pl. 48, fig. 5; pl. 49, figs. 1-2.
1913 *Ostrea diluviana* LINNAEUS – WOODS: 342, text-figs. 98-108, 110-114, 122-123, 135-138, non figs. 109, 115, 118-119, 124-125.
1918 *Alectryonia* (*Arctostrea*) *diluviana* LINNAEUS – GRECO: 14 (196), pl. 2 (18), figs. 14, non. 13.
1971 *Rastellum* (*Arctostrea*) *carinatum* (LAMARCK) – STENZEL: N1165, fig. J139/2a-b.
2001 *Rastellum* (*Arctostrea*) *carinatum* (LAMARCK) – KORA et al.: pl. 1, fig. 5.
2002 *Rastellum* (*Arctostrea*) *carinatum* (LAMARCK) – ABDEL-GAWAD & GAMEIL: 88, pl. 2, fig. 13.
2002 *Arctostrea carinatum* (LAMARCK) – KASSAB & ZAKHERA: 23, fig. 6/10.
2004a *Rastellum carinatum* (LAMARCK) – ABDEL-GAWAD et al.: pl. 8, figs. 9-10.
2004b *Rastellum* (*Arctostrea*) *carinatum* (LAMARCK) – ABDEL-GAWAD et al.: pl. 2, fig. 5.

2006 *Rastellum carinatum* (LAMARCK) – EL QOT: 59, pl. 11, figs. 5, 6-7.

Material and occurrence. Eight incomplete shells from the upper carbonate member of the Upper Cenomanian Galala Formation, bed 44 at Wadi Quseib (MGDMU:WQ.Bi.**44**.85-92).

Description. Medium-sized, long, and curved shell. Left valve strongly convex with prominent keel in the middle of the valve. Ornamentation composed of many angular ribs that extend from the median keel to the margin. Umbo not preserved. Margins of the valves strongly serrated.

Temporal and spatial distribution. *Rastellum carinatum* has been recorded from the Upper Createceous of India (STOLICZKA, 1871) and England (WOODS, 1913). In Egypt, it occurs in the Upper Cenomanian of Gebel Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), El-Fallig (ABDEL-GAWAD et al.: 2004b), from the Cenomanian of the Eastern Desert (GRECO, 1918; KASSAB & ZAKHERA, 2002), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), and from the Lower Turonian of Gebel Mukattab (KORA et al., 2001).

According to EL QOT (2006: 60), *R. carinatum* is a cosmopolitan species and ranges from the Upper Neocomian to the Cenomanian, but in Africa the species is restricted to the Cenomanian.

Discussion. *Rastellum colubrina* (LAMARCK), figured by COQUAND (1869: pl. 29, figs. 1-7) from the Santonian of Algeria, resembles the present species in having the same ornamentation but differs in having a narrow shell with sharp-crested plicae.

EXPLANATION OF PLATE 9

Figs. 1-2. *Rastellum carinatum* (LAMARCK, 1806). Incomplete left valves from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **1**. External view of left valve, x1; MGDMU:WQ.Bi.44. - **2**. External view of left valve, x2; MGDMU:WQ.Bi.**44**.85.

Figs. 3-4. *Chondrodonta joannae* (CHOFFAT, 1886). Articulated valves from the upper carbonate/marl member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **3**. Side view of left valve, x1; MGDMU:AEN.Bi.**17**.2. - **4**. Side view of ?left valve, x2; MGDMU:AEN.Bi.**19**.3.

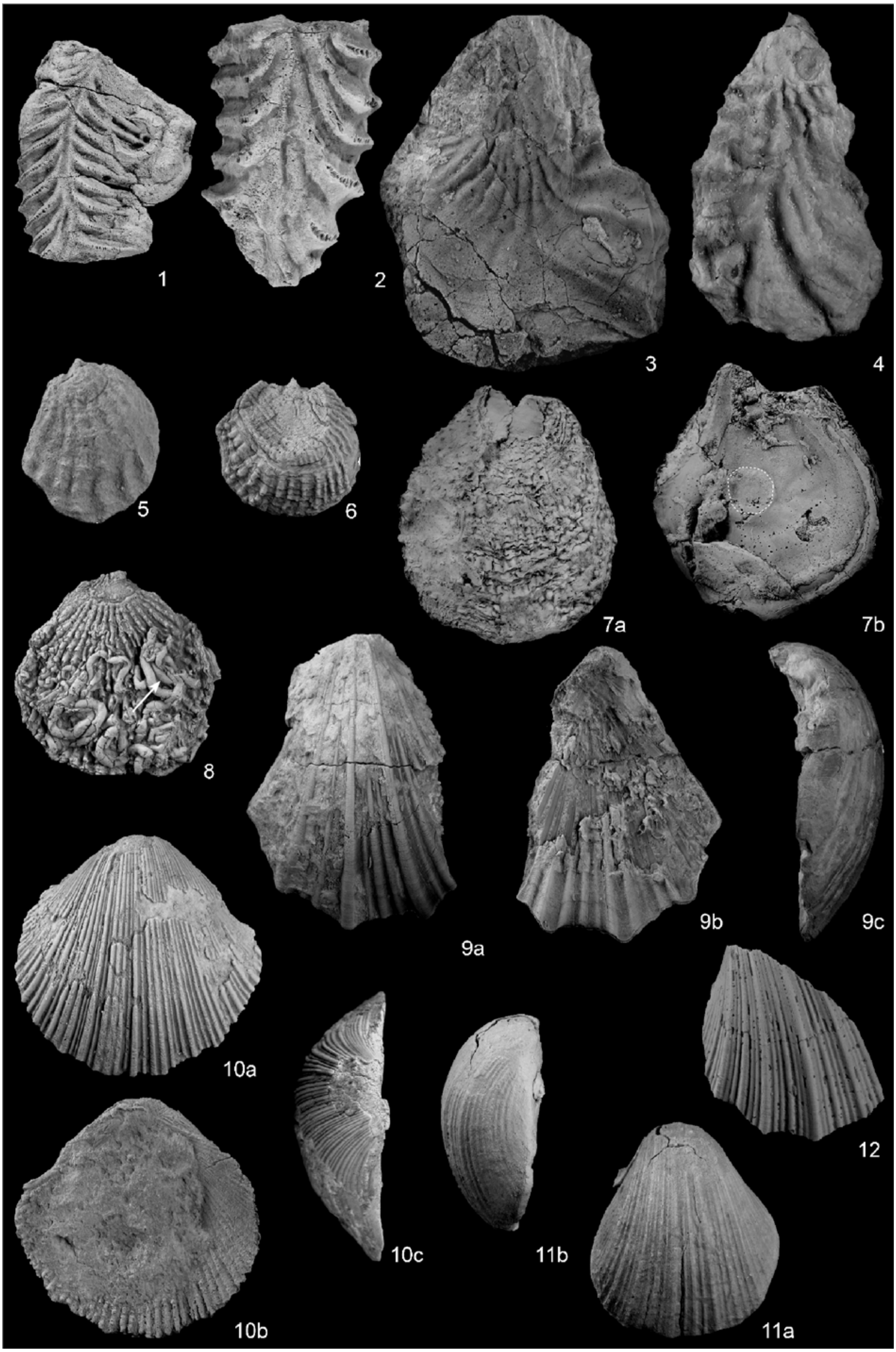
Figs. 5-6. *Plicatula* (*Plicatula*) *auressensis* COQUAND, 1862. **5**. Articulated specimen from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. Side view of left valve; MGDMU:AEN.Bi.**15**.64. - **6**. Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1.5. Side view of right valve; MGDMU:ET.Bi.**23**.13.

Figs. 7-8. *Plicatula* (*Plicatula*) *ferryi* COQUAND, 1862. **7**. Disarticulated specimen from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area. **a**: Side view of right valve, x1, **b**: side view of left valve, x1; MGDMU:ET.Bi.**26**.84. - **8**. Lower Turonian Abu Qada Formation at Wadi Quseib. External view with serpulids, x2; MGDMU:WQ.Bi.**45**.1.

Fig. 9. *Neithea* (*Neithea*) *coquandi* (PÉRON, 1877). Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **a**: Side view of right valve, **b**: side view of left valve, **c**: posterior view; MGDMU:ET.Bi.**17**.87.

Fig. 10. *Neithea* (*Neithea*) *dutrugei* (COQUAND, 1862). Articulated valves from the upper carbonate/marl member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa. x2. **a**: Side view of right valve, **b**: side view of left valve, **c**: dorsal view; MGDMU:AEN.Bi.**19**.7.

Figs. 11-12. *Neithea* (*Neithea*) *quinquecostata* (J. SOWERBY, 1814). Articulated valves from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area. **11a**: Side view of right valve, x1.5, **b**: anterior view, x1.5; MGDMU:ET.Bi.**16**.428. - **12**. Side view of fragmented right valve, x2; MGDMU:ET.Bi.**16**.429.


1
2
3
4
5
6
7a
7b
8
9a
9b
9c
10a
12
10c
11b
10b
11a

Family Chondrodontidae FRENEIX, 1959

Genus *Chondrodonta* STANTON, 1901
Chondrodonta joannae (CHOFFAT, 1886)
Pl. 9, Figs. 3-4

1886 *Ostrea Joannae* sp. nov. – CHOFFAT: 34, pl. Ostreidae 1, figs. 1-7; pl. Ostreidae 2, figs. 8-9.
1902 *Chondrodonta Joannae* CHOFFAT – CHOFFAT: 157, pl. 6, figs. 15-16.
1917 *Chondrodonta Joannae* CHOFFAT – FOURTAU: 13.
1934 *Ostreavicula* n. g. *dayi* n. sp. – BLANCKENHORN: 179, pl. 7, figs. 3-4.
1934 *Chondrodonta joannae* (CHOFFAT) – BLANCKENHORN: 204.
1971 *Chondrodonta* (*Chondrodonta*) *joannae* (CHOFFAT) – STENZEL: N1198, fig. J149/1a-b.
1992 *Chondrodonta joannae* (CHOFFAT) – DHONDT & DIENI: 212, figs. 2-3.
1993 *Chondrodonta joannae* (CHOFFAT) – DHONDT & DIENI: 210, pl. 14, figs. 1-3; pl. 15, figs. 1-10; pl. 16, fig. 1-5; pl. 17, figs. 1-5; pl. 18, figs. 1-7; pl. 19, figs. 1-5; text-figs. 15-17 (with extensive synonymy).
2004b *Chondrodonta joannae* (CHOFFAT) – ABDEL-GAWAD et al.: pl. 2, fig. 6.
2006 *Chondrodonta joannae* (CHOFFAT) – EL QOT: 60, pl. 12, figs. 1, 12.
2007b *Chondrodonta joannae* (CHOFFAT) – MEKAWY: 223.

Material and occurrence. Six articulated valves from the upper carbonate member of the Cenomanian Halal Formation, beds 17 and 19 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**17**.2-5,**19**.3-4), and about 335 fragments (*Chondrodonta* Bed) from the lower shale, middle siliciclastic/carbonate, and upper carbonate members of the Cenomanian Galala and Lower Turonian Abu Qada formations, beds 12, 14-15, 17, 21, 30, 32, 44, and 46 at Wadi Quseib (MGDMU:WQ.Bi.**12**.29-35,**14**.9-43,**15**.6-30,**17**.1-80,**21**.17-21,**30**.1-100,**32**.1-5,**44**.93-112,**46**.1-60), and about 94 fragments from the Upper Cenomanian Galala Formation, beds 3, 9, and 11 at the East Themed area (MGDMU:ET.Bi.**3**.12-32,**9**.6-8,**11**.1-70).

Measurements (in mm).

n=5	L	H	C	nr	H/L	C/L	C/H
Range	19-78	29-105	5-43	4-20	1.11-1.5	0.25-0.43	0.17-0.41
Mean	40.20	52.60	15	13	1.35	0.34	0.24

Description. Shell small -to large-sized, variable in outline, sub-rounded, triangular to fan-shaped, height greater than length (on average H/L=1.35), and compressed (C/H=0.24). Umbonal part pointed, generally elongated to very elongated, and triangular. Right valve slightly convex. Left valve slightly concave and smaller than the right one. Attachment area small to large and restricted to the right valve (attached valve). Ventral margin strongly curved and plicated. Shell plicated, plicae starting in the umbonal region, some of them straight and others diverging laterally with variable angle towards the median ribs (Pl. 9, Fig. 3). These plications are sharp, angular, occasionally dichotomous and separated by wide and deep interspaces especially along the postero-ventral area. These interspaces become narrower towards the umbonal area.

Temporal and spatial distribution. *Chondrodonta joannae* has been recorded from the Upper Turonian of Portugal (CHOFFAT, 1902), Cenomanian-Turonian of Syria (BLANCKENHORN, 1934), and from the Upper Cenomanian of Italy (DHONDT & DIENI, 1993). In Egypt, it is known from the Turonian of the Eastern Desert (FOURTAU, 1917; MEKAWY, 2007b), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and of East Themed and G. Yelleg, Sinai (EL QOT, 2006).

According to DHONDT & DIENI (1993), *Chondrodonta joannae* has been dated as Upper Cenomanian to Turonian, but new stratigraphic data suggest that the species is present only in the Late (but not latest) Cenomanian.

Discussion. FRENEIX (1960) erected the family Chondrodontidae. Subsequently, FRENEIX & LEFÉVRE (1968) discussed the morphology of chondrodontids in detail, redefined the family, and erected new subgenera on the base of hinge characteristics. STENZEL (1971) also recognized three subgenera of the genus *Chondrodonta*; *Ch.* (*Chondrodonta*), *Ch.* (*Freneixita*), and *Ch.* (*Cleidochondrela*) on the basis of internal characters. The present material consists of articulated valves and all internal features e.g. hinge, teeth, and chondrophore are not seen. For this reason, the subgeneric level in the present work is not used. DHONDT & DIENI (1993) studied the family in detail and considered the genus *Ostreavicula* BLANCKENHORN, 1934; *Lamellotis* HORVÁTH, 1966, *Grypheolamellotis* HORVÁTH, 1966, *Kosmolamellotis* HORVÁTH, 1966, and *Tenuilamellotis* HORVÁTH, 1966 as synonyms of the genus *Chondrodonta*.

The wide morphologic variability of *Ch. joannae* (CHOFFAT) led many authors to establish new taxa which actually are junior synonyms. DHONDT & DIENI (1993: 214) pointed out that this species has all the kinds of outline from elongate-ovate to fan-shaped, but can also be triangular or subcircular. According to the variability of the outline, SCHUBENT (1903) divided *Ch. joannae* from Istria into several varieties, such as var. *angusta*, *elongata*, *levis*, etc. Similarly, PARONA (1912: pl. 18, fig. 5) noted a saddle-like shape in his specimens from the rudist limestone of central Italy and described it as a new species, *Ch. sellaeformis*. Such saddle-shaped morphotypes are common in populations of *Ch. joannae* from different areas (DHONDT & DIENI 1993). BOEHM (1895) erected two new taxa, *Ostrea schiosensis* and *Terquemia forojuliensis*, which were placed in *Chondrodonta* by STANTON (1901) and FRENEIX & LEFÉVRE (1968). DHONDT & DIENI (1993) also regarded the two species of BOEHM, *Ostreavicula dayi* (BLANCKENHORN, 1934), and *Chondrodonta sellaeformis* (BARONA, 1912) as synonyms of *Chondrodonta joannae* (for detailed discussion see DHONDT & DIENI, 1993: 216, 218-220).

Superfamily Plicatulacea WATSON, 1930
Family Plicatulidae WATSON, 1930
Genus *Plicatula* LAMARCK, 1801
Subgenus *Plicatula* LAMARCK, 1801
Plicatula (*Plicatula*) *auressensis* COQUAND, 1862
Pl. 9, Figs. 5-6

1862 *Plicatula auressensis* sp. nov. – COQUAND: 222, pl. 16, figs. 14-16.
1862 *Plicatula Reynesi* sp. nov – COQUAND: 222, pl. 17, figs. 1-2.
1912 *Plicatula Auressensis* COQUAND – PERVINQUIÈRE: 156, pl. 11, figs. 2-18 (with different varieties).
1917 *Plicatula auressensis* COQUAND – FOURTAU: 20.
1934 *Plicatula reynesi* COQUAND – BLANCKENHORN: 193.
1937 *Plicatula auressensis* COQUAND – TREVISAN: 60, pl. 3, figs. 5-10.
1958 *Plicatula auressensis* COQUAND – BARBER: 20, pl. 7, fig. 4.
1962 *Plicatula auressensis* COQUAND – ABBASS: 61, pl. 7, figs. 17-19.
1962 *Plicatula reynesi* COQUAND – ABBASS: 62, pl. 7, fig. 11.

1963 *Plicatula auressensis* COQUAND – FAWZI: 32.
1971 *Plicatula auressensis* COQUAND – COLLIGNON: 29, pl. E, fig. 4.
1972 *Plicatula auressensis* COQUAND – FRENEIX: 82, pl. 4, figs. 7-10.
1981 *Plicatula auressensis* COQUAND – AMARD et al.: 72.
1993 *Plicatula reynesi* COQUAND – ORABI: pl. 1, figs. 25-26.
1994 *Plicatula reynesi* COQUAND – KASSAB & ISMAEL: 234, fig. 5/ 2, 3.
2002 *Plicatula auressensis* COQUAND – ABDEL-GAWAD & GAMEIL: 85, pl. 2, figs. 1-2.
2004b *Plicatula reynesi* COQUAND – ABDEL-GAWAD et al.: pl. 1, fig. 13.
2006 *Plicatula auressensis* COQUAND – EL QOT: 62, pl. 12, figs. 2a-b, 3-4.

Material and occurrence. 88 specimens, mostly articulated, in shell preservation from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 19, 22, 23, and 25 of the East Themed area (MGDMU:ET.Bi.**19**.80-82,**22**.8-70,**23**.13-32,**25**.62-63), 17 specimens from the middle siliciclastic/carbonate and upper carbonate members, beds 42, 43, and 44 at Wadi Quseib (MGDMU:WQ.Bi.**42**.64-73,**43**.4-5,**44**.113-117), and five specimens from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.64-68).

Measurements (in mm).

n=3	L	H	C	nr	H/L	C/L	C/H
Range	10-12	14-18	3-4	8-18	1.38-1.40	0.30-0.33	0.21-0.22
Mean	11	16	3.5	15	1.39	0.31	0.21

Description. Small-sized, pear-shaped, slightly inequilateral, equivalved, and compressed. Anterior margin straight to slightly concave. Posterior margin convex, meeting the ventral margin in even curve. Right valve mostly convex. Left valve either slightly convex to slightly concave. Umbo low and small. Attachment area small to medium (Pl. 9, Fig. 6). Ornamentation consisting of relatively few, strong, radial ribs (8-18). These ribs start at the umbonal area in the right valve but at a distance from the umbo in the left one, occasionally carrying small spines near the ventral margin, and crossed by commarginal lamellae at irregular intervals.

Temporal and spatial distribution. *Plicatula auressensis* has been recorded from the Cenomanian of Algeria (COQUAND, 1862; AMARD et al., 1981), Italy (TREVISAN, 1937), Tunisia (PERVINQUIÈRE, 1912), Syria (BLANCKENHORN, 1934), Coniacian of Nigeria (BARBER, 1958), Maastrichtian of Algeria (COLLIGNON, 1971), and the Cenomanian-Turonian of Morocco (FRENEIX, 1972). In Egypt, it occurs in the Cenomanian of the Eastern Desert (ABBASS, 1962), Lower Turonian of Wadi Watir (ORABI, 1993), Upper Cenomanian-Lower Turonian of Abu Zuneima (KASSAB & ISMAEL, 1994), G. Nezzazat (FAWZI, 1963; ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and in the Upper Cenomanian-Lower Turonian of G. Ekma and the East Themed area (EL QOT, 2006).

Plicatula auressensis is geographically widely distributed, widespread in the Cenomanian, and ranges from the Albian to the Maastrichtian.

Discussion. The present species is assigned herein to the subgenus *Plicatula* according to the presence of radial ribs, which may range from fine costellae to broad costae, and with imbricating growth laminae (COX, 1969: N378).

COQUAND (1862) erected two species of *Plicatula*; *P. auressensis* and *P. reynesi* from the same stratigraphic level (Cenomanian) of Algeria. He noted that *P. auressensis* is oval in outline, while *P. reynesi* is circular and has finer radial ribs. ABBASS (1962) agreed with

COQUAND'S opinion and regarded them also as two different species. According to COX (1969: N377), the valves of the family Plicatulidae are variable in outline from oval to orbicular and/or subtriangular. PERVINQUIÈRE (1912), FOURTAU (1917), FAWZI (1963), FRENEIX (1972), and EL QOT (2006) considered *P. reynesi* as a junior synonym of *P. auressensis,* as all these differences are not great enough to separate them into two species. In agreement with the latter authors, *P. reynesi* is regareded as a junior synonym of the present species.

P. ferryi COQUAND differs from the present species in being larger and in having a greater number of radial ribs (20-45 principal ribs) with additional intercalated ribs, tubercles, and relatively larger attachment area.

P. fourneli COQUAND (1862: 220, pl. 16, figs. 5-6) from the Cenomanian of Algeria differs in being larger (L=35 mm) and in having five intercalated ribs in the concave interspaces and strongly imbricated growth lamellae.

Plicatula (*Plicatula*) *ferryi* COQUAND, 1862
Pl. 9, Figs. 7-8

1862 *Plicatula Ferryi* sp. nov. – COQUAND: 221, pl. 16, figs. 7-10.
1880 *Plicatula Batnensis* sp. nov. – COQUAND: 162, (photo HEINZ: pl. 3).
1891 *Plicatula Batnensis* COQUAND – PERON: 205, pl. 26, fig. 16.
1891 *Plicatula Ferryi* COQUAND – PERON: 207, pl. 26, figs. 18-19.
1904 *Plicatula Batnensis* COQUAND – FOURTAU: 312.
1904 *Plicatula Ferryi* COQUAND – FOURTAU: 313, pl. 3, figs. 2-3.
1912 *Plicatula Ferryi* COQUAND – PERVINQUIÈRE: 160, pl. 9, fig. 22a-b; pl. 12, figs. 6-14.
1912 *Plicatula Batnensis* COQUAND – PERVINQUIÈRE: 162, pl. 9, fig. 21a-c.
1917 *Plicatula batnensis* COQUAND – FOURTAU: 22.
1917 *Plicatula Ferryi* COQUAND – FOURTAU: 22.
1934 *Plicatula ferryi* COQUAND – BLANCKENHORN: 194.
1958 *Plicatula ferryi* COQUAND – BARBER: 19, pl. 7, fig. 5.
1962 *Plicatula ferryi* COQUAND – ABBASS: 63, pl. 7, figs. 1-5, 26.
1963 *Plicatula* aff. *batnensis* COQUAND – FAWZI: 33.
1972 *Plicatula* cf. *batnensis* COQUAND – FRENEIX: 83, pl. 4, fig. 12a-b.
1987 *Plicatula ferryi* COQUAND – KORA & HAMAMA: pl. 1, fig. 6.
1992 *Plicatula ferryi* COQUAND – ABDEL-GAWAD & ZALAT: pl. 5, fig. 2.
1998 *Plicatula ferryi* COQUAND – EL-SHEIKH et al: pl. 2, fig. h.
2001 *Plicatula ferryi* COQUAND – EL-HEDENY et al.: 299, fig. 3a-d.
2002 *Plicatula batnensis* COQUAND – ABDEL-GAWAD & GAMEIL: 84, pl. 1, fig. 22.
2002 *Plicatula ferryi* COQUAND – KORA et al.: pl. 2, fig. 8.
2004a *Plicatula ferryi* COQUAND – ABDEL-GAWAD et al.: pl. 5, fig. 12.
2006 *Plicatula ferryi* COQUAND – EL QOT: 63, pl. 12, figs. 5-10; text-fig. 10b.
2006 *Plicatula* cf. *ferryi* COQUAND – PERRILLIAT et al.: 99, figs. 12, 13.
2007 *Plicatula ferryi* COQUAND – ABDEL-GAWAD et al.: pl. 5, fig. 7.
2007b *Plicatula ferryi* COQUAND – MEKAWY: 224, pl. 4, figs. 4, 5.

Material and occurrence. Two articulated valves in shell preservation from the upper carbonate/marl member of the Upper Albian-Cenomanian Halal Formation, bed 19 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**19**.5-6), 15 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 at East Themed (MGDMU:ET.Bi.**26**.84-98), and numerous shell fragments from the Lower Turonian Abu Qada Formation, beds 45 and 47 at Wadi Quseib (MGDMU:WQ.Bi.**45**.1-85,**47**.17-31).

Measurements (in mm).

n=3	L	H	C	nr	H/L	C/L	C/H
Range	12-39	13-47	3.25-22	20-45	0.83-1.20	0.23-0.56	0.23-0.46
Mean	23	25	12.6	33	1.06	0.35	0.32

Description. Shell small- to large-sized, pear-shaped, or oval to subrounded, slightly inequivalved, slightly equilateral, and compressed. Both anterior and posterior margins convex. Ventral margin rounded, crenulated, meeting the anterior and posterior margins in even curves. Umbones terminal, pointed, and orthogyrate. Attachment area small to large and restricted to the umbonal area of the right valve (Pl. 9, Fig. 7a). Adductor muscle scar small, rounded and situated centrally. Ornamentation consisting of numerous fine radial ribs separated by wider interspaces. These ribs are crossed by commarginal growth lamellae. At their points of intersection scaly tubercles are produced, which commonly become spinose on the ventral part of the shell.

Temporal and spatial distribution. *Plicatula ferryi* has been recorded from the Santonian of Algeria (COQUAND, 1862), Cenomanian-Santonian of Tunisia (PERON, 1891; PERVINQUIÈRE, 1912), Santonian of Syria (BLANCKENHORN, 1934), Lower Turonian of Nigeria (BARBER, 1958), Cenomanian of Morocco (FRENEIX, 1972), and Upper Cenomanian-Lower Turonian of Jordan (PERRILLIAT et al., 2006). In Egypt, it occurs in the Lower Turonian-Santonian of the Eastern Desert (ABBASS, 1962; ABDEL-GAWAD et al., 2007; MEKAWY, 2007b), Upper Cenomanian-Turonian of Gebel Nezzazat (FAWZI, 1963; ABDEL-GAWAD & GAMEIL, 2002), Coniacian of Um Heriba (ABDEL-GAWAD & ZALAT, 1992), Coniacian-Santonian of G. El-Hamra (EL-SHEIKH et al., 1998), Wadi Sudr (EL-HEDENY et al., 2001), and in the Upper Cenomanian-Lower Campanian of G. Ekma, East Themed, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Discussion. ABBASS (1962: 64) considered *Plicatula batnensis* COQUAND (1862) as a variety of *P. ferryi.* According to him, *P. batnensis* differs only in having a more inflated shell and in being larger. In fact *P. ferryi* closely resembles *P. batnensis* in general outline and ornamentation but differs in having a relatively large attachment area and in being larger. According to EL QOT (2006) the two forms have nearly the same morphology and that there is a gradual increase in size stratigraphically from the Cenomanian-Turonian to the Coniacian-Santonian. Therefore, he considered *P. batnensis* as a junior synonym of *P. ferryi*. This view is followed here.

P. flattersi COQUAND (1862: 221, pl. 16, figs. 10-13) from the Upper Cretaceous of Algeria differs in having fewer and stronger radial ribs with wide and deep interspaces. *P. multicostata* FORBES as figured and described by STOLICZKA (1871: 446, pl. 34, figs. 15-16, 18; pl. 46, figs. 5, 6) from the Upper Cretaceous of India resembles the present species in general outline and ornamentation but differs in being more inflated. STOLICZKA noted that *P. multicostata* differs in being more convex and in possessing fewer radial ribs and assumed that these two differences are sufficient to separate these species. In contrast, PERVINQUIÈRE (1912) regarded *P. multicostata* as very similar to *P. ferryi* especially in outline, convexity of both valves, and ornamentation style.

Order Pectinoida NEWELL & BOYD, 1995
(=Pectinina WALLER, 1978)
Superfamily Pectinacea WILKES, 1810
Family Pectinidae WILKES, 1810

Subfamily Neitheinae SOBETSKIJ, 1960
Genus *Neithea* DROUET, 1824
Subgenus *Neithea* DROUET, 1824
Neithea (*Neithea*) *coquandi* (PÉRON, 1877)
Pl. 9, Fig. 9; Text-fig. 3.11

1862 *Janira tricostata* sp. nov. - COQUAND: 219, pl. 13, figs. 3-4.
1877 *Janira coquandi* sp. nov. – PÉRON: 501-509, pl. 7, frig. 2.
1912 *Pecten* (*Neithea*) *Shawi* sp. nov. - PERVINQUIÈRE: 136, pl. 9, figs. 1-6.
1917 *Pecten Shawi* PERVINQUIÈRE – FOURTAU: 18.
1934 *Pecten* (*Vola*) *Shawi* PERVINQUIÈRE - BLANCKENHORN: 191, pl. 9, fig. 24
1937 *Pecten* (*Neithea*) *Shawi* PERVINQUIÈRE – TREVISAN: 55, pl. 3, fig. 2.
1973 *Neithea* (*Neithea*) *coquandi* (PÉRON) – DHONDT: 26, pl. 3, fig. 1a-c.
2004 *Neithea* (*Neithea*) *coquandi* (PÉRON) – ANDRADE et al.: 29, figs.4.1-4.5.
2004b *Neithea* (*Neithea*) *coquandi* (PÉRON) – ABDEL-GAWAD et al.: pl. 1, fig. 11.

Material and occurrence. One articulated specimen (in shell preservation) from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 17 at the East Themed section (MGDMU:ET.Bi.**17**.87).

Measurements (in mm).

n=1	L	H	C	H/L
Range	39	53	14	1.36

Description. Shell large-sized, oval, inequivalved, equilateral, its height greater than width. Right valve strongly convex. Left valve slightly concave. Ventral margin with concave parts between the terminations of the primary ribs. Umbones orthogyrate and strongly incurved. Auricles not preserved. Ornamentation consisting of five prominent smooth principal ribs (P). Three intercalatory ribs (ic) lie between each two primary ribs. These intercalatories are unequally developed and the middle one is more strongly developed than the side-intercalatories (lying close to the principal ribs; see Text-fig. 3.11).

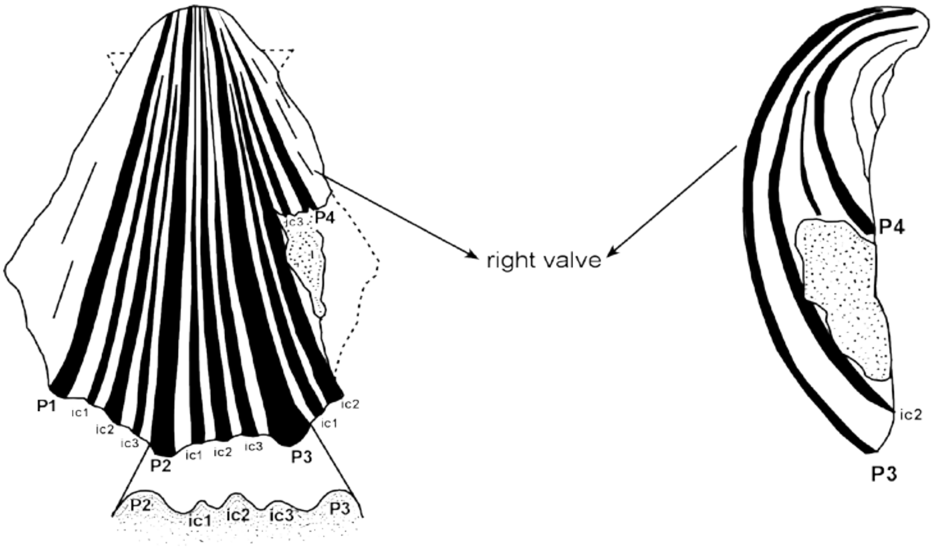
Temporal and spatial distribution. *Neithea* (*Neithea*) *coquandi* has been recorded from the Santonian of Algeria (COQUAND, 1862), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Syria (BLANCKENHORN, 1934), Italy (TREVISAN, 1937), and Upper Aptian-Cenomanian of Brazil (ANDRADE et al., 2004). In Egypt, it occurs in the Cenomanian of Gebel El-Fallig (ABDEL-GAWAD et al., 2004b).

According to DHONDT (1973: 29), this species has been recorded from the Albian-Cenomanian of Angola, Cenomanian of Egypt, Iraq, Israel, Turonian of France, and the Santonian of Somalia and Turkey. It therefore has a wide stratigraphic range from the Albian to the Santonian.

Discussion. *Neithea* (*Neithea*) *coquandi* is easily distinguished from other *Neithea* species in having three intercalatory ribs which are mostly unequal, the middle one being most strongly developed (Text-fig. 3.11).

DHONDT (1973: 28) pointed out that *Janira tricostata* of COQUAND (1862) was erected without taking *Pecten tricostatus* BAYLE, 1848 into consideration. Therefore, PÉRON corrected the nomenclature and changed the name to *Janira coquandi* (PÉRON, 1877).

N. (*N.*) *shawi* (PERVINQUIÈRE, 1912) from the Cenomanian of Tunisia strongly resembles *N.* (*N.*) *coquandi* in having the same distribution pattern of the primary and intercalatory ribs. It is therefore, considered herein as a junior synonym of *N.* (*N.*) *coquandi* (for more detailed discussion see DHONDT, 1973: 28-29).



Text-fig. 3.11. Distribution pattern of the primary (P) and intercalatory (ic) ribs of *Neithea* (*Neithea*) *coquandi* (PÉRON, 1877). White parts refer to parts where shell material is lacking. The cross-section shows the strength of intercalatory ribs between the primary ribs.

Neithea (*Neithea*) *dutrugei* (COQUAND, 1862)
Pl. 9, Fig. 10; Text-fig. 3.12

1862 *Janira Dutrugei* sp. nov. – COQUAND: 219, pl. 13, figs. 1-2.
1902 *Vola Dutrujei* COQUAND var. *Beirensis* CHOFFAT: 150, pl. 2, figs. 1-2.
1918 *Pecten* (*Neithea*) *Dutrugei* COQUAND – GRECO: 24 (206), pl. 3 (19), figs. 7-9.
1934 *Pecten* (*Vola*) *dutrugei* COQUAND – BLANCKENHORN: 192, pl. 9, fig. 25.
1934 *Pecten* (*Vola*) *zakarjensis* sp. nov. – BLANCKENHORN: 192, pl. 9, figs, 26.
1973 *Neithea* (*Neithea*?) *dutrugei* (COQUAND) – DHONDT: 59, pl. 4, fig. 3; pl. 5, fig. 4.
1992 *Neithea dutrugei* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 2, fig. 3.
1993 *Neithea* (*Neithea*) *dutrugei* (COQUAND) - DHONDT & DIENI: 190, pl. 4, fig. 17; text-fig. 4.
2001 *Neithea dutrugei* (COQUAND) – ABDALLAH et al.: pl. 2, fig. 3.
2002 *Neithea* (*Neithea*?) *dutrugei* (COQUAND) – ABDEL-GAWAD & GAMEIL: 84, pl. 1, fig. 20.
2002 *Neithea dutrugei* (COQUAND) – ABDELHAMID & EL QOT: 263, pl. 2, fig. 1.
2004b *Neithea* (*Neithea*) *dutrugei* (COQUAND) – ABDEL-GAWAD et al.: 323, pl. 1, fig. 12a-b.
2006 *Neithea* (*Neithea*) *dutrugei* (COQUAND) – EL QOT: 65, pl. 12, figs. 16-17.
2006 *Neithea* (*Neithea*) *dutrugei* (COQUAND) – PERRILLIANT et al.: 101, figs. 14-16.
2007b *Neithea* (*Neithea*) *dutrugei* (COQUAND) – MEKAWY: 225, pl. 4, fig. 6.

Material and occurrence. Ten specimens in shell preservation from the middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation, beds 34 and 44 at Wadi Quseib (MGDMU:WQ.Bi.**34**.4-8,**44**.118-122), four speciemens from the Upper Cenomanian Galala Formation, bed 3 at East Themed (MGDMU:ET.Bi.**3**.33-36), and two specimens from the upper carbonate/marl member of the Cenomanian Halal Formation, bed 19 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**19**.7-8).

Measurements (in mm).

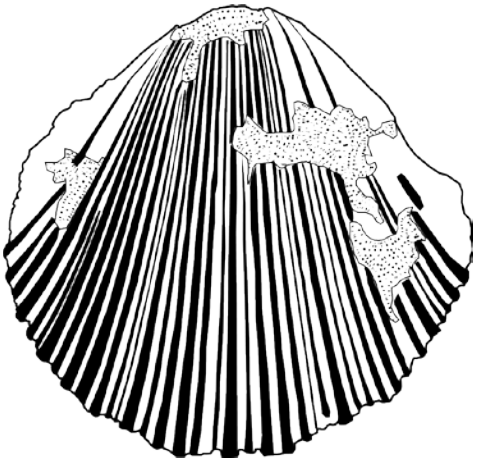
n=2	L	H	C	H/L
Range	18-22	18-22	7-13	1.00-1.00
Mean	20	20	10	1.00

Description. Shell small-sized, oval in outline, ineqivalved, and slightly inequilateral. Right valve convex. Left valve slightly concave. Umbo incurved. Shell margin convex and finely crenulated ventrally. Ornamentation consisting of numerous ribs (both primary and intercalatory ribs), which become finer dorsally (Text-fig. 3.12). Occasionally, the principal ribs split into 2-3 ribs. No auricles preserved.

Temporal and spatial distribution. *Neithea* (*Neithea*) *dutrugei* has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862), Lower Turonian of Jordan (PERRILLIANT et al. 2006), Cenomanian of Syria and Palestine (BLANCKENHORN, 1934), Portugal (CHOFFAT, 1902), Italy (DHONDT & DIENI, 1993), and from the Cretaceous of various other European countries (DHONDT, 1973), In Egypt, it is known from the Cenomanian of Gebel El-Minsherah and G. El-Hamra (ABDELHAMID & EL QOT, 2002), Um Heriba (ABDEL-GAWAD & ZALAT, 1992), Upper Cenomanian-Santonian of the Eastern Desert (GRECO, 1918; MEKAWY, 2007b), El Giddi Pass (ABDALLAH et al., 2001), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and G. Ekma (EL QOT, 2006).

According to DHONDT (1973: 60), *N.* (*N.*) *dutrugei* has a wide stratigraphic range from the Albian to the Senonian.

Discussion. *Neithea* (*Neithea*) *dutrugei* is easily distinguished from other *Neithea* species by having numerous irregular ribs. Many authors (e.g. DHONDT, 1973; DHONDT & DIENI, 1993) noted that this species carries six principal ribs with five intercalatories in each interval, among which the median one reach the same strength as the principal ribs. In the present material, it is difficult to recognize the number of intercalatories due to the irregularity of ribbing. Occasionally, the intercalatories reach the same strength as the principal ribs (Text-fig. 3.12).



Text-fig. 3.12. Irregular distribution pattern of the primary and intercalatory ribs of *Neithea* (*Neithea*) *dutrugei* (COQUAND, 1862).

Both the principal and median intercalatory ribs of *N. dutrugei* var. *beirensis* (CHOFFAT) split into three ribs, so that the rib number is greatly increased. Therefore, CHOFFAT's variety is considered herein as a junior synonym of *N.* (*N.*) *dutrugei.*

N. zakarjensis (BLANCKENHORN) is identical to the present species (the most common form) in the distribution pattern of ribs and in general outline. Therefore and in agreement with DHONDT (1973), BLANCKENHORN's species is considered a junior synonymy to *N.* (*N.*) *dutrugei.*

Neithea (*Neithea*) *quinquecostata* (J. SOWERBY, 1814)

Pl. 9, Figs. 11-12; Text-fig. 3.13

1814 *Pecten quinquecostata* sp. nov. – J. SOWERBY: 122, pl. 56, figs. 4-8.
1902 *Vola Quinquecostata* J. SOWERBY – CHOFFAT: 149, pl. 3, fig. 7.
1908 *Pecten* (*Neithea*) *quinquecostata* J. SOWERBY – WOODS: 202, pl. 39, figs. 14-17; pl. 40, figs. 1-5.
1962 *Neithea quinquecostata* (RÖMER) – ABBASS: 52, pl. 6, fig. 10, non figs. 9, 11, 14.
1973 *Neithea* (*Neithea*) *quinquecostata* (J. SOWERBY) – DHONDT: 29, pl. 2, fig. 2 (with cumulative synonymy).
1993 *Neithea* (*Neithea*) *quinquecostata* (J. SOWERBY) – DHONDT & DIENI: 194, pl. 5, figs. 1-3.
2008 *Neithea* (*Neithea*) *quinquecostata* (J. SOWERBY) – MEKAWY & ABU-ZIED: 305, pl. 2, fig. 9.

Material and occurrence. Two specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 16 of the East Themed area (MGDMU:ET.Bi.**16**.428-429) and one incomplete specimen from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 1 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.92).

Measurements (in mm).

n=2	L	H	C	H/L
Range	36-45	38-48	22-25	1.05-1.07
Mean	40.5	43	23.5	1.06

Description. Shell medium-sized, subtriangular, inequivalved, and slightly inequilateral. Height slightly greater than length (H/L=1.06 mm). Right valve moderately convex, left valve slightly concave. Umbo incurved. Ventral margin regularly curved. Antero- and postero-dorsal margins slightly concave. Ornamentation consisting of six principal ribs with five intercalated ribs. Middle one of the intercalatories is more developed than the outer ones (Text-fig. 3.13). Auricles not complete (mostly broken) but the preserved part shows faint radial striae.

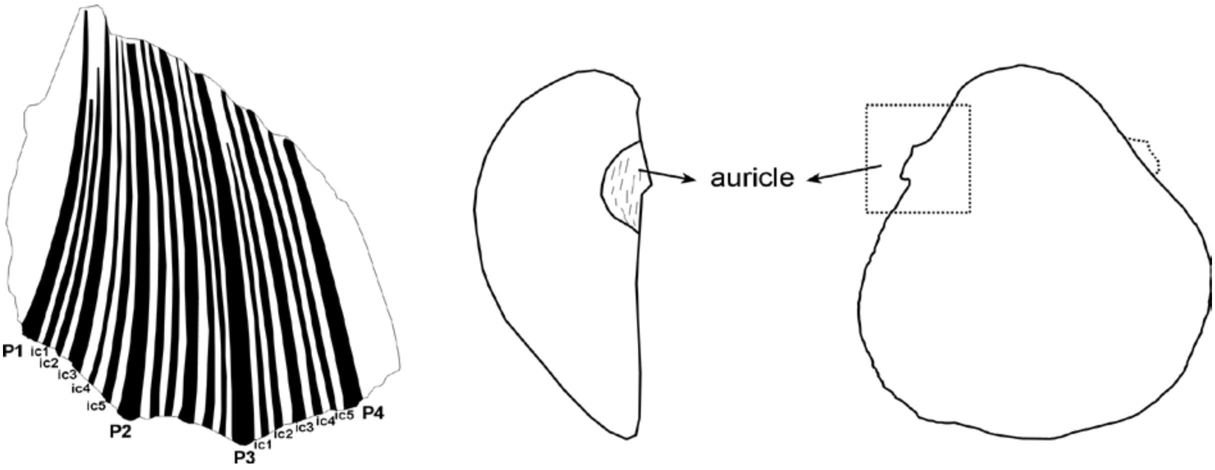
Temporal and spatial distribution. *Neithea* (*Neithea*) *quinquecostata* has been recorded from the Turonian-Maastrichtian of Italy (DHONDT & DIENI, 1993), Cenomanian of England (WOODS, 1908), and Portugal (CHOFFAT, 1902). In Egypt, it is known from the Santonian of Ain Areyida (ABBASS, 1962) and from the Upper Barremian-Maastrichtian of Gebel Risan Aneiza, G. Mistan, G. El Tourkumanyia, and G. Manzour (MEKAWY & ABU-ZIED, 2008).

According to DHONDT & DIENI (1993: 196), *N.* (*N.*) *quinquecostata* has a very wide geographic distribution and ranges from the Barremian to Upper Maastrichtian (see DHONDT, 1973: 32).

Discussion. *Neithea* (*Neithea*) *quinquecostata* is characterized by a moderately convex right valve, six principal ribs with five intercalatories (the middle one stronger), and small auricles which are covered by radial striae of equal length (Text-fig. 3.13).

The great similarity between *N.* (*N.*) *quinquecostata* and *N.* (*N.*) *syriaca* (Conrad) caused much confusion among authors (see the synonymy list of Dhondt, 1973: 32). The two latter species are similar in general outline and ribbing. However, Vokes, (1946: 167) argued that *N.* (*N.*) *syriaca* can easily be distinguished from *N.* (*N.*) *quinquecostata* by having a more slender shell, less inflated umbones, prominent and sharper primary ribs, smooth auricles, and fewer radial ribs on the left valve.

N. (*N.*) *sexcostata* (Woodward) differs from the present species in being smaller, having a strongly convex right valve, flattened left valve, and six very salient ribs with deep intercostal intervals.



Text-fig. 3.13. Ribbing pattern and auricle of *Neithea* (*Neithea*) *quinquecostata* (J. Sowerby, 1814). P: primary ribs; ic: intercalatory ribs.

Neithea (*Neithea*) sp.

Pl. 10, Fig. 1; Text-fig. 3.14

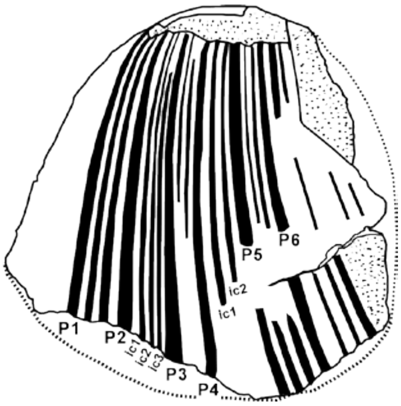
Material and occurrence. One incomplete specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 31 at Wadi Quseib (MGDMU:WQ.Bi.**31**.8).

Measurements (in mm).

n=1	L	H	H/L
	33	30	0.91

Description. Shell medium-sized, right valve strongly convex, ovate, and inequilateral. Umbo orthogyrate. Auricles not preserved. Right valve ornamented with about 28 ribs; ten principal ribs with two well-developed intercalatory ribs between each two principal ribs. Only three intercalatories are well developed near the middle part of the shell, while the rest of principal ribs consist only of two intercalatories (Text-fig. 3.14). These intercalatories vary also in their development; in some cases they reach the same strength of principal ribs.

Discussion. The present material closely resembles *Neithea* (*Neithea*) *alpina* (d'Orbigny, 1847) described by Dhondt (1973: 15-19) in having two intercalatory ribs between each two principal ribs but the latter species is ornamented with six primary ribs (in contrast to about 10 principal ribs in the present material) and with concentric striae. *Neithea* (*Neithea*) *hispanica* (D'ORBIGNY, 1850) differs in having fewer ribs (18-22) than the present material (about 28 ribs).



Text-fig. 3.14. Ribbing pattern of *Neithea* (*Neithea*) sp. from the Cenomanian Galala Formation of Wadi Quseib. P: primary ribs; ic: intercalatory ribs.

Subclass Heteroconchia HERTWIG, 1895
Superorder Palaeoheterodonta NEWELL, 1965
Order Trigonioida DALL, 1889
Superfamily Trigoniacea LAMARCK, 1819
Family Trigoniidae LAMARCK, 1819
Genus *Pterotrigonia* VAN HOEPEN, 1929
Subgenus *Scabrotrigonia* DIETRICH, 1933
Pterotrigonia (*Scabrotrigonia*) *scabra* (LAMARCK, 1819)
Pl. 10, Fig. 2; Text-fig. 3.15

1819 *Trigonia scabra* sp. nov. – LAMARCK: 63, no. 2.
1819 *Trigonia crenulata* sp. nov. – LAMARCK: 63, no. 3.
1844 *Trigonia limbata* sp. nov. – D'ORBIGNY: 156, pl. 298, figs. 1-4.
1871 *Trigonia scabra* LAMARCK – STOLICZKA: 314, pl. 15, figs. 24-26; pl. 16, figs. 35-40.
1880 *Lyriodon Ethra* sp. nov. – COQUAND: 388.

EXPLANATION OF PLATE 10

Fig. 1. *Neithea* (*Neithea*) sp. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **a**: Right valve, **b**: posterior view; MGDMU:WQ.Bi.**31**.8.

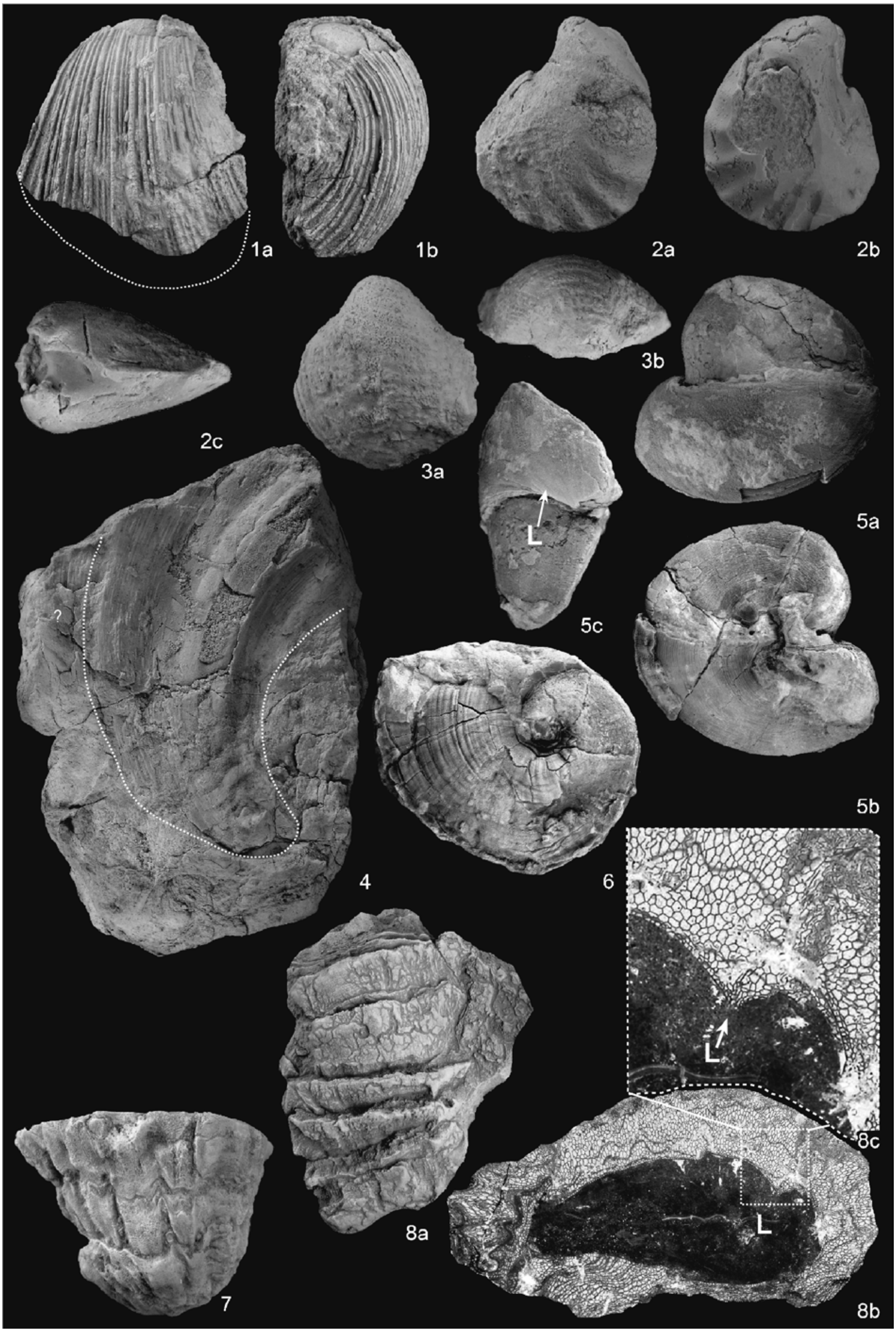
Fig. 2. *Pterotrigonia* (*Scabrotrigonia*) *scabra* (LAMARCK, 1819). Articulated specimen from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x2. **a**: External view of right valve, **b**: external view of left valve, **c**: dorsal view; MGDMU:AEN.Bi.**1**.93.

Fig. 3. *Corbula* (*Corbula*) sp. Upper Cenomanian Galala Formation of the East Themed area, x3. **a**: Side view of left valve, **b**: dorsal view; MGDMU:ET.Bi.**12**.62.

Fig. 4. *Ichthyosarcolites* sp. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x0.75. Side view of right valve; MGDMU:WQ.Bi.**31**.9.

Figs. 5-6. *Toucasia*? *matheroni* (COQUAND, 1862) from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. **5a-b**: Side view of articulated specimen, c: dorsal view (L=Ligamental groove); MGDMU:WQ.Bi.**31**.14. - **6**. Side view of ?left valve; MGDMU:WQ.Bi.**31**.15.

Figs. 7-8. *Radiolites sauvagesi* (D'HOMBRES-FIRMAS, 1838). **7**. Upper carbonate/marl member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. Side view of right valve; MGDMU:AEN.Bi.**21**.1. - **8**. Upper Turonian Wata Formation of the East Themed area. **a**: Side view of right valve, x1, **b**: transverse section (L=Ligamental ridge), x2, **c**: close-up of the ligamental ridge, x4; MGDMU:ET.Bi.**37**.1.


1a
1b
2a
2b
2c
3a
3b
5a
L
5c
?
4
6
5b
L
8c
8a
L
7
8b

1912 *Trigonia Ethra* COQUAND – PERVINQUIÈRE: 218, pl. 15, figs. 4-7.
1912 *Trigonia scabra* LAMARCK – PERVINQUIÈRE: 220, pl. 15, figs. 1-3.
1916 *Trigonia orientalis* sp. nov. – DOUVILLÈ: 168, pl. 21, figs. 13-15 (non FORBES' species, 1846).
1917 *Trigonia Ethra* COQUAND – FOURTAU: 59.
1918 *Trigonia Ethra* COQUAND – GRECO: 30 (212), pl. 4 (20), figs. 1-3.
1937 *Trigonia Ethra* COQUAND – TREVISAN: 81, pl. 5, fig. 13a-b.
1962 *Trigonia scabra* LAMARCK – ABBASS: 89, pl. 15, figs. 1-3, 5, 7.
1962 *Trigonia limbata* D'ORBIGNY – ABBASS: 91, pl. 15, figs. 4, 6.
1963 *Trigonia Ethra* COQUAND – FAWZI: 53.
1969 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – COX: N487, fig. D73/1.
1985 *Trigonia* sp. - DOMINIK: pl. 16, fig. 10.
1991 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – ABUL ELA et al.: pl. 5, figs. 6-7.
1993 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – DHONDT & DIENI: 222 (with extensive synonyms).
2001 *Trigonia limbata* D'ORBIGNY – ABDALLAH et al.: pl. 2, fig. 15.
2002 *Pterotrigonia* (*Scabrotrigoni*a) *ethra* (COQUAND) – ABDEL-GAWAD & GAMEIL: 89, pl. 2, fig. 14.
2002 *Pterotrigonia* (*Scabrotrigoni*a) *limbata* (D'ORBIGNY) - ABDELHAMID & EL QOT: 273, pl. 4, fig. 3.
2002 *Pterotrigonia* (*Scabrotrigoni*a) sp. – ABDELHAMID & EL QOT: 273, pl. 4, fig. 4.
2002 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – KORA et al.: pl. 2, fig. 12.
2004b *Trigonia ethra* COQUAND – ABDEL-GAWAD et al.: pl. 2, fig. 7.
2006 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – EL-HEDENY: 711, pls. 1-2 (with additional synonymy).
2006 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – EL QOT: 65, pl. 13, figs. 3-5.
2007b *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – MEKAWY: 226, pl. 4, fig. 10.
2008 *Pterotrigonia* (*Scabrotrigoni*a) *scabra* (LAMARCK) – MEKAWY & ABU-ZIED: 307, pl. 2, fig. 13.

Material and occurrence. Seven articulated specimens from the lower marly member of the Upper-Albian Halal Formation, bed 1 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.93-99) and one specimen from the Cenomanian Galala Formation, bed 3 of the East Themed area (MGDMU:ET.Bi.**3**.37).

Measurements (in mm).

n=7		L	H	C	nr	H/L	C/L	C/H
Range		16-37	19-46	11-27	8-12	0.93-1.25	0.57-0.81	0.54-0.69
Mean	23.43	27.28	16.57	10	1.17	0.7	0.61	

Description. Valves small-to medium-sized, heigth greater than long (H/L=1.17; Text-fig. 3.15). Outline variable, from trigonal to crescentic-shaped, compressed and elongated posteriorly; strongly inequilateral and equivalved. Maximum inflation at around one-third from the anterior end. Postero-dorsal margin strongly concave, anterior margin strongly convex, meeting the ventral margin in an even curve. Dorsal margin moderately concave. Ventral margin crenulated and broadly arched. Escutcheon heart-shaped, slightly depressed, and narrow to moderately wide. Umbones narrow, pointed, prominent and opisthogyrate. Ornamentation of flank consisting of radial ribs separated by wide, smooth, and concave interspaces. In some specimens, the ribs are straight and subsequently tend to bend towards the anterior margin. The interspaces are narrower towards the postero-dorsal side and wider than the ribs.

Temporal and spatial distribution. *Pterotrigonia* (*Scabrotrigonia*) *scabra* has been recorded from the Santonian of southern India (STOLICZKA, 1871; COX, 1952), Cenomanian-Senonian of Tunisia (PERVINQUIÈRE, 1912), and Italy (TREVISAN, 1937; DHONDT & DIENI, 1993). In Egypt, it is known from the Upper Albian of Gebel Manzour (DOUVILLÈ, 1916; ABBASS, 1962; ABUL ELA et al., 1991), Cenomanian-Santonian of the Eastern Desert (FOURTAU, 1917; ABBASS, 1962; MEKAWY, 2007b), Cenomanian of G. Ekma and the East Themed area and Coniacian of G. Yelleg (EL QOT, 2006), Cenomanian of El Giddi Pass (ABDALLAH et al., 2001), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. El-Minsherah (FAWZI, 1963; ABDELHAMID & EL QOT, 2002), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), and from the Upper Campanian of El-Bahariya Oasis, Western Desert (DOMINIK, 1985).

According to EL-HEDENY (2006: 714), *P.* (*S.*) *scabra* is a very well known trigoniid species in the Cretaceous of Egypt and ranges from the uppermost Albian to the Coniacian-Santonian. TONI (1969) recorded it even from the Campanian to questionably Maastrichtian of Gebel El-Rokham, Eastern Desert. Therefore, this species has a wide stratigraphic range, from the Upper Albian to possibly the Maastrichtian.

Discussion. *Pterotrigonia* (*Scabrotrigonia*) *scabra* exhibits an unusually wide range of variability in shape and ornamentation of the valves, which caused much confusion among authors (see the synonymy list).

DOUVILLÈ (1916) divided the Egyptian Trigonioida into two groups: the first group included forms with particularly smooth concentric ridges such as *Trigonia picteti* COQUAND, 1865; *T. analoga* DOUVILLÈ, 1916; and *T. depauperata* DOUVILLÈ, 1916. The second group included forms with variable degree of tuberculation, such as *T. orientalis* FORBES, 1846 and *T. pseudo-crenulata* NÖTLING, 1886. According to EL-HEDENY (2006: 714), the two species of DOUVILLÈ were collected from the same locality and even within the same bed and therefore suggested that they may be intraspecific variations of a single species.

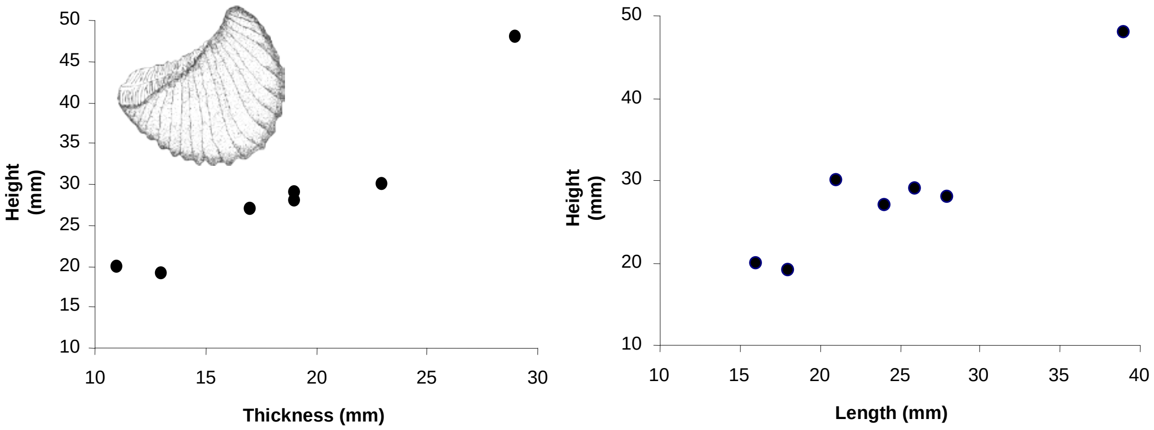
ABBASS (1962) and EL QOT (2006) considered *T. orientalis* and *T. crenulata* LAMARCK as synonyms of the present species. They stated that the posterior area of the young stage of *T. crenulata* is similar to that *T. scabra* but differs only in later stages. In addition, D'ORBIGNY mentioned a great similarity between *T. crenulata* and the present species. According to him the ribs (costae) of *T. scabra* carry rounded tubercle, while *T. crenulata* has fine and obliquely elongated crenulations. According to EL-HEDENY (2006: 713) all these characters may fall with the intraspecific variation of a single species and could be considered as reflecting the prevailing palaeoecological conditions. Therefore, and in agreement with ABBASS (1962), EL QOT (2006), and EL-HEDENY (2006), *T. crenulata* is regarded as a junior synonym of *T. scabra*.

Scabrotrigonia undulata KASSAB & ISMAEL (1994: 239, fig. 5/17-21) from the Santonian of the Matulla Formation of Gebel Musabaa Salama, Sinai differs in having fewer crenulated costae, wider interspaces, and terminal and incurved umbones.

STOLICZKA (1871) stated that *Trigonia limbata* D'ORBIGNY from the Coniacian-? Maastrichtian of France is similar to *T.* s*cabra*, but has straighter, numerous, and equally tuberculated ribs and a less concave margin. D'ORBIGNY (1850: 240) considered the Indian form of *scabra* as *T. limbata.* According to DHONDT & DIENI (1993), *P.* (*S.*) *limbata* and

P. (*S*.) *scabra* are synonyms and *P*. (*S*.) *crenulata* (Lamarck) is also identical with the two previous taxa. In contrast, Abbass (1962) noted that *T*. *scabra* differs from *T*. *limbata* in the ornamentation pattern and separated them into different species.

El Qot (2006) agreed with Abbass (1962), who considered *T*. *ethra* Coquand as a synonym of *T*. *limbata* d'Orbigny and mentioned that the latter species differs from *T*. *ethra* mainly in that the ribs on the anterior side are crenulated (for a more extensive discussion see El-Hedeny, 2006: 712-714).



Text-fig. 3.15. Length- height and thickness-height ratio of *Pterotrigonia* (*Scabrotrigonia*) *scabra* (Lamarck, 1819) from the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

Superorder Heterodonta Neumayr, 1883
Order Myoida Stoliczka, 1870
Suborder Myina Stoliczka, 1870
Superfamily Myacea Lamarck, 1809
Family Corbulidae Lamarck, 1818
Subfamily Corbulinae Gray, 1823
Genus *Corbula* Bruguière, 1797
Subgenus *Corbula* Bruguière, 1797
Corbula (*Corbula*) sp.
Pl. 10, Fig. 3

Material and occurrence. One composite mould from the Cenomanian Galala Formation, bed 12 of the East Themed area (MGDMU:ET.Bi.**12**.62).

Measurements (in mm).

n=1	L	H	H/L
	17	18	1.05

Description. Specimen small-sized, subtrigonal, strongly inflated, slightly higher than long (H/L= 1.05), and inequilateral. Anterior margin rounded, higher than the posterior one, and meeting the ventral margin in an even curve. Antero-dorsal margin slightly concave. Rostrum broken off. Umbones prominent and strongly incurved anteriorly. Left valve ornamented with strong commarginal ribs separated by narrow interspaces.

Discussion. According to COX (1969: N692), the subgenus *Corbula* is characterized by the presence of a rostrum and well-developed commarginal ribs.

The present material resembles *Corbula parsura* STOLICZKA (1871: 44, pl. 1, figs 23-24; pl. 16, figs. 3-4) from the Cretaceous of South India and *C. striatuloides* FORBIS, 1846 as figured by QUAAS (1902: 25, figs. 12-15) from the Cretaceous of Egypt in general shape, narrow rostrum, and ornamentation but the latter two species differ in being smaller (H=8 mm, L=10 mm for STOLICZKA'S material).

C. peroni FOURTAU (1917: pl. 3, figs. 5-7) from the Turonian of Abu Roash (Egypt) differs in being more elongated and in having a more convex anterior margin and slightly concave postero-dorsal margin.

Order Hippuritoida NEWELL, 1965
Superfamily Hippuritacea GRAY, 1848
Family Caprinidae D'ORBIGNY, 1850

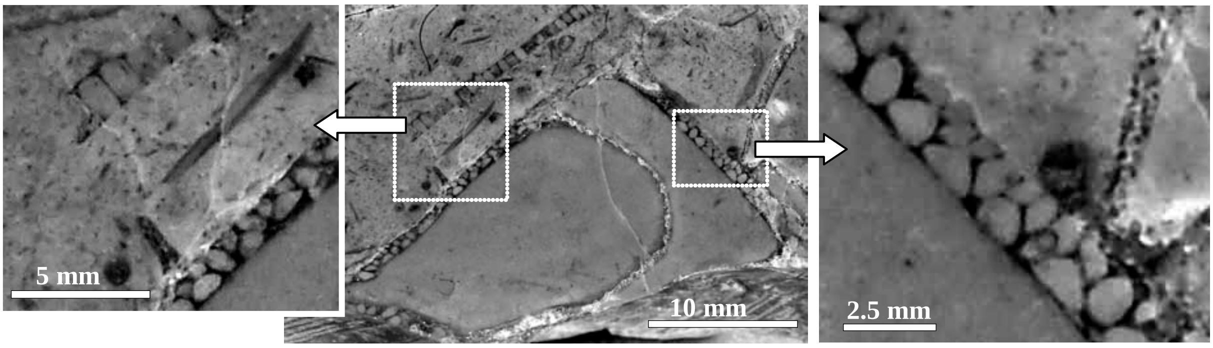
Genus *Ichthyosarcolites* DESMAREST, 1817
Ichthyosarcolites sp.
Pl. 10, Fig. 4; Text-fig. 3.16

Material and occurrence. 20 specimens (mostly fragmented) from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 13, 21, 22, 31, and 37 at Wadi Quseib (MGDMU:WQ.Bi.**13**.28-30,**21**.22-25,**22**.71-72,**31**.9-13,**37**.4-9).

Description and remarks. Specimen very large, very elongated, up to 110 mm long, and strongly carinated. Attached valve (right valve) conical, strongly coiled, and the lower end pointed. The cross-section of the valve is subtrigonal. The Wadi Quseib's specimens can, without doubt, be placed in the genus *Ichthyosarcolites* based mainly on the subpolygonal canals and accessory cavities.

According to COX in MOORE (1969: N762), the longitudinal, thin-walled canals are called pallial canals. Both pallial canals and accessory cavities are the main characters of the shell of most caprinids. In the present material, the inner cavity of the valve is oval in cross-section. The outer wall is thick with numerous polygonal canals which differ in size and shape, display an irregulary distribution pattern occasionally appear as rounded because of diagenesis. The size of these canals increases from the outside to the inside of the wall (Text-fig. 3.16). The latter pattern of pallial canals closely resembles the genus *Caprinula* D'ORBIGNY, 1847 but the latter genus differs in having a less coiled, nearly straight right valve. According to SCOTT (2002: 421), the status of the genus *Caprinula* erected by D'ORBIGNY has been debated by several authors who placed it in the genus *Ichthyosarcolites* DESMAREST, which also includes *Caprinella* named by D'ORBIGNY without good reason. Eventually, ZITTEL (1885) united both of D'ORBIGNY'S genera (*Caprina* and *Caprinella*) under *Ichthyosarcolites*. For more information on the historical and taxonomic background of the genus *Ichthyosarcolites* and its relation with other caprinid genera see BONANNO & SIRNA (1995: 135, 136).

The present material closely resembles *Ichthyosarcolites monocarinatus* SLIŠKOVIC as figured and described by CESTARI et al. (1998: 69, fig. 2/1-6) from the Cenomanian of Italy in having the subpolygonal canals (internal microstructure) but differs in being circular in transverse section. SLIŠKOVIC (1966) erected the new species *I. rotundus* from the Upper Cenomanian of Istria. According to CESTARI et al. (1998: 72) the detailed microstructure of SLIŠKOVIC'S specimens is not well preserved and found it difficult to evaluate the species.



Text-fig. 3.16. Transverse cross-section of *Ichthyosarcolites* sp. from the Cenomanian Galala Formation of Wadi Quseib showing the numerous polygonal canals which differ in size and shape.

Family Requieniidae Douvillé, 1914 (1919)

Genus *Toucasia* Munier-Chalmas 1873
Toucasia? *matheroni* (Coquand, 1862)
Pl. 10, Figs. 5-6; Text-fig. 3.17

1862 *Caprina matheroni* sp. nov. – Coquand: 223, pl. 17, figs. 10-11.
cf. 2002 *Toucasia matheroni* (Coquand) – Berndt: 132, pl. 7, fig. 18; pl. 8, fig. 1.

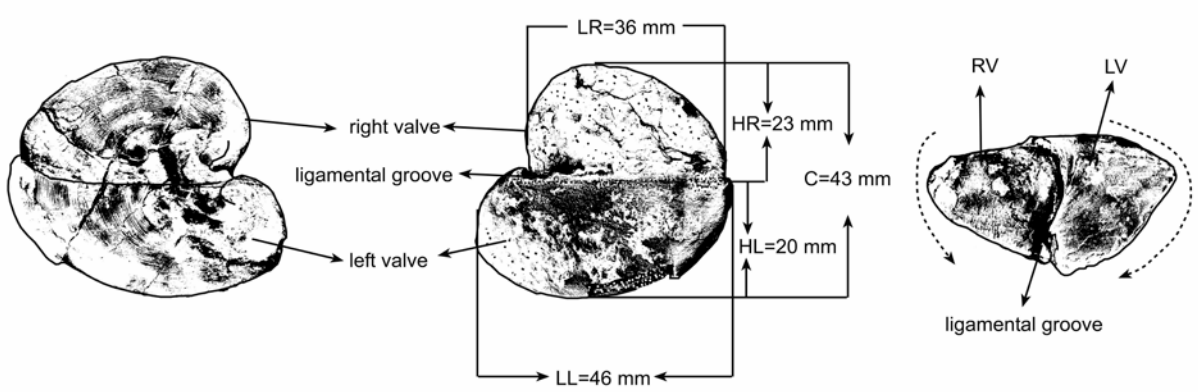
Material and occurrence. 11 articulated specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 21, 22, and 31 at Wadi Quseib (MGDMU:WQ.Bi.**21**.26-27,**22**.73-75,**31**.14-19).

Description. Specimen medium- to large-sized, inequivalved, left valve larger than the right one (Text-fig. 3.17), both valves coiled, *Diceras*-shaped, left valve more strongly incurved than the right one. Shell wall very thin (<3 mm). Attached valve (left valve) carinate while the right one is slightly depressed and lacks a keel. Ornamentation consisting of radial striae, crossed by fine commarginal growth lines. Hinge and other internal characters not seen.

Temporal and spatial distribution. *Toucasia*? *matheroni* has been recorded from the Cretaceous of Algeria by Coquand (1862) and from the Cenomanian of Jordan (Berndt, 2002). This is the first record of the species from Egypt.

Discussion. The present material closely resembles *Caprina matheroni* Coquand from the Cretaceous of Algeria in general shape, umbo coiling, and ornamentation. Many genera of the family Requieniidae have been described and have been distinguished according to their internal structure e.g., hinge and muscle insertion. For instance, the genera *Toucasia* and *Kugleria* Bouwman, 1938 are very similar superficially and differ only in features of the hinge and muscle scars. The latter characters are not seen in the present materials (due to the articulation state of the valves). Cox (1969: N751) pointed out that the diameter of coiled rudist valves ranges from about 20 cm (*Toucasia*) to at least 30 cm (Caprinuloidea). The general outline and ornamentation of the present material closely resemble the genus *Toucasia* Bouwman, 1938 with respect to size.

Kugleria steinmanni (Schnarrenberger, 1901) as figured by Cox (1969: N781, fig. E247/4) and Masse et al. (1998: 49, figs. 3-6) from the Cenomanian of Italy is similar to the present species in general outline and ornamentation but differs in having a higher left valve, and in being larger and more inflated.



Text-fig. 3.17. Outline, dimension, and coiling of *Toucasia*? *matheroni* (COQUAND, 1862) from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation of Wadi Quseib. LL= length of left valve, HL= heigth of left vale, C= thickness, LR= length of right valve, HR=height of right valve, RV=right valve, LV=left valve.

Family Radiolitidae GRAY, 1848

Subfamily Radiolitinae GRAY, 1848

Genus *Radiolites* LAMARCK, 1801

Radiolites sauvagesi (D'HOMBRES-FIRMAS, 1838)

Pl. 10, Figs. 7-8; Text-fig. 3.18

1838 *Sphaerulites sauvagesi* sp. nov. - D'HOMBRES-FIRMAS: 193, pl. 2.
1908 *Radiolites Sauvagesi* D'HOMBRES-FIRMAS – TOUCAS: 65, 75, pl. 12, figs. 9-11; text-figs. 34-36.
1910 *Radiolites sauvagesi* D'HOMBRES-FIRMAS – DOUVILLÉ: text-fig. 13.
1999 *Radiolites sauvagesi* (D'HOMBRES-FIRMAS) – STEUBER: 101, pl. 17, figs. 1-14; pl. 18, figs. 1-5; text-figs. 40-41 (with additional synonymies).
2005 *Radiolites sauvagesi* (D'HOMBRES-FIRMAS) - ALY et al.: 263, pl. 6, figs. 4-5; pl. 7, fig. 1a-b.
2007 *Radiolites sauvagesi* (D'HOMBRES-FIRMAS) - EL-HEDENY: 91, fig. 8e-h.

Material and occurrence. 12 incomplete right valves from the upper carbonate/marl member of the Halal Formation (Upper Cenomanian), bed 21 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**21**.1-12), 15 incomplete right valves from the Upper Turonian Wata Formation, bed 37 at the East Themed area (MGDMU:ET.Bi.**37**.1-21), and 77 incomplete specimens from the upper carbonate member of the Galala Formation (Upper Cenomanian), and Lower Turonian Abu Qada Formation, beds 44 and 73 at Wadi Quseib (MGDMU:WQ.Bi.**44**.123-134,**73**.1-65).

Description. Right valve elongated-cylindrical, subrounded in cross-section, up to 110 mm high, 35 mm in transverse diameter. Ligamental ridge well developed (Pl. 10, Fig. 8b-c; Text-fig. 3.18A). Ornamentation consisting of regularly plicated and steeply inclined lamellae with salient longitudinal ribs. In transverse section, the cells of the outer layer are irregular, radially elongated, polygonal, pentagonal to heptagonal (mainly hexagonal; mean diameter 0.40 mm) at the inner part and lengthened polygons outwards with open invaginations of radial folds (Text-fig. 3.18B).

Temporal and spatial distribution. *Radiolites sauvagesi* has been recorded from the Coniacian of Greece (STEUBER, 1999). In Egypt, it occurs in the Turonian of Abu Roash (EL-HEDENY, 2007) and Turonian of Gebel Yelleg (ALY et al., 2005).

According to STEUBER (1999: 105), *R. sauvagesi* has been recorded from the Coniacian of southern France, Istria, Bosnia, and Serbia, the Upper Turonian-Coniacian of the external Dinarid; and the Campanian of northern Castile. Stratigraphically, it has a long vertical range from the Cenomanian to the Maastrichtain (e.g., CAMOIN, 1983).

Discussion. The internal structure of *Radiolites sauvagesi* closely resembles that of *Durania arnaudi* (CHOFFAT, 1891) but differs in having a well developed ligamental ridge (Pl. 10, Fig. 8b-c). According to STEUBER (1999: 105), the ornamentation of *Radiolites sauvagesi* varies widely. In the present material, the ligamental ridge, ornamentation, and cell microstructures closely resemble the middle Turonian *Radiolites sauvagesi* as described and figured by STEUBER (1999) from Greece, by ALI et al. (2005) from the Turonian of Gebel Yelleg (Sinai, Egypt), and by EL-HEDENY (2007) from the Abu Roash area (Western Desert, Egypt). Many authors e.g., TOUCAS (1908), STEUBER (1999), and ALI et al. (2005) considered *R. lefebvrei lefebvrei* (BAYLE) and *R. lefebvrei senescence* PARNES in PARNES (1987) as a synonym of the present species. *R. lefebvrei lefebvrei* differs from the present species only in having ascending lamellae in the interband (Ib), while *R. lefebvrei senescence* has less steeply inclined lamellae especially in the adult growth stage when compared to the juvenile shell (STEUBER,1999). According to EL-HEDENY (2007), *R. sauvagesi* differs from *R. lefebvrei lefebvrei* in having a highly folded posterior band (Pb) and a strong downplication of the interband (Ib) (For more detailed discussion see STEUBER, 1999: 105, 106).

The present material resembles the Turonian *R. lefebvrei lefebvrei* as figured by PARNES (1987: pl. 2, figs. 4-15) in general outline and ornamentation (regular plicated lamellae) but unfortunately, its radial bands e.g., Pb, Vb, and Ib are not seen.

Genus *Eoradiolites* DOUVILLÈ, 1909

Eoradiolites liratus (CONRAD, 1852)

Pl. 11, Figs. 1-3; Text-fig. 3.19

EXPLANATION OF PLATE 11

Figs. 1-3. *Eoradiolites liratus* (CONRAD, 1852) from the lower marly and upper carbonate members of the Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El-Naqa. **1-2**. Side view of right valve, x1; 1:MGDMU:AEN.Bi.**2**.1., 2:MGDMU:AEN.Bi.17. - **3**: Apical view of left valve (LV), x1.5; MGDMU:AEN.Bi.**2**.2.

Fig. 4. *Praeradiolites biskraensis* (COQUAND, 1880). Cenomanian Galala Formation of the East Themed area. **a**: Side view of right valve, x1, **b**: transverse section, x1, **c**: close-up of the ligamental ridge (L) with cellular microstructure, x6; MGDMU:ET.Bi.**3**.38.

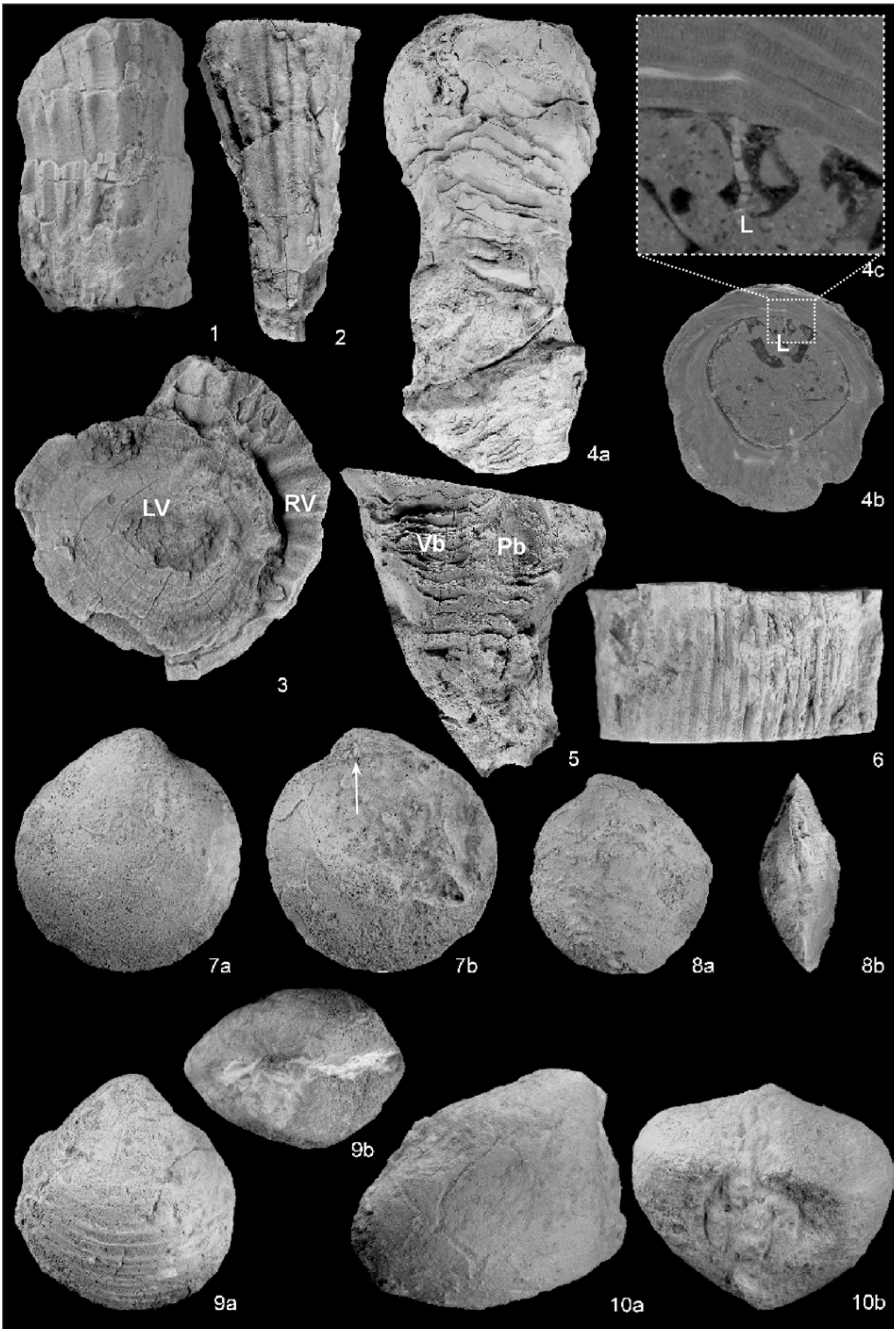
Fig. 5. *Praeradiolites* sp. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. External view of right valve (Pb: posterior radial band, Vb: ventral radial band); MGDMU:WQ.Bi.**31**.20.

Fig. 6. *Durania arnaudi* (CHOFFAT, 1891). Upper Turonian Wata Formation of Gebel Areif El-Naqa, x2. Side view of right valve (fragmented); MGDMU:AEN.Bi.**31**.1.

Figs. 7-8. *Lucina fallax* FORBES, 1846 from the middle carbonate of the Upper Albian-Cenomanian Halal Formation of Gebel Areif El-Naqa. **7a**: Side view of right valve, x1.5, **b**: side view of left valve with part of cardinal teeth (arrowed), x1.5; MGDMU:AEN.Bi.**15**.69. - **8a**: Internal mould, side view of left valve, x1, **b**: dorsal view, x1; MGDMU:AEN.Bi.**15**.70.

Fig. 9. *Clisocolus corrugatus* POPENOE, 1937. Composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. **a**: External view of right valve, **b**: dorsal view; MGDMU:AEN.Bi.**15**.75.

Fig. 10. *Cardita*? *nicaisei* COQUAND, 1862. Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1.5. **a**: Side view of right valve, **b**: antero-dorsal view; MGDMU:WQ.Bi.**42**.74.


1
2
4c
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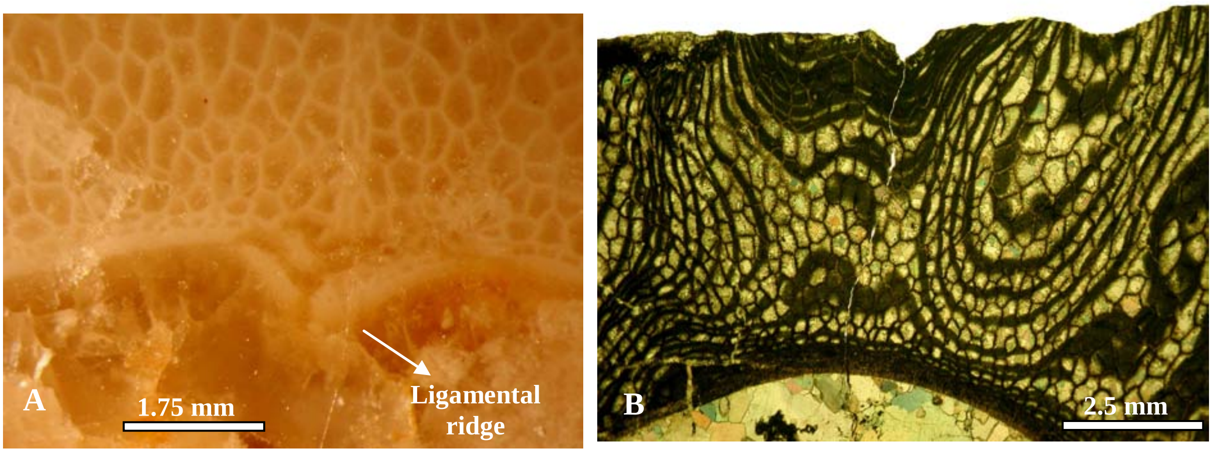


Text fig. 3.18. Transverse sections of the right valve of *Radiolites sauvagesi* (d'Hombres-Firmas, 1838); A. A Well-developed ligamental ridge; B. Adapical view showing the folding of the growth lamellae in the outer shell layere (open invaginations) with polygonal, penta- and hexagonal cells microstructure. Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El-Naqa.

1852 *Hippurites liratus* sp. nov. – Conrad: 234, pl. 7, figs. 47-48.
1883 *Sphaerulites Schweinfurthi* von Zittel: 29.
1910 *Eoradiolities lyratus* (Conrad) – Douvillè: 70, pl. 1, figs. 2-4; pl. 4, fig. 6; pl. 5, fig. 3.
1913 *Eoradiolities lyratus* (Conrad) – Douvillè: 244, pl. 14 (1), figs. 3-11; pl. 16 (3), fig. 8; text-fig. 6.
1926 *Eoradiolities lyratus* (Conrad) – Douvillè: 346, pl. 12, fig. 1a-b.
1998 *Eoradiolities lyratus* (Conrad) – Masse et al.: 54, figs. 9/1-9
1998 *Eoradiolities lyratus* (Conrad) – Bachmann & Kuss: 269, text-fig. 6c.
2002 *Eoradiolites liratus* (Conrad) – Steuber & Bachmann: 738, text-figs. 8a-b, 9a (with extensive synonymy).
2004a *Eoradiolites liratus* (Conrad) – Abdel-Gawad et al.: pl. 9, figs. 8-9.
2004b *Eoradiolites liratus* (Conrad) – Abdel-Gawad et al.: 372, pl. 4, fig. 2.
2005 *Eoradiolites liratus* (Conrad) – El-Hedeny & El-Sabbagh: 555, figs. 6-9 (with extensional synonymy).
2005 *Eoradiolites liratus* (Conrad) – Sadooni: 220, text-fig. 5.
2005 *Eoradiolites liratus* (Conrad) – Aly et al.: 256, pl. 1, figs. 4-8; pl. 2, fig. 2a-b.
2006 *Eoradiolites liratus* (Conrad) – El Qot: 69, pl. 13, figs. 13-15.
2007 *Eoradiolites liratus* (Conrad) – El-Hedeny: 90, fig. 6/n-r.
2007b *Eoradiolites liratus* (Conrad) – Mekawy: 227, pl. 4, figs. 11, 12.
2008 *Eoradiolites liratus* (Conrad) – Mekawy & Abu-Zied: 308, pl. 2, fig. 15.

Material and occurrence. 30 right valves, mostly incomplete, and one left valve from the lower marly and upper carbonate/marl members of the Upper Albian-Cenomanian Halal Formation, beds 2, 17, and 19 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**2**.1-25,**17**.6-8,**19**.9-10) and two specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 37 at Wadi Quseib (MGDMU:WQ.Bi.**37**.10-11).

Measurements (in mm).

n=15	C	nr.
Range	12-48	8-22
Mean	30	15

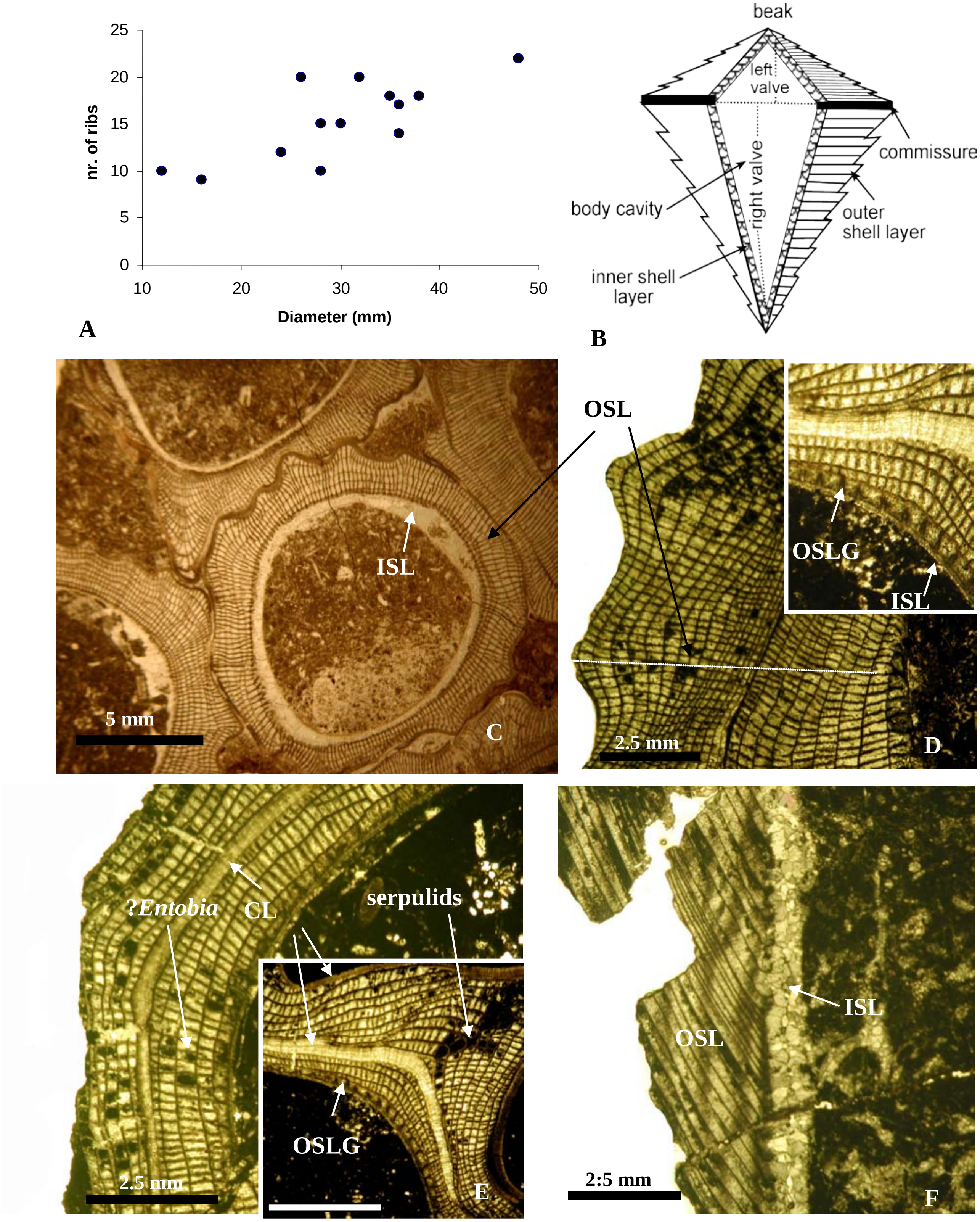
Description. RVs conical to cylindrical and uncoiled, with sub-circular to rectangular outline in transverse cross-section (Text-fig. 3.19B). Outer shell layer fairly thick. Valve ornamented with numerous regular longitudinal ribs crossed by concentric lamellae. These ribs are separated by wide interspaces. The radial bands are difficult to distinguish (e.g. Vb and Pb) from the radial ribs in the present materials. Left valve slightly convex, operculiform (cap-like) with fine concentric laminae, and central to subcentral apex. In transverse cross-section, it exhibits a fine, regularly rectangular to quadrangular celluloprismatic microstructure. Transverse sections display the compact structure developed irregulary within different parts of outer shell layer (Text-fig. 3.19C-D). In most specimens, a downwards concentric folds is frequent, surrounding the inner margin (inner-marginal groove) (Text-fig. 3.19D, E). The simple cellular structure is formed by stacked funnel-shaped plates that are crossed by radial muri, which produce a regular pattern of rectangular cells in transverse section. In longitudinal cross-section, the funnel-shaped plates are oriented upward, with different degrees of upward extension producing the costae and interspaces (Text-fig. 3.19F).

Temporal and spatial distribution. *Eoradiolites liratus* has been recorded from the Cenomanian of Iraq (SADOONI, 2005) and Italy (MASSE et al., 1998). In Egypt, it is known from the Cenomanian of Sinai (DOUVILLÉ, 1913; STEUBER & BACHMANN, 2002), Saint Paul, Eastern Desert (EL-HEDENY & EL-SABBAGH, 2005; MEKAWY, 2007b), Gebel El-Fallig (ABDEL-GAWAD et al., 2004b), G. Yelleg and G. El Minsherah (ABDEL-GAWAD et al., 2004a; ALI et al., 2005; EL QOT, 2006), Middle Albian-Lower Cenomanian of G. Tourkumanyia (North Sinai) (MEKAWY & ABU-ZIED, 2008), and Abu Roash, northern Western Desert (EL-HEDENY, 2007).

Eoradiolites liratus is a long-ranging and geographically widely distributed species, with records from both the southern areas of the Mediterranean Tethyan Realm (EL-HEDENY, 2005: 553). According to the latter author, it has been recorded also from the Albian-Lower Turonain of the eastern Mediterranean and the Near East, the Albian-Cenomanian of Morocco, Somalia, Algeria, and from the Turonian of Mexico.

Discussion. PARONA (1909), DOUVILLÉ (1910, 1913), and GALLO MARESCA (1994) discussed in detail the outer and inner shell attributes of *Eoradiolites liratus*. Radiolitid rudist bivalves shells comprise two main layers in each of their two valves, as in other rudists. The inner layers, originally of aragonite (SKELTON, 1974), when preserved is normally recrytallized (Text-fig. 3.19C). The outer layer, originally calcite, is the most suitable to be preserved and normally keeps its original microstructure (PONS & VICENS 2008). The celluloprismatic structure of the outer shell layer, together with ornamentation and external folds (e.g, posterior fold, ventral fold) are an important diagnostic features in the taxonomy of Radiolitidae. The present specimens have the same shape, outline, ornamentation, and internal microstructure of *E. liratus* as described and figured by DOUVILLÉ (1910, 1913) and EL-HEDENY & EL-SABBAGH (2005).

ALY et al. (2005) noted that the adult individuals have less prominent external ribs. In the present material, the number of radial ribs increases with increasing valve diameter (Text-fig. 3.19A). STEUBER & BACHMANN (2002) considered the succession of *E. plicatus* (CONRAD, 1852), *E. murgensis* TORRE, 1964, and *E. liratus* to represent a chronospecies lineage. According to them, the shell becomes distinctively ribbed in *E. murgensis*, and ribs are almost evenly distributed around the entire shell in *E. liratus* while only a few faint



Text-fig. 3.19. A. Biometric data of *Eoradiolites liratus* (CONRAD). B. Scheme of the radial section of both valves in a radiolitid (modified after PONS & VICENS 2008). C. Transverse section through the right valve shows the thick rectangular cellular structure of the outer shell layer of *E. liratus*. D, E. Transverse sections show the compact interlayer, thin inner shell layer, and down-fold of the growth lamellae at inner margin. F. Radial section of the attache valve (right valve). OSL= outer shell layer; ISL= inner shell layer; CL=compact layer (non- cellular structure); OSLG= outer shell layer's inner marginal groove (narrow concentric down-fold of the growth lamellae at inner margin).

longitudinal ribs may be present in *E. plicatus*. In addition, the left valve of the latter species differs in the present species in being deeply concave (for more detailed discussion see EL-HEDENY & EL-SABBAGH, 2005; PONS et al., 2010).

According to MASSE et al. (1998) and STEUBER & BACHMANN (2002) in some specimens of *E. liratus* the outer shell layer is compact. This compact structure is common or dominates in the early ontogenetic stages while the cellular one may be absent or is only of limited thickness. In contrast, ALY et al. (2005) noted that the entire section shows well developed cellular microstructure without compact interlayer. In the present study, the compact structure developed irregulary within different parts of outer shell layer. (Text-fig. 3.19D, E). In agreement with PONS & VICENS (2008: 222, fig. 5) and PONS et al. (2010: 342), the compact layers are due to the continously growth with continous stacking lamellae (Text-fig. 3.19E). In many others, developed of the growth lamellae is not uniform and their stacking is not continous, in such a way that voids are left between them; these voids occupy most of the width of the outer shell layer and are arranged following patterns (celluloprismatic microstructure).

Genus *Praeradiolites* DOUVILLÈ, 1902
Praeradiolites biskraensis (COQUAND, 1880)
Pl. 11, Fig. 4

1880 *Sphaerulites biskraensis* sp. nov. – COQUAND: 194.
1890 *Radiolites biskraensis* COQUAND – PERON: 286, pl. 28, figs. 17-19.
1912 *Praeradiolites biskraensis* (COQUAND) – PERVINQUIÈRE: 307, pl. 21, fig. 10; pl. 23, figs. 3-4.
2004a *Praeradiolites biskraensis* (COQUAND) – ABDEL-GAWAD et al.: pl. 9, figs. 1, 3.
2005 *Praeradiolites biskraensis* (COQUAND) – ALY et al.: 257, pl. 2, fig. 3; pl. 3, figs. 1-3.
?2006 *Praeradiolites* cf. *biskraensis* (COQUAND) – EL QOT: 69, pl. 14, figs. 1, 3.

Material and occurrence. 83 incomplete right valves from the Upper Cenomanian Galala Formation, beds 3 and 15 of the East Themed area (MGDMU:ET.Bi.3,**15**.38-120).

Description. Right valve fragmentary, conical to sub-conical, more than 85 mm high, commissural diameter up to 50 mm. Ligamental ridge well-devloped (Pl. 11, Fig. 4c) Ornamentation consisting of folded lamellae without radial ribs. Right valves consisting of strong longitudinal costae separated by wide and depressed radial bands (Vb and Pb). In transverse section, the radial muri cross the funnel plates and form a reticulate structure (rectangular cellular microstructure) (Pl. 11, Fig. 4b-c).

Temporal and spatial distribution. *Praeradiolites biskraensis* has been recorded from the Cenomanian of Tunisia (PERON, 1890; PERVINQUIÈRE, 1912). In Egypt it is known from the Cenomanian of Gebel El-Fallig (ABDEL-GAWAD et al., 2004b), Gebel El Minsherah (ALY et al., 2005), East Themed and Gebel Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

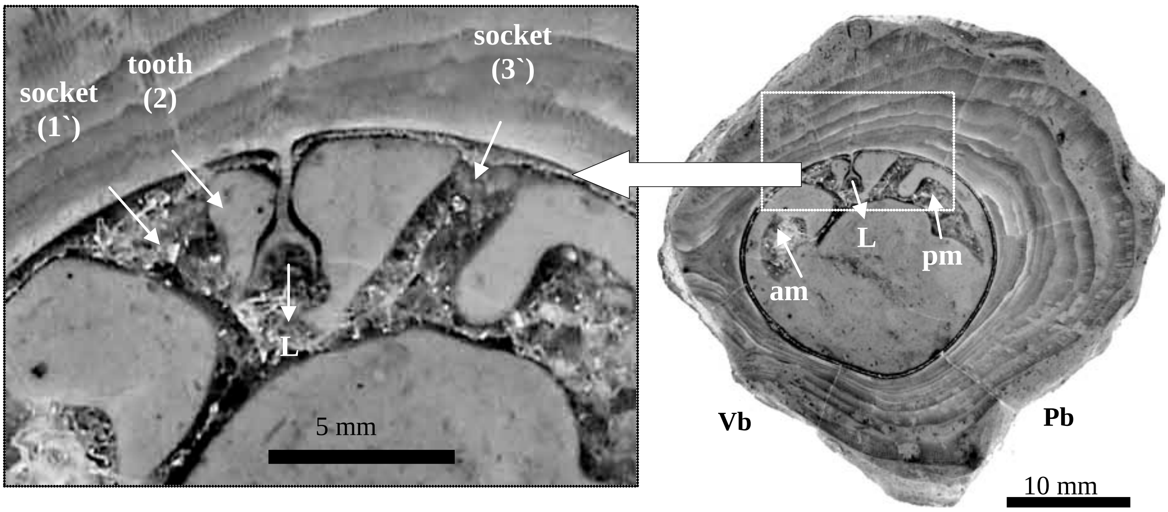
Discussion. The presence of folded lamellae, depressed radial bands (ventral band, Vb; posterior band, Pb), and lack of longitudinal ribs are the main characters of genus *Praeradiolites* DOUVILLÈ, 1902. According to ALI et al. (2005: 262), the cellular structure of *Praeradiolites* in a few of their specimens is the same as in the genus *Durania* DOUVILLÉ, 1908 (subpentagonal cells). But the latter genus differs in lacking a well-developed ligamental ridge even the cellular structure is similar to the genus *Praeradiolites*. In the present material, the cellular structure is reticulate due to the intersection the funnel shaped plates and radial muri with a well-developed ligamental ridge.

P. biskraensis, figured by Abdel-Gawad et al. (2004b) from the Cenomanian of Gebel El-Fallig, differs in having numerous longitudinal ribs and therefore belong to *Eoradiolites* rather than *Praeradiolites.* Their specimen closely resembles *Eoradiolites sinaiticus* Douvillé, 1913 from the Cenomanian of Wadi Ethal, Sinai (Aly et. al., 2005: 256).

Praeradiolites sp.
Pl. 11, Fig. 5; Text-fig. 3.20

Material and occurrence 12 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 13, 21, and 31 at Wadi Quseib (MGDMU:WQ.Bi.**13**.31-32,**21**.28-30,**31**.20-26).

Remarks. Cone-shaped right valve short, 50-55 mm long and with a commissural diameter of 39.45 mm. Ligamental ridge (L) well-developed (Text-fig. 3.20). Transverse section of right valve subrounded with well developed radial bands. External lamellae erected and non-folded. Near the radial bands (Pb and Vb), the external lamellae become folded. Both bands are wide (about 10 mm) and separated by one fold. In transverse section, the right valve has two teeth sockets (1` and 3`) filled by sparry calcite and one tooth (2) (Text-fig. 3.20). The two anterior and posterior myophore cavities are filled with sparry calcite and nearly similar in general outline but differ in size. The outer layer appears to be 6-12 mm thick, becoming thicker along the postero-dorsal side. The radial muri cross the funnel-shaped plates and form a reticulate cellular structure (rectangular cells). The vertical spacing of the funnel plates are variable in but do not exceed 0.5 mm.



Text-fig. 3.20. Transverse section through the right valve of *Praeradiolites* sp. from the Cenomanian Galala Formation of Wadi Quseib showing rectangular cellular structure. L: ligamental ridge, pm: posterior myophore, am: anterior myophore, Vb: ventral radial band, Pb: posterior radial band.

Subfamily Sauvagesiinae Douvillé, 1908
Genus *Durania* Douvillé, 1908
Durania arnaudi (Choffat, 1891)
Pl. 11, Fig. 6; Text-fig. 3.21

1891 *Biradiolites arnaudi* sp. nov. – Choffat: 203, 210-211.

1902 *Biradiolites arnaudi* CHOFFAT – CHOFFAT: 138, pl. 6; pl. 7.
1910 *Durania arnaudi* CHOFFAT – DOUVILLÉ: 50, pl. 3, fig. 1.
1912 *Durania arnaudi* CHOFFAT – PERVINQUIÉRE: 321, pl. 22, fig. 9.
1913*Durania arnaudi* CHOFFAT – DOUVILLÉ: 252, pl. 16 (3), fig. 1.
1973 *Durania arnaudi* (CHOFFAT) – PLENIČAR: 221, pl. 4, fig. 1; pl. 12, fig. 3; pl. 13, fig. 1.
1996 *Durania arnaudi* (CHOFFAT) – DE CASTRO & SIRNA: 78, figs. 6-9.
2000 *Durania arnaudi* CHOFFAT – STEUBER & LÖSER: 96.
2003 *Durania cornupastoris* (DES MOULINS) – EL-SABBAGH & EL-HEDENY: 247, 255, pl. 1, figs. 1-4; pl. 4, figs. 1-4; pl. 5, fig. 1.
2004a *Durania arnaudi* (CHOFFAT) – ABDEL-GAWAD et al.: pl. 9, figs. 4-5.
2005 *Durania arnaudi* (CHOFFAT) – ALY et al.: 273, pl. 10, figs. 3-9; pl. 11, figs. 2-3.
2006 *Durania arnaudi* (CHOFFAT) – EL QOT: 70, pl. 14, figs. 4-5.
2008 *Durania arnaudi* (CHOFFAT) – PONS & VICENS: 226, fig. 9A-C.

Material and occurrence. Two incomplete right valves from the Upper Turonian Wata Formation, bed 31 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**31**.1-2).

Description. External surface ornamented with numerous fine, rounded radial ribs separated by wide interspaces. Occasionally, pairs of ribs are closely spaced, thus resembling double ribs. No megarhythmus marking the shell are observed. No ligamental ridge. In transverse section, the outer layer consists of polygonal cellular structures produced by the intersection of the funnel-shaped plates and muri forming polygonal cells (Text-fig. 3.21). The polygonal cells are mainly pentagonal and hexagonal with subordinate subpolygonal cells in the outer margin of the outer layer.

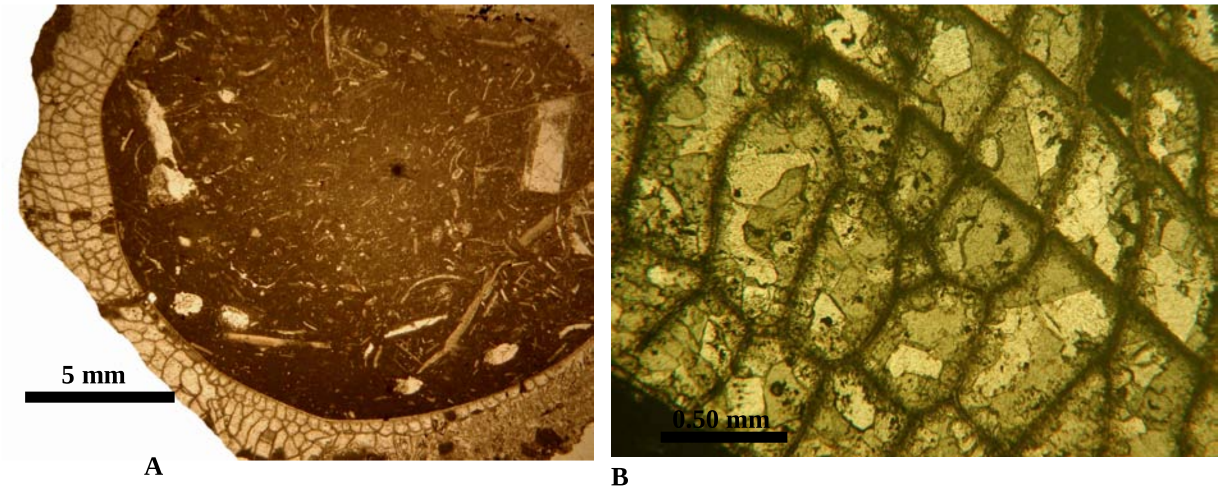
Temporal and spatial distribution. *Durania arnaudi* is known from the Upper Turonian of the Mediterranean Tethys (PONS & SIRNA, 1992). It is known also from the Turonian of Croatia (POLŠAK, 1967) and Tunisia (PERVINQUIÈRE, 1912). In Egypt, it is known from the Upper Turonian of Abu Roash (DOUVILLÉ, 1910, 1913; DE CASTRO & SIRNA, 1996) and the Turonian of Gebel Yelleg (ABDEL-GAWAD et al. 2004a; ALY et al. 2005).

HATABA & AMMAR (1990) recorded the species from the Coniacian of the *Actaeonella* “Series” of Abu Roash, Egypt, a unit, which is made up mostly of radiolitids.

Discussion. The present material closely resembles *Durania cornuputoris* (DES MOULINS) of EL-SABBAGH & EL-HEDENY (2003) from the Turonian of Abu Roash, which is considered herein as a synonym of the present species. COBBAN et al. (1991) noted that *D. cornupastoris* and *D. arnaudi* are rather arbitrarily separated because of differing width of the interband. STEUBER (1999) considered the main character of *D. cornupastoris* to be the large number of costellae.

D. gaensis (DACQUÈ, 1903) of ALY et al. (2005: 272, pl. 9, fig. 4a-b; pl. 10, fig. 1) from the Turonian of Gebel Yelleg differs in having a wide megarhythmus of the shells with few radial ribs.

Order Veneroida H. ADAMS & A. ADAMS, 1856
Superfamily Lucinacea FLEMING, 1828
Family Lucinidae FLEMING, 1828
Genus *Lucina* BRUGUIÉRE, 1797



Text fig. 3.21. A, B. Transverse section through right valve of *Durania arnaudi* (CHOFFAT), showing the polygonal cellular microstructure (hexagonal and pentagonal cells) from the Lower Turonian of Gebel Areif El-Naqa.

Lucina fallax FORBES, 1846
Pl. 11, Figs. 7-8; Text-fig. 3.22

1846 *Lucina fallax* sp. nov. - FORBES: 143, pl. 17, fig. 8.
1871 *Lucina fallax* FORBES – STOLICZKA: 256, pl. 13, figs. 13, 15-17; pl. 14, figs. 3-5, 7-8.
1953 *Lucina fallax* FORBES – BARONI et al.: 95, pl. 6, fig. 1.
1963 *Lucina* aff. *fallax* FORBES – FAWZI: 66.
2006 *Lucina fallax* FORBES – EL QOT: 70, pl. 14, figs. 7-8, 9a-b, 10a-b.

Material and occurrence. Six specimens from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.69-74).

Measurements (in mm).

n=4	L	H	C	H/L	C/L	C/H
Range	28-37	30-38	11-14	1.00-1.09	0.31-0.39	0.29-0.38
Mean	33.22	35.25	12.25	1.06	0.37	0.35

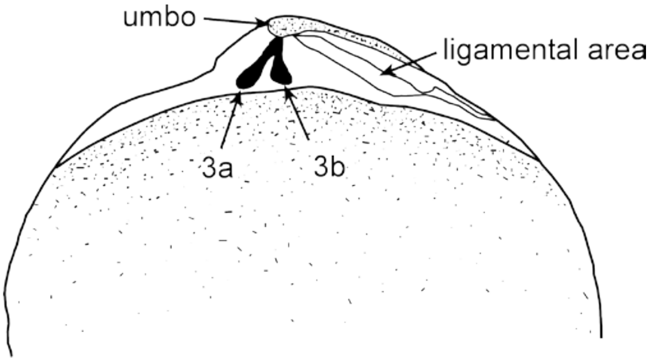
Description. Valves medium-sized, sub-circular to circular, equivalved, inequilateral, and moderately inflated. Ventral margin well rounded, meeting the anterior and posterior margins in rounded curves. Postero-dorsal margin slightly convex to straight. Antero-dorsal margin slightly concave and shorter than postero-dorsal one. Umbones less prominent, small, prosogyrate, and placed nearly medially. Two cardinal teeth followed by small tear-shaped socket seen in one specimen (Text-fig. 3.22). Lunule small, asymmetrical, and narrow. Ornamentation consisting of faint, regular commarginal growth lines, well developed near the ventral margin.

Temporal and spatial distribution. *Lucina fallax* has been recorded from the Upper Cretaceous of South India (FORBES, 1846; STOLICZKA, 1871) and Libya (BARONI et al., 1953). In Egypt, it is known from the Cenomanian of Gebel El-Minsherah (FAWZI, 1963) and from the Upper Cenomanian of Gebel Ekma (EL QOT, 2006).

Discussion. Based on the shape, ornamentation, and inflation of the shell, STOLICZKA (1871) subdivided *Lucina fallax* into four varieties. The present material shows only commarginal growth lines and a less inflated shell and it is very similar to the forma typica of STOLICZKA (1871).

The ornamentation pattern of *L.* (*Loripes*) *cenomanensis* ABBASS (1962: 108, pl. 22, fig. 1) from the Cenomanian of Gebel Qabaliat, is similar to *L. fallax* but differs only in being smaller and triangular in outline. *L. nicaisei* COQUAND (1862: 203, pl. 12, figs. 5-6) from the Albian of Algeria differs in having a more prominent umbo, concave antero- and postero-dorsal margins, and fine radial threads, crossed by commarginal ribs. The deep, wide, and long lunule and large size of *L. masylaea* COQUAND (1862: 203, pl. 12, figs. 7-8) from the Cenomanian of Algeria distinguish this species from *L. fallax.*

Lucina sp., which figured and described by WOODS (1907: pl. 24, figs. 3-6) from the Lower Greensand of England, closely resembles the present species in general outline, inflation, and ornamentation but differs only in having an ovate and wide lunule. The general outline of *L. pisum* J. DE C. SOWERBY, 1836 of WOODS (1907: 156, pl. 24, figs. 16-19) and *L. usieli* SHALEM as figured by BLANCKENHORN (1934: 235, pl. 2, fig. 118) is similar also to the present species but the latter two species differ in being smaller (L=6.7-7.7 mm, H=6.2-6.6 mm, C=3.2-3.7 mm in BLANCKENHORN'S material) and more inflated (C/L=0.49).



Text-fig. 3.22. Polished section of the hinge of the right valve of *Lucina fallax* FORBES, 1846 from the Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El-Naqa.

Family Mactromyidae COX, 1929

Genus *Clisocolus* GABB, 1869
Clisocolus corrugatus POPENOE, 1937
Pl. 11, Fig. 9

1937 *Clisocolus corrugatus* sp. nov. - POPENOE: 390, pl. 47, figs. 9, 10, 12.

Material and occurrence. Two articulated specimens from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.75-76), one specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 31 at Wadi Quseib (MGDMU:WQ.Bi.**31**.27), and one specimen from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 23 of the East Themed area (MGDMU:ET.Bi.**23**.33).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	23-27	26-29	17-19	1.07-1.13	0.70-0.74	0.65-0.65
Mean	25	27.50	18	1.10	0.72	0.65

Description. Specimens medium-sized, trigonal to rounded, inequilateral, inequivalved, and strongly inflated. Antero-dorsal margin concave. Postero-dorsal margin slightly straight (truncated). Both anterior and posterior margins strongly rounded. Ventral margin strongly curved and meeting the posterior and anterior margins in even curves. Umbones prominent, sharply pointed, and anteriorly incurved. Ornamentation consisting of strong commarginal ribs, separated by wide interspaces (2 mm between two adjacent commarginal ribs). These interspaces become narrower towards the dorsal side.

Temporal and spatial distribution. *Clisocolus corrugatus* has been recorded from the Upper Cretaceous of the Santa Ana Mountains, southern California by POPENOE (1937). This is the first record of the species from Egypt.

Discussion. *Clisocolus corrugatus* POPENOE can easily distinguished by its coarse and widely spaced concentric corrugations.

According to POPENOE (1937: 390), *C. cordatus* WHITEAVES, 1903 differs from *C. corrugatus* in being larger, more globose and in having finer commarginal ribs. *C. dubius* (GABB, 1864) as figured by MOORE (1969: N511, fig. E16/1) from the Cretaceous of California differs in having wider interspaces and finer commarginal ribs.

Superfamily Carditacea FLEMING, 1820 (1828)
Family Carditidae FLEMING, 1820 (1828)
Subfamily Carditesinae CHAVAN, 1969
Genus *Cardita* BRUGUIÈRE, 1792
Cardita? *nicaisei* COQUAND, 1862
Pl. 11, Fig. 10

1862 *Cardita Nicaisei* sp. nov. - COQUAND: 200, pl. 14, figs. 16-17.
1912 *Cardita Nicaisei* COQUAND – PERVINQUIÈRE: 340, pl. 17, figs. 16-17.

Material and occurrence. One internal mould from the middle siliciclastic/carbonate member of the Upper Cenomanian Galala Formation, bed 42 at Wadi Quseib (MGDMU:WQ.Bi.**42**.74).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	35	26	44	0.74	0.94	1.27

Description. Mould medium-sized, outline subtrapezoidal, longer than hight (H/L=0.74), strongly inequilateral, equivalved, and strongly inflated (H/L=0.94). Anterior end shorter than the posterior one. Umbo very prominent, sharply pointed, prosogyrate, and shifted anteriorly. Postero-dorsal margin slightly convex, oblique ventrally, and meeting the posterior margin in a nearly right angle. Anterior margin slightly concave. Ventral margin convex, meeting the anterior and posterior margins in a rounded obtuse angle. Lunule cordate in outline, medium-sized, and shallow. The present material is an internal mould but shows faint radial ribs near the anterior margin.

Temporal and spatial distribution. *Cardita nicaisei* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862) and from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912).

Discussion. Without the hinge structure a precise identification is not possible, but the present material corresponds perfectly to the Algerian and Tunisian specimens of COQUAND (1862) and PERVINQUIÈRE (1912).

Genus *Venericardia* LAMARCK, 1801

Venericardia? *forgemoli* (COQUAND, 1862)

Pl. 12, Fig. 1

1862 *Cardita Forgemoli* sp. nov. - COQUAND: 199, pl. 14, figs. 14-15.
1862 *Cardita Delettrei* sp. nov. – COQUAND: 200, pl. 14, figs. 18-19.
1862 *Cardita Beuquei* sp. nov. – COQUAND: 200, pl. 15, figs. 1-2.
1891 *Cardita Beuquei* COQUAND – PERON: 264.
1912 *Cardita Forgemoli* COQUAND – PERVINQUIÈRE: 238, pl. 17, figs. 5-12.
?1916 *Cardita Dupini* D'ORBIGNY var. *deserti* var. nov. – DOUVILLÉ: 162, pl. 21, figs. 1-2.
1917 *Cardita Forgemoli* COQUAND – FOURTAU: 71.
1918 *Cardita Forgemoli* COQUAND – GRECO: 32 (214), pl. 4 (20), figs. 4-7.
1937 *Cardita Forgemoli* COQUAND – TREVISAN: 94, pl. 7, figs. 10-13.
1962 *Cardita* (*Pteromeris*) *forgemoli* (COQUAND) – ABBASS: 112, pl. 17, figs. 10-12.
1963 *Cardita forgemoli* COQUAND – FAWZI: 61, pl. 5, figs. 9-10.
1972 *Maghrebella forgemoli* (COQUAND) – FRENEIX: 131.
1992 *Venericardia forgemoli* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 3, fig. 4.
1998 *Maghrebella forgemoli* (COQUAND) – EL-SHEIKH et al.: pl. 1, fig. F.
2001 *Venericardia forgemoli* (COQUAND) – ABDALLAH et al.: pl. 2, fig. 16.
2002 *Venericardia* (*Venericardia*) *forgemoli* (COQUAND) – ABDEL-GAWAD & GAMEIL: 89, pl. 2, figs. 15-16.
2002 *Venericardia forgemoli* (COQUAND) – ABDELHAMID & EL QOT: 276, pl. 5, fig. 3.
2004b *Venericardia forgemoli* (COQUAND) – ABDEL-GAWAD et al.: pl. 2, fig. 10.

EXPLANATION OF PLATE 12

Fig. 1. *Venericardia*? *forgemoli* (COQUAND, 1862). Composite mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El-Naqa, x3. **a**: Side view of left valve, **b**: anterior view; MGDMU:AEN.Bi.**1**.100.

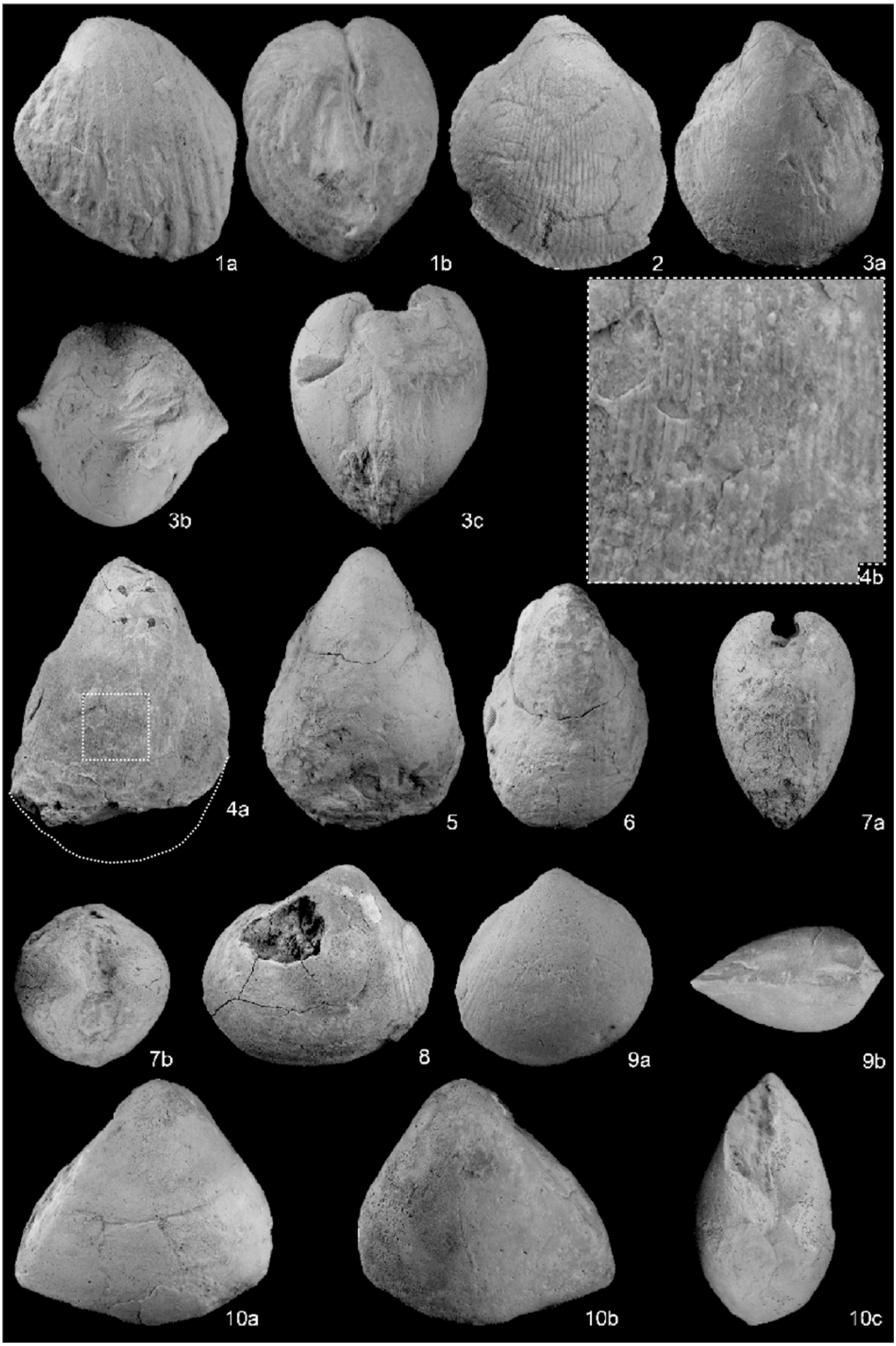
Figs. 2-3. *Granocardium* (*Granocardium*) *carolinum* (D'ORBIGNY, 1843). **2**. Composite mould from the Upper Turonian Wata Formation of the East Themed area, x1.5. External view of right valve; MGDMU:ET.Bi.**53**.1. - **3**. Composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. **a**: Side view of right valve, **b**: dorsal view, **c**: anterior view; MGDMU:AEN.Bi.**15**.81.

Fig. 4. *Granocardium* (*Granocardium*) *desvauxi* (COQUAND, 1862). Composite mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Side view of ?left valve, **b**: close-up view showing the radial ribs, arranged in pairs, x4; MGDMU:WQ.Bi.**31**.28.

Figs. 5-7. *Granocardium* (*Granocardium*) *productum* (J. DE C. SOWERBY, 1832). **5**. Internal mould from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. External view of right valve; MGDMU:AEN.Bi.**15**.82. - **6**. Composite mould from the lower marly member of the same formation and same area, x1.5. External view of right valve; MGDMU:AEN.Bi.**9**.43. - **7**. Internal mould from the Cenomanian Galala Formation of the East Themed area, x1. **a**: External view of the posterior side, **b**: dorsal view; MGDMU:ET.Bi.**12**.63.

Figs. 8-9. *Protocardia hillana* (J. SOWERBY, 1813). **8**. Composite mould from the Cenomanian Galala Formation of the East Themed area, x1. External view of left valve; MGDMU:ET.Bi.**12**.83. - **9**. Composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x2. **a**: External view of right valve, **b**: dorsal view; MGDMU:AEN.Bi.**15**.85.

Fig. 10. *Protocardia*? *regulare* (COQUAND, 1862). Composite mould from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El-Naqa, x1.5. **a**: External view of right valve, **b**: side view of left valve, **c**: postero-dorsal view; MGDMU:AEN.Bi.**15**.86.


1a
1b
2
3a
3b
3c
4b
4a
5
6
7a
7b
8
9a
9b
10a
10b
10c

2006 *Maghrebella forgemoli* (COQUAND) – EL QOT: 73, pl. 15, figs. 6-8.
2007b *Maghrebella forgemoli* (COQUAND) – MEKAWY: 228, pl. 5, fig. 1.

Material and occurrence. Six composite moulds from the lower marly and middle carbonate members of the Upper Albian-Cenomanian Halal Formation, beds 1 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.100-101,**15**.77-80), and one specimen from the Cenomanian Galala Formation, bed 3 of the East Themed area (MGDMU:ET.Bi.**3**.121).

Measurements (in mm).

n=6	L	H	C	nr	H/L	C/L	C/H
Range	11-16	12-19	9-21	15-25	1.09-1.73	0.80-1.31	0.58-1.10
Mean	13.60	16.60	13.60	20	1.24	0.98	0.81

Description. Outline triangular, small- to medium-sized, mostly higher than long (H/L=1.24), strongly inflated, inequilateral, and enlarged posteriorly. Ventral margin strongly convex, meeting the anterior and posterior margins in a rounded curve. Anterior margin nearly straight, posterior one convex. Umbones prominent, relatively broad, and strongly prosogyrate. Lunule heart-shaped and shallow. Ornamentation consisting of strong radial ribs, separated by wide interspaces. These interspaces are concave and become narrower towards the umbonal area.

Temporal and spatial distribution. *Venericardia forgemoli* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), and Italy (TREVISAN, 1937). In Egypt, it is known from the Albian of Gebel Manzour (DOUVILLÉ, 1916), Cenomanian of Gebel Tih (ABBASS, 1962), Wadi Araba and G. Shabrawit (GRECO, 1918; FAWZI, 1963), G. El-Hamra (ABDEL-GAWAD & ZALAT, 1992), G. El-Minsherah (EL-SHEIKH et al., 1998; ABDELHAMID & EL QOT, 2002), El-Giddi Pass (ABDALLAH et al., 2001), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and of G. Ekma, East Themed, and G. Yelleg (EL QOT, 2006).

Discussion. FRENEIX (1972) erected the genus *Maghrebella* and referred it to the subfamily Carditesinae. She based her new genus on the hinge of the right valve and referred *Cardita forgemoli* COQUAND, 1862 to her new genus *Maghrebella*. Unfortunately, the present material is an articulated valves without information about the internal characters (such as hinge, muscle scars, and teeth). Thus, the genus *Venericardia* is used herein with some doubt.

C. beuquei and *C. delettrei* of COQUAND, 1862 closely resemble *Venericardia forgemoli* in general outline, size, and ornamentation. In agreement with PERVINQUIÈRE (1912), FOURTAU (1917), GRECO (1918), ABBASS (1962), FAWZI (1963), and EL QOT (2006), COQUAND'S species are considered as junior synonyms of *V. forgemoli*.

C. dupini D'ORBIGNY var. *deserti* DOUVILLÉ (1916) is also similar to *V. forgemoli* but its ribs are finer and carry small pointed tubercles and it is less inflated than the present species (C/L=0.68). According to COX in MOORE (1969: N555), the nature of the radial ribs changes during ontogeny; numerous and sharp in juveniles, they become flattened and enlarged in adults. In this case, the style of ornamentation is not sufficient to erect a new species.

C. nicaisei COQUAND (1862: 200, pl. 14, figs. 16-17) from the Cretaceous of Algeria and *V. abbassi* ABBASS (1962: 113, pl. 17, fig. 13) from the Aptian of Maghara area, Sinai, differ in general outline (e.g., trapezoidal, H/L=0.50 in the case of COQUAND'S material), the low number of radial ribs, crossed with commarginal riblets and separated by wider interspaces.

Superfamily Cardiacea, LAMARCK, 1809
Family Cardiidae LAMARCK, 1809

Subfamily Cardiinae LAMARCK, 1809
Genus *Granocardium* GABB, 1868
Subgenus *Granocardium* GABB, 1868
Granocardium (*Granocardium*) *carolinum* (D'ORBIGNY, 1843)
Pl. 12, Figs. 2-3

1843 *Cardium carolinum* sp. nov. - D'ORBIGNY: 29, pl. 245.
1981 *Granocardium* cf. *carolinum* (D'ORBIGNY) – AMARD et al.: 75, pl. 1, figs. 1-2.
1999 *Granocardium* aff. *carolinum* (D'ORBIGNY) – BUSSON et al.: 36.
?2006 *Granocardium* (*Criocardium* ?) sp. – PERRILLIAT et al.: 101, figs. 19-24.

Material and occurrence. One articulated specimen from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.81), and one specimen from the Upper Turonian Wata Formation, bed 53 at the East Themed area (MGDMU:ET.Bi.**53**.1).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	28	30	25	1.07	0.96	0.83

Description. Medium-sized, outline circular to ovate, slightly higher than long (H/L=1.07), strongly inflated (C/L=0.96), equivalved, and slightly equilateral. Maximum inflation along the umbonal region. Both anterior and posterior margins strongly convex. Ventral margin regularly rounded, meeting the anterior and posterior margins in even curves. Umbonal area triangular and moderately wide. Umbones prominent, sub-centric, sharply pointed, and slightly incurved posteriorly. Ornamentation consisting of numerous, fine, spinosy radial threads separated by narrow interspaces. These radial threads are better developed near the ventral margin.

Temporal and spatial distribution. *Granocardium* (*Granocardium*) *carolinum* has been recorded from the Upper Cretaceous of France (D'ORBIGNY, 1843), Cenomanian of Algeria (AMARD et al., 1981), and from the Upper Cenomanian-Lower Turonian of Jordan (PERRILLIAT et al., 2006). Stratigraphically, the species ranges from the Cenomanian to the Turonian. This is the first record of the species from the Cenomanian-Upper Turonian of Egypt.

Discussion. The present material closely resembles *Granocardium* (*Granocardium*) *carolinum* as figured by COX (1969) and AMARD et al. (1981) in general outline and ornamentation pattern. *Trachycardium noeggerathi* MÜLLER in COLLIGNON (1971: 41, pl. H, fig. 12) from the Maastrichtian of Algeria differs in having a wider umbonal area.

G. (*G.*) *pullatum* (STOLICZKA, 1871: 218, pl. 11, figs. 8-10) from the Upper Cretaceous of South India differs in having thicker radial ribs and in being less hight. *G.* (*G.*) *scrobiculatum* (STOLICZKA, 1871: 219, pl. 11, fig. 14) from the same locality differs in being smaller than the present species (H=17 mm, L=17 mm, H/L=1) and in having a well-rounded shell.

G. (*G.*) *carolinum* also closely resembles *Granocardium* (*Criocardium*?) sp. of PERRILLIAT et al. (2006) from the Upper Cenomanian-Lower Turonian of Jordan in general outline and ornamentation but the latter differs in having a greater heigth-length ratio (1.24) and a triangular umbonal area in some specimens. The latter author suggested that *Granocardium conradi* (STEPHENSON: 1923, 296, pl. 72, figs. 1-4) from the Black Greek Formation (upper part of *Exogyra ponderosa* Zone) of North Carolina is similar to their material in having a relatively broad shell, flat bifid ribs with narrow interspaces but differs in being smaller and recorded from a different stratigraphic horizon.

Granocardium (*Granocardium*) *desvauxi* (COQUAND, 1862)
Pl. 12, Fig. 4

1862 *Cardium Desvauxi* sp. nov. – COQUAND: 206, pl. 11, figs. 3-4.
1912 *Cardium* (*Trachycardium*) *Desvauxi* COQUAND – PERIVINQUIÈRE: 260.
1962 *Granocardium hassani* sp. nov. – ABBASS: 122, pl. 20, figs. 2-3.

Material and occurrence. One composite mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 31 at Wadi Quseib (MGDMU:WQ.Bi.**31**.28).

Measurements (in mm).

n=1	L	H	H/L
	42	51	1.21

Description. Large-sized, subtriangular, higher than long (H/L=1.21), strongly inflated, and nearly equilateral. Anterior and posterior margins slightly convex. Umboness prominent, sharply pointed, and nearly orthogyrate. Ventral margin regularly rounded. Hinge short and straight. Ornamentation consisting of fine radial ribs which are arranged in pairs, and radial rows of fine tubercles in the interspaces between the pairs.

Temporal and spatial distribution. *Granocardium* (*Granocardium*) *desvauxi* has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862) and from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912). In Egypt, it is known from the Cenomanian of Wadi Abu Qada (ABBASS, 1962).

Discussion. The most conspicuous feature of the present species is ornamentation (radial ribs, arranged in pairs). The present material is closely similar to *Granocardium* (*Granocardium*) *desvauxi* from Algeria as figured by COQUAND (1862) and and to the Egyptian *Granocardium hassani* by ABBASS (1962).

DHONDT & DIENI (1993) and EL QOT (2006) pointed out that *Granocardium hassani* ABBASS (1962) closely resembles *G. productum* (J.DE C. SOWERBY, 1832) and regarded the former as a possible junior synonym. According to ABBASS (1962) the ornamentation of his species consists mainly of numerous finely radial ribs, which are fine tuberculated, and usually arranged in pairs. Therefore, his species more closely resembles *G.* (*G.*) *desvauxi* (COQUAND, 1862) than *G. productum* and ABBASS' species is considered herein as a junior synonym of the present species.

Granocardium quinquecostatum DOUVILLÉ (1916: 160, pl. 20, fig. 5) from the Albian of Gebel Manzour differs in having a greater number of radial ribs with narrower interspaces. *G. bicostatum* ABBASS (1962: 122, pl. 20, fig. 1) from the Albian of the Maghara area and of ABOUL ELA et al. (1991: pl. 6, fig. 5) from the same locality has a wider umbonal area and its interspaces are occupied by radial tuberculated threads of different strength.

Cardium (*Granocardium*) *proboscideum* SOWERBY as figured by WOODS (1908: 205, pl. 32, figs. 18-19; pl. 33, figs. 1-3) from the Upper Greensand of England differs in having strongly tuberculated radial ribs, which are separated by wide interspaces. These ribs bear prominent, angular, laterally compressed tooth like-projections (EL QOT, 2006).

Granocardium (*Granocardium*) *productum* (J. DE C. SOWERBY, 1832)
Pl. 12, Figs. 5-7; Text-fig. 3.23

1832 *Cardium productum* sp. nov. - J. DE C. SOWERBY: 417, pl. 39, fig. 15.
1850 *Cardium Olisiponensis* sp. nov. – SHARPE: 181, pl. 14, fig. 4a-b.
1871 *Cardium* (*Trachycardium*) *productum* SOWERBY – STOLICZKA: 217, pl. 11, figs. 15-16.
1912 *Cardium* (*Trachycardium*) *productum* SOWERBY – PERVINQUIÈRE: 259, pl. 19, figs. 25-27.
1917 *Cardium productum* SOWERBY – FOURTAU: 81.
1934 *Cardium* (*Trachycardium*) *productum* SOWERBY – BLANCKENHORN: 238.
1937 *Cardium* (*Trachycardium*) *productum* SOWERBY – TREVISAN: 102.
1958 *Cardium* (*Trachycardium*) *productum* SOWERBY - BARBER: 26, pl. 9, figs. 2a-b, 3.
1963 *Cardium* aff. *productum* SOWERBY – FAWZI: 70.
1971 *Trachycardium productum* SOWERBY – COLLIGNON: 41, pl. H, fig. 10.
1993 *Granocardium productum* (SOWERBY) – DHONDT & DIENI: 229, pl. 14, figs. 4-9b (with extensive synonymy list).
1993 *Granocardium hassani* ABBASS – ORABI: pl. 1, figs. 15-16.
2002 *Granocardium productum* (SOWERBY) – ABDELHAMID & EL QOT: 277, pl. 5, figs. 7-8.
2004b *Granocardium hassani* ABBASS – ABDEL-GAWAD et al: pl. 2, fig. 11.
2006 *Granocardium productum* (SOWERBY) – EL QOT: 77, pl. 16, figs. 2a-b, 3.

Material and occurrence. 114 specimens (internal and composite moulds) from the lower shale, middle siliciclastic/carbonate, and upper carbonate members of the Galala Formation (Cenomanian), beds 12, 41, 44, 55, 58, 62, and 72 at Wadi Quseib (MGDMU:WQ.Bi.**12**.36-40,**41**.16-39,**44**.135-136,**55**.1-20,**58**.1-30,**62**.1-23,**72**.1-10), 24 specimens from the Cenomanian Galala and Upper Cenomanian-Lower Turonian Abu Qada formations, beds 12 and 23 of the East Themed area (MGDMU:ET.Bi.**12**.63-82,**23**.35-37), and four specimens from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 9 and 15 at Gebel Areif El-Naqa (MGDMU:ET.Bi.**9**.43, **15**.82-84).

Measurements (in mm).

n=11	L	H	C	H/L	C/L	C/H
Range	16-50	18-65	13-41	1.12-1.42	0.67-1.19	0.57-0.83
Mean	32	40.72	26.54	1.24	0.84	0.67

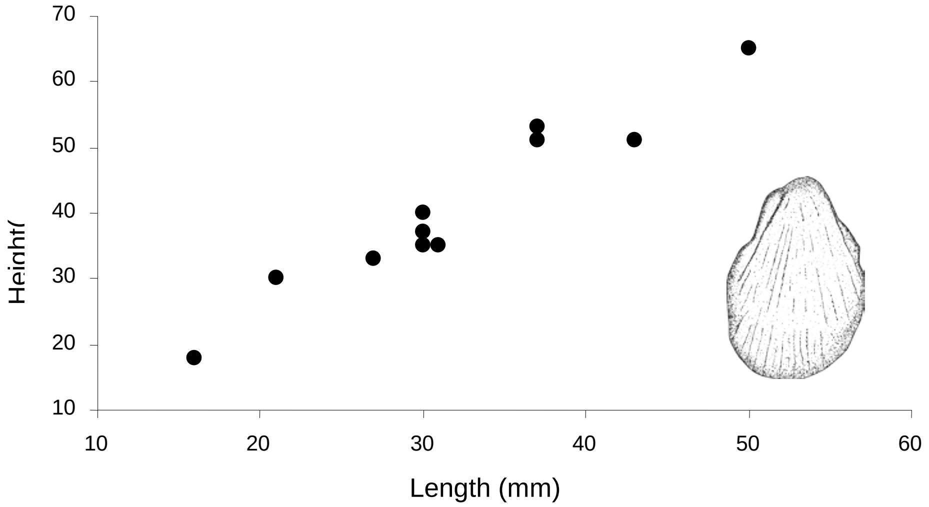
Description. Valves small- to large-sized, outline oval to sub-triangular, higher than long (H/L=1.24; Text-fig. 3.23), strongly inflated, slightly inequilateral, and equivalved. Anterior and posterior margins nearly straight to slightly convex, meeting the ventral margin in even curves. Umbones relatively broad, prominent, orthogyrate, and incurved, protruding beyond hinge line. Hinge line short and nearly straight. Ornamentation consisting of fine radial ribs, separated by wide interspaces.

Temporal and spatial distribution. *Granocardium* (*Granocardium*) *productum* has been recorded from the Cenomanian of Portugal (Sharpe, 1850), Upper Cretaceous of South India (Stoliczka, 1871), Turonian of Tunisia (Pervinquière, 1912), Lower Turonian of Nigeria (Barber, 1958), Maastrichtian of Algeria (Collignon, 1971), and from the Cenomanian of Italy (Dhondt & Dieni, 1993). In Egypt, it is known from the Cenomanian of Gebel Qubaliat (Fourtau, 1917), G. El-Minsherah (Fawzi, 1963), Cenomanian-Santonian of G. El-Hamra and G. El-Minsherah (Abdelhamid & El Qot, 2002), Cenomanian of Gebel El-Fallig (Abdel-Gawad et al., 2004b), and the Cenomanian-Turonian of G. Ekma, East Themed, and G. Yelleg (El Qot, 2006).

G. (*G.*) *productum* is a cosmopolitan taxon and has a wide stratigraphic range from the Cenomanian to the Maastrichtian (Dhondt & Dieni, 1993; El Qot, 2006).

Discussion. *Granocardium olisiponensis* (Sharpe, 1850) from the Cenomanian of Portugal closely resembles *G. productum* in the general outline, ornamentation, and size (H/L=1.32). In addition, it has been recorded from the same stratigraphic level. Therefore and in agreement with Dhondt & Dieni (1993), Sharpe's species is considered herein as a junior synonym of *G.* (*G.*) *productum*.

G. mermiti (Coquand, 1862: 207, pl. 11, figs. 6-7) from the Upper Cretaceous of Algeria differs in having strong radial ribs, a narrower umbonal area, and in being larger.



Text-fig. 3.23. Length-height ratio of *Granocardium* (*Granocardium*) *productum* (J. de C. Sowerby, 1832).

Subfamily Protocardiinae Keen, 1951
Genus *Protocardia* Beyrich, 1845
Protocardia hillana (J. Sowerby, 1813)
Pl. 12, Figs. 8-9

1813 *Cardium Hillanum* sp. nov. – J. Sowerby: 41, pl. 14.
1871 *Protocardium hillanum* Sowerby – Stoliczka: 219, pl. 12, figs. 8-10; pl. 13, figs. 1-3.
1902 *Protocardia hillana* (Sowerby) – Quaas: 218, pl. 34, figs. 18, 19.
1908 *Protocardia Hillana* (Sowerby) – Woods: 197, pl. 31, fig. 6a-c; pl. 32; figs. 1-6.
1916 *Protocardia hillana* (Sowerby) – Douvillé: 158, pl. 20, fig. 1.

1916 *Protocardia hillana* (Sowerby) – var. *prisca* Douvillé: 158, pl. 20, figs. 2-3.
1934 *Protocardia hillana* (Sowerby) – Blanckenhorn: 244.
1962 *Protocardia hillana* (Sowerby) – Abbass: 123, pl. 21, figs. 1, 3, 13.
1963 *Protocardia hillana* (Sowerby) – Fawzi: 73, pl. 6, fig. 2.
1991 *Protocardia* (*Protocardia*) *hillana* (Sowerby) – Aboul Ela et al.: pl. 6, fig. 6.
1992 *Protocardia hillana* (Sowerby) – Abdel-Gawad & Zalat: pl. 3, fig. 5.
2001 *Protocardia hillana* (Sowerby) – Abdallah et al.: pl. 2, fig. 17.
2002 *Protocardia hillana* (Sowerby) – Abdel-Gawad & Gameil: 92, pl. 3, fig. 10.
2002 *Protocardia hillana* (Sowerby) – Abdelhamid & El Qot: 279, pl. 6, fig. 1.
2006 *Protocardia hillana* (Sowerby) – El Qot: 78, pl. 16, figs. 4-6.
2007b *Protocardia hillana* (Sowerby) – Mekawy: 229, pl. 5, fig. 3.
2008 *Protocardia hillana* (Sowerby) – Mekawy & Abu-Zied: 312, pl. 3, fig. 7.

Material and occurrence. 21 composite moulds from the Cenomanian Galala Formation and Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 12 and 19 of the East Themed area (MGDMU:ET.Bi.**12**.83-94,**19**.83-91), eight specimens from the middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation, beds 41 and 44 at Wadi Quseib (MGDMU:WQ.Bi.**41**.40-44,**44**.137-139), and one composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.85).

Measurements (in mm).

n=2	L	H	C	nr.	H/L	C/L	C/H
Range	18-45	18-38	10-29	11-13	0.85-1	0.55-0.64	0.55-0.76
Mean	31.5	28	19.5	11	0.92	0.59	0.65

Description. Valves small- to medium-sized, subcircular to oval, moderately inflated, nearly equilateral and equivalved. Antero- and postero-dorsal margins straight to slightly concave. Posterior margin slightly convex, forming an obtuse angle with the hinge. Ventral margin broadly rounded, meeting the anterior and posterior margins in even curves. Umbones prominent, pointed, sub-central, and orthogyrate. Hinge line long and faintly arched. Lunule small, oval, and shallow. Anterior and median surfaces of valve ornamented with numerous, fine, regular commarginal ribs, separated by wide interspaces. Posterior area ornamented with 10 to 13 strong radial ribs, which become finer posteriorly and antero-dorsally. These ribs are separated by relatively broad and rounded interspaces without secondary riblets.

Temporal and spatial distribution. *Protocardia hillana* has been recorded from the Upper Cretaceous of South India (Stoliczka, 1871), Upper Greensand of England (Woods, 1908) and from Syria (Blanckenhorn, 1934). In Egypt, it is known from the Aptian-Albian of Maghara (Abbass, 1962; Aboul Ela et al., 1991; Mekawy & Abu-Zied, 2008), G. Manzour (Douvillé, 1916), Cenomanian of G. El-Minsherah (Fawzi, 1963), Um Heriba (Abdel-Gawad & Zalat, 1992), El-Giddi Pass (Abdallah et al., 2001), G. Nezzazat (Abdel-Gawad & Gameil, 2002), G. El-Minsherah, and G. El-Hamra (Abdelhamid & El Qot, 2002), and from the Lower Cenomanian-Lower Campanian of G. Ekma, East Themed, and G. Yelleg (El Qot, 2006). The species has been also recorded from the Cenomanian-Santonian of the Eastern Desert by Mekawy (2007b). Thus, *P. hillana* has a wide stratigraphic range from the Aptian to the Campanian.

Discussion. *Protocardia hillana* is characterized by 10-13 radial ribs on the posterior third of the shell with numerous fine and regular commarginal ribs on the rest of shell. According to El Qot (2006: 80), the maximum number of radial ribs in his material is 20. Therefore, *Protocardia shabrawitensis* Abbass (1962: 126, pl. 21, fig. 6) from the Cenomanian of Gebel Shabrawit differs from the present species in having a greater number of radial ribs (about 25) and in being larger than *P. hillana* (H=62, L=57, C=50 mm).

P. hillana (Sowerby) var. *prisca* Douvillé (1916) from the Aptian of Gebel Manzour closely resembles the present species in general outline and ornamentation style, and this variety is considered herein as a junior synonym of *P. hillana*. Abbass (1962) used Douvillé's variety as a separated species, *P. prisca.* According to him the species differs from *P. hillana* in having tuberculated radial ribs and this difference is probably due to sexual dimorphism. In fact, this tuberculation is also observed in *P. hillana* (see Woods, 1908: pl. 32, figs. 1, 3) and this difference is not sufficient to separate the two into different species.

El Qot (2006: 80) pointed out that the number of radial ribs in *P. hillana* increases with size; in small individuals there are 8-12 ribs, in medium-sized (Woods 1908; Abbass, 1962) 10-15 ribs, and in his material 11-20 ribs. In the present material, the number of ribs in small specimen (L=18 mm, H=18 mm, C=10 mm) is about 11, while larger specimens carry about 13 ribs. Thus, the number of radial ribs is not proportional to the size of shell.

Protocardia beiha (Vokes: 1946: 188, pl. 8, figs. 9-12) from the Aptian of Lebanon closely resembles the present species in general outline and ornamentation (8 radial ribs) but differs in being smaller than the *P. hillana* (L=5.9-7.6 mm, H=5.9-7.9 mm, C=3.4 mm) and in having less developed concentric ribs. Similarly, *P. darwishi* Abbass (1962: pl. 21, figs. 8-9) from the Albian of Maghara resembles the present species in general outline but differs in having strong radial and concentric ribs (6-8 ribs).

Protocardia? *regulare* (Coquand, 1862)

Pl. 12, Fig. 10

1862 *Cardium regulare* sp. nov. - Coquand: 205, pl. 10, figs. 13, 14.
?2002 *Protocardia* sp. - Abdelhamid & El Qot: 281, pl. 6, figs. 3-4.
?2006 ?*Protocardia* sp. - Perrilliat et al.: 103, fig. 26.

Material and occurrence. One composite mould from the middle carbonate member of the Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.86).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	32	30	18	0.94	0.56	0.60

Description. Specimen subtriangular, medium-sized, strongly inequilateral, equivalved, and moderately inflated. The inflation dies out towards the ventral margin. Anterior margin slightly convex and shorter than the posterior one. Posterior margin sloping obliquely, truncated, and forming an obtuse angle with the hinge line and a nearly right angle with the ventral margin. Ventral margin broad, moderately convex, and meeting the anterior and posterior margins in sharp angles. Lunule ovate and shallowly depressed. Umbones prominent, broad, and slightly incurved anteriorly. Both valves with postero-dorsal keel. Area between this keel and posterior margin small, concave, and smooth (ribs not preserved), while the rest of shell is more inflated and ornamented by faint commarginal ribs.

Temporal and spatial distribution. *Protocardia regulare* has been recorded from the Lower Cenomanian (Rhotomagien) of Algeria by COQUAND (1862) and Lower Turonian of Jordan (PERRILLIAT et al., 2006). In Egypt, it is known from the Cenomanian of Gebel El-Minsherah (ABDELHAMID & EL QOT, 2002).

Discussion. The present material closely resembles the Algerian specimens as figured by COQUAND (1862) in general outline and shape, but the lack of radial ribs in the posterior side causes some doubts about the generic identification.

Protocardia sp. as figured and described by ABDELHAMID & EL QOT (2002) and PERRILLIAT et al. (2006) are also similar to COQUAND'S species.

Granocardium pauli COQUAND (1862: 204, pl. 10, figs. 5-6) from the Lower Cenomanian of Algeria differs from the present species in being larger (L=102 mm, H/L=1.10) and in having narrower interspaces between the commarginal ribs and a strongly concave antero-dorsal margin.

Protocardia sp.
Text-fig. 3.24

Material and occurrence. One composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 1 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.102).

Measurements (in mm).

n=1	L	H	C	nr	H/L	C/L	C/H
	4	18	9	28	1.28	0.64	0.50

Description. Specimen small-sized, oval, moderately inflated, nearly equilateral, equivalved and higher than long (H/L=1.28). Anterior and posterior margins convex and meeting the ventral margin in rounded angles. Umbones little prominent and subcentral. Ornamentation consisting of about 28 radial ribs (about 8 ribs/2 mm; Text-fig. 3.24) on the posterior area, covering about 44% of the shell length from the posterior end. These ribs are less-developed near the postero-dorsal side. Rest of the shell surface ornamented with strong commarginal ribs, separated by wide interspaces.

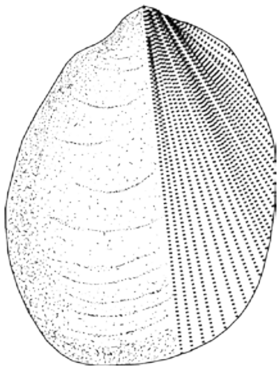
Discussion. The present material differs from other *Protocardia* species in having a much greater number of radial ribs with a wider posterior area.

Protocardium bisectum FORBES as figured by STOLICZKA (1871: 221, pl. 12, fig. 2) from the Upper Cretaceous of South India closely resembles the present material in ornamentation and size but the present material is slightly distorted and too poorly preserved to evaluated this relationship.

Superfamily Arcticacea NEWTON, 1891
Family Arcticidae NEWTON, 1891

Genus *Arctica* SCHUMACHER, 1817
Arctica? *rostrata* (FITTON, 1836)
Pl. 13, Fig. 1

1836 *Cyprina rostrata* sp. nov. – FITTON: 4, pl. 17, fig. 1.
1844 *Cyprina rostrata* FITTON – D'ORBIGNY: 98, pl. 271.



Text-fig. 3.24. Ouline and ornamentation of *Protocardia* sp. from the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

1962 *Cyprina rostrata* FITTON – ABBASS: 132, pl. 18, fig. 5.

Material and occurrence. One internal mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 5 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**5**.30).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	47	42	41	0.89	0.87	0.97

Description. Specimen large-sized, oval, strongly inequilateral, equivalved, and strongly inflated with slightly gaping valves. Antero-dorsal margin below umbones concave. Postero-dorsal margin behind umbo long, steeply inclined, and slightly convex. Anterior margin convex and meeting the ventral margin in even curve. Umbones prominent, broad and prosogyrate. Distance between umbones wide. Lunule small, heart-shaped, and forming a concave depression below the umbones. The present material is an internal mould without elements of ornamentation.

EXPLANATION OF PLATE 13

Fig. 1. *Arctica*? *rostrata* (FITTON, 1836). Internal mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: External view of left valve, **b**: dorsal view; MGDMU:AEN.Bi.**5**.30.

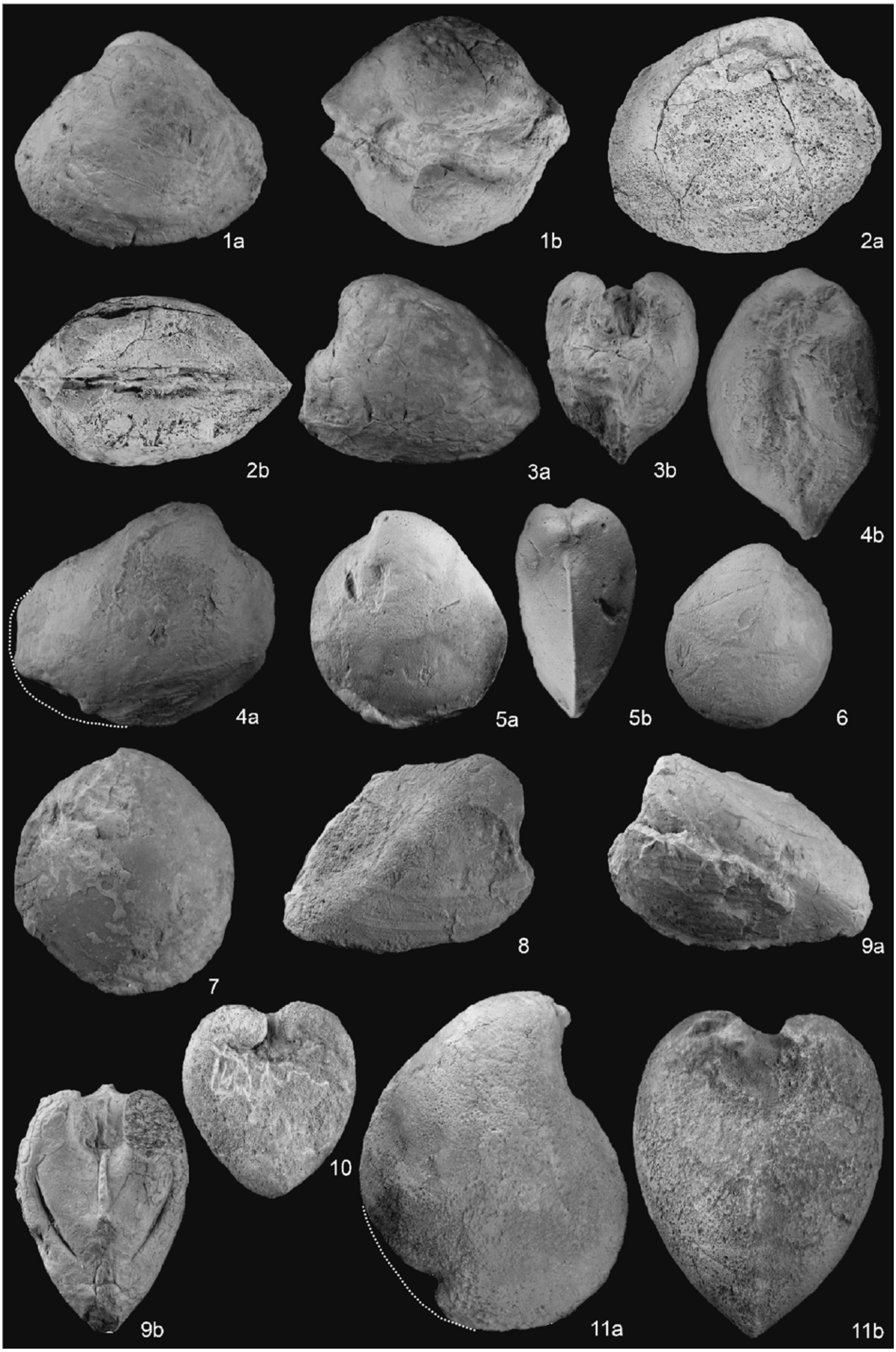
Fig. 2. *Arctica*? *inornata* (D'ORBIGNY, 1844). Internal mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. **a**: Side view of right valve, **b**: dorsal view; MGDMU:AEN.Bi.**15**.87.

Figs. 3-4. *Arctica*? *picteti* (COQUAND, 1862). Internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) of Gebel Areif El.Naqa. **3a**: External view of left valve, x1, b: anterior view; MGDMU:AEN.Bi.**9**.44. - **4a**. Side view of right valve, x1.5, **b**: dorsal view, x1.5; MGDMU:AEN.Bi.**9**.45.

Figs. 5-7. *Tenea delettrei* (COQUAND, 1862). Internal moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **5a**: External view of left valve, x2, **b**: anterior view, x2; MGDMU:AEN.Bi.**5**.31. - **6**. Side view of left valve, x2; MGDMU:AEN.Bi.**1**.103. - **7**. Side view of left valve, x1.5; MGDMU:AEN.Bi.**1**.104.

Figs. 8-9. *Veniella* cf. *trapezoidalis* (COQUAND, 1862). **8**. Composite mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. External view of right valve; MGDMU:WQ.Bi.**47**.32. - **9**. Composite mould with part of original shell from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **a**: External view of left valve, **b**: postero-dorsal view; MGDMU:ET.Bi.**19**.92.

Figs. 10-11. *Glossus aquilinus* (COQUAND, 1862). **10**. Internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. Anterior view; MGDMU:AEN.Bi.**1**.105. - **11**. Internal mould from the Cenomanian Galala Formation of the East Themed area, x1.5. **a**: External view of right valve, **b**: anterior view; MGDMU:ET.Bi.**12**.112.


1a
1b
2a
2b
3a
3b
4b
4a
5a
5b
6
7
8
9a
9b
10
11a
11b

Temporal and spatial distribution. *Arctica rostrata* has been recorded from the Upper Cretaceous of England (FITTON, 1836), and France (D'ORIBGNY, 1844). In Egypt, it is known from the Albian of Maghara by ABBASS (1962).

Discussion. A precise identification of the genus *Arctica* is impossible because of the preservation state (articulated internal mould) and therefore all the internal characters such as hinge and teeth are not seen. Moreover the ornamentation is not preserved. However, superficially the present material carries a great similarity to *Arctica rostrata* (FITTON) as described and figured by ABBASS (1962) from Sinai.

A. (*Venilicardia*) *angulata* (J. SOWERBY, 1814), as figured and described by WOODS (1907: 141, pl. 22, figs. 1-4) and *A.* (*V.*) *lineolata* (SOWERBY) of the same author (1907: 143, pl. 22, figs. 5-8) from the Upper Greensand of England differ in having a postero-ventral keel and strongly convex posterior margin (higher than the anterior end).

A. cordata (SHARPE, 1850: 182, pl. 15, fig. 2) from the Cenomanian of Portugal and *A. africana* (COQUAND, 1862: 202, pl. 11, figs. 18-19) from the Upper Cretaceous of Algeria have nearly rounded, less inflated shells, and less prominent umbones with strongly convex anterior margins. According to ABBASS (1962: 133), *A. inornata* (D'ORIBGNY: 1844: 272, figs. 1-2) differs from *A. rostrata* in having a relatively higher shell.

Arctica? *inornata* (D'ORBIGNY, 1844)
Pl. 13, Fig. 2

1844 *Cyprina inornata* sp. nov. - D'ORBIGNY: 99, pl. 272, figs. 1-2.
1903 *Cyprina inornata* D'ORBIGNY - PERVINQUIÈRE: 48-49.
1912 *Cyprina inornata* D'ORBIGNY - PERVINQUIÈRE: 222.
1918 *Cyprina inornata* D'ORBIGNY – GRECO: 44 (226), pl. 5 (21), fig. 1.
1963 *Cyprina inornata* D'ORBIGNY – FAWZI: 53.
2006 *Arctica inornata* (D'ORBIGNY) – EL QOT: 82, pl. 16, fig. 13; pl. 17, fig. 1a-b.
2007b *Arctica inornata* (D'ORBIGNY) – MEKAWY: 232, pl. 5, fig. 8.

Material and occurrence. Three internal moulds from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.87), and two specimens from the Cenomanian Galala Formation, bed 12 of the East Themed area (MGDMU:ET.Bi.**12**.95-96).

Measurements (in mm).

n=3	L	H	C	H/L	C/L	C/H
Range	23-33	20-30	16-20	0.86-0.91	0.58-0.69	0.66-0.80
Mean	28.75	25.25	17.75	0.87	0.62	0.71

Description. Moulds medium-sized, ovate to nearly subrounded, inequilateral, equivalved, and moderately inflated. Antero-dorsal margin below the umbo slightly concave. Postero-dorsal margin slightly convex. Both anterior and posterior margins convex and meeting the ventral margin in even curve. Umbones less prominent, broad, and anteriorly incurved (Pl. 13, Fig. 2b). Lunule small, ovate, and shallow. All specimens are internal moulds without signs of ornamentation.

Temporal and spatial distribution. *Arctica inornata* has been recorded from the Aptian of France (D'ORBIGNY, 1844) and Tunisia (PERVINQUIÈRE, 1912). In Egypt, this species is restricted to the Cenomanian of the Eastern Desert (GRECO, 1918; MEKAWY, 2007b) and Sinai (FAWZI, 1963; EL QOT, 2006).

Discussion. The present material closely resembles *Arctica inornata* (D'ORBIGNY, 1844), which has been described and figured by GRECO (1918) from the Cenomanian of the Eastern Desert. It is distinguished from other *Arctica* species in having less prominent umbones and a shallow antero-dorsal margin (EL QOT, 2006: 82). *A. cordata* (SHARPE, 1850) from the Cenomanian of Portugal differs in having a large lunule, more prominent umbones, and strongly rounded margins.

Arctica? *picteti* (COQUAND, 1862)
Pl. 13, Figs. 3-4

1862 *Crassatella Picteti* sp. nov. - COQUAND: 199, pl. 13, figs. 10-11.
1890 *Cyprina Picteti* COQUAND – PERON: 293.
1912 *Cyprina Picteti* COQUAND – PERVINQUIÈRE: 223, pl. 16, figs. 7-8, non fig. 6.
1937 *Cyprina Picteti* COQUAND – TREVISAN: 88, pl. 6, figs. 15-18.
1963 *Cyprina picteti* COQUAND var. *allongata* var. nov. - FAWZI: 55, pl. 5, fig. 6a-b.
2006 *Arctica picteti* (COQUAND) – EL QOT: 84, pl. 17, figs. 2a-b, 3.
2007b *Arctica picteti* (COQUAND) – MEKAWY: 233, pl. 5, fig. 10.

Material and occurrence. Three internal moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 9 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**9**.44-46).

Measurements (in mm).

n=3	L	H	C	H/L	C/L	C/H
Range	35-42	28-33	20-27	0.78-0.80	0.57-0.64	0.71-0.81
Mean	38	30	22.6	0.78	0.59	0.75

Description. Valves medium-sized, subtriangular to ovate, elongated posteriorly, longer than high (H/L=0.78), strongly inflated, equivalved, and strongly inequilateral. Anterior margin rounded, shorter than the posterior one, and curving rapidly to passing gradually into the broadly rounded and convex ventral margin. Posterior margin broadly rounded. Antero-dorsal margin strongly concave. Umbones broad, prominent, strongly prosogyrate and situated about one-fourth of shell length from the anterior end. Hinge nearly straight and inclined towards the ventral margin at the two extremities. Lunule small, shallow, and ovate. Postero-dorsal keel well developed and separating a slightly concave posterior part from the flank. All specimens are internal moulds without elements of ornamentation.

Temporal and spatial distribution. *Arctica picteti* is very abundant in the Cenomanian of North Africa (EL QOT, 2006: 84). It has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), and Italy (TREVISAN, 1937). In Egypt, it is known from the Cenomanian of Gebel El-Minsherah (FAWZI, 1963) and G. Ekma and G. Yelleg (EL QOT, 2006). The species has been also recorded from the Eastern Desert by MEKAWY (2007b).

Discussion. *Arctica picteti* can be easily distinguished from other *Arctica* species in the present study by having a well developed postero-ventral keel and in being more elongated

(H/L=0.75). The general outline and ornamentation of *Arctica picteti* (COQUAND) as figured by PERVINQUIÈRE (1912: pl. 16, fig. 6) from the Cenomanian of Tunisia more closely resembles *Veniella cordialis* (STOLICZKA, 1871) from South India than *A. picteti.*

FAWZI (1963) erected a new variety, var. *allongata*, which is more elongated (H/L= 0.73) than *A. picteti* forma typica. In addition, *A. angulata* (FAWZI, 1957) as figured by FAWZI (1963: 57, pl. 5, fig. 7) from the Cenomanian of Gebel El Minsherah closely resembles the present species but differs in having a more elongated shell with a short hinge. *A. moreti* (MAHMOUD, 1955) from the Albian of El Maghara is similar to *A. picteti* in having a postero-dorsal keel and in general outline but differs in being smaller than the present species (L=30 mm, H=18 mm, C=14.5 mm) and in having more prominent umbones. *A. cuneata* (J. SOWERBY, 1833), as figured by WOODS (1906: 134, pl. 20, figs. 7-12) from the Upper Greensand of England has a higher shell, slightly concave ventral margin, and strongly oblique hinge (posteriorly inclined). The latter author described *A. saussuri* (BRONGNIART, 1821) (1906: 131, pl. 19, figs. 7-13) which differs from *A. picteti* in being more elongated (H/L=0.84) with nearly rounded margins.

According to ABBASS (1962) *A. elongata* (D'ORBIGNY, 1846: 277, figs. 5-6) from the Middle Cenomanian of France also resembles the present species but differs in having a nearly vertical, truncated posterior margin.

Genus *Tenea* CONRAD, 1870
Tenea delettrei (COQUAND, 1862)
Pl. 13, Figs. 5-7; Text-fig. 3.25

1862 *Venus Delettrei* sp. nov. - COQUAND: 194, pl. 8, figs. 3-4
1862 *Venus Forgemoli* sp. nov. – COQUAND: 194, pl. 8, figs. 7-8.
1912 *Dosinia Delettrei* COQUAND - PERVINQUIÈRE: 270, pl. 20, figs. 4-8.
1917 *Dosinia Delettrei* COQUAND - FOURTAU: 87.
1917 *Dosinia Delettrei* var. *forgemoli* COQUAND – FOURTAU: 87, pl. 7, fig. 8.
1918 *Dosinia Delettrei* COQUAND - GRECO: 49 (231), pl. 5 (21), figs. 6-10.
1934 *Dosinia delettrei* COQUAND - BLANCKENHORN: 250.
1937 *Dosinia Delettrei* COQUAND - TREVISAN: 113, pl. 7, figs. 29-31.
1937 *Dosinia Forgemoli* COQUAND - TREVISAN: 114, pl. 7, figs. 32-33.
1962 *Dosinia delettrei* (COQUAND) - ABBASS: 151, pl. 23, figs. 8-9.
1962 *Dosinia forgemoli* (COQUAND) – ABBASS: 152, pl. 23, figs. 6-7.
1963 *Dosinia delettrei* (COQUAND) – FAWZI: 76, pl. 6, figs. 5-6.
1963 *Dosinia delettrei* var *forgemoli* (COQUAND) – FAWZI: 76, pl. 6, fig. 7.
1981 *Dosinia delettrei* (COQUAND) – AMARD et al.: 81, pl. 1, fig. 5.
1992 *Dosinia delettrei* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 3, fig. 3.
1993 *Dosinia delettrei* (COQUAND) – ORABI: pl. 1, figs. 14, 31.
1994 *Dosinia delettrei* (COQUAND) – KASSAB & ISMAEL: 238, fig. 5/13.
2001 *Dosinia delettrei* (COQUAND) – ABDALLAH et al.: pl. 2, fig. 22.
2002 *Dosinia delettrei* (COQUAND) – ABDEL-GAWAD & GAMEIL: 94, pl. 3, figs. 21-22.
2002 *Dosinobia delettrei* (COQUAND) – ABDELHAMID & EL QOT: 283, pl. 6, figs. 7-8.
2002 *Dosinobia forgemoli* (COQUAND) – ABDELHAMID & EL QOT: 283, pl. 6, fig. 9; pl. 7, fig. 1.
2004b *Dosinia delettrei* (COQUAND) – ABDEL-GAWAD et al.: pl. 3, fig. 7.
2006 *Tenea delettrei* (COQUAND) – EL QOT: 84, pl. 17, figs. 4-9; Text-fig. 11b.
2007b *Tenea delettrei* (COQUAND) – MEKAWY: 233, pl. 5, fig. 11.

Material and occurrence. 52 specimens from the Cenomanian Galala and Upper Cenomanian-Lower Turonian Abu Qada formations, beds 5, 12, 16, 22, and 26 at East Themed area (MGDMU:ET.Bi.**5**.156-159,**12**.97-111,**16**.430-434,**22**.71-78,**26**.99-118), 25 specimens from the lower marly and middle carbonate members of the Upper Albian-Cenomanian Halal Formation, beds 1, 5, 9, and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.103-104,**5**.31-33,**9**.47-49,**15**.90-106), and 12 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 41 at Wadi Quseib (MGDMU:WQ.Bi.**41**.45-56).

Measurements (in mm).

n=24	L	H	C	H/L	C/L	C/H
Range	13-27	14-29	8-13	0.95-1.20	0.70-0.72	0.38-0.64
Mean	19.90	20.62	10.30	1.13	0.55	0.53

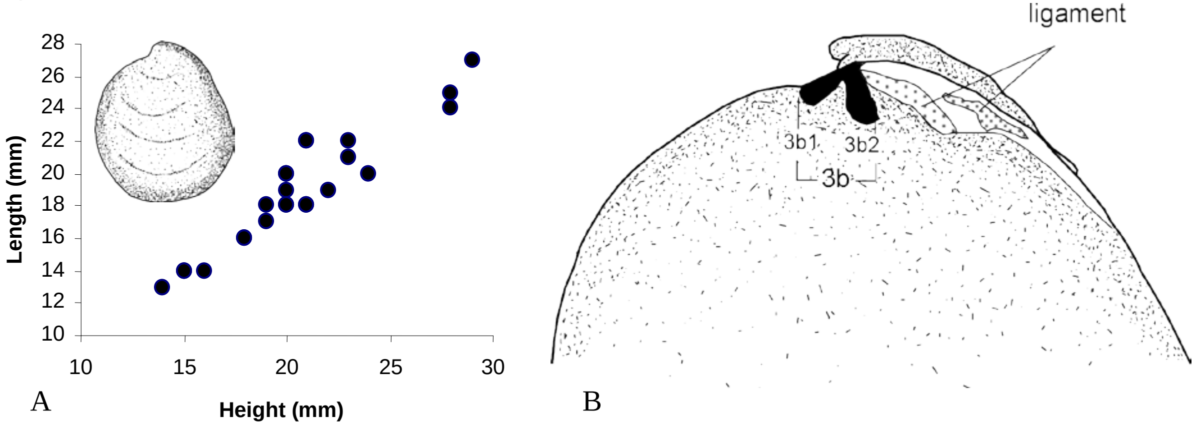
Description. Moulds small to medium-sized, circular to suborbicular, higher than long (H/L=1.13; Text-fig. 3.25A), moderately inflated, inequilateral, and equivalved. Anterior and posterior margins strongly convex and forming a continuous curve with the regularly rounded ventral margin. Antero-dorsal margin below the umbones slightly concave. Postero-dorsal margin slightly convex. Umbones small, prosogyrate, and situated slightly anteriorly of the mid-line. Lunule small, shallow, and subcircular. Escutcheon narrow. Hinge of the right valve with bifid 3b (Text-fig. 3.25B). Ornamentation consisting of fine commarginal striae.

Temporal and spatial distribution. *Tenea delettrei* has been recorded from the Upper Cretaceous (Mornasien-Rhotomagien) of Algeria (COQUAND, 1862, AMARD et al., 1981), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Cenomanian-Turonian of Syria (BLANCKENHORN, 1934), and Cenomanian of Italy (TREVISAN, 1937). In Egypt, it is known from the Cenomanian of the Eastern Desert (GRECO, 1918; MEKAWY, 2007b), Gebel El-Hamra and G. El Minsherah (FAWZI, 1963; ABDEL-GAWAD & ZALAT, 1992; ABDELHAMID & EL QOT, 2002), Cenomanian-Turonian of G. Musabaa Salama (KASSAB & ISMAEL, 1994), El Giddi Pass (ABDALLAH et al., 2001), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and of G. Ekma, G. Yelleg, and East Themed (EL QOT, 2006).

Discussion. The general outline of the present material more closely resembles the genus *Tenea* CONRAD, 1870 of the family Arcticidae NEWTON, 1891, than the genera *Dosinia* SCOPOLI, 1777 and *Dosinobia* FINLAY & MARWICK, 1937 of the family Veneridae RAFINESQUE, 1815 (see the synonymy list). A polished section of some specimens, indicates that the hinge structure closely resembles that of the genus *Tenea* (bifid 3b, Text-fig. 3.25B). EL QOT (2006: 86) also confirmed that the species belongs to the genus *Tenea* according to the hinge character (pl. 17, fig. 15). Moreover, the genus *Dosinia* is characterized by the presence of a well defined lunule, strongly curved prosogyrate umbones, and is restricted to the Upper Eocene to the Recent.

PERVINQUIÈRE (1912), GRECO (1918), BLANCKENHORN (1934), KASSAB & ISMAEL (1994), and EL QOT (2006) considered *D. forgemoli* (COQUAND) as a synonym of *D. delettrei* (COQUAND). FOURTAU (1917) and FAWZI (1963) pointed out that *D. forgemoli* is a variety of *D. delettrei*. In contrast, TREVISAN (1937) and ABBASS (1962) separated *D. delettrei* and *D. forgemoli* on the basis of the general shape and probably reflect sexual dimorphism as both forms are found in the same bed.

The present material shows a continuous variation in shell shape from the orbicular outline of *Dosinia delettrei* (COQUAND) to the elongated *D. forgemoli* (COQUAND). This difference in shape is not significant enough to separate them into two different species (Text-fig. 3.25A).



Text-fig. 3.25. Biometric data (A) and polished section of the hinge of the right valve (B) of *Tenea delettrei* (COQUAND, 1862).

Genus *Veniella* STOLICZKA, 1870
Veniella cf. *trapezoidalis* (COQUAND, 1862)
Pl. 13, Figs. 8-9

cf. 1862 *Cyprina trapezoidalis* sp. nov. - COQUAND: 201, pl. 11, figs. 16-17.
cf.1912 *Cyprina trapezoidalis* COQUAND – PERVINQUIÈRE: 223, pl. 16, fig. 10a-b.
cf.1963 *Cyprina trapezoidalis* COQUAND – FAWZI: 56.
cf. 2002 *Arctica trapezoidalis* (COQUAND) – ABDEL-GAWAD & GAMEIL: 94, pl. 3, fig. 18.

Material and occurrence. Three composite moulds from the Turonian Abu Qada and Wata formations, beds 47, 93 at Wadi Quseib (MGDMU:WQ.Bi.**47**.32-33,**93**.3), and one specimen, with remains of shell from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 19 of the East Themed area (MGDMU:ET.Bi.**19**.92).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	49	36	33	0.73	0.67	0.92

Description. Large-sized, trapezoidal, posteriorly oblique, longer than high (H/L=0.73), strongly inequilateral, equivalved, and strongly inflated. Maximum inflation near the umbonal area. Postero-dorsal margin slightly convex, long, and meeting the posterior margin in an obtuse angle. Antero-dorsal area short and slightly concave. Ventral margin broad, slightly convex, meeting the anterior margin in an even curve. Anterior margin convex and lower than the posterior one. Umbones prominent, relatively pointed and prosogyrate. Lunule cordate and large. Postero-dorsal keel well developed, straight, separating a small, slightly concave posterior part from the flank. Ornamentation consisting of commarginal ribs and separated by wide interspaces. These interspaces carry fine commarginal threads.

Temporal and spatial distribution. *Veniella trapezoidalis* has been recorded from the Cenomanian of Algeria (COQUAND, 1862) and Tunisia (PERVINQUIÈRE, 1912). In Egypt, it is known from the Cenomanian of the Eastern Desert (FAWZI, 1963) and Sinai (ABDEL-GAWAD & GAMEIL, 2002).

Discussion. The present material is assigned herein to the genus *Veniella* according to the trapezoidal outline, postero-ventral keel, and ornamentation (commarginal ribs), as all internal characters (e.g. teeth, hinge, and adductor muscle scars) are not seen. The general outline of the present material closely resembles *Cyprina trapezoidalis* COQUAND (1862) from Algeria differing only in being more inflated.

Cyprina (*Roudairea*) *checchiai* TREVISAN (1937: pl. 6, figs. 1-4) from the Cenomanian of Italy resembles the present material in general outline and size but differs in being higher and in having thicker commarginal ribs with wider interspaces. *Cyprina forbesiana* STOLICZKA (1871: 197, pl. 9, figs. 2-8) from the Cretaceous of South India differs also in having thicker commarginal ribs, separated by wide and smooth interspaces, a small lunule, and a more strongly developed postero-ventral keel. *Roudaireia arabica* ABBASS (1962: 141, pl. 19, figs. 8, 10) from the Maastrichtian of Wadi Araba, Eastern Desert differs in being larger (H=64 mm, L=68 mm, C=35 mm), in having thick commarginal ribs, and a truncated and higher posterior margin.

Superfamily Glossacea GRAY, 1847
Family Glossidae GRAY, 1847
Genus *Glossus* POLI, 1795
Glossus aquilinus (COQUAND, 1862)
Pl. 13, Figs. 10-11

1862 *Isocardia aquilina* sp. nov. – COQUAND: 209, pl. 9, figs. 11-12.
?1902 *Isocardia Hermitei* sp. nov. – CHOFFAT: 133, pl. 9, figs. 6, 7.
1904 *Isocardia aquilina* COQUAND – FOURTAU: 334.
1912 *Anisocardia aquilina* COQUAND - PERVINQUIÈRE: 234. pl. 17, figs. 18-19.
1916 *Anisocardia hermeti* (CHOFFAT) – DOUVILLÉ: 156, pl. 19, figs. 14-16.
1917 *Anisocardia aquilina* COQUAND – FOURTAU: 65.
1918 *Anisocardia aquilina* COQUAND – GRECO: 44 (226), pl. 5, (21), fig. 2.
1934 *Anisocardia aquilina* COQUAND – BLANCKENHORN: 247.
1955 *Anisocardia* (*Collignonicardia*) *simplex* sp. nov. – MAHMOUD: 121, pl. 10, figs. 5-8.
1963 *Anisocardia aquilina* COQUAND – FAWZI: 58.
1981 *Glossus aquilinus* (COQUAND) – AMARD et al.: 105, pl. 14, fig. 9.
2001 *Anisocardia aquilina* COQUAND – ABDALLAH et al.: pl. 2, figs. 18-20.
2006 *Glossus aquilinus* (COQUAND) – EL QOT: 87, pl. 17, figs. 15, 16a-b.
2007b *Glossus aquilinus* (COQUAND) – MEKAWY: 234, pl. 5, fig. 12.
2008 *Glossus aquilinus* (COQUAND) – MEKAWY & ABU-ZIED: 313, pl. 3, fig. 10.

Material and occurrence. Eight internal moulds from the Upper Cenomanian Galala Formation, beds 3 and 12 at East Themed (MGDMU:ET.Bi.**3**.122-128,**12**.112), nine internal moulds from the upper carbonate member of the Cenomanian Galala Formation, bed 44 at Wadi Quseib (MGDMU:WQ.Bi.**44**.140-148), and two internal moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation, beds 1 and 9 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.105,**9**.50).

Measurements (in mm).

n=3	L	H	C	H/L	C/L	C/H
Range	15-23	16-24	12-21	1.04-1.06	0.80-0.91	0.87- 0.87
Mean	19	20	16.50	1.05	0.85	0.87

Description. Moulds small to medium-sized, subtrigonal to cordiform, inequilateral, equivalved, and strongly inflated (C/H=0.87). Antero-dorsal margin below the umbones strongly concave. Postero-dorsal margin slightly convex and meeting the posterior margin in an even curve. Ventral margin strongly convex and meeting the anterior and posterior margins in rounded curves. Umbones more prominent, sharply pointed, coiled, and strongly prosogyrate. Lunule small, concave, and cordate in outline. The present material is an internal mould without elements of ornamentation.

Temporal and spatial distribution. *Glossus aquilinus* has been recorded from the Upper Cretaceous (Rhotomagien) of Algeria (COQUAND, 1862; AMARD et al., 1982), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), and Syria (BLANCKENHORN, 1934). In Egypt, it occurs in the Cenomanian of Gebel El Tih (FOURTAU, 1917), Eastern Desert (GRECO, 1918; MEKAWY, 2007b), El-Maghara (MAHMOUD, 1955), G. El Minsherah (FAWZI, 1963), El Giddi Pass (ABDALLAH et al., 2001), and from the Upper Albian-Cenomanian of the East Themed area and Gebel Yelleg (EL QOT, 2006).

According to COX (1969), the stratigraphic range of the genus *Glossus* (=*Isocardia*) is Paleocene to Recent. EL QOT (2006: 87) extended the range of the genus into the Cretaceous, at least back to the Cenomanian.

Discussion. The genus *Glossus* is characterized by the prominent coiled, strongly prosogyrate umbones, and by its distinct cordiform outline. According to these diagnostic charactes and in agreement with AMARD et al. (1981) and EL QOT (2006), *Isocardia aquiline* COQUAND, 1862 is placed in the genus *Glossus* POLI, 1795 (=*Isocardia* LAMARCK, 1795) rather than in *Anisocardia* MUNIER-CHALMAS, 1863.

G. solimani (ABBASS, 1962: 137, pl. 18, fig. 6) from the Cenomanian of Wadi Abu Qada, Sinai, closely resembles *G. aquilinus* in general outline and strongly coiled umbones (prosogyrate) but differs in being larger (H=58 mm, L=51 mm, C= 34 mm), having a wider umbonal area, and a nearly central umbo. *G. jubae* (COQUAND, 1862: 209, pl. 9, figs. 13-14) from the Santonian of Algeria differs in having more strongly coiled umbones and more convex postero-dorsal margin. *G. hermeti* (CHOFFAT) of DOUVILLÉ (1916) and *G. simplex* (MAHMOUD, 1955) are also similar to the present material in shape and umbo coiling but differ in having more strongly inflated shells. This difference is not so strong to separate them into two different species. Therefore, the latter two species are considered herein a junior synonym of *G. aquilinus*.

G. hermitei which has been described and figured by CHOFFAT (1902) from the Upper Cenomanian-Turonian of Portugal differs in having a small lunule and more truncated postero-dorsal side. *Anisocardia minuta* FAWZI (1963: 60, pl. 5, fig. 8), from the Cenomanian of Wadi Araba and El-Minisherah differs in being smaller (L=9.2-10.4 mm, H=7.7-10.7 mm) and in having a less concave antero-dorsal margin.

Superfamily Veneracea RAFINESQUE, 1815

Family Veneridae RAFINESQUE, 1815

Subfamily Tapetinae ADAMS & ADAMS, 1857

Genus *Paraesa* CASEY, 1952

Paraesa faba (J. DE C. SOWERBY, 1827)
Pl. 14, Fig. 1; Text-fig. 3.26

1827 *Venus Faba* sp. nov. - J. DE C. SOWERBY: 129, pl. 567, fig. 3.
1836 *Venus* (?) *sublaevis* sp. nov. - J. DE C. SOWERBY: 243, 342, pl. 17, fig. 5.
1836 *Venus immersa* sp. nov. - J. DE C. SOWERBY: 242, 342, pl. 17, fig. 6.
1862 *Venus Reynesi* sp. nov. – COQUAND: 193, pl. 7, figs. 11-12.
?1862 *Venus Dutrugei* sp. nov. – COQUAND: 193, pl. 7, figs. 5-6.
1908 *Cyprimeria* (*Cyclorisma*) *faba* (SOWERBY) – WOODS: 187, pl. 29, figs. 7-13.
1908 *Cyprimeria* (*Cyclorisma*) *sublaevis* (SOWERBY) – WOODS: 189, pl. 29, fig. 14.
1908 *Cyprimeria* (*Cyclorisma*) *immersa* (SOWERBY) – WOODS: 189, pl. 29, fig. 15.
1912 *Venus* (?) *Reynesi* COQUAND – PERVINQUIÈRE: 274.
1917 *Venus Reynesi* COQUAND – FOURTAU: 89.
1918 *Venus Reynesi* COQUAND – GRECO: 47 (229), pl. 5 (21), fig. 4.
1934 *Venus reynesi* COQUAND – BLANCKENHORN: 251, pl. 13, fig. 151; pl. 14, fig. 154.
1937 *Venus Reynesi* COQUAND – TREVISAN: 109, pl. 7, fig. 23.
1962 *Meretrix faba* (SOWERBY) – ABBASS: 146, pl. 22, fig. 21.
?1962 *Meretrix dutragei* (COQUAND) – ABBASS: 147, pl. 22, fig. 22.
1963 *Venus reynesi* COQUAND – FAWZI: 80, pl. 6, fig. 8.
1972 *Paraesa faba faba* (SOWERBY) – FRENEIX: 178, pl. 18, figs. 10-12; Text-fig. 36.
?1972 *Paraesa faba* (SOWERBY) *subfaba* (D'ORBIGNY) – FRENEIX: 180, pl. 18, figs. 13-14.
1994 *Venus reynesi* COQUAND – KASSAB & ISMAEL: 238, pl. 5/12.
?2002 *Meretrix faba* (SOWERBY) – ABDELHAMID & EL QOT: 284, pl. 7, figs. 2-3.
2004b *Meretrix faba* (SOWERBY) – ABDEL-GAWAD et al.: pl. 3, fig. 5.
2006 *Paraesa faba faba* (SOWERBY) – EL QOT: 88, pl. 18, figs. 1, 3; text-fig. 11a.

EXPLANATION OF PLATE 14

Fig. 1. *Paraesa faba* (J. DE C. SOWERBY, 1827). Composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x2. **a**: Side view of right valve, **b**: dorsal view, MGDMU:AEN.Bi.**1**.106.

Fig. 2. *Meretrix desvauxi* (COQUAND, 1862). Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **a**: Side view of left valve, **b**: dorsal view; MGDMU:ET.Bi.**26**.123.

Fig. 3. *Meretrix orientalis* DOUVILLÉ, 1916. Internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. **a**: Side view of right valve, **b**: external view of left valve, **c**: dorsal view; MGDMU:AEN.Bi.**5**.34.

Fig. 4. Bivalve gen. et sp. indet. Incomplete composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. External view of right valve; MGDMU:AEN.Bi.**15**.126.

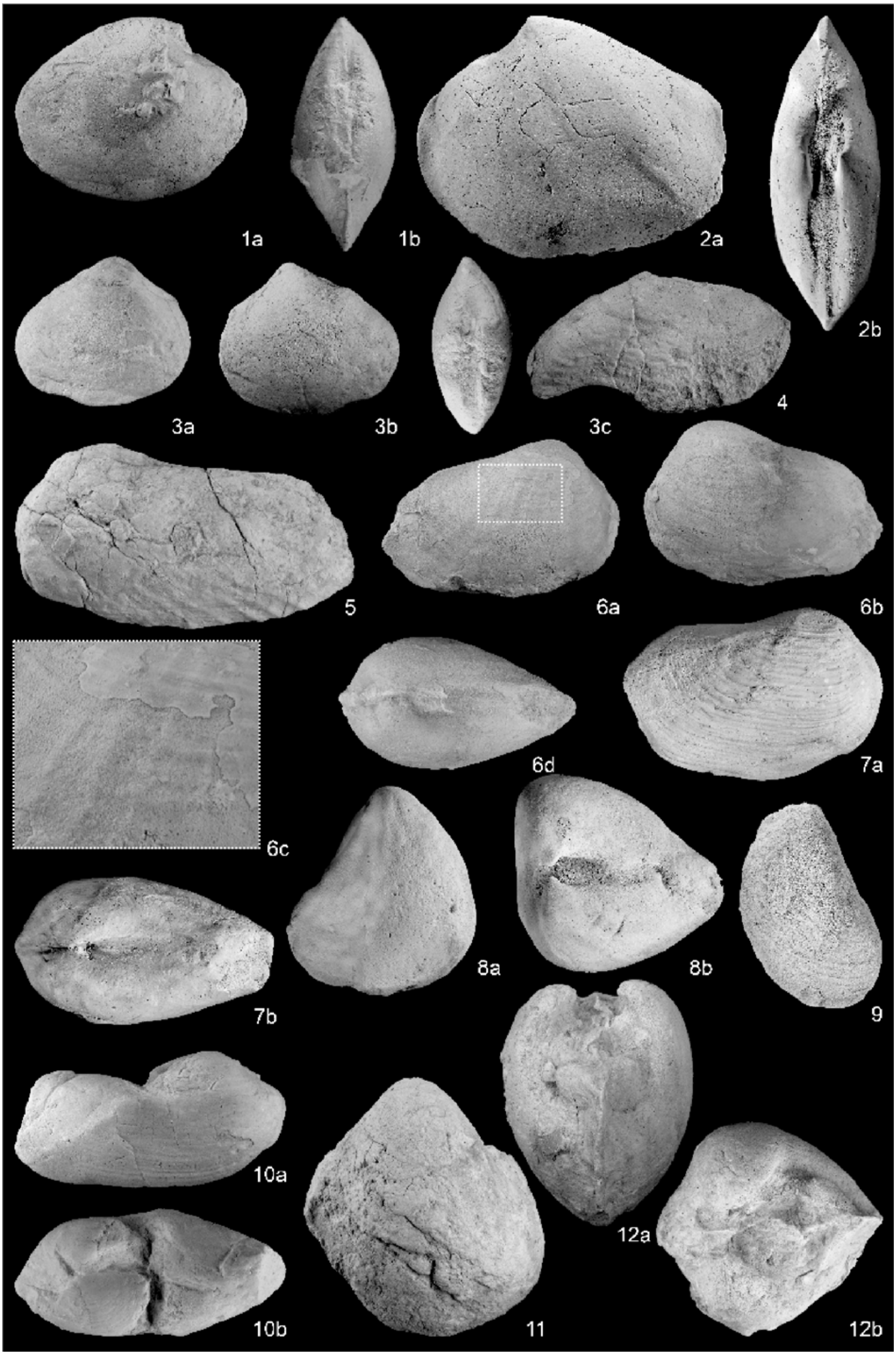
Fig. 5. *Pholadomya fabrina* D'ORBIGNY, 1845. Composite mould from the Upper Turonian Wata Formation of Wadi Quseib, x1.5. External view of left valve; MGDMU:WQ.Bi.**97**.28.

Figs. 6-7. *Pholadomya pedernalis* ROEMER, 1852. Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area. **6a**: Composite mould, external view of right valve, x1, **b**: side view of left valve, x1, **c**: close-up of ornamentation of right valve, x3, **d**: dorsal view, x1; MGDMU:ET.Bi.**23**.46. - **7a**: External view of right valve, x1; **b**: dorsal view, x1; MGDMU:ET.Bi.**23**.47.

Figs. 8-9. *Pholadomya vignesi* LARTET, 1877. Composite mould from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. **8a**: Side view of right valve, **b**: dorsal view; MGDMU:WQ.Bi.**44**.209. - **9**. External view of left valve; MGDMU:WQ.Bi.**44**.210.

Fig. 10. *Osteomya* sp., from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. a: Composite mould, external view of right valve, b: dorsal view; MGDMU:AEN.Bi.**13**.31.

Figs. 11-12. *Poromya*? *ligeriensis* (D'ORBIGNY, 1845). Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x0.75. **11**. Side view of left valve; MGDMU:WQ.Bi.**39**.183. - **12a**: Posterior view, **12b**: dorsal view; MGDMU:WQ.Bi.**39**.184.


1a
1b
2a
2b
3a
3b
3c
4
5
6a
6b
6c
6d
7a
7b
8a
8b
9
10a
10b
11
12a
12b

?2006 *Paraesa faba subfaba* (D'ORBIGNY) – EL QOT: 90, pl. 18, fig.2.
2007b *Paraesa faba faba* (SOWERBY) – MEKAWY: 235, pl. 5, figs. 14, 15.

Material and occurrence. 127 specimens from middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation and Turonian Abu Qada and Wata formations, beds 22, 44, 47, 49, 76, 93, and 97 at Wadi Quseib (MGDMU:WQ.Bi.**22**.76-78., **44**.149-198,**47**.34-55,**49**.1-10,**76**.1-20,**93**.4-13,**97**.16-27), 50 specimens from the Cenomanian Galala Formation and Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 12, 16, 17, 23, and 26 at East Themed (MGDMU:ET.Bi.**12**.113-117,**16**.435-464,**17**.88-90,**23**.38-45, **26**.119-122), and 24 articulate specimens from the lower marly and middle carbonate members of the Upper Albian-Cenomanian Halal Formation, beds 1 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**1**.106-110,**15**.91-125).

Measurements (in mm).

n=28	L	H	C	H/L	C/L	C/H
Range	13-30	13-27	9-15	0.76-1.09	0.31-0.68	0.38-0.79
Mean	19.46	17.21	12.25	0.88	0.50	0.56

Description. Valves small to medium-sized, ovate, inequilateral, equivalved, and moderately inflated. Length slightly exceeding height (H/L=0.88; Text-fig. 3.26A). Antero-dorsal margin below the umbones concave. Postero-dorsal margin slightly convex to straight and gently inclined. Anterior and posterior margins strongly convex. Ventral margin smooth, rounded, and merging into the anterior and posterior margins in even curves. Hinge of the right valve consisting of moderately well-developed teeth (3a and 3b, Text-fig. 3.26B). Lunule heart-shaped, shallow, and small. Umbones small, less prominent, and strongly incurved anteriorly. Ornamentation consisting of few, faint, commarginal ribs separated by wide interspaces.

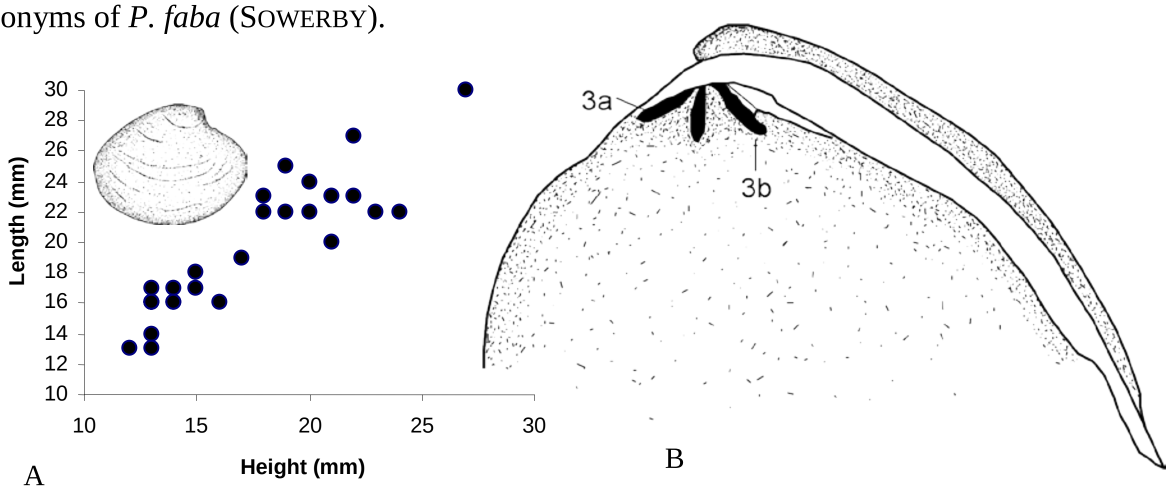
Temporal and spatial distribution. *Paraesa faba* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862), Upper Greensand of England (WOODS, 1908), Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Italy (TREVISAN, 1937), and Upper Albian-Upper Turonian of Morocco (FRENEIX, 1972). In Egypt, it occurs in the Cenomanian of the Eastern Desert (FOURTAU, 1917; GRECO, 1918; ABBASS, 1962; MEKAWY, 2007b), Gebel El Halal (FAWZI, 1963), G. El-Minsherah and G. El-Hamra (ABDEL-GAWAD & ZALAT, 1992; ABDELHAMID & EL QOT, 2002), Upper Cenomanian-Lower Turonian of G. Musabaa Salama (KASSAB & ISMAEL, 1994), G. El-Fallig (ABDEL-GAWAD et al., 2004b), and of the Cenomanian-Lower Campanian of G. Ekma, East Themed, and G. Yelleg (EL QOT, 2006).

Discussion. Many authors referred the present species to the genus *Meretrix* LAMARCK, 1799. Recently, FRENEIX (1972), ORABI (1993), and EL QOT (2006) used the genus *Paraesa* GASEY, 1952 instead of the genus *Meretrix*. All the collected specimens are either internal moulds or articulated valves and the hinge and other internal characters of the specimens are unknown. However, a polished section of the hinge indicates that the hinge is closely similar to the hinge of the genus *Paraesa* (Text-fig. 3.26B). In addition, morphologically the present material is closely similar to the genus *Paraesa* in general outline (ovate) and ornamentation. Therefore, the species is referred herein to the genus *Paraesa*.

Venus reynesi COQUAND, 1862 and *V. dutrugei* COQUAND, 1862 closely resemble the present species in general outline and ornamentation and are considered herein as a junior synonym of *P. faba*. In agreement with FRENEIX (1972) and EL QOT (2006) both *Venus* (?)

sublaevis and *V. immersus* of J. DE C. SOWERBY, 1836 as figured by WOODS (1908) are also regarded as junior synonyms of *P. faba* the latter having priority.

FRENEIX (1972) subdivided this species into two subspecies, *P. faba faba* (SOWERBY) and *P. faba subfaba* (D'ORBIGNY). She pointed out that the latter subspecies differs in having finer and more numerous commarginal ribs and it is widely distributed in the Senonian of Europe, but in Africa only occurs in the Cenomanian and Turonian. In fact, FRENEIX'S specimens are not well preserved and her two subspecies are closely similar in general outline, size, and ornamentation. Therefore, the two subspecies of FRENEIX probably are synonyms of *P. faba* (SOWERBY).



Text-fig. 3.26. Biometric data (A) and hinge of the right valve (B) of *Paraesa faba* (J. DE C. SOWERBY, 1827).

Subfamily Meretricinae GRAY, 1847
Genus *Meretrix* LAMARCK, 1799
Meretrix desvauxi (COQUAND, 1862)
Pl. 14, Fig. 2

1862 *Venus Desvauxi* sp. nov. – COQUAND: 194, pl. 8, figs. 1-2.
1962 *Meretrix desvauxi* COQUAND – ABBASS: 145, pl. 23, fig. 2.

Material and occurrence. 52 internal moulds from the upper carbonate member of the Cenomanian Galala Formation and Lower Turonian Abu Qada Formation, beds 44, 57, and 58 at Wadi Quseib (MGDMU:WQ.Bi.**44**.199-208,**57**.1-12,**58**.31-60) and 24 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 25, 26 at the East Themed area (MGDMU:ET.Bi.**25**.63-67,**26**.123-142).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	54-57	40-44	18-20	0.74-0.77	0.33-0.35	0.45-0.45
Mean	55.5	42	19	0.75	0.34	0.45

Description. Valves large, elongated-ovate, equivalved, inequilateral, and compressed (C/L=0.34). Antero-dorsal margin slightly concave. Postero-dorsal margin convex and higher than the antero-dorsal one. Ventral margin broadly curved. Umbones little prominent, slightly incurved anteriorly, and placed about 33% of the shell length from the anterior end. Lunule small, narrow, and ovate. Escutcheon deep and long. Ornamentation not preserved.

Temporal and spatial distribution. *Meretrix desvauxi* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862). In Egypt, it occurs in the Cenomanian of Sinai (ABBASS, 1962).

Discussion. The present species can be easily distinguished from other *Meretrix* species described here in being larger and in having a deep and long lunule and escutcheon. *M. ricordlana* (D'ORBIGNY, 1844) as figured by ABBASS (1962: 147, pl. 22, fig. 20) from the Cenomanian of Sinai differs in being subtriangular, more concave antero-dorsally, and slightly longer than high (H/L=0.85).

Meretrix orientalis DOUVILLÉ, 1916
Pl. 14, Fig. 3

1916 *Meretrix* (*Flaventia*) *orientalis* sp. nov. – DOUVILLÉ: 150, pl. 19, figs. 12-13.
1955 *Meretrix* (*Flaventia*) *orientalis* DOUVILLÉ – MAHMOUD: 124, pl. 10, figs. 23-27.

Material and occurrence. 12 articulated specimens (internal and composite moulds) from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 5 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**5**.34-45).

Measurements (in mm).

n=12	L	H	C	H/L	C/L	C/H
Range	12-22	10-28	5-12	0.74-1.16	0.42-0.61	0.39-0.78
Mean	18.47	17.52	9.29	0.95	0.50	0.54

Description. Valves small, subtriangular, moderately inflated, inequilateral and equivalved. Antero-dorsal margin below umbo slightly concave. Postero-dorsal margin straight. Ventral margin convex and meeting the anterior and posterior margins in even curves. Umbones less prominent, nearly prosogyrate, and situated about 45% of shell length from the anterior end. Ornamentation consisting of a few commarginal ribs separated by wide interspaces of nearly equal width.

Temporal and spatial distribution. *Meretrix orientalis* has been recorded from the Upper Albian of Gebel Manzour, Sinai (DOUVILLÉ, 1916; MAHMOUD, 1955).

Discussion. The present specimen closely resembles *Meretrix orientalis* DOUVILLÉ (1916). *M. orientalis* differs from *Paraesa faba* (J. DE C. SOWERBY, 1827) in having a triangular shell, more prominent umbones, and a slightly concave postero-dorsal margin. *M. magharensis* ABBASS (1962: 144, pl. 22, figs. 12-14) from the Albian of El Maghara area differs only in having a nearly truncated postero-dorsal margin.

Bivalve gen. et sp. indet.
Pl. 14, Fig. 4; Text-fig. 3.27

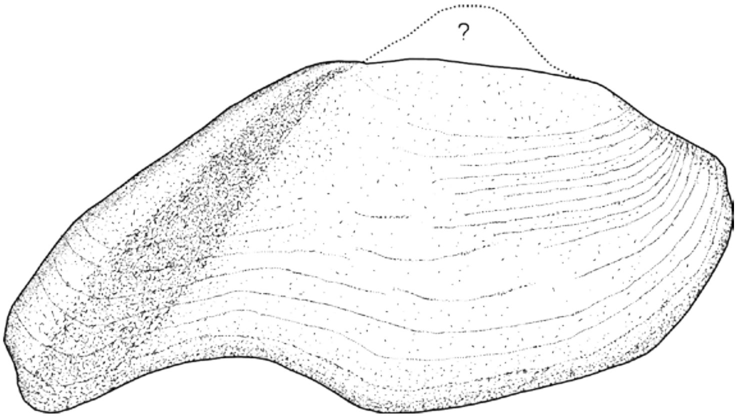
Material and occurrence. One incomplete composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**15**.126).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	45	28	13	0.62	0.29	0.46

Description. Outline subtrapezoidal, medium-sized, length greatly exceeds height (H/L=0.62), strongly inequilateral, and moderately inflated. Anterior margin convex. Postero-dorsal margin long, convex, and steeply inclined ventrally. Ventral margin folded and broad. Both valves with large and wide keel. This keel extends from the umbonal area towards the postero-ventral side. Umbones not preserved. Hinge and internal features not seen. Ornamentation consisting of strong commarginal ribs, separated by wide and concave interspaces. These ribs parallel the ventral margin (Text-fig. 3.27). The interspaces become wider towards the postero-ventral margin and narrower towards the antero-dorsal side.

Discussion. The present material resembles the genus *Rostrocorbula* Harper et al. (2002: 764, text-fig. 3a-b), of the family Corbulidae Lamarck, 1818, in general outline and ornamentation. *Rostrocorbula ibbetsoni* (Morris, 1853) of Harper et al. (2002) differs in being much smaller and having a more inflated shell with more spatulated posteior margin. In addition, this species has been recorded from an older stratigraphic level (Middle Jurassic) of England.



Text fig. 3.27. External view and ornamentation of right valve of bivalve gen. et sp. indet. from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa.

Superorder Anomalodesmata Dall, 1889 (1899)
Order Pholadomyoida Newell, 1965
Superfamily Pholadomyacea (King 1844) Gray 1847
Family Pholadomyidae Gray, 1847

Genus *Pholadomya* J. de C. Sowerby, 1823
Pholadomya fabrina d'Orbigny, 1845
Pl. 14, Fig. 5

1845 *Pholadomya Fabrina* sp. nov. – d'Orbigny: 345, pl. 363, figs. 6-7.
1909 *Pholadomya Fabrina* d'Orbigny – Woods: 250, pl. 41, fig. 6.

Material and occurrence. Three composite moulds from the Upper Turonian Wata Formation, bed 97 at Wadi Quseib (MGDMU:WQ.Bi.**97**.28-30).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	41	22	17	0.54	0.41	0.77

Description. Specimen medium-sized, elongated-ovate, equivalved, strongly inequilateral, and slightly inflated below umbones. Posterior part of the specimen more compressed than the anterior one. Posterior end higher than anterior end. Both anterior and posterior margins strongly convex and meeting the broad undulating ventral margin in even curves. Antero-dorsal margin short and straight. Postero-dorsal margin long and slightly concave. Umbones broad, little prominent and placed anteriorly. Ornamentation consisting of strong radial ribs (about 13) separated by smooth interspaces. Interspaces wide ventrally and narrow dorsally. The radial ribs of the two valves meet at the ventral margin and cause its wavy or undulating course. Radials crossed by numerous, fine, commarginal growth lines.

Temporal and spatial distribution. *Pholadomya fabrina* has been recorded from the Upper Cretaceous of England (WOODS, 1909). This is the first record of the species from the Turonian of Egypt.

Discussion. *Pholadomya sinaiensis* ABBASS (1962: 159, pl. 24, fig. 5) from the Cenomanian of Gebel Safra (Sinia) resembles the present species in general shape and outline but differs in having a longer anterior part and more prominent umbones.

Ph. (*Ph.*) *romani* AMARD et al. (1981: 105, pl. 15, figs. 1-2) from the Maastrichtian of Algeria differs in having just a few strong radial ribs, wider interspaces, and a higher shell.

Ph. pedisulcata STOLICZKA (1871: pl. 4, fig. 1) from the Upper Cretaceous of India is similar to the present material in having an elongated-ovate shell but differs in having well developed commarginal ribs, the radial ribs being restricted to the anterior side.

Pholadomya pedernalis ROEMER, 1852
Pl. 14, Figs. 6-7

1852 *Pholadomya pedernalis* sp. nov. – ROEMER: 45, pl. 6, fig. 4.
1912 *Pholadomya Pedernalis* ROEMER – PERVINQUIÈRE: 288, pl. 21, figs. 5-7.
1934 *Pholadomya pedernalis* ROEMER – BLANCKENHORN: 261.
1958 *Pholadomya pedernalis* ROEMER – BARBER: 28, pl. 8, fig. 5; pl. 9, figs. 8, 9.
1962 *Pholadomya pedernalis* ROEMER – ABBASS: 161, pl. 24, fig. 4.
2002 *Pholadomya pedernalis* ROEMER – ABDEL-GAWAD & GAMEIL: 97, pl. 4, figs. 9, 10.
2002 *Pholadomya pedernalis* ROEMER – ABDELHAMID & EL QOT: 284, pl. 7, fig. 6.
2004b *Pholadomya pedernalis* ROEMER – ABDEL-GAWAD et al.: pl. 4, fig. 5.
2006 *Pholadomya* (*Pholadomya*) *pedernalis* ROEMER – EL QOT: 90, pl. 18, figs. 4, 5a-b.
2007b *Pholadomya* (*Pholadomya*) *pedernalis* ROEMER – MEKAWY: 236, pl. 5, figs. 16, 17.
2008 *Pholadomya* (*Pholadomya*) *pedernalis* ROEMER – MEKAWY & ABU-ZIED: 314, pl. 3, fig. 13.

Material and occurrence. 41 composite moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation and Upper Turonian Wata Formation, beds 17, 19, 23, 25, 26, and 31 at East Themed (MGDMU:ET.Bi.**17**.91-92,**19**.93-100,**23**.46-49,**25**.68-73,**26**.143-154, **31**.41-49), and six composite moulds from the Upper Turonian Wata Formation, beds 72 and 93 at Wadi Quseib (MGDMU:WQ.Bi.**72**.11,**93**.14-18).

Measurements (in mm).

n=4	L	H	C	H/L	C/L	C/H
Range	37-46	27-31	20-27	0.61-0.78	0.50-0.62	0.74-0.90
Mean	42	29	24	0.69	0.56	0.82

Description. Moulds medium-sized, ovate to subtrigonal, equivalved, strongly inequilateral, and more inflated anteriorly. Anterior and posterior margins strongly convex. Anterior end nearly as high as posterior end. Ventral margin broadly convex and meeting both anterior and posterior margin in even curves. Antero-dorsal margin short and straight, postero-dorsal margin long and slightly concave. Umbones broad, incurved, and placed anteriorly. Escutcheon shallow. Ornamentation consisting of faint tuberculate radial ribs separated by wide interspaces. These ribs are crossed by coarse, irregular commarginal ribs, which are well developed posteriorly and die out anteriorly. In a few specimens ornamentation consists mainly of strong commarginal ribs without radial ribs (Pl. 14, Fig. 7).

Temporal and spatial distribution. *Pholadomya pedernalis* has been recorded from the Turonian of Texas (ROEMER, 1852), Nigeria (BARBER, 1958), Tunisia (PERVINQUIÈRE, 1912), and Syria (BLANCKENHORN, 1934). In Egypt, it is known from the Cenomanian-Turonian of Gebel Ekma, East Themed, and G. Yelleg (EL QOT, 2006), Cenomanian of G. El-Fallig (ABDEL-GAWAD et al., 2004b), and the Turonian of G. El-Hamra (ABDELHAMID & EL QOT, 2002), and G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002). The species has been recorded also from the Cenomanian-Turonian of the Eastern Desert (MEKAWY & ABU-ZIED, 2007).

According to PERVINQUIÈRE (1912: 289), this species occurs also in the Aptian of France and Algeria and the "Vraconian" (latest Albian) of Texas. In addition, ZIKO et al. (1993: 142) collected the species from the Santonian Themed Formation, Egypt. Its total range is therefore Aptian to Santonian.

Discussion. The general outline and ornamentation of the present material agrees with *Pholadomya pedernalis* ROEMER (1852). However, a few specimens in the present study lack radial ribs and are composed mainly of strong commarginal ribs. According to PANDEY et al. (1996: 54), *Ph.* (*Ph.*) *inornata* of BASSE (1955) (also in their material (pl. 2, fig. 1 from India)) lacks any radial ribs. In their description of their new species *Ph.* (*Ph.*) *kachchhensis* (1996: 53, pl. 1, figs. 1-4, 6-10) from India the same auhtors noted that the radial ribs are virtually absent in some populations.

Ph. coxi ABBASS (1962: 158, pl. 24, fig. 3) from the Cenomanian of Gebel El Tih differs from the present species in having a more triangular outline and radial ribs which are well developed anteriorly below the umbones. *Ph. safrensis* ABBASS (1962: 160, pl. 24, fig. 2) from the Cenomanian of G. Safra differs in having a higher shell with more numerous radial ribs (14-18). ABBASS (1962: 161) discussed the differences between *Ph. pedernalis* and other European and American species such as *Ph. elliptica* STURM (1900: pl. 8, fig. 9), *Ph. parvula* ROEMER (1846: pl. 10, fig. 19), and *Ph. papyracea* MEEK (1893: pl. 26, fig. 1).

According to MEKAWY (1007b: 315), *Ph.* (*Ph.*) *gigantea* (J. DE C. SOWERBY, 1836) differs from the present species in being less elongated and in having fewer and strong commarginal ribs, which are crossed by strong radial ribs.

Ph. connectans FORBES (1846: 140, pl. 17, fig. 5) from the Upper Cretaceous of southern India is similar to *Ph. pedernalis* in style of ornamentation but differs in having more prominent umbones (nearly orthogyrate) and radial ribs being confined to the posterior flank.

According to BARBER (1958: 29), *Ph. fontannesi* CHOFFAT from the Cenomanian of Portugal has finer and more numerous radial ribs, while the umbones of *Ph. nauliensis* COX (1952: 28, pl. 2, fig. 7) are not anteriorly placed.

Pholadomya vignesi LARTET, 1877
Pl. 14, Figs. 8-9

1880 *Pholadomya Vignesi* sp. nov. – LARTET: 126, pl. 11, fig. 9.
1912 *Pholadomya Vignesi* LARTET – PERVINQUIÈRE: 290, pl. 21, figs. 8-9.
1917 *Pholadomya Vignesi* LARTET – FOURTAU: 93, pl. 7, fig. 6.
1934 *Pholadomya vignesi* LARTET – BLANCKENHORN: 261.
1962 *Pholadomya vignesi* LARTET – ABBASS: 157, pl. 24, figs. 7-8.
1963 *Pholadomya vignesi* LARTET – FAWZI: 86.
1981 *Pholadomya* (*Procardia*) *vignesi* LARTET – AMARD et al.: 82, pl. 2, figs. 3-4.
2002 *Pholadomya vignesi* LARTET – ABDEL-GAWAD & GAMEIL: 97, pl. 4, fig. 11.
2002 *Pholadomya vignesi* LARTET – ABDELHAMID & EL QOT: 286, pl. 7, figs. 7-8.
2006 *Pholadomya* (*Pholadomya*) *vignesi* LARTET – EL QOT: 91, pl. 18, fig. 8.

Material and occurrence. 18 composite moulds from the lower 3 m (nodular rudstone) of the upper carbonate member of the Cenomanian Galala Formation, bed 44 at Wadi Quseib (MGDMU:WQ.Bi.**44**.209-226), and 15 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 12 of the East Themed area (MGDMU:ET.Bi.**12**.118-132).

Measurements (in mm).

n=5	L	H	C	H/L	C/L	C/H
Range	30-38	21-38	18-34	0.70-1.03	0.58-0.92	0.61-0.89
Mean	33.6	30.80	24	0.91	0.71	0.79

Description. Valves medium-sized, subtrigonal, equivalved, inequilateral, slightly longer than high, and strongly inflated (C/H=0.79). Umbones prominent, sharply pointed, and slightly incurved anteriorly. Anterior part shorter and higher than the posterior one. Anterior margin convex and meeting the ventral margin in rounded angle. Ventral margin strongly convex. Postero-dorsal margin straight and sloping gently the from the umbones. Ornamentation consisting of strong commarginal ribs separated by narrow interspaces, and crossed by few, strong, radial ribs. These commarginal ribs are well developed near the ventral margin.

Temporal and spatial distribution. *Pholadomya vignesi* has been recorded fron the Upper Cenomanian of Tunisia (PERVINQUIÈRE, 1912), Syria (BLANCKENHORN, 1934), and Algeria AMARD et al. (1981). In Egypt, it is known from the Cenomanian of the Eastern Desert (FOURTAU, 1917; ABBASS, 1962; FAWZI, 1963), G. El-Minsherah and G. El-Hamra (ABDELHAMID & EL QOT, 2002), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 2002), and G. Ekma, East Themed (EL QOT, 2006). According to EL QOT (2006: 91), the present species is widespread in the Cenomanian, and has been recorded from the Turonian of Madagascar. Therefore, the stratigraphic range of *Ph. vignesi* ranges from the Cenomanian to the Turonian.

Discussion. *Pholadomya vignesi* differs from *Ph. pedernalis* in style of ornamentation and general outline. ABBASS (1962: 158, pl. 24, fig. 3) erected the new species *Ph. coxi* from the Cenomanian of Gebel El Tih. He noted that his new species differs from the other Egyptian Cretaceous pholadomyids in having a more triangular outline and radial ribs which are well developed anteriorly (below the umbones). The present species resembles ABBASS'S species in general outline but differs only in having strong commarginal ribs which cover the entire surface. *Ph. subcaudata* BRIART & CONRAD (1867: pl. 6, figs. 19-20) resembles *Ph. vignesi* in outline but has finer and more numerous radial and commarginal ribs (for more detalied discussion, see ABBASS, 1962: 157-158).

Genus *Osteomya* MOESCH, 1874
Osteomya sp.
Pl. 14, Fig. 10

Material and occurrence. One composite mould from the middle carbonate member of the Halal Formation, bed 13 at Gebel Areif El-Naqa (MGDMU:AEN.Bi.**13**.31).

Measurements (in mm).

n=1	L	H	C	H/L	C/L	C/H
	49	23	21	0.47	0.43	0.91

Description. Medium-sized, broadly ovate, equivalved, strongly inequilateral, and strongly inflated. Posterior end much longer than the anterior one. Ventral margin long, broadly rounded, and meeting the posterior and anterior margins in even curves. Antero-dorsal margin short and slightly concave. Postero-dorsal margin long and slightly concave. Umbones broad, prosogyrate, and located at about one-fourth of the shell length from the anterior end. Ornamentation consisting of irregular commarginal ribs separated by wide interspaces. These ribs become regular and finer towards the umbonal area.

Order Septibranchia PELSENEER, 1889
Superfamily Poromyacea DALL, 1886
Family Poromyidae DALL, 1886

Genus *Poromya* FORBES, 1844
Poromya? *ligeriensis* (D'ORBIGNY, 1845)
Pl. 14, Figs. 11-12

1845 *Pholadomya ligeriensis* sp. nov. – D'ORBIGNY: 395, pl. 363, figs. 8-9.
1912 *Liopistha* (*Psilomya*) *Ligeriensis* D'ORBIGNY – PERVINQUIÈRE: 292, pl. 20, fig. 22.

Material and occurrence. Two internal moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 39 at Wadi Quseib (MGDMU:WQ.Bi.**39**.183-184).

Measurements (in mm).

n=2	L	H	C	H/L	C/L	C/H
Range	52-58	66-68	52-55	1.17-1.26	0.95-1	0.79-0.81
Mean	55	67	53.5	1.21	0.97	0.80

Description. Valves quadrangular, large-sized, elongated posteriorly, higher than long (H/L=1.21), strongly inequilateral, equivalved, and strongly inflated (C/L=0.97). Both anterior and posterior margins straight, truncated, and forming an approximately right angle with the hinge. Anterior margin shouldered and higher than the posterior one. Ventral margin broadly convex and meeting the anterior and posterior margins in an even curve. Umbones broad, prominent, sharply pointed, widely separated, slightly incurved anteriorly, and situated approximately two-fifths of the shell length from the anterior end. Imprints of the large and ovate distinct posterior adductor scars (Pl. 14, Fig. 12a). Hinge margin straight, long, and inclined posteriorly. Ornamentation consisting of fine commarginal ribs.

Temporal and spatial distribution. *Poromya ligeriensis* has been recorded from the Cenomanian of Tunisia (PERVINQUIÈRE, 1912). This is the first record of the species from Egypt.

Discussion. The classification as *Poromya* was mainly based on outline and ornamentation. The present material is an articulated mould, so the hinge and other internal characters are not seen. Therefore, the genus *Poromya* herein is doubtfully used. The present material is very similar to the forms described by PERVINQUIÈRE (1912) from Tunisia in general outline. *Liopistha* (*Psilomya*) *giggantea* J. DE C SOWERBY 1909 as figured by PERVINQUIÈRE (1912: 292, pl. 20, fig. 21) from the Aptian of Tunisia differs in having strong commarginal ribs, less inflated, less sharp umbones, and a compressed posterior side.

3.3. Class Gastropoda CUVIER, 1797

The terminology for the description of the gastropods follows the glossary presented by COX (1960) in the *Treatise on Invertebrate Paleontology*, Part 1 (Gastropoda). For the spire and size of the specimens, the present work follows HONG-FU & YOCHELSON (1983). They divided the specimens according to the size into small (< 1.0 cm); moderately small (1.0 to 1.5 cm); medium (1.5-2.0 cm); moderately large (2.0-2.5 cm); and large (>2.5 cm). They classified the spire into low-spired (pleural angle >110º); moderately low-spired (angle 90º-110º); moderately high-spired (angle 50º-90º), and high-spired (< 50º). The classification used here is that of BOUCHET & ROCROI (2005).

All linear measurements (taken with Vernier Caliper) are given in millimetres.
Abbreviations of measured parameters:

n: number of measured specimens;
H: height;
D: maximum diameter;
HL: height of last whorl;
HA: height of aperture;
WA: width of aperture;
PAº: pleural angle (in degrees);
nr: number of axial ribs;
ns: number of spiral lines; and
nw: number of whorls.

Clade Vetigastropoda SALVINI-PLAWEN, 1980
Superfamily Trochoidea RAFINESQUE, 1815
Family Trochidae RAFINESQUE, 1815

Subfamily Trochinae RAFINESQUE, 1815
Genus *Calliomphalus* COSSMANN, 1888
Calliomphalus orientalis (DOUVILLÉ, 1916)
Pl. 15, Fig. 1

1916 *Metriomphalus orientalis* sp. nov. – DOUVILLÉ: 145, pl. 18, fig. 31.
1991 *Metriomphalus orientalis* DOUVILLÉ – ABOUL ELA et al.: pl. 2, fig. 1.
1992 *Calliomphalus* (*Calliomphalus*) *orientalis* (DOUVILLÉ) – ABDEL-GAWAD & GAMEIL: 71, fig. 2/1.
2002 *Calliomphalus orientalis* (DOUVILLÉ) – BERNDT: 138, pl. 9, fig. 3.
2006 *Calliomphalus* (*Calliomphalus*) *orientalis* (DOUVILLÉ) – EL QOT: 93, pl. 19, fig. 1.

2008 *Calliomphalus* (*Calliomphalus*) *orientalis* (DOUVILLÉ) – MEKAWY & ABU ZIED: 317, pl. 4, fig. 3.

Material and occurrence. Two composite moulds from the upper carbonate member of the Cenomanian Galala Formation, bed 44 at Wadi Quseib (MGDMU:WQ.G.**44**.227-228).

Measurements (in mm).

n=1	H	D	HL	HA	WA	D/H	HL/H	WA/HA
	21	27	13	12	15	1.28	0.62	1.25

Description. Medium-sized, turbiniform, moderately high-spired, wider than high (D/H=1.28), and phaneromphalous. Spire conical and consisting of two overlapping convex whorls. Sutures weakly impressed. Body whorl accounting for more than half of the shell height. Aperture large and rounded. Inner lip concave. Base convex. Ornamentation consisting of fine spiral cords separated by wide interspaces, which are well developed on body whorl.

Temporal and spatial distribution. *Calliomphalus orientalis* has been recorded from the Cenomanian of Jordan (BERNDT, 2002). In Egypt, it is known from the Vraconian (=Latest Albian) of Gebel Manzour (DOUVILLÉ, 1916; ABOUL ELA et al., 1991), Cenomanian of Gebel Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. Ekma (EL QOT, 2006), and from the Upper Barremian-Upper Cenomanian of G. Risan Aneiza and G. Tourkumanyia (MEKAWY & ABU-ZIED, 2008). The stratigraphic range of the species ranges from the Barremian to the Cenomanian.

Discussion. The present specimen closely resembles *Calliomphalus orientalis* (DOUVILLÉ, 1916), which was originally described from the Upper Vraconian (=Latest Albian) of Gebel Manzour, Sinai in size and general outline. It is also very similar to *C. orientalis* (DOUVILLÉ) as figured and described by MEKAWY & ABU-ZIED(2008) from Upper Barremian-Lower Albian of Sinai.

EXPLANATION OF PLATE 15

Fig. 1. *Calliomphalus orientalis* (DOUVILLÉ, 1916). Composite mould from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x2. **a**: Abapertural view, **b**: apertural view, **c**: apical view; MGDMU:WQ.G.**44**.227.

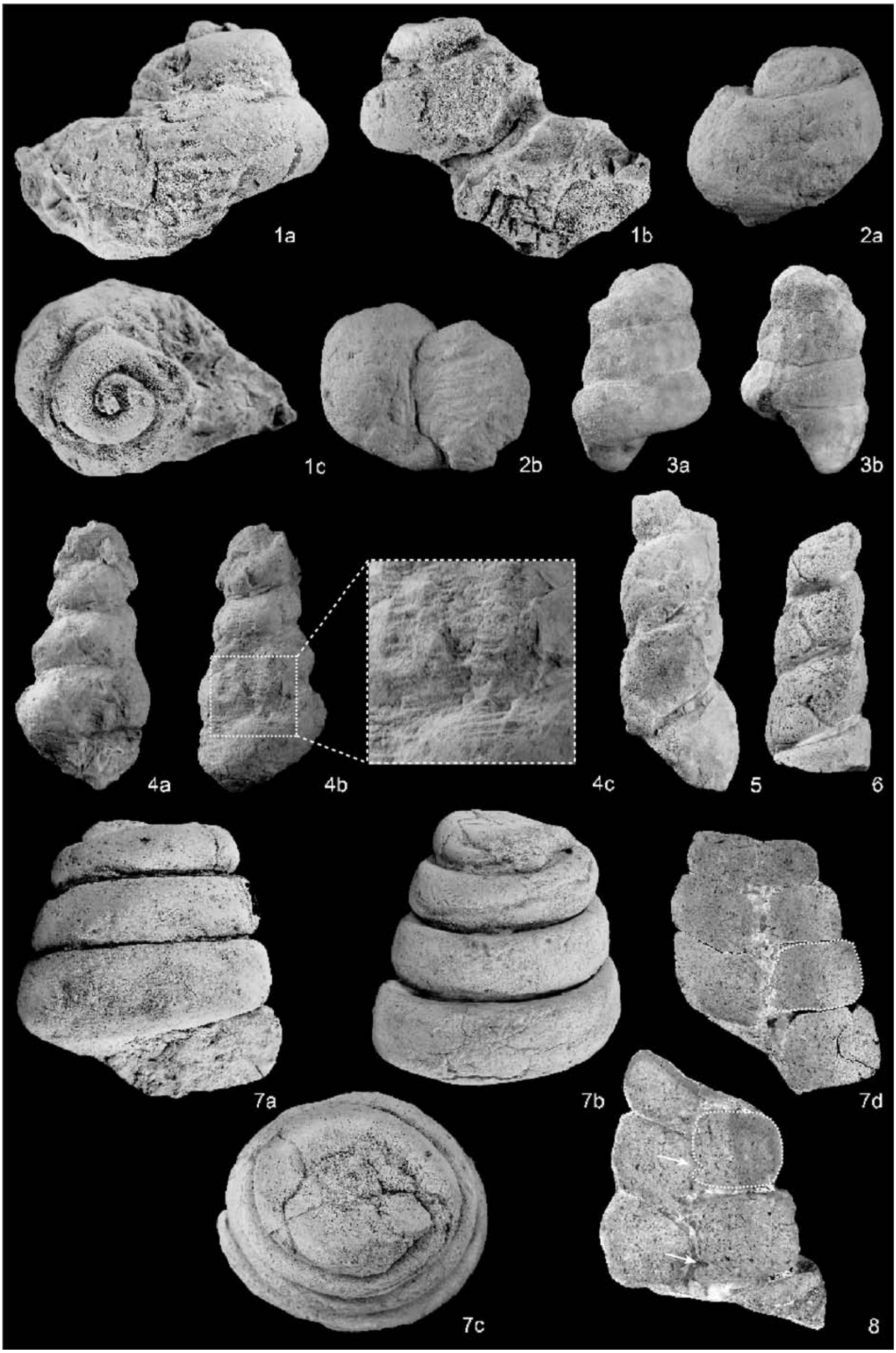
Fig. 2. *Neritopsis* sp. Composite mould from the Cenomanian Galala Formation of the East Themed area, x1. **a**: Abapertural view, **b**: apertural view, x1; MGDMU:ET.G.**3**.129.

Fig. 3. *Cerithium* cf. *mogharense* DOUVILLÉ, 1916. Composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. **a, b**: Side view; MGDMU:AEN.G.**15**.127.

Fig. 4. *Pyrazus valeriae* (DE VERNEUIL & DE LORIÈRE, 1868). Composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **a**: Apertural view, x1, **b**: abapertural view, x1, **c**: details of the abapertural spiral ornamentation, x3; MGDMU:AEN.G.**15**.128.

Figs. 5-6. *Turritella* cf. *difficilis* D'ORBIGNY, 1842. Internal mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **5**. Side view, x1; MGDMU:AEN.G.**15**.131. – **6**. Side view, x1.5; MGDMU:AEN.G.**15**.132.

Figs. 7-8. *Campanile* (*Campanile*) *ganesha* (NOETLING, 1897). Internal mould from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. **7a**: Apertural view, **b**: abapertural view, **c**: apical view, **d**: axial whorl section; MGDMU:WQ.G.**44**.229. - **8**. Axial section showing the whorl folds (arrowed); MGDMU:WQ.G.**44**.244.


1a
1b
2a
1c
2b
3a
3b
4a
4b
4c
5
6
7a
7b
7d
7c
8

According to Abdel-Gawad & Gameil (1992), *C. orientalis* differs from *C.* (*C.*) *dichotomus* (Alth, 1850) by its less convex whorls and the possession of tubercles. *C.* (*C.*) *biomstrofensis* (Griepenkerl, 1889) differs in having a large number of spiral cords with narrow interspaces.

Clade Neritimorpha Golikoc & Starobogatov, 1975
(=Neritopsina Gray, 1847)
Clade Cycloneritimorpha (Bandel & Frỳda, 1999)
Superfamily Neritopsoidea Gray, 1847
Family Neritopsoidae Gray, 1847
Subfamily Neritopsinae Gray, 1847
Genus *Neritopsis* Grateloup, 1832
Neritopsis sp.
Pl. 15, Fig. 2

Material and occurrence. One composite mould from the Cenomanian Galala Formation, bed 3 of the East Themed area (MGDMU:ET.G.**3**.129).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
	34	37	32	27	21	113°	1.10	0.94	0.78

Description. Large-sized, neritoid, globose, and low-spired gastropod. Spire slightly protruding above the last whorl and consisting of two rapidly enlarging whorls. Whorls slightly convex and separated by moderately deep sutures. Body whorl globose with evenly convex flanks and forming the main part of the specimen (about 94% of the total height). Base broadly rounded with small and slightly closed umbilicus. Aperture rounded and relatively large with convex outer lip and concave inner lip. Ornamentation consisting of fine spiral cprds separated by narrow interspaces. These spiral lines are well developed anteriorly (Pl. 15, Fig. 2b).

Discussion. The genus *Neritopsis* is characterized by a low-spired shell with two compressed whorls. The aperture is rounded, large, and umbilicate,.the inner lip is concave, and the surface is covered by numerous fine spiral threads.

The present specimen closely resembles *Neritopsis kasei* Kiel & Bandel (2004: 116, fig. 6N-O) from the Cenomanian of Kassenberg (Germany) in having spiral cords, a concave inner lip, and a similar aperture outline, but differs in having wider whorls and being large. *N. abbatei* Peron & Fourtau, 1904 of Greco (1916: 118, pl. 15, fig. 7) from the Maastrichtian of Egypt is similar to the present specimen in its general shape and ornamentation but differs in being smaller with more depressed whorls. In addition, its stratigraphic range is from the Coniacian to the Maastrichtian (El Qot, 2006: 94). *N. ilerdensis* Vidal, 1921 of Bandel & Kiel (2003: 54, pl. 1, figs. 1-3) from the Campanian of Spain differs in being smaller with pointed apex.

Clade Caenogastropoda Cox, 1960
Clade Sorbeoconcha Ponder & Lindberg, 1996
Superfamily Cerithioidea Fleming, 1822
Family Cerithiidae Fleming, 1822
Subfamily Cerithiinae Fleming, 1822

Genus *Cerithium* BRUGUIÉRE, 1789
Cerithium cf. *mogharense* DOUVILLÉ, 1916
Pl. 15, Fig. 3

cf. 1916 *Cerithium* (*Uchauxia*) *mogharense* sp. nov. – DOUVILLÉ: 137, pl. 18, fig. 9.

Material and occurrence. One incomplete composite mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**15**.127).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
	>25	15	11	9	7	42°	5	0.60	0.44	0.77

Description. Medium-sized, turriculate, and high-spired gastropod. Spire moderately wide and consisting of four overlapping whorls, which are slightly convex in outline. Diameter increases gradually from the apex to the aperture. Whorls separated by moderately deep sutures. Apex not preserved. Body whorl small with slightly convex flanks and a sharp base. Aperture small and lanceolate. Ornamentation consisting of about 22 tuberculate axial ribs separated by wide interspaces.

Temporal and spatial distribution. *Cerithium mogharense* has been recorded from the Upper Albian of Gebel Manzour, Sinai (DOUVILLÉ, 1916).

Discussion. The present material is very similar to *Cerithium* (*Uchauxia*) *mogharense* DOUVILLÉ in general shape, ornamentation, and suture, but differs in having wider and compressed whorls. *Libycerithium dachelense* (WANNER, 1902), which has been described by ABBASS (1963: 57, pl. 3, figs. 17-18) from the Danian of the Dakhla Oasis, resembles the present material in general shape but differs in having 25 strong axial ribs, crossed by 4-5 spiral cords with deep suture. In addition, ABBASS (1963: 57) differentiated *C. formosum* ZEKELI (1852) from his materials by having only 10 axial ribs crossed by five strong spirals.

Metacerithium? sp. of KIEL & BANDEL (2004: 118, fig. 7C) from the Cenomanian of Germany differs in having two tuberculate ridges, one at the upper suture, the other at the lower suture with nearly flat sides.

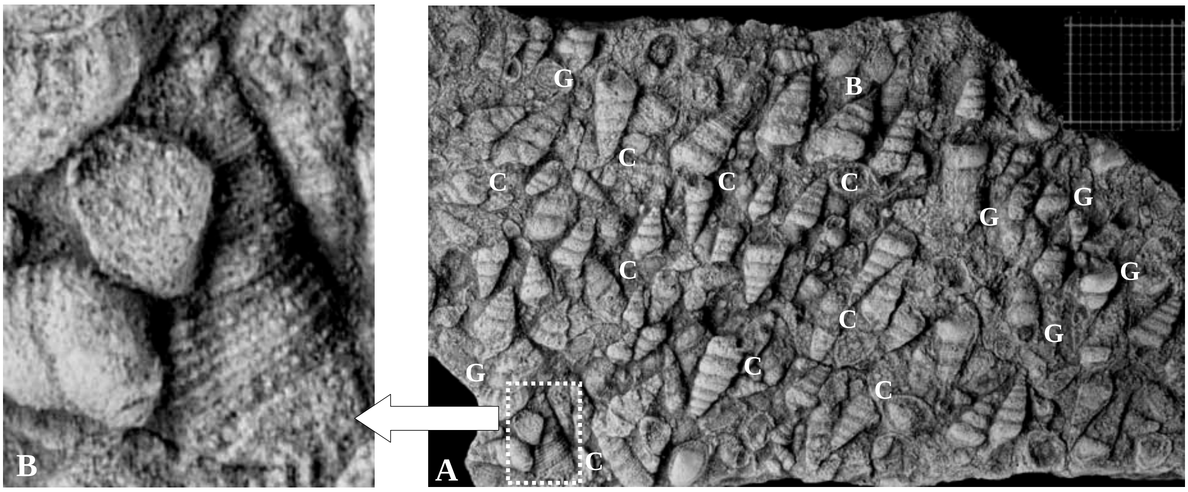
Cerithium? sp.
Text-fig. 3-28

Material and occurrence. Numerous composite moulds (about 100 specimens) from the Upper Turonian Wata Formation, beds 55, 85, and 92 at Wadi Quseib (MGDMU:WQ.G.**55**.21-70,**85**.1-100,**92**.1-3).

Description. Small- to moderately small-sized (H=5-13 mm, D=3-5 mm), turriculate to conical, and high-spired gastropods (spire angle 28˚-38˚). Spire elongated and consisting of about 6-8 overlapping whorls separated by moderately deep sutures. Whorl surfaces slightly convex to flat and its width nearly twice the height of the specimen. In other specimens, aperture small and lanceolate with small anterior notch. Each whorl ornamented with about 6-8 tuberculate spiral cords.

Discussion. These small specimens are too poorly preserved for a precise determination. The whorls in most individuals are also fairly similar to the genus *Mesalia* GRAY, 1842. The aperture is not complete in many specimens. For these reasons, the present specimens are assigned herein tentatively to the genus *Cerithium*.

Tympanotonos (*Exechocirsus*) *cingillatus* ZEKELI, 1852 of KIEL & BANDEL (2004: 120, fig. 7D-E) from the Cenomanian of Germany resembles the present material in general shape (turriculate-shaped), size (H=12 mm, D= 5 mm), and whorl width, but differs in the tuberculation style.



Text-fig. 3.28. Near-monospecific concentration of composite moulds of *Cerithium*? sp., (C) and very rare gastropod indet. (G) from the Wadi Quseib section. Scale in mm. B. Enlargement of (A).

Family Batillariidae THIELE, 1929
(=Pyrazidae HACOBJAN, 1972 = Tiaracerithiinae BOUNIOL, 1981)

Genus *Pyrazus* MONTFORT, 1810
Pyrazus valeriae (DE VERNEUIL & DE LORIÈRE, 1868)
Pl. 15, Fig. 4

1868 *Cerithium Valeriae* sp. nov. – DE VERNEUIL & DE LORIÈRE: 11, pl. 2, fig. 1.
1916 *Pyrazus Valeriae* DE VERNEUIL & DE LORIÈRE – DOUVILLÉ: 136, pl. 18, figs. 6-8.
?1927 *Cerithium* (?*Pyrazus*) *magnicostatum* CONRAD – BLANCKENHORN: 161, pl. 8 (4), fig. 75.
1992 *Pyrazus valeriae* (DE VERNEUIL & DE LORIÈRE) – ABDEL-GAWAD & GAMEIL: 74, fig. 2/11-12.
1995 *Pyrazus* (*Echinobathra*) *valeriae* (DE VERNEUIL & DE LORIÈRE) – SÁNCHEZ & TINAJERO: 162, pl. 1, figs. 7-9.
2002 *Pyrazus* cf. *valeriae* (DE VERNEUIL & DE LORIÈRE) – BERNDT: 140, pl. 9, fig. 4.
2004b *Pyrazus valeriae* (DE VERNEUIL & DE LORIÈRE) – ABDEL-GAWAD et al.: pl. 5, fig. 1.
2006 *Pyrazus* (*Pyrazus*) *valeriae* (DE VERNEUIL & DE LORIÈRE) – EL QOT: 97, pl. 19, figs. 9-11.
2008 *Pyrazus* (*Pyrazus*) *valeriae* (DE VERNEUIL & DE LORIÈRE) – MEKAWY & ABU-ZIED: 322, pl. 4, fig. 14.

Material and occurrence. 16 composite moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 3 and 16 at East Themed (MGDMU:ET.G.**3**.130-132, **16**.465-477), three composite moulds from the middle carbonate member of the Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**15**.128-130), and a single specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 31 at Wadi Quseib (MGDMU:WQ.G.**31**.29).

Measurements (in mm).

n= 2	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	23-50	15-23	10-26	9-17	8-13	38° -42°-	3-5	0.46-0.65	0.43-0.52	0.76-0.88
Mean	36.50	19	18	13	10.50	40 °	4	0.55	0.47	0.82

Description. Large-sized and turriculate gastropod. Spire long (elevated) and consisting of 3-4 overlapping whorls, forming about 72% of the total height. Whorls strongly convex, their width nearly twice the height, and separated by deep sutures. Diameter of whorls increasing gradually from apex to aperture. Apex commonly damaged. Body whorl small with strongly convex flanks. Base slightly rounded. Aperture oval, with incomplete outer lip, inner lip concave. Each whorl ornamented with 11-14 fine spiral cords, separated by smooth interspaces, and crossed by 6-8 strong axial ribs (Pl. 15, Fig. 4c).

Temporal and spatial distribution. *Pyrazus valeriae* has been recorded from the Lower Cretaceous of Spain (de Verneuil & de Lorière, 1868), Mexico (Sánchez & Tinajero, 1995), Aptian of Syria (Blanckenhorn, 1927), and Cenomanian of Jordan (Berndt, 2002). In Egypt, it is known from the Albian of Gebel Manzour (Douvillé, 1916), Cenomanian of Gebel Nezzazat (Abdel-Gawad & Gameil, 1992), Gebel Ekma and the East Themed area (EL QOT, 2006), G. El-Fallig (Abdel-Gawad et al., 2004b), and from the Middle Albian-Upper Cenomanian of G. El Tourkumanyia (Mekawy & Abu-Zied, 2008).

Discussion. *Pyrazus* (*Echinobathra*) *magharensis* Abbass (1963: 54, pl. 3, fig. 11) from the Albian of the Maghara area is similar to the present species in turriculate shape but differs in having a greater number of axial ribs (11-12 ribs) and spiral cords (20-25). *P. themedensis* (Abbass, 1963: 56, pl. 3, figs. 13-16) from the Santonian of the Themed area differs in having a wavy and deep suture with six primary spiral cords separated by wide interspaces with secondary spiral lines.

Cerithium (*Pyrazus*) *zumoffeni* Blanckenhorn (1927: 160, pl. 8, fig. 73) from the Aptian of Syria resembles *P. valeriae* in the general shape and ornamentation but differs in having more developed spiral cords in the upper half of the middle whorls which weaken in the lower half. *C.* (*P.*?) *magnicostatum* (Conrad, 1852) figured by Blanckenhorn, 1927 differs in having deep sutures. However, this difference is not distinct enough to recognize two different species. Therefore, Blanckenhorn's specimen may be belonging to *P. valeriae.*

Family Turritellidae Lovén, 1847

Subfamily Turritellinae Lovén, 1847
Genus *Turritella* Lamarck, 1799
Turritella cf. *difficilis* d'Drbigny, 1842
Pl. 15, Figs. 5-6

cf.1927 *Turritella* cf. *difficilis* d'Drbigny – Blanckenhorn: 141, pl. 3, fig. 37.
cf.1971 *Turritella* cf. *difficilis* d'Drbigny – Collignon: 6, pl. B, fig. 1.

Material and occurrence. Two incomplete internal moulds from the middle carbonate member of the Cenomanain Halal Formation, bed 15 at the Gebel Areif El-Naqa section (MGDMU:AEN.G.**15**.131-132).

Description. Small- to medium-sized, turriculate, and high-spired gastropod (spire angle=25°). Spire consisting of about four overlapping whorls. Whorls slightly convex and separated by moderately deep and oblique sutures. Aperture small and ovate with convex outer lip. Apex commonly damaged. The present materials are internal moulds without any trace of ornamentation.

Temporal and spatial distribution. *Turritella* cf. *difficilis* has been recorded from the Cenomanian of Syria (BLANCKENHORN, 1927) and Maastrichtian of Algeria (COLLIGNON, 1971) and therefore has a wide stratigraphic range.

Discussion. The present material closely resembles *Turritella* cf. *difficilis*, described by BLANCKENHORN, 1927, in the general outline, convexity of whorls, and suture angle. *Turritella maussi* LARTET of BLANCKENHORN (1927:142, pl. 5, fig. 25b) differs in having more convex whorls and more depressed sutures. *Turritella* (*Torcula*) *clava* described as a new species by ZAKHERA (2002: 300, fig. 2/1-5) from the Cenomanian of Wadi Malha, Eastern Desert, differs in being more cylindrical than the present material due to the slight gradual increase of whorl width from the apex to base.

Superfamily Campaniloidea DOUVILLÉ, 1904
Family Campanilidae DOUVILLÉ, 1904

Genus *Campanile* BAYLE (in P. FISCHER, 1884)
Subgenus *Campanile* BAYLE (in P. FISCHER, 1884)
Campanile (*Campanile*) *ganesha* (NOETLING, 1897)
Pl. 15, Figs. 7-8; Text-fig. 3.29

1897 *Nerinea Ganesha* sp. nov. – NOETLING: 58, pl. 15, figs. 1-2; pl. 16, figs. 1-2.
1916 *Nerinea Ganesha* NOETLING – GRECO: 121 (63), pl. 15 (7), figs. 10-11.
1971 *Nerinea* (*Ptygmatis*) *ganesha* NOETLING – COLLIGNON: 17 (159), pl. C, fig. 5.
1974 *Campanile* (*Campanile*) *ganesha* (NOETLING) – ALBANESI & BUSSON: 299.
2006 *Campanile* (*Campanile*) *ganesha* (NOETLING) – EL QOT: 98, pl. 19, figs. 12, 14.

Material and occurrence. 11 composite moulds from the middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation, beds 31, 44, and 47 at Wadi Quseib (MGDMU:WQ.G.**31**.30,**44**.229-233,**47**.56-60).

Measurements (in mm).

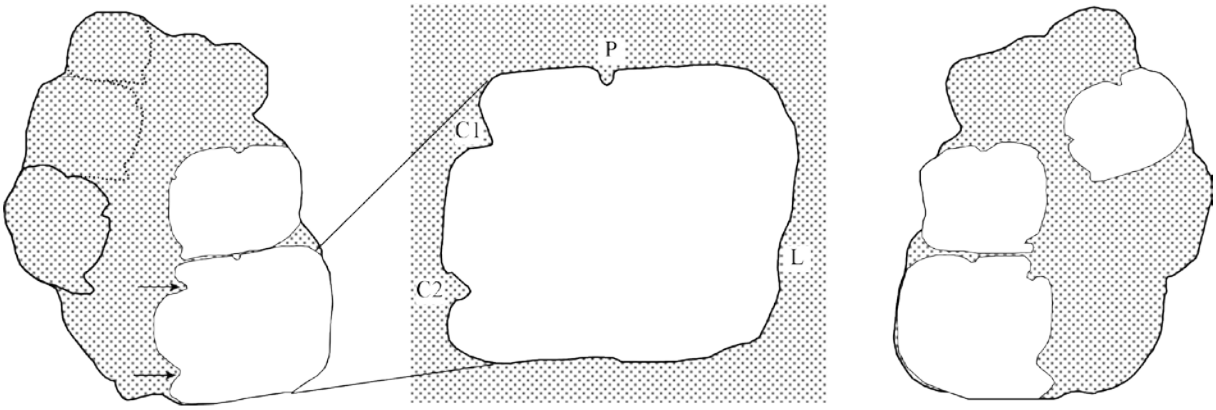
n=3	H	D	HL	PA°	nw	D/H	HL/H
Range	?40-70	34-43	12-30	45-50	4	0.61-0.85	0.30-0.42
Mean	55	39	20	48	4	0.73	0.36

Description. Moulds large-sized, turriculate, and moderately high-spired. Spire consisting of three overlapping wide whorls which have slightly convex surfaces and form about 65% of the total height. Whorls separated by moderately deep sutures and gradually decreasing toward the apex. Base flat. Apex commonly damaged. Aperture small and ovate to rectangular with convex outer lip. Ornamentation not preserved, although some faint spiral lines can be observed. The longitudinal whorl section shows two small columellar folds (C1 and C2) with medium and slightly deep parietal fold (P) (Text-fig. 3.29).

Temporal and spatial distribution. *Campanile* (*Campanile*) *ganesha* has been recorded from the Maastrichtian of Algeria (COLLIGNON, 1971; ALBANESI & BUSSON, 1974). In Egypt, it occurs in the Maastrichtian of the Eastern Desert (GRECO, 1916) and Cenomanian-Lower Turonian of Gebel Ekma, Sinai (EL QOT, 2006). Therefore, its stratigraphic range is from the Cenomanian to the Maastrichtian.

Discussion. Early workers classified *Campanile* FISCHER, 1884 as cerithiid (COSSMANN, 1906, WENZ 1938-44) due to similarities of shell ornament and shape. WENZ (1938-44) united *Campanile* and *Plesiotrochus* FISCHER, 1878 among a few other doubtful genera in the subfamily Campanilinae DOUVILLÉ, 1904 within the Cerithiidae FÉRRUSAC, 1819.

According to DELPEY (1939: 208), the longitudinal whorl section of the genus *Campanile* is characterized by a medium parietal fold with two columellar folds (Text-fig. 3.29). The latter characters are observed in the present material. Moreover, the longitudinal sections of *C.* (*C.*) *bussoni* of ALBANESI & BUSSON (1974: pl. 22, fig. 2a) from Algeria and *Cerithium* sp. (cf.) *inauguratum* STOLICZKA of QUAAS (1902: pl. 26, fig. 27) from the Western Desert (Egypt) closely resemble the longitudinal whorl section of the present material. Morphologically, ALBANESI & BUSSON and QUAAS' material differs in having a longer spire with 6-8 overlapping convex whorls, and the whorl height is greater than in the present species with wider and deeper sutures.



Text-fig. 3.29. Longitudinal whorl sections and internal characters of *Campanile* (*Campanile*) *ganesha* (NOETLING, 1897) from the Cenomanian Galala Formation at Wadi Quseib. C: Columellar fold, P: parietal fold, L: palatal fold.

Order and family uncertain

Genus *Cimolithium* COSSMANN, 1906

Cimolithium tenouklense (COQUAND, 1862)

Pl. 16, Figs. 1-3; Text-fig. 3.30

1862 *Turritella Tenouklensis* sp. nov. – COQUAND: 176, pl. 4, fig. 6.
1889 *Cerithium Tenouklense* COQUAND – PERON: pl. 20, fig. 2.
1912 *Cerithium Tenouklense* COQUAND – PERVINQUIÈRE: 16, pl. 1, figs. 20-22.
1916 *Cerithium* (*Cimolithium*) *Tenouklense* COQUAND – GRECO: 154 (96), pl. 19 (11), figs. 3-5.
1927 *Cerithium tenouklense* COQUAND – BLANCKENHORN: 162, pl. 8 (4), figs. 77-80.
1963 *Cerithium tenouklense* (COQUAND) – FAWZI: 100, pl. 7, fig. 9.
1971 *Cimolithium tenouklense* (COQUAND) – COLLIGNON: 149.
1974 *Cimolithium tenouklense* (COQUAND) – ALBANESI & BUSSON: 295, pl. 22, fig. 1.
1992 *Cimolithium tenouklense* (COQUAND) – ABDEL-GAWAD & GAMEIL: 76, fig. 3/7-8.

1992 *Cimolithium tenouklense* (COQUAND) – ABDEL-GAWAD & ZALAT: pl. 1, figs. 4-5.
2001 *Cimolithium tenouklense* (COQUAND) – ABDALLAH et al.: pl. 1, fig. 1.
2001 *Cimolithium tenouklense* (COQUAND) – KORA et al.: pl. 3, fig. 2.
?2001 *Cimolithium tenouklense* (COQUAND) – ZAKHERA: pl. 3, figs. 11-12.
2002 *Cimolithium tenouklense* (COQUAND) – ZAKHERA: 310, fig. 5/1.
2002 *Cimolithium tenouklense* (COQUAND) – KORA et al.: pl. 4, fig. 3.
2004b *Cimolithium tenouklense* (COQUAND) – ABDEL-GAWAD et al.: pl. 5, fig. 2.
2006 *Cimolithium tenouklense* (COQUAND) – EL QOT: 97, pl. 19, fig. 8.
2007a *Cimolithium tenouklense* (COQUAND) – MEKAWY: 157, pl. 1, fig. 5.

Material and occurrence. Eight internal moulds from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 1 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.111-113,**15**.133-137), and two specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation and the Lower Turonian Abu Qada Formation, beds 29 and 45 at Wadi Quseib (MGDMU:WQ.G.**29**.13.**45**.86).

Measurements (in mm).

n= 5	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	19-37	17-24	7-12	4-10	6-14	35°-41°	4-6	0.65-0.89	0.26-0.36	1.00-1.20
Mean	27	20	8.66	7.33	9.33	38 °	5	0.77	0.31	1.13

Description. Moderately large- to large-sized, turriculate, high-spired gastropod. Spire long, consisting of 4-6 overlapping whorls, and forming about 69% of the total height. Whorls strongly convex in some individuals, their width having nearly twice the height, with very deep sutures. In other individuals, the flanks of the whorls are nearly flat, less-elevated, and separated by moderately deep sutures. Diameter of specimens increasing gradually from the apex to the aperture. Apex commonly damaged. Body whorl small and strongly convex with nearly flat base. Aperture small, narrow, and oval to rectangular in outline. Most specimens are internal moulds that do not record features of the original ornamentation but show some spiral cords regularly spreading from the earliest to the last whorl and separated by wider

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EXPLANATION OF PLATE 16

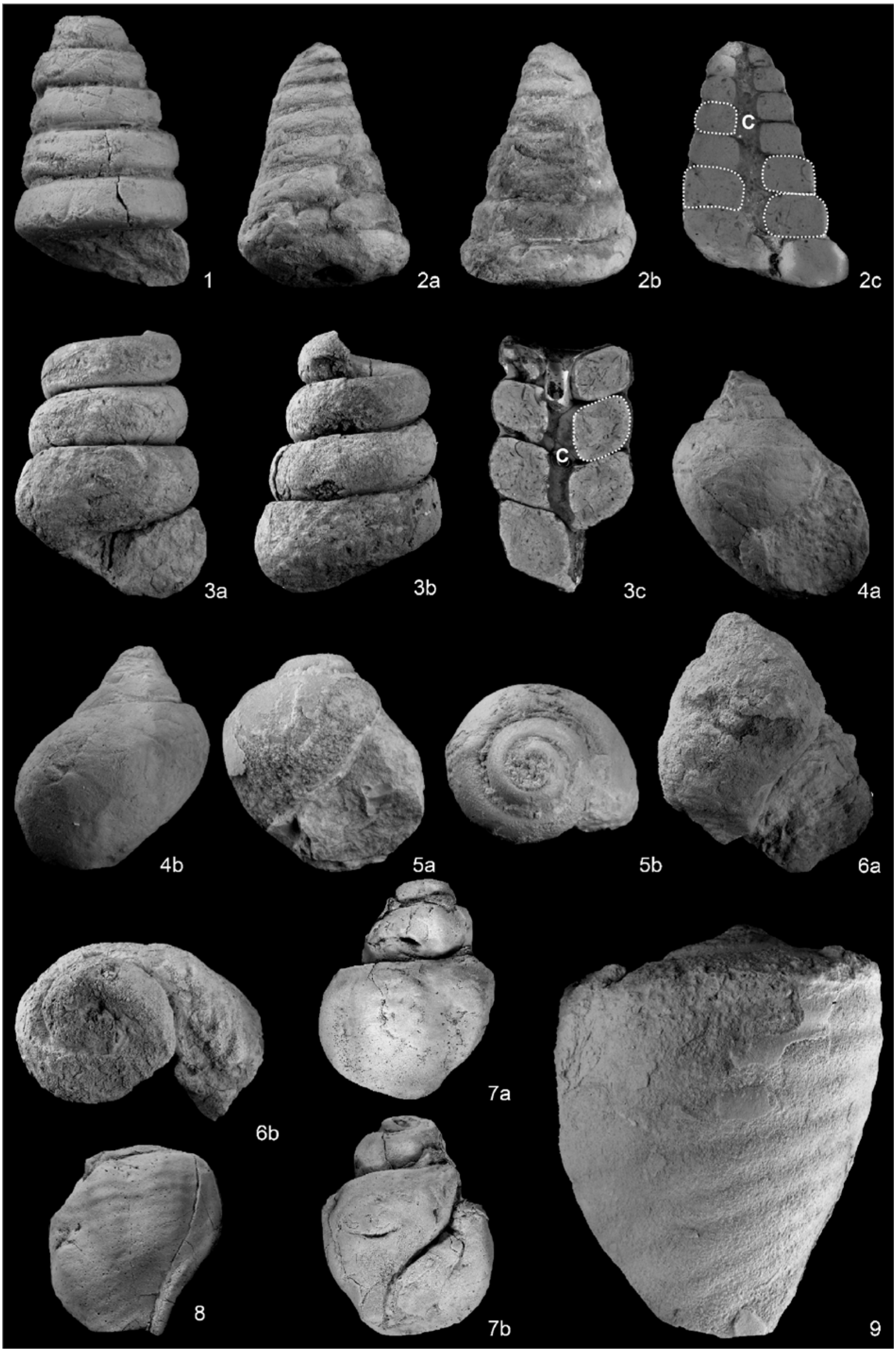
Figs. 1-3. *Cimolithium tenouklense* (COQUAND, 1862), internal moulds. **1**. Specimen from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, apertural view, x2; MGDMU:AEN.G.**1**.111. – **2**. Specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Apertural view, x1.5, **b**: abapertural view, x1.5, **c**: axial whorl section (C: columella), x1.5; MGDMU:WQ.G.**29**.13. – **3**. Specimen from the Lower Turonian Abu Qada Formation at Wadi Quseib. **a**: Apertural view, x1, **b**: abapertural view; **c**: axial section, x1; MGDMU:WQ.G.**45**.86.

Figs. 4-5. *Ampullina*? *abeihensis* (HAMLIN, 1884). **4**. Internal mould from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa. **a**: Apertural view, x1.5, **b**: abapertural view, x1.5; MGDMU:AEN.G.**15**.138. – **5**. Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x2. **a**: Apertural view, **b**: apical view, x2; MGDMU:WQ.G.**22**.79.

Fig. 6. *Ampullina*? cf. *quaasi* (MAXIA, 1941). Internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. **a**: apertural view, **b**: apical view; MGDMU:AEN.G.**9**.51.

Figs. 7-8. *Coronatica* cf. *ornata* (FRAAS, 1878). Composite moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area. **7.a**: Abapertural view, x1.5, **b**: apertural view, x1.5; MGDMU:ET.G.**16**.478. - **8**. Abapertural view, x2; MGDMU:ET.G.**19**.101.

Fig. 9. "*Strombus*" *incertus* (D'ORBIGNY) 1842. Composite mould from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1.5. Abapertural view; MGDMU:AEN.G.**15**.140.


1
2a
2b
C
2c
3a
3b
C
3c
4a
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5a
5b
6a
7a
6b
8
7b
9

interspaces (bands). Longitudinal section shows quadrangular whorls without distinct folds (Text-fig. 3.30).

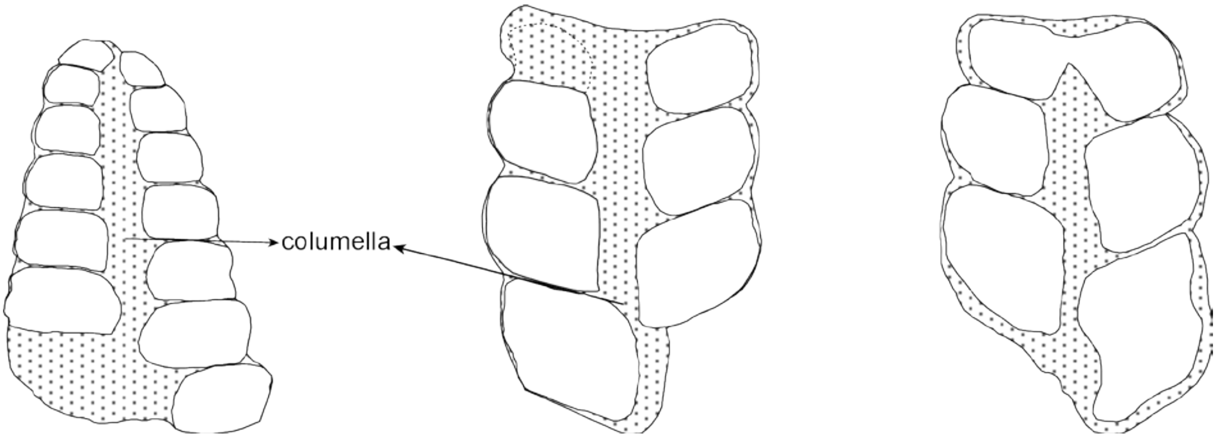
Temporal and spatial distribution. *Cimolithium tenouklense* has been recorded from the Cenomanian of Tunisia (PERON, 1889; PERVINQUIÈRE, 1912), Upper Cretaceous of Algeria (COQUAND, 1862; COLLIGNON, 1971; ALBANESI & BUSSON, 1974), and Cenomanian of Syria (BLANCKENHORN, 1927). In Egypt, it is known from the Cenomanian of Wadi Abu Had (KORA et al., 2001), Gebel El-Fallig (ABDEL-GAWAD et al., 2004b), Eastern Desert (GRECO, 1916, MEKAWY, 2007a), G. EL-Hamra, G. Um Heriba (ABDEL-GAWAD & ZALAT, 1992), El-Giddi Pass (ABDALLAH et al., 2001), G. Nezzazat (FAWZI, 1963; ABDEL-GAWAD & GAMEIL, 1992), G. Musabaa Salama (ZAKHERA, 2001), G. Ekma (EL QOT, 2006), Campanian of W. Tarfa (ZAKHERA, 2002), and the Coniacian-Santonian of W. Feiran (KORA et al., 2002).

According to ZAKHERA (2001: 311), *C. tenouklense* has a wide stratigraphic range from the Cenomanian to the Maastrichtian. It has also been recorded from the Turonian of Palestine, Santonian of Sinai, and Maastrichtian of Libya.

Discussion. The genus *Cimolithium* was placed within the Metacerithiinae by COSSMANN (1906) and WENZ (1938). COSSMANN was uncertain as to the existence of an anterior canal, but WENZ (1938: 735) mentioned a weak anterior canal in the genus. ABBASS (1973: 138) however, placed the genus within the family Procerithiidae, COSSMANN, 1906 and pointed out that the presence of such a canal causes some doubts about its inclusion in the Procerithiidae. NÜTZEL (1998) interpreted ABBASS' (1973) species as member of the Protorculidae BANDEL, 1991. DELPEY (1941) considered the type species, *C. belgicum* D'ARCHIAC, 1846, as a possible early member of the Campanilidae DOUVILLÈ, 1904. However, KIEL & BANDEL (2004: 118) stated that the protoconch of the type species of *Cimolithium* has not yet been described, and thus the taxonomic position of the genus remains uncertain. In addition, in the classification of BOUCHET & ROCROI (2005) there is no comment about the taxonomic position of the genus.

Cimolithium inauguratum (STOLICZKA, 1871), described by ZAKHERA (2002: 311, fig. 5/2-3) from the Upper Turonian of northern and southern Galala (Eastern Desert), resembles the present species in the convexity of whorls and general outline (turriform), but differs in being higher and narrower, with wider and deeper sutures. *C.* cf. *belgicum* D'ARCHIAC, figured by KIEL & BANDEL (2004: 118, fig. 7A-B) from the Cenomanian of Germany resembles the present species in having the quadrangular aperture but differs in having concave whorls, a long conical spire (about 10 whorls), and sharp base.

The internal characters of *Campanile* (*Diozoptyxis*) *moniliferum* D'ORBIGNY (1842), figured and described by DELPEY (1939: 209; text-figs. 166-167) from the Cenomanian of Lebanon, are identical to the present species, but morphologically the specimens differ in having well preserved axial and spiral ribs. However, as COQUAND'S material of *C. tenouklense* lacks any feature of the original ornamentation. *C.* (*D.*) *moniliferum* of DELPEY (1939) may be a synonym of *C. tenouklense* and the absence or presence of axial and spiral ribs related to the preservational state of specimens. According to ABDEL-GAWAD & GAMEIL (1992: 76) the original shell is ornamented with rounded tubercles arranged in a spiral manner.



Text-fig. 3.30. Rectangular whorls without distinct folds of *Cimolithium tenouklense* (Coquand, 1862) from the Cenomanian Galala Formation and Turonian Abu Qada Formation of Wadi Quseib.

Family Ampullinidae Cossmann, 1919
Subfamily Ampullininae Cossmann**, 1919**
Genus *Ampullina* Bowdich, 1822
Ampullina? *abeihensis* (Hamlin, 1884)
Pl. 16, Figs. 4-5

1884 *Amauropsis Abeihensis* sp. nov. – Hamlin: 17, pl. 1, fig. 2.
1890 *Amauropsis Abeihensis* Hamlin – Blanckenhorn: 103.
1927 *Natica* (*Euspira*) *abeihensis* (Hamlin) – Blanckenhorn: 131, pl. 1, figs. 21-22.
1939 *Tylostoma* (*Odostomopis*) *abeihensis* (Hamlin) – Delpey: 80, fig. 55.

Material and occurrence. Five internal moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 22, 31, and 39 at Wadi Quseib (MGDMU:WQ.G.**22**.79-80,**31**.31-32,**39**.185), and two specimens from the middle carbonate member of the Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**15**.138-139).

Measurements (in mm).

n= 4	H	D	HL	HA	WA	PAº	nw	D/H	HL/H	WA/HA
Range	21-27	20-24	19-23	15-17	11-14	82-87	2-4	0.88-1.04	0.85-0.95	0.70-0.82
Mean	23	22	20	16.5	12.25	85º	3	0.94	0.88	0.74

Description. Moderately large, globose to ovate, and moderately high-spired gastropod. Spire conical and consisting of at least four overlapping whorls separated by moderately deep sutures. Whorls rapidly decreasing toward the apex with straight to slightly convex surfaces. Body whorl large and forming the main part of the specimen (about 88% of the total height) with rounded flanks. Aperture relatively large (about 61% of the total height), broad, and loop-shaped with shallow umbilicus. Outer lip strongly convex, inner lip slightly convex. Apex is pointed, base rounded to nearly flat. Ornamentation not preserved.

Temporal and spatial distribution. *Ampullina abeihensis* (Hamlin, 1884) has been recorded from the Aptian of Syria (Blanckenhorn, 1927) and North Sinai (Hoppe, 1922 from Blanckenhorn, 1927).

Discussion. The huge aperture and last whorl, relatively low spire (with narrow whorls), slightly depressed spherical outline, and sharp apex indicate a relation to the family Ampullinidae COSSMANN, 1919. Unfortunately, the present material is an internal mould and lacking many important features to a certain identification. However, superficially, the present material closely resembles *Natica* (*Euspira*) *abeihensis* (HAMLIN) of BLANCKENHORN (1927). Similarities are in the shape of aperture, spire angle, and roundness of base.

A. (*A.*) *plesiolyrata* (PETHÖ) of ALBANESI & BUSSON (1974: pl. 24, fig. 3) from Algeria differs in having a low spire and wider whorls. *A. ervyna* (D'ORBIGNY, 1842) of DOUVILLÉ (1916: 145, pl. 14, fig. 5) and MAHMOUD (1955: 140, pl. 15, figs. 14-18) from the Upper Albian of Gebel Manzour (Sinai) differs in being smaller and having a wider aperture with broadly rounded base.

Ampullina? cf. *quaasi* (MAXIA, 1941)
Pl. 16, Fig. 6

cf.1902 *Natica* sp. – QUAAS: 240, pl. 25, figs. 31-32.
cf.1974 *Ampullina* (*Ampullina*) *quaasi* (MAXIA) – ALBANESI & BUSSON: 307, pl. 24, figs. 4-5.
cf.2006 *Ampullina* (*Ampullina*) *quaasi* (MAXIA) – EL QOT: 106, pl. 22, fig. 2a-b.

Material and occurrence. A single internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), bed 9 at Gebel Areif El-Naqa (MGDMU:AEN.G.**9**.51).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
	>43	51	49	29	27	72°	3	1.18	1.13	0.93

Description. Large-sized and globose gastropod. Spire incomplete. Body whorl large, globose, and constituting the main part of the total height with rounded flanks. Base broad and slightly rounded. Aperture large and lanceolate with strongly convex outer lip and concave Inner lip. The present material is an internal mould without elements of ornamentation.

Temporal and spatial distribution. *Ampullina* (*Ampullina*) *quaasi* has been recorded from the Maastrichtian of the Western Desert (QUAAS, 1902), Libya (MAXIA, 1941), and from the Turonian of Algeria (ALBANESI & BUSSON, 1974). In Egypt, it occurs in the Cenomanian of East Themed and Gebel Yelleg (EL QOT, 2006). The stratigraphic range of *A.* (*A.*) *quaasi* is accordingly Cenomanian to Maastrichtian.

Discussion. The present material closely resembles *Ampullina* (*Ampullina*) *quaasi* (MAXIA, 1941) of ALBANESI & BUSSON (1974) and EL QOT (2006) in general shape and apertural view but differs in being larger and a poorly preserved internal mould. In agreement with EL QOT (2006), the description and dimensions of *Natica* sp. of QUAAS (1902) from the Maastrichtian of the Western Desert (=*Natica quaasi*, MAXIA, 1941) of Libya, are similar to *A.* (*A.*) *quaasi* from the Turonian of Algeria (ALBANESI & BUSSON, 1974).

Clade Hypsogastropoda PONDER & LINDBERG, 1997
Clade Littorinimorpha GOLIKOV & STAROBOGATOV, 1975
Superfamily Littorinoidea CHILDREN, 1834
Family Purpurinidae ZITTEL, 1895

(=Pseudotritoniinae GOLIKOV & STAROBOGATOV, 1987)

Genus *Coronatica* BLANCKENHORN, 1927
Coronatica cf. *ornata* (FRAAS, 1878)
Pl. 16, Figs. 7-8

cf.1878 *Neritopsis ornata* sp. nov. – FRAAS: 66, pl. 6, fig. 6.
cf.1900 *Natica ornata* FRAAS – BÖHM: 197, figs. 7-9.
cf.1927 *Coronatica ornata* gen. nov. FRAAS – BLANCKENHORN: 134.
cf.2002 *Coronatica* cf. *ornata* (FRAAS) – BERNDT: 140, pl. 9, fig. 7.

Material and occurrence. Two composite moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 16 of the East Themed area (MGDMU:ET.G.**16**.478-479).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	ns	D/H	HL/H	WA/HA
	27	20	19	18	10	2	0.74	0.70	0.55

Description. Medium-sized, globose, naticid-shaped, and low-spired gastropod. Spire consisitng of three overlapping whorls (rapidly enlarging towards the last whorl) with moderately deep sutures. Body whorl large, semi-rounded, and accounting for the main part of shell (about 70% of the total height). Aperture large and oval. Outer lip convex, inner lip straight to slightly concave. Body whorl ornamented by fine spiral cords, crossed by thick axial ribs which form distinct knobs at the outer margin.

Temporal and spatial distribution. *Coronatica ornata* has been recorded from the Lower Cretaceous sandstones from Lebanon (BÖHM, 1900; BLANCKENHORN, 1927) and from the Cenomanian of Jordan (BERNDT, 2002).

Discussion. BLANCKENHORN (1927) erected the genus *Coronatica* on the basis of ornamentation (distinct knobs at the outer margin). He included *Neritopsis ornata* FRAAS, 1878 and two new species (*C. Purpuroidea* and *C. Bioconica*) into his new genus *Coronatica.*

The present material resembles *Natica ornata* FRAAS of BÖHM (1900) from Lebanon in general outline, size, and ornamentation (strong axial ribs with knobs) but differs in having a higher spire. *C. biconica* BLANCKENHORN (1927: 135, pl. 11, fig. 27) from the Cenomanian of Lebanon differs in having a more globose shell, while *C. purpuroidea* BLANCKENHORN (1927: 135, pl. 11, fig. 26) differs in being larger.

Superfamily Stromboidea RAFINESQUE, 1815

Family Strombidae RAFINESQUE, 1815

Subfamily Strombinae RAFINESQUE, 1815
Genus *Strombus* LINNÉ, 1758
"Strombus" incertus (D'ORBIGNY, 1842)
Pl. 16, Fig. 9; Pl. 17, Figs. 1-2

1842 *Pterocera incerta* sp. nov. – D'ORBIGNY: 308, pl. 215, fig. 1.
1912 *Strombus* (?) *incertus* D'ORBIGNY – PERVINQUIÈRE: 27, pl. 2, figs. 19-23.
1916 *Strombus* (?) *incertus* D'ORBIGNY – GRECO: 160 (102), pl. 11 (14), fig. 10.
1939 *Strombus incertus* D'ORBIGNY – DELPEY: 117; text-figs. 81-83.
1958 *Strombus incertus* (D'ORBIGNY) – BARBER: 33, pl. 9, fig. 1.

1963 *Strombus incertus* (d’Orbigny) – Fawzi: 96, pl. 7, fig. 6.
1963 *Strombus* (*Dilatilabrum*) *tihensis* sp. nov. – Abbass: 84, pl. 8, figs. 7-8.
1971 *Strombus incertus* (d’Orbigny) – Collignon: 10 (152), pl. A, fig. 5.
1981 *Strombus incertus* (d’Orbigny) – Amard et al.: pl. 15, fig. 9.
1985 *Harpagodes incertus* (d’Orbigny) – Kollmann: 101, fig. 4j-k.
1992 *Strombus incerta* (d’Orbigny) – Abdel-Gawad & Gameil: 81, fig. 3/17.
1992 *Pterocera incerta* d’Orbigny – Abdel-Gawad & Zalat: pl. 1, fig. 2a-b.
1993 *Strombus* (*Dilatilabrum*) *tihensis* Abbass – Orabi: pl. 1, fig. 24.
1994 *Strombus incertus* (d’Orbigny) – Kassab & Ismael: 230, fig. 4/2.
2001 *Pterocera incerta* d’Orbigny – Abdallah et al.: pl. 1, figs. 8-9.
2001 *Strombus incerta* (d’Orbigny) – Zakhera: pl. 3, fig. 3.
2001 *Strombus tihensis* Abbass – Zakhera: pl. 3, fig. 4.
2002 “*Strombus*” *incertus* (d’Orbigny) – Berndt: 141, pl. 10, figs. 1-2.
2004 *Strombus incertus* (d’Orbigny) – Khalil & Mashaly: pl. 2, fig. 9.
2004a *Pterocera incerta* d’Orbigny – Abdel-Gawad et al.: pl. 6, fig. 1.
2004b *Pterocera incerta* d’Orbigny – Abdel-Gawad et al.: pl. 5, fig. 11.
2006 *Pterocera incerta* d’Orbigny – El Qot: 105, pl. 22, fig. 1.
2007a *Pterocera incerta* d’Orbigny – Mekawy: 163, pl. 2, fig. 6.
2008 *Pterocera incerta* d’Orbigny – Mekawy & Abu-Zied: 326, pl. 5, fig. 2.

Material and occurrence. 30 internal moulds from the lower marly, middle carbonate, and upper carbonate/marl members of the Halal Formation (Upper Albian-Cenomanian), beds 1, 15, 17, and 19 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.114-118,**15**.140-157,**17**.9-12,**19**.11-13), 15 specimens from Cenomanian Galala Formation and Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 15 and 19 of the East Themed area (MGDMU:ET.G.**15**.11-21,**19**.101-104), and four specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 37 and 42 at Wadi Quseib (MGDMU:WQ.G.**37**.12,**42**.75-77).

Measurements (in mm).

n= 5	H	D	HL	HA	WA	PA°	ns	D/H	HL/H	WA/HA
Range	75-111	59-81	69-95	70-84	30-39	112°-140°	9-10	0.61-0.98	0.68-0.79	0.43-0.48
Mean	94	70.20	48.60	78.60	34.80	56.66 °	10	0.76	0.84	0.44

EXPLANATION OF PLATE 17

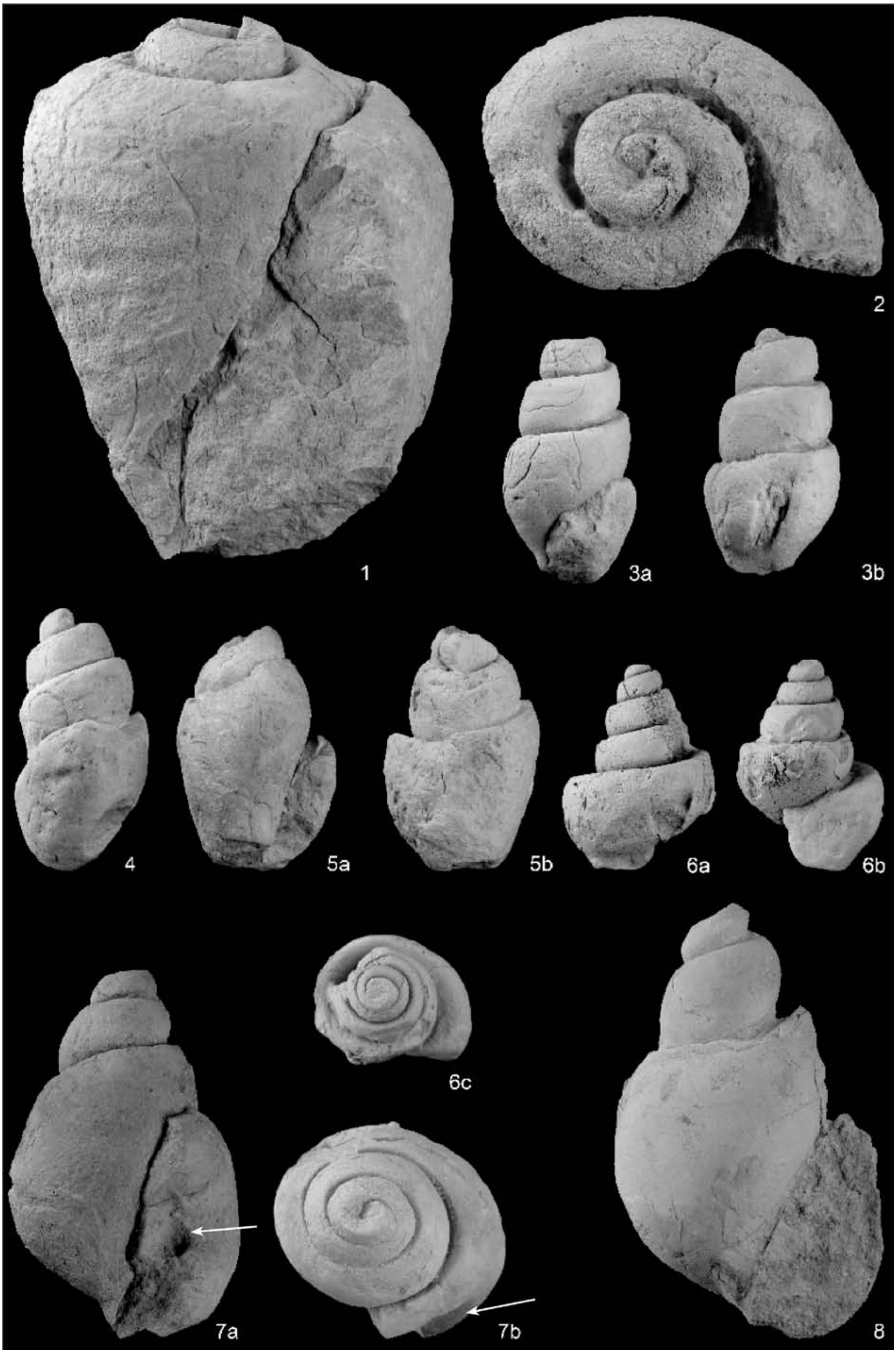
Figs. 1-2. “*Strombus*” *incertus* (d’Orbigny, 1842), **1**. Internal mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. Apertural view; MGDMU:AEN.G.**1**.114. - **2**. Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. Apical view; MGDMU:WQ.G.**42**.75.

Figs. 3-4. “*Aporrhais*” *dutrugei* (Coquand, 1862). Internal moulds from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **3. a**: Apertural view, x1.5, **b**: adapertural view, x1.5; MGDMU:AEN.G.**15**.158. – **4**. Abapertural view, x2.5; MGDMU:AEN.G.**15**.159.

Fig. 5. “*Aporrhais*” sp. **1**. Internal mould from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x1. **a**: Apertural view, **b**: abapertural view; MGDMU:AEN.G.**23**.1.

Fig. 6. “*Aporrhais*” sp. 2. Internal mould from the Lower Turonian Abu Qada Formation of Wadi Quseib, x1.5. **a**: Abapertural view, **b**: side view, **c**: apical view; MGDMU:WQ.G.**45**.87.

Figs. 7-8. *Harpagodes heberti* (Thomas & Peron, 1889). Internal moulds from the middle carbonate and upper carbonate/marl members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa. **7. a**: Apertural view (arrows refer to the spiral abapertural groove), x1, **b**: apical view, x1; MGDMU:AEN.G.**15**.166. - **8**. Apertural view, x0.75; MGDMU:AEN.G.**19**.15.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3a
3b
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5a
5b
6a
6b
6c
7a
7b
8

Description. Very large, obconical, and low-spired gastropod. Spire slightly protruding above the basal whorl and consisting of two compressed whorls with deep sutures. Body whorl very large, conical, with straight or slightly convex flanks, and accounting for the main part of shell (about 90% of the total height). Body whorl ornamented with ten strong spiral cords, separated by wide and flat interspaces (Pl. 16, Fig. 9). Aperture large, elongated, and lanceolate to quadrangular (Pl. 17, Fig. 1). Outer lip thick and expanded posteriorly into a wing-like expansion. Inner lip straight to slightly concave.

Temporal and spatial distribution. "*Strombus*" *incertus* has been recorded from the Cenomanian of France (KOLLMANN, 1985), Tunisia (PERVINQUIÈRE, 1912), Algeria (COLLIGNON, 1971; AMARD et al., 1981), Jordan (BERNDT, 2002), Lebanon (DELPEY, 1939), and Lower Turonian of Nigeria (BARBER, 1958). In Egypt, it is known from the Cenomanian of the Eastern Desert (GRECO, 1916; MEKAWY, 2007), Gebel El-Minsherah (FAWZI, 1963), G. Yelleg, G. Ekma, and East Themed (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), G. El-Fallig (ABDEL-GAWAD et al., 2004b), W. Watir (ORABI, 1993), El Giddi Pass (ABDALLAH et al., 2001), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. Tih (ABBASS, 1963), the Cenomanian-Turonian of G. Musabaa Salama (KASSAB & ISMAEL, 1994; ZAKHERA, 2002; KHALIL & MASHALY, 2004), and the Lower Albian-Cenomanian of the Maghara area (MEKAWY & ABU-ZIED, 2008).

According to EL QOT (2006: 106), the species is widely distributed in the Upper Albian-Cenomanian of the Tethys.

Discussion. Strombids are very similar to aporrhaids in general outline and it is difficult to separate between them by the shape alone. Superficially, aporrhaids are characterized by their finger-like extension of the outer lip, a moderate to high spire, and axial and spiral ornament. According to ELDER (1990), SAUL (1998), and KIEL & PERRILLIAT (2001) in KIEL & BANDEL (2002), the presence of the posterior canal which extends from the aperture to the spire and bends downwards near the apex, distinguishes early strombids from the Aporrhaidae. The general outline of the present specimens (mostly internal moulds) point to a representative of the family Strombidae. However, a precise identification in both Strombidae and Aporrhaidae is not possible due to lack of important information about the shell.

DELPEY (1939) noted that the smaller specimens are double cone-shaped (biconical) but in adult individuals, the basal part exhibits an acute angulation. *Pterocera incerta* of ABDEL-GAWAD et al. (2004a) and EL QOT (2006) is small-sized and biconical rather than obconical. The latter authors noted that the spire varies from short to very short, particularly in large forms. In the present study, two forms of *P. incerta* are recognized; biconical small individuals as mentioned by DELPEY (1939) and as figured by ABDEL-GAWAD et al. (2004a) and EL QOT (2006), and obconical adult individuals as observed in the present material.

According to ABDEL-GAWAD & GAMEIL (1992), the young individuals are ornamented with spiral ribs on the last whorl, whereas adults are smooth. In agreement with EL QOT (2006: 106), both young and adult forms are ornamented with 8-12 strong spiral cords.

ABBASS (1962) erected the new species *Strombus* (*Dilatilabrum*) *tihensis* from the Cenomanian of Gebel Tih, Sinai, differing from *S. incertus* in having shouldered whorls with a less expanded outer lip. However, his figures (pl. 8, figs. 7-8) are identical to *S. incertus* as figured by ABDEL-GAWAD & ZALAT (1992), KASSAB & ISMAEL (1994), and ABDEL-GAWAD et al. (2004b). Therefore, *S.* (*D.*) *tihensis* ABBASS is considered herein as a junior synonym of *P. incerta*.

S. numidus COQUAND (1862: 183, pl. 5, fig. 1) from the Upper Cretaceous of Algeria resembles the present species in adapical view but differs in lacking spiral cords. Moreover, *S.*

mermeti of the same author (Coquand, 1862: 184, pl. 5, fig. 2) differs in having a flattened outline and sinuous spiral cords, separated by wider interspaces and crossed by axial ribs.

Family Aporrhaidae Gray, 1850

Subfamily Aporrhainae Gray, 1850
Genus *Aporrhais* Da Costa, 1778
"*Aporrhais*" *dutrugei* (Coquand, 1862)
Pl. 17, Figs. 3-4

1862 *Rostellaria Dutrugei* sp. nov. – Coquand: 185, pl. 5, fig. 4.
1889 *Pterodonta* (?) *Dutrugei* Coquand – Peron: 83, pl. 20, figs. 15-16.
1912 *Aporrhais* (?) *Dutrugei* Coquand – Pervinquière: 24, pl. 2, figs. 1-7.
1916 *Aporrhais* (?) *Dutrugei* Coquand – Greco: 155 (97).
1927 *Pterodonticeras Dutrugei* Coquand – Blanckenhorn: 168, pl. 9 (5), fig. 93.
1937 *Aporrhais* (?) *Dutrugei* Coquand – Trevisan: 35, pl. 2, fig. 8.
1963 *Aporrhais* (?) *dutrugei* (Coquand) – Fawzi: 94.
1992 "*Aporrhais*" *dutrugei* (Coquand) – Abdel-Gawad & Gameil: 77, fig. 3/13.
2001 *Aporrhais dutrugei* (Coquand) – Abdallah et al.: pl. 1, figs. 2-3.
2001 *Aporrhais dutrugei* (Coquand) – Kora et al.: pl. 3, fig. 5.
2001 *Aporrhais dutrugei* (Coquand) – Zakhera: pl. 3, figs. 22-24.
2002 *Aporrhais dutrugei* (Coquand) – Zakhera: 317, fig. 6/8-10.
2004b *Aporrhais dutrugei* (Coquand) – Abdel-Gawad et al.: pl. 5, fig. 6.
2006 *Aporrhais dutrugei* (Coquand) – El Qot: 100, pl. 20, figs. 7-8.
2007a *Aporrhais dutrugei* (Coquand) – Mekawy: 160, pl. 1, fig. 15.

Material and occurrence. 20 internal moulds from the lower marly, middle carbonate, and upper carbonate/marl members of the Halal Formation (Upper Albian-Cenomanian) beds 1, 5, 15, and 19 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.119-122,**5**.46-52,**15**.158-165,**19**.14), 11 specimens from the Cenomanian Galala Formation, bed 15 of the East Themed area (MGDMU:ET.G.**15**.22-32), and two specimens from the upper carbonate member of the Cenomanian Galala Formation, bed 44 at Wadi Quseib (MGDMU:WQ.G.**44**.234-235).

Measurements (in mm).

n=11	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	18-35	12-20	14-30	9-10	7-10	45°-63°	3-5	0.53-0.78	0.63-0.85	0.37-0.83
Mean	26.5	15.8	19.20	13.5	8.50	54.20°	4	0.60	0.72	0.63

Description. Medium to large-sized, spindle-shaped, and moderately high-spired gastropod. Spire consisting of three overlapping whorls, which have a convex outline and form about 28% of the total height and continuously enlarge anteriorly. Whorls separated by deeply impressed sutures. Apex damaged in most specimens. Body whorl relatively large and accounting for about half of the specimen height with a short anterior canal. Aperture small and oval with commonly incomplete outer lip. Some specimens ornamented with faint spiral cords separated by narrow interspaces.

Temporal and spatial distribution. *Aporrhais dutrugei* has been recorded from the Upper Cretaceous of Algeria (Coquand, 1862), Cenomanian of Tunisia (Peron, 1898; Pervinquière, 1912), Syria (Blanckenhorn, 1927), and Italy (Trevisan, 1937). In Egypt, it is known from the Cenomanian-Turonian of the Eastern Desert (Greco, 1916; Kora et al., 2001; ZAKHERA, 2002; MEKWAY, 2007a), Gebel Ekma, East Themed, and G. Yelleg (EL QOT, 2006), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. Halal (FAWZI, 1963), El-Giddi Pass (ABDALLAH et al., 2001), and G. Musabaa Salama (ZAKHERA, 2001).

Discussion. The present specimens resemble moulds of Apporhaidae, the basal whorl extending slightly over the earlier whorl indicating the wing- or finger-shaped processes.

Aporrhais fourneli (COQUAND, 1862) of ABDEL-GAWAD & ZALAT (1992: pl. 5, fig. 1) from the Coniacian of Um Heriba (Sinai) and EL QOT (2006: 100, pl. 20, fig. 9) from the Coniacian of East Themed (Sinai), differs in having three carinae on the last whorl.

According to BERNDT (2002: 142), *Aporrhais turriculoides* (CONRAD, 1852) is very similar to *A. dutrugei* (COQUAND, 1862), which has a relatively angular and nearly quadrangular outer surface of the whorls. He suggested that *A. dutrugei* described by PERVINQUIÈRE (1912) and *Pterodonticeras*? *dutrugei* of ALBANESI & BUSSON (1974) might belong to *A. turriculoides*. BLANCKENHORN (1927: 171) noted that the spire of *A. turriculoides* consists of 5-6 overlapping convex whorls and the upper part of the body whorl is ornamented with three strong spiral cords separated by wide interspaces. All these characters are not seen in BERNDT'S specimen and his specimens may be a synonym to *A. dutrugei*.

"*Aporrhais*" sp.1.

Pl. 17, Fig. 5

Material and occurrence. One internal mould from the lower member of the Lower Turonian Abu Qada Formation, 23 at Gebel Areif El-Naqa (MGDMU:WQ.G.**23**.1).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
	50	28	32	27	10	68°	2	0.56	0.64	0.37

Description. Mould moderately large and moderately high-spired gastropod. Spire conical and consisting of two overlapping convex-sided whorls separated by deep sutures. Body whorl accounting for two-thirds of the total height of the specimen. Aperture long, narrow, oval with incomplete outer lip. The specimen lack any sign of ornamentation.

Discussion. The last whorl extending slightly over the earlier whorl indicating the wing- or finger-shaped processes of the family Apporhaidae (Pl. 17, Fig. 5b).

The present specimen differs from "*Aporrhais*" *dutrugei* (COQUAND, 1862) in being larger and in having a less number of whorls and the last whorl represents by two-thirds of the total height of the specimen.

ZAKHERA (2002: 318, pl. 7/1, 2) erected a new species *Aporrhais blanckenhorni* from the Cenomanian of the Eastern Desert on the basis of internal moulds. The present material resembles ZAKHERA' species in general outline and size but differs in lacking a big shoulder with a blunt median carina.

"*Aporrhais*" sp.2.

Pl. 17, Fig. 6

Material and occurrence. One internal mould from the Lower Turonian Abu Qada Formation, bed 45 at Wadi Quseib (MGDMU:WQ.G.**45**.87).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
	24	17	15	11	11	58°	0.71	0.62	1

Description. Moderately large and moderately high-spired gastropod. Spire conical and consisting of four overlapping convex-sided whorls separated by very deep sutures. Body whorl large, globose, with flanks nearly rounded, and accounting for more than half of the total height of the specimen. Aperture oval with incomplete outer lip. The specimen lack any sign of ornamentation.

Discussion. *Aporrhais bekariensis* (COQUAND, 1862:185, pl. 5, fig. 3) from the Upper Cretaceous of Algeria ("Mornasien") differs in being larger (H= 60 mm), and in having a higher spire and smaller body whorl. *Aporrhais* (*Dimorphosoma*) sp. of BLANCKENHORN (1927: 166, pl. 4, fig, 84) from the Cenomanian of Syria differs in having a small body whorl (with spiral keel), strongly convex whorls, and a moderately deep suture.

Subfamily Harpagodinae PCHELINTSEV, 1963
Genus *Harpagodes* GILL, 1870
Harpagodes heberti (THOMAS & PERON, 1889)
Pl. 17, Figs. 7-8; Pl. 18, Fig. 1

1889 *Pterocera Heberti* sp. nov. – THOMAS & PERON in PERON: 77, pl. 21, figs. 1-2.
1916 *Harpagodes Heberti* THOMAS & PERON – GRECO: 157 (99), pl. 18 (10), fig. 7.
1963 *Harpagodes* aff. *heberti* (THOMAS & PERON) – FAWZI: 95, pl. 7, fig. 5.
1992 *Harpagodes heberti* (THOMAS & PERON) – ABDEL-GAWAD & GAMEIL: 80, fig. 4/10.
2004b *Harpagodes heberti* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 5, fig. 7.
2006 *Harpagodes heberti* (THOMAS & PERON) – EL QOT: 102, pl. 21, figs. 2-3.
2007a *Harpagodes heberti* (THOMAS & PERON) – MEKAWY: 161, pl. 2, fig. 1.

Material and occurrence. 12 internal moulds from the lower marly, middle carbonate, and upper carbonate/marl members of the Halal Formation (Upper Albian-Cenomanian), beds 1,

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EXPLANATION OF PLATE 18

Fig. 1. *Harpagodes heberti* (THOMAS & PERON, 1889). Internal mould from the middle carbonate member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. Side view with abapertural groove (arrowed); MGDMU:AEN.G.**15**.167.

Fig. 2. *Columbellina* (*Columbellina*) *fusiformis* DOUVILLÉ, 1916. Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x2. **a**: Apertural view, **b**: abapertural view; MGDMU:ET.G.**26**.155.

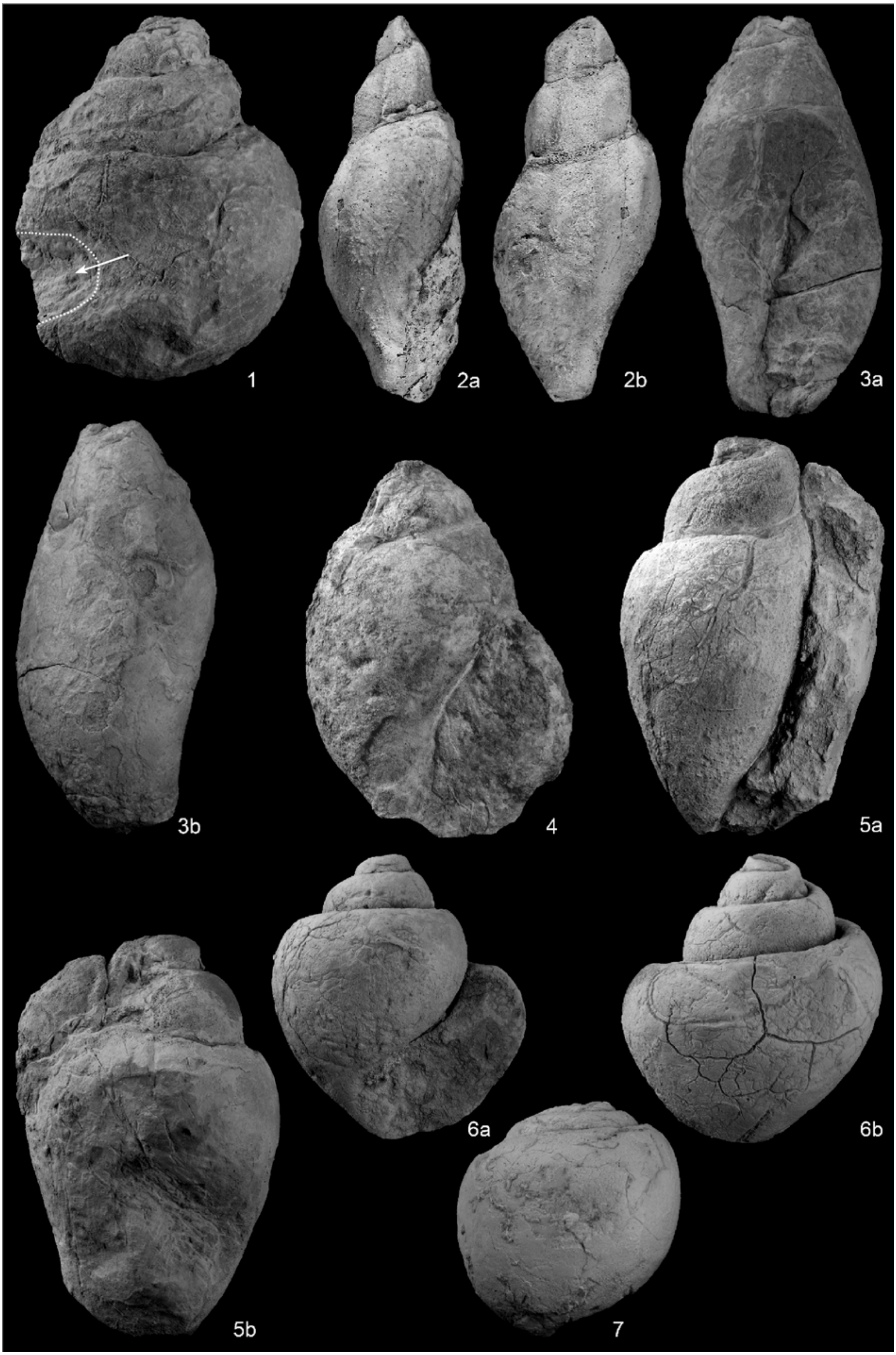
Fig. 3. *Pterodonta deffisi* THOMAS & PERON, 1889. Internal mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1.5. **a**: Apertural view, **b**: abapertural view; MGDMU:AEN.G.**1**.133.

Fig. 4. *Pterodonta* cf. *subinflata* (COQUAND, 1862). Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib, x1. Apertural view; MGDMU:WQ.G.**42**.80.

Fig. 5. ?*Pterodonticeras germeri* BLANCKENHORN, 1927. Internal mould from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: Apertural view, **b**: Abapertural view; MGDMU:AEN.G.**15**.174.

Fig. 6. *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON, 1889. Internal mould from the Upper Turonian Wata Formation at Wadi Quseib, x1. **a**: Apertural view, **b**; abapertural view; MGDMU:WQ.G.**97**.29.

Fig. 7. *Tylostoma* (*Tylostoma*) *globosum* SHARPE, 1849. Internal mould from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x1. Abapertural view; MGDMU:AEN.G.**23**.2.


1
2a
2b
3a
3b
4
5a
5b
6a
6b
7

15 and 19 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.123-129,**15**.166-169,**19**.15), 9 specimens from the Cenomanian Galala Formation, bed 15 of the East Themed area (MGDMU:ET.G.**15**.33-41), and two specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 42 at Wadi Quseib (MGDMU:WQ.G.**42**.78-79).

Measurements (in mm).

n=5	H	D	HL	HA	WA	PAº	D/H	HL/H	WA/HA
Range	55-79	35-63	44-62	37-49	15-27	56º-72º	0.66-0.80	0.72-0.80	0.53-0.86
Mean	66	49.20	50.40	42.60	21.80	62º	0.74	0.76	0.60

Description. Specimens large-sized, spindle-shaped to globular, and moderately high-spired gastropod. Spire consisting of 2-3 overlapping convex-sided whorls, which form about 35% of the total height. These whorls are separated by deep sutures. Body whorl large, rounded, globular, with rounded flanks, and accounting for more than half of the total height, with spiral groove restricted to the outer lip (Pl. 17, Fig. 7a; Pl. 18, Fig. 1). Base broadly rounded. Aperture oval to lanceolate with a somewhat short anterior canal. Outer lip thick, incomplete, slightly expanded and folded externally. All specimens lack any features of the original ornamentation.

Temporal and spatial distribution. *Harpagodes heberti* has been recorded from the Cenomanian of Tunisia (PERON, 1898). In Egypt, it occurs in the Cenomanian of Gebel Ekma and East Themed area (EL QOT, 2006), G. Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. El-Minsherah (FAWZI, 1963), and from the Eastern Desert (GRECO, 1916; MEKAWY, 2007a).

Discussion. According to DELPEY (1939: 111) and WENZ (1938: 921), the genus *Harpagodes* is characterized by a globose last whorl, large aperture, strongly convex outer lip (with digitations), and short spire. They also pointed out that the whorls are ornamented with spiral cords with secondary fine spiral lines and the last whorl carries prominent carinae.

Harpagodes heberti is characterized by the presence of two strong carinae on the adapical side of the last whorl. Two forms recognized in *H. heberti*, the first one with two carinae which extend over the entire last whorl (see ABDEL-GAWAD & GAMEIL, 1992; EL QOT, 2006). In the second one, these carinae are restricted to the outer lip (not extending over the entire last whorl) as observed in the present material and also by PERON (1889: pl. 21, fig. 1) from Tunisia.

H. pelagi (BRONGNIART, 1822) described by DELPEY (1939: 113, fig. 79) and *H. jaccardi* PICTET & CAMPICHE (1864) described by the same author (1939: 114, fig. 80) from Lebanon differ from the present species in having three strong carinae separated by wide interspaces (spiral bands), which are occupied by 3-7 spiral ribs.

Family Colombellinidae FISCHER, 1884
(=Columbellariidae ZITTEL, 1895; = Zitteliidae, SCHILDER, 1936)

Genus *Columbellina* D'ORBIGNY, 1842

Subgenus *Columbellina* D'ORBIGNY, 1842

Columbellina (*Columbellina*) *fusiformis* DOUVILLÉ, 1916

Pl. 18, Fig. 2

1916 *Columbellina fusiformis* sp. nov. – DOUVILLÉ: 132, pl. 18, figs. 1-3.

1963 *Columbellina* (*Columbellina*) *fusiformis* DOUVILLÉ – ABBASS: 82, pl. 8, figs. 1-3.

1982 *Columbellina fusiformis* DOUVILLÉ – BÖTTCHER: 32, pl. 5, fig. 8.
1992 *Columbellina* (*Columbellina*) *fusiformis* DOUVILLÉ – ABDEL-GAWAD & GAMEIL: 80, fig. 3/9-12.
2001 *Columbellina fusiformis* DOUVILLÉ – ABDALLAH et al.: pl. 1, figs. 4-5.
2001 *Columbellina* (*Columbellina*) *fusiformis* DOUVILLÉ – ZAKHERA: pl. 3, figs. 25-27.
2002 *Columbellina fusiformis* DOUVILLÉ – BERNDT: 144, pl. 9, fig. 8.
2004b *Columbellina* (*Columbellina*) *fusiformis* DOUVILLÉ – ABDEL-GAWAD et al.: pl. 5, fig. 9.
2006 *Colombellina* (*Colombellina*) *fusiformis* DOUVILLÉ – EL QOT: 104, pl. 21, figs. 6, 7.
2008 *Colombellina* (*Colombellina*) *fusiformis* DOUVILLÉ – MEKAWY & ABU-ZIED: 325, pl. 5, fig. 1.

Material and occurrence. Five internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 of the East Themed (MGDMU:ET.G.**26**.155-159), and four internal moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation, beds 1 and 9 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.130-132,**9**.52).

Measurements (in mm).

n= 3	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
Range	20-35	12-19	14-17	11-19	6-10	57°-62°	0.40-0.60	0.40-0.70	0.53-0.66
Mean	29.33	15	15	14	8	59 °	0.52	0.54	0.58

Description. Moderately large-sized, fusiform, and moderately high-spired gastropod. Spire conical and consisting of 2-3 overlapping whorls with slightly convex surfaces. Whorls separated by moderately deep sutures. Body whorl accounting for about 54% of the total height. Apex broken off. Base nearly sharp. Aperture narrow, slightly elongated, and lanceolate to ovate. Ornamentation consisting of 10-14 slightly oblique, strong axial ribs.

Temporal and spatial distribution. *Columbellina* (*Columbellina*) *fusiformis* has been recorded from the Cenomanian of Jordan (BERNDT, 2002). In Egypt, it is known from the Albian of Gebel Manzour (DOUVILLÉ, 1916), Um Rekeib and Maghara area (ABBASS, 1963), Cenomanian of G. Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. El-Fallig (ABDEL-GAWAD et al., 2004b), G. Musabaa Salama (ZAKHERA, 2001), El Giddi Pass (ABDALLA et al., 2001), Upper Albian-Cenomanian of G. Ekma, G. Yelleg, and G. El-Minsherah (EL QOT, 2006), and Upper Barremain-Cenomanian of G. Mistan and Tourkumanyia (MEKAWY & ABU-ZIED, 2008).

Discussion. The present specimens closely resemble *Columbellina fusiformis* as figured and described by DOUVILLÉ (1916) from the Albian of Egypt. DELPEY (1939) and FAWZI (1963) considered *Columbellina* (*Columbellina*) *fusiformis* as a synonym of *C. petrosa* CONRAD, 1852. *C. petrosa* CONRAD of DELPEY (1939: 122, figs. 85-86) has nodose whorls and a flat base (ABDEL-GAWAD & GAMEIL, 1992).

According to ABBASS (1963), the outline of *C.* (*C.*) *fusiformis* strongly resembles that of *Fusus martinez* GABB, but differs in having more numerous axial ribs and an evenly convex whorl outline. The fusiform, ovate to elongated aperture, sharp base, and axial ribs with fine spiral cords are the most distinct characteristics of *C.*(*C.*) *fusiformis*. The latter characters are not clearly seen in *C.* (*C.*) *fusiformis* DOUVILLÉ figured by KORA et al (2001: pl. 3, fig. 3) from the Lower Turonian of Gebel Mukattab, which have a more globular last whorl with nearly flat base.

Genus *Pterodonta* d'Orbigny, 1842
Pterodonta deffisi Thomas & Peron, 1889
Pl. 18, Fig. 3

1889 *Pterodonta Deffisi* sp. nov. – Thomas & Peron in Peron: 83, pl. 20, figs. 17-18.
1916 *Pterodonta Deffisi* Thomas & Peron – Greco: 158 (100), pl. 19 (11), figs. 6-9.
?1927 *Pterodonta homarensis* sp. nov. – Blanckenhorn: 169, pl. 9 (5), fig. 94.
1934 *Pterodonta deffisi* Thomas & Peron – Blanckenhorn: 272.
1963 *Pterodonta gigantica* sp. nov. – Abbass: 83, pl. 7, figs. 1-2, 6-7, non. figs. 4-5.
1963 *Pterodonta deffisi* Thomas & Peron – Fawzi: 98, pl. 7, fig. 7.
1992 *Pterodonta deffisi* Thomas & Peron – Abdel-Gawad & Gameil: 80, fig. 3/14-16.
1992 *Pterodonta deffisi* Thomas & Peron – Abdel-Gawad & Zalat: pl. 1, fig. 6.
2001 *Pterodonta deffisi* Thomas & Peron – Abdallah et al.: pl. 1, figs. 12-13.
2001 *Pterodonta gigantica* Abbass – Zakhera: pl. 3, fig. 1.
2002 *Pterodonta deffisi* Thomas & Peron – Berndt: 144, pl. 9, figs. 10-14.
?2002 *Pterodonta homarensis* Blanckenhorn - Zakhera: 325, fig. 7/8-10.
2004 *Pterodonta gigantica* Abbass – Khalil & Mashaly: pl. 2, fig. 10.
2004b *Pterodonta deffisi* Thomas & Peron – Abdel-Gawad et al.: pl. 5, fig. 10.
2006 *Pterodonta deffisi* Thomas & Peron – El Qot: 105, pl. 21, figs. 9, 10.

Material and occurrence. Eight internal moulds from the lower marly, middle carbonate, and upper carbonate/marl members of the Upper Albian-Cenomanian Halal Formation, beds 1, 15, and 19 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.133-134,**9**.16-17,**15**.170-173), eight specimens from the Cenomanain Galala Formation, beds 3 and 15 of the East Themed area (MGDMU:ET.G.**3**.133-134,**15**.42-47), and eight internal moulds from the lower shale and middle siliciclastic/carbonate members of the Cenomanian Galala Formation, beds 12 and 41 at Wadi Quseib (MGDMU:WQ.G.**12**.41-44;**41**.57-60).

Measurements (in mm).

n= 3	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
Range	58-65	33-38	46-53	38-43	19-21	50°-57°	0.52-0.61	0.79-0.85	0.44-0.55
Mean	61.66	35	50.33	40	20.33	52.66 °	0.57	0.81	0.51

Description. Moulds large-sized, fusiform, and moderately high-spired. Spire consisting of two overlapping whorls with damaged apex. These whorls are slightly convex and separated by moderately deep sutures. Body whorl large, elongated, and accounting for about 81% the total height with slightly convex flanks. Base narrow and nearly acute. Aperture relatively narrow and elongate to oval in shape. Outer lip slightly convex and inner lip nearly straight to slightly concave. Ornamentation not preserved.

Temporal and spatial distribution. *Pterodonta deffisi* has been recorded from the Cenomanian of Jordan (Berndt, 2002) and Syria (Blanckenhorn, 1934). In Egypt, it has been collected from the Cenomanian of Gebel Ekma, East Themed area, and G. Yelleg (El Qot, 2006), Um Heriba (Abdel-Gawad & Zalat (1992), EL Giddi Pass (Abdalla et al., 2001), G. El-Fallig (Abdel-Gawad et al., 2004b), G. Nezzazat (Fawzi, 1963; Abdel-Gawad & Gameil, 1992), Wadi Feiran and W. Abu Qada (Kora et al., 1993), W. Hawashia (Abbass, 1963); W. Malha (Zakhera, 2002), and from the Cenomanian-Turonian of G. Musabaa Salama (Zakhera, 2001; Khalil & Mashaly, 2004).

Discussion. The present specimens closely resemble *Pterodonta gigantica* ABBASS, 1963 from the Cenomanian of Sinai in general outline and shape of aperture and spire. In agreement with ABDEL-GAWAD & GAMEIL (1992), BERNDT (2002), and EL QOT (2006) considered *P. gigantica* as a junior synonym of *P. deffisi.*

P. homarensis BLANCKENHORN, 1927 from the Cenomanian of Syria also closely resembles *P. gigantica* of ABBASS (1963: pl. 7, figs. 1-2) in having the same aperture outline and abapertural groove. In addition, his material is poorly preserved and only one view (abapertural view) is shown. Therefore, BLANCKENHORN'S material may be a synonym of *P. deffisi*. *P. ovata* D'ORBIGNY of ALBANESI & BUSSON (1974: pl. 24, fig. 1) from the Upper Cretaceous of Libya differs in having a sharp base and narrower aperture.

P. subinflata COQUAND (1862: 179, pl. 6, fig. 1) and *P. inflata* D'ORBIGNY, 1842 described by COLLIGNON (1971: 11, 153, pl. A, fig. 4) from the Lower Turonian of Algeria differ from the present species in being more inflated, and in having strongly convex outer and inner lips with a nearly rounded base. *P. elongata* D'ORBIGNY, 1842 of KOLLMANN (1985: 97, fig. 5f-g) from the Cenomanian-Santonian of France differs in having a sharp base with a concave inner lip.

Pterodonta cf. *subinflata* (COQUAND, 1862)
Pl. 18, Fig. 4

cf. 1862 *Pterodonta subinflata* sp. nov. – COQUAND: 179, pl. 6, fig. 1.
cf. 2002 *Pterodonta* cf. *subinflata* COQUAND – BERNDT: 145, pl. 9, fig. 12.

Material and occurrence. One internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 42 at Wadi Quseib (MGDMU:WQ.G.**42**.80).

Measurements (in mm).

n=1	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
	69	49	58	41	21	79°	3	0.71	0.84	0.51

Description. Large-sized, ovate gastropod. Spire conical and consisting of two rapidly enlarging whorls, separated by a shallow sutures. Whorl sides slightly convex. Body whorl inflated and accounting for about 84% of the total height. Basal part broadly rounded. Aperture loop-shaped with strongly convex outer lip and concave inner lip. Ornamentation not preserved.

Temporal and spatial distribution. *Pterodonta subinflata* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862) and the Cenomanian of Jordan (BERNDT, 2002).

Discussion. The present material resembles *Pterodonta subinflata* of COQUAND (1862) in general shape, convexity of whorls, and shape of inner and outer lips but differs in having a wider aperture and a broadly rounded base. *P. subinflata* of BERNDT (2002) from the Cenomanian of Jordan differs in being smaller than the present specimen (H=33-35 mm, D=22-23 mm).

Genus *Pterodonticeras* BLANCKENHORN, 1927
?*Pterodonticeras germeri* BLANCKENHORN, 1927
Pl. 18, Fig. 5

1927 *Pterodonticeras Germeri* sp. nov. – BLANCKENHORN: 168, pl. 5, figs. 90-92.
1938 *Pterodonticeras germeri* BLANCKENHORN – WENZ: 927, fig. 2716.
2001 *Pterodonticeras germeri* BLANCKENHORN – ZAKHERA: pl. 3, fig. 2.
2002 *Pterodonticeras germeri* BLANCKENHORN – BERNDT: 145, pl. 10, fig. 9.

Material and occurrence. Three internal moulds from the middle carbonate and upper carbonate/marl members of the Cenomanian Halal Formation, beds 15 and 19 at Gebel Areif El-Naqa (MGDMU:AEN.G.**15**.174,**19**.18-19).

Measurements (in mm).

n= 2	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	60-75	42-65	52-56	51-70	18-20	67°-80°	3-4	0.66-0.70	0.75-0.86	0.28-0.35
Mean	67.50	46	54	60.50	19	73°.50	4	0.68	0.80	0.31

Description. Large-sized, ovate, and moderately high-spired gastropods. Spire conical and consisting of three continuously enlarging convex whorls separated by moderately deep sutures. Body whorl large, broad, and accounting for about 80% of the total height. The basal whorl with a broadly concave medium groove is strongly enlarged at the aperture forming a large, wing-shaped structure. Apex not preserved. Base nearly flat. Aperture narrow, ovate, and elevated. Outer lip nearly flat with slightly convex inner lip. The specimens are internal moulds without traces of ornamentation.

Temporal and spatial distribution. *Pterodonticeras germeri* has been recorded from the Cenomanian of Jordan (BERNDT, 2002) and Syria (BLANCKENHORN, 1927). In Egypt, it occurs in the Upper Cenomanian of Gebel Musabaa Salama (ZAKHERA, 2001).

Discussion. BLANCKENHORN (1927: 167) noted that his new genus is transitional between the genus *Pterodonta* D'ORBIGNY, 1842 and the genus *Harpagodes* GILL, 1870. He pointed out that the spiral groove of the last whorl (along the abapertural side) may be due to artificial processes. In addition, his material is poorly preserved, no apertural view is figured, and his discussion is not sufficient to erect a new genus. Therefore, the genus *Pterodonticeras* is used herein with some doubts, especially as its characters are very similar to the genus *Harpagodes.*

Pterodonticeras germeri resembles *Harpagodes heberti* (THOMAS & PERON, 1889) in having spiral carinae and in the convexity of whorls but differs in having a large and ovate aperture, straight outer lip, broad base, and a moderately high spire.

According to BERNDT (2002: 146), the first whorls of this species are ornamented by three axial ribs crossed by spiral cords which are not preserved in the present material. However, the typical shape points to *Pterodonticeras germeri* BLANCKENHORN, 1927.

Pterocera augei (COQUAND, 1862: 186, pl. 5, fig. 5) from the Santonian of Algeria differs from the present species in being more slender and having a slightly convex outer lip with an acute base and apex. *P. peini* COQUAND (1862: 184, pl. 5, fig. 8) from the Turonian of Algeria is smaller than the present material and possesses a strongly convex outer lip.

Family Tylostomatidae STOLICZKA, 1868

Genus *Tylostoma* SHARPE, 1849
Subgenus *Tylostoma* SHARPE, 1849
Tylostoma (*Tylostoma*) *cossoni* THOMAS & PERON, 1889
Pl. 18, Fig. 6

1889 *Tylostoma Cossoni* sp. nov. – THOMAS & PERON in PERON: 57, pl. 19, figs. 24-25.

1912 *Tylostoma Cossoni* THOMAS & PERON – PERVINQUIÈRE: 54, pl. 4, figs. 11-12.
1916 *Tylostoma Cossoni* THOMAS & PERON – GRECO: 144 (86), pl. 17 (9), fig. 13.
1971 *Tylostoma cossoni* THOMAS & PERON – COLLIGNON: 5 (147), pl. A, fig. 7.
1974 *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON – ALBANESI & BUSSON: 308, pl. 25, figs. 2-3.
1981 *Tylostoma cossoni* THOMAS & PERON – AMARD et al.: 70, pl. 6, fig. 7.
1992 *Tylostoma cossoni* THOMAS & PERON – ABDEL-GAWAD & GAMEIL: 82, fig. 3/18-19.
2002 *Tylostoma cossoni* THOMAS & PERON – BERNDT: 143, pl. 9, fig. 6a-b.
2004b *Tylostoma cossoni* THOMAS & PERON – ABDEL-GAWAD et al.: pl. 5, fig. 12a-b.
2006 *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON – EL QOT: 108, pl. 22, figs. 6, 7a-b.
2007a *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON – MEKAWY: 166, pl. 3, fig. 3.

Material and occurrence. 13 internal moulds from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) and Lower Turonian Abu Qada Formation, beds 1, 15, and 30 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.135-136,**15**.175-183,**30**.26-27); 10 internal moulds from the lower shale and middle siliciclastic/carbonate members of the Cenomanian Galala Formation and Upper Turonian Wata Formation, beds 12, 31, 93, and 97 at Wadi Quseib (MGDMU:WQ.G.**12**.45,**31**.33-34,**93**.19-21,**97**.29-34), and eight specimens from the Cenomanian Galala Formation, bed 15 of the East Themed area (MGDMU:ET.G.**15**.43-55).

Measurements (in mm).

n= 11	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	22-67	17-60	20-58	15-50	9-28	70° -90°	3-4	0.75-1.09	0.69-0.97	0.33-0.76
Mean	43.27	36.27	37.90	32	16.70	81°	4	0.85	0.87	0.52

Description. Moulds moderately large- to large-sized, globular to ovate, and moderately low-spired gastropod. Spire conical and consisting of 3-5 overlapping, moderately convex whorls separated by deep sutures. Body whorl large, rounded in outline, much inflated, and accounting for the main part of the shell (about 87% of the total height). Base broadly rounded. Apex commonly damaged. Aperture oval and narrow with strongly convex outer lip and sinuous inner lip. All specimens are internal moulds without elements of ornamentation.

Temporal and spatial distribution. *Tylostoma* (*Tylostoma*) *cossoni* has been recorded from the Turonian of Tunisia (THOMAS & PERON, 1889; PERVINQUIÈRE, 1912), Cenomanian-Turonian of Algeria (COLLIGNON, 1971; ALBANESI & DUSSON, 1974; AMARD et al., 1981), and Cenomanian of Jordan (BERNDT, 2002). In Egypt, it is known from the Albian-Cenomanian of Gebel Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), G. EL-Fallig (ABDEL-GAWAD et al., 2004b), and the Upper Cenomanian-Turonian of Gebel Ekma and East Themed (EL QOT, 2006). The species has also been recorded from the Upper Cenomanian-Lower Turonian of the Eastern Desert (GRECO, 1916; MEKAWY, 2007a).

Discussion. The genus *Tylostoma* was erected by SHARPE (1849), who described four species from the Turonian of Portugal. KOLLMAN et al. (2003) placed Tylostomatidae in Stromboidea (for more details about the systematic history see BOUCHET & ROCROI, 2005: 179, 277).

Tylostoma? sp., described by KIEL & BANDEL (2004: 118, pl. 7F-G) from the Cenomanian of Germany, closely resembles the present species in general shape, size, and apertural outline. *T. syriacum* CONRAD, 1852 of BLANCKENHORN (1927: 137, pl. 11, fig. 29) from the Cenomanian of Syria also resembles the present material in having an ovate aperture, convexity, number of whorls, and suture but differs in being larger. *T. choffati*

(DOUVILLÉ: 1916: 143, pl. 19, figs. 1, 3) from the Upper Albian of Gebel Manzour differs in having six strongly convex whorls, relatively longer spire, and in being larger. While the whorl sides of *T* (*T.*) *canaliculata* ABOUL ELA et al. (1991: 211, pl. 3, figs. 1-2) from the Lower Albian of Gebel Manzour are concave with canaliculated sutures.

According to BERNDT (2002: 143), *T. punctatum* SHARPE (1849: 378, figs. 3-4) differs in having a more elevated last whorl than *T.* (*T.*) *cossoni*.

Tylostoma (*Tylostoma*) *globosum* SHARPE, 1849
Pl. 18, Fig. 7; Pl. 19, Figs.1-2

1849 *Tylostoma globosum* sp. nov. – SHARPE: 379, pl. 9, figs. 5-6.
1912 *Tylostoma globosum* SHARPE – PERVINQUIÈRE: 53, pl. 4, figs. 9-10.
1916 *Tylostoma globosum* SHARPE – GRECO: 143 (85), pl. 17 (9), figs. 11-12.
1938 *Tylostoma* (*Tylostoma*) *globosum* SHARPE – WENZ: 1027; text-fig. 2941.
1963 *Tylostoma* (*Tylostoma*) *gadensis* sp. nov. - ABBASS: 90, pl. 10, figs. 2-5.
1974 *Tylostoma* (*Tylostoma*) *globosum* SHARPE – ALBANESI & BUSSON: 309, pl. 25, fig. 1.
1981 *Tylostoma globosum* SHARPE – AMARD et al.: 70, pl. 5, fig. 3.
1985 *Tylostoma* aff. *globosa* SHARPE – KOLLMANN: 102, fig. 5k.
1991 *Tylostoma* (*Tylostoma*) *globosum* SHARPE – ABOUL ELA et al.: 211, pl. 4, fig. 1.
1992 *Tylostoma globosum* SHARPE – ABDEL-GAWAD & GAMEIL: 81, fig. 4/9.
2001 *Tylostoma globosum* SHARPE – ABDALLAH et al.: pl. 1, figs. 14-15.
2001 *Tylostoma globosum* SHARPE – KORA et al.: pl. 3, fig. 4.
2001 *Tylostoma globosum* SHARPE – ZAKHERA: pl. 3, fig. 10.
?2001 *Tylostoma gadensis* ABBASS – ZAKHERA: pl. 3, figs. 13-14.
2002 *Tylostoma globosum* SHARPE – BERNDT: 143, pl. 9, fig. 5.
2004a *Tylostoma* (*Tylostoma*) *globosum* SHARPE – ABDEL-GAWAD et al.: pl. 6, fig. 2.
2006 *Tylostoma* (*Tylostoma*) *globosum* SHARPE – EL QOT: 109, pl. 22, fig. 8.
2007a *Tylostoma* (*Tylostoma*) *globosum* SHARPE – MEKAWY: 166, pl. 3, fig. 4.
2008 *Tylostoma* (*Tylostoma*) *globosum* SHARPE – MEKAWY & ABU-ZEID: 329, pl. 5, fig. 8.

EXPLANATION OF PLATE 19

Figs. 1-2. *Tylostoma* (*Tylostoma*) *globosum* SHARPE, 1849. **1**. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. **a**: Apertural view, **b**: apical view; MGDMU:WQ.G.**55**.71. - **2**. Internal mould from the Upper Turonian Wata Formation of the East Themed area, x1. Abapertural view; MGDMU:ET.G.**31**.50.

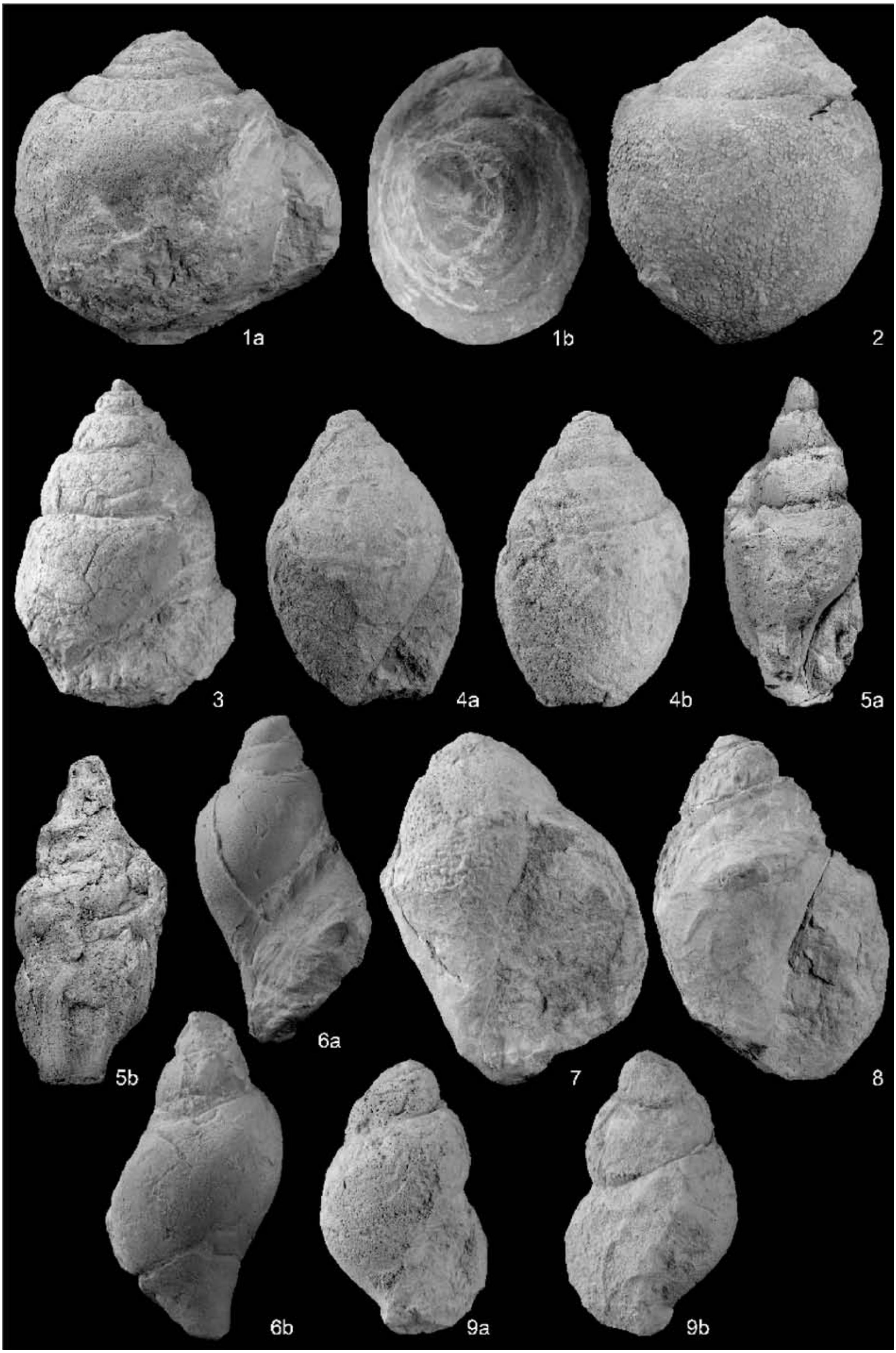
Figs. 3-4. *Tylostoma* (*Tylostoma*) *pallaryi* (PERON & FOURTAU, 1904). Internal moulds from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa. **3**. Apertural view, x1.5; MGDMU:AEN.G.**1**.137. – **4.a**: Apertural view x1, **b**: abapertural view, x1; MGDMU:AEN.G.**15**.176.

Fig. 5. *Fasciolaria tournoueri* THOMAS & PERON, 1889. Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1.5. **a**: Apertural view, **b**: Abapertural view; MGDMU:ET.G.**26**.160.

Fig. 6. *Palaeatractus* cf. *figarii* (GRECO, 1916). Internal mould from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa, x2. **a**: Apertural view, **b**: abapertural view; MGDMU:AEN.G.**23**.5.

Figs. 7-8. *Caricella*? sp. Internal moulds from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa, x1. **7**. Apertural view; MGDMU:AEN.G.**15**.140. - **8**. Apertural view; MGDMU:AEN.G.**15**.189.

Fig. 9. Gastropod indet. Internal mould from the Cenomanian Galala Formation of the East Themed area, x1,5. **a**: Apertural view, **b**: abapertural view; MGDMU:ET.G.**11**.71.


1a
1b
2
3
4a
4b
5a
5b
6a
7
8
6b
9a
9b

Material and occurrence. 22 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation and Upper Turonian Wata Formation, beds 25, 31, 50, and 53 (MGDMU:ET.G.**25**.74-77,**31**.50-61,**50**.1,**53**.2-6) of the East Themed area, five specimens from the Lower Turonian Abu Qada Formation, beds 47, 55, and 76 (MGDMU:WQ.G.**47**.61-62,**55**.71-72,**76**.21) at Wadi Quseib and three specimens from the lower member of the Lower Turonian Abu Qada Formation, bed 23 (MGDMU:AEN.G.**23**.2-4) at Gebel Areif El-Naqa.

Measurements (in mm).

n= 6	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	23-62	18-55	20-58	17-47	9-21	100 ° -115 °	3-4	0.78-0.98	0.85-0.96	0.30-0.53
Mean	51	45.5	46.16	38.16	15	108°	4	0.88	0.90	0.43

Description. Moderately large- to large-sized, ovoid to globose, and low-spired gastropods. Spire consisting of 3-4 rounded and nearly smooth whorls. These whorls are wide, compressed, and separated by slightly depressed sutures. Body whorl inflated with rounded flanks, smooth, and forming the greater part of the specimen (about 90% of the total height). Base broadly rounded. Aperture narrow and semi-lunar. Outer lip strongly convex, inner lip slightly convex.

Temporal and spatial distribution. *Tylostoma* (*Tylostoma*) *globosum* is a widespread and easily identifiable Cretaceous gastropod of the Tethyan realm occurring especially in the Turonian of Portugal (SHARPE, 1849), Tunisia (PERVINQUIÈRE, 1912), Cenomanian-Turonian of Algeria (ALBANESI & BUSSON, 1974; AMARD et al., 1981), Cenomanian of Jordan (BERNDT, 2002), and Santonian of France (KOLLMANN, 1985). In Egypt, it is known from the Lower Turonian of Gebel Mukattab (KORA et al., 2001), G. Musabaa Salama (ZAKHERA, 2001), Cenomanian-Turonian of G. Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), Turonian of El Giddi Pass (ABDALLAH et al., 2001), East Themed and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006), and from the Upper Aptian-Turonian of G. Mistan (MEKAWY & ABU-ZEID, 2008). The species has been recorded also from the Eastern Desert (GRECO, 1916; ABBASS, 1963; MEKAWY, 2007a). Its stratigraphic range is from the Aptian to the Turonain.

Discussion. *Tylostoma* (*Tylostoma*) *globosum* is easily recognized by its globose to broadly oval shape and the low spire. *T.* (*T.*) *cossoni* THOMAS & PERON differs in having a moderately high spire. *T.* (*T.*) *gadensis* ABBASS, 1963 from the Turonian of Wadi Abu Qada is identical to *T. globosum* in the general shape (globose), aperture outline, rounded base, and whorls number. ZAKHERA (2001) figured the two latter species from the Upper Cretaceous of west central Sinai but without discussion. *T.* (*T.*) *gadensis* is regarded herein as a junior synonym of *T. globosum*.

Tylostoma (*Tylostoma*) *pallaryi* (PERON & FOURTAU, 1904)

Pl. 19, Figs. 3-4

1904 *Pseudomelania Pallaryi* sp. nov. – PERON & FOURTAU in FOURTAU: 270, pl. 1, fig. 22.
1916 *Tylostoma Pallaryi* PERON & FOURTAU – GRECO: 151 (93), pl. 18 (10), figs. 2-4.
1963 *Tylostoma pallaryi* PERON & FOURTAU – FAWZI: 91, pl. 7, figs. 1-3.
1974 *Tylostoma* (*Tylostoma*) *pallaryi* (PERON & FOURTAU) – ALBANESI & BUSSON: 310, pl. 24, fig. 6.
1985 *Tylostoma* cf. *pallaryi* (PERON & FOURTAU) – DOMINIK: pl. 15, fig. 7.
?2001 *Tylostoma cossoni* (THOMAS & PERON) – ABDALLAH et al.: pl. 1, figs. 10-11.
2001 *Tylostoma pallaryi* (PERON & FOURTAU) – ZAKHERA: pl. 3, fig. 9.

2002 *Tylostoma pallaryi* (Peron & Fourtau) – Zakhera: 320, fig. 2/12-14.
2004b *Tylostoma pallaryi* (Peron & Fourtau) – Abdel-Gawad et al.: pl. 5, fig. 13.
2006 *Tylostoma* (*Tylostoma*) *pallaryi* (Peron & Fourtau) – El Qot: 109, pl. 22, fig. 10.
2007a *Tylostoma* (*Tylostoma*) *pallaryi* (Peron & Fourtau) – Mekawy: 167, pl. 3, fig. 5.

Material and occurrence. 10 internal moulds from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 1, 12, and 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.137-140,**12**.37,**15**.176-188), and three specimens from the Cenomanian Galala Formation, bed 12 of the East Themed area (MGDMU:ET.G.**12**.133-135).

Measurements (in mm).

n= 5	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
Range	34-40	23-26	23-31	15-22	8-14	62°-70°	3-5	0.57-0.73	0.59-0.82	0.40-0.65
Mean	37.80	24.20	28.20	19.80	10.80	64°.40	4	0.64	0.75	0.54

Description. Moderately large- to large-sized, ovate, and moderately high-spired gastropod. Spire conical and consisting of three overlapping smooth whorls. These whorls are slightly convex and separated by slightly depressed sutures. Body whorl large, semi-conical, with convex flanks, and accounting for about 2/3 of the total height. Aperture partly broken but most probably narrow and lanceolate. Ornamentation not seen.

Temporal and spatial distribution. *Tylostoma* (*Tylostoma*) *pallaryi* has been recorded from the Cenomanian of Algeria (Albanesi & Busson, 1974). In Egypt, it is known from the Cenomanian-Lower Turonian of Gebel Ekma and G. Yelleg (El Qot, 2006), Cenomanian of the Eastern Desert (Greco, 1916; Zakhera, 2002; Mekawy, 2007a), G. El-Fallig (Abdel-Gawad et al., 2004b), G. Nezzazat (Fawzi, 1963), G. Dist (Bahariya Oasis, Western Desert) (Dominik, 1985), and G. Musabaa Salama (Zakhera, 2001).

Discussion. *Tylostoma pallaryi* (Peron & Fourtau) is smaller than *T. globosum* Sharpe and has a relatively high spire. *T. syriacum* (Conrad, 1852) of Blanckenhorn (1927: 137, pl. 2, fig. 2) from the Cenomanian of Syria closely resembles *T. pallaryi* in general shape but differs in being larger and having a shallow umbilicus with slightly deep sutures.

Clade Neogastropoda Wenz, 1938
Superfamily Buccinoidea Rafinesque, 1815
Family Fasciolariidae Gray, 1853
Subfamily Fasciolariinae Gray, 1853
Genus *Fasciolaria* Lamarck, 1799
Fasciolaria tournoueri Thomas & Peron, 1889
Pl. 19, Fig. 5

1889 *Fusus Tournoueri* sp. nov. – Thomas & Peron in Peron: 91, pl. 21, figs. 19-20.
1912 *Fasciolaria* (*Cryptorhytis) Tournoueri* Thomas & Peron – Pervinquière: 71, pl. 5, fig. 16.

Material and occurrence. Two composite moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26, of the East Themed area (MGDMU:ET.G.**26**.160-161).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PAº	nw	D/H	HL/H	WA/HA
	43	19	30	22	6	25º	4	0.44	0.70	0.27

Description. Medium-sized, fusiform, elongated, and high-spired gastropod. Spire narrow, conical, consisting of four overlapping whorls with slightly convex surfaces. Whorls separated by moderately deep sutures. Body whorl accounting for about 70% of the total height. Aperture small, oval, elongated, extending anteriorly into an elongated narrow canal. Base nearly sharp. Inner lip concave, outer one slightly convex. Spire ornamented with strong axial ribs separated by wide and concave interspaces. The spiral cords are not preserved due to the poor preservation. Body whorl ornamented with finer axial ribs, separated by narrow interspaces.

Temporal and spatial distribution. *Fasciolaria tournoueri* has been recorded from the Turonian of Tunisia (Thomas & Peron, 1889; Pervinquière, 1912).

Discussion. The present species is characterized by a high spire and a fusiform shaped with a strong axial sculpture.

Fasciolaria (*Cryptorhytis*) *bleicheri* (Thomas & Peron) of Pervinquière (1912: 70, pl. 5, figs. 12-13, 15) from the Coniacian of Tunisia differs in having a wider shell and a larger drop-shaped aperture. In addition, the body whorl is ornamented with strong axial ribs, separated by wide interspaces (see Thomas & Peron, 1889: pl. 22, fig. 6). The present species also resembles *Fasciolaria safrensis* Abbass (1963: 93, pl. 8, figs, 4-6) from the Cenomanian of Gebel Safra, Egypt in general outline but the latter species differs in being larger (H= 77 mm) and in having a different ornamentation.

Fusus tevesthensis Coquand (1862: 187, pl. 4, fig. 13) from the Upper Cretaceous of Algeria resembles *Fasciolaria tournoueri* in general shape (fusiform) and aperture outline but differs in having wider interspaces between the axial ribs and in being larger (H=100 mm).

Family Melongenidae Gill, 1871 (1854)

Subfamily Melongeninae Gill, 1871
Genus *Palaeatractus* Gabb, 1869
Palaeatractus cf. *figarii* (Greco, 1916)
Pl. 19, Fig. 6

cf.1916 *Sycum* (*Palaeatractus*) *Figarrii* sp. nov. – Greco: 163, pl. 19, fig. 11.
cf.1963 *Sycum* (*Palaeatractus*) *figarrii* Greco – Fawzi: 114.
cf.2006 *Palaeatractus figarii* (Greco) – El Qot: 110, pl. 22, fig. 9; pl. 23, fig. 1a-b.

Material and occurrence. Two internal moulds from the lower member of the Lower Turonian Abu Qada Formation, bed 23 at Gebel Areif El-Naqa (MGDMU:AEN.G.**23**.5-6).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	PAº	nw	D/H	HL/H	WA/HA
	34	18	25	20	11	60	3	0.53	0.73	0.55

Description. Specimens large-sized, fusiform, and moderately high-spired. Spire consisting of two overlapping, slightly convex whorls separated by moderately deep sutures. Body whorl large and accounting for about 73% of the total height. Base nearly acute. Aperture large and lanceolate with strongly convex outer lip and slightly concave inner lip. Ornamentation in the form of faint axial ribs on the last whorl near the outer lip.

Temporal and spatial distribution. *Palaeatractus figarii* has been recorded from the Cenomanian of the Eastern Desert (Greco, 1916; Fawzi, 1963) and G. El-Hamra, and G. Yelleg (Sinai) (El Qot, 2006).

Discussion. Greco's species has numerous axial ribs crossed by numerous spiral cords forming a characteristic network pattern. The present material closely resembles *Palaeatractus figarii* (Greco, 1916) in general shape and aperture outline but differs in lacking this reticulate pattern. Also, the suture angle is steeper than in Greco's species.

Superfamily Muricoidea Rafinesque, 1815
Family Volutidae Rafinesque, 1815
Subfamily Scaphellinae Gray, 1857
[=Priamidae Sismonda, 1842;= Haliinae Kobelt, 1888;
=Caricellinae Dall, 1907;=Auriniinae Smith, 1942;
=Ampullidae Winckworth, 1945]
Genus *Caricella* Conrad, 1835
Caricella? sp.
Pl. 19, Figs. 7-8

Material and occurrence. Two internal moulds from the middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.G.**15**.189-190).

Measurements (in mm).

n= 2	H	D	HL	HA	WA	PAº	nw	D/H	HL/H	WA/HA
Range	63-67	42-47	48-54	42-51	23-30	60º-85º	3-4	0.66-0.70	0.72-0.86	0.54-0.59
Mean	65	44.50	51	46.50	26.50	72º.50	4	0.68	0.79	0.56

Description. Large-sized, stromboid-shaped, and moderately low-spired gastropod. Spire consisting of three slightly convex whorls with shouldered sutures. Body whorl large, globular, and accounting for about 79% of the total height. Aperture large and semi-lanceolate with a strongly convex outer lip. Inner lip straight to slightly concave. Ornamentation not preserved.

Discussion. Most of volutid shells are ovate to strombiform with high or low spire. Moreover, the ornamentation consists mainly of axial riblets often forming strong nodes on the shoulder, occasionally the shells are completely smooth. Therefore, no precise identification for the present specimens is possible due to the poor preservation. The present material is an internal mould but it shows similarities to *Caricella stromboides* (Munier–Chalmas, 1882) of Abdel-Gawad (2000: 1522, pl. 2, figs. 5-6) from the Coniacian-Santonian of Gebel Nezzazat and Magmar (Sinai) in general shape but the latter species differs in being smaller and in having slightly concave whorls and a small aperture. *C. pyriformis* (Forbes) of Albanesi & Busson (1974: pl. 28, fig. 1) from the Senonian of Algeria differs in lacking the shouldered sutures, having a low spire, and a more convex last whorl.

Gastropod indet.
Pl. 19, Fig. 9

Material and occurrence. A single internal mould from the Cenomanian Galala Formation, bed 11 of East Themed (MGDMU:ET.G.**11**.71).

Measurements (in mm).

n=1	H	D	HL	HA	WA	PA°	nw	D/H	HL/H	WA/HA
	35	23	27	19	12	75°	3	0.66	0.77	0.63

Description. Mould large-sized, fusiform, and moderately high-spired. Spire consisting of at least three overlapping convex whorls separated by moderately deep sutures. Body whorl large, conical, and accounting for the main part of specimen (about 77% of the total height). Aperture moderately large and ovate. Outer lip strongly convex, inner lip straight. Apex not preserved. Base nearly rounded. Ornamentation not preserved.

Discussion. This specimen shows similarities to *Amaurellina degensis* (SACCO), described by WENZ (1938: 1026, fig. 2939), in the shape of the aperture, suture angle, and convexity of whorls. But due to the poor preservation (as internal mould), an identification even at the generic level is not possible.

Clade Heterobranchia GRAY, 1840
Informal Group "Lower Heterobranchia"
(=Allogastropoda PONDER, 1986)
Superfamily Acteonoidea D'ORBIGNY, 1843
Family Acteonidae D'ORBIGNY, 1843

Subfamily Acteoninae D'ORBIGNY, 1843
Genus *Acteon* MONTFORT, 1810
Acteon? sp.
Pl. 20, Fig. 1

Material and occurrence. Three internal moulds from the lower marly member of the Upper Albian-Cenomanian Halal Formation, bed 9, at Gebel Areif El-Naqa (MGDMU:AEN.G.**9**.53-55).

EXPLANATION OF PLATE 20

Fig. 1. *Acteon*? sp. Internal mould from the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: Apertural view, **b**: abapertural view, **c**: apical view; MGDMU:AEN.G.**9**.53.

Fig. 2. *Globiconcha* cf. *rotundata* D'ORBIGNY, 1843. Internal mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, x1. **a**: Apertural view, **b**: abapertural view; MGDMU:AEN.G.**1**.141.

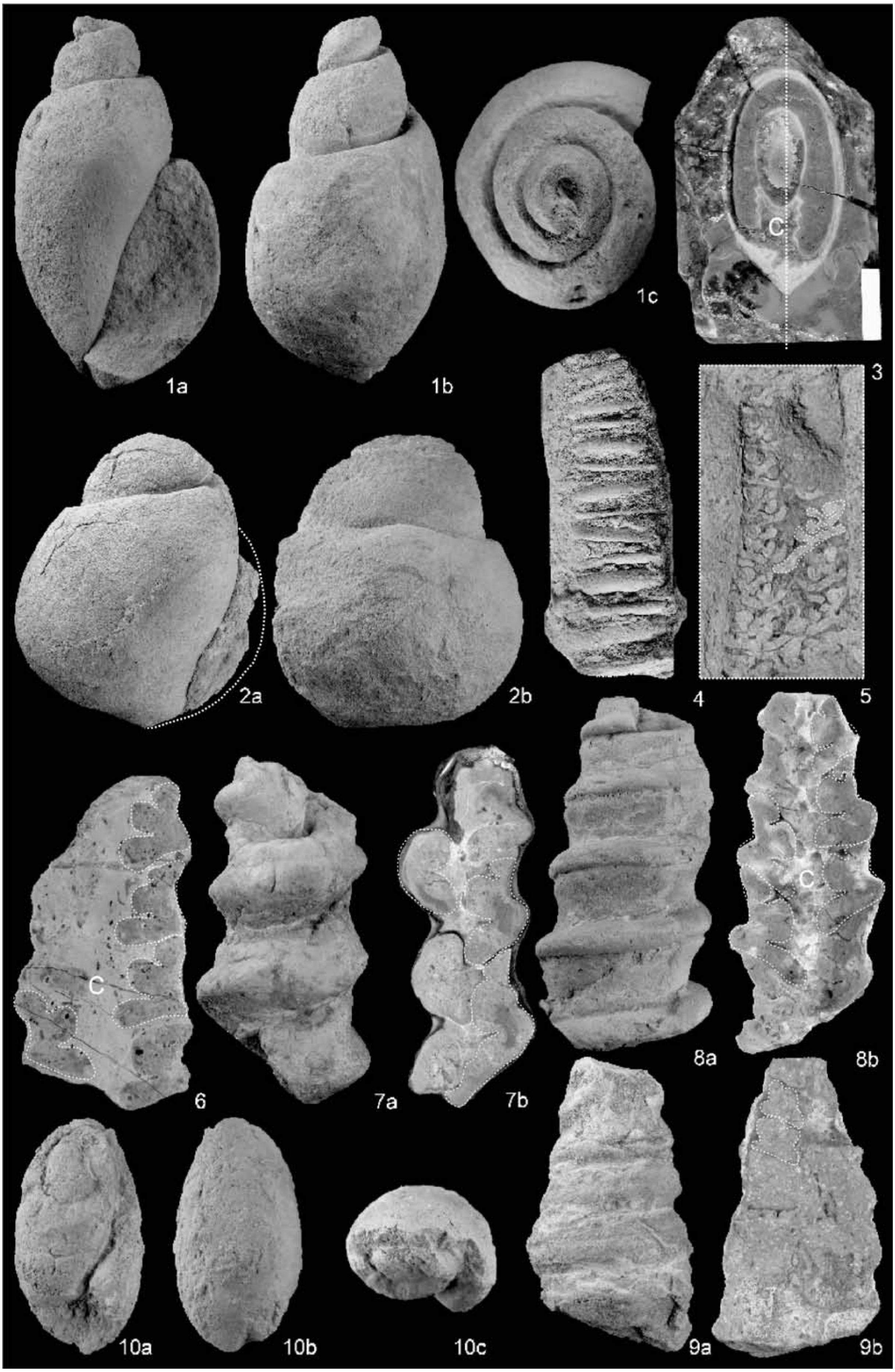
Fig. 3. *Sogdianella*? *laevis laevis* (J. DE C. SOWERBY, 1835). Lower Turonian Abu Qada Formation at Wadi Quseib. Axial section, bar scale=1 cm; MGDMU:WQ.G.**55**.73.

Figs. 4-5. *Neoptyxis olisiponensis* (SHARPE, 1850). Internal moulds from the middle siliciclastic/carbonate and upper carbonate members of the Cenomanian Galala Formation at Wadi Quseib. **4**. Side view, x1.5; MGDMU:WQ.G.**15**.31. – **5**. Longitudinal whorl section, x1; MGDMU:WQ.G.**44**.236.

Fig. 6-8. *Pchelinsevia coquandiana* (D'ORBIGNY, 1842). Internal moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. – **6**. Longitudinal whorl section, x1; MGDMU:WQ.G.**31**.35. – **7.a.** Side view, **b**: longitudinal whorl section, x1; MGDMU:WQ.G.**22**.81. **8. a**. Side view, x1, **b**: longitudinal whorl section, x1; MGDMU:WQ.G.**12**.47.

Fig. 9. *Diozoptyxis*? *blancheti* (PICTET & CAMPICHE, 1864). Internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Side view, x1, **b**: longitudinal whorl section, x1; MGDMU:WQ.G.**29**.14.

Fig. 10. *Akera thevestensis* (COQUAND, 1862). Internal mould from the Upper Cenomanian Galala Formation of the East Themed area, x1. **a**: Apertural view, **b**: abapertural view; **c**: apical view, x1; MGDMU:ET.G.**3**.160.


1a
1b
1c
C
3
4
5
2a
2b
C
6
7a
7b
8a
C
8b
10a
10b
10c
9a
9b

Measurements (in mm).

n= 2	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
Range	63-66	39-42	50-53	42-42	19-21	52°-54°	0.59-0.67	0.79-0.80	0.45-0.50
Mean	64.5	40.50	51.5	42	20	53°	0.63	0.79	0.47

Description. Specimens moderately large-sized, globose, and moderately high-spired. Spire consisting of two slightly inflated whorls separated by deep sutures with slightly tilted protoconch. Body whorl large, moderately inflated, elongated, and accounting for more than 80% of the total height. Basal part rounded. Aperture tear-shaped, elongated, and anteriorly rounded. Inner lip nearly straight, outer lip strongly convex. The present specimen is an internal mould that does not record any feature of the original ornamentation.

Discussion. According to STILWELL & HENDERSON (2002: 463), the genus *Acteon* is characterized by a moderately high spire of three subquadrate teleoconch whorls and a slightly tilted heterostrophic protoconch with spiral ornamentation. The present specimens show similarities to *Acteon pistilliformis* (SOHL, 1964: 287, pl. 47, figs. 24-28) from the Upper Cretaceous of southwestern Tennessee, but due to their poor preservation (internal moulds), the spiral cords are not visible. Moreover, SOHL'S species differs in being smaller (H=2.7-4.7 mm) and the aperture is posteriorly narrowed and anteriorly rounded. *A. pistilliformis* SOHL as figured by KORA et al. (1993: pl. 3, fig. 5) from the Cenomanian of Sinai is larger than SOHL'S materials.

Acteon (*Tenuiactaeon*) *antarcitihadrum* STILLWELL & ZINSMEISTER (2002: 1103, fig.2/1-4) from the Upper Cretaceous of Antarctica resembles the present material in size (>40 mm high) but differs in being narrower and in having a higher spire (45% of total shell height).

Genus *Globiconcha* D'ORBIGNY, 1842
Globiconcha cf. *rotundata* D'ORBIGNY, 1843
Pl. 20, Fig. 2

cf.1843 *Globiconcha rotundata* sp. nov. – D'ORBIGNY: 143, pl. 169, fig. 17.
cf.1971 *Globiconcha rotundata* D'ORBIGNY – COLLIGNON: 161, pl. A, fig. 3.
cf.1974 *Globiconcha* (*Globiconcha*) *rotundata* D'ORBIGNY – ALBANESI & BUSSON: 320, pl. 28, figs. 3-4.
cf.1981 *Globiconcha rotundata* D'ORBIGNY – AMARD et al: 65, pl. 5, figs. 5-6.
cf.2002 *Globiconcha rotundata* D'ORBIGNY – BERNDT: 146, pl. 9, fig. 11.

Material and occurrence. Two internal moulds from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), bed 1 at Gebel Areif El-Naqa (MGDMU:AEN.G.**1**.141-142).

Measurements (in mm).

n= 2	H	D	HL	HA	WA	PA°	D/H	HL/H	WA/HA
Range	26-54	20-43	22-42	15-31	8-14	85°-91°	0.77-0.79	0.77-0.85	0.53-0.55
Mean	40	31.50	32	23	11	88°	0.78	0.81	0.54

Description. Specimens moderately large to large, globose, and moderately low-spired. Spire consisting of two rapidly expanding convex whorls separated by moderately deep sutures. Body whorl large, globose and accounting for more than 81% of the total height. Basal part broad and strongly rounded. Aperture narrowly ovate. Inner lip nearly straight, while outer lip incomplete. The present specimens are internal moulds that do not record any feature of the original ornamentation.

Temporal and spatial distribution. *Globiconcha rotundata* has been recorded from the Turonian of France (D'ORBIGNY, 1842), Lower Turonian of Algeria (COLLIGNON, 1971; ALBANESI & BUSSON, 1974; AMARD et al., 1981), and from the Cenomanian or Turonian of Jordan (BERNDT, 2002).

Discussion. The present material resembles *Globiconcha rotundata* D'ORBIGNY of ALBANESI & BUSSON (1974) and BERNDT (2002) in general outline, spire, and apertural shape but differ in being larger and deformed moulds. According to KOLLMANN (1985: 105), *G. intermedia* COQUAND differs in having a low spire.

Family Acteonellidae GILL, 1871

Subfamily Itieriinae COSSMANN, 1896
Genus *Sogdianella* DJALILOV, 1972

Remarks. The genus *Sogdianella* was included in the Acteonellidae by DJALILOV (1972). KOLLMANN & SOHL (1979: A4) pointed out that the genus *Sogdianella* is closely similar to the genus *Peruviella* OLSSON, 1944 but differs from the genus *Actaeonella* D'ORBIGNY, 1842, and, therefore, reassigned it to the Itieriidae in the superfamily Nerinaecea. In the classification of BOUCHET & ROCROI (2005), the Itieriinae are considered as a subfamily of the Acteonellidae. *Peruviella* has wide whorls with a longer anterior canal than *Sogdianella*, and the columella has much hollow space between the central pillar and the columellar lip of the following whorls. The genus *Actaeonella* has convex sides, the whorls are broader interiorly than *Sogdianella*, and the columella has more or less parallel sides and is solid. Apart from a small projecting beak at the base of the body whorl, *Sogdianella* differs from *Actaeonella* in the posterior extension of the aperture being twisted antispirally.

KOLLMANN & SOHL (1979: A9) and SQUIRES & SAUL (2002: 47) characterized that the genus *Sogdianella* by a sharp base of the body whorl, very narrow and numerous whorls (widened in the lower part of the shell), and a columella which forms an angle with the axis at the lower end and bears three folds (Text-fig. 3.31). Sampling of *Sogdianella* from the hard dolomitic limestone in the Wadi Quseib section (Lower Turonian Abu Qada Formation) was difficult. Therefore, some important characters such as the aperture is not seen and subsequently the specific identification is also difficult. However, the sharp base of the body whorl, the three columellar folds, narrow and numerous whorls, and a columella, which forms an angle with the axis are diagnostic features of *Sogdianella.*

Sogdianella ranges from the Albian to the Upper Cretaceous and is known only from central Europe, the Middle East, and Transcaucasia (KOLLMANN & SOHL 1979: A11). Thus the genus is the first record from the Lower Turonian of Egypt and North Africa.

Sogdianella? *laevis laevis* (J. DE C. SOWERBY, 1835)
Pl. 20, Fig. 3; Text-fig. 3.31

1835 *Volvaria laevis* sp. nov. – J. DE C. SOWERBY in SEDGWICK & MURCHISON: pl. 39, fig. 33.
?1845 *Actaeonella laevis* SOWERBY – REUSS: 50, pl. 10, fig. 21a-b.
1865 *Volvulina laevis* SOWERBY – STOLICZKA: 39.
?1902 *Actaeonella laevis* SOWERBY – CHOFFAT: 110, pl. 1, figs. 6, 7.
1965 *Actaeonella laevis laevis* (SOWERBY) – KOLLMANN: 247, pl. 1, figs. 5-8; pl. 4, fig. 23.

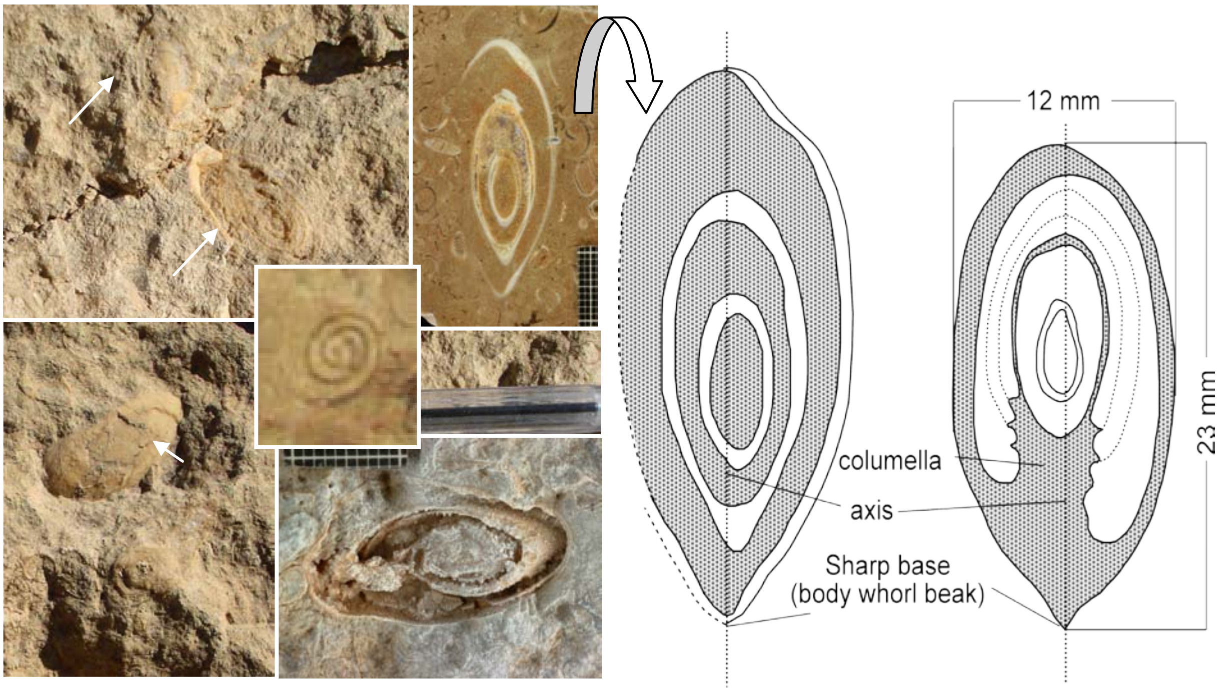
Material and occurrence. 78 specimens observed on bedding planes of the Lower Turonian Abu Qada Formation, beds 55, 59 and 78 at Wadi Quseib (MGDMU:WQ.G.**55**.73-130,**59**.1-10,**78**.5-14).

Description. Small-sized (20-25 mm in height, 7-12 mm in diameter), subcylindrical to slender, widest at middle and pointed at terminal apices. Whorl sides convex. External surface smooth (Text-fig. 3.31). Columella short with three plaits that decrease in strength anteriorly and are strongly inclined towards the axis at the lower end (Text-fig. 3.31). Whorls narrow, numerous, and only slightly widened in the lower part of shell. Aperture not seen.

Temporal and spatial distribution. *Sogdianella laevis laevis* has been recorded from the Upper Cenomanian-Lower Turonian of Portugal (Choffat, 1902), Czech Republic (Reuss, 1845), and the Santonian-Campanian of the eastern Alps (Kollmann, 1965). This is the first record of the species from Egypt.

Discussion. *Sodianella*? *laevis laevis* can be easily distinguished by its small size, cylindrical shell, convex whorl sides, pointed apices, and short columella with three plaits that decrease in strength anteriorly and are strongly inclined towards the axis at the lower end. The present material strongly resembles *S. laevis laevis* (J. de C. Sowerby) which described and figured by Kollmann (1965) from the Santonian-Campanian of the Alps in shell-diameters (length: 10-30 mm, W: 3-10 mm), cylindrical outline, and fold pattern.

Sogdianella syriaca (Conrad, 1852), described by Kollmann (1987: 50, pl. 3, figs. 39-40) from the Cenomanian of Greece, and *S. subcyclindrica* Kollmann & Sohl (1979: A11, figs. 6a-c) from the Maastrichtian of Cuba differ in being larger and in having well developed columellar folds. *Actaeonella caucasica grossouvrei* Zekeli and *A. caucasica caucasica* Cossmann differ from the present species in having wider shells, more convex whorl sides and in being larger (40-70 and 30-65 mm in length, respectively). *A. elongata* Kollmann resembles *Sogdianella laevis laevis* in shell-size but differs in being much higher



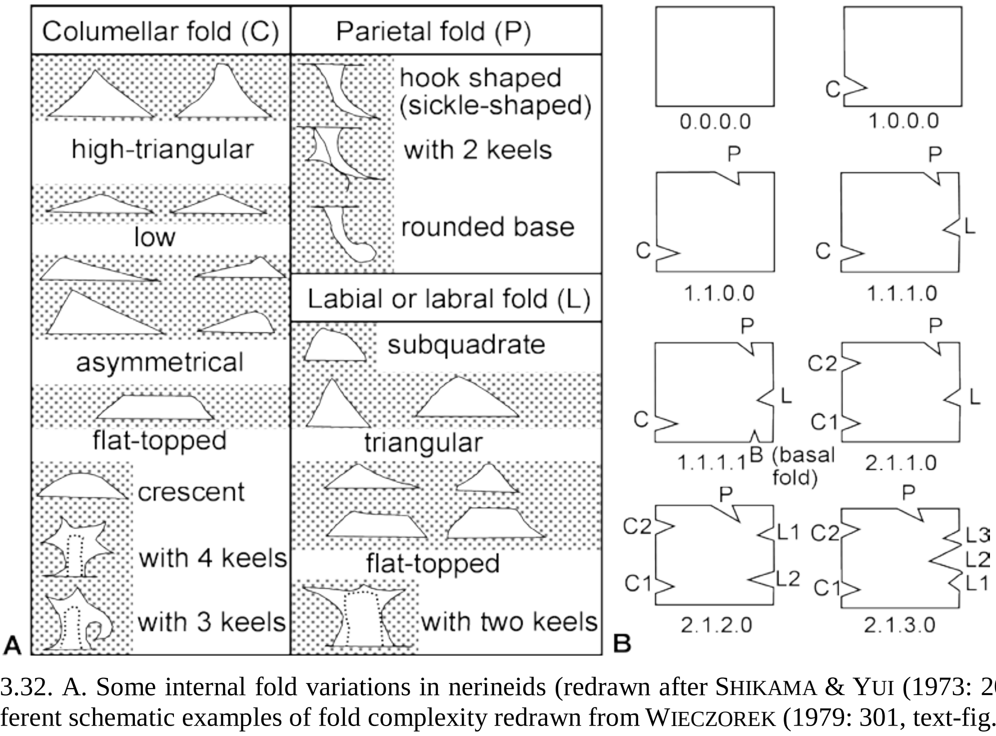
Text-fig. 3.31. Axial sections and internal characters of *Sogdianella*? *laevis laevis* (J. de C. Sowerby, 1835) from bedding planes of the Lower Turonian Abu Qada Formation at Wadi Quseib.

and narrower, and in having three well developed plaits. The size and columellar fold of *S. oregonensis* from the lower Cenomanian of east-central Oregon figured by SQUIRES & SAUL (2002: 47, fig. 1/11-15) are similar to the present species. Their species differs only in being slightly wider than *S. laevis laevis.*

Superfamily Nerineoidea ZITTEL, 1873
Family Nerineidae ZITTEL, 1873
(=Phaneroptyxidae PCHELINTSEV, 1965= Fibuloptygmatididae Hacobjan, 1973)

Remarks. Nerineids vary in outline and some also in their ornamentation, but the most important taxonomic elements for the generic classification exist in the internal structure of shell. The internal structure of most nerineids characterized by the presence of internal folds on the columella and outer lip, which may carry from one to seven folds. The spiral folds have a variable shape and are referred to as parietal (P), columellar (C), labial or labral (L), and basal folds (B) (BARKER, 1990) (Text-fig. 3.32A). The number, arrangement, and strength of these internal folds are very important for the generic classification of nerineids. For instance, the fold formula of the genus *Neoptyxis* PCHELINTSEV, 1934 is 2110, where C=2, P=1, L=1, and B=0 (WIECZOREK, 1979; Text-fig. 3.32B). DELPEY (1939) pointed out that nerineids with four internal folds belong for example the genera *Neoptyxis* and *Plesioptygmatis* BOSE, 1906. Nerineids with three internal folds, in contrast, belong to the genera *Eunerinea* COX, 1949 and *Diozoptyxis* COSSMANN, 1896. In addition, the general shape, presence or absence of an umbilicus, and ornamentation are other important features of nerineids, on which the classification is based. For more details about the taxonomy of nerineids see DELPEY (1939), COX (1949), WIECZOREK (1979), BARKER (1990), and SIRNA (1995).

Three genera were identified in the present study. Two of these, namely *Neoptyxis* and *Pchelinsevia* LISENKO & ALIYEV, 1987, can easily be classified, because they exhibit a characteristic fold pattern. The third genus, *Diozoptyxis*, is not well preserved.



Text-fig. 3.32. A. Some internal fold variations in nerineids (redrawn after SHIKAMA & YUI (1973: 20, text-fig. 4). B. Different schematic examples of fold complexity redrawn from WIECZOREK (1979: 301, text-fig. 2).

Genus *Neoptyxis* PCHELINTSEV, 1934
Neoptyxis olisiponensis (SHARPE, 1850)
Pl. 20, Figs. 4-5; Text-fig. 3.33

1850 *Ptygmatis olisiponensis* sp. nov. – SHARPE: 114, pl. 13, fig. 3.
1916 *Nerinea* (*Ptygmatis*) *olisiponensis* SHARPE – GRECO: 145 (87), pl. 17 (9), figs. 14-15.
1939 *Nerinea olisiponensis* SHARPE – DELPEY: 196, pl. 11, figs. 1-4.
1952 *Nerinea olisiponensis* (SHARPE) – AWAD: 28, pl. 1, fig. 6.
1982 *Neoptyxis olisiponensis* (SHARPE) – ACCORDI et al.: 776, fig. 12a.
1987 *Neoptyxis olisiponensis* (SHARPE) – KOLLMANN: 45, pl. 2, figs. 26-27.
1992 *Nerinea olisiponensis* (SHARPE) – ABDEL-GAWAD & GAMEIL: 76, fig. 2/15-18; fig. 3/1-2.
1993 *Multiptyxis olisiponensis* (SHARPE) – SIRNA & MASTROIANNI: pl. 2, fig. 3; pl. 3, fig. 1.
1995 *Multiptyxis olisiponensis* (SHARPE) – SIRNA: pl. 2, fig. 1; pl. 3, fig. 1.
2006 *Nerinea olisiponensis* (SHARPE) – EL QOT: 98, pl. 20, fig. 1.
2007a *Nerinea olisiponensis* (SHARPE) – MEKAWY: 158, pl. 1, figs. 9, 10.

Material and occurrence. Five internal moulds (mostly fragmented) from the lower shale, middle siliciclastic/carbonate, and upper carbonate members of the Cenomanian Galala Formation, beds 12, 15, and 44 at Wadi Quseib (MGDMU:WQ.G.**12**.46,**15**.31,**44**.236-238).

Measurements (in mm).

n=1	H	D	PA°	nw	D/H
	?40	18	43°	15	0.45

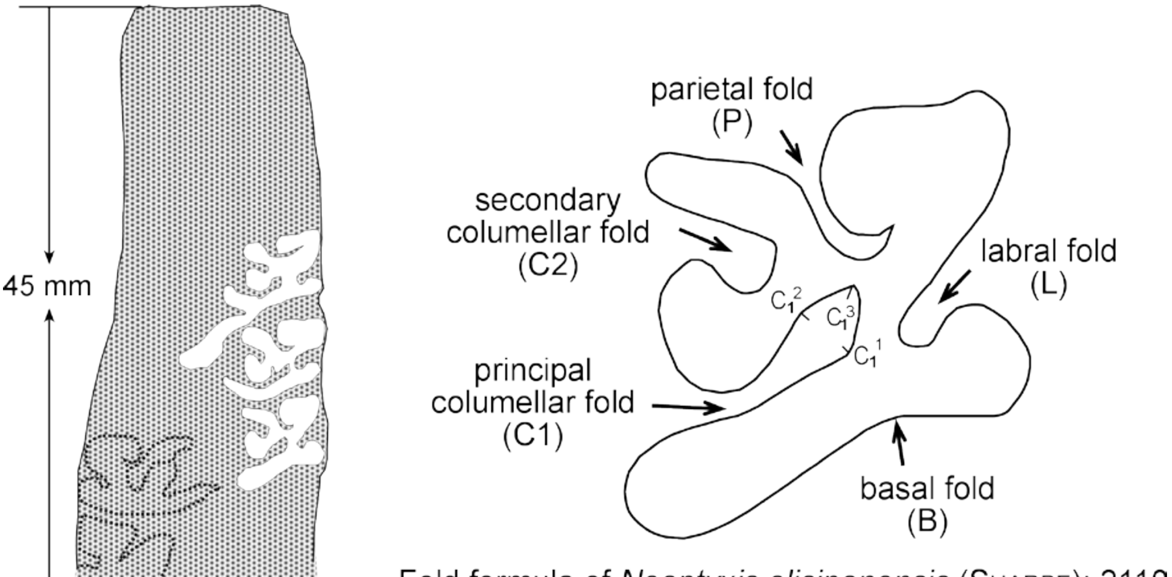
Description. Fragments indicate a turriform to slightly conical, high-spired nerineid. Spire consisting of ?9-14 overlapping whorls with nearly flat surfaces. Suture slightly impressed. Aperture small. Base flat without anterior notch. Apex broken off. Ornamentation not seen. Internally, the quadrate whorl cross-section shows five folds: a principal columellar fold (C1: narrow, deep, directed upwards and with triangular apex); a secondary columellar fold (C2: small with rounded apex, and located in the middle between the parietal and principal columellar folds); a parietal fold (P: sickle-shaped and bent towards the outer lip); a labial fold (L: subtriangular with slightly convex apex); and a basal fold (B: large, triangular with very shallow flexure (broad basis)) (Text-fig. 3.33). Subordinate folds are present only in the principal columellar fold C1 (C_1^1, C_1^2, C_1^3) and are situated in the apex corners (Text-fig. 3.33).

Temporal and spatial distribution. *Neoptyxis olisiponensis* has been recorded from the Cenomanian-Turonian of Portugal (SHARPE, 1850), Lebanon (DELPEY, 1939) and from the Upper Cenomanian of Italy (ACCORDI et al., 1982; SIRNA & MASTROIANNI, 1993; SIRNA, 1995). In Egypt, it is known from the Cenomanian of Saint Paul (GRECO, 1916), Gebel Nezzazat (ABDEL-GAWAD & GAMEIL, 1992), and from the Cenomanian of the Eastern Desert (MEKAWY, 2007a). According to ACCORDI et al. (1982: 776), *Neoptyxis olisiponensis* is typical of sediments of to the Upper Cenomanian of Istria, Syria, and the south-central Apennines (Italy).

Discussion. *Neoptyxis olisiponensis* can be easily distinguished by its concave whorls, the medium-sized secondary columellar fold, and truncated apex of labial fold (KOLLMANN, 1987; SIRNA & MASTROIANNI, 1993). *N. olisiponensis* (SHARPE) resembles *N. requieniana*

D’ORBIGNY, 1842 in having nearly flat whorls and shallow sutures but differs in having a larger number of whorls. Internally, *N. requieniana* differs in lacking a deep sickle-shaped parietal fold with slight principal columellar fold. *Neoptyxis schiosensis* PIRONA, 1884 from the Upper Cenomanian of Portugal differs from the present species in having a shallow, acute, and triangular parietal fold, two equal-sized columellar folds, flat to moderately concave whorls, and raised sutures. According to KOLLMANN (1987: 46), *N. cylindrica* HACOBJAN, 1976; *N. similis* HACOBJAN, *N: fleuriausa* HACOBJAN; *N. subgemmifera* HACOBJAN, and *N. djogasensis* HANCOBJAN closely resemble *Neoptyxis olisiponensis* and the differences are not sufficiant to separate them into different species.

N. sinaiensis FAWZI (1963: 110, pl. 8, fig. 5) from the Cenomanian of the Minsherah area resembles the present species in general outline but differs in having a very shallow labial fold and a bifid columellar fold. FAWZI (1963: 109, pl. 8, fig. 4) also erected *N. minsherehensis* from the same locality based on fragmented material but his species slightly differs in the columellar structure.



Fold formula of *Neoptyxis olisiponensis* (SHARPE): 2110

Text-fig. 3.33. Longitudinal whorl section showing the fold pattern and internal character of *Neoptyxis olisiponensis* (SHARPE, 1850) from the Cenomanian Galala Formation at Wadi Quseib.

Genus *Pchelinsevia* LISENKO & ALIYEV, 1987
Pchelinsevia coquandiana (D’ORBIGNY, 1842)
Pl. 20, Figs. 6-8; Text-fig. 3.34

1842 *Nerinea coquandiana* sp. nov. – D’ORBIGNY: 75, pl. 156, figs. 3-4.
?1916 *Nerinea bicatenata* sp. nov. – COQUAND in GRECO: 152 (94), pl. 18 (10), fig. 5.
?1927 *Nerinea cochleaeformis* CONRAD var. *subgigantea* BLANCKENHORN: 150, pl. 7 (3), figs. 58-59.
1939 *Nerinea coquandi* D’ORBIGNY – DELPEY: 180, pl. 4, figs. 1-5.
?1963 *Nerinea* (*Neoptyxis*) *akaadi* sp. nov. – ABBASS: 74, pl. 5, fig. 6.
1976 *Nerinea coquandi* D’ORBIGNY – PRATURLON & SIRNA: 100, fig. 19 (with extensive synonymy).
1982 *Diozoptyxis coquandi* (D’ORBIGNY) – ACCORDI et al.: 775, fig. 16a, c.
1992 *Nerinea gemmifera* COQUAND – ABDEL-GAWAD & GAMEIL: 77, fig. 3/3-4.
1993 *Pchelinsevia coquandiana* (D’ORBIGNY) – SIRNA & MASTROIANNI: 143, pl. 1, fig. 7; pl. 3, fig. 8.

1993 *Nerinea gemmifera* COQUAND – ORABI: pl. 2, fig. 18.
1995 *Pchelinsevia coquandiana* (D'ORBIGNY) – SIRNA: pl. 2, fig. 3.
2001 *Nerinea gemmifera* COQUAND – ABDALLAH et al.: pl. 1, figs. 6-7.
2004b *Nerinea gemmifera* COQUAND – ABDEL-GAWAD et al.: pl. 5, fig. 4.
2007a *Nerinea gemmifera* COQUAND – MEKAWY: 158, pl. 1, fig. 8.

Material and occurrence. 34 internal and composite moulds (mostly fragmented) from the upper carbonate/marl member of the Cenomanian Halal Formation, beds 19 and 20 at Gebel Areif El-Naqa (MGDMU:AEN.G.**19**.20-34,**20**.1-19); 72 internal moulds from the Cenomanian Galala Formation, beds 2, 3, and 15 at the East Themed area (MGDMU:ET.G.**2**.1-45,**3**.135-159,**15**.56-57); 39 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, beds 12, 21, 22, 31, and 37 at Wadi Quseib (MGDMU:WQ.G.**12**.47-51,**21**.31-35,**22**.81,**31**.35-60,G.**37**.13-15).

Measurements (in mm).

n= 12	H	D	HL	PA°	nw	D/H	HL/H
Range	>33-80	18-36	9-20	29-39°	5-8	0.45-0.88	0.25-0.47
Mean	44.16	26	15.66	33.66	6	0.52	0.33

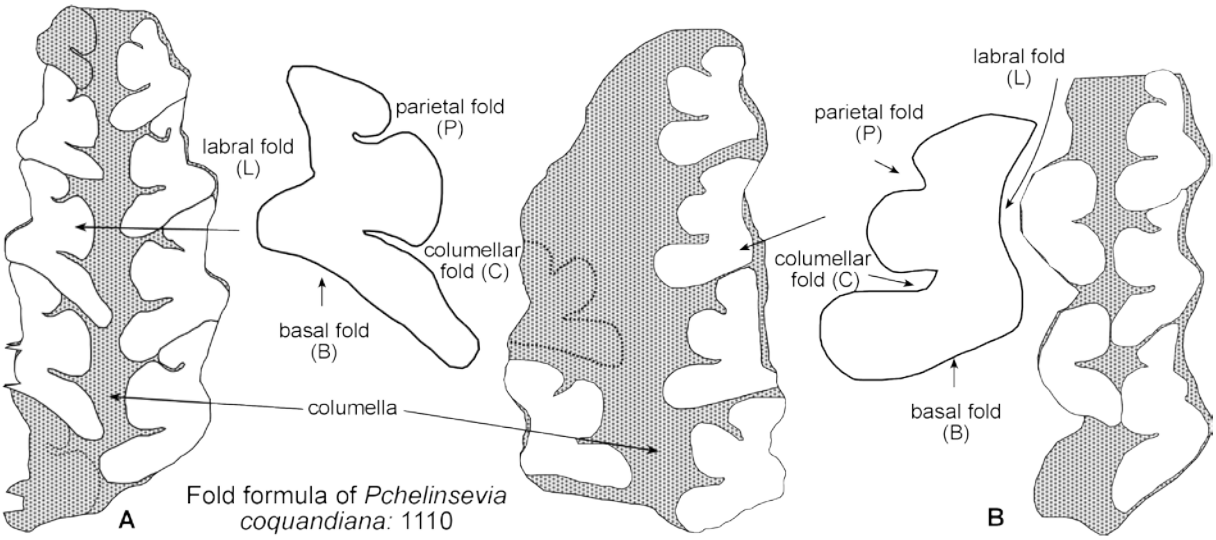
Description. Specimens medium- to large-sized, turriculate, and high-spired. Spire long and consisting of 5-8 overlapping wide whorls and strongly concave surfaces with raised sutures. Apex commonly damaged. Aperture small and ovate. Longitudinal whorl section displaying a large columellar and rhomboidal whorl cross-section which shows three simple folds. Parietal fold triangular with rounded apex; columellar one also triangular, larger and with more acute apex; labial fold with large base, shallow, and situated at middle part of the outer lip. In few other whorl sections, parietal folds show a sickle-shape (Text-fig. 3.34A). The fold formula of *Pchelinsevia coquandiana* is 1110 (C=1, P=1, L=1, and B=0). In some specimens, the whorls are closely spaced adaxially without distinct axial columella in-between. These specimens are crushed, because the internal whorl sections are touching each other and this surly was not the original state (Text-fig. 3.34B).

Temporal and spatial distribution. *Pchelinsevia coquandiana* has been recorded from the Aptian of southern France (D'ORBIGNY, 1842), Italy (ACCORDI et al., 1982; SIRNA & MASTROIANNI, 1993; SIRNA, 1995), and Lebanon (DELPEY, 1939). According to ACCORDI et al. (1982: 775) and SIRNA & MASTROIANNI (1993), *P. coquandiana* is known from the Aptian of Portugal, Spain, Lebanon, North Africa, Somaliland, and Asia. In the present study, the species has been recorded from the Cenomanian sediments. Thus *P. coquandiana* ranges from the Aptian to the Cenomanian.

Discussion. *Pchelinsevia coquandiana* can be easily distinguished by its strongly concave whorls which are separated by a strongly raised suture, a wide columella, rhomboidal whorl cross-section, and lack of a sickle-shaped parietal fold in most individuals. The present material closely resembles *Nerinea coquandiana,* described and figured by D'ORBIGNY (1842) from the Lower Cretaceous of France, in general whorl outline and fold pattern. Most of the nerineids from Egypt, which have been identified as *Nerinea gemmifera* COQUENT (1862) by many taxonomists such as ABDEL-GAWAD & GAMEIL (1992) and MEKAWY (2007a) (see synonymy list), more closely resemble D'ORBIGNY's species than COQUAND's species. *N. gemmifera* COQUAND (1862: 177, pl. 4, fig. 4) from the Crteaceous of Algeria differs in having a conical shell (shorter spire), sharp apex, and concave whorls with a distinct medium spiral furrow separating an upper and a lower half, both of which exhibit axial ribs ending in two rows of small tubercles.

Nerinea (*Neoptyxis*) *akaadi* ABBASS (1963: pl. 5, figs. 3, 5; non. fig. 6) from the Albian of the Maghara area, Sinai, is identical to *N. gemmifera* in general shape, whorl concavity, ornamentation, and whorl number. Other specimens (his pl. 5, fig. 6) closely resemble *P. coquandiana*. ABBASS did not discuss the differences between his new species and other nerineid species such as *P. coquandiana*. *N.* (*N.*) *akaadi* is therefore regarded as a junior synonym of the present species.

Nerinea cochleaeformis CONRAD var. *subgigantea* BLANCKENHORN, 1927 from the Turonian of Syria also resembles the present material in having a large columella and strongly concave whorls. In addition the internal characters of BLANCKENHORN'S variety (columellar, parietal, and palatal folds) are identical to those of *P. coquandiana*. Therefore, *N. cochleaeformis* CONRAD var. *subgigantea* BLANCKENHORN is regarded herein as a junior synonym of the present species.



Text-fig. 3.34. Longitudinal whorl sections showing the fold pattern and internal characters of *Pchelinsevia coquandiana* (D'ORBIGNY, 1842) from the Cenomanian Galala Formation at Wadi Quseib.

Genus *Diozoptyxis* COSSMANN, 1896

Diozoptyxis? *blancheti* (PICTET & CAMPICHE, 1864)

Pl. 20, Fig. 9; Text-fig. 3.35

1864 *Nerinea Blancheti* sp. nov. – PICTET & CAMPICHE: pl. 1, figs. 2-3.
1939 *Nerinea Blancheti* PICTET & CAMPICHE – DELPEY: 183, pl. 3, fig. 7.
1982 *Diozoptyxis blancheti* (PICTET & CAMPICHE) – ACCORDI et al.: 774.

Material and occurrence. A single internal mould from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 29 at Wadi Quseib (MGDMU:WQ.G.**29**.14).

Measurements (in mm).

n= 1	H	D	PA°	nw	D/H
	52	28	48	7	0.54

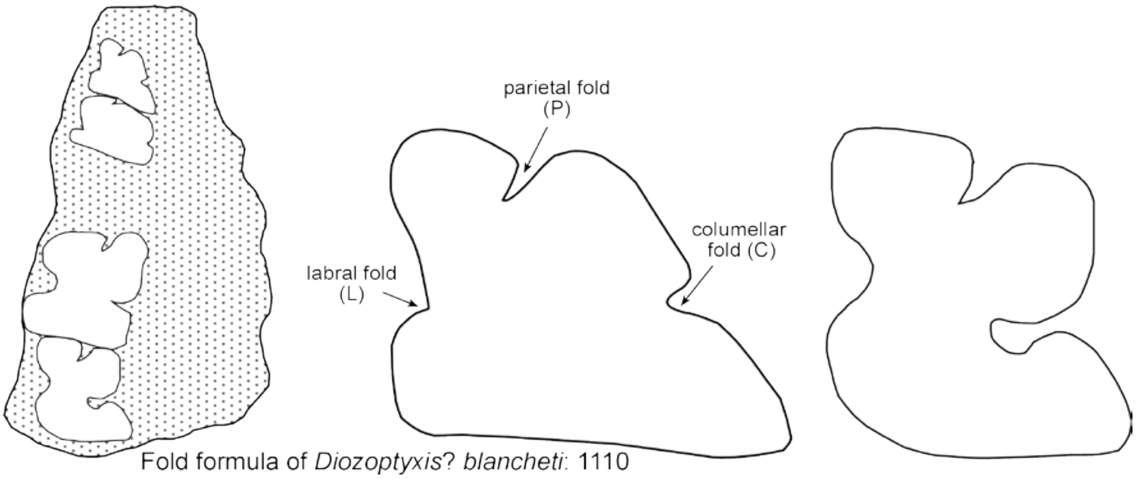
Description. Specimen moderately-sized, turriculate, and high-spired. Spire consisting of five overlapping whorls with slightly concave sides. The whorls are separated by acute and deep sutures. Aperture incomplete with nearly flat base. Apex not preserved. The internal mould lacks elements of ornamentation. The fold formula of *Diozoptyxis*? *blancheti* is 1110 (C=1, P=1, L=1, and B=0). The rhomboidal whorl cross-section shows three folds: a slight and sickle-shaped parietal fold; well developed triangular columellar fold with acute apex, and triangular labral fold with variable apical angle.

Temporal and spatial distribution. *Diozoptyxis blancheti* has been recorded from the Aptian of southern France (PICTET & CAMPICHE, 1861-64), Italy (ACCORDI et al., 1982), and Lebanon (DELPEY, 1939). This is the first record of the species from Egypt.

Discussion. DELPEY (1941) considered the genus *Campanile* BAYLE (in P. FISCHER, 1884) to be a descendant of the genus *Diozoptyxis*. He thought that a close relationship existed between the two genera. In the present study, *Campanile* (*Campanile*) *ganesha* (Pl. 15, Figs. 7-8; Text-fig. 3.29) is characterized by the presence of two small columellar folds with a medium and slightly deep parietal fold (fold formula=2110). In contrast, *Diozoptyxis*? *blancheti* has slight columellar and parietal folds (fold formula=1110).

The present material is very similar to *Nerinea blancheti* PICTET & CAMPICHE in general outline and the internal fold pattern. *Diozoptyxis blancheti* can be easily distinguished by its shallow sickle-shaped columellar and parietal folds (simple folds) with rhomboidal whorls. However, the parietal, columellar, and labial folds slightly vary from apex to base. According to WAITE et al. (2008: 553), the internal sculpture of fold-bearing nerineoids is unique. However, folds are incrementally emplaced as the animal grows, and their morphology becomes progressively more complex. Therefore, the differences in the folding style of *D. blancheti* are probably related to the ontogeny of organism.

The internal folds show some strong resemblance to those of *Nerinea* sp. described by DELPEY (1939: 195, pl. 7, fig. 13) from the Cenomanian of Lebanon. DELPEY's species differs in having a high-spired shell with larger number of whorls.



Text-fig. 3.35. Whorl section and internal character of *Diozoptyxis*? *blancheti* (PICTET & CAMPICHE, 1864) from the Cenomanian Galala Formation at Wadi Quseib.

Clade Aplysiomorpha (Anasidea)
Superfamily Akeroidea MAZZARELLI, 1891
Family Akeridae MAZZARELLI, 1891
Genus *Akera* MÜLLER, 1776

Akera thevestensis (COQUAND, 1862)
Pl. 20, fig. 10

1862 *Bulla Tevesthensis* sp. nov. – COQUAND: 189, pl. 5, fig. 9.
1912 *Acera Thevesthensis* COQUAND – PERVINQUIÈRE: 88, pl. 6, fig. 1.
1927 *Acera modjibensis* sp. nov. – BLANCKENHORN: 184, pl. 10 (6), fig. 117.
1974 *Akera thevestensis* (COQUAND) – ALBANESI & BUSSON: 321, pl. 28, fig. 6.
2006 *Akera* cf. *thevestensis* (COQUAND) – EL QOT: 113, pl. 23, fig. 12.

Material and occurrence. A single internal mould from the Upper Cenomanian Galala Formation, bed 3 of the East Themed area (MGDMU:ET.G.**3**.160).

Measurements (in mm).

n= 1	H	D	HL	HA	WA	nw	D/H	HL/H	WA/HA
	39	22	38	36	8	3	0.56	0.98	0.23

Description. Medium-sized and subcylindrical gastropods with very low spire. Spire consisting of two compressed whorls. Body whorl large, accounting for the main part of specimen (about 98% of total height), and extending over the earlier whorl suggesting the existence of wing-shaped processes. Base nearly rounded. Inner lip slightly convex. Aperture large and ovate. Apex damaged. The specimen is an internal mould lacking ornamentation.

Temporal and spatial distribution. *Akera thevestensis* has been recorded from the Turonian of Algeria (COQUAND, 1862; ALBANEST & BUSSON, 1974), Tunisia (PERVINQUIÈRE, 1912), and the Cenomanian of Syria (BLANCKENHORN, 1927). In Egypt, it is known from the Cenomanian of Gebel Yelleg (EL QOT, 2006).

Discussion. The present species closely resembles *Acera modjibensis* BLANCKENHORN, 1927 in general shape, dimension of the last whorl, and coiling style. Therefore, *A. modjibensis* is regarded herein as a junior synonym of *A. thevenstensis*.

3.4. Class Cephalopoda CUVIER, 1795

The ammonites are classified according to the scheme of WRIGHT et al. (1996). The terminology used for the description of the taxa follows the glossary in the *Treatise on Invertebrate Paleontology*, Part L, Mollusca 4 (WRIGHT et al. 1996).

All linear measurements, taken with a Varnier Caliper, are given in millimeters. Abbreviations used are as follows:

D : diameter;
Wb : whorl breadth;
Wh : whorls height;
U : width of umbilicus;
WQ : Wadi Quseib section;
ET : East Themed section;
AEN : Gebel Areif El-Naqa section;
Amm : ammonite.

Order Nautilida DE BLAINVILLE, 1825
Suborder Nautilina DE BLAINVILLE, 1825
Family Nautilidae DE BLAINVILLE, 1825
Genus *Angulithes* MONTFORT, 1808

Angulithes mermeti (COQUAND, 1862)
Pl. 21, Fig. 1; Text-fig. 3.36

1862 *Nautilus Mermeti* sp. nov. – COQUAND: 166, pl. 2, figs. 1-2.
1907 *Nautilus Mermeti* COQUAND - PERVINQUIÈRE: 46.
1914 *Nautilus Mermeti* COQUAND – ECK: 183, pl. 9, fig. 1.
1960 *Angulithes* (*Angulithes*) *triangularis mermeti* (COQUAND) – WIEDMANN: 188, pl. 22, fig. h; pl. 25, figs. 8-9; pl. 26, fig. 4; pl. 27, figs. 1-2; text-figs. 16-20.
1992 *Deltoidonautilus mermeti* (COQUAND) – ABDEL-GAWAD et al.: 326, pl. 1, fig. 1.
2000 *Angulithes mermeti* (COQUAND) – WILMSEN: 35, pl. 5, fig. 3; text-fig. 5.
2002 *Angulithes* sp. – MEISTER & RHALMI: 768, pl. 5, figs. 1, 3; text-fig. 13/b-c.
2006 *Angulithes mermeti* (COQUAND) – EL QOT: 114, pl. 24, figs. 1-2.

Material and occurrence. 12 incomplete internal moulds from the Upper Cenomanian Galala Formation, bed 12 of East Themed area (MGDMU:ET.Amm.**12**.136-147) (Upper Cenomanian *Neolobites vibrayeanus* Zone) and five moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 41 at Wadi Quseib (MGDMU:WQ.Amm.**41**.61-65).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
WQ.Amm.	125 (100%)	46 (36.8%)	91 (72.8%)	0.50	9 (7.2%)

Description. Large, involute mould with strongly compressed whorls. Whorl section triangular (Text-fig. 3.36A). Maximum width near umbilicus. Inner flank more convex than the outer one. Umbilicus shallow and small (9.2% of total diameter) with rounded umbilical wall. Venter angular to slightly rounded. Suture very simple and sinuous (Text-fig. 3.36B). Sinphuncle located in the dorsal half (Text-fig. 3.36A).

Temporal and spatial distribution. *Angulithes mermeti* (COQUAND) has been recorded from the Upper Cenomanian of Tunisia (PERVINQUIÈRE, 1907; MEISTER & RHALMI, 2002) and Spain (WIEDMANN, 1960). It is known from the Cenomanian of Gebel Nezzazat (ABDEL-GAWAT et al., 1992), Gebel Ekma, and East Themed (EL QOT, 2006).

Discussion. *Angulithes mermeti* (COQUAND) can be easily distinguished by its compressed shape, small umbilicus (about 9.2% of total diameter), and simple sutute. The present material closely resembles *A. mermeti* as described and figured by COQUAND (1862), WIEDMANN (1960), and EL QOT (2006). According to WIEDMANN (1960), *A. mermeti* and *A. triangularis* are conspecific, the former being a as subspecies of *A. triangularis*.

EXPLANATION OF PLATE 21

Fig. 1. *Angulithes mermeti* (COQUAND, 1862). Internal mould from the middle siliciclastic/carbonate member of Cenomanian Galala Formation (*Neolobites vibrayeanus* Zone) of Wadi Quseib, x1. **a**: Side view, **b**: ventral view; MGDMU:WQ.Amm.**41**.61.

Fig. 2. *Knemiceras deserti* MAHMOUD, 1956. Composite mould from the lower marly member of the Upper Albian-Cenomanian Halal Formation (Upper Albian *Knemiceras deserti* Zone) at Gebel Areif El-Naqa, x3. **a**: Side view, **b**: ventral view; MGDMU:AEN.Amm.**12**.38.

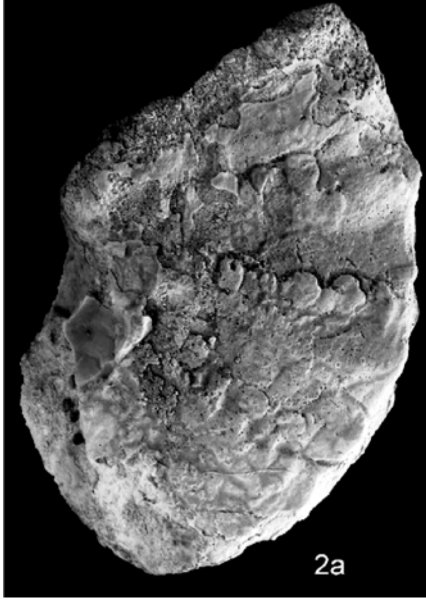
Fig. 3. *Neolobites vibrayeanus* (D'ORBIGNY, 1841). Internal mould from the Cenomanian Galala Formation of the East Themed area (lower Upper Cenomanian *Neolobites vibrayeanus* Zone), x1. **a**: Side view, **b**: ventral view; MGDMU:ET.Amm.**12**.148.

1a

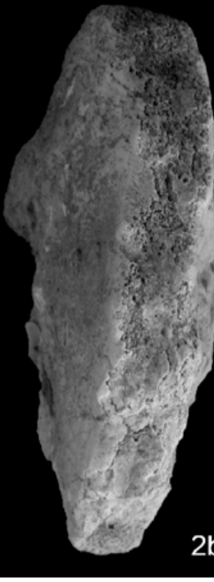
1b

3b

3a

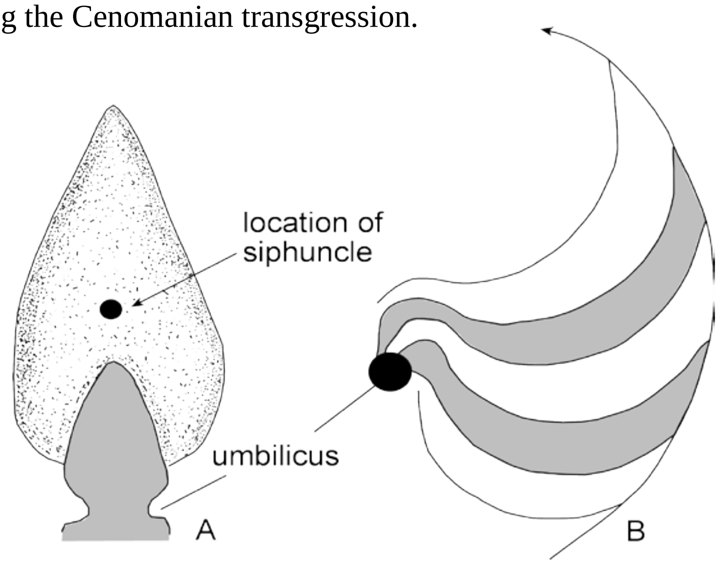


2a



2b

WILMSEN (2000) pointed out that *A. triangularis* from the Middle Cenomanian of Spain differs from *A. mermeti* in having a less compressed whorl section and less sinuous suture, but also regarded *A. mermeti* as an intraspecific variant of *A. triangularis*. According to WILMSEN (2000) the development of sutures from simple to complex in Cenomanian *Angulithes* [*fleuriausianus* (D'ORBIGNY) – *triangularis* (MONTFORT) – *mermeti* (COQUAND) – *vascogoticus* WIEDMANN] as well as shift of the siphuncle to a more dorsal position took place within an evolutionary lineage and may be connected with the depending of the marine environment during the Cenomanian transgression.



Text-fig. 3.36. Whorl section and suture of *Angulithes mermeti* (COQUAND, 1862) from the Upper Cenomanian Galala Formation at Wadi Quseib (MGDMU:WQ.Amm.**41**.61).

Order Ammonoidea ZITTEL, 1884
Suborder Ammonitina HYATT, 1889
Superfamily Hoplitaceae DOUVILLÈ, 1890

?Family Engonoceratidae HYATT, 1900
Genus *Knemiceras* BÖHM, 1898
Knemiceras deserti MAHMOUD, 1956
Pl. 21, Fig. 2; Text-fig. 3.37

1955 *Knemiceras deserti* sp. nov. – MAHMOUD: 63, figs. 3-5; text-figs. 39-41.
2001b *Knemiceras deserti* MAHMOUD – ALY & ABDEL-GAWAD: 48, pl. 5, fig. 2.

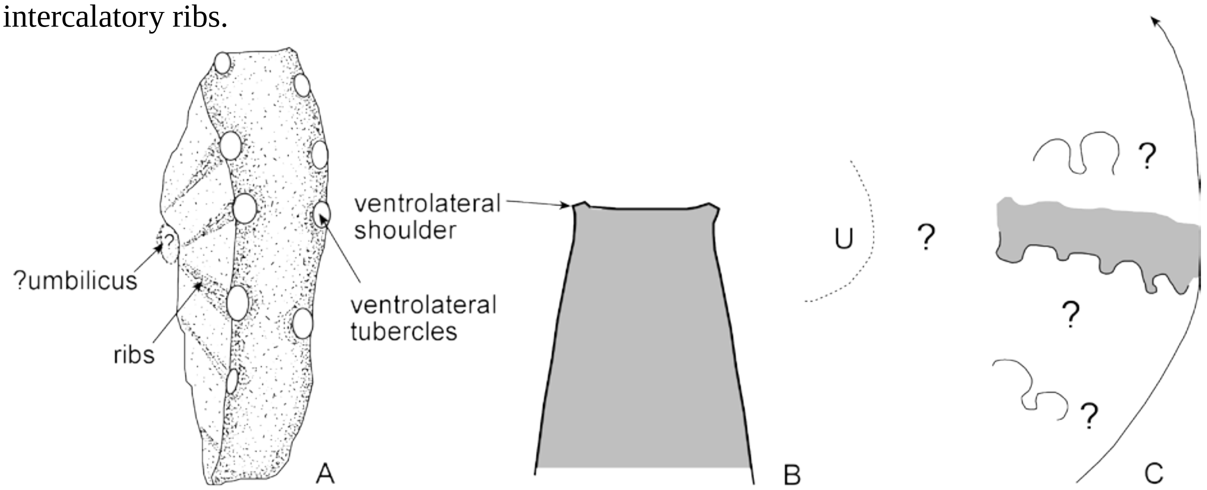
Material and occurrence. One incomplete composite mould from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), bed 12 at Gebel Areif El-Naqa (MGDMU:AEN.Amm.**12**.38).

Dscription. Whorl section rectangular, greatest width near the umbilicus. Venter thin and flat. Ventrolateral shoulders sharp and tuberculate (Text-figs. 4.37A-B). Umbilicus not preserved. Ornamentation consisting of fine ribs, separated by wide and smooth interspaces. Suture not completely preserved but preserved part consisting of narrow and smooth lobes with broad saddles (Text-fig. 3.37C).

Temporal and spatial distribution. *Knemiceras deserti* MAHMOUD, 1955 has been recorded from the Upper Albian of the Maghara area, Sinai (MAHMOUD, 1955; ALY & ABDEL-GAWAD, 2001b).

Discussion. The present material closely resembles *Knemiceras deserti* MAHMOUD with respect to the shape of venter, suture pattern, and ornamentation.

K. deserti is also similar to *K. spathi* MAHMOUD, (1955: 48, pl. 5, figs. 1-11; pl. 2, fig, 1) from the Albian of the Maghara area in having a flat and tabulate venter but the latter species differs in having narrow flank with strong ribs. According to ALY & ABDEL-GAWAD (2001b: text-fig. 17), the lobes and saddles of *K. spathi* have secondary elements. According to the latter author *K. rittmanni* MAHMOUD, 1955 from the same area is characterized by being nearly as broad as high and by interspaces between major ribs that contain two short intercalatory ribs.



Text-fig. 3.37. Whorl section and suture of *Knemiceras deserti* MAHMOUD, 1955 from the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa (MGDMU:AEN.Amm.**12**.38).

Genus *Neolobites* FISCHER, 1882
Neolobites vibrayeanus (D'ORBIGNY, 1841)
Pl. 21, Fig. 3; Pl. 22, Figs. 1-2; Text-fig. 3.38

1841 *Ammonites vibrayeanus* sp. nov. – D'ORBIGNY: 322, pl. 96, figs. 1, 3.
1914 *Neolobites Vibrayeanus* D'ORBIGNY – ECK: 185.
1914 *Neolobites Schweinfurthi* ECK – ECK: 186, pl. 11, fig. 1.
1914 *Neolobites Brancai* ECK – ECK: 188, pl. 12, fig. 1.
1981 *Neolobites vibrayeanus* D'ORBIGNY – KENNEDY & JUIGNET: 23, figs. 3-4, 6a; text-fig. 5.
1989 *Neolobites vibrayeanus* D'ORBIGNY – LUGER & GRÖSCHKE: 366, pl. 39, fig. 3; text-fig. 5.
1989 *Neolobites* sp. – LUGER & GRÖSCHKE: 366, pl. 38, figs. 4-6; text-fig. 13D, E.
1991 *Neolobites vibrayeanus* (D'ORBIGNY) – KENNEDY & SIMMONS: 134, pl. 2D-G.
1992 *Neolobites vibrayeanus* (D'ORBIGNY) – MEISTER et al.: 59, pl. 1, figs. 1-4, 6; text-fig. 8.
1996 *Neolobites vibrayeanus* (D'ORBIGNY) – KASSAB: pl. 1, figs. 1-3.
?1998 *Neolobites fourtaui* PERVINQUIÉRE – EL-SHEIKH et al.: pl. 1, fig. H.
2001a *Neolobites vibrayeanus* (D'ORBIGNY) – ALY & ABDEL-GAWAD: 29, pl. 1, figs. 2-4; text-fig. 3a-b.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) – EL-HEDENY: 401, fig. 3a-b; text-figs. 7d, 8e.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) – BERNDT: pl. 13, figs. 2-5.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) – MEISTER & RHALMI: 763, pl. 1, figs. 1-3; pl. 2, fig. 5.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) *brancai* ECK - MEISTER & RHALMI: 764, pl. 2, figs. 1-3.
2003 *Neolobites vibrayeanus* (D'ORBIGNY) – HEWAIDY et al.: 340, pl.1, figs. 7-8.

?2003 *Neolobites fourtaui* PERVINQUIÈRE – HEWAIDY et al.: 340, pl. 1, fig. 6.
2004a *Neolobites vibrayeanus* (D'ORBIGNY) – ABDEL-GAWAD et al.: pl. 1, fig. 2.
2005 *Neolobites vibrayeanus vibrayeanus* (D'ORBIGNY) – MEISTER & ABDALLAH: 123, pl. 1, figs. 3-6, 8; pl. 2, figs. 2, 3, 6.
2005 *Neolobites vibrayeanus brancai* ECK – MEISTER & ABDALLAH: 123, pl. 1, figs. 1, 2, 7; pl. 2, figs. 1, 5.
2005 *Neolobites vibrayeanus* (D'ORBIGNY) – WIESE & SCHULZE: 933, figs. 4A-E; 5A-D; 6A-J; 7A-E; 8A, B, H, 9A, B, D (with extensive synonymy).
2006 *Neolobites vibrayeanus* (D'ORBIGNY) – EL QOT: 116, pl. 24, figs. 4, 5.
2008 *Neolobites vibrayeanus* (D'ORBIGNY) – ALY et al.: 46, pl. 3, figs. 2-3.
2008 *Neolobites vibrayeanus* (D'ORBIGNY) – EL QOT: 250, pl. 1, figs. 1, 2.

Material and occurrence. 35 incomplete internal moulds from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 41 at Wadi Quseib (MGDMU:WQ.Amm.**41**.66-100), and 48 incomplete specimens from the Upper Cenomanian Galala Formation, bed 12 of the East Themed area (MGDMU:ET.Amm.**12**.148-195).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
WQ.Amm.41	90 (100%)	21 (23%)	62 (69%)	0.34	10 (11%)
WQ.Amm.41	90 (100%)	21 (23%)	54 (60%)	0.39	7 (7%)
WQ.Amm.41	73 (100%)	21 (28%)	44 (60%)	0.47	--
WQ.Amm.41	72 (100%)	15 (21%)	39 (54%)	0.38	7 (9%)
WQ.Amm.41	68 (100%)	14 (20%)	41 (60%)	0.34	6 (8%)
ET.Amm.12	73 (100%)	15 (20%)	47 (64%)	0.32	5 (7%)
ET.Amm.12	88 (100%)	16 (18%)	45 (51%)	0.35	5 (6%)

Description. Very involute, medium-sized, and slightly convex inner flank. Outer flank convergent towards the venterolateral shoulder. Umbilicus small (7-11% of total diameter) and shallow. Umbilical wall low and rounded without umbilical shoulder. Whorls compressed and elevated (Wb/Wh ranges from 0.32 to 0.47 mm). Whorl section lanceolate and greatest width well away from the umbilicus. Venter thin and flat to subsulcate (Text-fig. 3.38A). Ventrolateral shoulders sharp with faint small rows of tubercles. Sutures overlap each other and consist of five narrow and lanceolated lobes with five broad saddles (Text-fig. 3.38B). Ventrolateral lobes deeper and narrower than the second ventrolateral one. Umbilical lobes smaller and shallower than others. All saddles broad with slightly convex to flat end and becoming shallower near umbilicus. Ornamentation not preserved.

EXPLANATION OF PLATE 22

Figs. 1-2. *Neolobites vibrayeanus* (D'ORBIGNY, 1841). Internal moulds from the middle siliciclastic/carbonate member of the lower Upper Cenomanian Galala Formation at Wadi Quseib (lower Upper Cenomanian *Neolobites vibrayeanus* Zone), x1. **1**. Side view; MGDMU:WQ.Amm.**41**.66 - **2**. Apertural view; MGDMU:WQ. Amm.**41**.67.

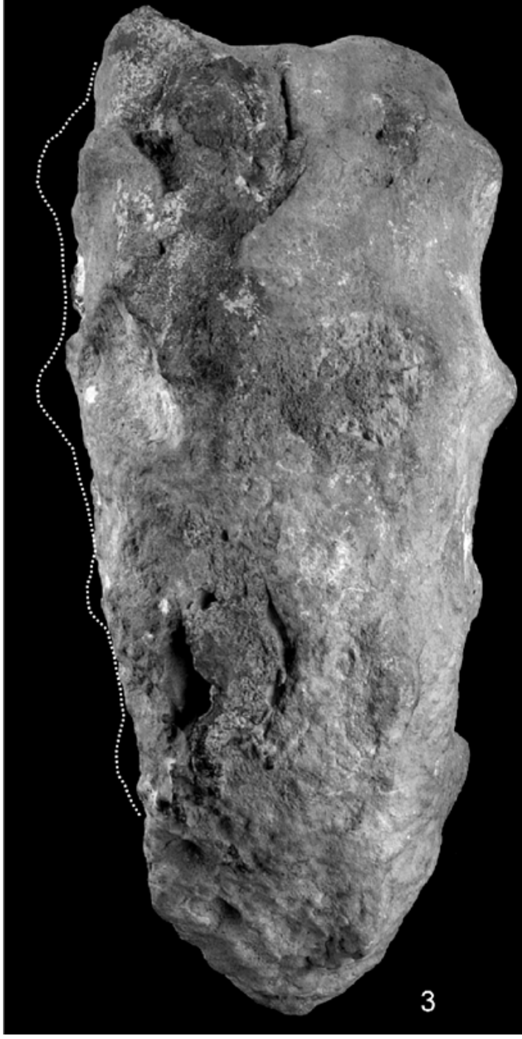
Fig. 3. *Kamerunoceras turoniense* (D'ORBIGNY, 1850). Composite mould from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa (Lower Turonian *Choffaticeras* (*Ch.*) *segne* Zone), x0.75. Ventral view; MGDMU:AEN.Amm.**22**.1.

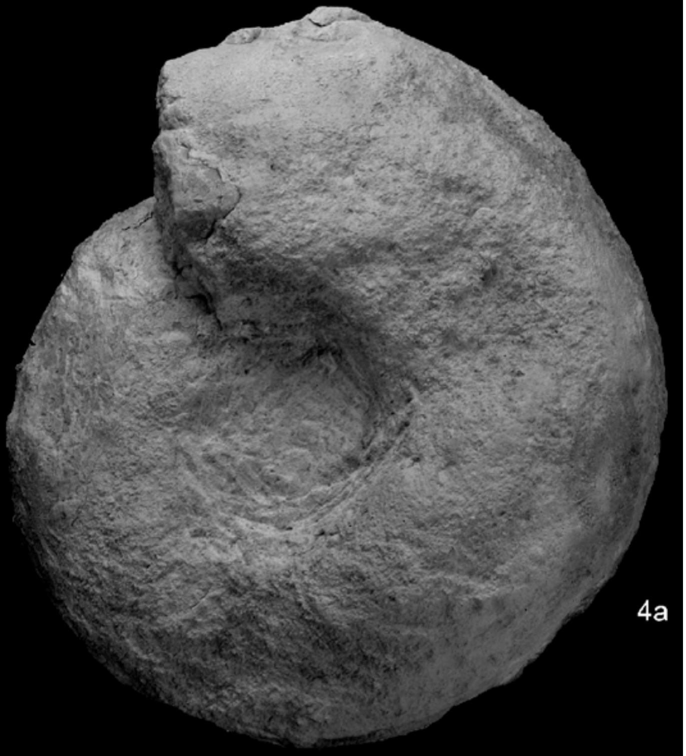
Fig. 4. *Vascoceras durandi* (THOMAS & PERON, 1890). Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed area, x1. **a**: Side view, **b**: apertural view, x1; MGDMU:ET. Amm.**23**.53.


1


2


4b


3


4a

Temporal and spatial distribution. *Neolobites vibrayeanus* has been recorded from the Late Cenomanian of France (KENNEDY & JUIGNET, 1981); Niger (MEISTER et al., 1992); Morocco (MEISTER & RHALMI, 2002); Tunisia (MEISTER & ABDALLAH, 2005); Oman (KENNEDY & SIMMONS, 1991); and Jordan and Egypt (BERNDT, 2002; WIESE & SCHULZE, 2005; ALI et al., 2008). In Egypt, it has been recorded from Wadi Mor, W. Um El-Tennasseb, and Baharyia Oasis (ECK, 1914); the lower Upper Cenomanian of W. Qena (LUGER & GRÖSCHKE, 1989); Gebel Ekma, East Themed, G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006); G. El-Minsherah, Khashm El Tarif, and G. Ekma (ALI & ABDEL-GAWAD, 2001a); Gulf of Suez (KASSAB, 1996); G. Musaba Salama (EL-HEDENY, 2002); W. Ghonima and W. Askhar (HEWAIDY et al., 2003), and Galala Plateaux (EL QOT, 2008).

According to KENNEDY & JUIGNET (1981: 28), *N. vibrayeanus* is known from the lower Upper Cenomanian of Western Europe (France, Spain, Portugal), North Africa and the Middle East (Morocco, Algeria, Tunisia, Egypt, Israel, Lebanon), and South America (Peru and Bolivia).

Discussion. *Neolobites vibrayeanus* can be easily distinguished by its compressed whorls, wide venter (flat to subsulcate), feeble ornament, and small umbilicus with distinct suture.

KENNEDY & JUIGNET (1981: 28) and WIESE & SCHULZE (2005: 937) noted that *N. fourtaui* PERVINQUIÈRE (1907: 209, pl. 8, figs. 2-6) from Tunisia differs from *N. vibrayeanus* in having more elongated umbilical bullae with well developed ventrolateral nodes, strongly concave ribs on the outer flank, and a wider umbilicus that is already present in juvenile growth stages. *N. fourtaui*, figured and described by EL-SHEIKH et al. (1998) and HEWAIDY et al. (2003), is not complete and lacks umbilici, ribs, and ventrolateral tubercles. According to them, the first and second lateral lobes are more inclined towards the ventral side. WIESE & SCHULZE (2005: 940) noted that the sutures of *N. vibrayeanus* are variable according to its size. They noted sutural crowding as evidence for adulthold (adult macroconch with a diameter of 160 mm), also in small individuals (adult microconch with a diameter ranging from 60-130 mm), while the adult ones still show comparatively widely spaced sutures. Therefore, the specimens of EL-SHEIKH et al. (1998) and HEWAIDY et al. (2003) are more closely related to *N. vibrayeanus* than to *N. fourtaui.*

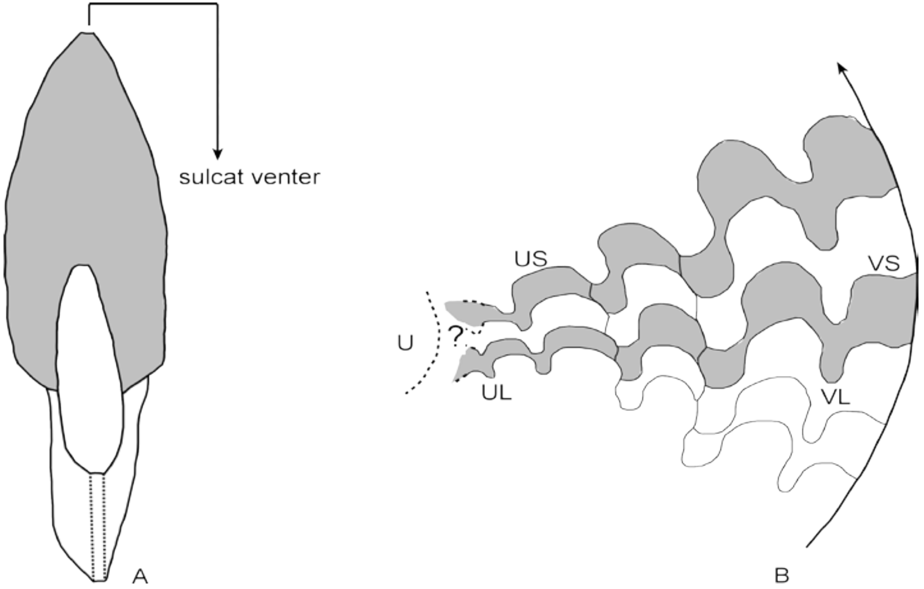
Neolobites sp., described and figured by LUGER & GRÖSCHKE (1989) from the Eastern Desert (Egypt), is considered herein as a junior synonym of *N. vibrayeanus*. The latter authors pointed out that their specimen differs from *N. vibrayeanus* by having a wider umbilicus (11%) and a rounded venter. The umbilicus of *N. vibrayeanus* is variable in size and shape (about 18% of test diameter) and the venter (in some specimens) is narrower and without ventrolateral shoulder (WIESE & SCHULZE, 2005).

The suture and venter of *N. vibrayeanus*, figured by KORA et al. (2001: pl. 2, figs. 9, 10) from the Cenomanian of Wadi Abu Qada (Gulf of Suez region), are more similar to *Choffaticeras segne* (SOLGER) than to *N. vibrayeanus*. Also, ABDEL-GAWAD et al. (2004b: pl. 6, fig. 1) figured *N. vibrayeanus* from the Upper Cenomanian of Gebel El-Fallig (northern Sinai) but the venter and suture belong to the family Acanthoceratidae GROSSOUVRE, 1894.

KENNEDY & JUIGNET (1981) and WIESE & SCHULZE (2005) in their long list of synonymies, considered *N. schweinfurthi* ECK, *N. brancai* ECK, *N. isidis* GRECO and *N. peroni* HYATT var. *pervinquierei* STAFF & ECK, 1908 as junior synonyms of *N. vibrayeanus*. The latter authors concluded that *N. vibrayeanus*, *N. peroni*, and *N. fourtaui* can be easily separated into three different species according to specific features. In addition, *N. brancai* was separated from *N. vibrayeanus* on the basis of its large size, strong compression, very weak ribs, and small ventrolateral tubercles. However, the holotype is an incomplete and corroded specimen without ribs and ventrolateral tubercles. Moreover, MEISTER & RHALMI

(2002: 765, fig. 8) carried out a morphometric analysis among the latter species from several localities in Africa, in which the diameter of the umbilicus, whorl height, and breadth were plotted against diameter and formed nearly a straight line which confirms that *N. brancai,* and *N. schweinfurthi,* lie within the intraspecific variation of *N. vibrayeanus*.

Meister & Rhalmi (2002) and Meister & Abdallah (2005) included *N. brancai* in *N. vibrayeanus* but treated it as a subspecies, *N. vibrayeanus brancai*, in which they included all non/weakly ribbed forms, while *N. vibrayeanus* comprised all well ribbed specimens. In contrast, Kennedy & Juignet (1981: 28) pointed out that *N. vibrayeanus* is similar to the feebly ornamented species *N. brancai, N. schweinfurthi,* and *N. isidis* and has the same geographic distribution. In agreement with the latter authors *N. brancai* (with subspecies) and *N. schweinfurthi* are synonyms of the present species and the presence or absence of ribs may be related to the preservational state of specimens.



Text-fig. 3.38. Whorl section and suture of *Neolobites vibrayeanus* (d'Orbigny, 1841) from the Upper Cenomanian Galala Formation of Wadi Quseib (A) (MGDMU:WQ:Amm.**41**.67) and East Themed (B) (MGDMU:ET:Amm.**12**.148). U: Umbilicus, VL: Ventral lobe, VS: Ventral saddle, UL: Umbilical lobe, US: Umbilical saddle.

Superfamily Acanthocerataceae Grossouvre, 1894

Family Acanthoceratidae Grossouvre, 1894

Subfamily Euomphaloceratinae Cooper, 1978

Genus *Kamerunoceras* Reyment, 1954

Kamerunoceras turoniense (d'Orbigny, 1850)
Pl. 22, Fig. 3; Pl. 23, Figs. 1-2; Text-fig. 3.39

1850 *Ammonites turoniensis* sp. nov. – d'Orbigny: 190.
1867 *Ammonites salmuriensis* sp. nov. – Courtiller: 6, pl. 6, figs. 1-4.
1907 *Mammites* (*Pseudaspidoceras*) *salmuriensis* Courtiller – Pervinquière: 314, pl. 19, fig. 1a-b; (var. *Byzacenica*); fig. A. (var. *zerhalmensis*).
1907 *Mammites* (*Pseudaspidoceras*) *armatus* sp. nov. – Pervinquière: 317, pl. 19, figs. 2-3, 4 (including var. *fraichichensis*).
1969 *Protexanites salmuriensis* (Courtiller) – Freund & Raab: 69, pl. 5, figs. 4-6; text-fig. 14c-j.
1979a *Kamerunoceras turoniense* (d'Orbigny) – Kennedy & Wright: 1170, pl. 2, figs. 1-11; pl. 3, figs. 1-2; pl. 4, figs. 1-3; text-figs. 2-3.

1981 *Pseudaspidoceras armatum* (Pervinquière) – Wright & Kennedy: 57, pl. 14, figs. 1, 2, 10.
1982 *Pseudaspidoceras armatum* (Pervinquière) – Renz: 97, pl. 30, figs. 1-5, 9.
1990 *Kamerunoceras turoniense* (d'Orbigny) – Robaszynski et al.: 262, pl. 15, figs. 1-2.
1994 *Kamerunoceras turoniense* (d'Orbigny) – Chancellor et al.: 26, pl. 4, figs. 1-3; pl. 5, figs. 1-3; pl. 6, figs. 6-7; pl. 7, figs. 3-4; pl. 8, figs. 8-9; text-fig. 11A, G.
2001 *Protexanites* cf. *salmuriensis* (Courtiller) – Galal et al.: pl. 5, figs. 8-9.
2008 *Kamerunoceras turoniense* (d'Orbigny) – El Qot: 260, pl. 2, fig. 3; text-figs. 1A, 2C.

Material and occurrence. Three incomplete composite moulds (one measured) from the lower member of the Abu Qada Formation (Lower Turonian), bed 22 (MGDMU:AEN.Amm.**22**.1-3) at Gebel Areif El-Naqa, and three moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 23 of East Themed (MGDMU:ET.Amm.**23**.50-52).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
AEN.Amm.22.2	220 (100%)	55 (25%)	78 (35%)	0.70	93 (42%)

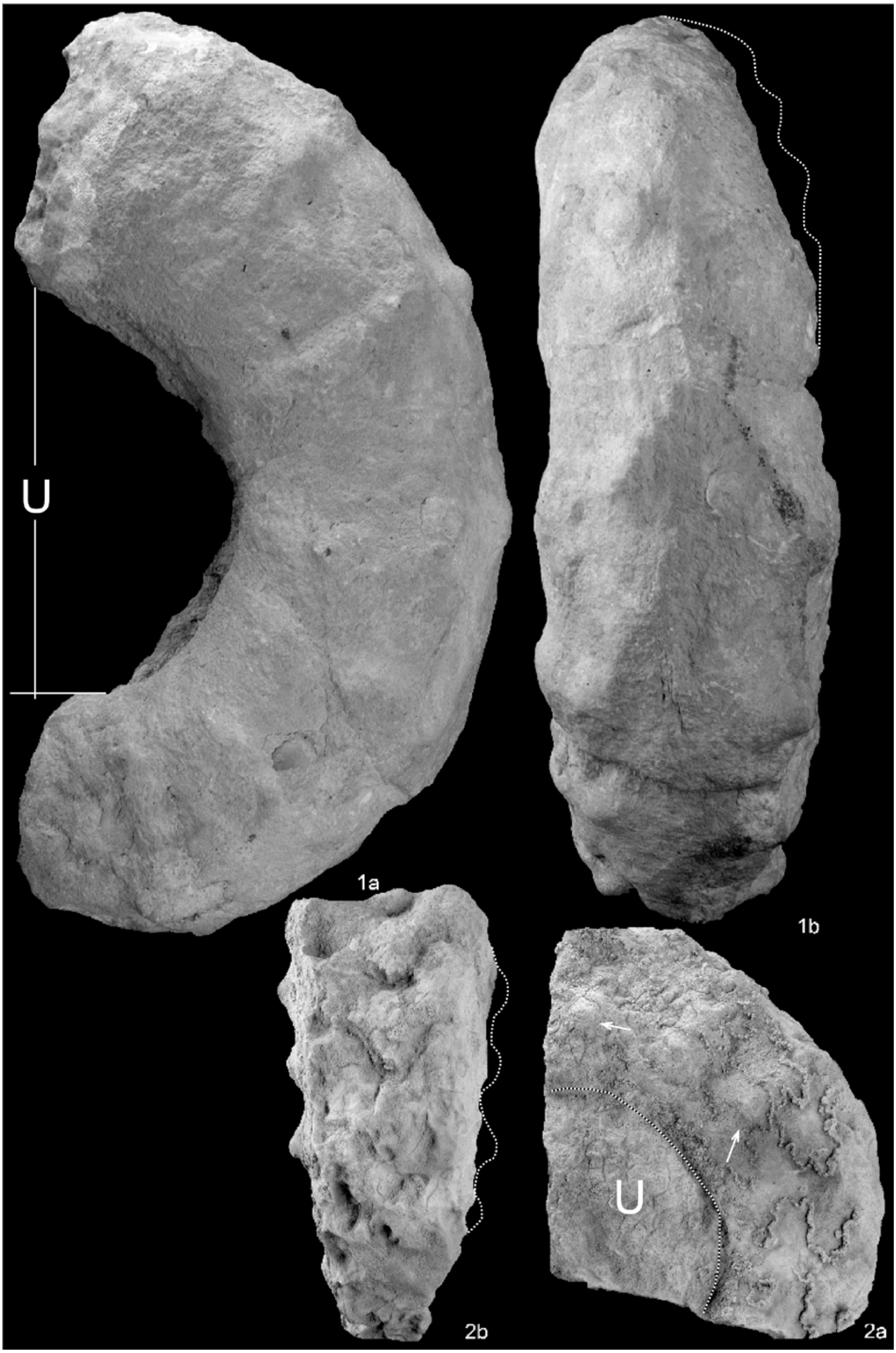
Description. Very evolute, large-sized, compressed (Wb/Wh=0.70 mm) shell with the greatest width below the mid-flank. Flanks narrow and slightly convex with broadly rounded ventrolateral shoulder. Umbilicus wide (42% of the total diameter) and moderately deep. Umbilical shoulder broadly rounded with subvertical umbilical wall. Whorl section rectangular to squarish-rounded (Text-fig. 3.39A-B). Venter flat to slightly convex and smooth with weak ridge marking the site of the siphuncle. Ornamentation consists of straight ribs, separated by wide interspaces. Each rib extends from the umbilicus to the venter but does not cross it and bears strong and well developed outer and inner ventrolateral tubercles (2-4 tubercles per rib). Some of these tubercles migrate to the middle flank (Pl. 23, Fig. 2a). The umbilical tubercles are weak, and rarely rounded and strong. Suture consists of two lobes and saddles. The first ventrolateral lobe is wider and deeper than the umbilical one and subdivided by secondary saddles. The ventrolateral saddle is square, wide, and divided into two equal parts by a deep secondary lobe. The second saddle is not complete, narrower than the ventrolateral one, and without secondaries (Text-fig. 3.39C).

Temporal and spatial distribution. The genus *Kamerunoceras* is an Early to early Middle Turonian ammonite genus known from Europe, the Middle East, north and west Africa, Madagascar, South and Central America.

Kamerunoceras turoniense has been recorded from the Lower Turonian of Israel (Freund & Raab, 1969); Tunisia (Pervinquière, 1907; Robaszynski et al., 1990; Chancellor et al., 1994); France (Kennedy & Wright, 1979a); South America (Renz, 1982), and England (Wright & Kennedy, 1981). In Egypt, it is known from the Lower Turonian of Gebel Areif El-Naqa, Sinai (Abde et al., 1996), from the lower Upper Turonian of Wadi El-Tarfa (Galal et al., 2001), Lower Turonian of Galala Plateaux (El Qot, 2008).

EXPLANATION OF PLATE 23

Figs. 1-2. *Kamerunoceras turoniense* (d'Orbigny, 1850). Incomplete composite moulds from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa. **1. a**: Side view, x0.75, **b**: ventral view, x0.75 MGDMU:AEN.Amm.**22**.2. **2.a**: Lateral view, x1, **b**: ventral view, x1; MGDMU:AEN.Amm.**22**.3.

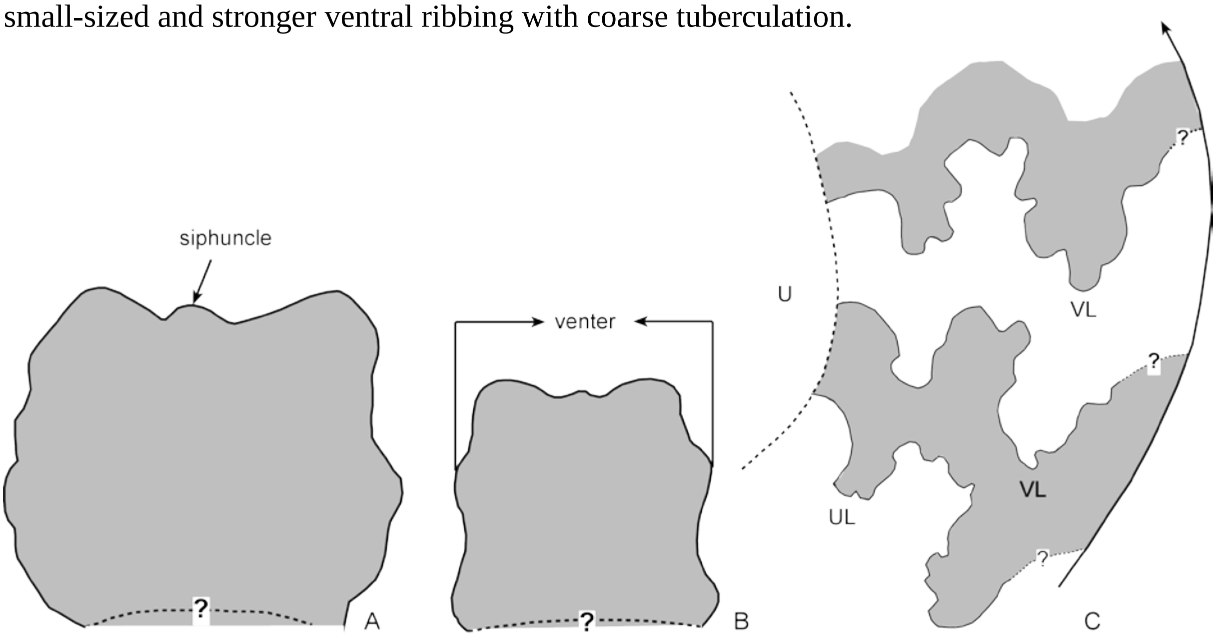

U
1a
1b
U
2b
2a

Discussion. KENNEDY & WRIGHT (1979a), ROBASZYNSKI et al. (1990), and CHANCELLOR et al. (1994) considered *Ammonites salmuriensis* COURTILLER, 1867, *Mammites* (*Pseudaspidoceras*) *salmuriensis* (COURTILLER) of PERVINQUIÈRE (1907) var. *byzacenica* and *zerhalmensis*, and *Mammites* (*Pseudaspidoceras*) *armatus* PERVINQUIÈRE (1907) with var. *fraichichensis* as synonyms of *Kamerunoceras turoniense*.

KENNEDY & WRIGHT (1979a) noted that in *M.* (*P.*) *salmuriensis* var. *zerhalmensis* the umbilical tubercles migrated outwards to the mid-flank with new umbilical tubercles originating, together with elongated inner and outer ventrolateral tubercles originating. This migration of tubercles is observed in *K. turoniense* of CHANCELLOR et al. (1994: pl. 6, fig. 6) and also in the present material (Pl. 23, Fig. 2a). Moreover, *M.* (*P.*) *salmuriensis* var. *zerhalmensis* PERVINQUIÈRE (1907) is illustrated only by whorl section. CHANCELLOR et al. (1994) noted that the ornamentation of PERVINQUIÈRE'S varieties is similar to the rib density of typical *K. turoniense* and that separation of the two taxa is unnecessary. Therefore, *M.* (*P.*) *salmuriensis* (COURTILLER) of PERVINQUIÈRE (1907) var. *byzacenica* and *zerhalmensis* are considered herein as synonyms of the present species.

PERVINQUIÈRE (1907) separated *M.* (*P.*) *armatus* from *M.* (*P.*) *salmuriensis* on the basis of its small umbilicus, much stronger ribbing, and strong outer ventrolateral tubercles with different sutures. Moreover, his *M.* (*P.*) *armatus* var. *fraichichensis* has very weak tubercles seen in two fragmented specimens. FREUND & RAAB (1969: 70) studied a large population from the Lower Turonian of Israel and described individuals with all possible combinations of whorl proportions, ribs and tubercle strengths of *K. salmuriensis* and *K. armatum*, which led them to regard the two as synonyms. In contrast, RENZ (1982) maintained *P. armatum* as a separate species according to the presence of a slight siphonal ridge, but no tubercles. CHANCELLOR et al. (1994: 28) noted that the material from Touraine (France) shows great variation in the timing of appearance, strength, differentiation and loss of siphonal tubercles, and they pointed out that RENZ' material falls within the range of variation of *K. turoniense*.

According to CHANCELLOR et al. (1994: 30), *K. douvillei* (PERVINQUIÈRE, 1907: 274, pl. 12, figs. 2, 3) from the Turonian of Tunisia differs from the present species by having small-sized and stronger ventral ribbing with coarse tuberculation.



Text-fig. 3.39. Whorl section and suture of *Kamerunoceras turoniense* (D'ORBIGNY, 1850) from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa (A: MGDMU:AEN:Amm.**22**.1, B-C: MGDMU:AEN:Amm.**22**.3).

KENNEDY & WRIGHT (1979a) discussed the differences between *K. turoniense* and *K. antsaronense* COLLIGNON (1965: 28, pl. 387, fig. 1661), *K. jacobsoni* REYMENT (1955: 59, pl. 13, fig. 5; text-fig. 26), *K. eschii* (SOLGER, 1904: 124, pl. 4, figs. 1-4), *K. tinrhertense* COLLIGNON (1965: 13, pl. D), and others (for more details see KENNEDY & WRIGHT,1979a: 1175-1176 and FREUND & RAAB, 1969: 70).

Family Vascoceratidae DOUVILLÉ, 1912

Genus *Vascoceras* CHOFFAT, 1898

Vascoceras durandi (THOMAS & PERON, 1890)

Pl. 22, Fig. 4; Text-fig. 3.40A

1890 *Pachydiscus Durandi* sp. nov. – THOMAS & PERON in PERON: 27, pl. 18, figs. 5-8.
?1898 *Vascoceras Douvillei* sp. nov. – CHOFFAT: 59, pl. 10, fig. 6; pl. 11, figs. 2-5.
?1898 *Vascoceras* sp. aff. *Douvillei* CHOFFAT: 60, pl. 10, fig. 3; pl. 21, fig. 16.
?1898 *Vascoceras Amieirensis* sp. nov. – CHOFFAT: 61, pl. 12, figs. 1, 2; pl. 13, figs. 1-2.
1907 *Vascoceras Durandi* THOMAS & PERON – PERVINQUIÈRE: 332, pl. 21, fig. 1.
1928 *Vascoceras* sp. – DOUVILLÈ: 15, pl. 1, fig. 6.
1969 *Vascoceras durandi* (THOMAS & PERON) – FREUND & RAAB: 29, text-fig. 6h-i.
1969 *Vascoceras* cf. *V. amieirense* CHOFFAT – FREUND & RAAB: 32, text-fig. 6k-l.
1989 *Vascoceras durandi* (THOMAS & PERON) – LUGER & GRÖSCHKE: 376, pl. 43, figs. 1, 2; text-fig. 8A.
1994 *Vascoceras durandi* (THOMAS & PERON) – CHANCELLOR et al.: 48, pl. 2, fig. 1; pl. 10, figs. 1-4; pl. 11, figs. 1-2; pl. 12, figs. 1-3; pl. 13, figs. 3-4; pl. 14, figs. 2, 5.
1996 *Vascoceras* (*Paravascoceras*) aff. *durandi* (THOMAS & PERON) – MEISTER & ADBALLAH: 10, pl. 4, fig. 1; pl. 5, fig. 2; fig. 5c.
2003 *Vascoceras durandi* (THOMAS & PERON) – HEWAIDY et al.: 343, pl. 2, figs. 1-2.
?2004a *Vascoceras* cf. *durandi* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 4, fig. 4.
2005 *Vascoceras durandi* (THOMAS & PERON) – MEISTER & ABDALLAH: 135, pl. 14, fig. 1; pl. 26, fig. 1; pl. 27, fig. 1.
?2006 *Vascoceras* cf. *durandi* (THOMAS & PERON) – EL QOT: 118, pl. 25, fig. 4; pl. 26, fig. 1.
2008 *Vascoceras durandi* (THOMAS & PERON) – EL QOT: 264, pl. 3, fig. 5; pl. 4, fig. 1.

Material and occurrence. 17 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 23 of the East Themed area (MGDMU:ET.Amm.**23**.53-69), and one poorly preserved specimen from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.Amm.**47**.63).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
ET.Amm.23	107 (100%)	45 (42%)	37 (35%)	1.22	22 (20%)
ET.Amm.23	91 (100%)	42 (46%)	42 (46%)	1.00	30 (33%)
WQ.Amm.47	94 (100%)	43 (46%)	38 (40%)	1.13	25 (27%)

Description. Medium-sized, involute, slightly compressed, and rounded. Umbilicus moderately wide (about 27% of total diameter) and deep with vertical umbilical wall. Umbilical shoulder broadly rounded. Whorl section rounded at first and becoming slightly subtriangular and narrow at the last whorl. Flank moderately wide and strongly convex. Ventrolateral shoulder broadly rounded with moderately convex venter (Text-fig. 3.40A). Ornamentation and suture not seen.

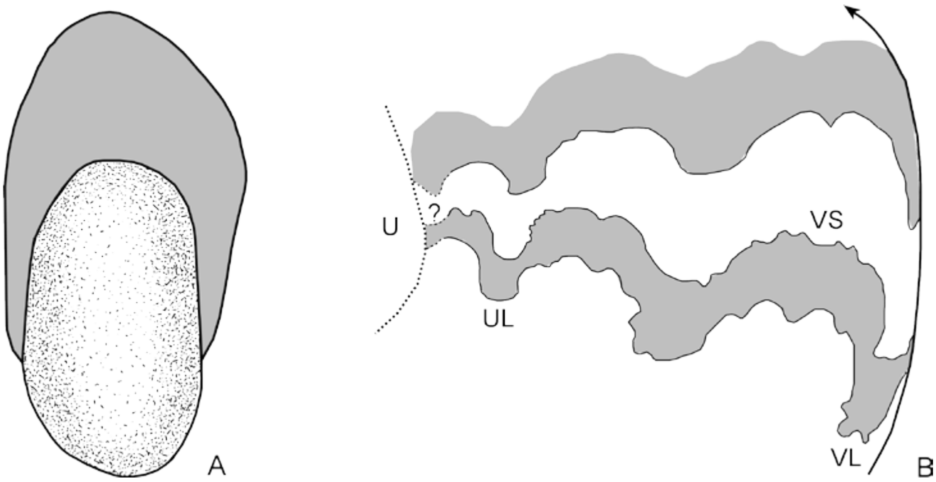
Temporal and spatial distribution. *Vascoceras durandi* has been recorded from the Lower Turonian of Israel (FREUND & RAAB, 1969) and Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994; MEISTER & ADBALLAH, 1996, 2005). In Egypt, it occurs in the Lower Turonian of the Eastern Desert (LUGER & GRÖSCHKE, 1989; HEWAIDY et al., 2003; EL QOT, 2008); and from the Upper Cenomanian-Lower Turonian of Sinai (DOUVILLÈ, 1928; ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

LUGER & GRÖSCHKE (1989: 378) pointed out that *V. durandi* has been recorded from the Upper Cenomanian to Lower Turonian of Portugal (CHOFFAT'S beds), and Lower Turonian of Spain, Japan, and questionably of Angola, Mexico, and Brazil (BERTHOU et al., 1985).

Discussion. The present material is identical with the Tunisian one described by PERVINQUIÈRE (1907). The latter author suggested that CHOFFAT's species from Portugal constitute a single species. According to FREUND & RAAB (1969), *V.* cf. *V. amieirense* CHOFFAT differs from *V. durandi* by its compressed cross-section. CHANCELLOR et al. (1994: 52) stated that the degree of inflation varies considerably (Wb:Wh 0.86-1.58 mm), although this is no doubt exaggerated by post-mortem distortion. Umbilical width is also variable (26-54% of total diameter) and although the smallest specimens tend to have the narrowest umbilicus there is no clear increase in umbilical width with increasing size. Moreover, PERVINQUIÈRE (1907) described the later growth stage of *V. durandi*, and the tendency of some specimens to develop a subtriangular whorl section. CHANCELLOR et al. (1994) noted also that the subtriangular whorl section is not a common feature in *V. durandi* and found the same feature in several populations of globose vascoceratids. For these reasons, many authors (e.g., LUGER & GRÖSCHKE, 1989; CHANCELLOR et al., 1994) considered CHOFFAT's *Vascoceras* spp. as well as *Vascoceras* sp. of DOUVILLÈ (1928) as junior synonyms of *V. durandi* (for a more extensive discussion see CHANCELLOR et al., 1994: 52, 54, 56). The present material represents a smooth variety of *V. durandi* and also resembles CHOFFAT's species in the shape and size of venter and whorl but differs in lacking well preserved ornamentation.

V. durandi, figured by GALAL et al. (2001: pl. 5, fig. 3) from the Lower Turonian of Wadi El-Tarfa (Eastern Desert), is shown only in side view. It is a fragment without umbilicus. For these reasons, it very difficult to identify this material even at the generic level.

V. durandi is very similar to *V. cauvini* CHUDEAU, 1909 in general outline but the latter species differs in having a narrower umbilicus and more compressed shell.



Text-fig. 3.40. A. Whorl section of *Vascoceras durandi* (THOMAS & PERON, 1890) from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area (MGDMU:ET:Amm.**23**.53). B. Suture of *Vascoceras* sp. from the Lower Turonian Abu Qada Formation at Wadi Quseib (MGDMU:WQ:Amm.**47**.64).

Vascoceras sp.

Pl. 24, Fig. 1; Text-fig. 3.40B

Material and occurrence. Two incomplete internal moulds from the Abu Qada Formation (Lower Turonian), bed 47 at Wadi Quseib (MGDMU:WQ.Amm.**47**.64-65) and two specimen from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 of the East Themed area (MGDMU:ET.Amm.**26**.164-165).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
WQ.Amm.47	96 (100%)	72 (75%)	46 (48%)	1.56	20 (21%)

Description. Incomplete, medium-sized, highly involute, depressed, and ovate-shaped. Flanks moderately wide and strongly convex ventrally. Venter broadly rounded. Umbilicus medium-sized and moderately deep. Umbilical wall flat and steeply sloping with broadly rounded umbilical shoulder. Ornamentation not preserved. Suture consisting of three broad saddles and deep lobes. Ventrolateral lobe narrow and containing secondary elements. Second ventrolateral lobe wider than the ventrolateral and umbilical ones and divided by secondary elements. Ventrolateral saddle denticular, convex, and wider than the second ventrolateral one. Umbilical saddle smoother and narrower than the first and second ones (Text-fig. 3.40B).

Discussion. The present material is similar to *Vascoceras globosum costatum* (REYMENT, 1954) of ZOBORSKI (1996: 78, fig. 38) from the Lower Turonian of Nigeria in shape and size of umbilicus and roundness of the venter, but differs in being less well preserved and exhibiting simpler sutures. Moreover, *V. obscurum* BARBER (1957), figured and described by ZOBORSKI (1996: 81, figs. 53-54, 59, 61, 62), resembles the present material in the suture style but differs in having a flattened to tabulate venter and well-ribbed earlier whorls with a narrower umbilicus.

Genus *Neoptychites* KOSSMAT, 1895

Neoptychites cephalotus (COURTILLER, 1860)

Pl. 24, Fig. 2; Text-fig. 3.41A-B

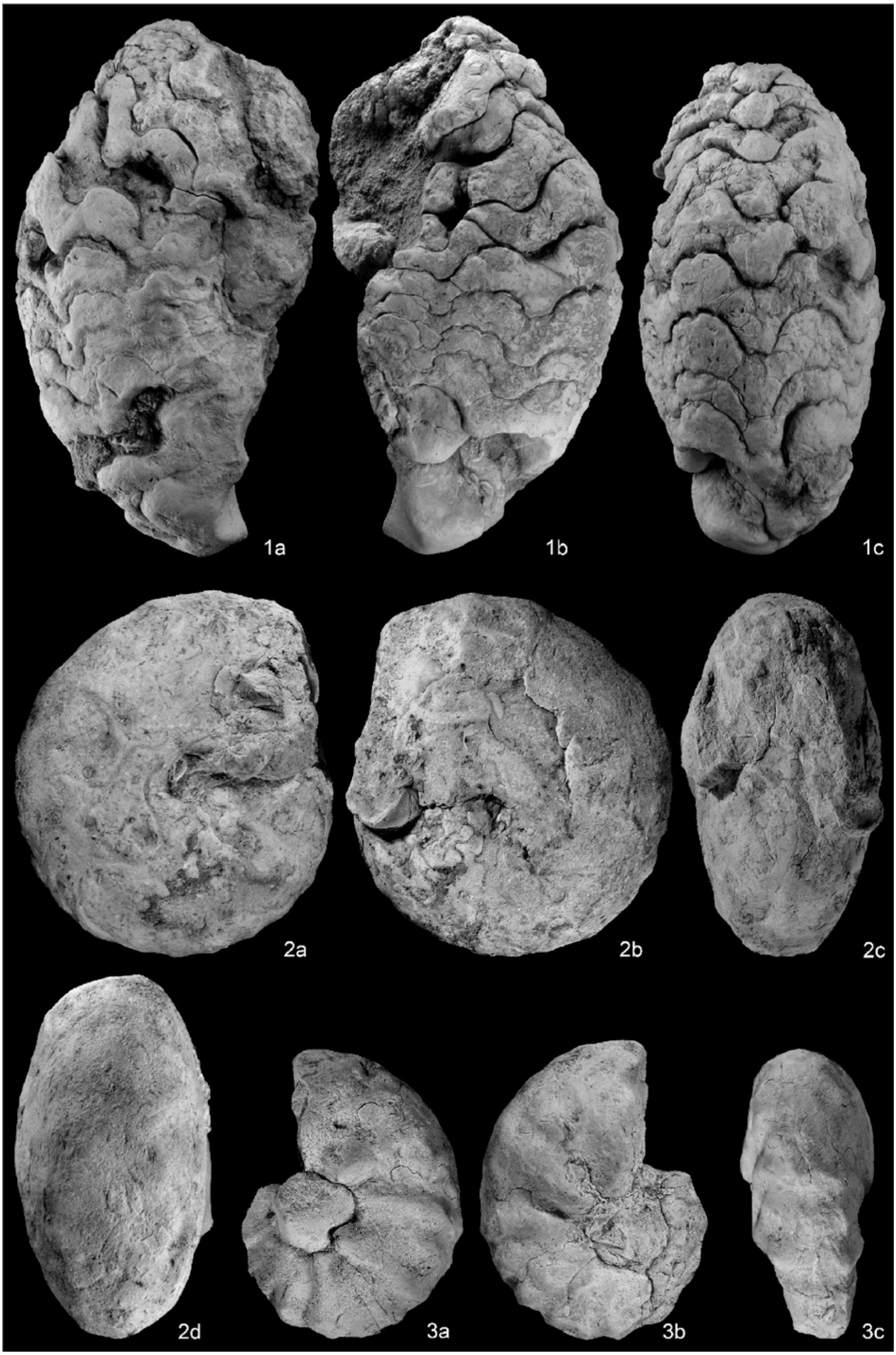
1860 *Ammonites cephalotus* sp. nov. – COURTILLER: 248, 77, pl. 2, figs. 1-4.
1907 *Neoptychites cephalotus* (COURTILLER) – PERVINQUIÈRE: 393, pl. 27, figs. 1-4, text-fig. 152.
1907 *Neoptychites Xetriformis* sp. nov. – PERVINQUIÈRE: 398, pl. 27, figs. 5-7; text-figs. 153, 154.
1969 *Neoptychites cephalotus* (COURTILLER) – FREUND & RAAB: 48.

EXPLANATION OF PLATE 24

Fig. 1. *Vascoceras* sp. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. **a**, **b**: Side views, **c**: ventral view; MGDMU:WQ. Amm.**47**.64.

Fig. 2. *Neoptychites cephalotus* (COURTILLER, 1860). Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x1. **a**, **b**: Side view, **c**: apertural view, **d**: ventral view; MGDMU:ET. Amm.**26**.162.

Fig. 3. *Thomasites rollandi* (THOMAS & PERON, 1889). Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x3. **a**, **b**: Side view, **c**: ventral view; MGDMU:ET. Amm.**25**.78.


1a
1b
1c
2a
2b
2c
2d
3a
3b
3c

1979b *Neoptychites cephalotus* (Courtiller) – Kennedy & Wright: 670, pl. 82, figs. 3-5; pl. 83, figs. 1-3; pl. 84, fig. 3; pl. 85, figs. 1-5; pl. 86, figs. 5-6; text-fig. 2 (with full synonymy).
1990 *Neoptychites cephalotus* (Courtiller) – Robaszynski et al.: 266, pl. 20, figs. 2, 3; pl. 21, fig. 3.
1994 *Neoptychites cephalotus* (Courtiller) – Chancellor et al.: 70, pl. 16, figs. 1-9; pl. 17, fig. 1; pl. 18, figs. 1-3; pl. 26, figs. 2-4.
2001a *Neoptychites cephalotus* (Courtiller) – Aly & Abdel-Gawad: 39, pl. 6, fig. 1.
2005 *Neoptychites* gr. *cephalotus* (Courtiller) – Meister & Abdallah: 136, pl. 15, figs. 1, 2; pl. 16, fig. 1; pl. 20, fig. 1 (with full synonymy).
2008 *Neoptychites cephalotus* (Courtiller) – Aly et al.: 49, pl. 6, fig. 1.
2008 *Neoptychites cephalotus* (Courtiller) – El Qot: 266, pl. 4, figs. 4-5; text-fig. 1B.
2009 *Neoptychites cephalotus* (Courtiller) – Barroso-Barroso & Goy:34, fig. 9/4-6, fig. 10/1-3(with full synonymy).

Material and occurrence. Three composite moulds from the lower member of the Lower Turonian Abu Qada Formation, bed 22 at Gebel Areif El-Naqa (MGDMU:AEN.Amm.**22**.4-6), and two specimens from Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 at East Themed (MGDMU:ET.Amm.**26**.162-163).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
AEN.Amm.22	95 (100%)	40 (42%)	48 (50%)	0.83	10 (10%)
AEN.Amm.22	97 (100%)	35 (39%)	48 (49%)	0.73	15 (15%)
AEN.Amm.22	110 (100%)	50 (45%)	61 (55%)	0.82	18 (16%)

Description. Very involute, ovate-shaped, medium-to large-sized, and compressed (Wb/Wh 0.73 to 0.83mm) ammonites. Greatest width near the rounded umbilical shoulder. Flanks slightly convex and converging to the narrowly rounded venter (Text-fig. 3.41A). Umbilicus narrow (10-16% of total diameter) and shallow. Umbilical shoulder slightly rounded. Whorl section more or less rectangular, as the whorl width nearly equals its height. Ornamentation consisting of faint, broad, folded ribs which pass over the venter (Pl. 24; Fig. 2d). These ribs are separated by wide interspaces. Suture not completely preserved but preserved part consisting of narrow and denticular lobes with wide, convex, and denticular saddles (Text-fig. 3.41B).

Temporal and spatial distribution. *Neoptychites cephalotus* has been recorded from the Lower Turonian of Tunisia (Pervinquière, 1907; Robaszynski et al., 1990; Chancellor et al., 1994; Meister & Abdallah, 2005), Jordan (Aly et al., 2008), Israel (Freund & Raab, 1969), Spain (Barroso-Barroso & Goy, 2009), and France (Kennedy & Wright, 1979b). In Egypt, it is known from the Lower Turonian of Khashm El Tarif, central East Sinai (Aly & Abdel-Gawad, 2001a). The species has been also recorded from the Lower Turonian of the Eastern Desert by El Qot (2008).

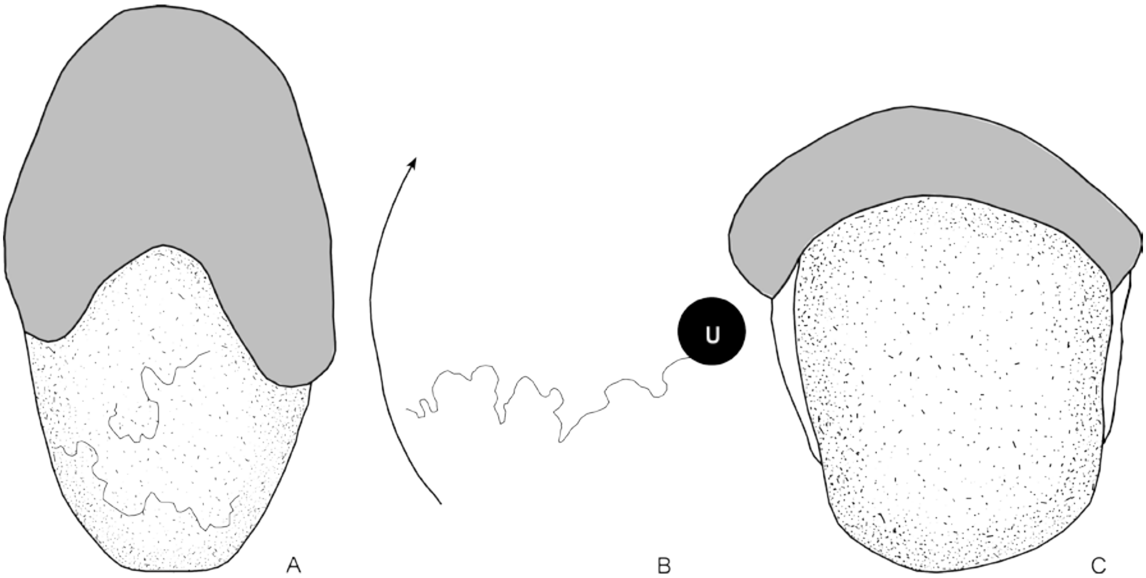
According to Chancellor et al. (1994: 72), the total range of *N. cephalotus* is middle-Lower to lower Middle Turonian, with records from Spain, Cameroon, Madagascar, south India, New Mexico, Brazil, Niger, and Nigeria.

Discussion. Chancellor et al. (1994: 69) pointed out that mature specimens of the genus *Neoptychites* are similar to mature specimens of the genus *Thomasites* Pervinquière (1907:

339), but that the early whorls of the two genera have a distinctly different ornamentation. Species of *Thomasites* retain their ventrolateral shoulder ornament throughout ontogeny and rarely develop the rounded venter of *Neoptychites* with a less inflated body chamber. Moreover, the suture of *Thomasites* is generally simpler than that of *Neoptychites.*

Freund & Raab (1969) and Kennedy & Wright (1979b) regarded *N. cephalotus* and *N. xetriformis* (Pervinquière, 1907) as two different species because the latter has a greater inflation, remains of ribs on the body chamber, and a smaller size. Moreover, according to the former authors, *N. xetriformis* has less strongly inflated body chamber. In agreement with Robaszynski et al. (1990) and Chancellor et al. (1994), *N. xetriformis* is regarded here as a junior synonym of *N. cephalotus*, based mainly on the normal range of variation in ammonites (strongly ornamented in juveniles, slender, less ornamented in adults).

N. subxetriformis (Collignon, 1965) from the Upper Turonian of Madagascar differs from the present species in having a sharp venter and being smooth. In contrast, *N. hottingeri* Collignon (1966) from the Turonian of Morocco has a tabulate venter and is quite distinct from *N. cephalotus* (for a more detailed discussion see Kennedy & Wright, 1979b: 676, 678-681 and Barroso-Barroso & Goy, 2009: 37).



Text-fig. 3.41. Whorl section and suture. A-B. *Neoptychites cephalotus* (Courtiller, 1860) from the Upper Cenomanian-Lower Turonian Abu Qada Formation of East Themed (MGDMU:ET:Amm.**26**.162). B. *Fagesia* cf. *peroni* Pervinquière, 1907 from the same formation of East Themed (MGDMU:ET:Amm.**23**.70).

Genus *Fagesia* Pervinquière, 1907
Fagesia cf. *peroni* Pervinquière, 1907
Pl. 25, Figs. 1-2; Text-fig. 3.41C

cf. 1907 *Fagesia peroni* sp. nov. – Pervinquière: 329, pl. 20, figs. 7, 8.
cf.1994 *Fagesia peroni* Pervinquière – Chancellor et al.: 64, pl. 14, figs. 6-10.

Material and occurrence. 22 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 23 of the East Themed area (MGDMU:ET.Amm.**23**.70-91).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
ET.Amm.23	98 (100%)	72 (73%)	47 (48%)	1.53	39 (40%)
ET.Amm.23	101 (100%)	67 (66%)	40 (39%)	1.67	33 (32%)

Description. Large-sized, very involute, and wide whorl (about 69% of total diameter). Whorl section very depressed (Wb:Wh=1.6, Text-fig. 3.41C) reniform. Venter very broadly rounded. Umbilicus deep and wide (about 36% of total diameter). Umbilical wall vertical and flat with broadly rounded umbilical shoulder. Ornamentation and suture not preserved.

Temporal and spatial distribution. *Fagesia peroni* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994).

Discussion. The present specimens resemble *Fagesia peroni* figured by CHANCELLOR et al. (1994) in shape of venter and shape and size of umbilicus, but due to the lack of umbilical tubercles and ornamentation, it is attributed herein with some doubts to *F. peroni*.

Family Pseudotissotiidae HYATT, 1903

Subfamily Pseudotissotiinae HYATT, 1903
Genus *Thomasites* PERVINQUIÈRE, 1907
Thomasites rollandi (THOMAS & PERON, 1889)
Pl. 24, Fig. 3; Pl. 25, Figs. 3-4; Pl. 26, Fig. 1; Text-fig. 3.42

1889 *Pachydiscus rollandi* sp. nov. – THOMAS & PERON in PERON: 25, pl. 17, figs. 1-3.
1907 *Thomasites Mesli* sp. nov. – PERVINQUIÈRE: 345, pl. 22, figs. 8-9; text-fig. 131.
1907 *Thomasites Jordani* sp. nov. – PERVINQUIÈRE: 347, pl. 22, figs. 10-13; text-figs. 132-133 (with varieties).
1928 *Thomasites lefevrei* sp. nov. – DOUVILLÉ: 16, pl. 2, fig. 4.
1928 *Thomasites jordani* PERVINQUIÈRE, race *sinaitica* - DOUVILLÉ: 17, pl. 2, figs. 5-6.
1928 *Thomasites egyptiacus* sp. nov. – DOUVILLÉ: 16, pl. 2, fig. 3.
1969 *Thomasites rollandi rollandi* (THOMAS & PERON) – FREUND & RAAB: 43, text-figs. 9f-i.
1969 *Thomasites jordani jordani* PERVINQUIÈRE – FREUND & RAAB: 45, text-fig. 10a.
1981 *Thomasites* cf. *rollandi* (THOMAS & PERON) – WRIGHT & KENNEDY: 99, pl. 22, fig. 1.
1990 *Thomasites rollandi* (THOMAS & PERON) – ROBASZYNSKI et al.: 267, pl. 22, figs. 1, 4.
1994 *Thomasites rollandi* (THOMAS & PERON) – CHANCELLOR et al.: 75, pl. 19, figs. 1, 2; pl. 20, figs. 4-5; pl. 21, figs. 1-3, 7-9; pl. 22, figs. 1, 4-5; pl. 23, figs. 1-7.
1996 *Thomasites rollandi* (THOMAS & PERON) – MEISTER & ABDALLAH: 12, pl. 7, figs. 1-2; pl. 11, fig. 2; pl. 14, fig. 1; text-figs. 5h-I, k.
1996 *Thomasites rollandi* (THOMAS & PERON) forme *jordani* PERVINQUIÈRE – MEISTER & ABDALLAH: 12, pl. 6, fig. 2; text-fig. 5j.
1996 *Thomasites rollandi* (THOMAS & PERON) forme *meslei* PERVINQUIÈRE – MEISTER & ABDALLAH: 13, pl. 8, figs. 1-3; pl. 9, fig. 2; pl. 10, fig. 2; text-fig. 6a-d.
2004a *Thomasites rollandi* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 2, figs. 4-5; pl. 3, fig. 1.
2005 *Thomasites rollandi rollandi* (THOMAS & PERON) – MEISTER & ABDALLAH: 137, pl. 18, figs. 1, 3.

EXPLANATION OF PLATE 25

Figs. 1-2. *Fagesia* cf. *peroni* PERVINQUIÈRE, 1907. Internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation at the East Themed area, x1. **1**. Side view; MGDMU:ET. Amm.23. **2**. Apertural view, x1; MGDMU:ET. Amm.**23**.70.

Figs. 3-4. *Thomasites rollandi* (THOMAS & PERON, 1889). **3**. Composite mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed, x1.5. **a**: Side view, **b**: ventral view; MGDMU:ET.Am.**25**.79 - **4**. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. **a**: Side view, **b**: apertural view, x1; MGDMU:WQ. Amm.**47**.66.


1
2
3a
3b
4a
4b

2005 *Thomasites rollandi* forme *jordani* PERVINQUIÈRE – MEISTER & ABDALLAH: 137, pl. 17, figs. 1, 6.
2005 *Thomasites rollandi* forme *meslei* PERVINQUIÈRE – MEISTER & ABDALLAH: 138, pl. 17, figs. 2, 3, 5, 7.
2006 *Thomasites rollandi* (THOMAS & PERON) – EL QOT: 122, pl. 27, figs. 4a-b, 5; pl. 28, fig. 1.
2008 *Thomasites rollandi* (THOMAS & PERON) – EL QOT: 269, pl. 4, fig. 6; pl. 5, figs. 3-4; text-fig. 1D.

Material and occurrence. 45 composite and internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 25 of the East Themed area (MGDMU:ET.Amm.**25**.78-122); two specimens from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.Amm.**47**.66-67); and one specimen from the lower member of the Lower Turonian Abu Qada Formation, bed 22 at Gebel Areif El-Naqa (MGDMU:AEN.Amm.**22**.7).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
ET.Amm.25	?45 (100%)	29 (64%)	26 (58%)	1.11	5 (11%)
ET.Amm.25	65 (100%)	23 (35%)	41 (63%)	0.63	8 (12%)
AEN.Amm.22	87 (100%)	40 (46%)	52 (59%)	0.76	9 (10%)
WQ.Amm.47	93 (100%)	38 (41%)	55 (59%)	0.69	12 (13%)

Description. Very involute, small-to medium-sized shell, greatest width at the umbilical shoulder. Whorl section compressed to globose and inflated (Text-fig. 3.42A-C). Umbilicus narrow (10-13% of total diameter) and moderately deep. Umbilical wall subvertical, with narrowly rounded umbilical shoulder. Umbilical tubercles observed in juveniles, and moderately developed in adults. Outer flank flattened and convergent towards the ventrolateral shoulder. Inner flank strongly convex. Venter slightly convex to flat, wide, and ornamented with a single row of ventrolateral bullae with siphonal keel (Pl. 24, Fig. 4b). Ornamentation consisting of well developed ribs, which become thick at the ventrolateral shoulder (Pl. 24, Fig. 3). Suture not completely preserved; preserved part consisting of narrow, denticular lobes with wide, convex, and smooth saddles (Text-fig. 3.42D).

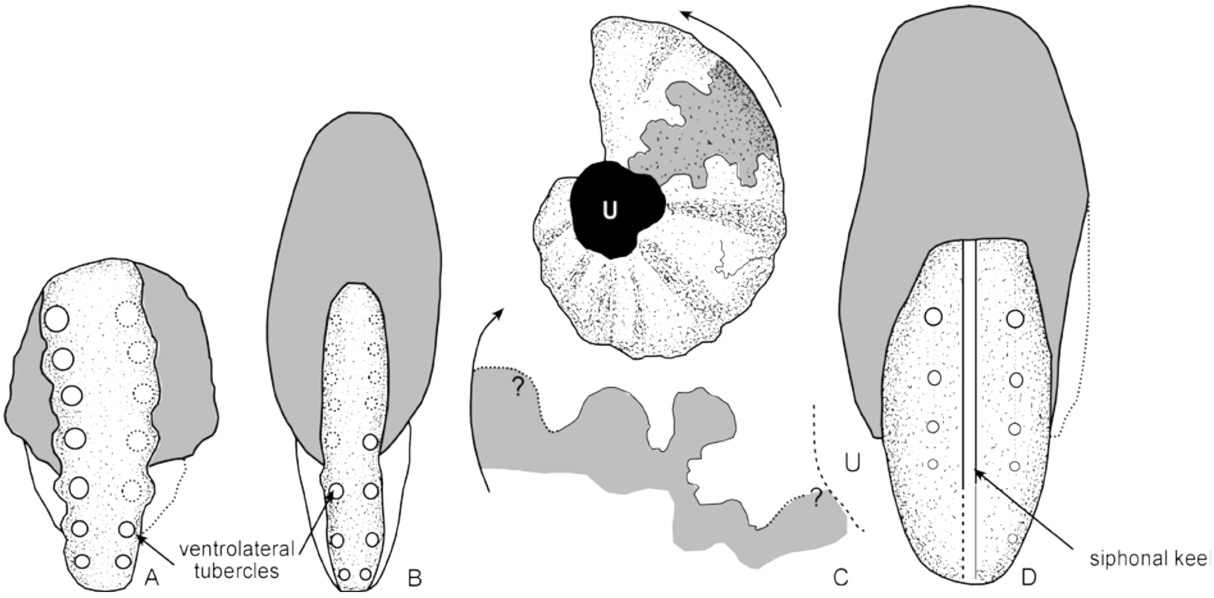
Temporal and spatial distribution. *Thomasites rollandi* has been recorded from the Lower Turonian of Israel (FREUND & RAAB, 1969), England (WRIGHT & KENNEDY, 1981), and Tunisia (THOMAS & PERON, 1889; PERVINQUIÈRE, 1907; ROBASZYNSKI et al., 1990; MEISTER & ABDALLAH, 1996 & 2005; CHANELLOR et al. 1994). In Egypt, it occurs in the Lower Turonian of Sinai (DOUVILLÉ, 1928; ABDEL-GAWAD et al., 2004a; EL QOT, 2006) and the Eastern Desert (EL QOT, 2008).

Discussion. PERVINQUIÈRE (1907) distinguished three species and seven subspecies of *Thomasites* from Tunisia according to the size of whorls, slight differences in sutures, and presence or absence of ventrolateral tubercles and ornamentation. FREUND & RAAB (1969: 43) pointed out that the majority of PERVINQUIÈRE'S specimens consist only of the body chamber, whereas juvenile whorls are not available and that it is difficult to distinguish between the various varieties. They noted that only the thickness can be observed in his specimens. WRIGTH & KENNEDY (1981: 100) agree with FREUND & RAAB that PERVINQUIÈRE'S species and varieties consitiute a single species. DOUVILLÉ (1928) described two new species (*T.*

egyptiacus and *T. lefevrei*) but did not mention how they differ from *T. rollandi*. Therefore, Freund & Raab (1969) and Chancellor et al. (1994) considered all of Douvillé's (1928) species from Egypt as *T. rollandi*. In contrast, Meister & Abdallah (1996, 2005) distinguished three forms of *T. rollandi* from the Turonian of Tunisia (see synonymy list).

According to Chancellor et al. (1994) all of Pervinquière's and Peron's types plus their collections (about 150 specimens from Tunisia) are synonyms of *T. rollandi*. In the present study, two forms of *Thomasites rollandi* are recognized; *T. rollandi meslei* (compressed form) and *T. rollandi jordani*. In agreement with the latter authors, these forms are considered as junior synonyms of *T. rollandi*. For more detailed discussion about the varities of *T. rollandi* see Chancellor et al. (1994: 75).

Mammites nodosoides (Schlüter, 1871) of Zakhera (2001: pl. 4, figs. 4-5) from the Lower Turonian of Sinai closely resembles *T. rollandi* (*jordani* form) in the style of tuberculation, flat venter, and size of umbilicus.



Text-fig. 3.42. Variation in shape and whorl sections of *Thomasites rollandi* (Thomas & Peron, 1889). A-C. Composite moulds and part of suture line from the Upper Cenomanian-Lower Turonian Abu Qada Formation of East Themed (MGDMU:ET:Amm.**25**.79,80,78 respectively). D. Mould from the Lower Turonian Abu Qada Formation at Wadi Quseib (MGDMU:WQ:Amm.**47**.66).

Genus *Wrightoceras* Reyment, 1954
Wrightoceras munieri (Pervinquière, 1907)
Pl. 26, Fig. 2; Text-fig. 3.43

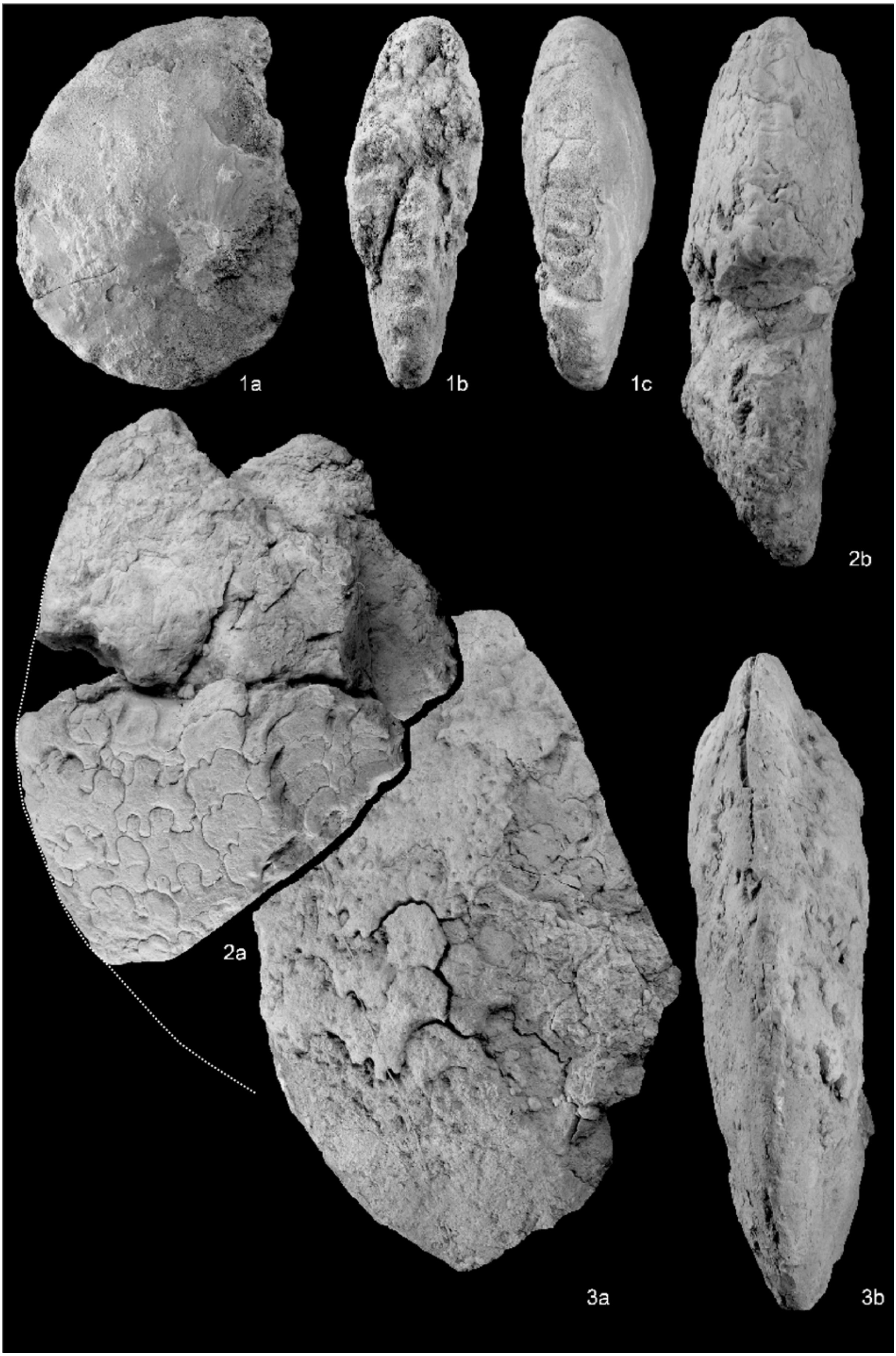
1907 *Hoplitoides Munieri* sp. nov. – Pervinquière: 217, pl. 10, figs. 1-2; text-fig. 83.
1982 *Hoplitoides munieri* (Pervinquière) – Renz: 100, pl. 31, figs. 3-6, 11.

EXPLANATION OF PLATE 26

Fig. 1. *Thomasites rollandi* (Thomas & Peron, 1889). Specimen with remains of shell from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed, x1. **a**: Side view, **b**: apertural view, **c**: ventral view x1; MGDMU:ET. Amm.**25**.80.

Fig. 2. *Wrightoceras munieri* (Pervinquière, 1907). Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed, x1. **a**: Side view, **b**: ventral view; MGDMU:ET.Amm.**26**.164.

Fig. 3. *Choffaticeras* (*Choffaticeras*) *securiforme* (Eck, 1909). Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x0.5. **a**: Side view, **b**: ventral view; MGDMU:WQ. Amm.**47**.68.


1a
1b
1c
2b
2a
3a
3b

1987 *Wrightoceras munieri* (PERVINQUIÈRE) – KENNEDY et al.: 58, pl. 10, figs. 9-11; text-fig. 2e.
1987 *Wrightoceras* cf. *munieri* (PERVINQUIÈRE) – ZABORSKI: 51, figs. 38; Text-fig. 30.
1994 *Wrightoceras munieri* (PERVINQUIÈRE) – CHANCELLOR et al.: 96, pl. 26, figs. 1, 5, 8; pl. 28, figs. 1-4; pl. 29, figs. 3-8; pl. 36, figs. 1-2; text- figs. 18G-H, 19H-I.
2007 *Wrightoceras munieri* (PERVINQUIÈRE) – BARROSO-BARCENILLA & GOY: 480, fig. 10/3, 4.
2008 *Wrightoceras munieri* (PERVINQUIÈRE) – EL QOT: 272, pl. 5, figs. 1-2, 5; text-figs. 1C, 2E.

Material and occurrence. A single incomplete internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 of the East Themed area (MGDMU:AEN.Amm.**26**.166).

Description. Specimen slightly compressed with feebly convex inner flank. Outer flank flattened and converging towards the ventrolateral shoulder. Venter narrow, sulcate, and bicarinate (Text-fig. 3. 43A). Whorl section sub-ogival with the greatest width near the mid-flank. Ornamentation not preserved. Sutures consist of three broad saddles and one broad and two narrow lobes. Ventrolateral saddle broad, denticular, and with a secondary deep lobe which is divides into two unequal parts. The second ventrolateral and the umbilical saddle simpler and slightly narrower than the ventrolateral one with shallower secondaries. Ventrolateral lobe broad and nearly equal in size as the ventrolateral saddle and with three secondary saddles, the middle one larger and higher than the lateral ones. The second ventrolateral and the umbilical lobe narrower and simpler than the venterolateral one (Text-fig. 3. 43B).

Temporal and spatial distribution. *Wrightoceras munieri* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994); North America (KENNEDY et al., 1987), South America (RENZ, 1982), Nigeria (ZABORSKI, 1987) and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, the taxon has been reported from the Lower Turonian of the Eastern Desert (EL QOT, 2008).

Discussion. The genus *Wrightoceras* is characterized by its distinct suture (many simplified elements), sub-ogival to subrectangular whorl sections, slightly convex flanks, and flat or concave venter with sharp ventrolateral shoulders, which become rounded during ontogeny. In addition, mature specimens lack ornamentation. According to ZABORSKI (1987: 49), the genus *Wrightoceras* is distinguished mainly by lacking a siphonal keel.

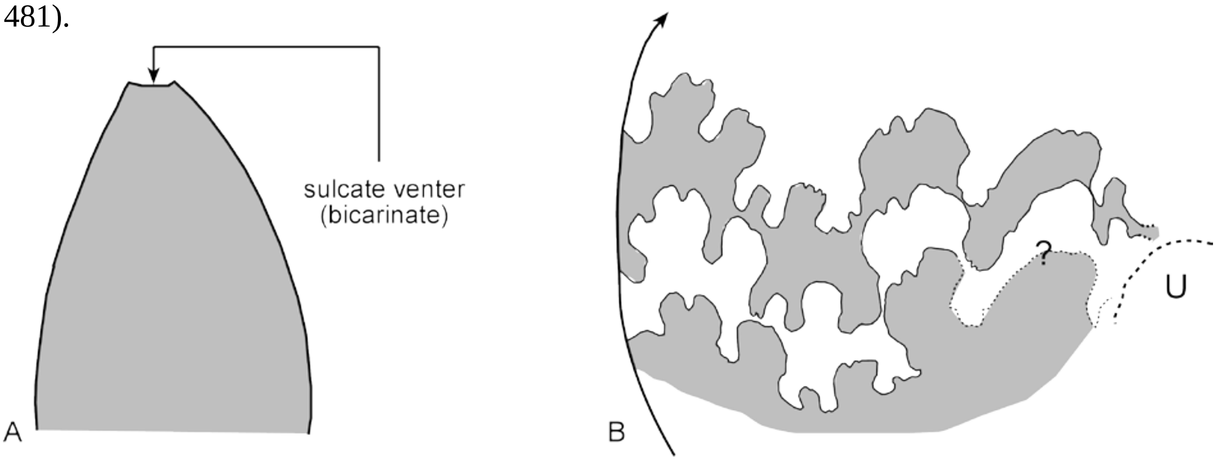
The present material closely fits the description and dimensions of *Wrightoceras munieri* which originally was described and figured by PERVINQUIÈRE (1907) and by CHANCELLOR et al. (1994) from Tunisia.

REYMENT (1954) proposed *Wrightoceras* as a subgenus of *Bauchioceras* REYMENT, 1954, in which he included *B.* (*W.*) *wallsi* as type species along with *Hoplitoides muniri* and *H. mirabilis*. Later, REYMENT (1955) regarded both taxa as subgenera of *Pseudotissotia* PERON, 1897 (for more details about the genus history see ZABORSKI, 1987: 49). After a detailed discussion, BARROSO-BARCENILLA & GOY (2007: 478) recognized REYMENT's taxon as a separate genus. This view was accepted by many other authors (e.g. KENNEDY et al., 1979). They also pointed out that the genera *Imlayiceras* LEANZA, 1967 and *Herrickiceras* COBBAN & HOOK, 1980 are synonyms of the genus *Wrightoceras*. FREUND & RAAB (1969:

65) noted that the suture of *Hoplitoides inca* BENAVIDES-CÁCERAS, 1956 and *H. munieri* lacks the typical features of the family Coilopoceratidae HYATT, 1903, and thought it more adequate to assign it to *Wrightoceras.* CHANCELLOR et al. (1994) noted that the suture line of *H. mirabilis* PERVINQUIÈRE (1907) resembles that of the family Coilopoceratidae more than that of Pseudotissotiidae. Consequently, they assigned the species to the genus *Hoplitoides*. As noted above, the different characters of sutures play an important role to distinguish between the two genera.

W. wallsi REMNET, 1954, described and figured by ZABORSKI (1987: 51, figs. 36-37) from the Lower Turonian of Nigeria and *Engonoceras toussainti* PERVINQUIÈRE,1907 which figured and described by HEWAIDY et al. (2003: 339, pl. 1, figs. 3-5) from the *Choffaticeras luciae* Zone (upper Lower Turonian) of the Eastern desert closely resemble *W. munieri* in whorl section, convexity of flank, and flat venter but ZABORSKI'S material differs in having a broad venter. Moreover, EL QOT (2008: 272) pointed out that HEWAIDY et al. (2003)'s material closely resembles *W. munieri* and considered it as a synonym to the latter species.

Wrightoceras reymenti sp. nov. AMARD et al. (1980: Pl. 9, Fig. 7) from the Lower Turonian of Algeria differs from the present species by having a larger umbilicus and wider venter. KENNEDY et al. (1987) noted that *Imlayiceras washbournei* LEANZA (1967) bears great resemblance to *W. munieri* and differs only in having tiny tubercles and fine ribs on its first whorls. (For more detailed discussion, see BARROSO-BARCENILLA & GOY, 2007: 476, 478, 481).



Text-fig. 3.43. Whorl section and suture of *Wrightoceras munieri* (PERVINQUIÈRE, 1907) from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed (MGDMU:ET:Amm.**26**.164).

Genus *Choffaticeras* HYATT, 1903
Subgenus *Choffaticeras* HYATT, 1903
Choffaticeras (*Choffaticeras*) *securiforme* (ECK, 1909)
Pl. 26, Fig. 3; Pl. 27, Fig. 1; Text-fig. 3.44

1909 *Tissotia securiformis* sp. nov. – ECK: 187, figs. 9-13.
1914 *Tissotia securiformis* ECK - ECK: 216, pl. 19, fig. 3.
?1914 *Pseudiotissotia segnis* SOLGER – ECK: 204, pl. 15, fig. 3; pl. 16, figs. 1-3; text-figs. 10-20.
?1928 *Leoniceras segne* SOLGER – DOUVILLÉ: pl. 26, pl. 5; text-fig. 17; non text-fig.16.
1969 *Choffaticeras securiforme* (ECK) – FREUND & RAAB: 60, pl. 9, fig. 1; text-figs. 11i-k.
1996 *Choffaticeras* gr. *securiforme* (ECK) – MEISTER & ABDALLAH: 15, pl. 9, fig. 1; text-fig. 6g.
?2001 *Choffaticeras schweinfurthi* (ECK) – GALAL et al.: pl. 5, figs. 4-5.
?2003 *Choffaticeras segne* (SOLGER) – HEWAIDY et al.: 351, pl. 3, figs. 1-3.

2004a *Choffaticeras securiforme* (ECK) – ABDEL-GAWAD et al.: pl. 3, fig. 4.
?2005 *Choffaticeras securiforme* (ECK) – *luciae* PERVINQUIÈRE – MEISTER & ABDALLAH: 140, pl. 24, fig. 1.
2006 *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK) – EL QOT: 124, pl. 28, fig. 4.
2008 *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK) – EL QOT: 274, pl. 6, figs. 2-5; text-fig. 2D.

Material and occurrence. 43 incomplete internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada Formation, beds 22 and 23 of the East Themed area (MGDMU:ET.Amm.**22**.79-98,**23**.92-114) and two specimen from the Lower Turonain Abu Qada Formation, bed 47 of Wadi Quseib (MGDMU:WQ.Amm.**47**.68-69).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
ET.Amm.23	173 (100%)	38 (22%)	60 (34%)	0.63	55 (32%)
WQ.Amm.47	?160 (100%)	42 (26%)	68 (42%)	0.62	---

Description. Very involute, large, and strongly compressed specimen. Flanks converge towards the venter and separated from it by rounded ventrolateral shoulder. Inner flank slightly convex while the outer one slightly concave. Whorl section lanceolate. Umbilicus moderately wide (32% of total diameter) with subvertical and concave umbilical wall. Umbilical shoulder wide and strongly rounded. Venter nearly sharp with ventrolateral keel. This keel forms a deep spiral groove appearing near the venter (Text-fig. 3.44A-B). Suture not complete, the preserved parts consisting of three saddles and two lobes. First ventrolateral saddle broad, more denticular than others, and with a secondary lobe, which divides the saddle into two unequal parts. The second ventrolateral saddle broader and simpler than the umbilical one. Ventrolateral lobe wide with secondary saddles, the biggest one in the middle. Second ventrolateral lobe smaller and simpler than the first one with small accessories, which divide it into three unequal parts (Text-fig. 3.44C). Ornamentation not preserved.

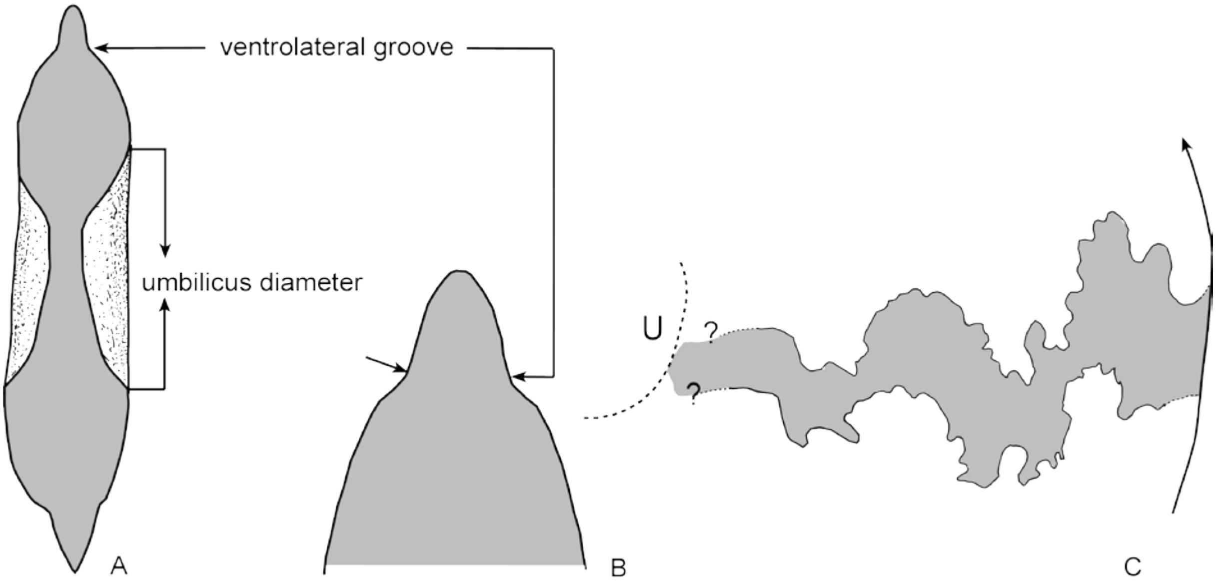
Temporal and spatial distribution. *Choffaticeras* (*Choffaticeras*) *securiforme* has been recorded from the Early Turonian of Israel (FREUND & RAAB, 1969) and Tunisia (MEISTER & ABDALLA, 1996, 2005). In Egypt, it known from the Eastern Desert (ECK, 1914; GALAL et al., 2001; HEWAIDY et al., 2003; EL QOT, 2008) and Sinai (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Discussion. REYMENT (1955) redefined the genus *Choffaticeras* on the basis of the observations of PERVINQUIÈRE (1907), dividing the group into the tricarinate *Choffaticeras* (*Choffaticeras*) HYATT, 1903, and the monocarinate *Choffaticeras* (*Leoniceras*) DOUVILLÉ, 1912.

Pseudotissotia segnis of ECK (1914, see synonym list) and *Leoniceras segne* of DOUVILLÉ (1928) closely resemble *C.* (*C.*) *securiforme* by having ventrolateral grooves (concave flank), a similar whorl width, and a similar ventral shape. They show an umbilicus that is proportionally narrower than that of *C.* (*C.*) *securiforme.* FREUND & RAAB (1969: 55) stated that *T. schweinfurthi* is a transitional form between *C.* (*C.*) *segne* and *C.* (*C.*) *securiforme.* Similarly, BARROSO-BARCENILLA & GOY (2007: 469) pointed out that the specimens of ECK (1914) and DOUVILLÉ (1928) seem to correspond to forms intermediate between *C.* (*C.*) *segne* and *C.* (*C.*) *securifome*. They also noted that the morphology of *T. schweinfurthi* probably corresponds more closely to specimens of *C. (C.) securiforme* than of

C. (C.) segne. Therefore, the specimens of ECK (1914), DOVILLÉ (1928), GALAL et al. (2001), and HEWAIDY et al. (2003) are regarded herein to be belong to *C.* (*C.*) *securiforme*.

FREUND & RAAB (1969: 61) thought that the adults of *C. luciae* (PERVINQUIÈRE, 1907) are rather similar to adults of *C. securiforme*, but the single keel (monocarinate), the shallow spiral groove, and the flat umbilical wall of *C. luciae* distinguish it from *C. securiforme*. For these reasons, many authors (e.g. BARROSO-BARCENILLA & GOY, 2007) used the subgenus *Choffaticeras* (*Leoniceras*) for this species. Moreover, *C. securiforme* (ECK) *luciae* PERVINQUIÈRE of MEISTER & ABDALLAH (2005) seems bicarinated with a wide umbilicus and is attributed herein with some doubts to be subspecies *luciae*.



Text-fig. 3.44. Whorl section and suture of *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK, 1909). A. From the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area (MGDMU:ET:Amm.**23**.92). B-C. Lower Turonian Abu Qada Formation of Wadi Quseib (MGDMU:WQ:Amm.**47**.68).

Choffaticeras (*Choffaticeras*) *segne* (SOLGER, 1903)
Pl. 27, Fig. 2; Pl. 28, Fig. 1; Text-fig. 3.45

1903 *Pseudotissotia segnis* sp. nov. – SOLGER: 77, pl. 4, figs. 1-2; text-figs. 16-21.
1907 *Pseudotissotia* (*Choffaticeras*) *segnis* SOLGER – PERVINQUIÈRE: 351, pl. 23, figs. 1, 2.
1914 *Tissotia Schweinfurti* ECK – ECK: 204, pl. 19, figs. 1, 2.
1969 *Choffaticeras segne* (SOLGER) – FREUND & RAAB: 54, text-fig. 10j-i.
1987 *Choffaticeras segne* (SOLGER) – KORA & HAMAMA: pl. 1, fig. 7.
1992 *Choffaticeras segne* (SOLGER) – ABDEL-GAWAD et al.: pl. 1, fig. 6.
1994 *Choffaticeras segne* (SOLGER) – KASSAB & ISMAEL: 228, fig. 3/4-7.
1996 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – CHANCELLOR et al.: 88
2001a *Choffaticeras segne* (SOLGER) – ALY & ABDEL-GAWAD: 41, pl. 7, fig. 1; Text-fig. 3g.
2001 *Choffaticeras segne* (SOLGER) – GALAL et al.: pl. 4, figs. 5-8.
2001 *Choffaticeras segne* (SOLGER) – KORA et al.: pl. 2, figs. 1, 2.
2003 *Choffaticeras segne* (SOLGER) – HEWAIDY et al.: 351, pl. 2, figs. 9-10.
2004a *Choffaticeras segne* (SOLGER) – ABDEL-GAWAD et al.: pl. 3, figs. 2, 6.
2005 *Choffaticeras* aff. *segne* (SOLGER) – MEISTER & ABDALLAH: 140, pl. 22, fig. 1.
2006 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – EL QOT: 124, pl. 28, figs. 2, 6.
2007 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – BARROSO-BARCENILLA & GOY: 468, figs. 5/5; 6/1-3.

2008 *Choffaticeras segne* (SOLGER) – ALY et al.: 50, pl. 2, figs. A-F; pl. 6, fig. 2; pl. 7, fig. 1c.
2008 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – EL QOT: 276, pl. 6, figs. 1, 6-7; text-fig-2G.

Material and occurrence. 113 internal moulds from the Upper Cenomanian-Lower Turonian Abu Qada, bed 23 of the East Themed area (MGDMU:ET.Amm.**23**.115-227), 14 specimens from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.Amm.**47**.70-83), and ten internal moulds from the lower member of the Lower Turonian Abu Qada Formation, bed 22 of Gebel Areif El-Naqa (MGDMU:AEN.Amm.**22**.8-17).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
ET.Amm.23	69 (100%)	22 (31%)	35 (50%)	0.62	10 (15%)
ET.Amm.23	81 (100%)	23 (28%)	33 (41%)	0.69	11 (14%)
ET.Amm.23	210 (100%)	61 (29%)	87 (41%)	0.70	48 (23%)
WQ.Amm.47	131 (100%)	38 (29%)	64 (49%)	0.59	23 (17%)
WQ.Amm.47	200 (100%)	62 (31%)	88 (44%)	0.70	27 (13%)
AEN.Amm.22	190 (100%)	51 (26%)	82 (43%)	0.62	38 (20%)

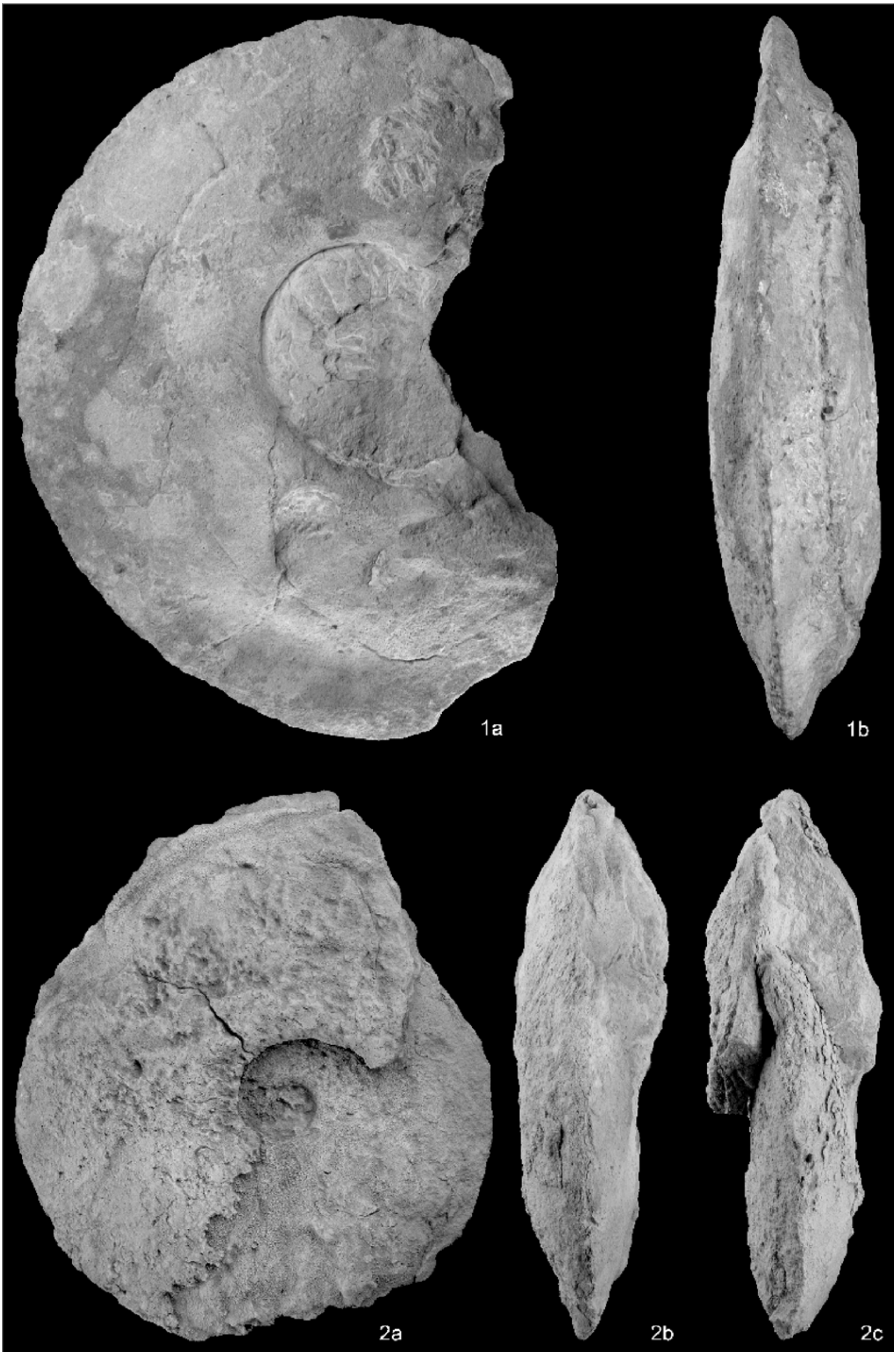
Description. Involute, medium- to very large-sized, lenticular, and slightly compressed specimen. Maximum width near the umbilical shoulder. Flanks slightly convex, broad, and converging towards the venter. Umbilicus medium-sized (13-22% of total diameter) and moderately deep. Umbilical shoulder broadly rounded with deep, vertical umbilical wall in adults, subvertical and shallower in juveniles. Venter sharp to acute (Text-fig. 3.45A-B). Whorl sections suboval to lanceolate. Sutures consisting of 3-4 saddles and three lobes. Ventrolateral saddle broad and high with few secondary elements. Umbilical saddle simpler, smoother, and narrower than the ventrolateral one. Ventrolateral lobe broad and containing secondary saddles, which divide it into two unequal parts. The second ventrolateral and the umbilical lobe are simpler, narrower, and shallower than the first ventrolateral one (Text-fig. 3.45C-D). All specimens lack ornamentation.

Temporal and spatial distribution. *Choffaticeras* (*Choffaticeras*) *segne* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1996; MEISTER & ABDALLAH, 2005), Jordan (ALY et al., 2008), Israel (FREUND & RAAB, 1969), and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it is known from the Lower Turonian of Wadi Ghonima (HEWAIDY et al., 2003), W. El-Tarfa, Eastern Desert (GALAL et al., 2001; EL QOT, 2008), W. Abu Had (KORA et al., 2001), Gebel Minsherah and Khashm El Tarif (ALY & ABDEL-GAWAD, 2001a), G. Gunna (KORA & HAMAMA, 1987), G. Nezzazat (ABDEL-GAWAD et al., 1992), Abu Zuneima (KASSAB & ISMAEL, 1994), and East Themed, G. Ekma, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

EXPLANATION OF PLATE 27

Fig. 1. *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK, 1909). Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation at East Themed, x0.75. **a**: Side view, **b**: ventral view; MGDMU:ET. Amm.**23**.92.

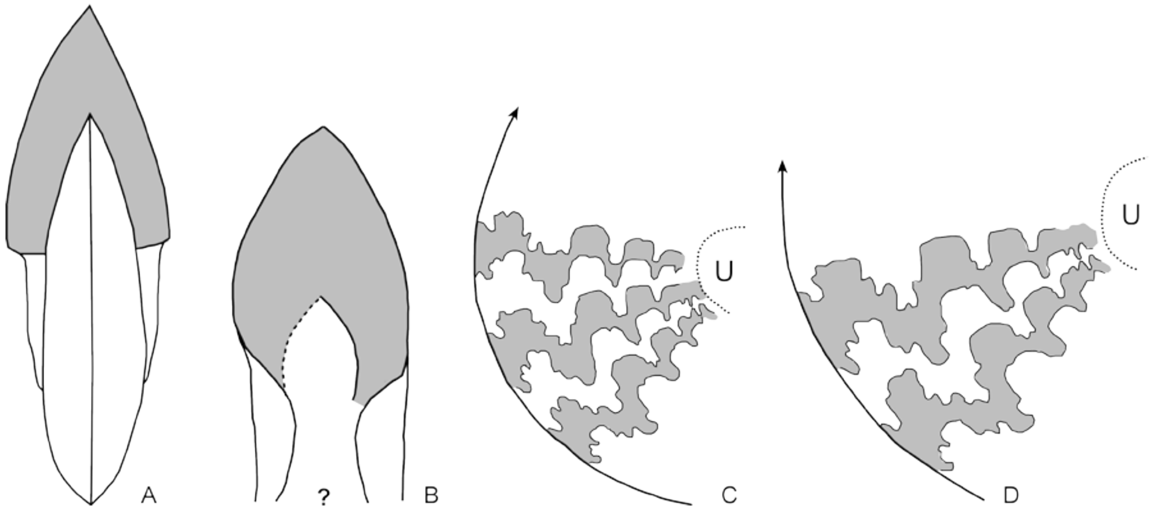
Fig. 2. *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER, 1903). **1**. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib, x1. **a**: Side view, b: ventral view, **c**: apertural view; MGDMU:WQ. Amm.**47**.70.


1a
1b
2a
2b
2c

Discussion. According to FREUND & RAAB (1969: 55) the umbilicus of *Choffaticeras* (*Choffaticeras*) *segne* becomes larger with growth, its wall becomes vertical and the rounded borders become more distinct. At about the diameter of 100 mm, the ornamentation, the ventrolateral shoulders, and the median keel (in most cases) disappear. From this diameter onward, the venter becomes rounded. In addition, BARROSO-BARCENILLA & GOY (2007: 469) noted that identifcation of *C.* (*C.*) *segne* is difficult because its dimensions are highly variable. In the present study, some of specimens (with diameter more than 100 mm) have a semi-rounded venter, deep and wide umbilicus, vertical umbilical wall, and lack ornamentation.

KASSAB (1991b: 29) considered *C. Pavillieri* PERVINQUIÈRE, *C. securiforme* (ECK), *C. schweinfurthi* (ECK), *C. luciae* PERVINQUIÈRE, and probably *C. quaasi* (PERON) from the Lower Turonian northern Eastern Desert as synonyms of *C. segne* (the *Choffaticersa segne* Zone). In agreement with BARROSO-BARCENILLA & GOY (2007), KASSAB (1991) ignored the different stratigraphic ranges of these species and different morphologies that have even been attributed to different subgenera.

Pseudotissotia segnis SOLGER, var. *discoidalis* PERVINQUIÈRE (1907: 207, pl. 13, fig. 3) from the Turonian of Tunisia differs in having a broad ventrolateral shoulder and a tricarinate, broad venter even in adult individuals. For these reasons, FREUND & RAAB (1969), BARROSO-BARCENILLA & GOY (2007), and others considered the latter variety as synonym of *C.* (*C.*) *quaasi* (PERON, 1904). The latter authors also realised that to distinguish between *C.* (*C.*) *segne*, *C.* (*C.*) *quaasi*, and *C.* (*C.*) *pavillieri* (PERVINQUIÈRE, 1907) is quite difficult. However, the latter species can be easily recognized by its compressed shape and very narrow umbilicus. According to FREUND & RAAB (1969: 59) the differences between *C.* (*C.*) *pavillieri* and *C.* (*C.*) *sinaiticum* (DOUVILLÈ) are slight and transitional forms exist between them. The latter species lacks the ventrolateral keels and has a wider umbilicus. In addition, *C.* (*C.*) *meslei* (PERON, 1897) has a wider whorl and maintains a marked tricarinate venter (three blunt keels) during ontogeny (for more detailed discussion, see FREUND & RAAB, 1969: 55-56, 58; BARROSO-BARCENILLA & GOY, 2007: 466-467, 469).



Text-fig. 3.45. Whorl section and suture of *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER, 1903). A. Internal mould from the Lower Turonian Abu Qada Formation at Wadi Quseib (MGDMU:WQ:Amm.**47**.70**)**. B-D. From the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area (MGDMU:ET:Amm.**23**.115).

Genus *Hemitissotia* PERON, 1897
Hemitissotia sp.
Pl. 29, Fig. 1; Text-fig. 3.46

Material and occurrence. One internal mould from the Upper Turonian Wata Formation, bed 97 at Wadi Quseib (MGDMU:WQ.Amm.**97**.35).

Measurements (in mm).

Specimen no.	D	Wb	Wh	Wb/Wh	U
WQ.Amm.97	132 (100%)	48 (37%)	50 (38%)	0.96	22 (17%)

Description. Large-sized and ovate specimen. Greatest whorl width at the umbilical shoulder. Flank moderately wide, strongly inflated, and converging steeply towards the venter. Umbilicus narrow (about 17% of total diameter) and moderately deep with slightly rounded umbilical shoulder. Venter sharp and without ventrolateral shoulders. Whorl section lanceolate (Text-fig. 3.46A). Ornamentation not preserved. Sutures not complete but the preserved parts consisting of three saddles and lobes on the flank. Ventrolateral saddle considerably wide and divided into two unequal parts by small, shallow accessory lobe. Umbilical saddle wider than the ventrolateral one with few shallow accessories. Ventrolateral lobe deep, divided by an accessory saddle into two unequal parts and broader than umbilical lobe (Text-fig. 3.46B).

Discussion. CHANCELLOR et al. (1994) pointed out that the difference between the genera *Choffaticeras* and *Hemitissotia* is fine. The latter genus has semi-entire saddles and not more denticulate saddles of *Choffaticeras*. This difference can also be observed in the present materials (Text-fig. 3.46B).

The present specimen resembles *Hemitissotia morreni* of COQUAND (1862: 173, pl. 1, figs. 3-4) from Algeria and of CHANCELLOR et al. (1994: 92, pl. 2, figs. 4-5; pl. 7, figs. 1-2; pl. 31, figs. 1-6; pl. 32, figs. 1-3, 5-6) from the Upper Turonian of Tunisia with respect to ventral shape, umbilical area, size, and suture pattern.

PERVINQUIÈRE (1907) and CHANCELLOR et al. (1994) regarded *H. batnensis* PERON (1897) and *H. czini* PERON (1897) as synonyms of *H. morreni*. The latter author noted a great variability in *H. morreni*. For this reason, they considered the various taxa of PERON (1897: varieties *praecipua*, *coquandi*, and *tissotiaeformis*) to fall well within the range of intraspecific variation of *H. morreni* (for more discussion, see CHANCELLOR et al., 1994: 95-96).

Family Coilopoceratidae HYATT, 1903

Genus *Coilopoceras* HYATT, 1903

Coilopoceras requienianum (D'ORBIGNY, 1841)

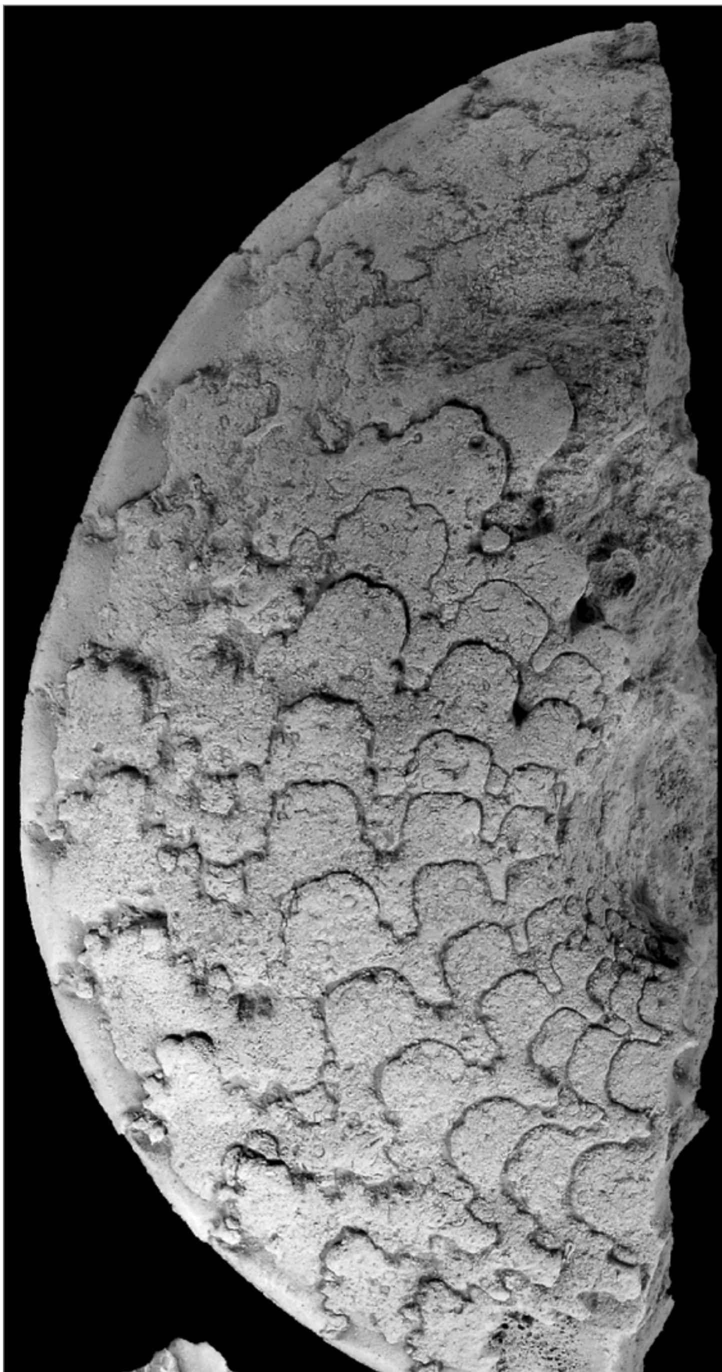
Pl. 28, Fig. 2; Pl. 29, Figs. 2-3; Text-figs. 3.47

1841 *Ammonites Requienianum* sp. nov. – D'ORBIGNY: 315, pl. 93, figs. 1-4.
1989 *Coilopoceras requienianum* (D'ORBIGNY) – LUGER & GRÖSCHKE: 388, pl. 46, figs. 1-3; text-figs. 6A, E, 11, 12, 13A-C.
?1990 *Coilopoceras* cf. *requienianum* (D'ORBIGNY) – ROBASZYNSKI et al.: pl. 26, figs. (?) 1, 2.

EXPLANATION OF PLATE 28

Fig. 1. *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER, 1903). Internal mould from the Upper Cenomanian-Lower Turonian Abu Qada Formation of the East Themed area, x0.75. **a**: Side view, **b**: ventral view; MGDMU:ET. Amm.**23**.115.

Fig. 2. *Coilopoceras requienianum* (D'ORBIGNY, 1841). Internal mould from the Upper Turonian Wata Formation at Wadi Quseib, x1. **a**: Side view, **b**: ventral view; MGDMU:WQ. Amm.**97**.36.

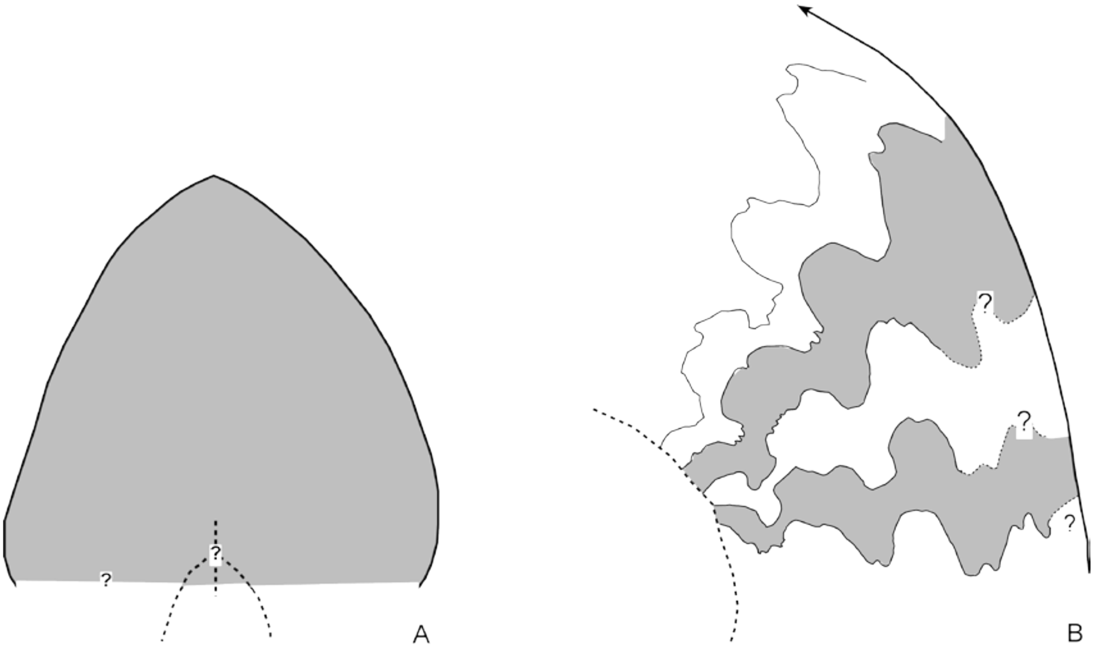


1a

1b

2a

2b



Text-fig. 3.46. Whorl section and suture of *Hemitissotia* sp. from the Upper Turonian Wata Formation at Wadi Quseib (MGDMU:WQ:Amm.**97**.35).

?2001 *Coilopoceras requienianum* (d’Orbigny) – Kora et al.: pl. 2, figs. 11-12.
?2002 *Coilopoceras requienianum* (d’Orbigny) – El-Hedeny: 415, fig. 6d-f; text-figs. (?) 7g, 8b.
2002 *Coilopoceras* gr. *requienianum* (d’Orbigny) – Meister & Rhalmi: 766, pl. 2, fig. 4; pl. 3, figs. 1, 2; pl. 4, fig. 2.
2003 *Coilopoceras requienianum* (d’Orbigny) – Hewaidy et al.: 354, pl. 6, figs. 4-5.
2004a *Coilopoceras requienianum* (d’Orbigny) – Abdel-Gawad et al.: pl. 1, figs. 3-5.
2006 *Coilopoceras requienianum* (d’Orbigny) – El Qot: 128, pl. 29, figs. 1-3.
2008 *Coilopoceras requienianum* (d’Orbigny) – El Qot: 279, pl. 8, figs. 1-4; text-figs. 2H, I.

Material and occurrence. 14 fragments (internal moulds) from the upper Middle-Upper Turonian Wata Formation, beds 93 and 97 at Wadi Quseib (MGDMU:WQ.Amm.**93**.22-29;**97**.36-41).

Description. Moulds incomplete, involute, oxycone, and compressed. Whorl section lanceolate with sharpened venter (Text-fig. 3.47A). Umbilicus narrow. Greatest width near the umbilicus. Umbilical shoulder broad and slightly convex with low and subvertical umbilical wall. All specimens lack ornamentation. Suture consisting of four saddles and three lobes. First ventrolateral saddle broad, denticulate and with a secondary element (deep and narrow lobe), which divides it into two unequal parts. Second ventrolateral saddle simpler and narrower than the first one with small secondary elements. Ventrolateral lobe broad, denticulate, and with a high secondary saddle in the middle part of the lobe which divides it into two equal parts. Second ventrolateral and the umbilical lobe narrower and simpler than the first one with tiny secondary elements (Text-fig. 3.47B).

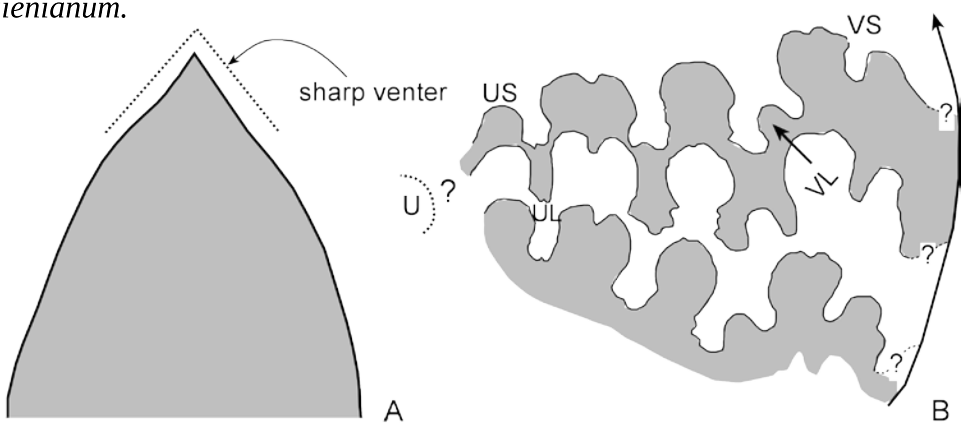
Temporal and spatial distribution. *Coilopoceras requienianum* has been recorded from the Upper Turonian of Morocco (Meister & Rhalmi, 2002) and Tunisia (Robaszynski et al., 1990). In Egypt, it has been found in the Eastern Desert (Luger & Gröscke, 1989; Kora et al., 2001; Hewaidy et al., 2003; El Qot, 2008) and Sinai (El-Hedeny, 2002; Abdel-Gawad et al., 2004a; El Qot, 2006).

According to Luger & Gröscke (1989: 393), *C. requienianum* occurs also in the Upper Turonian of France and Germany. Based on the occurrence of *C. requienianum* in the European *Romaniceras deverianum* Zone, the species is indicative of the upper Middle Turonian. Lewy (1989) recorded the species from above this zone in Israel. In Egypt, many authors consider the *requienianum* Zone latest Turonian in age, but Abdel-Gawad et al. (2004a: 281) recorded two biozones above the *requienianum* Zone and considers it upper Middle to lower Upper Turonian.

Discussion. Luger & Gröscke (1989: 391) distinguish two morphotypes of *Coilopoceras requienianum*; smooth and ribbed oxycone forms, and interpreted them as representing sexual dimorphism. All present specimens are smooth and belong to the first form. In addition, the form is closely similar to *C. requienianum* which has been described and figured by Luger & Gröscke (1989). *C. requienianum* is characterized by a very sharp venter, narrow umbilicus, and distinct suture. The same authors (393: text-fig. 13A-C) noted also that the venter of this species is sharp and becomes blunt on body-chamber.

Coilopoceras cf. *requienianum* of Robaszynski et al. (1990) is corroded and has a flat and strongly rounded venter. Also, *C. requienianum* of Kora et al. (2001) and El-Hedeny (2002) have a rounded to flat, broad venter, and the sutures are not completely identical with those of *C. requienianum.* Moreover, the whorl section drawn by El-Hedeny (2002: text-fig. 7g) is not similar to his specimen (pl. 6f). Therefore, the specimens of these authors are placed in the synonymy of the present species with some doubts.

According to Luger & Gröscke (1989), the specimens figured by Lewy (1975: 42, pl. 1, fig. 3; text-fig. 15i-l) as *C. sinaiense* n. sp. and *C. multicostatum* (Lewy, 1975: 42, pl. 1, figs. 1, 2; text-figs. 1-5) have been collected from the *C. requienianum* Zone of Sinai and the Eastern Desert and are closely similar to *C. requienianum.* According to them, Lewy's material is poorly preserved and these species can only questionably be regarded as synonyms of *C. requienianum.*

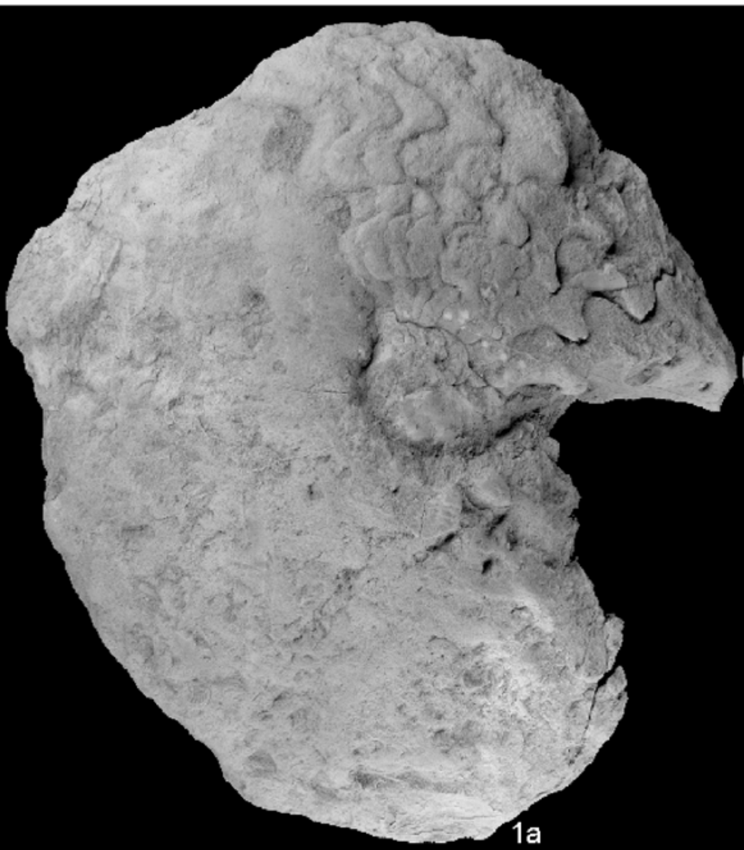


Text-fig. 3.47. Whorl section and suture of *Coilopoceras requienianum* (d'Orbigny, 1841) from the Upper Turonian Wata Formation at Wadi Quseib (MGDMU:WQ:Amm.**97**.36-37).

EXPLANATION OF PLATE 29

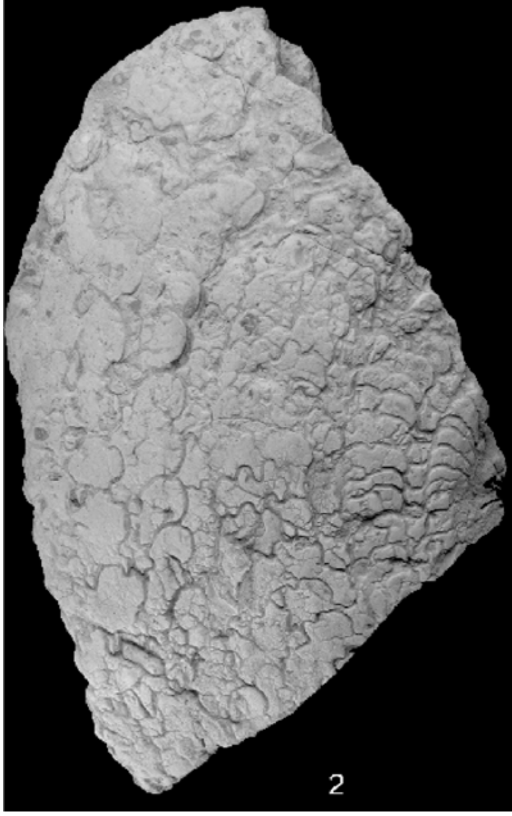
Fig. 1. *Hemitissotia* sp. Internal mould from the Upper Turonian Wata Formation at Wadi Quseib, x0.75. **a**: Side view, **b**: ventral view; MGDMU:WQ. Amm.**97**.35.

Figs. 2-3. *Coilopoceras requienianum* (d'Orbigny, 1841). Internal moulds from the Upper Turonian Wata Formation at Wadi Quseib. **2**. Side view, x1; MGDMU:WQ.Am.93. - **3**. Side view, x1.5; MGDMU:WQ. Amm.**97**.37.



1a

1b



2

3

3.5. Phylum Echinodermata KLEIN, 1734

The systematic classification of echinoids follows the classification of Cretaceous echinoids from Great Britain (SMITH & WRIGHT 1989, 1990, 1993, 1996, 1999, and 2000) and from the United Arab Emirates-Oman border region (SMITH, 1995). The terminology used in the description of the taxa is that of DURHAM & WAGNER (1966).

All linear measurements (taken with Vernier Caliper) are given in millimeters. The abbreviations of measured parameters are:

D= test diameter;
dp= diameter of peristome (in regular echinoids);
H= test height;
L= test length;
W= test width;
Ls= length of apical disc;
Lk= length of periproct;
Lp= length of peristome;
Wp= width of peristome;
Wa= width of ambulacral area at ambitus;
Wi= width of interambulacral area at ambitus;
LI= length of petal I or V;
LII= length of petal II or IV;
LIII= length of petal III up to the peripetalous fasciole;
NI= number of pore pairs in petal I or V;
NII= number of pore pairs in petal II or IV;
NIII= number of pore pairs in ambulacral III until fasciole;
WQ: Wadi Quseib;
AEN: Gebel Areif El-Naqa.

Class Echinoidea LESKE, 1778
Order Cidaroida CLAUS, 1880
Family Cidaridae GRAY, 1825

Subfamily Cidarinae GRAY, 1825
Genus *Sinaecidaris* FOURTAU, 1921
Sinaecidaris cf. *gauthieri* FOURTAU, 1921
Pl. 30, Fig. 1.

cf.1921 *Sinaecidaris Gauthieri* sp. nov. – FOURTAU: 9, pl. 3, fig. 11.

Material and occurrence. Two incomplete specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 12 at Wadi Quseib (MGDMU:WQ.E.**12**.52-53).

Description. Adapical and adoral sides of test flattened above and below. Ambulacral area narrow (about 20% of interambulacral width) and weakly sinuous. Poriferous zone wide and uniserial. Pores rounded, equal, slightly oblique, non-conjugated, and separated by elevated ridge. Interporiferous zones nearly as wide as poriferous zones and slightly swollen, with 2-4 rows of granules that are well developed near ambitus. Interambulacral area wide, carrying two rows of large and weakly crenulated primary tubercles with 5 plates in a series. Areole moderately deep, rounded, and surrounded by about 14 scrobicular tubercles. Interradial extrascrobicular surface wider than adradial extrascrobicular surface and occupied by equal-sized, non-oriented granules. Peristome not preserved.

Temporal and spatial distribution. *Sinaecidaris gauthieri* has been erected based on material collected from the Upper Aptian of North Sinai, Egypt (FOURTAU, 1921).

Discussion. FOURTAU's genus differs from the genus *Typocidaris* and all other Stereocidarinae by having primary interambulacral tubercles with confluent scrobicular circles, which are separated in *Typocidaris*. The present material shows much similarity to *Sinaecidaris gauthieri*, which has been originally described from the Upper Aptian of Gebel Manzour by FOURTAU (1921). It is characterized by the presence of flat adapical and adoral surfaces with crenulated tubercles.

Subclass Acroechinoidea SMITH, 1981
Superorder Pedinacea MORTENSEN, 1939 [after JENSEN, 1981]
Order Pedinoida MORTENSEN, 1939
Family Pedinidae POMIEL, 1883

Genus *Micropedina* COTTEAU, 1866
Micropedina olisiponensis (FORBES, 1850)
Pl. 30, Fig. 2

1850 *Echinus olisiponensis* sp. nov. – FORBES in SHARPE: 195, pl. 25, fig. 1.
1912 *Micropedina olisiponensis* FORBES – FOURTAU: 156, pl. 2, fig. 2.
1914 *Micropedina olisiponensis* FORBES – FOURTAU: 27.
1981 *Micropedina olisiponensis* FORBES – AMARD et al.: 88.
1991 *Micropedina olisiponensis* (FORBES) – SMITH & BENGTSON: 32, pl. 6/A-I, text-figs. 24, 25.
1992 *Micropedina olisiponensis* (FORBES) – GEYS: 143, pl. 1, figs. 8-14.
1995 *Micropedina olisiponensis* (FORBES) – NÉRAUDEAU et al.: 411, fig. 3d.

EXPLANATION OF PLATE 30

Fig. 1. *Sinaecidaris* cf. *gauthieri* FOURATU, 1921. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. Side view, x 2; MGDMU:WQ.E.**12**.52.

Fig. 2. *Micropedina olisiponensis* (FORBES, 1850). from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1, **b**: adoral view, x1, **c**: side viw, x1; MGDMU:WQ.E.**44**.239.

Fig. 3. *Orthopsis ovata* (COQUAND, 1862). from the Lower Turonian Abu Qada Formation at Wadi Quseib. **a**: Adapical view, x1, **b**: side view, x1, **c**: detail of ambital interambulacrum, x4, **d**: detail of ambital ambulacrum, x5; MGDMU:WQ.E.**47**.84.

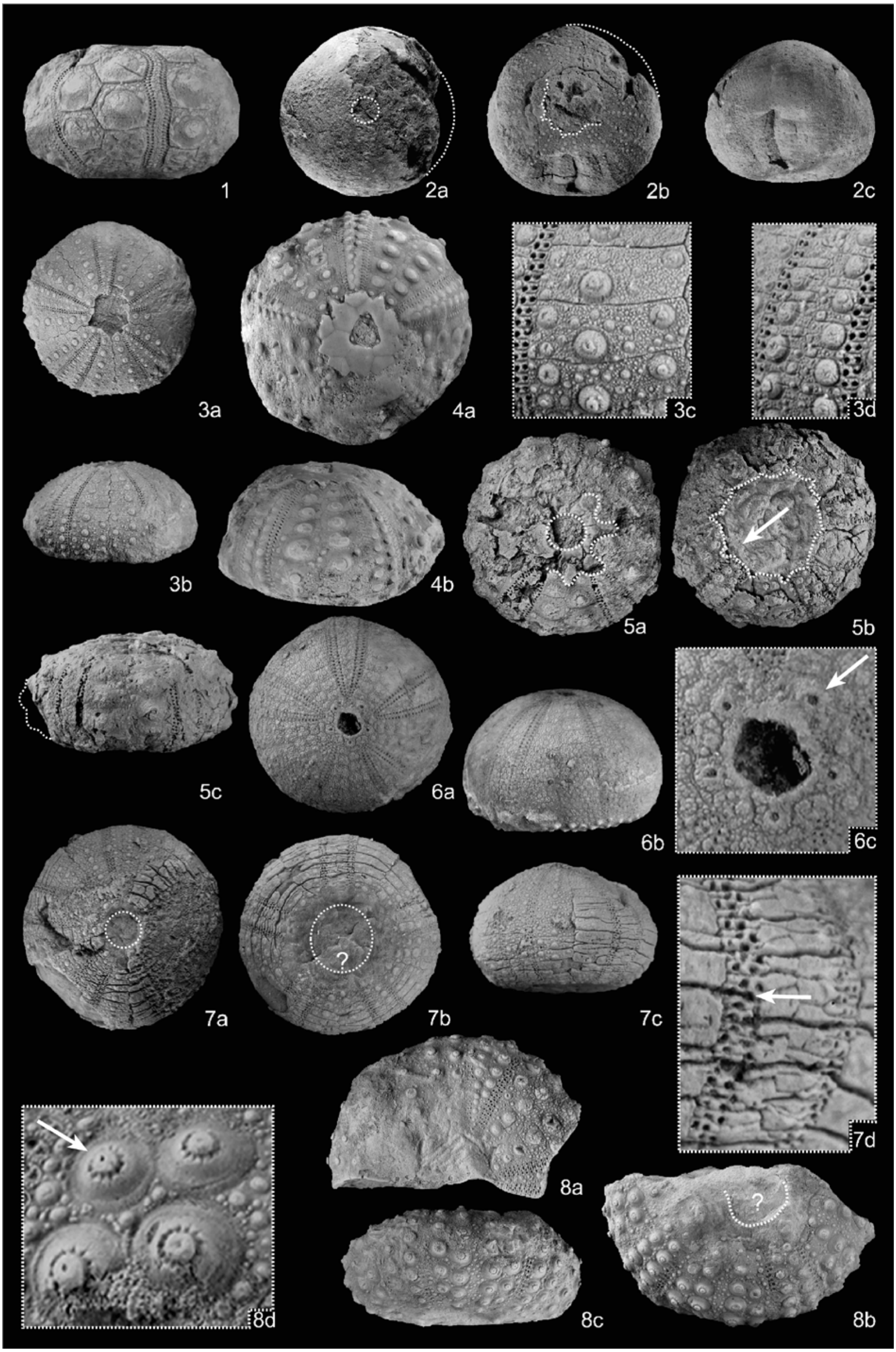
Fig. 4. *Goniopygus menardi* (DESMAREST, 1825). from the upper carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x2, **b**: side view, x2; MGDMU:WQ.E.**44**.240.

Fig. 5. *Goniopygus* cf. *peroni* THOMAS & GAUTHIER, 1889. from the Upper Turonian Wata Formation at Gebel Areif El-Naqa. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5; MGDMU:AEN.E.**31**.3.

Fig. 6. *Codiopsis* sp. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: side view, x1.5, **c**: detail of apical disc, x5; MGDMU:WQ.E.**12**.54.

Fig. 7. *Pedinopsis desori* (COQUAND, 1862). from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **a**: Adapical view, x2.5, **b**: adoral view, x2.5, c: side view, x2.5, **d**: detail of ambital ambulacrum, x12; MGDMU:AEN.E.**15**.191.

Fig. 8. *Tetragramma variolare* (BRONGNIART, 1822). from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5, **d**: detail of ambital interambulacrum, x8; MGDMU:AEN.E.**15**.192.


1
2a
2b
2c
3a
4a
3c
3d
3b
4b
5a
5b
5c
6a
6b
6c
7a
7b
?
7c
7d
8a
8d
?
8c
8b

1997 *Micropedina olisiponensis* (Forbes) – Néraudeau & Courville: 840, figs. 6/1, 8, 11.
2003 *Micropedina olisiponensis* (Forbes) – Abdelhamid & Azab: 854, pl. 1, fig. F.
2003 *Micropedina olisiponensis* (Forbes) – Berndt: 80, fig. 3/4a-c.
2006 *Micropedina olisiponensis* (Forbes) – El Qot: 129, pl. 30, figs. 1, 2.

Material and occurrence. One specimen from the upper carbonate member of the Galala Formation (Upper Cenomanian), bed 44 at Wadi Quseib (MGDMU:WQ.E.**44**.239).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wa/D	Wi	Wi/D	Wa/Wi
	30	25	0.83	7	0.23	11	0.37	7	0.23	12	0.40	0.58

Description. Test medium-sized, circular in outline, subconical, its height reaches 83% of test diameter. Ambitus strongly rounded and one-third of the test height above the base. Adapical surface dome-shaped. Adoral surface flattened. Apical disc not preserved but its size can be measured (23% of test diameter). Ambulacra straight from apex to peristome, flush, relatively broad, 23% of test diameter wide at ambitus, and 58% of interambulacral width. Poriferous zone wide and straight, not narrowing or broadening near the peristome. Pore-pairs arranged in oblique weak arcs of three (arranged in triads). Interporiferous zone carrying two rows of large tubercles with occasional militaries. Interambulacra broad, 40% of the test diameter, with irregular row of small, equal-sized tubercles that are perforated and crenulated. Peristome circular, its diameter 37% of test diameter.

Temporal and spatial distribution. *Micropedina olisiponensis* is a well known Cenomanian echinoids (Néraudeau & Courville, 1997). It was first described by Forbes (in Sharpe, 1850) from the Cenomanian of Portugal. The species has been also recorded from the Middle Cenomanian of Brazil (Smith & Bengtson, 1991), Upper Cenomanian of Saudi Arabia (Néraudeau et al., 1995), Nigeria (Néraudeau & Courville, 1997), Algeria (Amard et al., 1981), and Jordan (Berndt, 2003). It is characteristic of the Upper Cenomanian throughout the Tethys (Néraudeau et al., 1993).

In Egypt, *M. olisiponensis* is known from the Upper Cenomanian of the Eastern Desert and Sinai (Geys, 1992: 153; El Qot, 2006: 30).

Cohort Echinacea Claus, 1876
Order Orthopsida Mortensen, 1942
Family Orthopsidae Duncan, 1889

Genus *Orthopsis* Cotteau, 1864
Orthopsis ovata (Coquand, 1862)
Pl. 30, Fig. 3

1862 *Pseudodiadema ovatum* sp. nov. – Coquand: 256, pl. 27, figs. 19-21.
1880 *Orthopsis ovata* Coquand – Coquand: 330.
1932 *Orthopsis ovata* Coquand – Lambert: 95.
2006 *Orthopsis* cf. *ovata* Coquand – El Qot: 141, pl. 32, fig. 8.

Material and occurrence. One specimen from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.E.**47**.84), and one specimen from Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 23 of the East Themed area (MGDMU:ET.E.**23**.228).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	Wa	Wa/D	Wi	Wi/D	Wa/Wi
	30	16	0.54	7	0.23	5	0.17	13	0.43	0.38

Description. Test medium-sized, nearly circular, its height about 54% of test diameter. Adapical surface with a depressed domal profile. Adoral surface flattened. Ambitus rounded, lying about one-third of the height above the base. Ambulacra 17% of test diameter in width at ambitus and 38% of interambulacral width. Plating trigeminate ambitally. Poriferous zone narrow, uniserial, and straight. Pores well-rounded, equal-sized, and isolated. Interporiferous zone carries two rows of perforated, non-crenulated, non-confluent primary tubercles, which are smaller than the primary tubercles of interambulacral areas. These tubercles are separated by two rows of secondary tubercles (Pl. 30, Fig. 3d). Interambulacral plates simple, wide, and slightly curved with two rows of perforated, non-crenulated primary tubercles and reaching the apical disc and peristome. In addition, two external and two internal rows of secondary tubercles exist, which disappear before the apex (Pl. 30, Fig. 3c). There are also two rows of very small tubercles around the interradial suture at the ambitus. Peristome not well preserved.

Temporal and spatial distribution. *Orthopsis ovata* have been recorded from the Cenomanian-Turonian of Algeria (COQUAND, 1862) and Turonian of Morocco (LAMBERT, 1932). In Egypt, it has been recorded from the Turonian of Sinai by EL QOT (2006).
According to EL QOT (2006: 142), *O. ovata* in Egypt apparently was restricted to Turonian.

Discussion. *Orthopsis ovata* differs from *O. miliaris* (D'ARCHIAC, 1835) figured by SMITH & BENGTSON (1991: 30, pl. 8B-F; text-fig. 23) from the Lower Albian-Middle Cenomanian of Brazil in the latter being smaller, having narrower ambulacra, and less developed tubercles on the interambulacral area.

Order Arbacioida GREGORY, 1900
Suborder Arbaciina GREGORY, 1900
Family Acropeltidae LAMBERT & THIÉRY, 1914

Genus *Goniopygus* AGASSIZ, 1838
Goniopygus menardi (DESMAREST, 1825)
Pl. 30, Fig. 4

1825 *Echinus Menardi* sp. nov. – DESMAREST: 101.
1914 *Goniopygus Menardi* DESMAREST var. *Brossardi* COQUAND – FOURTAU: 40.
1921 *Goniopygus Menardi* DESMAREST var. *Brossardi* COQUAND –FOURTAU: 45.
1925 *Goniopygus Menardi* DESMAREST – BLANCKENHORN: 84.
1985 *Goniopygus menardi* (DESMAREST) – BANDEL & GEYS: 111, pl. 9, figs. 2-6.
1992 *Goniopygus menardi* (DESMAREST) – GEYS: 147, pl. 2, figs. 10-13.
1993 *Goniopygus menardi* (DESMAREST) – NÉRAUDEAU et al.: 286, pl. 1, figs. I-K.
1993 *Goniopygus menardi* (DESMAREST) – SMITH & WRIGHT: 215, text-fig. 71.
2001 *Goniopygus menardi* (DESMAREST) – ABDELHAMID & EL QOT: 18, fig. 5I-J.
2003 *Goniopygus menardi* (DESMAREST) – ABDELHAMID & AZAB: 862, pl. 3, figs. H-I.
2003 *Goniopygus menardi* (DESMAREST) – BERNDT: 81, fig. 3/5-6.
2006 *Goniopygus menardi* (DESMAREST) – EL QOT: 140, pl. 32, figs. 5-6.

Material and occurrence. 20 specimens from the upper carbonate member of the Galala Formation (Upper Cenomanian), bed 44 at Wadi Quseib (MGDMU:WQ.E.**44**.240-259).

Measurements (in mm).

n=3	D	H	H/D	Ls	Ls/D	Wa	Wi	Wa/Wi
Range	6-21	11-15	0.65-0.75	7-8	0.38-0.50	3-5	7-10	0.34-0.50
Mean	18	12.7	0.70	7.6	0.43	3.7	8.7	0.42

Description. Test small-sized, hemispherical, circular in outline, its height about 70% of the total diameter. Adapical surface slightly convex with rounded ambitus. Adoral surface flattened. Apical disc large (about 53% of test diameter), flat, and sub-pentagonal to rounded. Ambulacral area narrow (42% of interambulacral width), slightly swollen, straight, and not closed adorally. Poriferous zone narrow and uniserial. Pores rounded, equal, and non-conjugated. Interporiferous zone with two rows of relatively small, imperforated, and non-crenulated primary tubercles (14-17 tubercles in each row). Interambulacral area relatively broad throughout and carrying two rows of well developed, large-sized, imperforated, and non-crenulated primary tubercles (7-10 tubercles in each row). These tubercles are not contiguous with their neighbours and surrounded by several non-contiguous secondaries. Peristome not preserved.

Temporal and spatial distribution. *Goniopygus menardi* has been recorded from the Cenomanian of Syria (BLANCKENHORN, 1925), Jordan (BANDEL & GEYS, 1985; BERNDT, 2003), and Upper Albian of England (SMITH & WRIGHT, 1993). In Egypt, it is known from the Cenomanian of Sinai and the Eastern Desert (FOURTAU, 1914; 1921; GEYS, 1992; EL QOT, 2006). The species has been also recorded from France, Germany, Portugal, Algeria, and Tunisia (GEYS, 1992: 148).

Discussion. COQUAND in COTTEAU (1865) erected *Goniopygus brossardi* as a new species from Algeria. COQUAND's species closely resembles *G. menardi* in general outline, size, and structure of the apical disc. Therefore, FOURTAU (1914) considered his species as a variety of *G. menardi*. Following BLANCKENHORN (1925) and EL QOT (2006), *G. brossardi* is regarded a junior synonym of *G. menardi*.

According to GEYS (1992), *G. innesi* GAUTHIER, 1901 in FOURTAU (1901) differs from the present species in the structure of the apical disc and in having fewer and larger ambulacral tubercles. *G. coquandi* COTTEAU, 1865, from the Cenomanian of Algeria, differs in being higher, more spherical, possessing a larger periproct, and a greater number of tubercles. The narrow interambulacral area and high test of *G. peroni* THOMAS & GAUTHIER, 1889 distinguish this species from *G. menardi* (EL QOT, 2006). The specimen, which has been described and figured by FOURTAU (1904) as *G. peroni*, is an incomplete and poorly preserved specimen. It resembles *G. menardi* more closely than *G. peroni*.

According to ABDELHAMID & AZAB (2003: 862), *G. noguesi* COTTEAU, 1863 differs from the present species in having a smaller and more depressed test and fewer granules in interambulacral areas.

Goniopygus cf. *peroni* THOMAS & GAUTHIER, 1889

Pl. 30, Fig. 5

cf.1889 *Goniopygus Peroni* sp. nov. – THOMAS & GAUTHIER in GAUTHIER: 86, pl. 5, figs. 17-23.
cf.1914 *Goniopygus Peroni* THOMAS & GAUTHIER – FOURTAU: 40.
cf.2006 *Goniopygus peroni* THOMAS & GAUTHIER – EL QOT: 141, pl. 32, fig. 7.

Material and occurrence. One relatively poorly preserved specimen from the Wata Formation (Upper Turonian), bed 31 at Gebel Areif El-Naqa (MGDMU:AEN.E.**31**.3).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
	24	15	0.62	13	0.55	10	0.41	5	11	0.45

Description. Test medium-sized, subspherical, its height about 62% of total test diameter. Adapical surface slightly convex with rounded ambitus. Adoral surface flattened and not sunken around peristome (Pl. 30, Fig. 5b). Apical disc large (about 55% of test diameter), flat, and rounded. Ambulacral area narrow (about 21% of test diameter, 45% of interambulacral width), slightly swollen, straight, and not closed adorally. Poriferous zone narrow and uniserial. Pores rounded, equal, mostly isolated and conjugated in some parts. Interporiferous zone with two rows of relatively small primary tubercles (12-14 tubercles in each row). Interambulacral area relatively broad throughout and carrying two rows of well developed, large-sized, imperforated, and non-crenulated primary tubercles. These tubercles are not contiguous with their neighbours and surrounded by several non-contiguous secondaries. Peristome rounded and slightly less than half (41%) of the test diameter. Gill slits moderately developed (Pl. 30, Fig. 5b).

Temporal and spatial distribution. *Goniopygus peroni* has been recorded from the Turonian of Tunisia (THOMAS & GAUTHIER, 1889). In Egypt, it is known from the Turonian of Sinai (EL QOT, 2006).

Discussion. The specimen is relatively poorly preserved, but it seems to be closely similar to the description and measurements of *Goniopygus peroni* THOMAS & GAUTHIER, 1889.

Family Arbaciidae GRAY, 1855

Genus *Codiopsis* AGASSIZ, 1840
Codiopsis sp.
Pl. 30, Fig. 6

Material and occurrence. A single specimen from the lower shale member of the Cenomanian Galala Formation, bed 12 at Wadi Quseib (MGDMU:WQ.E.**12**.54).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	Wa	Wi	Wa/Wi
	24	15	0.62	7	0.29	5	10	0.50

Description. Test medium-sized, rounded in outline, its height about 62% of test diameter. Adapical surface dome-like. Adoral surface flat and slightly depressed around peristome. Ambitus rounded, lying about one-third of the height above the base of the test. Apical disc medium-sized (29% of test diameter) and dicyclic with well-rounded gonopores (Pl. 30, Fig. 6c). Genital plates broad and crescentic in outline. Ocular plates small and subpentagonal. Ambulacral area about 21% of test diameter in width at the ambitus, 50% of interambulacral width, and lancet-shaped. Poriferous zones moderately wide, uniserial, straight, and close together near apical disc. Pores well-rounded, equal, and isolated. Interambulacral plates simple and with moderately developed tubercles with small granules. Adoral surface carrying randomly oriented and well-developed tubercles, which do not extend beyond the ambitus. Peristome not preserved.

Discussion. The present material resembles *Codiopsis doma* (DESMAREST, 1825) from the Cenomanian of France as figured by DURHAM et al. (1966: U411, fig. 208b-f) in structure of the apical disc, tuberculation style, and in the plating style of ambulacra and interambulacra but the latter species differs in being higher (H/L=79% of total test height) and in having a pentagonal outline. Moreover, the oral surface of the present material is not well preserved.

Order Phymosomatoida MORTENSEN, 1904
Family Diplopodiidae, SMITH & WRIGHT, 1993
Genus *Pedinopsis* COTTEAU, 1863
Pedinopsis desori (COQUAND, 1862)
Pl.30, Fig. 7

1862 *Magnosia Desori* sp. nov. – COQUAND: 254, pl. 27, figs. 13-15.
1866 *Pedinopsis Desori* COQUAND – COTTEAU: 826, pl. 1196, figs. 6-16.
1921 *Pedinopsis Desori* COQUAND – FOURTAU: 32.
1925 *Pedinopsis Desori* COQUAND – BLANCKENHORN: 89, pl. 7, fig. 7.
1990 *Pedinopsis desori* (COQUAND) – ALI: 102, fig. 3/1-3.
2003 *Pedinopsis desori* (COQUAND) – ABDELHAMID & AZAB: 857, pl. 2, fig. A.

Material and occurrence. One specimen from the middle carbonate member of the Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.E.**15**.191).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
	16	10	0.62	4	0.25	7	0.44	3	6	0.50

Description. Test small-sized, subconical, its height about 62% of test diameter, with strongly convex ambitus. Adapical surface dome-shaped. Adoral surface flattened, without depression around peristome. Ambulacral area slightly narrow (about 18% of test diameter and 50% of interambulacral width) and feebly swollen. Ambulacral plates compound, trigeminate adorally, and quadrigeminate at ambitus (Pl. 30, Fig. 7d). Poriferous zone wide, biserial from the apical disc to slightly below the ambitus, and nearly uniserial near peristome. Pores rounded, small adorally, wide and numerous adapically, and non-contiguous. Interporiferous zone carrying two rows of relatively small primary tubercles. Interambulacral plates narrow, simple, and separated by sutures (slightly convex adorally). Each plate with equal-sized, crenulated primary tubercles, the middle one lying in the middle of the adoral half of the plate, the other two tubercles on the adapical half of the same plate. Primary tubercles surrounded by other irregular secondary tubercles. Peristome not well preserved but apparently rounded, centric, not sunken, and large (44% of the test diameter). Apical disc much smaller than peristome (25% of test diameter).

Temporal and spatial distribution. *Pedinopsis desori* has been recorded from the Upper Cretaceous of Algeria (COQUAND, 1862), Palestine (BLANCKENHORN, 1925), and United Arab Emirates (ALI, 1990). In Egypt, it is known from the Cenomanian of the Eastern Desert by FOURTAU (1921) and ABDELHAMID & AZAB (2003).

Discussion. The genus *Pedinopsis* is characterized by having very complex ambulacral plates, which are trigeminate adorally, and quadrigeminate or polygeminate at ambitus. It resembles the genus *Tetragramma* in having biserial ambulacral pores adapically. However, the latter genus differs in having coarse primary tubercles, the apical disc being much larger and similar in size to the peristome, and in ambulacral plates that are trigeminate or quadrigeminate but not polygeminate ambitally.

SMITH et al. (1990) divided *Pedinopsis* into three subgenera, based on the structure of the major ambulacral plates: *P.* (*Pedinopsis*) includes species having compound ambulacral plates with six platelets adapically and four adorally; *P.* (*Dumblea*) includes species having trigeminate compound plating throughout; and *P.* (*Sinaiopsis*) with trigeminate compound plating adorally and quadrigeminate compound plating adapically. However, ABDELHAMID & EL QOT (2001: 12) argued that inclusion of the genus *Dumblea* as subgenus of *Pedinopsis* does not make sense because the former differs from the latter not only in the plating style of ambulacra but also in the system of tuberculation and in having straight, low, and long interambulacral plates.

P. sinaica (DESOR) of ABDELHAMID & EL QOT (2001: 11, fig. 4E-F) from the Cenomanian of Gebel El-Hamra and G. El-Minsherah (Sinai, Egypt) differs from the present species in having biserial poriferous zones between the apical disc and slightly above the ambitus, trigeminate ambulacral plates adorally and at the ambitus and quadrigeminate plates slightly above the ambitus.

P. sphaerica SMITH et al. (1990: 50, figs. 12a-e, 13) from the Cenomanian of Oman is characterized by its globular shape (H/L ranges from 85% to 87%) and a small, not sunken peristome. FOURTAU (1921) described *P. desori* from the Cenomanian of Gebel El-Tourkmania but the globular shape of the test and biserial arrangement of the poriferous zone indicates that the species may belong to *P. sphaerica* (for more detailed discussion, see SMITH et al., 1990: 48-54).

Genus *Tetragramma* AGASSIZ, 1840

Tetragramma variolare (BRONGNIART, 1822)

Pl.30, Fig. 8; pl. 31, Fig. 1

1822 *Cidarites variolaris* sp. nov. – BRONGNIART: 84, pl. 5, fig. 9.
1910 *Tetragramma variolare* (BRONGNIART) – LAMBERT & THIÉRY: 187.
1914 *Diplopodia variolaris* BRONGNIART – FOURTAU: 619.
1921 *Diplopodia variolaris* BRONGNIART – FOURTAU: 31.
1925 *Diplopodia variolaris* BRONGNIART – BLANCKENHORN: 85.
1985 *Tetragramma* cf. *variolare* (BRONGNIART) – BANDEL & GEYS: 107, pl. 5, figs. 3-4.
1989 *Tetragramma variolare* (BRONGNIART) – GEYS: 131, pl. 1, figs. 9-10.
1990 *Tetragramma variolare* (BRONGNIART) – ALI: 102, fig. 3/4-5.
1990 *Tetragramma variolare* (BRONGNIART) – SMITH et al.: 43, fig. 8b.
1991 *Tetragramma*? *variolare* (BRONGNIART) – SMITH & BENGTSON: 26, pl. 4C-D.
1993 *Tetragramma variolare* (BRONGNIART) – SMITH & WRIGHT: 232, pl. 79, figs. 1-9; pl. 80, figs. 1-5; pl. 81, figs. 1-8; text-figs. 74E, F, 75-76, 77A, C, 78-79.
1995 *Tetragramma variolare* (BRONGNIART) – NÉRAUDEAU et al.: 407, fig. 3C.
1997 *Tetragramma variolare* (BRONGNIART) – NÉRAUDEAU & COURVILLE: 839, fig. 6/4-5.
2001 *Tetragramma variolare* (BRONGNIART) – ABDELHAMID & EL QOT: 12, fig. 4G-I.
2001 *Tetragramma variolare* (BRONGNIART) – ABDALLAH et al.: pl. 3, fig. 11.
2003 *Tetragramma variolare* (BRONGNIART) – ABDELHAMID & AZAB: 859, pl. 2, figs. L-M.
2003 *Tetragramma variolare* (BRONGNIART) – BERNDT: 80, fig. 3/3a-b.

2006 *Tetragramma variolare* (BRONGNIART) – EL QOT: 133, pl. 30, figs. 10a-b, 11a-b.

Material and occurrence. Three specimens from the middle carbonate member of the Cenomanain Halal Formation, bed 15 (MGDMU:AEN.E.**15**.192-194) at Gebel Areif El-Naqa.

Measurements (in mm).

n=2	D	H	H/D	dp	dp/D	Wa	Wi	Wa/Wi		
Range	26-33	11-14	0.42-0.42		12-12	0.37-0.46		7-9	10-15	0.60-0.70
Mean	29.5	12.5	0.42	12	0.41	8	10	0.65		

Description. Test medium-to large-sized, nearly rounded, test height about 42% of total diameter with strongly convex sides. Both adapical and adoral surfaces flattened to slightly convex. Large pentagonal apical disc not preserved. Ambulacral width about 24% of test diameter, 65% of interambulacral width, and slightly swollen. Poriferous zone narrower adorally, becoming wider adapically, biserial at ambitus and near apical disc but uniserial near peristome. Pores rounded, non-conjugated, and wide adapically. Interporiferous zone bearing two rows of perforated and crenulated primary tubercles. Interambulacral area with two internal rows of perforated and crenulated primary tubercles extending between the apical disc and peristome (bigger one near ambitus; see Pl. 30, Fig. 8d), whereas two external ones do not persist to the apical disc. Peristome rounded and large (about 41% of test diameter). Gill slits not preserved.

Temporal and spatial distribution. *Tetragramma variolare* is a widespread Cenomanian echinoid. It has been recorded from Europe, Africa, the Arabian Peninsula, and America. The main North-Tethyan occurrences are Spain (LAMBERT, 1919, 1922), France (NÉRAUDEAU & MOREAU, 1989); and England (SMITH et al., 1988; SMITH & WRIGHT, 1993). In the South Tethyan area, it occurs in the Cenomanian of Palestine (BLANCKENHORN, 1925), United Arab Emirates (ALI, 1990), Oman (SMITH et al., 1990), Algeria (NÉRAUDEAU et al., 1993), Saudi Arabia (NÉRAUDEAU et al., 1995), Nigeria (NÉRAUDEAU & COURVILLE, 1997), and Jordan (BANDEL & GEYS, 1985; BERNDT, 2003). In Brazil, it has been recorded from the Early Cenomanian by SMITH & BENGTSON (1991). In Egypt, the species has been found in the Late Albian-Cenomanian of the Eastern Desert and Sinai (FOURTAU, 1921; GEYS, 1989; ABDELHAMID & AZAB, 2003; EL QOT, 2006).

Discussion. ALI (1990: 102) distinguished *Tetragramma brongniarti* (AGASSIZ) from *T. variolare* by its more elevated shape, less markedly diplopodous poriferous zones, and narrow periostome. Moreover, AGASSIZ (1840) had already pointed out that *T. brongniarti* differs in having smaller secondary interambulacral tubercles, larger tubercle bases, and smaller mamelons. SMITH & WRIGHT (1993: 237) discussed all differences between *T. variolare* and *T. brongniarti* and considered the latter species as synonym to *T. variolare*. GEYS (1989: 132) regarded the differences between *T. marticense* and *T. variolare* as small and considered *T. marticense* from France, Portugal, and Egypt as a synonym of the present species (for more detailed discussion, see SMITH & WRIGHT, 1993: 236).

Family Heterodiadematidae, SMITH & WRIGHT, 1993

Genus *Heterodiadema* COTTEAU, 1846

Heterodiadema libycum (AGASSIZ & DESOR, 1846)

Pl. 31, Figs. 2-4; Text-fig. 3-48

1846 *Hemicidaris libyca* sp. nov. – AGASSIZ & DESOR: 338.
1864 *Heterodiadema libycum* AGASSIZ & DESOR – COTTEAU: 522, pl. 1124.
1921 *Heterodiadema libycum* AGASSIZ & DESOR – FOURTAU: 16.
1925 *Heterodiadema libycum* AGASSIZ & DESOR – BLANCKENHORN: 85, pl.7, fig. 1a-c.
1963 *Heterodiadema libycum* AGASSIZ & DESOR – FAWZI: 5.
1985 *Heterodiadema lybicum* (AGASSIZ & DESOR) – BANDEL & GEYS: 106, pl. 4, figs. 6-7; pl. 5, figs. 1, 2.
1989 *Heterodiadema lybicum* (AGASSIZ & DESOR) – GEYS: 129, pl. 1, figs. 5-6.
1990 *Heterodiadema lybica* (AGASSIZ & DESOR) – SMITH et al.: 43, figs. 8c-g, 9-10.
1992 *Heterodiadema libycum* (AGASSIZ & DESOR) – ABDEL-GAWAD & ZALAT: pl. 3, fig. 11.
1995 *Heterodiadema lybicum* (AGASSIZ & DESOR) – NÉRAUDEAU et al.: 406, fig. 3e.
1995 *Heterodiadema buhaysensis* sp. nov. – SMITH: 133, pl. 2, figs. 1-3; text-figs. 10-11.
1997 *Heterodiadema libycum* (AGASSIZ & DESOR) – NÉRAUDEAU & COURVILLE: 839, fig. 6/6.
2001 *Heterodiadema libycum* (AGASSIZ & DESOR) – ABDELHAMID & EL QOT: 7, fig. 3L-N.
?2001 *Heterodiadema buhaysensis* SMITH – ABDELHAMID & EL QOT: 6, pl. 3K.
2002 *Heterodiadema lybicum* (AGASSIZ & DESOR) – AHMAD & AL-HAMMAD: 462, fig. 5/11-12.
2003 *Heterodiadema libycum* (AGASSIZ & DESOR) – BERNDT: 78, fig. 3/1-2.
2003 *Heterodiadema libycum* (AGASSIZ & DESOR) – ABDELHAMID & AZAB: 857, pl. 1, fig. Q.
2006 *Heterodiadema libycum* (AGASSIZ & DESOR) – EL QOT: 132, pl. 30, figs. 6-9.
?2006 *Heterodiadema buhaysensis* SMITH – EL QOT: 130, pl. 30, fig. 5a-c.
2007 *Heterodiadema libycum* (AGASSIZ & DESOR) – ABDEL-GAWAD et al.: pl. 6, fig. 6.

Material and occurrence. 21 mostly complete specimens from the middle carbonate member of the Cenomanian Halal Formation, bed 15 at Gebel Areif El-Naqa (MGDMU:AEN.E.**15**.195-215); 19 specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 12 and one specimen from the Lower Turonian Abu Qada Formation, bed 47 at Wadi Quseib (MGDMU:WQ.E.**12**.55-73,**47**.85), and nine specimens from the Upper Cenomanian Galala Formation, beds 12 and 16 of the East Themed area. (MGDMU:ET.E.**12**.196-201,**16**.480-482).

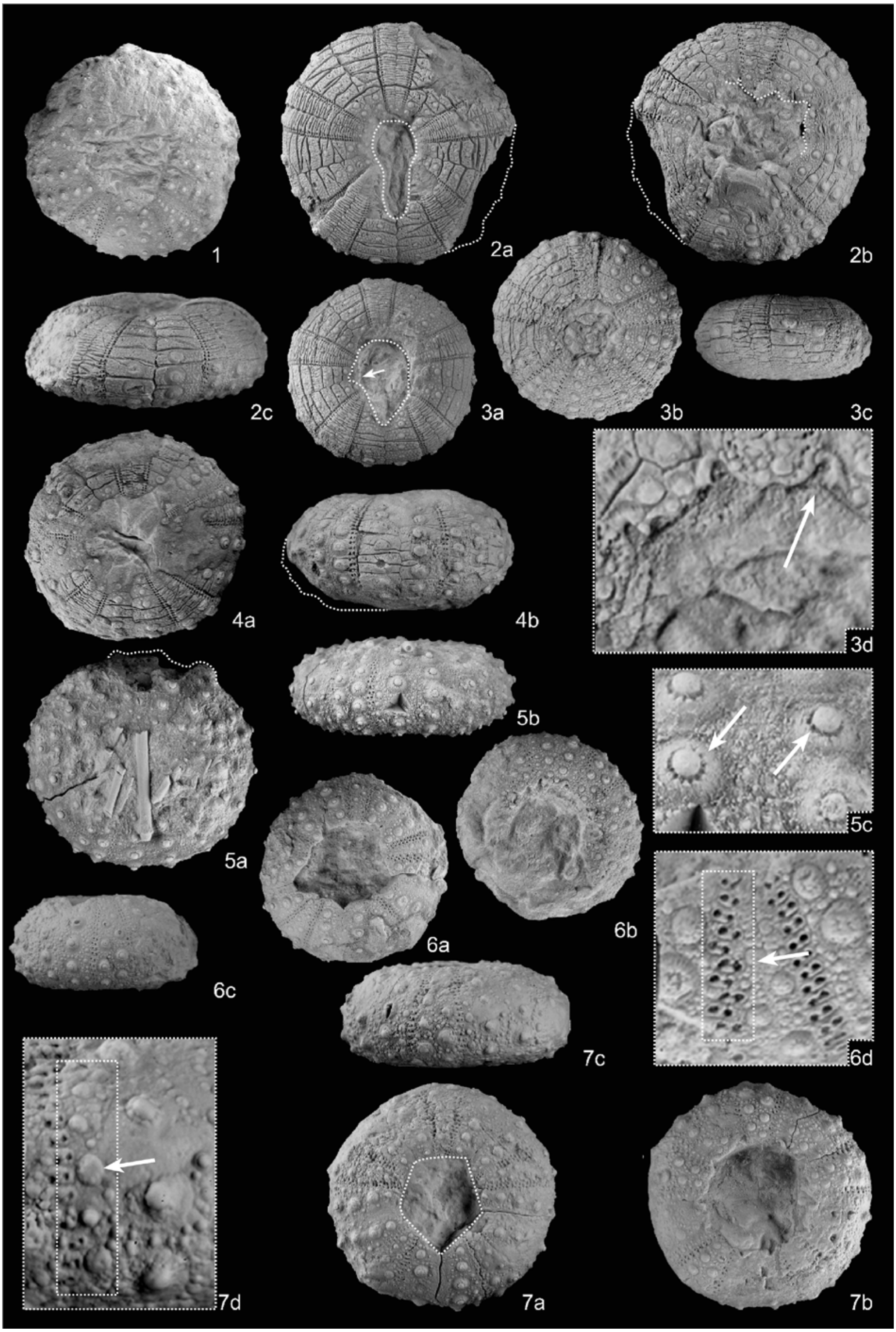
EXPLANATION OF PLATE 31

Fig. 1. *Tetragramma variolare* (BRONGNIART, 1822) from the middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. Adapical view, x1.5; MGDMU:AEN.E.**15**.193.

Figs. 2-4. *Heterodiadema libycum* (AGASSIZ & DESOR, 1846). **2-3**. Specimens from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa. **2a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5; MGDMU:AEN.E.**15**.195. - **3a**: Adapical view, x2, **b**: adoral view, x2, **c**: side view, x2, **d**: part of peristomal region, x10; MGDMU:AEN.E.**15**.196. - **4**. Specimen from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: side view, x1.5; MGDMU:WQ.E.**47**.85.

Figs. 5-6. *Phymosoma abbatei* (GAUTHIER, 1898). **5**. Specimen from the Upper Turonian Wata Formation at Wadi Quseib. **a**: Adapical view, x2, **b**: side view, x2, **c**: ambital interambulacrum, x6; MGDMU:WQ.G.**93**.30. - **6**. Specimen from the lower member of the Lower Turonian Abu Qada Formation at Gebel Areif El-Naqa. **a**: Adapical view, x2, **b**: adoral view, x2, **c**: side view, x1.5, **d**: adapical ambulacrum, x8; MGDMU:AEN.E.**22**.18.

Fig. 7. *Phymosoma sinaeum* (FOURTAU, 1914) from the Lower Turonian Abu Qada Formation at Wadi Quseib. **a**: Adapical view, x2.5, **b**: adoral view, x2.5, **c**: side view, x2.5, **d**: detail of ambital interambulacrum, x8; MGDMU:WQ.E.**47**.86.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7a
7b
7c
7d

Measurements (in mm).

n=16	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	17-37	8-18	0.36-0.55	6-9	0.22-0.40	7-12	0.37-0.50	5-9	7-13	0.54-0.75
Mean	26	11.75	0.45	7.66	0.31	9.9	0.42	6.25	10	0.61

Description. Test small-to medium-sized, nearly rounded, its height about 45% of test diameter, with strongly convex sides. Adapical surface slightly convex to flat. Adoral surface flattened and slightly depressed around peristome. Apical disc large (about 31% of test diameter) and key-shaped, deeply penetrating into the posterior interambulacrum. Posterior prolongation U-or V-shaped (Pl. 31, Figs. 2a, 3a). Interambulacra 1 to 4 with only faint interradial notches. Greatest width of apical disc along this penetration about 42% of test diameter, while the transverse width is only about 30% of test diameter. Ambulacral width about 24% of test diameter, 61% of the interambulacral width at the ambitus, and slightly swollen. Poriferous zone narrow, straight, and uniserial. Pores rounded, nearly equal, and non-conjugated. Interporiferous zone bearing compound plates with two rows of perforated and crenulated primary tubercles adorally, which become imperforate with either little or no crenulations adapically. Some of these tubercles distinctly reduced in size above the ambitus and others reduced sharply closer to the apical disc. This applies also to the interambulacral tubercles (Pl.31, Figs. 2c, 4b). Interambulacral area consisting of 12 simple and wide plates with two rows of strongly crenulated and perforated primary tubercles. Peristome circular in outline, and centric (about 42% of test diameter). Gill slits well developed (Pl. 31, Fig. 3d).

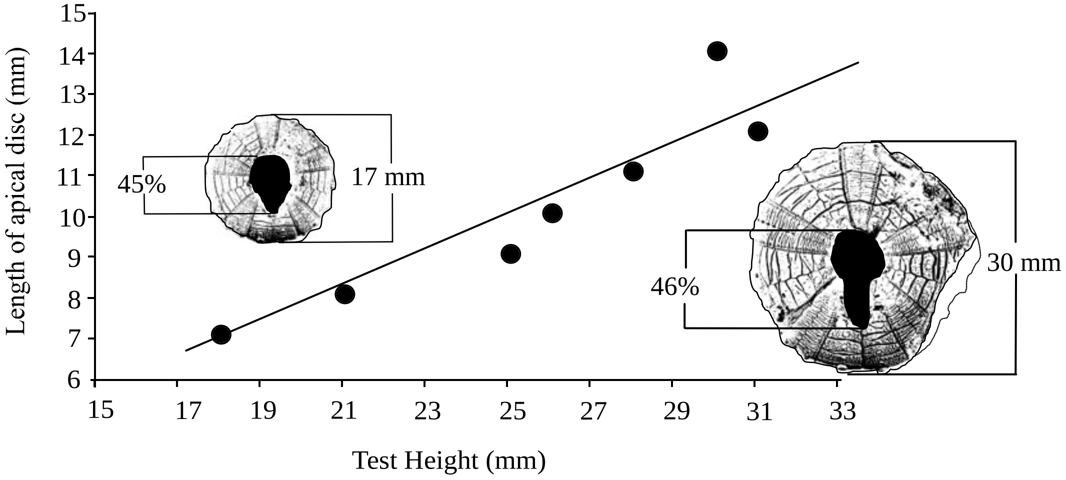
Temporal and spatial distribution. *Heterodiadema libycum* is a well known Cenomanian echinoid, especially abundant in North Africa and the Arabian Peninsula. It has been recorded from the Cenomanian of Palestine (Blanckenhorn, 1925), Cenomanian-Turonian of Central Jordan (Bandel & Geys, 1985; Ahmad & Al-Hammad, 2002; Berndt, 2003), Cenomanian of Oman (Smith et al. 1990), Maastrichtian of Oman and United Arab Emirates (Smith, 1995), Saudi Arabia (Néraudeau et al., 1993, 1995), and Nigeria (Néraudeau & Courville, 1997). In Egypt, it is known from the Cenomanian of the Eastern Desert and Sinai (Fourtau, 1921; Geys, 1989; Abdelhamid & Azab, 2003).

Discussion. The variability in *Heterodiadema libycum* is mainly confined to the degree of reduction in size of the primary tubercles above the ambitus and degree of penetration of the apical disc in the posterior interambulacrum (Abdelhamid & El Qot, 2001; El Qot, 2006). Smith et al. (1990) noted that the abruptness in size reduction of the primary tubercles above the ambitus differs from population to population. For instance, in specimens from Oman, the change is extremely abrupt, whereas in other populations such as from Algeria, the change tends to be less abrupt and the tubercle size decreases gradually adapically. In addition, Adelhamid & Azab (2003) distinguished two forms of *H. libycum* according to the general shape of the apical disc and the degree to which it penetrates into the posterior interambulacrum; the first population has been collected from Saint Paul, Wadi Dakhl, and W. Abu Qada and the specimens have an apical disc with straight to slightly convex sides and a V-shaped posterior prolongation of the apical disc, which penetrates 2-4 plates deep into the posterior interambulacrum. The second population has been collected from G. Gharamul and has an apical disc with highly convex sides towards the center, and a posterior prolongation which is U-shaped and penetrates 4-7 plates deep into the posterior interambulacrum. Lambert (1933) distinguished three varieties in addition to the typical form from Egypt. The var. *martini*, figured and described by Cotteau (1864), has a narrow and elongated apical

disc and has been collected from Egypt and Tunisia, the var. *batnense* COQUAND is of moderate size with well developed primary tubercles adapically and has been collected from Algeria, and the third var. *russoi* is characterized by its large size (D=50 mm, H=30 mm, H/D=0.60 mm) and by the primary tubercles being less developed adapically. The last variety has been collected from Algeria and Morocco. LAMBERT (1933) noted also that the typical forms from Egypt are small-sized with a less prolongated apical disc posteriorly.
GEYS (1989: 129) agrees with FOURTAU (1914) and BANDEL & GEYS (1985) that *H. libycum* seems to become larger in the course of its evolution.

SMITH (1995: 133, pl. 2, figs. 1-3) pointed out that his new species *H. buhaysensis* is most closely related to the Cenomanian *H. libycum* in having the same form of ambulacral compounding and tuberculation style but differs in having fewer reduced tubercles, which become smaller distinctly closer to the apex, and in lacking the extreme prolongation of the apical disc into the posterior interambulacrum. The latter differences have been discussed as different varieties of *H. libycum* by LAMBERT (1933), SMITH et al. (1990), and ABDELHAMID & AZAB (2003). Moreover, no photograph of the apical disc in SMITH's specimens documents its shorter prolongation into the posterior interambulacrum. The prolongation of the apical disc is due to the displacement of the periproct, which occurs relatively late in the ontogenetic sequence of the post-larva (SAUCÈDE et al., 2003). In addition, the degree of prolongation (eccentricity) is directly proportional to the size of specimens (Text-fig. 3.48). Therefore, *H. buhaysensis* is probably a variety of *H. libycum*.

H. libycum also resembles to *H. ouremense* DE LORIOL from the Cenomanian of Portugal with respect to shape of ambulacra, interambulacra, and apical disc, but the latter species differs in having a globular test. NÉRAUDEAU & COURVILLE (1997) suggested that *H. ouremense* probably is also a variety of *H. libycum*.



Text-fig. 3.48. Relationship of test height and the length of apical disc of *Heterodiadema libycum* (AGASSIZ & DESOR, 1846) from the Cenomanian of Gebel Areif El-Naqa.

Family Phymosomatidae POMEL, 1883

Genus *Phymosoma* HAIME in D'ARCHIAC & HAIME, 1853

Phymosoma abbatei (GAUTHIER, 1898)

Pl. 31, Figs. 5-6

1898 *Cyphosoma abbatei* sp. nov. – GAUTHIER in FOURTAU: 620, pl. 1, figs. 2-6.
1906 *Coptosoma abbatei* GAUTHIER – GREGORY: 223.
1914 *Cyphosoma abbatei* GAUTHIER – FOURTAU: 28.
1998 *Phymosoma abbatei* (GAUTHIER) – EL-SHEIKH et al.: pl. 2, fig. B.

1999 *Phymosoma abbatei* (GAUTHIER) – ABDELHAMID: pl. 2, fig. I; pl. 3, fig. A.
2001 *Phymosoma abbatei* (GAUTHIER) – ABDALLAH et al.: pl. 3, fig. 12.
2001 *Phymosoma abbatei* (GAUTHIER) – ABDELHAMID & EL QOT: 13, fig. 4J-K.
2004a *Phymosoma abbatei* (GAUTHIER) – ABDEL-GAWAD et al.: pl. 10, figs. 1, 4.
2006 *Phymosoma abbatei* (GAUTHIER) – EL QOT: 134, pl. 31, figs. 1-2, 4.

Material and occurrence. 27 specimens from the Upper Turonian Wata Formation, beds 31, 33, and 53 at East Themed (MGDMU:ET.E.**31**.62-77,**33**.1-8,**53**.7-8), 19 specimens from the Upper Turonian Wata Formation, beds 76, 93, and 97 at Wadi Quseib (MGDMU:WQ.E.**76**.22-26,**93**.30-37,**97**.42-47), and five specimens from the lower member of the Abu Qada Formation (Lower Turonian), bed 22 at Gebel Areif El-Naqa (MGDMU:AEN.E.**22**.18-22).

Measurements (in mm).

n=11	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	13-21	5-11	0.37-0.62	4-7	0.28-0.52	5-8	0.33-0.53	3-6	5-9	0.54-0.84
Mean	17	7.88	0.46	6.27	0.37	6.80	0.42	4.31	6.38	0.67

Description. Test small-sized, rounded, its height about 46% of test diameter, with strongly convex sides. Adapical surface flattened to slightly convex with spine fragments in a few specimens (Pl. 31, Fig. 5a). Adoral surface flattened and not sunken around peristome. Apical disc large (28% to 52% of test diameter) and pentagonal in outline without any plating remains. Ambulacral areas wide near the ambitus (about 30% of test diameter) and narrower adapically than peristome. Poriferous zone narrow, biserial in some poriferous zones (Pl. 31, Fig. 6d) near the apical disc, becoming uniserial near peristome. Pores nearly rounded, equal-sized, and isolated. Interporiferous zone carrying two rows of imperforated and crenulated primary tubercles as large as in interambulacral area (Pl. 31, Fig. 5c). Peristome semi-rounded, centric, and large (about 37% of test diameter). Gill slits well developed.

Temporal and spatial distribution. *Phymosoma abbatei* has been recorded from the Turonian of Egypt by GREGORY (1906); EL-SHEIKH et al. (1998); ABDELHAMID & EL QOT, 2001); ABDEL-GAWAD et al. (2004a); and EL QOT (2006).

Discussion. GREGORY (1906) referred the present species to the genus *Coptosoma* according to the uniserial arrangement of the pore pairs. According to FOURTAU (1914) the uniserial arrangement of the poriferous zone of *Cyphosoma abbatei* is restricted to specimens with a diameter of less than 16 mm. However, the poriferous zone in the present material is biserial adapically in some poriferous zones with a diameter of less than 15 mm.

Phymosoma major COQUAND (1862: 256, pl. 27, figs. 16-18) from Algeria differs from the present species in having four rows of primary tubercles in the interambulacral area and in being larger (D=39 mm, H=17 mm; H/D=0.43 mm).

Phymosoma sinaeum (FOURTAU, 1914)
Pl. 31, Fig. 7

1914 *Cyphosoma sinaeum* sp. nov. – FOURTAU: pl. 3, fig. 2.

Material and occurrence. Three specimens from the Lower Turonain Abu Qada Formation, bed 47 (MGDMU:WQ.E.**47**.86-88) at Wadi Quseib.

Measurements (in mm).

n=3	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	16-21	7-10	0.42-0.50	6-8	0.35-0.40	6-8	0.40-0.50	4-6	6-9	0.64-0.70
Mean	17.59	8.07	0.45	6.78	0.38	7.38	0.45	4.80	7.71	0.63

Description. Test small-sized and rounded. Height about 45% of test diameter with rounded ambitus. Both adapical and adoral surfaces flattened without depression around peristome. Apical disc large (about 38% of test diameter) and pentagonal in outline without any plating remains (Pl. 31, Fig. 7a). Ambulacral area wide near ambitus and narrower adapically than peristome. Poriferous zone narrow and biserial above ambitus to apical disc. Pores nearly rounded, equal-sized, and isolated. Interporiferous zone with two rows of imperforated and crenulated primary tubercles. Interambulacral area carrying two rows of imperforated and crenulated primary tubercles, which are better developed marginally and have internal and external secondary tubercles (Pl. 31, Fig. 7d). At ambitus and near peristome, each tubercle is surrounded by a circle of mamelonated granules. Peristome centric, semi-rounded, and wide (about 45% of test diameter). Gill slits well developed.

Temporal and spatial distribution. *Phymosoma sinaeum* has been recorded from the Turonian of Gebel Um Raiying, Egypt by FOURTAU (1914).

Discussion. The present species differs from *Phymosoma abbatei* (GAUTHIER) in having internal and external rows of secondary tubercles in each interambulacrum (Pl. 31, Fig. 7d) with biserial poriferous zones above the ambitus. In contrast, *Ph. thevestense* (PÉRON & GAUTHIER) from the Turonian of Algeria lacks secondary tubercles in interambulacra with wider ambulacra adapically.

Genus *Rachiosoma* POMEL, 1883
Rachiosoma geysi ABDELHAMID & EL QOT, 2001
Pl. 32, Figs. 1-2

1985 *Rachiosoma major* (COQUAND) – BANDEL & GEYS: 110, pl. 7, figs. 6-7; pl. 8, figs. 1-2.
2001 *Rachiosoma geysi* sp. nov. – ABDELHAMID & EL QOT: 14, fig. 5B-C.
2004a *Rachiosoma geysi* ABDELHAMID & EL QOT - ABDEL-GAWAD et al.: pl. 10, fig. 2.
2006 *Rachiosoma geysi* ABDELHAMID & EL QOT - EL QOT: 137, pl. 31, figs. 6a-b, 7, 9.

Material and occurrence. 57 specimens from the Upper Turonian Wata Formation , beds 31, 37, and 53 of the East Themed area (MGDMU:ET.E.**31**.78-122,**37**.22-29,**53**.9-12), and six specimens from the Wata Formation (Upper Turonian), beds 92 and 93 at Wadi Quseib (MGDMU:WQ.E.**92**.4-7,**93**.38-39).

Measurements (in mm).

n=4	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	20-33	11-14	0.43-0.54	6-7	0.20-0.22	6-8	0.25-0.32	4-7	7-13	0.43-0.65
Mean	26.15	12.12	0.50	6.34	0.21	7	0.29	5.45	10	0.56

Description. Test small-to medium-sized, wheel-shaped, rounded in outline, its height about 50% of test diameter. Adapical surface relatively high and slightly convex with rounded ambitus. Adoral surface flattened and slightly depressed around peristome. Apical disc pentagonal and medium-sized (about 21% of test diameter). Ambulacra slightly swollen ambitally, its width about 24% of test diameter and 56% of the interambulacra at the ambitus. Poriferous zone uniserial and feebly undulating. Pores rounded, equal-sized, isolated, and arranged in arcs of three pore pairs around peristome. Interporiferous zone carrying two rows of imperforated, crenulated primary tubercles. In addition, two rows of granules exist around the perradial suture. Interambulacral area wide (7-13 mm) with four rows of well-developed, imperforated, and crenulated primary tubercles (Pl. 32, Fig. 1c). The internal rows are non-confluent and slightly larger than those of the external ones. Peristome slightly sunken, rounded, its width ranging from 25% to 32% of test diameter. Gill slits well developed.

Temporal and spatial distribution. *Rachiosoma geysi* has been recorded from the Coniacian of Jordan (BANDEL & GEYS, 1985) and in Egypt from the Turonian of Sinai by ABDELHAMID & EL QOT (2001); ABDEL-GAWAD et al. (2004a); and EL QOT (2006). The stratigraphic range of this species is from Turonian to Coniacian.

Discussion. The present species can be easily distinguished from other *Rachiosoma* species by having uniserial poriferous zones and four rows of imperforated and crenulated primary tubercles on each interambulacrum (Pl. 32, Figs. 1c, 2). BANDEL & GEYS (1985) described the poriferous zones of *Phymosoma major* (COQUAND, 1862) in ten specimens from the Coniacian of Jordan as uniserial and referred them to the genus *Rachiosoma*. They argued that *Ph. major* is uniserial and that COQUAND (1862) did not describe the poriferous zone of this species. However, COQUAND stated that the pores are ‘’bigemine”. Moreover, his figures show a biserial poriferous zone on the adapical surface (COQUAND, 1862: pl. 25, figs. 16, 18). BANDEL & GEYS also mentioned that COTTEAU (1864) indicated that *Ph. major* has simple poriferous zones. However, COTTEAU (1864) pointed out that the simple arrangement of pores exists only in very small individuals. In the main description of the species he stated that the poriferous zones are adapically biserial. For these reasons, ABDELHAMID & EL QOT (2001) considered the Jordanian material to belong to their new species *Rachiosoma geysi*.

EXPLANATION OF PLATE 32

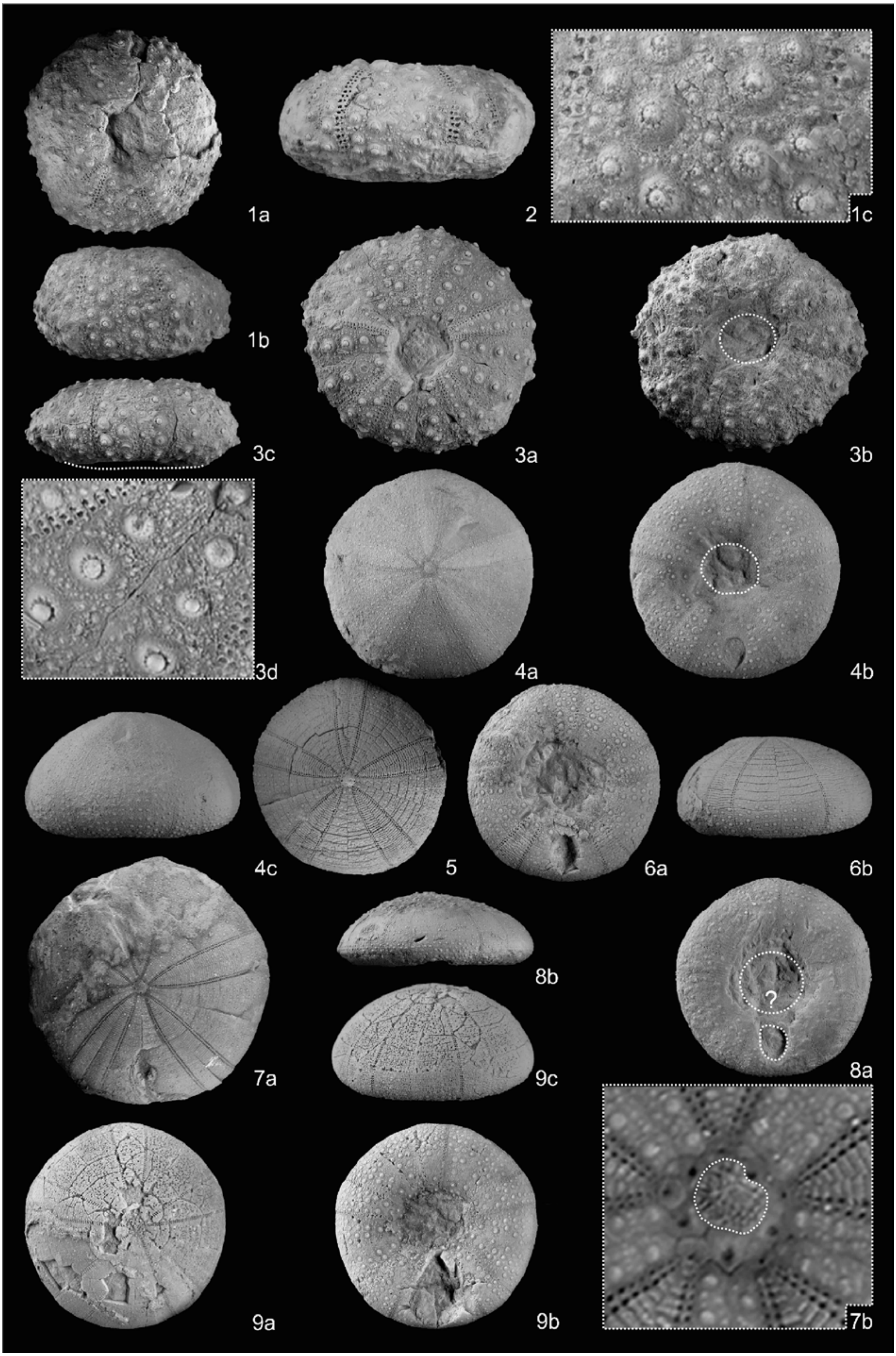
Figs. 1-2. *Rachiosoma geysi* ABDELHAMID & EL QOT, 2001 from the Upper Turonian Wata Formation at Wadi Quseib. **1a**: Adapical view, x1.5, **b**: side view, x1.5, **c**: ambital interambulacrum, x5; MGDMU:WQ.G.**93**.38. – **2**. Side view, x1.5; MGDMU:WQ.E.**92**.4.

Fig. 3. *Rachiosoma irregulare* FOURTAU, 1921 from the Upper Turonian Wata Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5, **d**: detail of interambulacrum, x5; MGDMU:WQ.E.**97**.48.

Figs. 4-6. *Coenholectypus larteti* (COTTEAU, 1869). 4. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5; MGDMU:WQ.E.**12**.74. - **5-6**. from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa. **5**. Adapical view, x2; MGDMU:AEN.E.**15**.216. **6a**: adoral view, x2, **b**: side view, x2; MGDMU:AEN.E.**15**.217.

Figs. 7-8. *Coenholectypus portentosus* COQUAND, 1876 from the lower marly and middle carbonate members of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **7a**: Adapical view, x1.5, **b**: detail of apical disc, x10; MGDMU:AEN.E.**9**.56. – **8a**: Adoral view, x1, **b**: side view, x1; MGDMU:AEN.E.**15**.239

Fig. 9. *Coenholectypus turonensis* (DESOR, 1847) from the Lower Turonian Abu Qada Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5; MGDMU:WQ.E.**47**.89.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2
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3d
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8a
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7a
9c
9a
9b
7b

Rachiosoma irregulare FOURTAU, 1921
Pl. 32, Fig. 3

1921 *Rachiosoma irregulare* sp. nov. – FOURTAU: 39, pl. 5, figs. 3-4.
1932 *Rachiosoma irregulare* FOURTAU – LAMBERT: 191.

2001 *Rachiosoma irregulare* FOURTAU – ABDELHAMID & EL QOT: 18, fig. 5D-E.
2004a *Rachiosoma irregulare* FOURTAU – ABDEL-GAWAD et al.: pl. 10, figs. 3,5.
2006 *Rachiosoma irregulare* FOURTAU – EL QOT: 137, pl. 31, fig. 10 a, b.

Material and occurrence. Three specimens from the Wata Formation (Upper Turonian), bed 97 at Wadi Quseib (MGDMU:WQ.E.**97**.48-50).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Wa	Wi	Wa/Wi
	26	11	0.42	8	0.31	11	0.42	7	10	0.70

Description. Test medium-sized, rounded, its height about 42% of test diameter. Adapical surface slightly convex with strongly rounded ambitus. Adoral surface flattened and slightly depressed around peristome. Apical disc pentagonal and medium-sized (31% of test diameter) without plating remains. Ambulacral area wide (27% of test diameter and 70% of interambulacral width). Poriferous zone uniserial, straight, and narrow. Pores well rounded, equal-sized, and non-conjugated. Interporiferous zone carrying two rows of imperforated and crenulated primary tubercles, which are separated by fine granules. Interambulacral area moderately wide with two rows of imperforated and crenulated primary tubercles, which are well developed ambitally, and separated from the neighbouring one by well-developed fine granules (Pl. 32, Fig. 3d). Adradial and interradial extrascrobicular surfaces wide and occupied by two rows of small granules. Peristome rounded and large (42% of test diameter). Gill slits moderately well developed.

Temporal and spatial distribution. *Rachiosoma irregulare* has been recorded from the Turonian of Gebel Um Kécheiba (FOURTAU, 1921), G. El-Minsherah (ABDELHAMID & EL QOT, 2001), and G. Ekma (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Discussion. *Rachiosoma irregulare* differs from *R. geysi* by having two rows of well-developed crenulated and imperforated primary tubercles in each interambulacrum (Pl. 32, Fig. 3d). *R. rectilineatum* (PERON & GAUTHIER) of BANDEL & GEYS (1985: 111, pl. 8, figs. 3-7; pl. 9, fig. 1) from the Coniacian of Algeria and of GEYS (1992: 147, pl. 2, figs. 8-9) from the Santonian of Wadi Qena are similar to the present species in having two rows of crenulated and imperforate primary tubercles in each interambulacrum, but differ in having a regular series of small secondary tubercles (two secondary tubercles for each primary) and well-developed ambulacral tubercles adapically.

Cohort Irregularia LATREILLE, 1825
Order Holectypoida DUNCAN, 1889
Suborder Holectypina DUNCAN, 1889
Family Holectypidae LAMBERT, 1900
Subfamily Coenholectypinae SMITH & WRIGHT, 1999
Genus *Coenholectypus* POMEL, 1883

Coenholectypus larteti (COTTEAU, 1869)
Pl. 32, Figs. 4-6; Text-fig. 3.49

1869 *Holectypus Larteti* sp. nov. – COTTEAU: 537.
1914 *Holectypus Larteti* COTTEAU – FOURTAU: 44, pl. 3, fig. 8.
1914 *Holectypus Larteti* COTTEAU race *sinaea* – FOURTAU: 46, pl. 4, figs. 1-4.
1914 *Holectypus Larteti* COTTEAU var. *dowsoni* var. nov. – FOURTAU: 47.
1921 *Holectypus Larteti* COTTEAU race *sinaea* var. nov. – FOURTAU: 55.
1925 *Holectypus Larteti* COTTEAU – BLANCKENHORN: 90, pl. 7, figs. 10-11.
1925 *Holectypus larteti* COTTEAU var. *major* var. nov. – BLANCKENHORN: 91, pl. 7, fig. 12a-d.
1963 *Holectypus larteti* COTTEAU – FAWZI: 9, pl. 1, fig. 1.
?1989 *Holectypus* (*Caenholectypus*) *larteti* (COTTEAU) – ALI: 401, fig. 5/10.
1990 *Coenholectypus larteti* (COTTEAU) – SMITH et al.: 57, fig. 14d-f; text-figs. 17-18.
1999 *Caenholectypus larteti* (COTTEAU) – ABDELHAMID: pl. 3, fig. D.
2001 *Caenholectypus larteti* (COTTEAU) – ABDELHAMID & EL QOT: 21, fig. 6A.
2003 *Caenholectypus larteti* (COTTEAU) – ABDELHAMID & AZAB: 864, pl. 4, figs. C-D.
2006 *Coenholectypus larteti* (COTTEAU) – EL QOT: 143, pl. 32, fig. 11a-b.

Material and occurrence. 23 specimens from the middle carbonate member of the Cenomanian Halal Formation, bed 15 (MGDMU:AEN.E.**15**.216-238) at Gebel Areif El-Naqa; 30 specimens from the middle siliciclastic/carbonate and upper carboante members of the Cenomanian Galala Formation and Lower Turonian Abu Qada Formation, beds 12, 13, 31, 44, and 55 at Wadi Quseib (MGDMU:WQ.E.**12**.74-81,**13**.33-34,**31**.61-62,**44**.260-274,**55**.131-133).

Measurements (in mm).

n=20	D	H	H/D	Lk	Lk/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	13-28	6-15	0.39-0.60	3-5	0.17-0.22	4-6	0.16-0.26	3-5	6-13	0.37-0.50
Mean	19.10	9.57	0.49	3.80	0.20	6.33	0.22	3.75	8.62	0.44

Description. Test small-to medium-sized and circular to sub-pentagonal. Test height ranges from 39% to 49% of total diameter (Text-fig. 3.49). Adapical surface strongly convex (low dome-shaped) with strongly rounded ambitus. Adoral surface flattened and slightly concave around peristome. Apical disc small (about 11% of test diameter) and carrying five gonopores; ocular pores are not seen. Ambulacral area flush to feebly swollen, lancet-shaped, and reaching about 44% of interambulacral width ambitally. Poriferous zone narrow, slightly convex to straight, and uniserial. Pore pairs small, circular, closer together adorally, wider adapically, and non-conjugated. Interporiferous zone with four rows of primary tubercles per plate marginally and 2-3 adapically. Ambulacral plate simple and narrow. Interambulacral plates twice the width of ambulacral ones and carrying 10 tubercles marginally and two adapically. The biggest tubercles occur on the adoral side close to the margin. Both ambulacral and interambulacral primary tubercles imperforated and crenulated. Peristome circular and small (range: 16% to 22% of test diameter). Periproct inframarginal, small, oval to drop-shaped, elongated, and nearer to the ambitus than peristome (Pl. 32, Fig. 6a).

Temporal and spatial distribution. *Coenholectypus larteti* has been recorded from the Cenomanian of Palestine (BLANCKENHORN, 1925), Oman (SMITH et al., 1990), and the

Maastrichtian of United Arab Emirates (ALI, 1989). In Egypt, it is known from the Cenomanian of Wadi Um Mitla and Gebel Yelleg (FOURTAU, 1921), G. El-Minsherah (FAWZI, 1963), G. El-Hamra (ABDELHAMID & EL QOT, 2001), Saint Paul and G. Musabba Salama (ABDELHAMID, 1999; ABDELHAMID & AZAB, 2003), and G. Yelleg (EL QOT, 2006). Stratigraphically, *C. larteti* has a wide range, from the Cenomanian to the Maastrichtian.

Discussion. The genus *Coenholectypus* differs from *Holectypus* DESOR (1842) mainly in having a perforate genital plate 5, which is imperforate in *Holectypus*. DUTHAM et al. (1966: U444) noted that *Coenholectypus* and *Caenholectypus* are synonyms with the first one having a priority.

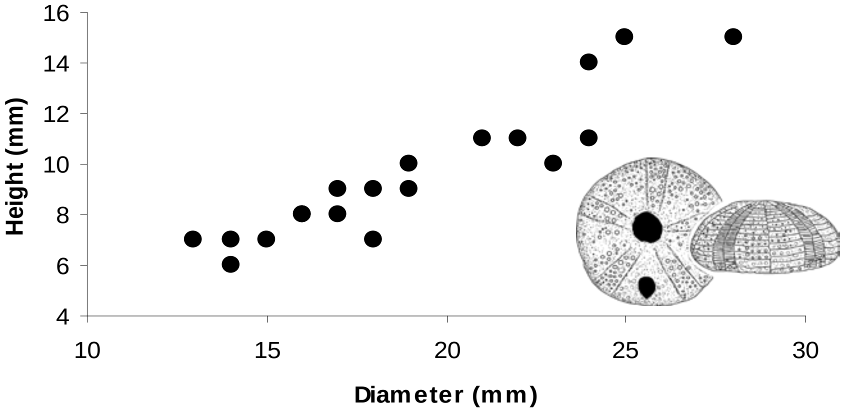
Many species of the genus *Coenholectypus* can be distinguished according to the size and position of the periproct, the size of the peristome, and the outline of the test.

Coenholectypus larteti differs from other *Coenholectypus* species recorded in the present study by its dome-shaped, rounded ambitus, and small peristome. In addition, its periproct is small and nearer to the ambitus than to the peristome.

FOURTAU (1914) differentiated his varieties (see synonymy list) according to test height and size of peristome and periproct. In agreement with SMITH et al. (1990) and EL QOT (2006), all varieties of *C. larteti* (e.g. the varieties of FOURTAU, 1914-1921 and BLANCKENHORN, 1925) are placed within the range of variation of *C. larteri*.

C. excisus (DESOR, 1847) differs in having a large marginal periproct, which extends from near the peristome up to a third to half the distance between apical disc and ambitus. Therefore, the periproct of *Holectypus excisus* (DESOR, 1847) figured by ABDEL-GAWAD et al. (2004b) from the Cenomanian of Gebel El-Fallig is completely inframarginal and large with a wide and depressed peristome. For these reasons, their specimen is more similar to *C. larteti* than to *C. excisus.*

C. inflatus (COTTEAU & GAUTHIER) of SMITH (1995: 178, pl. 18, figs. 7-11) from Oman differs from the present species by having a larger peristome and a periproct that extends much closer to the peristome than the ambitus and its tubercles are well developed adorally.



Text-fig. 3.49. Biometric data of *Coenholectypus larteti* (COTTEAU, 1869) from middle carbonate member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

Coenholectypus portentosus (COQUAND, 1876)
Pl. 32, Figs. 7-8

1876 *Holectypus portentosus* sp. nov. – COQUAND in COTTEAU et al.: 30, pl. 2, figs. 9-11.

1912 *Holectypus portentosus* COQUAND – FOURTAU: 46, pl. 12, fig. 6.

1921 *Holectypus portentosus* COQUAND – FOURTAU: 56.
1925 *Holectypus portentosus* COQUAND – BLANCKENHORN: 89, pl. 7, fig. 8a-b.
1990 *Holectypus* (*Coenholectypus*) *portentosus* COQUAND – ALI: 109, fig. 5/4-6.

Material and occurrence. Two specimens from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 9 and 15 at Gebel Areif El-Naqa (MGDMU:AEN.E.**9**.56,**15**.239).

Measurements (in mm).

n=2	D	H	H/D	Lk	Lk/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	31-33	11-12	0.35-0.36	5-7	0.16-0.21	9-10	0.29-0.30	5-6	13-15	0.38-0.40
Mean	32	11.50	0.35	6	0.19	8	0.29	5.5	14	0.39

Description. Test medium-sized, circular, its height about 35% of total test diameter (low conical-shaped). Adapical surface convex with sharp ambitus (Pl. 3, Fig. 8b). Adoral surface flattened and strongly concave around peristome. Apical disc small (7% of the test diameter), elevated, and yielding five genital plates with five gonopores and five ocular plates with five ocular pores. Madreporite well developed and separating the posterior gonopores 1 and 4, while the posterior gonopore 5 and the ocular pores are still behind the madreporite (Pl. 32, Fig. 7b). Ambulacral area lancet-shaped, flush to slightly swollen, reaching about 39% of interambulacral width, and about 18% of total test diameter. Poriferous zone narrow, straight, and uniserial. Pores small, circular, isolated, close together near ambitus, and less close on the adapical and adoral surfaces. Interporiferous zone carrying six primary tubercles marginally and 2-3 adapically. Ambulacral plates simple and narrow. Interambulacral area with about 16-18 primary tubercles marginally and two adapically. Both ambulacral and interambulacral primary tubercles imperforated, crenulated, and more developed below ambitus and adorally. Periproct small (about 19% of test diameter), oval, and inframarginal. Peristome centric, rounded, and medium-sized (about 30% of test diameter).

Temporal and spatial distribution. *Coenholectypus portentosus* has been recorded from the Cenomanian of Palestine (BLANCKENHORN, 1925) and United Arab Emirates (ALI, 1990). In Egypt, it occurs in the Aptian of Gebel Mandhour (FOURTAU, 1921).

ALI (1990: 109) mentioned that the species has been recorded also from the Aptian of Lebanon, and Algeria, the Aptian-Albian of Syria, and the Cenomanian of Algeria, France, Syria, and Portugal.

Discussion. *Coenholectypus portentosus* differs from other *Coenholectypus* species by its circular outline, very low conical test, sharp ambitus, and moderately-sized periproct that extends from near the peristome to near the posterior margin. The present species resembles *C. cenomanensis* (GUÈRANGER) in having the same shape of ambulacra and peristome, but differs in having a sharp ambitus and smaller periproct.

Coenholectypus turonensis (DESOR, 1847)
Pl. 32, Fig. 9

1847 *Holectypus turonensis* sp. nov. – DESOR in AGASSIZ & DESOR: 146.
1912 *Holectypus turonensis* DESOR – FOURTAU: 162.
1914 *Holectypus turonensis* DESOR – FOURTAU: 48.
1921 *Holectypus turonensis* DESOR – FOURTAU: 57.

2004a *Coenholectypus turonensis* (Desor) – Abdel-Gawad et al.: pl. 10, figs. 7, 9.
2006 *Coenholectypus turonensis* (Desor) – El Qot: 144, pl. 32, figs. 12-14.
2007 *Coenholectypus turonensis* (Desor) – Abdel-Gawad et al.: pl. 6, fig. 7.

Material and occurrence. 38 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 26 of the East Themed area (MGDMU:ET.E.**26**.167-205), and five specimens from the Abu Qada Formation (Lower Turonian), bed 47 of the Wadi Quseib section (MGDMU:WQ.E.**47**.89-93).

Measurements (in mm).

n=3	D	H	H/D	dp	dp/D	Wa	Wi	Wa/Wi
Range	21-32	9-14	0.43-0.45	6-7	0.22-0.28	4-7	12-13	0.33-0.53
Mean	26.50	11.50	0.44	6.50	0.25	5	12.50	0.43

Description. Test medium-sized, circular in outline, its height about 44% of test diameter. Adapical surface dome-shaped with rounded ambitus. Adoral surface flat and strongly concave around peristome. Apical disc medium-sized with five well-rounded gonopores. Madreporite well developed. Ambulacral width about 20% of test diameter and 43% of interambulacral width. Poriferous zone narrow, straight, and uniserial. Pores well-rounded, equal-sized, and isolated. Interporiferous zone yielding four rows of imperforated and crenulated primary tubercles, well developed adorally. Interambulacral area wide with 12-14 rows of primary tubercles. Periproct drop-shaped, large (about 31% of test diameter), and occupying the distance between the peristome and posterior margin (Pl. 32, Fig. 9b). Peristome circular and relatively small (about 25% of test diameter). Gill slits well developed.

Temporal and spatial distribution. *Coenholectypus turonensis* has been recorded from the Turonian of Gebel Dhalfa and G. Halal (Fourtau, 1921), Gebel Ekma, the East Themed area, and G. Yelleg (Abdel-Gawad et al., 2004a; El Qot, 2006).

Discussion. According to El Qot (2006: 146), *Coenholectypus turonensis* differs from *C. serialis* (Deshayes, 1847) in being higher and highly concave around the peristome. The two species have been recorded from the Turonian and their stratigraphic range is extended to the Santonian. According to Cotteau et al. (1881), *C. turonensis* is confined to the Turonian and *C. serialis* to the Santonian.

Suborder Pygasterina Durham & Melville, 1957

Family Anorthopygidae Wagner & Durham, 1966

Genus *Anorthopygus* Cotteau, 1869
Anorthopygus orbicularis (Grateloup, 1836)
Pl. 33, Fig. 1

1836 *Nucleolites orbicularis* sp. nov. – Grateloup: 180, pl. 2, fig. 21.
1878 *Anorthopygus orbicularis* (Grateloup) – Cotteau et al.: 175.
?1921 *Anorthopygus atavus* sp. nov. – Fourtau: 53, pl. 2, fig. 5.
?1990 *Anorthopygus arabicus* sp. nov. – Ali: 111, fig. 7/1-5.
1999 *Anorthopygus orbicularis* (Grateloup) – Smith & Wright: 362, pl. 115, figs. 3-6, 7-9; text-fig. 136.
2003 *Anorthopygus orbicularis* (Grateloup) – Abdelhamid & Azab: 866, pl. 4, fig. k.

Material and occurrence. A single well preserved specimen from the lower shale member of the Galala Formation (Cenomanian), bed 12 at Wadi Quseib (MGDMU:WQ.E.**12**.82).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Lk	Wk	Wa	Wi	Wa/Wi
	33	14	0.42	4	0.12	10	0.30	7.54	5.35	5	15	0.33

Description. Test large, wheel-shaped, rounded in outline, its height about 42% of test diameter. Adapical surface broad and flat with rounded ambitus. Adoral surface nearly flattened and slightly depressed around peristome. Apical disc ethmolytic (Pl. 33, Fig. 1d), nearly central, consisting of five genital plates with five gonopores and five ocular plates. Madreporite large and separating the posterior ocular plates as well as the posterior genital plates. Ambulacral area lancet-shaped, moderately swollen ambitally, and wide near ambitus (16% of test diameter and 33% of interambulacral width) but relatively narrow throughout. Poriferous zone narrow, straight, and uniserial. Pores well-rounded, equal-sized, and isolated. Interporiferous zone carrying 2-6 rows of imperforated and crenulated primary tubercles, which are well developed adorally. Interambulacral area wide (45% of test diameter) with simple and wide plates, and yielding 8-12 rows of perforated and crenulated primary tubercles with wide and deep areole. The external rows of primary tubercles reach the apical disc and peristome. Periproct opening immediately above the ambitus. It is oblique towards the anterior right and almost as wide as long. Peristome central, medium-sized (30% of test diameter), rounded, and situated in slightly deep depression.

Temporal and spatial distribution. *Anorthopygus orbicularis* has been recorded from the Cenomanian of United Arab Emirates (Ali, 1990) and England (Smith & Wright, 1999). In Egypt, it is known from the Albian of Gebel Mandhour (Fourtau, 1921) and G. Manzour (Abdelhamid & Azab, 2003). Stratigraphically, *A. orbicularis* ranges from the Albian to the Cenomanian.

Discussion. Fourtau (1921) distinguished his new species *Anorthopygus atavus* from *A. orbicularis* by having a regular periproct ambitally (nearer to ambitus than to apical disc) and by its ocular plate 4 reaching the madreporite. Smith & Wright (1999) noted that Fourtau's species is very similar to *A. orbicularis* in shape but has a slightly different apical disc, with ocular 4 inserted and completely separating genital plates 3 and 4. However, Lambert (1932) after having examined the French specimens of *A. orbicularis* noted that the ocular plate 4 in

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EXPLANATION OF PLATE 33

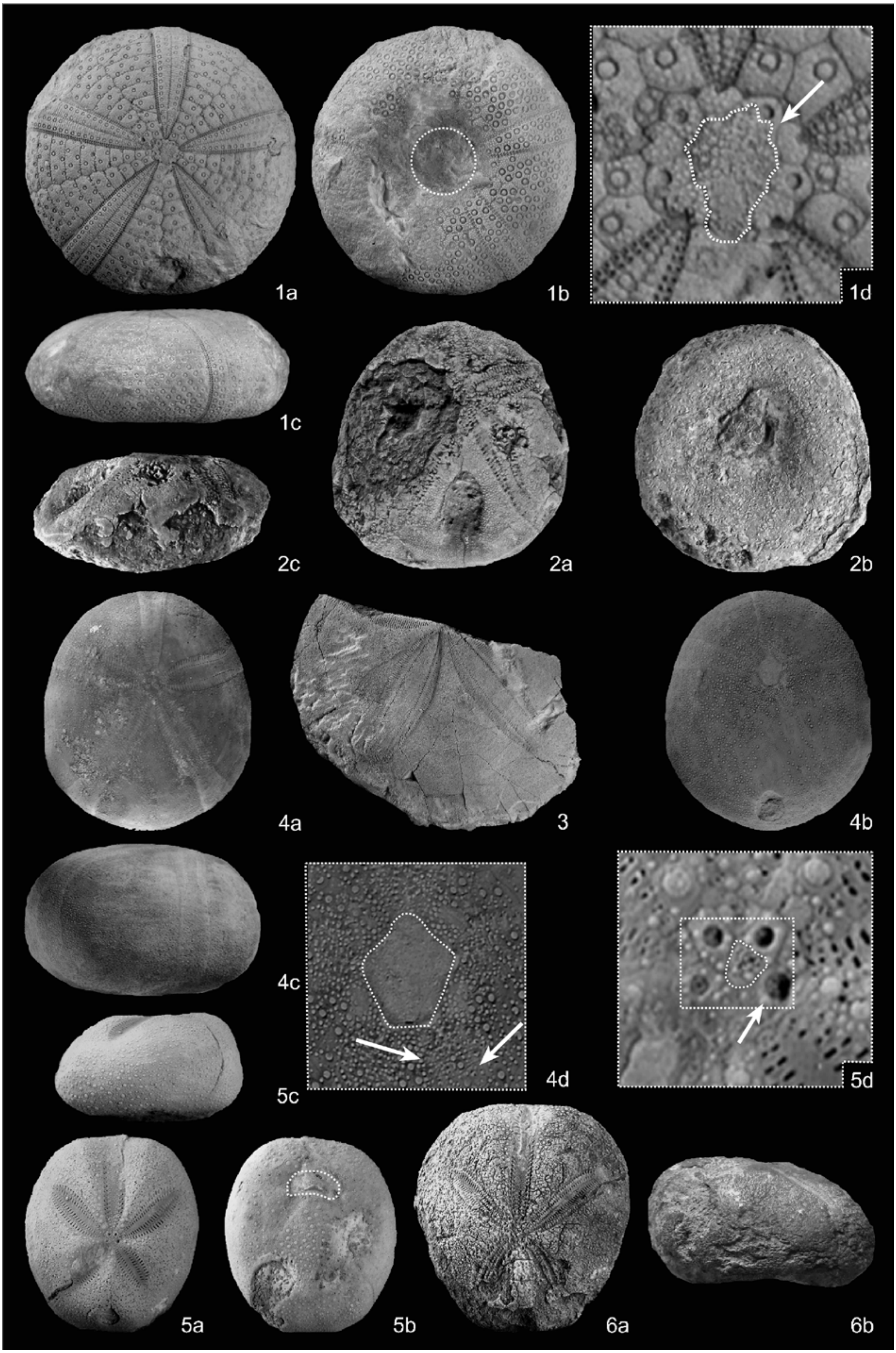
Fig. 1. *Anorthopygus orbicularis* (Grateloup, 1836) from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5, **d**: detail of the apical disc, x10; MGDMU:WQ.E.**12**.82.

Fig. 2. *Petalobrissus* cf. *pygmaeus* (Fourtau, 1921) from the Lower Turonian Abu Qada Formation at Wadi Quseib. **a**: Adapical view, x3, **b**: adoral view, x3, **c**: side view, x3; MGDMU:WQ.E.**76**.27.

Fig. 3. *Pygurus* cf. *subproductus* Fourtau, 1921 from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa, adapical view, x1.5; MGDMU:AEN.E.**12**.39.

Fig. 4. *Gentilia syriensis* Kier, 1962 from the upper carboante member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5, **d**: peristomal region, x5; MGDMU:WQ.E.**42**.81.

Figs. 5-6. *Hemiaster* (*Hemiaster*) *syriacus* (Conrad, 1852). **5**. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x2, **b**: adoral view, x2, **c**: side view, x2, **d**: detail of apical disc, x15; MGDMU:WQ.E.**42**.82. - **6**. from the middle carbonate member of the Cenomanian Halal Formation at Gebel Areif El-Naqa. **a**: Adapical view, x1.5, **b**: side view, x1.5; MGDMU:AEN.E.**15**.240.


1a
1b
1d
1c
2c
2a
2b
4a
3
4b
4c
4d
5d
5c
5a
5b
6a
6b

some forms extends the madreporite and that the periproct is more regular. Moreover, ABDELHAMID & AZAB (2003) pointed out a more regular periproct on some specimens of *A. orbicularis* from Portugal but that the periproct in some other specimens from Sarthe lies nearer to the posterior margin than to the apical disc. The present material closely resembles FOURTAU'S species in shape, size, and position of periproct but the slightly different apical disc makes the author doubt whether *A. atavus* is a synonym of *A. orbicularis*.

ALI (1990) pointed out that his new species *A. arabicus* is most closely related to *A. atavus* FOURTAU, but differs in having a narrower ambulacral area (12-15.4% of test diameter) and a larger apical disc and periproct (maximum height 25.7-29.6% and maximum width 18-21.3% of test diameter). SMITH & WRIGHT (1999) noted that the periproct of *A. orbicularis* occupies slightly more than 25% of the test diameter and that the width of ambulacral areas of some specimens (pl. 115, figs. 3-6) is relatively narrow (about 13% of test diameter). For these reasons, *A. arabicus* ALI may be a junior synonym of the present species. *A. michelini* COTTEAU & TRIGER (1860) differs from *A. orbicularis* by having a weakly subconical test (for a more extensive discussion, see SMITH & WRIGHT, 1999: 363).

Cohort Neognathostomata SMITH, 1981
Order Cassiduloida CLAUS, 1880
Family Nucleolitidae AGASSIZ & DESOR, 1847

Genus *Petalobrissus* LAMBERT, 1916
Petalobrissus cf. *pygmaeus* (FOURTAU, 1921)
Pl. 33, Fig. 2

cf. 1921 *Echinobrissus pygmaeus* sp. nov. – FOURTAU: 67, pl. 9, fig. 5.
cf. 1932 *Clitopygus pygmaeus* FOURTAU – LAMBERT: 193.
cf. 2001 *Petalobrissus pygmaeus* (FOURTAU) – ABDELHAMID & EL QOT: 22, fig. 6G.
cf. 2006 *Petalobrissus pygmaeus* (FOURTAU) – EL QOT: 147, pl. 33, figs. 5-6.

Material and occurrence. 35 specimens, two of them incomplete, from the Abu Qada Formation (Lower Turonian), bed 76 at Wadi Quseib (MGDMU:WQ.E.**76**.27-31), and 18 from the Upper Turonian Wata Formation, bed 53 of the East Themed area (MGDMU:ET.E.**53**.13-30).

Measurements (in mm).

n=1	L	W	H	W/L	H/L	LI	LII	LIII	NI	LK	WK
	19	17	9	0.89	0.47	10	9	?6	30	5	4

Description. Test small and oval in outline. Height about 47% of total diameter and maximum height at apical disc. Adapical surface convex to low dome-shaped. Adoral surface strongly concave with depressed peristome. Both anterior and posterior margins regularly rounded. Ambitus sharp. Apical disc tetrabasal, eccentric anteriorly with four gonopores. Ambulacral areas petaloid and narrow (about 12% of test diameter) with narrow poriferous zone. Pores rounded to oval, unequal, and non-conjugated. Interporiferous zone slightly wider than one poriferous zone and carrying fine granules. Periproct oval, large, and supramarginal.

Temporal and spatial distribution. *Petalobrissus pygmaeus* has been recorded from the Turonian of Gebel Dhalfa (FOURTAU, 1921), G. El-Minsherah (ABDELHAMID & EL QOT, 2001), and G. Ekma, East Themed, and G. Yelleg (EL QOT, 2006).

Discussion. The genus *Petalobrissus* is characterized by the presence of single pores in ambulacral plates outside the petals and by the possession of buccal pores (Abdelhamid & El Qot, 2001: 23). The present material is poorly preserved but it is closely similar to *P. pygmaeus* as figured by Fourtau (1921) with respect to shape and size of petals and also the position and size of periproct. According to El Qot (2006), *P. pygmaeus* differs from *P. humei* (Fourtau, 1906) in having a less round outline and lower test. *P. waltheri* (Gauthier, 1900) has a wider poriferous zone with a different petal system (relationship among petals).

Family Faujasiidae Lambert, 1905

Subfamily Faujasiinae Lambert, 1905

Genus *Pygurus* Agassiz, 1839

Pygurus cf. *subproductus* Fourtau, 1921

Pl. 33, Fig. 3

cf. 1921 *Pygurus subproductus* sp. nov. – Fourtau: 72, pl. 10, fig. 6.
cf. 1990 *Pygurus* (*Pygurus*) cf. *subproductus* Fourtau – Ali: 113, fig. 7/6.

Material and occurrence. A single incomplete specimen from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), bed 12 at Gebel Areif El-Naqa (MGDMU:AEN.E.**12**.39).

Measurements (in mm).

n=1	D	H	H/D	Wa	Wi	Wa/Wi
	34	6	0.17	6	16	0.37

Description. Test large-sized, compressed, its height about 17% of total test diameter. Adapical surface slightly convex. Adoral surface slightly concave. Posterior margin rounded and more prolongated. Ambulacral area moderately large (about 37% of interambulacral width), subpetaloid, lancet-shaped, and flush to feebly swollen. Poriferous zone wide and uniserial. Pores rounded, unequal, and conjugated. The outer pores slit-shaped, the inner ones, in contrast, rounded. Interporiferous zone slightly less than double the width of one poriferous zone. Interambulacral area wide and slightly raised. Tubercles of interambulacra small and numerous adapically and slightly larger adorally. Both peristome and periproct not preserved.

Temporal and spatial distribution. *Pygurus subproductus* has been recorded from the Cenomanian of United Arab Emirates (Ali, 1990), and in Egypt from the Albian of Gebel Abu Diab (Fourtau, 1921).

Discussion. The present material closely resembles *Pygurus subproductus* figured by Fourtau (1921) in shape and size of poriferous and interporiferous zones of the ambulacral area and the prolongation of the posterior margin but the specimen is not complete. Fourtau distinguished *P. productus* Agassiz from his new species by having a shorter posterior prolongation and by being slightly smaller than *P. subproductus*. Ali (1990) noted that his material differs from Fourtau’s species by having a broad inflation along the interradial suture of the posterior interambulacrum 5.

Family Archiaciidae Cotteau & Triger, 1869 [after Durham et al., 1966]

Genus *Gentilia* Lambert, 1918

Gentilia syriensis Kier, 1962
Pl. 33, Fig. 4

1962 *Gentilia syriensis* sp. nov. – Kier: 156, pl. 23, figs. 5-11, text-figs. 129-131.
1995 *Gentilia syriensis* Kier – Néraudeau et al.: 415, fig. 5f.

Material and occurrence. A single specimen from the upper carbonate member of the Cenomanian Galala Formation, bed 42 at Wadi Quseib (MGDMU:WQ.E.**42**.81).

Measurements (in mm).

n=1	D	H	H/D	Ls	Ls/D	dp	dp/D	Lk	Lk/D	Wa	Wi	Wa/Wi
	28	18	0.64	4	0.14	5	0.18	4	0.14	5	11	0.45

Description. Test medium-sized, ovate, globular, its height being 64% of test diameter. Both anterior and posterior borders rounded. Widest part of test lying about two-thirds the distance from the anterior. Adapical surface broad and slightly convex with rounded ambitus. Adoral surface flat with slight depression around peristome. Apical disc tetrabasal, lying anteriorly, and consisting of four large gonopores, but plating not seen. Ambulacral area petaloid (aborally), flush, the largest width close to the apex (18% of test diameter and 45% of interambulacral width), and open distally. Poriferous zone narrow, straight, and uniserial. Outer pores distinctly slit-like, but inner ones rounded and isolated. Ambulacrum III short and widely open. Interambulacral area wide (39% of test diameter) and slightly swollen with simple and wide plates, and yielding small granules. Periproct ovate-shaped, small (14% of test diameter), and occupying the distance between the peristome and posterior margin (inframarginal). Peristome pentagonal, very eccentric anteriorly (35% of test length from the anterior end), and relatively small (about 18% of test diameter) with well-rounded paired phyllodal pores (Pl. 33, Fig. 4d).

Temporal and spatial distribution. *Gentilia syriensis* was first described by Kier (1962) from the Cenomanian of Syria. It has been also recorded from the Cenomanian of Saudi Arabia by Néraudeau et al. (1995). This is the first record of the species from Egypt.

Order Spatangoida Claus, 1876
Family Hemiasteridae Clark, 1917
Genus *Hemiaster* Agassiz, in Agassiz & Desor, 1847
Subgenus *Hemiaster* Agassiz, in Agassiz & Desor, 1847
Hemiaster (*Hemiaster*) *syriacus* (Conrad, 1852)
Pl. 33, Figs. 5-6

1852 *Holaster syriacus* sp. nov. – Conrad in Lynch: 212, pl. 1, fig. 2.
1925 *Hemiaster syriacus* Conrad – Blanckenhorn: 103, pl. 8, figs. 33-35.
1990 *Hemiaster syriacus* (Conrad) – Smith et al.: 61, figs. 19a-b, 20.
?1995 *Mecaster orbignyanus* (Desor) – Néraudeau et al.: 419, fig. 6c.
2001 *Hemiaster syriacus* (Conrad) – Abdelhamid & El Qot: 28, fig. 7L.
2003 *Hemiaster syriacus* (Conrad) – Abdelhamid & Azab: 872, pl. 5, figs. R, P.
2003 *Hemiaster* (*Mecaster*) *syriacus* (Conrad) – Berndt: 84, fig. 4/1a-c.
2006 *Hemiaster* (*Hemiaster*) *syriacus* (Conrad) – El Qot: 150, pl. 34, fig. 7.

Material and ocrcurrence. 23 specimens from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian), beds 6, 13, and 15 at Gebel Areif El-Naqa (MGDMU:AEN.E.**6**.8-12;**13**.32;**15**.240-256); Six specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed, 42 at Wadi Quseib (MGDMU:WQ.E.**42**.82-87), and nine specimens from Upper Cenomanian Galala Formation, bed 12 of the East Themed area (MGDMU:ET.E.**12**.202-210).

Measurements (in mm).

n=13	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	NIII	LK	WK
Range	14-38	12-35	9-19	0.84-1	0.50-0.67	3-12	4-16	6-17	15-30	23-35	15-24	3-7	2-5
Mean	20	18.38	12	0.91	0.60	7	8.77	11.15	19.18	29.27	18.0	4.12	2.88

Description. Test small- to medium-sized, oval in outline, maximum height near the posterior end attaining about 60% of total test diameter. Adapical surface flattened to slightly convex and gradually sloping anteriorly. Adoral surface flattened. Greatest width slightly anterior of apical disc. Anterior margin almost rounded without central sulcus. Posterior margin nearly straight and vertically rounded. Apical disc large, quadrate, slightly eccentric posteriorly, and lying about 58% of the anterior-posterior distance from the anterior margin. Posterior gonopores slightly wider than the anterior ones (Pl. 33, Fig. 5d). Petals more or less straight, shallow, and rose-shaped. Anterior pairs petaloid and extending for about 62% of the distance from the apex to the ambitus (about 1.5 times longer as the posterior one). Posterior petals petaloid, shorter, and less divergent than the anterior ones (extending for about 48% of the distance from apex to ambitus). Poriferous zones wide (the width of two poriferous zones is about 95% of petal width). Pores slit-shaped, equal-sized, and conjugated. Frontal ambulacrum non-petaloid, narrow, and shallower than the anterior and posterior petals with nearly parallel sides. Poriferous zone narrow with oval, non-conjugated, and oblique pores. Periproct oval, small, and situated high on the test (about 72% of test height above the base). Peristome small (20% of total test height), semi-lunar, situated nearly one-third (17%) of the test length from the anterior end, and surrounded by well developed phyllodal pors. Peripetalous fasciole well developed.

Temporal and spatial distribution. *Hemiaster* (*Hemiaster*) *syriacus* has been recorded from the Cenomanian of Syria (Conrad, 1852), Palestine (Blanckenhorn, 1925), Oman (Smith et al., 1990), Saudi Arabua (Nèraudeau et al., 1995), and Jordan (Berndt, 2003). In Egypt, it has been documented from the Cenomanian of Gebel El-Hamra (Abdelhamid & El Qot, 2001), Saint Paul, Wadi Dakhl, and G. Gharamul (Abdelhamid & Azab, 2003), and G. Ekma and the East Themed area (El Qot, 2006).

Discussion. *Hemiaster orbignyanus* Desor, 1857 from the Cenomanian of Saudi Arabia of Néraudeau et al. (1995) closely resembles the present species in shape and size of petals and periproct. Smith et al. (1990) considered *H. orbignyanus* as a synonym of *H. syriacus.* Blanckenhorn (1925) pointed out that *H. orbignyanus* has very unequal petals like *H. syriacus* but that its petals are very narrow. *H. orbignyanus* has been originally described from the Turonian of France. According to Abdelhamid & El Qot (2001: 28) and El Qot (2006: 152), the specimens described from the Middle East as *H. orbignyanus* are thought to belong to *H. syriacus,* whereas *H. orbignyanus* sensu stricto is confined to the Turonian of France.

SMITH et al. (1990) noted that *H. lusitanicus* DE LORIOL (1888: 100, pl. 19, figs. 1-7) and *H. subtilis* DE LORIOL (1888: 106, pl. 21, figs. 1-3) from the Cenomanian of Portugal are very similar to *H. syriacus* and considered them as synonyms of *H. syriacus* with some doubts.

Hemiaster (*Hemiaster*) *gabrielis* PERON & GAUTHIER, 1878
Pl. 34, Figs. 1-2; Text-fig. 3.50

1878 *Hemiaster Gabrielis* sp. nov. – PERON & GAUTHIER in COTTEAU et al.: 116, pl. 4, figs. 9-12.
1914 *Hemiaster Gabrielis* PERON & GAUTHIER var. *aegyptiaca* var. nov. – FOURTAU: 74, pl. 6, fig. 7.
1921 *Hemiaster Gabrielis* PERON & GAUTHIER var. *aegyptiaca* var. nov. – FOURTAU : 87.
1932 *Hemiaster Gabrielis* PERON & GAUTHIER – LAMBERT: 125.
1998 *Hemiaster gabrielis* PERON & GAUTHIER – EL-SHEIKH et al.: pl. 1E.
1999 *Hemiaster gabrielis* PERON & GAUTHIER – ABDELHAMID: pl. 2, fig. B.
2001 *Hemiaster gabrielis* PERON & GAUTHIER – ABDELHAMID & EL QOT: 25, fig. 7E.
2003 *Hemiaster gabrielis* PERON & GAUTHIER – ABDELHAMID & AZAB: 871, pl. 5, figs. J-K.
2004a *Hemiaster* (*Hemiaster*) *gabrielis* PERON & GAUTHIER – ABDEL-GAWAD et al.: pl. 10, figs. 10-11.
2006 *Hemiaster* (*Hemiaster*) *gabrielis* PERON & GAUTHIER – EL QOT: 149, pl. 34, figs. 4-5.

Material and occurrence. 77 specimens from the lower marly member of the Halal Formation (Upper Albian-Cenomanian), beds 1, 6, 7, and 9 at Areif El-Naqa (MGDMU:AEN.E.**1**.143-175;**6**.13-33;**7**.1-2,**9**.57-77).

Measurements (in mm).

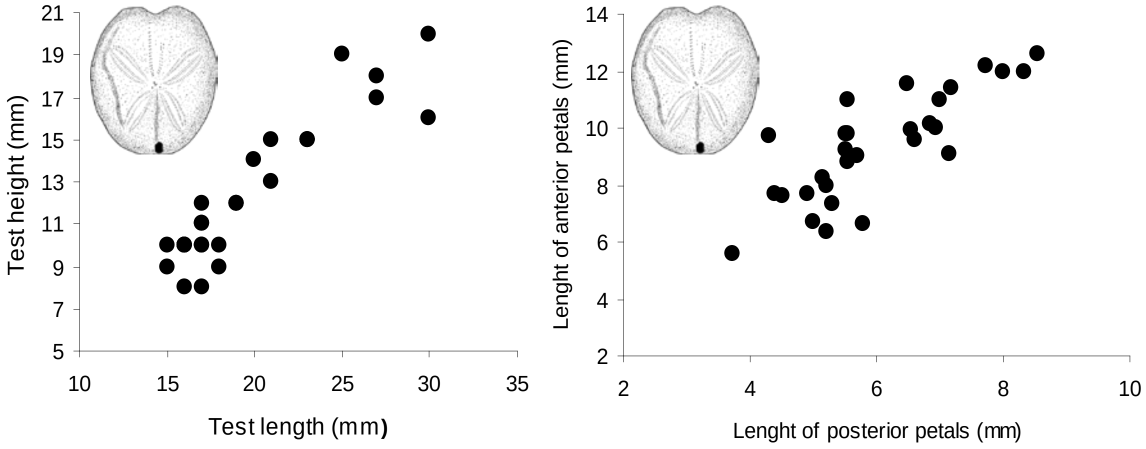
n=29	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	NIII	LK	WK
Range	15-30	14-25	8-20	0.83-1.00	0.47-0.76	4-10	6-15	8-17	16-31	23-43	10-25	2-7	2-4
Mean	19.72	18.24	11.86	0.89	0.59	6.89	9.31	11.89	23.31	30.62	18.36	3.16	2.40

Description. Test small-to medium-sized, heart-shaped, inflated, and posteriorly higher than anteriorly. Greatest width slightly anteriorly of apical disc, its height about 59% of test diameter. Anterior margin straight with moderately deep sulcus. Posterior margin rounded and oblique to subvertical. Adapical and adoral surfaces slightly convex and gradually sloping anteriorly. Apical disc slightly eccentric posteriorly (about 58% from the anterior margin) and large with four well developed gonopores. Madreporite well developed and separating gonopores 1 and 4. Anterior and posterior petals more or less straight, petaloid, moderately deep, and arranged in cross-like fashion. Length of anterior pairs about 1.5 times that of the posterior ones and extending from the apex to or nearly to the ambitus (Text-fig 3.50). Posterior pair shorter than anterior ones and covering only slightly more than half the distance from the apex to the ambitus. Poriferous zones of both anterior and posterior petals large with non-conjugated slit-pores. Frontal ambulacrum non-petaloid, deep, and narrow with nearly parallel poriferous zones. Pores round and non-conjugated. Peristome semi-rounded to semi-lunar, lying 30% of the length from the anterior end and surrounded by well developed phyllodal pores. Periproct medium-sized, circular to slightly ovate, and at the top of the posterior margin (above ambitus). Peripetalous fasciole well developed.

Temporal and spatial distribution. *Hemiaster* (*Hemiaster*) *gabrielis* has been recorded from the Cenomanian of Algeria (PERON & GAUTHIER, 1878), and Morocco (LAMBERT, 1932). In Egypt it is known from the Cenomanian of Sinai and the Eastern Desert by FOURTAU (1914, 1921), ABDELHAMID (1999), ABDELHAMID & AZAB (2003), ABDEL-GAWAD et al. (2004a), and EL QOT (2006).

Discussion. BLANCKENHORN (1925) and SMITH et al. (1990) regarded *Hemiaster gabrielis* from the Cenomanian of Algeria and *H. gabrielis* var. *aegyptiaca* FOURTAU (1914) from the Cenomanian of Sinai as synonyms of *H. syriacus*. The author agrees with EL QOT (2006) that *H. gabrielis* and *H. syriacus* are two different species. The more sinuous anterior margin, more depressed petals, rounded posterior, and the nearly centric apical disc of *H. gabrielis* suggest that it a separate species.

SMITH et al. (1990: 64) agreed with FOURTAU (1914: 75) that *H. lusitanicus* and *H. subtilis* are identical with the present species. COTTEAU et al. (1878) erected *H. gabrielis, H.*



Text-fig. 3.50. Biometric data of *Hemiaster* (*Hemiaster*) *gabrielis* PERON & GAUTHIER, 1878 from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa.

EXPLANATION OF PLATE 34

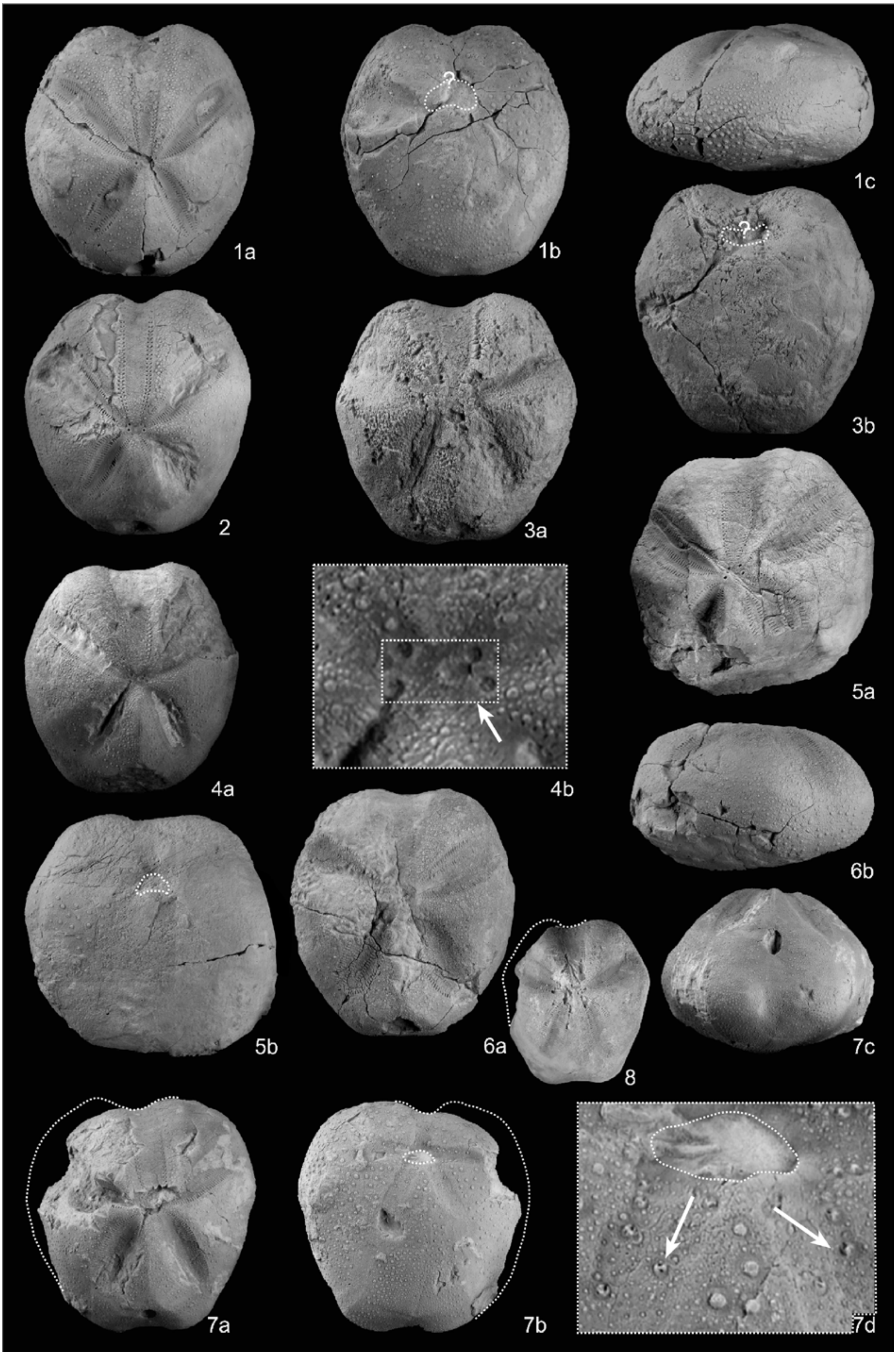
Figs. 1-2. *Hemiaster* (*Hemiaster*) *gabrielis* PERON & GAUTHIER, 1878. from the lower marly member of the Upper Albian-Cenomanian Halal Formation at Gebel Areif El-Naqa. **1a**: Adapical view, x1.5, **b**: adoral view, x1.5, **c**: side view, x1.5; MGDMU:AEN.E.**6**.13. – **2**. Adapical view, x1.5; MGDMU:AEN.E.**1**.143.

Figs. 3-4. *Hemiaster* (*Mecaster*) *fourneli* (DESHAYES, 1847). from the Upper Turonian Wata Formation at Gebel Areif El-Naqa. 3. **a**: Adapical view, x1.5, **b**: adoral view, x1.5; MGDMU:AEN.E.**31**.4. – **4a**: adapical view, x1.5, **b**: detail of apical disc, x8; MGDMU:AEN.E.**31**.5.

Fig. 5. *Hemiaster* (*Mecaster*) cf. *newtoni* FOURTAU, 1914. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5; MGDMU:WQ.E.**12**.83.

Fig. 6. *Hemiaster* (*Mecaster*) *pseudofourneli* PÉRON & GAUTHIER, 1878. from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. **a**: Adapical view, x1.5, **b**: adoral view, x1.5; MGDMU:WQ.E.**12**.84.

Figs. 7-8. *Hemiaster* (*Mecaster*) *heberti* (COQUAND, 1862) *turonensis* FOURTAU, 1921. **7**. Specimen from the Upper Turonian Wata Formation at Wadi Quseib. **a**: Adapical view, x1, **b**: adoral view, x1, **c**: posterior view, x1, **d**: ambulacra groove with well-developed phyllodal pores, x5; MGDMU:WQ.E.97.**85**. – **8**. Specimen from the Upper Turonian Wata Formation at Gebel Areif El-Naqa. Adapical view, x1; MGDMU:AEN.E.**31**.11.


1a
1b
1c
2
3a
3b
4a
4b
5a
5b
6a
6b
8
7c
7a
7b
7d
?
?

saadensis, and *H. zitteli* from the Cenomanian of Algeria. According to EL QOT (2006: 150), *H. zitteli* is a junior synonym of *H. gabrielis*, but *H. saadensis* differs in having a more elongated and flattened test.

subgenus *Mecaster* POMEL, 1883
Hemiaster (*Mecaster*) *fourneli* (DESHAYES, 1847)
Pl. 34, Figs. 3-4

1847 *Hemiaster fourneli* sp. nov. – DESHAYES in AGASSIZ & DESOR: 123.
1898 *Hemiaster fourneli* DESHAYES – FOURTAU: 631.
1912 *Hemiaster fourneli* DESHAYES – FOURTAU: 168.
1921 *Hemiaster Fourneli* DESHAYES – FOURTAU: 87.
1925 *Hemiaster fourneli* DESHAYES – BLANCKENHORN: 106, pl. 8, fig. 37a-b.
1991 *Mecaster fourneli* (DESHAYES) – SMITH & BENGTSON: 61, pl. 14, figs. A-M; pl. 15, figs. A-L; pl. 16, figs. E, F; text-figs. 45K, L, 48B, 50.
1997 *Mecraster* aff. *fourneli* (DESHAYES) – NÉRAUDEAU & COURVILLE: 842, fig. 6/12.
1998 *Hemiaster fourneli* DESHAYES – EL-SHEIKH et al.: pl. 2, fig. D.
2001 *Hemiaster fourneli* DESHAYES – ABDELHAMID & EL QOT: 25, fig. 7C-D.
2002 *Hemiaster fourneli* DESHAYES – KORA et al.: pl. 4, fig. 13.
2004a *Hemiaster* (*Mecaster*) *fourneli* DESHAYES – ABDEL-GAWAD et al.: pl. 10, figs. 12-13.
2006 *Hemiaster* (*Mecaster*) *fourneli* DESHAYES – EL QOT: 152, pl. 34, figs. 2-3.
2007 *Hemiaster* (*Mecaster*) *fourneli* DESHAYES – ABDEL-GAWAD et al.: pl. 4, figs. 9-10.

Material and occurrence. 15 specimens from the Upper Cenomanian-Lower Turonian Abu Qada Formation, bed 25 of the East Themed area (MGDMU:ET.E.25), 14 specimens from the Turonian Abu Qada and Wata formations, beds 47, 97 of Wadi Quseib (MGDMU:WQ.E.**47**.90-100;**97**.51-57), and seven specimens from the Wata Formation (Upper Turonian), bed 31 at Gebel Areif El-Naqa (MGDMU:AEN.E. **31**.4-10).

Measurements (in mm).

n=12	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	NIII	LK	WK
Range	15-30	14-29	8-20	0.83-1	0.53-0.69	5-14	8-15	8-20	18-30	22-38	14-31	2-6	2-4
Mean	24.58	22.75	15.66	0.92	0.63	9.16	12.25	15.50	24.73	28.82	21	3.55	2.36

Description. Test small-to medium-sized, subhexagonal; height about 63% of test diameter. Adapical surface strongly convex, adoral surface slightly convex. Maximum width slightly anterior of apical disc and slightly narrower posteriorly. Anterior margin sulcate. Apical disc large, centric to slightly eccentric anteriorly, and situated about 47% of the anterior-posterior distance from the anterior margin, laterally elongated, the pairs of gonopores on either side being close together (Pl. 34, Fig. 4b). Frontal ambulacrum non-petaloid, wide, deep, and covered by more regularly arranged and dense granules. Poriferous zone narrow with equal, oblique and non-conjugated pores. Both anterior and posterior paired petals petaloid, slightly depressed, and wide. Anterior paired petals longer and more divergent than the posterior ones. Poriferous zones equal and wide (the two poriferous zones occupy about 78% of petal width) with slit-shaped, conjugated, and equal-sized pores. Peristome large, lunular, lying 26%

nearly of the test length from the anterior end. Periproct medium-sized, oval to rounded, and lying at top of the posterior margin.

Temporal and spatial distribution. *Hemiaster* (*Mecaster*) *fourneli* has been recorded from the Santonian of Palestine (BLANCKENHORN, 1925), Turonian-Coniacian of Brazil (SMITH & BENGSTON, 1991), and the late Middle Turonian of Nigeria (NÉRAUDEAU & COURVILLE, 1997). According to PETITOT (1961) the species is relatively common in the Upper Turonian to Campanian of North Africa and most abundant in the Coniacian to Santonian. In Egypt, the species is known from the Santonian of Gebel Raha, G. El-Fallig, and G. Yelleg (FOURTAU, 1921), the Coniacian-Santonian of Wadi Sudr, W. Matulla (KORA et al., 2002), G. El-Hamra and G. El-Minsherah (EL-SHEIKH et al., 1998; ABDELHAMID & EL QOT, 2001), and of G. Ekma and the East Themed area (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Discussion. Some authors treated *Mecaster* as a subgenus of *Hemiaster*. SMITH & BENGTSON (1991) regarded *Mecaster* as a separate genus on account of its subequal petals and its laterally elongated apical disc, in which the madreporite separates genital plates 1 and 4. In *Hemiaster* the posterior genital plates are not separated by the madreporite and all four genital plates are sub-equal in size. In addition, the posterior petals are truncated in comparison to the anterior pairs and the apical disc lies posterior of the center. According to DURHAM & WAGNER (1966: U559, figs. 442/1, 443/1) *Hemiaster* (*Mecaster*) is relatively low, subhexagonal, and possesses subequal petals with wide frontal ambulacrum (with anterior sulcus).

COQUAND (1880) distinguished two varieties in *Hemiaster fourneli*, var. *ambiguous*, which is characterized by its nearly orbicular outline, and var. *refanensis*, which is elongated, polygonal, and narrow posteriorly. COTTEAU et al. (1881) distinguished three varieties, an elongated one, a relatively short test, and a third variety with a more obliquely truncated posterior margin.

SMITH & BENGTSON (1991) distinguished that *H. batnensis* from *Mecaster fourneli* by its slightly rounded form and relatively greater number of pores in the frontal ambulacrum between the apex and fasciole. Moreover, the apical disc in the two species also differs; in *M. fourneli* it is laterally elongated and the pairs of gonopores on either side are close together (Pl. 34, Fig. 4b). The tuberculation in the frontal ambulacrum is denser and more regularly arranged into horizontal rows in *M. fourneli* than in *H.* (*M.*) *batnensis* (SMITH & BENGTSON, 1991: 59, fig. 48a, b).

H. pseudofourneli PERON & GAUTHIER differs from *H.* (*M.*) *fourneli* by its longer and deeper posterior paired petals and more anteriorly displaced apical disc. *H.* (*M.*) *pseudofourneli* has been recorded from the Cenomanian of North Africa and the Middle East, whereas *H. fourneli* ranges from the Turonian to Campanian, but occurs predominantly in the Coniacian-Santonian.

According to SMITH & BENGTSON (1991: 62), *Mecaster texanum* (ROEMER) from the Santonian-Campanian of the United States differs in having a smaller peristome, more elongated apical disc, and a large madreporite, which separates the posterior ocular plates widely. In addition, *M. messai* (PERON & GAUTHIER) has a much wider frontal ambulacrum.

Hemiaster (*Mecaster*) cf. *newtoni* FOURTAU, 1914
Pl. 34, Fig. 5

cf. 1914 *Hemiaster Newtoni* sp. nov. – FOURTAU: 79, pl. 7, figs. 4-5.
cf. 1921 *Hemiaster Newtoni* FOURTAU – FOURTAU: 92

cf. 2001 *Hemiaster newtoni* FOURTAU – ABDELHAMID & EL QOT: 26, fig. 7I.
cf. 2003 *Hemiaster newtoni* FOURTAU – ABDELHAMID – AZAB: 872, pl. 5, figs. L, M.

Material and occurrence. A single deformed specimen from the lower shale member of the Cenomanian Galala Formation, bed 12 at the Wadi Quseib (MGDMU:WQ.E.**12**.83).

Measurements (in mm).

n=1	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	NIII
	?33	31	24	0.94	0.73	14	17	19	?20	41	38

Description. Test large-sized, polygonal in outline, inflated, posteriorly higher than anteriorly (about 73% of test diameter). Greatest width slightly anterior of apical disc. Adapical surface slightly convex. Adoral surface feebly convex with moderately deep anterior sinus. Apical disc large (much broader than long), quadrate, and nearly central with four gonopores, which are closer on both sides. Madreporite well developed. Frontal ambulacrum non-petaloid and in moderately deep sulcus that continues to the peristome. Pores oval, oblique, and non-conjugated. Interporiferous zone wide and covered with numerous fine granules. Both anterior and posterior petals very wide and deep. Poriferous zone wide (the two poriferous zones represent about 95% of petal width) with slit-shaped, non-conjugated, and equal-sized pores. Peristome moderately large, semi-lunar, and situated at about 22% of test length from the anterior end. Periproct not preserved.

Temporal and spatial distribution. *Hemiaster* (*Mecaster*) *newtoni* has been recorded from the Cenomanian of Qalaat El Karam and Gebel Um Asagil (FOURTAU, 1921), G. El-Hamra (ABDELHAMID & EL QOT, 2001), and G. Gharamul (ABDELHAMID & AZAB, 2003).

Discussion. The present material is not complete but closely resembles *Hemiaster newtoni* which has been described and figured by FOURTAU (1914). It can be easily distinguished from other *Hemiaster* species recorded in the present study by its higher test, wide and strongly depressed petals, and more angular outline. According to ABDELHAMID & EL QOT (2001) *Hemiaster newtoni* differs from *H. latigrunda* PÉRON & GAUTHIER from the Turonian of Algeria by having deeper petals, a higher test, and larger peristome.

Hemiaster (*Mecaster*) *pseudofourneli* PÉRON & GAUTHIER, 1878

Pl. 34, Fig. 6

1878 *Hemiaster pseudofourneli* sp. nov. – PÉRON & GAUTHIER in COTTEAU et al.: 113, pl. 4, figs. 5-8.
1914 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – FOURTAU: 82, 109.
1963 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – FAWZI: 14.
1981 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – AMARD et al.: 106, pl. 16, figs. 24-27.
1995 *Mecaster pseudofourneli* (PÉRON & GAUTHIER) – NÉRAUDEAU et al.: 418, fig. 6d-e; text- fig. 7.
2001 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – ABDELHAMID & EL QOT: 28, fig. 7j-k.
2001 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – KORA et al.: pl. 3, fig. 9.
2002 *Mecaster pseudofourneli* (PÉRON & GAUTHIER) – AHMAD & AL-HAMMAD: 459, fig. 5/ 1-4, 6, 8.
2003 *Hemiaster pseudofourneli* PÉRON & GAUTHIER – ABDELHAMID & AZAB: 872, pl. 5,

figs. N-O.
?2004b *Hemiaster cubicus* Desor – Abdel-Gawad et al.: pl. 6, fig. 4.

Material and occurrence. Three specimens from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation, bed 12 at Wadi Quseib (MGDMU:WQ.E.**12**.84).

Measurements (in mm).

n=2	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	LK	WK
Range	27-31	23-28	19-20	0.85-0.90	0.64-0.67	10-14	13-14	16-16	16-22	25-30	4-5	3-4
Mean	29	25.5	19.5	0.87	0.65	12	13.5	16	19	27.5	4.5	3.5

Description. Test medium-sized, subhexagonal to oval, its height about 65% of test diameter. Both adapical and adoral surfaces convex. Greatest width slightly anterior of apical disc. Posterior margin straight. Anterior margin moderately sulcate. Apical disc large, eccentric anteriorly, situated about 43% of test length from the anterior margin. The four gonopores well developed and close together on either side. Frontal ambulacrum non-petaloid, wide, and deep. Poriferous zone small and narrow. Pores equal, oblique, and non-conjugated. Both anterior and posterior paired petals petaloid, slightly depressed, and wide. Anterior paired petals nearly equal and more divergent than the posterior ones. Poriferous zones equal and wide (the two poriferous zones account for about 80% of petal width). Pores slit-shaped, conjugated, and equal-sized. Periproct medium-sized, slightly elongated vertically, and lying at the top of the posterior margin. Peristome not preserved. Peripetalous fasciole well developed.

Temporal and spatial distribution. *Hemiaster* (*Mecaster*) *pseudofourneli* has been recorded from the Cenomanian-Turonian of Algeria (Amard et al., 1981), Cenomanian of Saudi Arabia (Néraudeau et al., 1995), and Jordan (Ahmad & Al-Hammad, 2002). In Egypt, it is known from the Cenomanian of Gebel El-Minsherah (Fawzi, 1963), G. El-Hamra (Abdelhamid & El Qot, 2001), G. El-Fallig (Abdel-Gawad et al., 2004b), Wadi Abu Qada (Kora et al., 2001), and G. Gharamul and W. Dakhl (Abdelhamid & Azab, 2003).

H. (*M.*) *pseudofourneli* is a well known Cenomanian species reported from southwestern Europe, western Africa, Middle-East, and Brazil (Ahmad & Al-Hammad, 2002).

Discussion. *Hemiaster* (*Mecaster*) *pseudofournel* differs from *H.*(*M.*) *newtoni* by having narrower and equal-sized petals and a lower test. *H. cubicus* (Desor, 1847) is characterized by an extremely eccentric peristome very close to the anterior margin, a small periproct, and a deep anterior sulcus. The periproct of *H. cubicus* of Abdel-Gawad et al. (2004b) from the Cenomanian of Gebel El-Fallig (Sinai), which is not close to the anterior margin, may therefore be belong to *H. pseudofourneli* rather than to *H. cubicus*.

Hemiaster (*Mecaster*) *heberti* (Coquand, 1862) *turonensis* Fourtau, 1921

Pl. 34, Figs. 7, 8

1921 *Hemiaster Heberti* mutatio *Turonensis* Fourtau: 89, pl. 11, figs. 1-10.
1999 *Hemiaster heberti* (Coquand) *turonensis* Fourtau – Abdelhamid: pl. 1, figs. A-D, J, K-L; pl. 2, figs. D-E, F, G-H, J-K.
2001 *Hemiaster heberti* (Coquand) *turonensis* Fourtau – Abdelhamid & El Qot: 26, fig. 7G-H.

2004a *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU – ABDEL-GAWAD et al.: pl. 10, fig. 14a-b.
2006 *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU – EL QOT: 153, pl. 34, fig. 6a-b.
2007 *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU – ABDEL-GAWAD et al.: pl. 6, fig. 11.

Material and occurrence. 64 specimens from Upper Cenomanian/Lower Turonian Abu Qada and Upper Turonian Wata formations, beds 23, 26, and 53 of the East Themed area (MGDMU:ET.E.**23**.229-231,**26**.206-261,**53**.31-35), 31 specimens from the Lower Turonian Abu Qada and Upper Turonian Wata formations, beds 47, 81, 92, 93, and 97 at Wadi Quseib (MGDMU:WQ.E.**47**.101-115,**81**.1-3;**92**.8;**93**.40-43,**97**.85-65), and four specimens from the lower member of the Turonian Abu Qada and Wata formations, beds 23 and 31 at Gebel Areif El-Naqa (MGDMU:AEN.E.**23**.7-9;**31**.11).

Measurements (in mm).

n=15	L	W	H	W/L	H/L	LI	LII	LIII	NI	NII	NIII	LK	WK
Range	16-41	13-38	8-30	0.81-0.94	0.50-0.72	9-25	7-28	9-34	19-40	25-45	13-20	2-5	2-5
Mean	23.13	21	14.13	0.90	0.60	9.60	11.60	14	27	32	17.14	3.42	2.70

Description. Test small-to large-sized, polygonal, its maximum height about 60% of posterior test diameter. Adapical surface convex. Adoral surface slightly convex with slight depression around peristome. Posterior margin straight with shallow sulcus below periproct. Anterior margin rounded with slight depression centrally. Apical disc large and centric to slightly eccentric anteriorly. Madreporite well developed and separating the two posterior gonopores. Frontal ambulacrum non-petaloid, ovate, narrower and shallower than the anterior and posterior petals. Poriferous zone narrow. Pores oblique, ovate to short, slit-shaped, and equal. Interporiferous zone wide and covered with dense, small granules. Paired petals petaloid, large, wide, and depressed. Posterior petals slightly shorter and less divergent than anterior ones. Poriferous zones wide, equal, and slightly convergent near apical disc. Pores slit-shaped and slightly conjugated. Peristome medium-sized, sub-rounded, situated nearly one-third (29%) of test length from the anterior end, and surrounded by well developed phyllodal pores (Pl. 34, Fig. 7d). Periproct large, oval, and placed at the top of the posterior margin (Pl. 34, Fig. 7c).

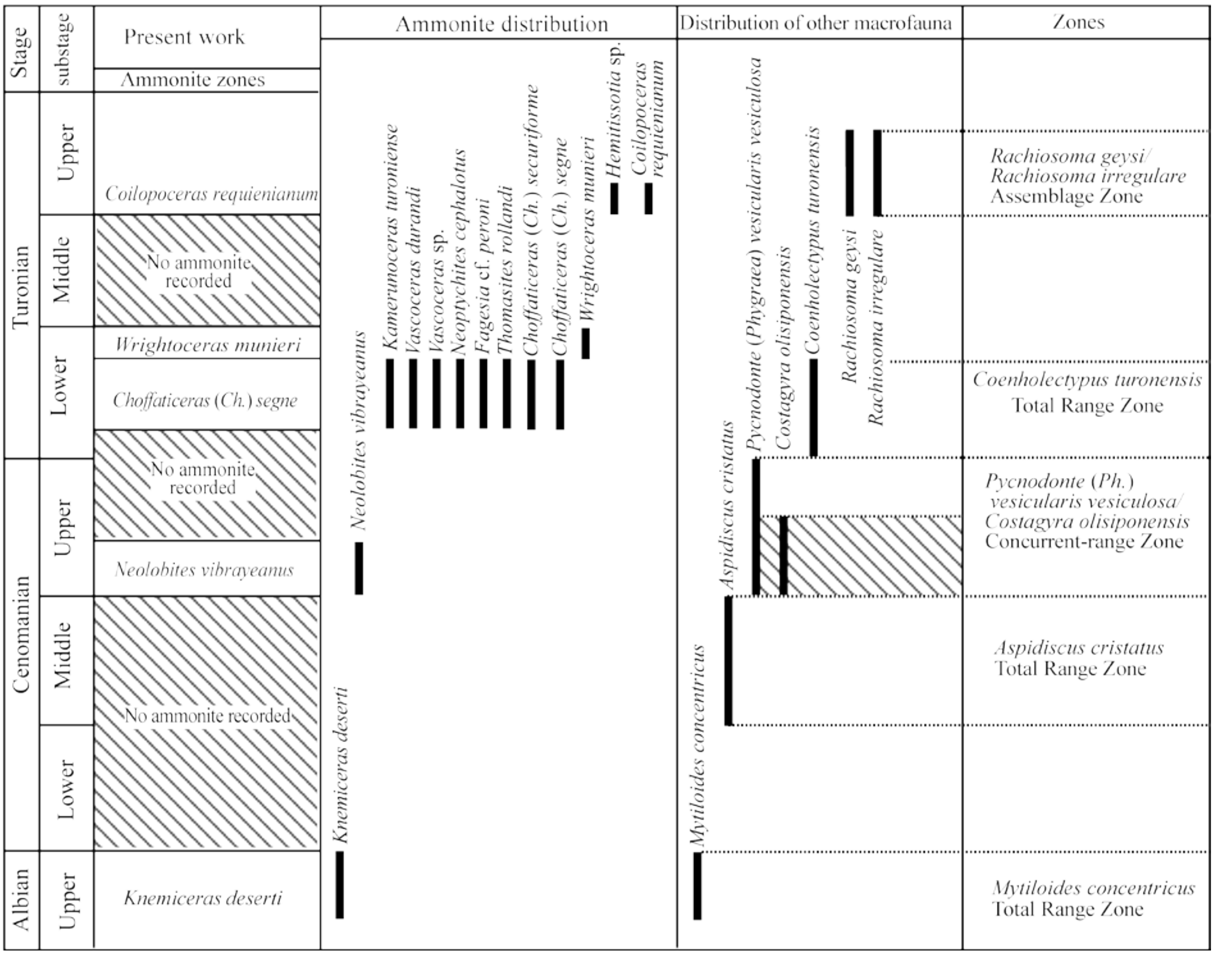
Temporal and spatial distribution. *Hemiaster* (*Mecaster*) *heberti turonensis* has been recorded from the Lower Turonian of Sinai, e.g. Gebel Libni (FOURTAU, 1921), G. El-Hamra, and G. Minsherah (ABDELHAMID & EL QOT, 2001), Wadi Dakhl, W. Abu Qada (ABDELHAMID, 1999), and of G. Ekma, East Themed area, and G. Yelleg (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Discussion. ABDELHAMID & EL QOT (2001) raised the rank of FOURTAU's ''mutatio'' to a subspecies, which differs from *H. heberti* sensu stricto by a higher test and wider and more developed petals. According to them the species differs from *Hemiaster latigrunda* PERON & GAUTHIER (1880) by having shallower paired petals and frontal ambulacrum. The latter species does not have a deeply excavated anterior margin.

4 BIOSTRATIGRAPHY

The stratigraphic distribution of the identified macrofossils enabled the subdivision of the Cenomanian-Turonian succession of the studied sections into ten biozones; five based on ammonites, two on echinoids, two on bivalves, and one on corals (Text-fig. 4.1). Most of the ammonites are preserved as internal moulds; the remaining ones as well as oysters and echinoids are in the shell preservation.

All ammonite zones are total range zones which are marked chiefly by the first occurrence (FO) and last occurrence (LO) of the taxon. The oldest zone is the *Knemiceras deserti* Zone (Upper Albian) from the Halal Formation of Gebel Areif El-Naqa. The lower Upper Cenomanian zone of the Galala Formation (Cenomanian) at the East Themed and Wadi Quseib sections is identified as the *Neolobites vibrayeanus* Zone. In addition, three Turonian ammonite zones have been recorded in the Abu Qada and Wata formations, (1) the Lower Turonian *Choffaticeras* (*Choffaticeras*) *segne* Zone, (2) the upper Lower Turonian *Wrightoceras munieri* Zone, and (3) the lower Upper Turonian *Coilopoceras requienianum* Zone (Text-fig. 4.1). The *W. munieri* and *C. requienianum* zones are separated by a barren interval (Middle Turonian).



Text-fig. 4.1. Proposed ammonite and other macrofossils zones in the study area.

The proposed zones are correlated with the standard ammonite zones of GRASTEIN et al. (2004) from the Western Interior of the United States and the Tethyan region. They are also compared with other ammonite zonal schemes of the adjacent Tethyan regions as well as the Cenomanian-Turonian ammonite zones of the Eastern Desert and the Sinai Peninsula.

In addition, five local biozones have been established for the studied sections on the bases of some macrofossils (bivalves, echinoids, and corals) other than ammonites. They are from base to top, (1) the inoceramid *Mytiloides concentricus* Total Range Zone (Upper Albian), (2) the coral *Aspidiscus cristatus* Total Range Zone (Middle-lower Upper Cenomanian), (3) the Upper Cenomanian oyster *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa/Costagyra olisiponensis* Concurrent-range Zone (from the Wadi Quseib and East Themed sections), (4) the echinoid *Coenholectypus turonensis* Total Range Zone (Lower Turonian), which co-occurs with the *Choffaticeras (Ch.) segne* Zone, and (5) the *Rachiosoma geysi/Rachiosoma irregulare* Assemblage Zone (Upper Turonian), which coincides with the *Coilopoceras requienianum* Zone.

The proposed biozones of are summarized in the following paragraphs.

4.1. Ammonite zones

Knemiceras deserti Zone (Upper Albian)

This is the oldest ammonite zone encountered in the study area. It is defined by the first and last occurrence of the zonal species. The *deserti* Zone is represented by the upper marly part (14 m thick) of the lower marly member of the Halal Formation at Gebel Areif El-Naqa. The *deserti* Zone is not recorded from the other two sections (Wadi Quseib and East Themed). It is associated with the abundant bivalves *Mytiloides concentricus* (PARKINSON), *Pinna* (*Pinna*) sp., *Granocardium* (*G.*) *productum* (J. DE. C SOWERBY), *Arctica*? *rostrata* (FITTON), *Arctica*? *picteti* (COQUAND), *Tenea delettrei* (COQUAND), *Glossus aquilinus* (COQUAND), as well as gastropods *Ampullina* (*Ampullina*) cf. *quaasi* (MAXIA), *Columbellina* (*C.*) *fusiformis* DOUVILLÉ, *Pterodonta deffisi* THOMAS & PERON, and the echinoids *Coenholectypus portentosus* COQUAND and *Hemiaster* (*Mecaster*) *gabrielis* PERON & GAUTHIER.

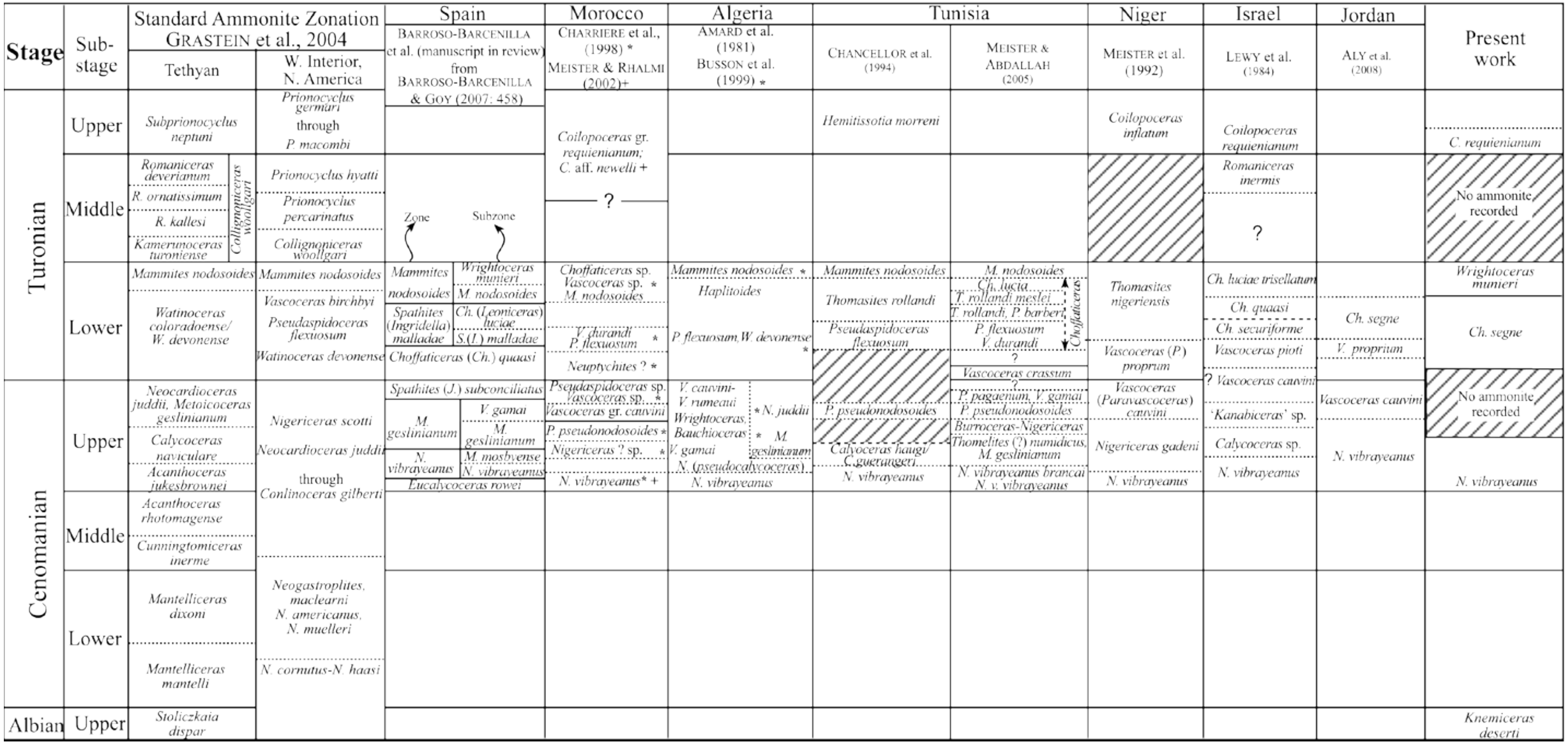
In Egypt, the Early Cretaceous cephalopods of Sinai (e.g., Maghara area) have been described and discussed by many authors e.g., DOUVILLÉ (1916), MAHMOUD (1955), and ABOUL ELA et al. (1991). The Albian-Cenomanian boundary is conventionally placed at the base of the widely recorded ammonite *Mantelliceras mantelli* Zone (BIRKELUND et al., 1984: 10). According to ALI & ABDEL-GAWAD (2001b: 27), the Albian-Cenomanian boundary at Gebel Lagama (North Sinai) is also detected by the last occurrence (LO) of *K. deserti* and the first occurrence (FO) of the Lower Cenomanian *M. mantelli* Zone. Unfortunately, the latter zone is not recorded from the studied sections, but the Cenomanian Stage is defined by the end (last occurrence) of the ammonite *K. deserti* and inoceramid *M. concentricus* zones.

The *deserti* Zone has been also recorded from the Upper Albian of the Maghara area MAHMOUD (1955) and ALI & ABDEL-GAWAD (2001b). Interregionally, this zone is also correlatable to the standard ammonite *Stoliczkaia dispar* Zone from the Tethyan region of GRADSTEIN et al. (2004) (Tables 1, 2).

Neolobites vibrayeanus Zone (lower Upper Cenomanian)

The lower and upper boundaries of this zone are defined by the total range of *Neolobites vibrayeanus* (D'ORBIGNY). The *vibrayeanus* Zone encompasses the upper part of the middle siliciclastic/carbonate member of the Galala Formation at Wadi Quseib and the

Table 1. Interregional correlation of the Cenomanian-Turonian ammonite zones of eastern Sinai.



Stage	Sub-stage	Standard Ammonite Zonation GRASTEIN et al., 2004		Spain	Morocco	Algeria	Tunisia		Niger	Israel	Jordan	Present work
		Tethyan	W. Interior, N. America	BARROSO-BARCENILLA et al. (manuscript in review) from BARROSO-BARCENILLA & GOY (2007: 458)	CHARRIERE et al., (1998) * MEISTER & RHALMI (2002)+	AMARD et al. (1981) BUSSON et al. (1999) *	CHANCELLOR et al. (1994)	MEISTER & ABDALLAH (2005)	MEISTER et al. (1992)	LEWY et al. (1984)	ALY et al. (2008)	
Turonian	Upper	*Subprionocyclus neptuni*	*Prionocyclus germari* through *P. macombi*		*Coilopoceras* gr. *requienianum;* *C.* aff. *newelli* +		*Hemitissotia morreni*		*Coilopoceras inflatum*	*Coilopoceras requienianum*		*C. requienianum*
	Middle	*Romaniceras deverianum* *R. ornatissimum* *R. kallesi* *Kamerunoceras turoniense* *Collignoniceras woollgari*	*Prionocyclus hyatti* *Prionocyclus percarinatus* *Collignoniceras woollgari*	Zone Subzone	?				▨	*Romaniceras inermis* ?		No ammonite recorded
	Lower	*Mammites nodosoides* *Watinoceras coloradoense/ W. devonense*	*Mammites nodosoides* *Vascoceras birchbyi* *Pseudaspidoceras flexuosum* *Watinoceras devonense*	*Mammites nodosoides* *Wrightoceras munieri* *M. nodosoides* *Spathites (Ingridella) malladae* *Ch. (Leoniceras) luciae* *S.(I.) malladae* *Choffaticeras (Ch.) quaasi*	*Choffaticeras* sp. *Vascoceras* sp. * *M. nodosoides* *V. durandi* *P. flexuosum* * *Neuptychites* ? *	*Mammites nodosoides* * *Haplitoides* *P. flexuosum, W. devonense* *	*Mammites nodosoides* *Thomasites rollandi* *Pseudaspidoceras flexuosum* ▨	*M. nodosoides* *Ch. lucia* *T. rollandi meslei* *T. rollandi, P. barberi* *P. flexuosum* *V. durandi* *Choffaticeras* ? *Vascoceras crassum*	*Thomasites nigeriensis* *Vascoceras (P.) proprum*	*Ch. luciae trisellatum* *Ch. quaasi* *Ch. securiforme* *Vascoceras pioti*	*Ch. segne* *V. proprium*	*Wrightoceras munieri* *Ch. segne*
Cenomanian	Upper	*Neocardioceras juddii, Metoicoceras geslinianum* *Calycoceras naviculare* *Acanthoceras jukesbrownei*	*Nigericeras scotti* *Neocardioceras juddii* through *Conlinoceras gilberti*	*Spathites (J.) subconciliatus* *M. geslinianum* *V. gamai* *M. geslinianum* *N. vibrayeanus* *M. mosbyense* *N. vibrayeanus* *Eucalycoceras rowei*	*Pseudaspidoceras* sp. *Vascoceras* sp. * *Vascoceras* gr. *cauvini* *P. pseudonodosoides* * *Nigericeras* ? sp. * *N. vibrayeanus** +	*V. cauvini-* *V. rumeaui* *Wrightoceras, Bauchioceras* * *N. juddii* * *M. geslinianum* *V. gamai* *N. (pseudocalycoceras)* *N. vibrayeanus*	▨ *P. pseudonodosoides* ▨ *Calycoceras haugi/ C. gueranggeri* *N. vibrayeanus*	? *P. pagaenum, V. gamai* *P. pseudonodosoides* *Burroceras-Nigericeras* *Thomelites (?) numidicus, M. geslinianum* *N. vibrayeanus brancai* *N. v. vibrayeanus*	*Vascoceras (Paravascoceras) cauvini* *Nigericeras gadeni* *N. vibrayeanus*	? *Vascoceras cauvini* '*Kanabiceras*' sp. *Calycoceras* sp. *N. vibrayeanus*	*Vascoceras cauvini* *N. vibrayeanus*	No ammonite recorded *N. vibrayeanus*
	Middle	*Acanthoceras rhotomagense* *Cunningtomiceras inerme*										
	Lower	*Mantelliceras dixoni* *Mantelliceras mantelli*	*Neogastroplites, maclearni* *N. americanus,* *N. muelleri* *N. cornutus-N. haasi*									
Albian	Upper	*Stoliczkaia dispar*										*Knemiceras deserti*

Table (2). Correlation of the proposed Cenomanian-Turonian ammonite zones with those proposed by previous authors in Egypt.

Stage	Sub-stage	Eastern Desert					Sinai					Present work
		LUGER & GRÖSCHKE (1989)	KASSAB (1991b)	KASSAB (1996)	HEWAIDY et al. (2003)	ABDEL-GAWAD et al. (2007)	ABDEL-GAWAD (1999) ALI & ABDEL-GAWAD (2001b)*	ALI & ABDEL-GAWAD (2001a) * ABDALLAH et al. (2001)+	KASSAB & OBAIDALLA (2001)	GALAL et al. (2001)	ABDEL-GAWAD et al. (2004a)	
Turonian	Upper		*Coilopoceras requienianum*		*C. requienianum*	*C. requienianum*	Global regressive cycle *Coilopoceras* sp.		*C. requienianum*	*C. requienianum*	*C. requienianum*	*C. requienianum*
	Middle		?		*Hoplitoides ingens*		Local regressive cycle (Red Beds)		?	Barren		No ammonites recorded
	Lower	*Mammites* sp. *Fagesia* cf. *superstes* *Vascoceras durandi*	*Choffaticeras segne* *Pseudaspidoceras flexuosum*	*P. flexuosum/ V. proprium*	*Ch. luciae* *Ch. segne* *V. pioti/V. proprium*	*Ch. segne*	*Mammites nodosoides* *Ch. segne- Thomasites* sp.	*Mammites nodosoides** *Ch. segne* *+ + < *P. flexuosum**/ *V. proprium*	*Ch. segne* *V. proprium / V. obesum*	*Ch. segne* Barren *V. proprium*	*Ch. sinaiticum - Thomasites rollandi* *Ch. segne - V. hartii* *Ch. securiforme - Ch. quaasi*	*Wrightoceras munieri* *Ch. (Ch.) segne*
Cenomanian	Upper	*V. cauvini, V. rumeaui* *V. gamai* *Metengonoceras cf. acutum* *Neolobites vibrayeanus*	*V. cauvini* *Metoicoceras geslinianum* *N. vibrayeanus*	*V. cauvini* *M. geslinianum* *N. vibrayeanus*	*N. vibrayeanus*	*Vascoceras cauvini*	*N. vibrayeanus*	*V. cauvini* *+ *M. geslinianum* * *N. vibrayeanus* *+	*V. cauvini* *N. vibrayeanus*	Undefined	*V. cauvini- P. pseudonodosoides- Rubroceras alatum* *N. vibrayeanus*	No ammonites recorded *N. vibrayeanus*
	Middle					*Acanthoceras amphibolum*						
	Lower						*Mantelliceras mantelli* *					
Albian	Upper						*Knemiceras deserti* *					*Knemiceras deserti*

upper part of the same formation at the East Themed section. It ranges in thickness from 2.5 m in Wadi Quseib (marly limestone) to 5 m in the East Themed section (marl). This zone is not recorded in the northern section (Gebel Areif El-Naqa).

Associated faunal elements are the bivalves *Nuculana* (*Nuculana*) sp., *Pseudolima itieriana* (PICTET & ROUX), *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. DE C. SOWERBY), *Ceratostreon flabellatum* (GOLDFUSS), *Ilymatogyra africana* (LAMARCK), *Plicatula* (*Plicatula*) *auressensis* COQUAND, *Corbula* (*Corbula*) sp., *Granocardium* (*Granocardium*) *productum* (J. DE C. SOWERBY), *Tenea delettrei* (COQUAND), *Glossus aquilinus* (COQUAND), the gastropods *Campanile* (*Campanile*) *ganesha* (NOETLING), *Pterodonta* cf. *subinflata* (COQUAND), *Tylostoma* (*Tylostoma*) *pallaryi* (PERON & FOURTAU), and the echinoid *Hemiaster* (*Hemiaster*) *syriacus* (CONRAD).

The *vibrayeanus* Zone is widely reported in the lower Upper Cenomanian prior to the occurrence of *Metoicoceras geslinianum* (D'ORBIGNY) and *Vascoceras gamai* CHOFFAT of the Middle East, North Africa, and Western Europe (LUGER & GRÖSCHKE, 1989; ABDEL-GAWAD 1999; ALI & ABDEL-GAWAD, 2001a; KASSAB & OBAIDALLA, 2001). It is equivalent to the standard ammonite *Acanthoceras jukesbrownei* Zone from the Tethyan region (GRASTEIN et al., 2004) and the *N. vibrayeanus* Zone of Morocco, Algeria, Tunisia, Niger, Israel, and Jordan by, AMARD et al. (1981), LEWY et al. (1984), MEISTER et al. (1992), CHANCELLAR et al. (1994), MEISTER & RHALMI (2002), and ALI et al. (2008) (Table 1).

In Egypt, it is also correlatable to the Egyptian Eastern Desert *vibrayeanus* Zone by LUGER & GRÖSCHKE (1989), KASSAB (1991b-1996), HEWAIDY et al. (2003), and ABDEL-GAWAD et al. (2007). It is equivalent to the same zone recorded in the Sinai Peninsula by many authors e.g., ABDEL-GAWAD (1999), ALI & ABDEL-GAWAD (2001a), KASSAB & OBAIDALLA (2001), and ABDEL-GAWAD et al. (2004a).

***Choffaticeras* (*Choffaticeras*) *segne* Zone (Lower Turonian)**

The *Ch.* (*Ch.*) *segne* Zone is defined by the total range of the zonal species. It is followed by the *Wrightoceras munieri* Zone (upper Lower Turonian). This zone has been recorded from the Wadi Quseib, East Themed, and Gebel Areif El-Naqa sections. In the Gebel Areif El-Naqa section, it comprises 5 m of marly limestone (lower member of the Abu Qada Formation) and is associated with the other large ammonites *Kamerunoceras turoniense* (D'ORBIGNY), *Neoptychites cephalotus* (COURTILLER), and *Thomasites rollandi* (THOMAS & PERON). The *segne* Zone at East Themed consists of 10 m thick marly limestone to calcareous marl with the large, lanceolate and compressed *Choffaticeras* (*Ch.*) *securiforme* (ECK), which is associated with *Vascoceras durandi* (THOMAS & PERON), *Vascoceras* sp., and *Th. rollandi*. In Wadi Quseib, this zone consists of 4 m marl to marly limestone.

The *segne* Zone is highly fossiliferous with abundant other macrofaunal elements such as the bivalves *Modiolus* (*Modiolus*) *aequalis* (J. DE C. SOWERBY), *Arca* (*Idonearca*) *trigona* (SEGUENZA), *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND), *Phelopteria gravida* (COQUAND), *Plicatula* (*Plicatula*) *ferryi* COQUAND, *Granocardium* (*G.*) *productum* (J. DE C. SOWERBY), *Veniella* cf. *trapezoidalis* (COQUAND), *Paraesa faba* (J. DE C. SOWERBY), *Pholadomya pedernalis* ROEMER, the abundant echinoids *Orthopsis miliaris* (D'ARCHIAC), *Heterodiadema libycum* (AGASSIZ & DESOR), *Coenholectypus turonensis* (DESOR), *Hemiaster* (*Mecaster*) *fourneli* DESHAYES, *H.* (*M.*) *heberti* (COQUAND) *turonensis* FOURTAU, and the gastropods *Cimolithium tenouklense* (COQUAND) and *Tylostoma* (*T.*) *globosum* SHARPE.

The characteristic Turonian *Choffaticeras* fauna has been restricted to the Mediterranean basin (ALY et al., 2008: 54). It is equivalent to the standard ammonite *Watinoceras coloradoense*/*W. devonense* Zone (Tethyan) and the *Vascoceras birchbyi*, *Pseudaspidoceras flexuosum*, and *W. devonense* zones (North America and Western Interior of the United States) of GRADSTEIN et al. (2004), to the *Choffaticeras (Ch.) quaasi* Zone and *Spathites (Ingridella) malladae* Zone (with subzones) of Spain (BARROSO-BARCENILLA & GOY, 2007), and to the *V. pioti*, *Ch. securiforme*, and *Ch. quaasi* zones of Israel (LEWY et al., 1984). It is also correlatable to the *Haplitoides* sp., *P. flexuosum*, and *W. devonense* zones of Algeria (AMARD et al., 1981; BUSSON et al., 1999), to the *P. flexuosum* and *Thomasites rollandi* zones of Tunisia (CHANCELLOR et al., 1994), and to the *V. proprium* and *Ch. segne* zones of Jordan (ALI et al., 2008) (Table 1). In Egypt, the *segne* Zone is equivalent to the *Mammites* sp. and *Fagesia* cf. *superstes* zones of LUGER & GRÖSCHKE (1989) and to the *Ch. segne* and *Ch. luciae* zones of HEWAIDY et al. (2003) and ABDEL-GAWAD et al. (2007) from the Eastern Desert. This zone is also correlatable to the same zone defined in the Lower Turonian of Sinai by many authors (e.g., ABDALLAH et al., 2001; ALY & ABDEL GAWAD, 2001a, and KASSAB & OBAIDALLA, 2001) (Table 2).

Wrightoceras munieri Zone (upper Lower Turonian)

The zone is defined by first occurrence (FO) and last occurrence (LO) of *Wrightoceras munieri* (PERVINQUIÈRE). It consists of 14 m calcareous marl in the upper part of the Lower Turonian Abu Qada Formation at the East Themed area. The *munieri* Zone is followed by the Buttum Formation (barren interval, ISSAWI et al., 1999), which is represented by mid-Turonian regressive siliciclastic red beds (ABDEL-GAWAD, 1999). KASSAB (1991b: 33) recognized an erosion surface at the top of the *Ch. segne* Zone and thus a hiatus with the Upper Turonian ammonite *Coilopoceras requienianum* Zone. In the present study, the gap is associated with this regressive cycle, which started just above the upper Lower Turonian *munierei* Zone and below the lower Upper *requinianum* Zone.

The zone contains the echinoid *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU and the gastropod *Tylostoma* (*Tylostoma*) *globosum* SHARPE.

The *munieri* Zone is equivalent to the standard ammonite *Mammites nodosoides* Zone of the Tethys, North America, and the Western Interior (GRASTEIN et al., 2004) and to the *Wrightoceras munieri* Subzone (of the *M. nodosoides* Zone) of Spain (BARROSO-BARCENILLA & GOY, 2007). It is also correlatable to the *M. nodosoides* Zone of Algeria and Tunisia (BUSSON et al., 1999; CHANCELLOR et al., 1994; and MEISTER & ABDALLAH et al., 2005), to the *Thomasites nigeriensis* Zone of MEISTER et al. (1992) from Niger, and to the *Ch. luciae trisellatum* Zone of Israel (LEWY et al., 1984). The *M. nodosoides* Zone, which has been recorded from Sinai by ABDEL-GAWAD (1999) and ALI & ABDEL-GAWAD (2001a), is also correlatable to the present zone (Table 2).

Coilopoceras requienianum Zone (lower Upper Turonian)

This zone is the latest Turonian ammonite zone encountered in the study area and is defined by the total range of the ammonite *Coilopoceras requienianum* (D'ORBIGNY). This is the only ammonite species recorded in this interval. It attains 11 m at the Wadi Quseib section and is restricted to the marl beds of the Upper Turonian Wata Formation.

Associated faunal elements are the bivalves *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND), *Phelopteria atra* (COQUAND), *Veniella* cf. *trapezoidalis* (COQUAND), *Paraesa faba* (J. DE C. SOWERBY), *Pholadomya fabrina* D'ORBIGNY and the echinoids *Phymosoma abbatei* (GAUTHIER), *Rachiosoma geysi* ABDELHAMID & EL QOT, *Rachiosoma irregulare* FOURTAU, *Hemiaster* (*M.*) *fourneli* (DESHAYES), and *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU.

Many authors correlated this zone with the European *Romaniceras deverianum* Zone on the basis of the common occurrence of *C. requienianum*. According to GRADSTEIN et al. (2004), *R. deverianum* occurs in the upper Middle Turonian. Therefore, ABDEL-GAWAD et al. (2004a) considered *C. requienianum* upper Middle to lower Upper Turonian based on the fact that the *R. devrianum* Zone is of upper Middle Turonian. They also pointed out that this zone does not extend to the uppermost Turonian interval on the basis of two other Turonian biozones (*Cucullaea* (*Idonearca*) *trigona-Rachiosoma geysi* Acme Zone and *Nerinea requieniana* Total Range Zone), overlying the *requienianum* Zone.

The *requienianum* zone is equivalent to the standard ammonite *Subprionocyclus neptuni* Zone of the Tethyan region and to the *Prionocyclus germari* Zone of the Western Interior of GRADSTEIN et al. (2004), to the *Coilopoceras* gr. *requienianum*/*C. aff. newelli* Zone of Morocco (MEISTER & RHALMI, 2002), to the *Coilopoceras inflatum* Zone of Niger (MEISTER et al., 1992), and to the C. *requienianum* Zone of Israel (LEWY et al., 1984). This zone can be also correlated with the ammonite *C. requienianum* Zone of KASSAB (1991b), HEWAIDY et al. (2003), and ABDEL-GAWAD et al. (2007) from the Eastern Desert and of KASSAB & OBAIDALLA (2001), GALAL et al. (2001), and ABDEL-GAWAD et al. (2004a) from Sinai (Table 3).

4.2. Cenomanian-Turonian boundary in East Sinai

Both ammonite and inoceramid species are widely accepted as international zonal markers for definition of the Cenomanian-Turonian boundary (BIRKELUND et al., 1984; KASSAB, 1996; BUSSON et al., 1999; ALY & ABDEL-GAWAD, 2001a). Much attention has been given to the C-T boundary in recent years, partly because there is a widespread marine anoxic event close to the boundary, and a possible mass extinction event near or at the C-T boundary (HANCOCK, 1991; BENGSTON, 1996). KASSAB (1996) noted that the C-T boundary along the Gulf of Suez region is marked also by a drop in diversity (shown by ammonites, bivalves, gastropods, echinoids, and corals). Therefore, a great controversy among stratigraphers is going on about the accurate position of the C-T boundary around the world. For instance, WRIGHT & KENNEDY (1981) suggested that the C-T boundary should be placed between the top of the *Metoicoceras geslinianum* Zone (Upper Cenomanian) and the base of the *Mammites nodosoides* Zone (Lower Turonian). HANCOCK (1991: 273) recommended the bottom of the *Pseudaspidoceras flexuosum* Assemblage Zone as the base of the Turonian. BIRKELUND et al. (1984: 12) suggested several possible boundary levels for definition of the base of the Turonian Stage. They also used the base of *P. flexuosum* in Mexico, Arizona, and California to determine the base of the Turonian Stage. However, they preferred the first appearance of vascoceratids such as *Vascoceras proprium* to define the basal part of the Turonian instead of *P. flexuosum,* because *V. proprium* can be traced to South America and West and North Africa. From these regions it should then be possible to the correlation to Madagascar, Japan, and Europe. BENGSTON (1996) defined the C-T boundary on the basis of the first occurrence of the ammonite *Watinoceras devonense* Zone. In the standard ammonite zonation of GRADSTEIN et al. (2004), *W. coloradoense* and *W.devonense* are combined in one zone to define the base of the Turonian Stage, while *Neocardioceras juddii,* and *Metoicoceras geslinianum* define the Upper Cenomanian Stage (Table 1).

In Egypt, the C-T boundary is generally defined as the interval between the top of the Upper Cenomanian *Neolobites vibrayeanus* Zone and the base of the Lower Turonian *P. flexuosum-Vascoceras proprium* Zone (KASSAB & OBAIDALLA, 2001: 110). Other authors such as ALI & ABDEL-GAWAD (2001a: 25) pointed out that the *Vascoceras cauvini* Zone (above the middle Upper Cenomanian *Metoicoceras geslinianum* Zone) is a typical Tethyan zone and represents the uppermost Cenomanian of Egypt, while the *P. flexuosum* Zone with its associated vascoceratids (e.g. *V. proprium*) is typical of the basal Turonian.

ABDEL-GAWAD (1999) and ALI & ABDEL-GAWAD (2001a) regarded the extinction of the planktonic foraminifer *Rotalipora cushmani* (MORROW) as a widespread event in the

Metoicoceras geslinianum Zone, and strongly recommended that the C-T boundary should be placed at this level.

The Cenomanian-Turonian boundary in the study area is drawn in the lower part of the Abu Qada Formation between the extinction of the oysters *Costagyra olisiponensis* SHARPE, *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (SOWERBY), and *Curvostrea rouvillei* (COQUAND) and the appearance of upper Lower Turonian ammonites such as *Choffaticeras (Ch.) segne* within the base of the ammonite bed. In fact, typical Upper Cenomanian ammonites such as *Metoicoceras geslinianum* (D'ORBIGNY) and *Vascoceras cauvini* CHUDEAU and the lower Lower Turonian ammonites such as *V. proprium* (REYMENT) and *P. flexuosum* POWELL are completely absent in the studied sections. KENNEDY & COBBAN (1991) suggested that the absence of some ammonite zones may reflect the original distribution pattern or post-mortem destruction. KASSAB (1996) and BAUER et al. (2001) argued that the first appearance of the upper Lower Turonian ammonites above the Cenomanian deposits indicates a hiatus between the Cenomanian and Turonian deposits due either to erosion or non-deposition. BARTOV et al. (1980a) had already suggested earlier on that the absence of the earlier Lower Turonian biozones in Sinai and Israel indicates that the study area was a structural high during that time (Syrian Arc System). Similarly, BIRKELUND et al. (1984: 11) found it difficult to detect the C-T boundary in Western Europe due to breaks in sedimentation and widespread condensation around the boundary.

4.3. Zonation based on other macrofossils

The Cenomanian-Turonian succession of the studied sections contains also various other macrofaunal assemblages. Abundant bivalves, gastropods, echinoids, and corals have been collected from the Galala/Halal, Abu Qada, and Wata formations. Based on these macrofaunal assemblages, four local biostratigraphic zones have been recorded, which are, from base to top as follows:

Mytiloides concentricus Total Range Zone (Upper Albian)

This is the oldest bivalve zone recognized in the study area. It is defined by the first and last occurrence of the zonal species *Mytiloides concentricus* (PARKINSON). The *concentricus* Zone is represented by the upper marly part (14 m) of the lower marly member of the Halal Formation at Gebel Areif El-Naqa. This zone co-occurs with the Upper Albian ammonite *Knemiceras deserti* Zone in the same section. The associated faunal elements of the zone are the same those of the *deserti* Zone (see above).

CRAME (1979) pointed out that *Mytiloides concentricus* ranges from the Middle to the Upper Albian of western Europe. In North America, it has beed recorded from the Aptian to the Middle-Upper Albian and range into the Lower Cenomanian (THOMSON & WILLEY, 1972; CRAME, 1979).

The co-occurence of *M. concentricus* and *K. deserti* herein is a good indicator that in Egypt, *M. concentricus* is typically Upper Albian.

The *concentricus* Zone is equivalent to the *Knemiceras deserti* Zone (Upper Albian of the Maghara area) of ALI & ABDEL-GAWAD (2001a) (Table 3) and also to the standard ammonite *Stoliczkaia dispar* Zone from the Tethyan region of GRADSTEIN et al. (2004) (Table 1).

Aspidiscus cristatus Zone (Middle Cenomanian)

This Middle Cenomanian zone is defined by the total range zone of *Aspidiscus cristatus* (LAMARCK). It is represented by the lower part of the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib (8 m of fossiliferous sandy

Table 3 . Correlation of the proposed non-ammonite Cenomanian-Turonian macro-biozones with those proposed by previous authors in Egypt.

Stage	Sub-stage	Sinai						Eastern Desert		Present work
		Kora & Hamama (1987)	Abdel-Gawad et al. (1992)	Ziko et al. (1993)	Zakhera & Kassab (2002a)	Abdel-Gawad et al. (2004a)	Abdel-Gawad et al. (2004b)	Kora et al. (2001)	Abdel-Gawad et al. (2007)	
Turonian	Upper	*Durania humei*	*Modiolus (M.) higazyi*	*Durania*	Barren	*Cucullaea (I.) trigona-Rachiosoma geysi-R. irregulare* *Trochactaeon salomonis*	*Bournonia fourtaui*		*Trochactaeon salomonis*	*Rachiosoma geysi/ Rachiosoma irregulare*
	Middle				*Pycnodonte kansasense/ Flaventia garudana*	*Durinea* spp.-*Praeradiolites* spp.				
	Lower				*Arca passyana* *Inoceramus opalensis elongata*	*Phymosoma abbaei-Tylostoma (T.) globosum* *Hemiaster (M.) heberti turonensis-Coenholectypus turonensis*			*Mytiloides labiatus* = *H. (M.) heberti turonensis-C. turonensis*	*Coenholectypus turonensis*
Cenomanian	Upper	*Exogyra (C.) olisiponensis/ Ilymatogyra africana*	*E. (C.) olisiponensis Crassatella (C.) seguenza, Ambigostrea pseudovillei* *Aspidiscus cristatus*	*E.(C.) olisiponensis* *Pycnodonte vesiculosa*	*P. vesiculosum/E. (C.) olisiponensis* *I. africana/Granocardium bimarginatum* *Ceratostreon flabellatum /Neithea dutrugei*	*Py. (Ph.) vesiculosa/ Rastellum carinatum* *Exogyra (C.) olisiponensis* *Ilymatogyra africana*	*Exogyra (C.) olisiponensis*	*C. olisiponensis* *I. (A.) africana/ Neolobites vibrayeanus* (ammonite)	*P. (Ph.) vesiculosa* *C. olisiponensis* *I. africana*	*Pycnodonte (Ph.) vesicularis vesiculosa/Costagyra olisiponensis*
	Middle					*Ceratostreon flabellatum*	*Amphidonte (C.) flabellatum-Rhynchostreon mermeti*		*Hemiaster (H.) cubicus*	*Aspidiscus cristatus*
	Lower							*Hemiaster (H.) cubicus*		
Alb-ian	Upper									*Mytiloides concentricus*

shale). Associated faunal elements are the bivalves *Ceratostreon flabellatum* (GOLDFUSS), *Ilymatogyra africana* (LAMARCK), *Rhynchostreon suborbiculatum* (LAMARCK), *Paraesa faba* (J. DE D. SOWERBY), and the gastropods *Ampullina* (*Ampullina*) *abeihensis* (HAMLIN) and *Pchelinsevia coquandiana* (D'ORBIGNY).

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According to GILL & CHIKHI (1991), *Aspidiscus cristatus* is concentrated around the Mediterranean with an exceptional abundance in North Africa. In Egypt, ABDEL-GAWAD et al. (1992: 327) and ABDEL-GAWAD & GAMEIL (1995: 23) recorded the species together with *Neolobites vibrayeanus*, which is of early Late Cenomanian Age. In the present study, this species has been recorded from the Galala Formation of Wadi Quseib below the *vibrayeanus* Zone (lower Upper Cenomanian). Therefore, this zone herein is assigned to the Middle-early Late Cenomanian.

The *cristatus* Zone is equivalent to the *Amphidonte* (*Ceratostreon*) *flabellatum* and *Rhynchostreon mermeti* zones from Sinai of ABDEL-GAWAD et al. (2004a, b) and to the *H.* (*H.*) *cubicus* Zone from the Eastern Desert of KORA et al. (2001) and ABDEL-GAWAD et al. (2007) (Table 3).

***Pycnodonte* (*Phygraea*) *vesicularis vesiculosa/Costagyra olisiponensis* Zone (Upper Cenomanian)**

This is the latest Cenomanian zone based on oysters in the present study. It is identified as a concurrent range zone of *Costagyra olisiponensis* (SHARPE) and *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. DE C. SOWERBY). No ammonites are reported in this zone. It encompasses the upper part of the Galala Formation of the East Themed section and is 2.5 m thick. This zone is equivalent to the total range zone of *Costagyra olisiponensis* from the upper part of the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib. The zone is characterized by the presence of other macrofossils, the bivalves *Phelopteria gravida* (COQUAND), *Ceratostreon flabellatum* (GOLDFUSS), *Ilymatogyra africana* (LAMARCK), *Rhynchostreon suborbiculatum* (LAMARCK), *Curvostrea rouvillei* (COQUAND), *Rastellum carinatum* (LAMARCK), *Neithea* (*Neithea*) *coquandi* (PÉRON), *N.* (*N.*) *quinquecostata* (J. SOWERBY), *Corbula* (*Corbula*) sp., *Granocardium* (*Granocardium*) *productum* (J. SOWERBY), *Tenea delettrei* (COQUAND), *Glossus aquilinus* (COQUAND), the gastropods "*Strombus*" *incertus* D'ORBIGNY, *Tylostoma* (*Tylostoma*) *pallaryi* (PERON & FOURTAU), and the echinoid *Hemiaster* (*Hemiaster*) *syriacus* (CONRAD).

The zone has been introduced by ZIKO et al. (1993) and reiterated by ZAKHERA & KASSAB (2002a) from the Upper Cenomanian of Sinai. It is equivalent to the same zone from the Eastern Desert of many authors (e.g., ABDEL-GAWAD et al., 2007). It also correlatable to the *Pycnodonte* (*Phygraea*) *vesiculosa* /*Rastellum carinatum* Zone with the *Exogyra* (*C.*) *olisiponensis* Zone of Sinai by ABDEL-GAWAD et al. (2004a, b) (Table 3).

***Coenholectypus turonensis* Zone (Lower Turonian)**

This zone is defined by the total range of the index species *Coenholectypus turonensis* (DESOR). The *turonensis* Zone is recorded from the Lower Turonian Abu Qada Formation at the East Themed section where it reaches a thickness of 7 m. The zone coincides with the ammonite *Choffaticeras* (*Choffaticers*) *segne* Zone. Therefore, the *turonensis* Zone is assigned an Early Turonian Age. Associated faunal elements are the bivalves *Modiolus* (*Modiolus*) *aequalis* (J. SOWERBY), *Arca* (*Idonearca*) *trigona* (SEGUENZA), *Plicatula* (*Plicatula*) *ferryi* COQUAND, *Veniella* cf. *trapezoidalis* (COQUAND), *Paraesa faba* (J. DE C. SOWERBY), the gastropods *Cimolithium tenouklense* (COQUAND), "*Aporrhais*" sp. 1, *Tylostoma*

(*Tylostoma*) *globosum* SHARPE, and the echinoids *Orthopsis ovata* (COQUAND), *Phymosoma sinaeum* (FOURTAU), and *Hemiaster* (*Mecaster*) *heberti* (COQUAND) *turonensis* FOURTAU.

The zone is equivalent to the *Hemiaster (M.) heberti turonensis-Coenholectypus turonensis* Acme Zone of ABDEL-GAWAD et al. (2004a), and to the *Inoceramus opalensis elongata* Zone of ZAKHERA & KASSAB (2002a) from Sinai. It can be also correlated with the *Mytiloides labiatus* Zone from the Lower Turonian of the Eastern Desert of ABDEL-GAWAD et al. (2007) (Table 3).

***Rachiosoma geysi/Rachiosoma irregulare* Zone (Upper Turonian)**

This zone is the latest Turonian echinoid zone recorded in the present study. It encompasses the lower and middle parts of the Upper Turonian Wata Formation at Wadi Quseib, is represented by 6 m of fossiliferous marl, and coincides with the ammonite *Coilopoceras requienianum* Zone. Therefore, the *geysi/irregulare* Zone is considered herein to be Late Turonian in age. The zone yields besides the two index species the echinoids *Phymosoma abbatei* (GAUTHIER), *Hemiaster* (*M.) fourneli* (DESHAYES), and *Hemiaster* (*M.*) *heberti* (COQUAND) *turonensis* FOURTAU, the bivalves *Cucullaea* (*Idonearca*) *thevestensis* (COQUAND), *Paraesa faba* (J. DE C. SOWERBY), *Pholadomya fabrina* D'ORBIGNY, and the gastropod *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON.

The *geysi/ irregulare* Zone is equivalent to the *Modiolus (M.) higazyi* Zone of ABDEL-GAWAD et al. (1992), to the *Cucullaea (I.) trigona-Rachiosoma geysi-R. irregulare* Zone of ABDEL-GAWAD et al. (2004a) from Sinai, and to the *Trochactaeon salomonis* Zone of ABDEL-GAWAD et al. (2007) from the Eastern Desert.

5 PALAEOECOLOGY

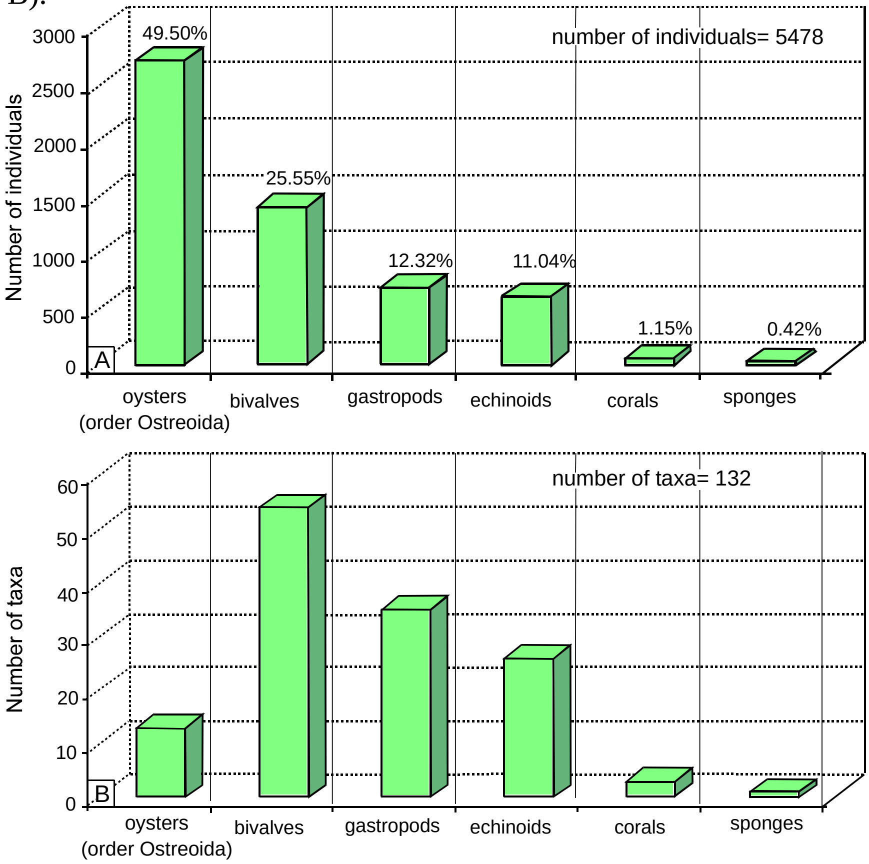
5.1. Faunal composition

The collected benthic fauna consists of altogether 5880 individuals, 5478 of which were included in the ecological analysis. The remaining 402 individuals are represented by cephalopods (ammonites and nautilids). The 5478 individuals represent 132 taxa are distributed among the bivalves, gastropods, echinoids, corals, and coralline sponges as shown in Table 1.

Table 5.1. Distribution of the macrobenthic and nektonic fauna of the Cenomanian-Turonian rocks of eastern Sinai in the various systematic categories.

Benthic fauna	Order/Clade	Family	Genus	Species	Individuals	Remarks
Bivalves	13	28	50	67	4117	Oysters:13 species Clade: order in gastropods
Gastropods	7	19	25	35	675	
Echinoids	8	14	16	26	605	
Corals	1	3	3	3	58	
Coralline sponges	1	1	1	2	23	
Nekton Cephalopods	2	6	12	14	402	ammonites and nautilids

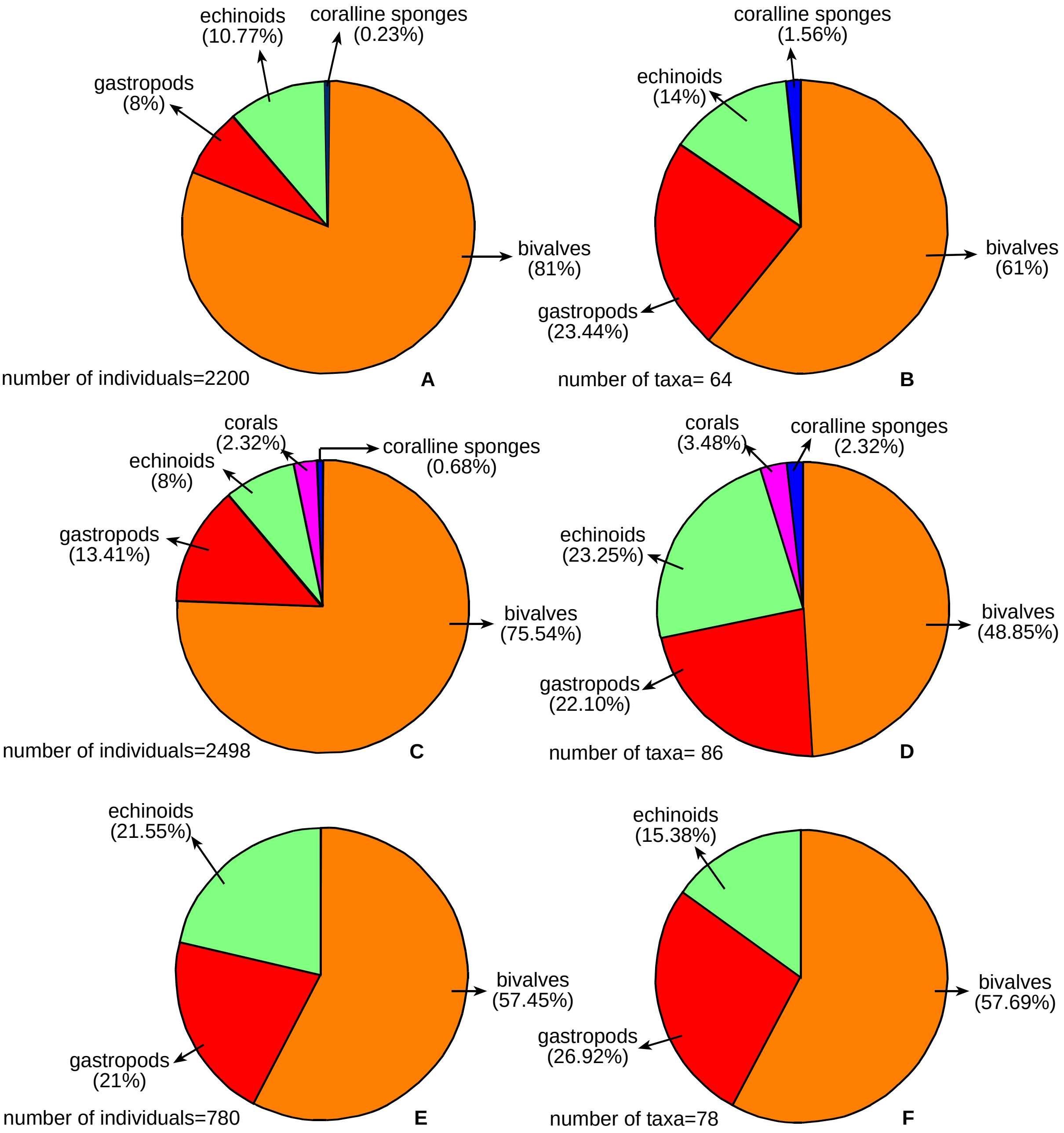
Among the benthic fauna, bivalves dominate in terms of taxa as well as individuals (81% of the total macrofauna at East Themed, 75.54% at Wadi Quseib, 57% at Gebel Areif El-Naqa; Text-fig. 5.1A-B).



Text-fig. 5.1. Distribution of the macrobenthic fauna in the terms of individuals (A) and taxa (B) in the Cenomanian-Turonian succession of the studied sections. Oysters are separately shown because of their high abundance.

In terms of relative abundance, gastropods occupy the second position in the three studied sections. In Wadi Quseib, 13.41% of the species are gastropods, in Gebel Areif El-Naqa 21%, and in the East Themed area 8% (average: 14.13%; Text-fig 5.2.). 605 individuals and 26 species of echinoids were collected (20 species from the Wadi Quseib section, 12 from Gebel Areif El-Naqa, and 9 from the East Themed area). Text-fig. 5.2 shows the composition of the macrobenthic fauna (in %) of the three sections.

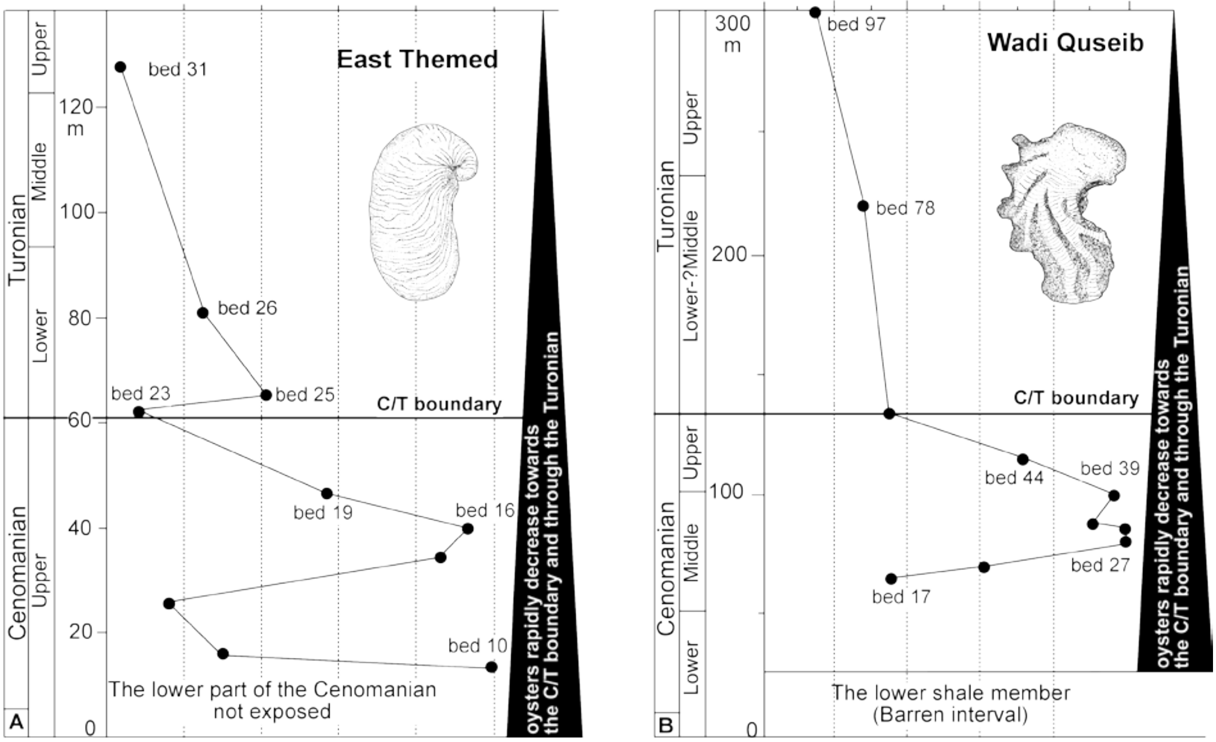
The lower shale member (33.5 m) of the Cenomanian Galala Formation of Wadi Quseib consists mainly of ochre shale with intercalations of fine- to coarse-grained sandstone and thin reddish clay horizons. The shale beds are varicoloured, glauconitic, gypsiferous, highly fissile, and lack any macrobenthic fauna. This facies represents a marginal-marine environment with a semi-arid to arid climate. The area was affected by small-scale sea level



Text-fig. 5.2. Composition of the benthic macrofauna (number of taxa and number of individuals) from the Cenomanian-Turonian rocks of the East Themed area (A-B), Wadi Quseib (C-D), and Gebel Areif El-Naqa (E-F).

fluctuations with lowstands causing subaerial exposure as documented by thin paleosoils. These unfavourable ecological conditions explain the complete absence of marine macrofossils in this member.

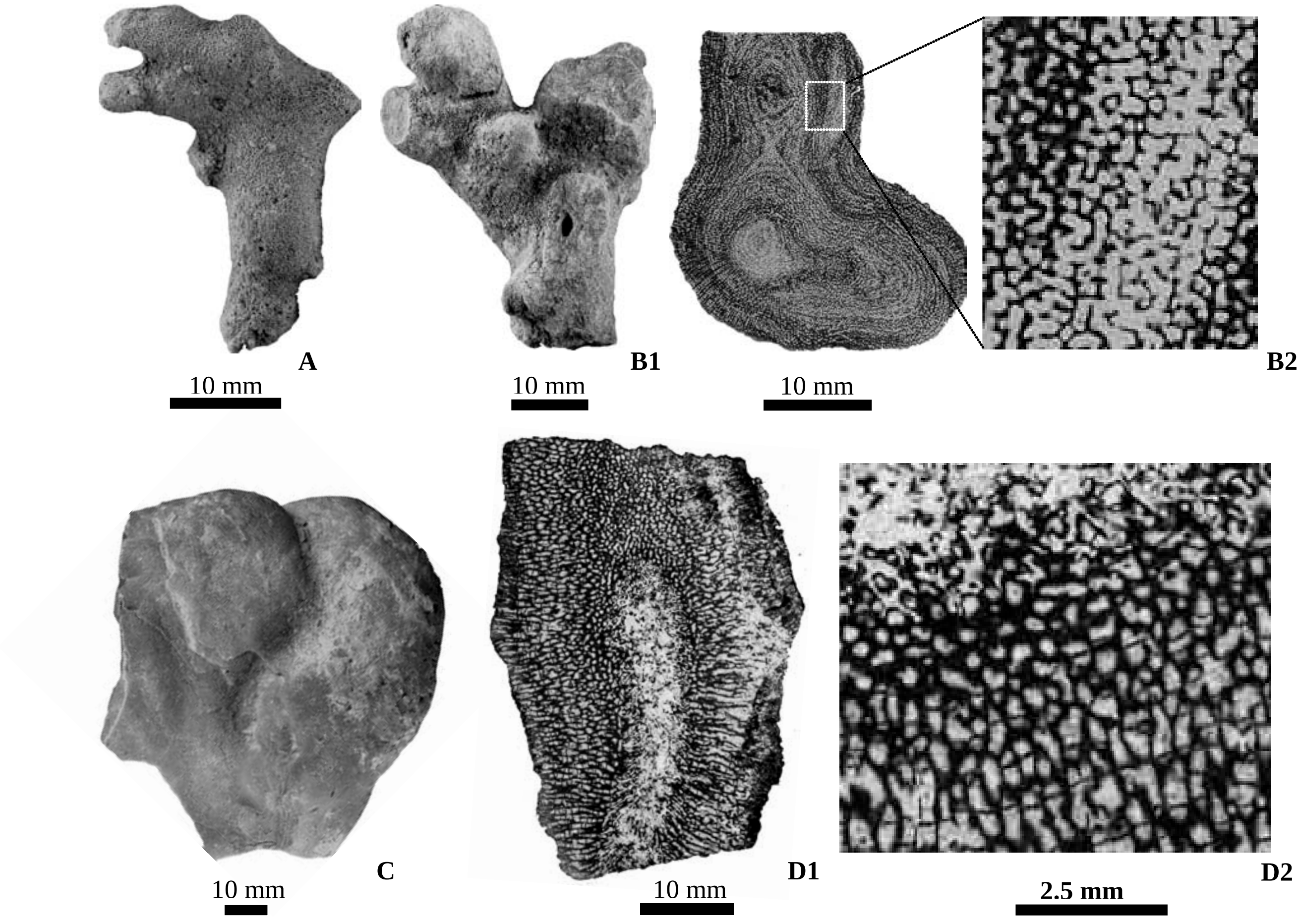
The oysters are dominated by genera of the subfamily Exogyrinae (*Exogyra*, *Costagyra*, *Ceratostreon*, *Ilymatogyra*, and *Rhynchostreon*) and of the subfamily Liostreinae (*Curvostrea*, *Gyrostrea*, *Ambigostrea*, *Lopha*, and *Rastellum*). In the Cenomanian Halal/Galala Formation oysters are concentrated in many layers (49.50% of the total number of individuals; Text-fig. 5.1A) and generally represent shallow-marine environments. In the Lower Turonian Abu Qada Formation, oysters become rarer and eventually vanish (Text-fig. 5.3A-B).



Text-fig. 5.3. Distribution of oysters (in %) along the Cenomanian-Turonian successions of the East themed (A) and Wadi Quseib (B) sections.

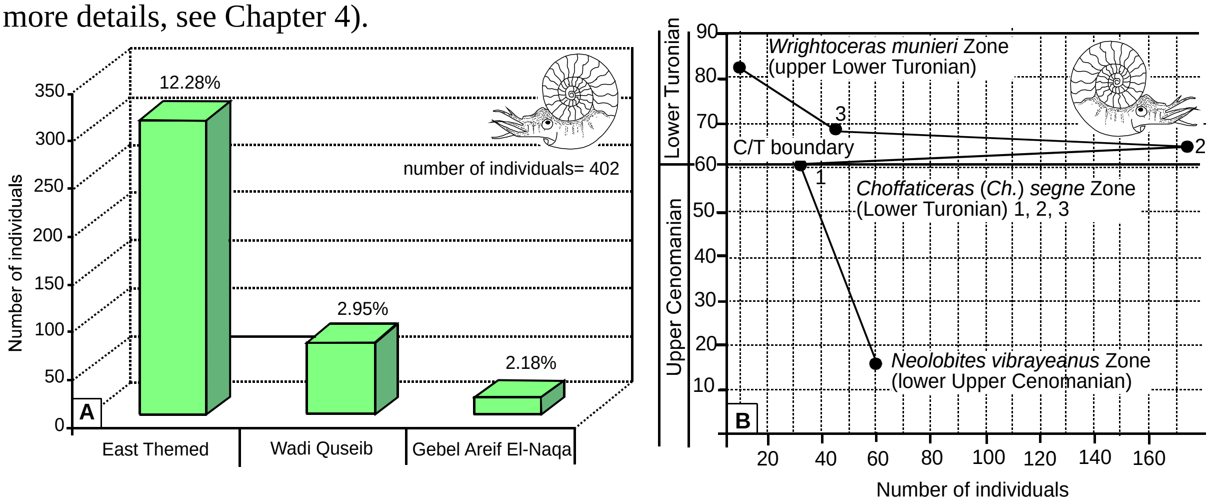
In spite of minor variations, the three sections show a general trend: The Cenomanian is characterized by fluctuating numbers of individuals including the highest ones, while abundances rapidly decrease towards the Cenomanian-Turonian boundary (Text-fig. 5.3A-B), remaining at low levels throughout the Turonian. Minor fluctuations in numbers of individuals in the Cenomanian are observed at different levels in the three sections, thus indicating small-scale variations of environmental conditions. The generally low abundances in the Turonian compared to the Cenomanian document a regional deterioration for oyster life. According to STENZEL (1971), BOTTJER (1981), and DHONDT et al. (1999), exogyrine oysters such as *Ceratostreon*, *Ilymatogyra* and *Rhynchostreon* preferred shallow waters, i.e., mid-shelf environments (25-50 m in depth). Hence, the global sea-level rise at the Cenomanian-Turonian boundary drowned the oyster habitats below optimum water depth. In addition, DHONDT et al. (1999) observed the same situation on Turonian oysters of North Africa.

Corals and coralline sponges are minor components of the benthic fauna (Text-fig. 5.2A-D). Among the corals, 58 individuals and three species were identified and systematically described from the Cenomanian Galala Formation of Wadi Quseib (2.32% of the total benthic fauna). No corals have been recorded until now from the Gebel Areif El-Naqa and East Themed sections. Coralline sponges were collected from the same formation of the Wadi Quseib and East Themed sections. They are not described in the taxonomic part of this study. Due to the lack of a spicular framework in the present material and their superficial resemblance to corals, the coralline sponges could not be determined accurately. Based on their general outline and internal microstructures the individuals of the present material belong to calcified desmosponges (Class Demospongiae SOLLAS, 1875; family Actionstromarianinidae WOOD, 1987) which possess long, thin, radially arranged styles or tylostyles (WOOD,1987: 74). Two basic morphotypes occur in the studied material: an encrusting nodular type (up to 12 cm in diameter) and a dendroid type (up to 7 cm height) showing a fine polygonal meshwork on the surface. Based on the cellular microstructure of both types which resembles the genus *Actinostromarianina* LECOMPTE (1952), two taxa can be questionably recognized as *Actinostromarianina*? sp. 1 (Text-fig. 5.4A-B) and *Actinostromarianina*? sp. 2 (Text-fig. 5.4C-D).



Text-fig. 5.4. A-B. *Actinostromarianina*? sp. 1 from the Upper Turonian Wata Formation of the East Themed area. A-B1. Gross morphology showing dendroid form. B2. Transverse cross-section showing the reticulate arrangement of pillars and continuous latilaminae as well as an irregular network of pillars in the center. C-D. *Actinostromarianina*? sp. 2 from the Cenomanian Galala Formation of Wadi Quseib. C. Nodular gross morphology, D. Longitudinal section showing the radial skeletal arrangement, reticulate network of thick pillars and thin tabulae.

Ammonites represent 12.28% of the total number of individuals from the East Themed area, 2.95% at Wadi Quseib and 2.18% at Gebel Areif El-Naqa (Text-fig. 5.5A). In the present study they are excluded from the ecological analysis because their mode of life and feeding mode are not completely understood (WIGNALL 1990: 12). Ammonites are used to subdivide the Cenomanian-Turonian succession of the studied sections into five biozones (for more details, see Chapter 4).

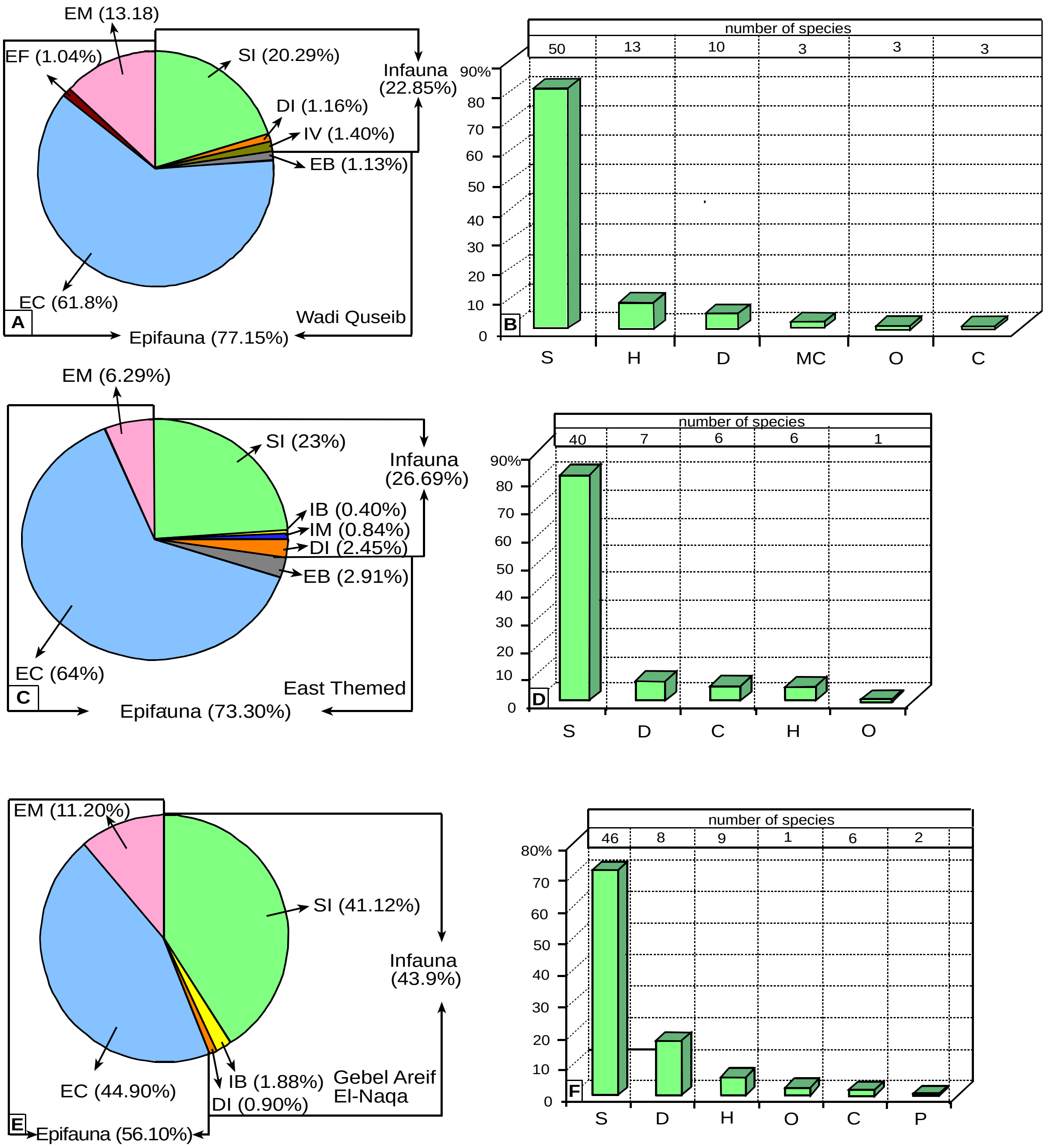


Text-fig. 5.5. A. Distribution of cephalopods (nautilids and ammonites) in the three sections. The percentage refers to the total macrofauna. B. C/T boundary in the East Themed section based on ammonite zones and abundance of ammonites across the boundary.

According to life habits, 77.15% of the species of the benthic fauna in Wadi Quseib, 73.30% in East Themed, and 56.10% in Gebel Areif El-Naqa were living epifaunally. Most of the epifaunal organisms are cemented on firm substratum (on average around 60%; see Text-fig. 5.6A, C, E). The Wadi Quseib and East Themed sections show nearly equal numbers of infaunal organisms (22.85% and 26.69%, respectively; Text-fig. 5.6A, C) which are mostly represented by shallow-infaunal taxa. In the deeper-water section further to the north (Gebel Areif El-Naqa), infaunal organisms comprise as much as 43.9% of the individuals (Text-fig. 5.6E). A conspicuous majority of epifaunal forms is represented by suspension-feeders. The latter dominate by far (78.17% on average) in the three sections, while deposit-feeders, herbivores, microcarnivores, omnivores, and others occur subordinately (Text-fig. 5.6B, D, F).

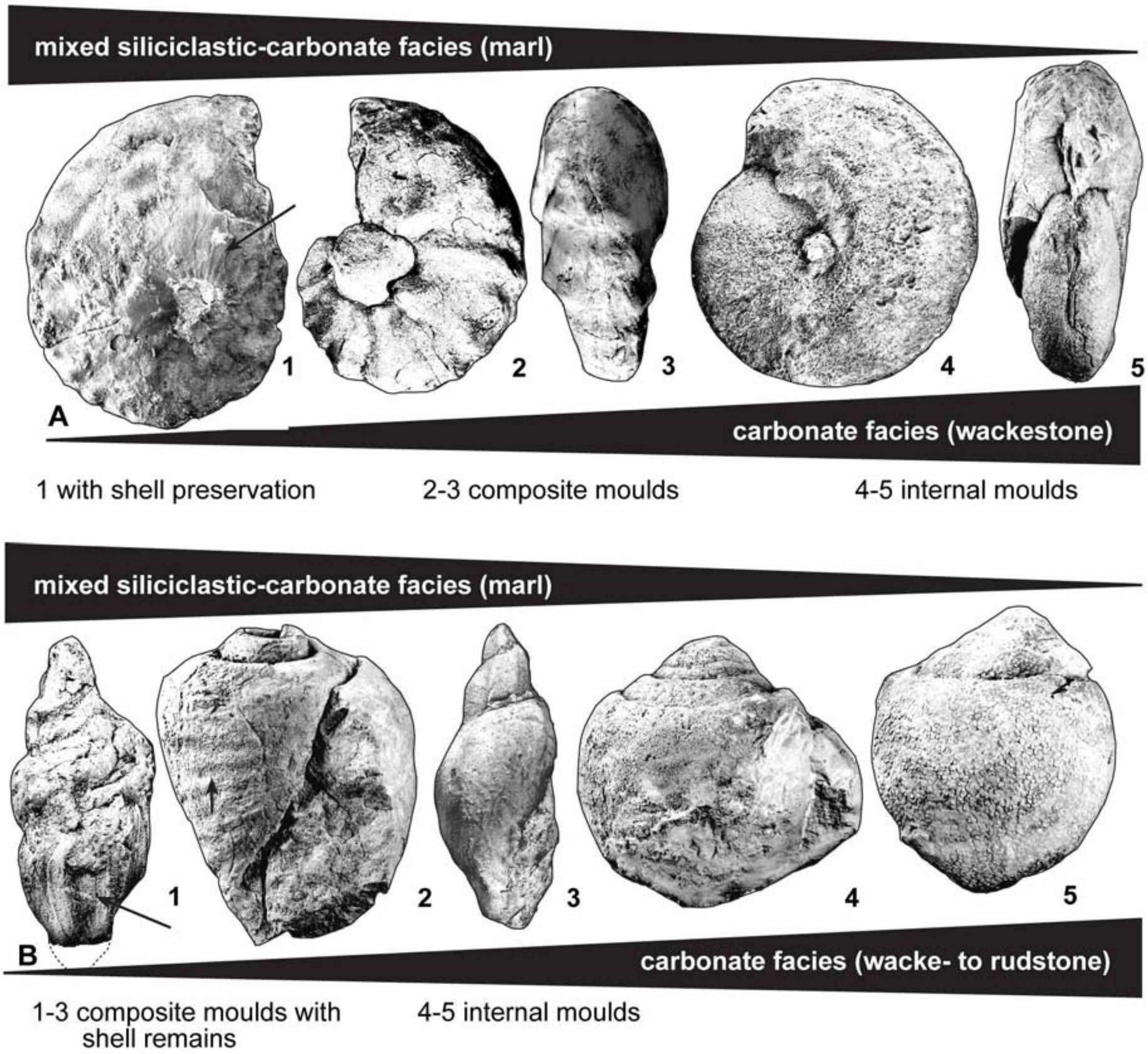
5.2. Preservational aspects

Due to diagenetic processes, the preservation of the faunal elements is, in general, poor. Aragonitic faunal elements are usually preserved as steinkerns or moulds. This is particularly true of shallow and deep infaunal bivalves (e.g., Lucinidae), because their shells have been entirely dissolved early on during diagenesis. The only faunal elements with well-preserved shell structures are calcitic taxa such as infaunal and epifaunal echinoids and epifaunal, thick-shelled oysters and plicatulid bivalves. Corals are partially recrystallized. Most of nektonic ammonites and nautilids are preserved as internal moulds in limestones, others e.g. *Thomasites rollandi* (THOMAS & PERON, 1889) from the mixed siliciclastic-carbonate facies (marl) in the East Themed area (bed 26), occur in shell preservation and as composite moulds (Text-fig. 5.7A). In contrast, *T. rollandi* from limestone facies (e.g. wackestone) are usually preserved as internal moulds. Gastropods are mostly complete and preserved as internal moulds except for large nerineids, which are commonly fragmented. Some gastropods from marl are also preserved as composite moulds, e.g. *“Strombus” incertus* (D’ORBIGNY, 1842) (Text-fig. 5.7B). In the case of internal mould preservation, most gastropods and some infaunal bivalves could only be identified at the generic level. Most Upper Cretaceous gastropods from North Africa and Middle East (e.g., Egypt, Algeria,



Text-Fig. 5.6. Life habits and modes of feeding of the Cenomanian-Turonian macrobenthic fauna of the three sections. See Table 2 for abbreviations. A-B. Wadi Quseib, C-D. East Themed, E-F. Gebel Areif El-Naqa.

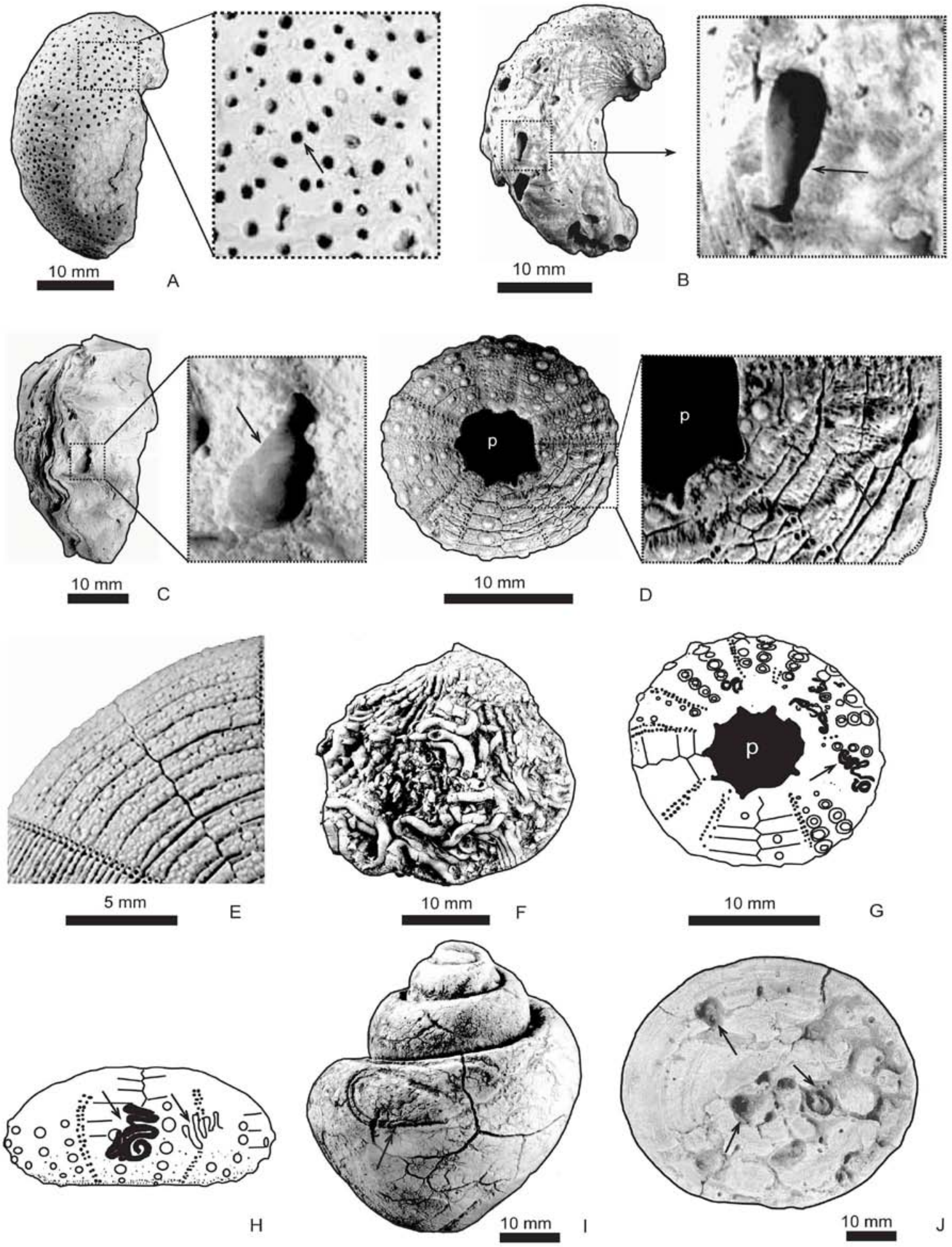
Tunisia, Lebanon) are preserved as internal and composite moulds (see COQUAND, 1862; PERVINQUIÈRE, 1912; GRECO, 1916; DELPEY, 1939; AMARD et al., 1981; ZAKHERA, 2002; EL QOT, 2006), while during the same time interval most of the European gastropods (e.g., in Germany) occur in shell preservation (KIEL & BANDEL, 2002). Apparently, the tectonic setting and facies type played an important role in the shell preservation. According to KUSS & BACHMANN (1996: 919) and BAUER et al. (2003: 388) the "Syrian Arc System" exerted a strong structural control sedimentation in the northeastern African from the Mesozoic to the Early Tertiary (see Chapter 1 for details). In addition, the aragonitic shells of gastropod species are metastable at normal surface temperatures/pressure conditions and thus are prone to freshwater alteration. According to WIGNALL (1989), a good preservational state may be a result of high sedimentation rates combined with frequent episodic burial, protecting the shells from diagenetic alteration. In summary, the sedimentation rate, burial events, facies type, shell fabric and mineralogy, and the tectonic setting are the main important factors controlling the preservational state of the faunal elements in particular of gastropods and heterodont bivalves.



Text-fig. 5.7. Relationship between preservation quality of molluscs and facies. A. The ammonite *Thomasites rollandi* (Thomas & Peron, 1889) (1-5). B. Gastropods, 1. *Fasciolaria tournoueri* Thomas & Peron, 1889, 2. *"Strombus" incertus* (d'Orbigny, 1842), 3. *Columbellina* (*Columbellina*) *fusiformis* Douvillé, 1916, 4-5. *Tylostoma* (*Tylostoma*) *globosum* Sharpe, 1849. Both figures illustrate a better preservation quality in the mixed siliciclastic-carbonate facies compared to the carbonate facies. All photos without scale.

5.3. Taphonomic observations

Some oyster shells and the echinoid tests (e.g., *Heterodiadema libycum* and *Coenholectypus larteti*) from the Cenomanian Halal and Galala formations have been bioeroded and encrusted. Some of the oysters such as *Ceratostreon flabellatum* and *Rhynchostreon suborbiculatum* exhibit micro- and macroborings (Text-fig. 5.8). As oyster shells in general are quite thick, borings are widely distributed on their shells. Most common are small, round, and closely spaced chambers of the ichnogenus *Entobia* Bronn, 1837, a product of clionid sponges which are restricted to fully lithified calcareous substrates (e.g., Bromley & d'Alessandro, 1984; Text-fig. 5.8A).



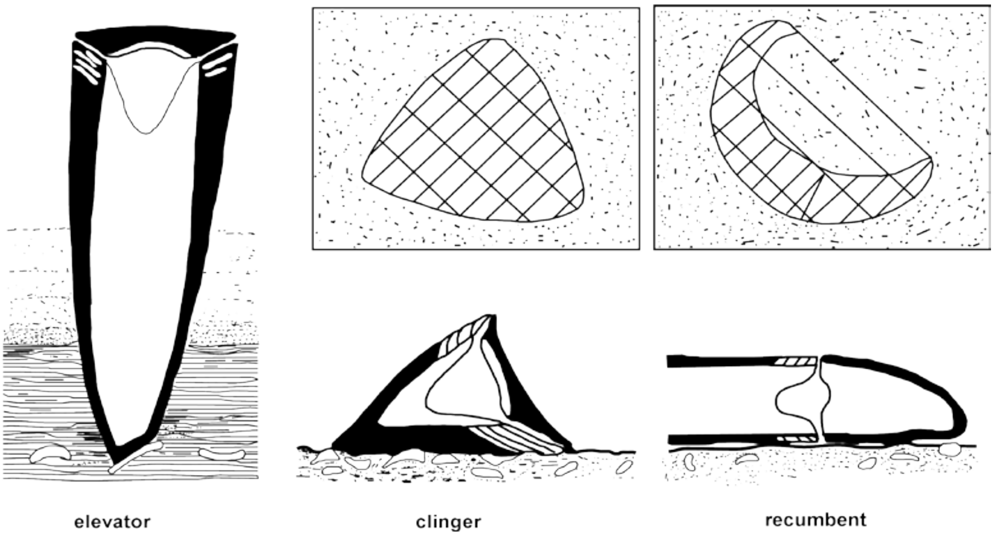
Text-fig. 5.8. Oysters, gastropods, echinoids, and corals with epibionts and endobionts (trace fossils). A. *Ilymatogyra africana* (LAMARCK, 1801) with *Entobia* BRONN, 1837. B. *Ceratostreon flabellatum* (GOLDFUSS, 1833) with comma-shaped apertures of acrothoracican barnacles. C. *C. flabellatum* with club-shaped chamber of the ichnogenus *Gastrochaenolites* LEYMARIE, 1842. D. *Heterodiadema libycum* (AGASSIZ & DESOR, 1846) with scratch marks of grazing gastropods. E. *Coenholectypus larteti* (COTTEAU, 1869) with microborings (?*Entobia*) F. *Plicatula* (*Plicatula*) *ferryi* COQUAND, 1862 encrusted with *Serpula* (*Cycloserpula*) sp. G-H. *H. libycum* encrusted with *Serpula* (*Cycloserpula*) sp. I. *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON, 1889 with traces of serpulids. J. The lower surface of coral *Aspidiscus cristatus* with large bores (diameter ranges from 4 to 8 mm). All material are from the Cenomanian Halal and Galala formations at Gebel Areif El-Naqa and East Themed. P. peristome (in echinoid).

A few oysters exhibit small pouch-shaped borings with comma-shaped apertures made by acrothoracican barnacles (e.g., LAMBERS & BOEKSCHOTEN, 1986; Text-fig. 5.8B). These borings extend obliquely from the upper surface of *C. flabellatum*. The latter species also carries club-shaped chambers produced by bivalves, which belong to the ichnogenus *Gastrochaenolites* LEYMARIE, 1842 (Text-fig. 5.8C). Most of the tests of epifaunal echinoids, such as *H. libycum* and *C. larteti* exhibit scratch marks of grazing gastropods along the ambitus and oral surface and small pores (*Entobia*?) (Text-fig. 5.8D-E). A common epibiont on echinoid tests and plicatulid valves is the serpulid *Serpula* (*Cycloserpula*) sp. (Text-fig. 5.8F-H). The encrusters started to grow after the death of the echinoids, because the echinoid tests were covered by tissue during life-time. Furthermore, the presence of serpulid worms on the adoral surface of the echinoid *H. libycum* clearly indicates post-mortem encrustation. Other echinoid species, e.g. *H.* (*H.*) *gabrielis* (78 individuals) from the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Areif El-Naqa lack any sign of bioeroders or encrusters. This suggests a short residence time of the tests on the sea floor. Few gastropods are also encrusted by serpulids (Text-fig. 5.8I). Most specimens of the coral *Aspidiscus cristatus* are also highly bioeroded (large bores), both on upper and lower surfaces (Text-fig. 5.8J). In addition, a few specimens are encrusted by oysters and serpulids. These features record a subsequent increase of the energy level, sufficient to dislodge the colonies.

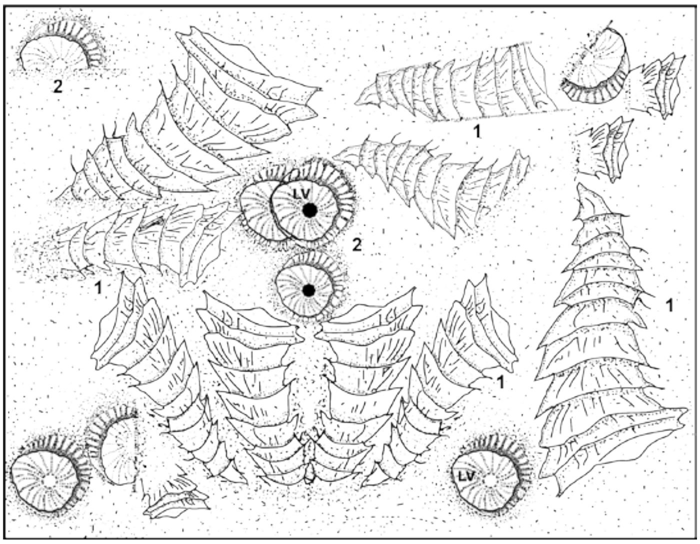
Apart from *Costagyra olisiponensis/Ceratostreon flabellatum* association, epifaunal oysters occur single-valved or articulated but mostly disarticulated and in a convex-up orientation. The degree of disarticulation is a reliable tool for determining the relative amount of reworking after death (BOUCOT et al., 1958). Consequently, these oysters rarely occur in situ, but commonly have been transported for a short distance under a moderately high energy regime, i.e., they are parautochthonous. Shell concentrations on bedding planes in the Cenomanian Galala Formation of Wadi Quseib consisting of *Chondrodonta* and disarticulated *Plicatula* from the same section are the result of higher water energy.

5.4. Autecology

Autecology is the study of the ecology of individual organisms and roughly equals to the term “mode of life” (WIGNALL, 1990: 11). The fossilized hard parts of organisms commonly reflect their mode of life (functional morphology). The autecology of the bivalves was therefore derived from analyzing the function of hard parts and from comparison with Recent species (STANLEY 1970, 1972). For gastropods, however, this concept is difficult to apply, because there is little relationship between shell morphology and mode of life. For instance, BARKER (1990) noted that all modern high-spired gastropods are at least partially infaunal. This may indicate that high-spired shell shape is advantageous for burrowing mode of life. In fact, not all burrowing gastropods are high spired, however, and it has been pointed out that by no means all high-spired forms are infaunal (e.g., WAITE et al., 2008: 553). The autecology of bivalves is best understood due to the large number of extant forms and extensive previous research. For instance, Upper Jurassic taxa have been discussed in some detail by WRIGHT (1974), FÜRSICH (1976, 1977, 1978, 1980, 1981, 1982, 1984, 1994), FÜRSICH & OSCHMANN (1986a, b), FÜRSICH & WERNER (1984, 1986, 1991), ABERHAN (1992, 1993a & b, 1994), ABERHAN & FÜRSICH (1997), FÜRSICH et al. (1995, 2001) and SCHOLZ et al. (2008). Most autecological data of the present study are based on these studies, assuming a similar mode of life for the Cretaceous taxa (Table 2). Rudists are an important group of fossil bivalves, common of a same levels (e.g., *Praeradiolites biskraensis* assemblage). They were sessile, epifaunal, suspension-feeders flourishing in many Cretaceous Tethyan shallow marine benthic communities (e.g., ROSS & SKELTON, 1993; STEUBER & LÖSER, 2000). Three ecological rudist morphotypes were recognized by SKELTON & GILI (1991): elevators (e.g., radiolitids), clingers (e.g., requieniids), and recumbents (e.g., caprinids) (Text-fig. 5.9). According to CESTARI & SARTORIO (1995: 54) and STEUBER & LÖSER (2000: 76), they were gregarious sediment dwellers, growing as single individuals or in associations with their shells being commonly in contact with each other. Some rudist groups lived partially buried in the sediments with a growth rate such as to overcome the sedimentation rate (annual growth rates up to 54 mm; STEUBER, 1996). In the studied sections, the rudists are either well-preserved or occur as disarticulated valves (scattered isolated and/or small bouquet elevators with a few fragments) in limestones (Text-fig. 5.10). In addition, most radiolitids are represented by large, conical, attached valves (right valve), whereas the left valves are rare or entirely missing. Some are preserved in life position, while the majority of valves are tilted, i.e. they are parautochthonous, indicating an environment of moderate current energy. The rare to missing light and small left valves (free valve) are evidence of sorting.



Text-fig. 5.9. Classification of rudist ecological morphotypes according to SKELTON & GILI (1991). Clinger and recumbents shown in plan view from above (hatched area of contact with the substrate) and profile below.



Text-fig. 5.10. Sketch showing a bedding plane with right valves of the elevator *Radiolites sauvagesi* (D'HOMBRES-FIRMAS) occurring scattered and as small bouquet. Lower Turonian Abu Qada Formation at Wadi Quseib. 1= right valves (RV), 2= valves in life position, topped by left valve (LV).

In the case of gastropods, the autecological data are very incomplete due to the difficulty to deduce the mode of life from their morphology. For instance, the Recent aporrhaid, e.g. genus *Aporrhais*, is an infaunal form, deriving food from suspension as well as from the surface sediments (YONGE, 1937); however, it may seasonally change its mode of feeding by becoming an epifaunal deposit-feeders (PERRON, 1978). Moreover, commonly species of the same genus occupy completely different niches. Therefore, some autecological data of gastropods in the present study were gained by comparison with Recent relatives.

Echinoids are conspicuous and important elements of Upper Cretaceous faunas and serve as valuable palaeoenvironmental indicators, because they are often highly facies-controlled (SMITH et al., 1988; SMITH & BENGTSON, 1991). Irregular echinoids are deposit-feeders that live within the sediment and are exclusively microphagous being able to ingest only small nutrient-bearing particles (DE RIDDER & LAWRENCE, 1982; SMITH, 1995). This feeding behaviour implies a specialization of the body form and appendages for feeding and for moving on or within soft sediments (KIER, 1974; SMITH, 1981; KANAZAWA, 1992; TELFORD & MOOI, 1996). According to SMITH (1984, 1995), SMITH et al. (1988, 1995), JAGT (2000), and SAUCÈDE et al. (2003) all regular echinoids are epifaunal, grazing and browsing rocky substrates. The taxonomy and palaeoecology of the Upper Cretaceous echinoids from eastern Sinai has been discussed by EL QOT et al. (2009).

The coral species *Aspidiscus cristatus* from the Cenomanian Galala Formation of Wadi Quseib forms dome-shaped colonies with a flat or slightly concave lower surface and a circular cross-section. The base is covered with a holotheca showing concentric folds and grooves. It lacks an attachment area and apparently has acquired the ability to move on soft substrates (GILL & CHIKHI, 1991). During its early ontogenetic stage, however, the colony probably lived attached to hard objects such as detrital grains or fossil fragments. During subsequent ontogenetic stages the concave to flat lower surface served to stabilize the colony on the substrate. *Aspidiscus cristatus* seems to have been highly facies-controlled and adapted to low energy, fine-grained, soft substrates and to high sedimentation rates.

FÜRSICH & WERNER (1991: 62) subdivided coralline sponges into five morphotypes: cylinders and half cylinders, dendroid forms, cushions, fans, and globular forms. In the Wadi Quseib and East Themed sections, coralline sponges occur scattered in small clumps on hard substrates, showing dendroid and globular morphotypes. According to observations on Recent demosponges, sedimentation rate is a very important factor with low rates favouring sponge growth. In addition, coralline sponges are suspension-feeders, requiring hard substrates.

A complete list of taxa occurring in the study area including information on life habits and feeding modes is given in Table 2.

Table. 5.2. List of the macrobenthic fauna of the Cenomanian-Turonian of Eastern Sinai, Egypt including autecological data (life habits and feeding modes). Life habits: SI=shallow-infaunal; DI=deep infaunal; EC=epifaunal cement; EB=epifaunal byssate; EM=epifaunal mobile; EF=epifaunal free living; IB=semi-infaunal byssate; IM=infaunal mobile. Feeding modes: S=suspension-feeding; G=grazing; D=deposit-feeding; H=herbivorous; O=omnivorous; C=carnivorous; MC=microcarnivorous; Cs=chemosymbionts.

Family	Species	Life habit	Feeding mode
1-Bivalves			
Nuculidae	*Nucula* (*N.*) *margaritifera*	SI	D
Nuculanidae	*Nuculana* (*Nuculana*) sp.	SI	D
Mytilidae	*Mytilus* cf. *bussoni*	EB	S
	Inoperna flagellifera	IB	S
	Modiolus (*M.*) *aequalis*	IB	S

Arcidae	*Arca* (*Idonearca*) *diceras*	EB	S
	Cucullaea (*Idonearca*) *trigona*	SI	S
	Cucullaea (*I.*) *thevestensis*	SI	S
	Cucullaea? cf. *favrei*	SI	S
Inoceramidae	*Mytiloides concentricus*	IB	S
Bakevelliidae	*Phelopteria atra*	EB	S
	Phelopteria gravida	EB	S
Malleidae	*Nayadina* (*Nayadina*) *gaudryi*	EB	S
Pinnidae	*Pinna* (*Pinna*) sp.	IB	S
Limidae	*Pseudolima itieriana*	EB	S
Gryphaeidae	*Pycnodonte* (*P.*) *vesiculosa*	EC	S
	Exogyra conica	EC	S
	Costagyra olisiponensis	EC	S
	Ceratostreon flabellatum	EC	S
	Ilymatogyra africana	EC/EF	S
	Rhynchostreon suborbiculatum	EC/EF	S
Ostreidae	*Curvostrea rouvillei*	EC/EF	S
	Gyrostrea delettrei	EC/EF	S
	Gyrostrea cf. *anubis*	EC/EF	S
	Ambigostrea pseudovillei	EC	S
	Lopha syphax	EC	S
	Rastellum carinatum	EC	S
Chondrodontidae	*Chondrodonta joannae*	EC	S
Plicatulidae	*Plicatula* (*Plicatula*) *ferryi*	EC	S
	Plicatula (*P.*) *auressensis*	EC	S
Pectinidae	*Neithea* (*Neithea*) *coquandi*	EB/EF	S
	Neithea (*N.*) *dutrugei*	EB/EF	S
	Neithea (*N.*) *quinquecostata*	EB/EF	S
	Neithea (*N.*) sp.	EB/EF	S
Trigoniidae	*Pterotrigonia* (*S.*) *scabra*	SI	S
Corbulidae	*Corbula* (*Corbula*) sp.1	SI	S
Caprinidae	*Ichthyosarcolites* sp.	EC	S
Requieniidae	*Toucasia*? *matheroni*	EF	S
Radiolitidae	*Radiolites sauvagesi*	EC	S
	Eoradiolites liratus	EC	S
	Praeradiolites biskraensis	EC	S
	Praeradiolites sp.	EC	S
	Durania arnaudi	EC	S
Lucinidae	*Lucina fallax*	DI	?CS
Mactromyidae	*Clisocolus corrugatus*	SI	?
Carditidae	*Cardita*? *nicaisei*	SI/IB	S
	Venericardia? *forgemoli*	SI	S
Cardiidae	*Granocardium* (*G.*) *carolinum*	SI	S
	Granocardium (*G.*) *desvauxi*	SI	S
	Granocardium (*G.*) *productum*	SI	S
	Protocardia hillana	SI	S
	Protocardia? *regulare*	SI	S
	Protocardia sp.	SI	S

Arcticidae	*Arctica*? *rostrata*	SI	S
	Arctica? *inornata*	SI	S
	Arctica? *picteti*	SI	S
	Tenea delettrei	SI	S
	Veniella cf. *trapezoidalis*	SI	S
Glossidae	*Glossus aquilinus*	?SI	S
Veneridae	*Paraesa faba*	SI	S
	Meretrix desvauxi	SI	S
	Meretrix orientalis	SI	S
Pholadomyidae	*Pholadomya fabrina*	DI	S
	Pholadomya pedernalis	DI	S
	Pholadomya vignesi	DI	S
	Osteomya sp.	DI	S
Poromyidae	*Poromya*? *ligeriensis*	DI	S
2-Gastropods			
Trochidae	*Calliomphalus orientalis*	EM	?H/D
Neritopsoidae	*Neritopsis* sp.	EM	?H
Cerithiidae	*Cerithium* cf. *mogharense*	EM	?H/D
	Cerithium? sp.	EM	?H/D
Batillariidae	*Pyrazus valeriae*	EM	?H
Turritellidae	*Turritella* cf. *difficilis*	SI	S
Campanilidae	*Campanile* (*C.*) *ganesha*	?	?
	Cimolithium tenouklense	?	?
Ampullinidae	*Ampullina*? *abeihensis*	?EM	H/D
	Ampullina? cf. *quaasi*	?EM	H/D
Purpurinidae	*Coronatica* cf. *ornata*	?SI/EM	C
Strombidae	*“Strombus” incertus*	EM	H/D
Aporrhaidae	“*Aporrhais*” *dutrugei*	SI	S/?D
	“*Aporrhais*” sp. 1	SI	S/?D
	“*Aporrhais*” sp. 2.	SI	S/?D
	Harpagodes heberti	SI	S/?D
Colombellinidae	*Columbellina* (*C.*) *fusiformis*	EM	?C
	Pterodonta deffisi	EM	?C/O
	Pterodonta cf. *subinflata*	EM	?C/O
	?*Pterodonticeras germeri*	?EM	?C/O
Tylostomatidae	*Tylostoma* (*T.*) *cossoni*	SI	C
	Tylostoma (*T.*) *globosum*	SI	C
	Tylostoma (*T.*) *pallaryi*	SI	C
Fasciolariidae	*Fasciolaria tournoueri*	EM	C
Melongenidae	*Palaeatractus* cf. *figarii*	EM	C
Volutidae	*Caricella*? sp.	EM	C
Acteonidae	*Acteon*? sp.	EM	?
	Globiconcha cf. *rotundata*	EM	?
Acteonellidae	*Sogdianella*? *laevis laevis*	EM	C
Nerineidae	*Neoptyxis olisiponensis*	SI/EM	S
	Pchelinsevia coquandiana	SI/EM	S
	Diozoptyxis? *blancheti*	SI/EM	S

Akeridae	*Akera thevestensis*	?	?
3) Echinoids			
Cidaridae	*Sinaecidaris* cf. *gauthieri*	EM	G/O
Pedinidae	*Micropedina olisiponensis*	EM	?H/C
Orthopsidae	*Orthopsis ovata*	EM	H
Acropeltidae	*Goniopygus menardi*	EM	?H/C
	Goniopygus cf. *peroni*	EM	?H/C
Arbaciidae	*Codiopsis* sp.	EM	O
Diplopodiidae	*Pedinopsis desori*	EM	?H
	Tetragramma variolare	EM	?H/C
Heterodiadematidae	*Heterodiadema libycum*	EM	O
Phymosomatidae	*Phymosoma abbatei*	EM	H
	Phymosoma sinaeum	EM	H
	Rachiosoma geysi	EM	H
	Rachiosoma irregulare	EM	H
Holectypidae	*Coenholectypus larteti*	SI/?EM	D
	Coenholectypus portentosus	SI	D
	Coenholectypus turonensis	SI	D
Anorthopygidae	*Anorthopygus orbicularis*	SI	D
Nucleolitidae	*Petalobrissus* cf. *pygmaeus*	IM	D
Faujasiidae	*Pygurus* cf. *subproductus*	SI	?D
Archiaciidae	*Gentilia syriensis*	SI	?D
Hemiasteridae	*Hemiaster* (*Hemiaster*) *syriacus*	IM	D
	Hemiaster (*H.*) *gabrielis*	IM	D
	Hemiaster (*Mecaster*) *fourneli*	IM	D
	Hemiaster (*M.*) cf. *newtoni*	IM	D
	Hemiaster (*M.*) *pseudofourneli*	IM	D
	Hemiaster (*M.*) *heberti turonensis*	IM	D
4) Corals			
Latomeandridae	*Aspidiscus cristatus*	EF	MC
Meandrinidae	*Tortoflabellum* sp.	EC	MC
Faviidae	*Cladocora* sp.	EC	MC
5) Coralline sponges	*Actinostromarianina*? sp. 1	EC	S
Actionstromarianinidae	*Actinostromarianina*? sp. 2	EC	S

5.5. Palaeosynecology

5.5.1. Introduction

Numerous case studies showed community palaeoecology to be a sensitive tool for reconstructing Mesozoic marine palaeoenvironments, if used in combination with sedimentological and taphonomic data (e.g., Duff, 1975; Fürsich, 1976, 1977, 1981, 1982, 1984, 1994; Fürsich & Werner, 1984, 1986; Oschmann, 1988; Fürsich & Aberhan, 1990; Wignall, 1990; Fürsich et al., 1991, 1995, 2001, 2004, 2005; Aberhan, 1992, 1993a, b; 1994; Röhl et al., 2001; Wilmsen et al., 2007). The occurrence of single taxa or organism groups may already indicate a certain environment (e.g., echinoderms or ammonites indicate open-marine conditions). However, the best results are obtained by the analysis of benthic community relicts. As soft-bodied organisms are rarely preserved, the taxonomic and trophic compositions as well as the diversity data are more or less biased if compared to former living communities. Nevertheless, palaeosynecological analyses provide useful information on environments and their biota and therefore received more and more attention during the last years (see above references).

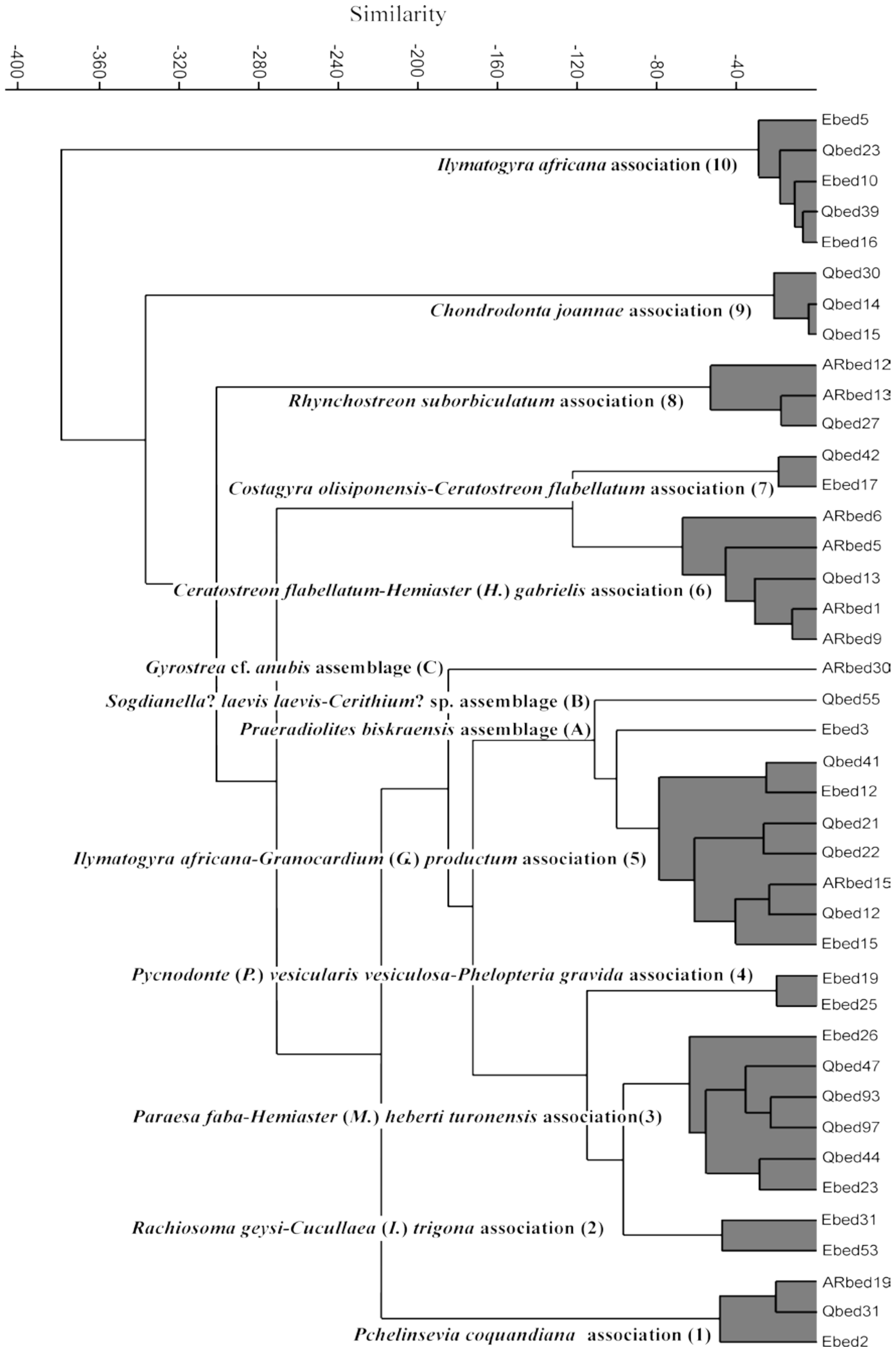
5.5.2. Material and methods

Three sections were described and measured bed-by-bed in order to obtain a complete vertical succession. The descriptions included the lithology, nature of contact, and faunal content. All faunal elements were counted and taphonomic and palaeoecological information was collected, including the state of preservation, degree of articulation, sorting, boring, encrustation, fragmentation, and distribution of the faunal elements in the sediments. The bulk of the data comes from the Cenomanian part of the succession, which is the most fossiliferous unit. The fauna was collected from marls and marly limestones at intervals of 1.5 and 5.0 m in East Themed, and 0.5 and 10 m in Wadi Quseib. Most samples derive from the middle siliciclastic/carbonate member of the Galala Formation (Cenomanian) at Wadi Quseib, East Themed, and from the lower marly and middle carbonate members of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif E-Naqa. In case of the thick glauconitic shaly slopes of the East Themed section (about 17 m thick) as well as in the upper carbonate member of the Galala Formation (24 m thick) at Wadi Quseib, the fauna was collected after dividing the slope into several parts, each 1-2 m thick, and sampled accordingly. In addition, many oyster banks were sampled in the studied sections, yielding a sufficient number of individuals being associated with other macrobenthic elements such as corals, gastropods, and echinoids. Occasionally these banks are separated by non-fossiliferous horizons. Sampling of some oysters and other macrobenthic fauna, which occur in hard limestone, however, was difficult. Therefore most of the taphonomic and palaeoecological investigations were carried out in the field. In the laboratory, the fossils were prepared mechanically and cleaned.

In order to reconstruct the benthic association, all rare and allochthonous individuals were removed from the database of the three sections, while the remaining 41 statistical samples were subjected to a cluster analysis. The latter was carried out using the program PAST (HAMMER et al. 2001; www.//folk.uio.no/ohamer/past). For calculations, the agglomerative method after the WARD method resulted in the most homogeneous and clearest clusters after transferring the absolute number of individuals into percentages. Each association and assemblage is named after its most prominent species (Text-fig. 5.11).

5.5.3. Cluster analysis

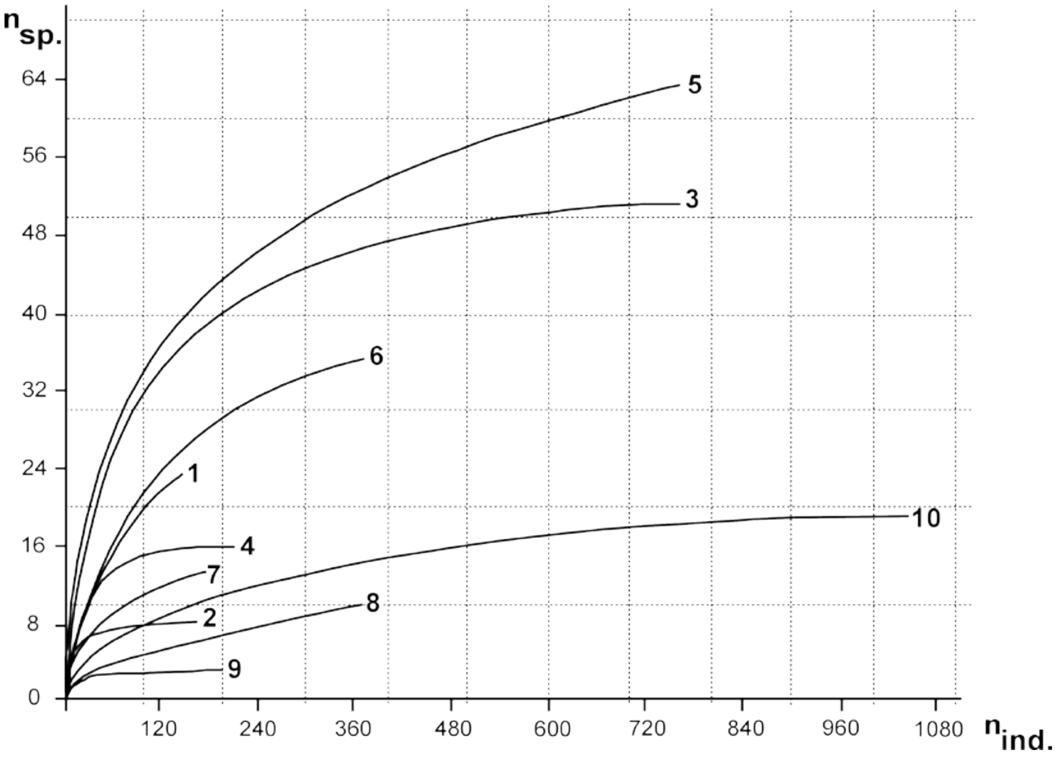
The occurrence and relative abundance of species was compared, and samples with a similar composition were combined into clusters. The samples were grouped into ten associations and three assemblages. The clusters are interpreted as relicts of benthic communities, here termed associations. Benthic associations are autochthonous to parautochthonous relics of repeatedly occurring communities, which were largely unaffected by diagenesis and taphonomic distortion and correspond to relics of palaeocommunities (e.g., FÜRSICH, 1977: 342; 1984: 315). In contrast, an assemblage is characterized by transport, faunal mixing (from different stratigraphic levels), single occurrence, and diagenetic alteration. For each association, the autecology of the members of the trophic nucleus is presented in an attempted reconstruction of the ancient community. The trophic nucleus concept was developed by NEYMAN (1967). It consists of species comprising 80% of the community biomass. In the resulting dendrogram (Text-fig. 5.11) the clusters contain samples from all studied sections (Gebel Areif El-Naqa, Wadi Quseib, and East Themed). This indicates that the benthic fauna of the area is very similar.



Text-fig. 5.11. Dendrogram of the cluster analysis of statistical samples from the Cenomanian-Turonian rocks of eastern Sinai, Egypt, based on the WARD method. The samples were grouped into ten associations and three assemblages.

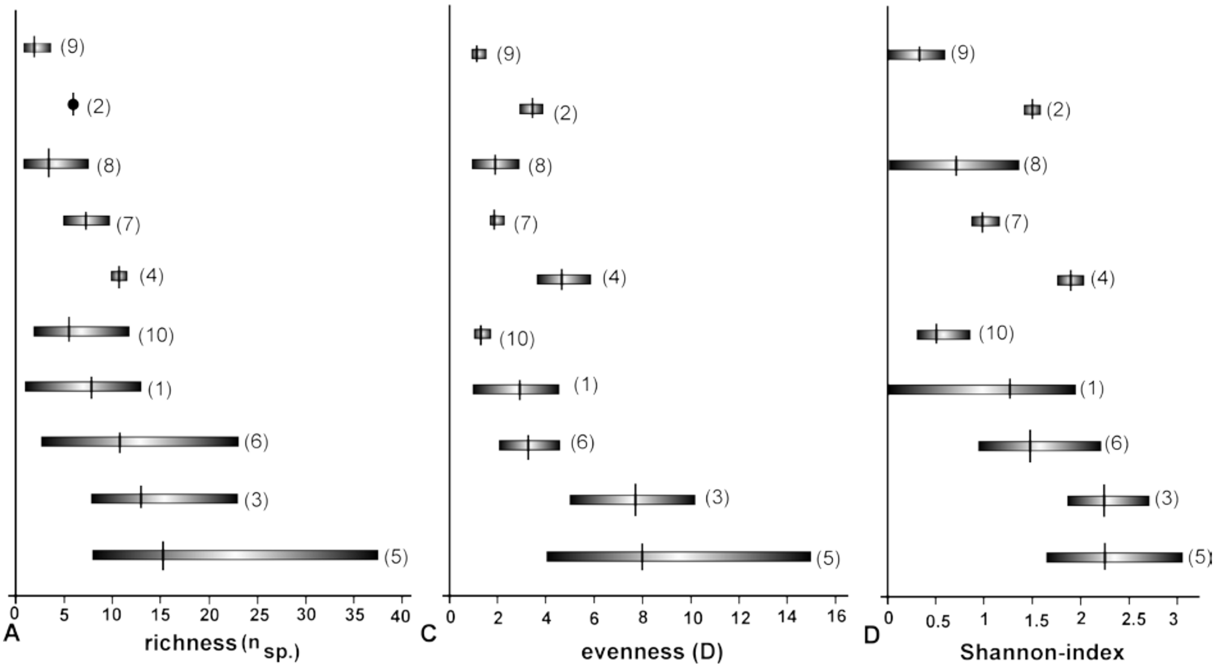
5.5.4. Diversity

In general, communities with more species are considered to be more diverse. In the present case, diversity values based on evenness are regarded to be more reliable, because differences in sample sizes strongly influence species richness. Rarefaction curves (Hammer & Harper, 2005: 202) were used to investigate the effect of sample size upon taxon counts, and to compare taxon counts in samples of different sizes. This means that small samples contain less species than large samples (Text-fig. 5.12). The rarefaction was carried out using the program PAST (Hammer et al., 2001). Strongly ascending curves indicate that further sampling might have recovered quite a few more taxa (incomplete sampling) while flattened curves indicate that further sampling would not increase the number of taxa substantially.



Text-fig. 5.12. Diversity values expressed by rarefaction curves of macrobenthic associations from eastern Sinai using PAST (Hammer et al., 2001). For abbreviations (numbers referring to clusters, see Text-fig. 5.13). Assemblages are not included.

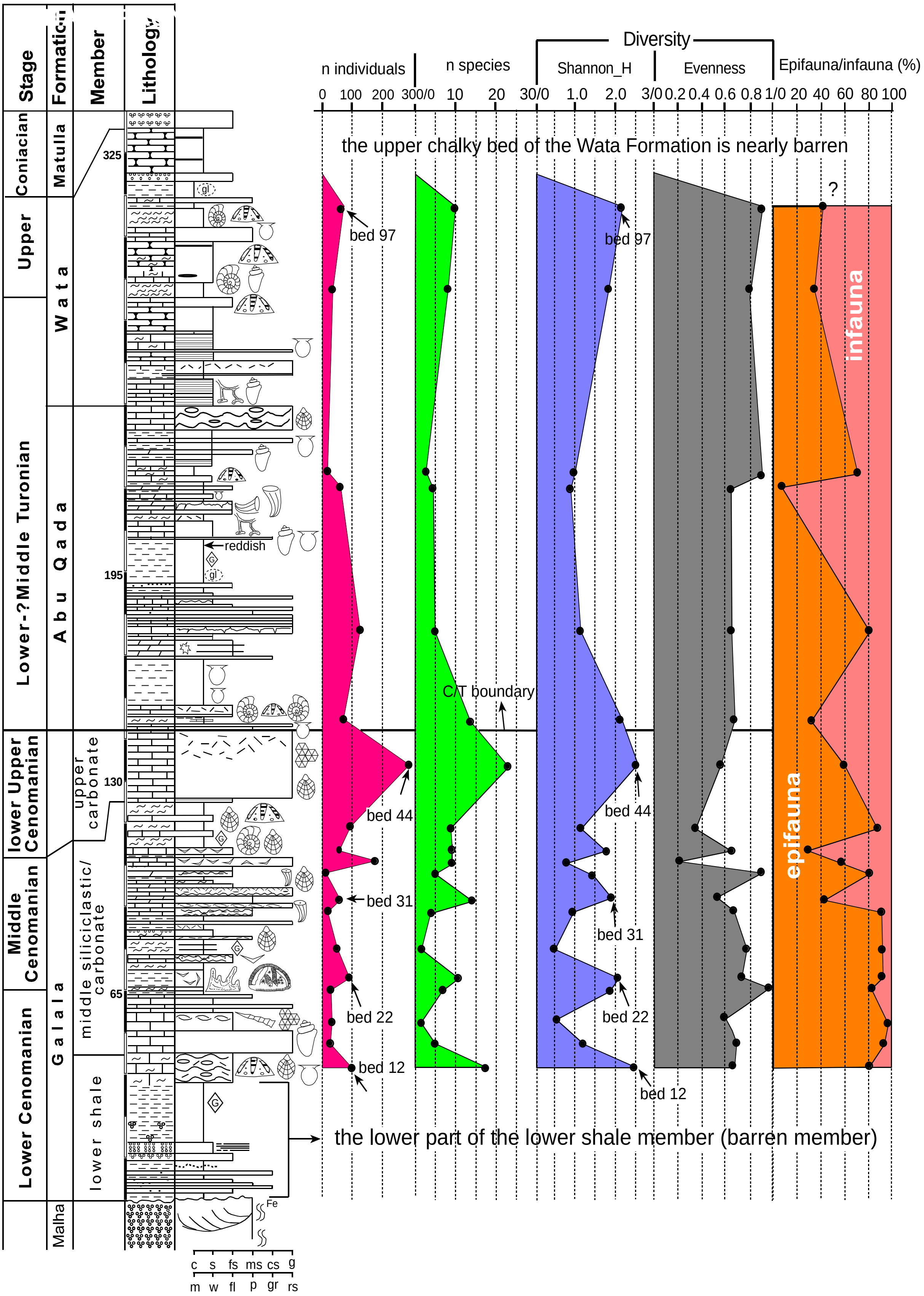
Species diversity has been measured as species richness (N), which is the number of species present in a sample, and evenness (D). The latter is conceptually inverse of the Simpson index of dominance (λ), $\lambda= (Pi^2)$ where $Pi=ni/n$ (the proportion of species *I*, Hammer & Harper, 2005: 188). Therefore, evenness (D) is derived from substitution in the expression $D=1/\lambda=1/[\Sigma(pi^2)]$, whereby pi is the relative frequency of the i-th species (MacArthur, 1972: 197). The evenness reflects the frequency distribution of species within an association; thus a low value for evenness indicates strong dominance of a particular species. In Text-fig. 5.13, mean values and ranges of species richness and evenness are plotted which show that the associations vary strongly in diversity. Another common diversity index is the Shannon-Wiener index, or entropy (Shannon & Weaver, 1949; Krebs, 1989), *H*, defined by the equation: $H=- Pi \ln P$, whereby *Pi* is the proportion of the *i*th species. The Shannon index varies from 0 for a single taxon community to high values for community rich in taxa. The Cenomanian Halal and Galala formations of the three sections is characterized by diversity values fluctuating at different levels (Shannon-index values), including the highest values (2.40 at East Themed, 2.56 at Wadi Quseib, and 3.07 at Gebel Areif El-Naqa).



Text-fig. 5.13. Range and mean values of species richness (A), evenness (B), and the Shannonn-Wiener index (C) of the Cenomanian-Turonian macrobenthic associations from eastern Sinai. 1: *Pchelinsevia coquandiana* association, 2. *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association, 3. *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association, 4. *Pycnodonte* (*Pycnodonte*) *vesicularis vesiculosa*/*Phelopteria gravida* association, 5. *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association, 6. *Ceratostreon flabellatum/Hemiaster* (*Hemiaster*) *gabrielis* association, 7. *Costagyra olisiponensis/Ceratostreon flabellatum* association, 8. *Rhynchostreon suborbiculatum* association, 9. *Chondrodonta joannae* association, 10. *Ilymatogyra africana* association. The associations have been arranged from base to top according to their species numbers and evenness values.

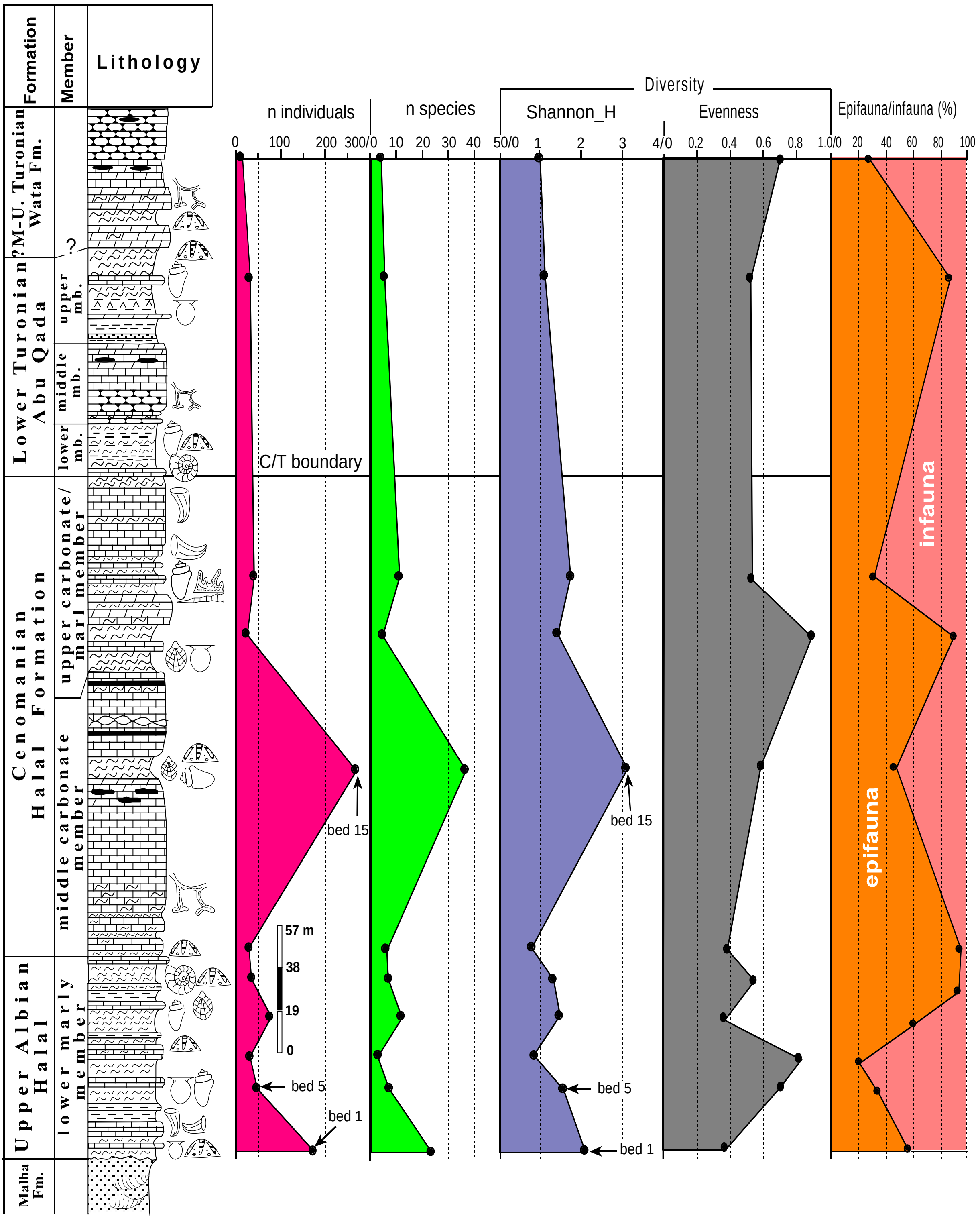
Towards the Cenomanian-Turonian boundary and throughout the Turonian, diversity values as well as species richness gradually decrease (Text-figs. 5.14-5.16). In the studied sections, the Shannon-index is relatively independent of sample size. For instance, the bed 12 in Wadi Quseib (upper part of the lower shale member) of the Cenomanian Galala Formation contains 97 specimens belonging to 18 species, and the *H* value amounts to 2.48. Another large sample (bed 44) was collected and counted from the same formation and contains 294 specimens. In the latter sample, the species richness increases to 23 taxa whilst *H* remains relatively unchanged (2.57). The same observation was recorded in the lower marly member of the Halal Formation (Upper Albian-Cenomanian) at Gebel Areif El-Naqa (beds 1 and 5). In the East Themed section, bed 16 contains 482 individuals belonging to 10 species, and with a *H* value of 0.75, while the *H* value of the bed 10 from the same interval (Cenomanian), which contains fewer individuals (185) increases to 2.3.

The low diversity values indicate stress conditions, whereas high faunal diversity points to stable, in this case fully marine conditions (e.g., FÜRSICH & WERNER, 1986: 283). Stress conditions are produced by extreme and/or highly fluctuating environmental parameters such as salinity, temperature, degree of oxygenation and water energy (e.g., WIGNALL, 1993; FÜRSICH, 1994). High-stress, unpredictable environments usually support low diversity communities which are dominantly physically controlled, whilst

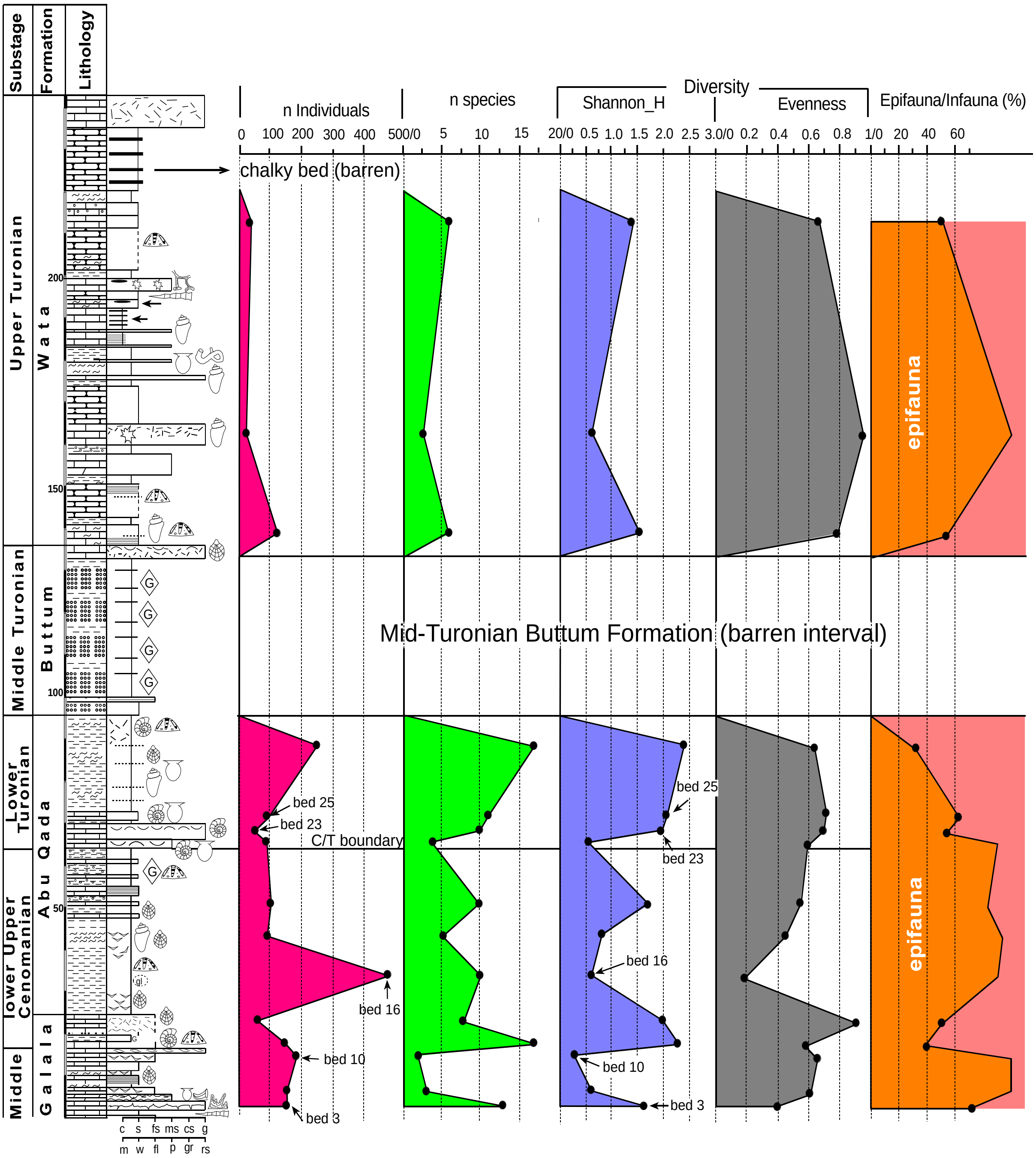


Text-fig. 5.14. Distribution of life habits, feeding modes, species richness, and evenness (using PAST software; HAMMER et al., 2001) within the Cenomanian-Turonian succession at Wadi Quseib. For key of symbols see Text-fig. 2.3 (Chapter 2).

low-stress, predictable environments are inhabited by biologically controlled, high diversity communities (e.g., SANDERS, 1968, 1969; SLOBODKIN & SANDERS, 1969; LEVINTON, 1970). However, species diversity is also influenced by biotic interactions such as predator/prey relationships (e.g., MENGE & SUTHERLAND, 1976).



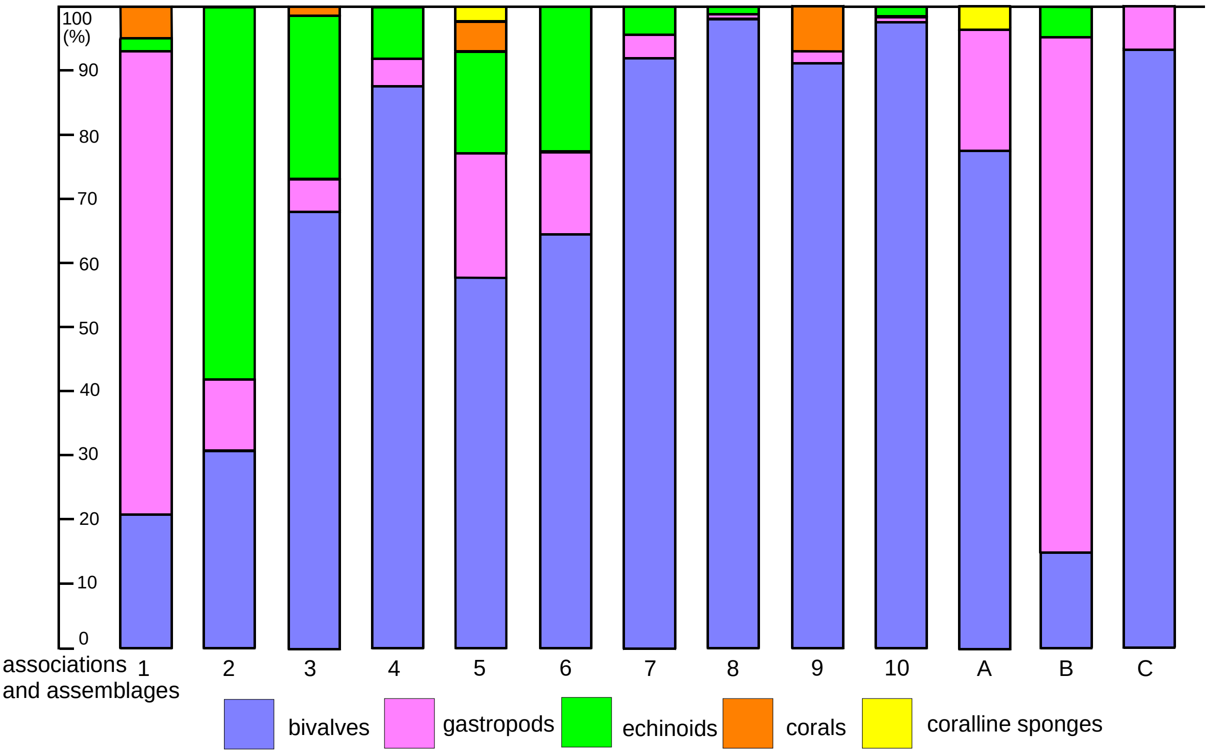
Text-fig. 5.15. Distribution of life habits, feeding modes, species richness, and evenness (using PAST software; HAMMER et al., 2001) in the Cenomanian-Turonian succession at Gebel Areif El-Naqa. For key of symbols see Text-fig. 2.3.



Text-fig. 5.16. Distribution of life habits, feeding modes, species richness, and evenness (using PAST software; HAMMER et al., 2001) in the Cenomanian-Turonian succession at East Themed. For key of symbols see Text-fig. 2.3.

5.6. Macrobenthic associations

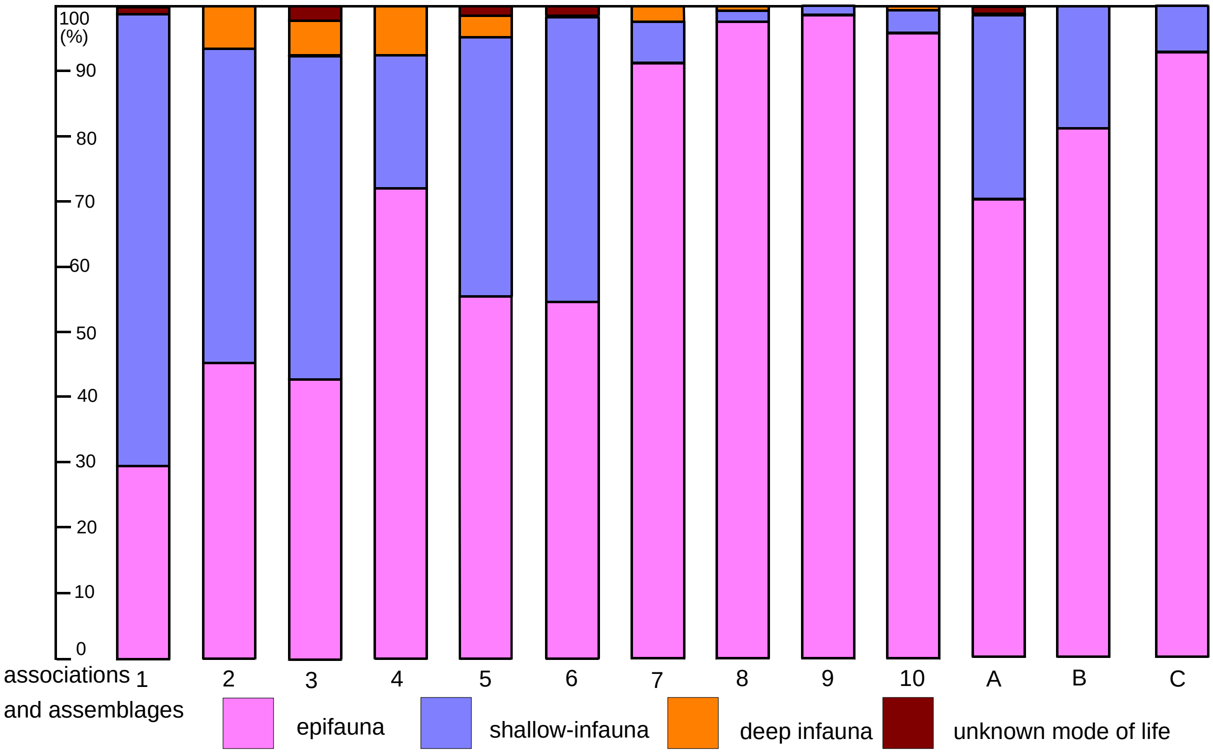
Text-fig. 5.17 shows the distribution of the different macrobenthic groups in the associations and assemblages. Most of the associations, which have been defined by means of cluster analysis (Text-fig. 5.11), as well as the assemblages are dominated by bivalves. For instance, in associations 7-10, and assemblage C, bivalves account for 91.95% to 99.18% of the total macrobenthos. The second most important group are gastropods, particularly in association 1 (72.79%) and assemblage B (82.70%). Echinoids are only minor elements except in associations 2 and 3 where they account for 57.32% and 26.51%, respectively. Corals and coralline sponges are rare. Corals occur only in four associations (1, 3, 5, 9), where they account for 0.66% to 7.47%.



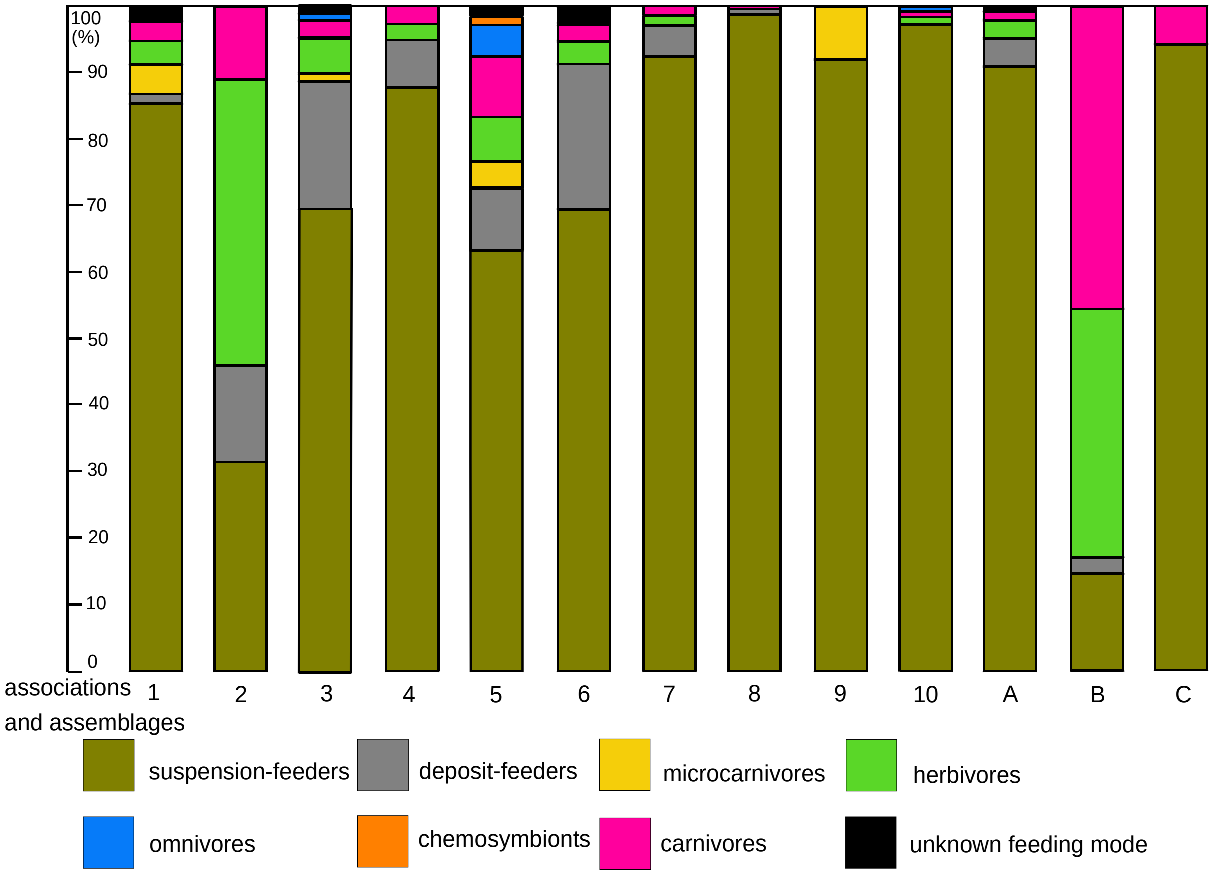
Text-fig. 5.17. Distribution of the major taxa in the associations and assemblages of eastern Sinai. Numbers refer to associations, letters to assemblages (Text-fig. 5.13). A. *Praeradiolites biskraensis* assemblage, B. *Sogdianella*? *laevis laevis*/*Cerithium*? sp. assemblage, C. *Gyrostrea* cf. *anubis* assemblage.

Coralline sponges represent 2.22% in association 5 and 2.51% in assemblage A (Text-fig. 5.17). With respect to life habits, the Cenomanian-Turonian rocks of the three sections are dominated by epifaunal elements. Text-figs. 5.14-5.16 show the relative abundance of epifaunal and infaunal organisms throughout the three sections. Most of the associations and assemblages are also dominated by epifauna. The distribution of epifauna, deep-infauna, and shallow-infauna is shown in Text-fig. 5.18. In most associations such as associations 7, 8, and 9 and assemblage C, epifaunal elements account for more than 90% of the total benthic fauna. Association 1 is dominated by shallow infaunal elements, which account for 69.38%. Epifaunal and infaunal elements are nearly equally abundant in associations 2 and 3. Deep infaunal elements play only a minor role accounting for 0.20% to 7.14% (e.g., associations 2, 3) (Text-fig. 5.18).

All benthic associations, except association 2 and assemblage B, are strongly dominated by suspension-feeders. Text-fig. 5.19 shows the distribution of feeding modes in the associations and assemblages. Suspension-feeders account for more than 65% of the individuals in all associations followed by deposit-feeders, which range from 0.54% to 14.65%. Herbivores are dominate only in association 2 (42.57%) and in assemblage B (37.60%). Other feeding groups such as omnivores, carnivores, microcarnivores, predators, and others are rarely represented. In conclusion, the different macrobenthic groups mostly represent different feeding modes and therefore the distribution of these groups in Text-fig. 5.17 is nearly similar to the distribution in Text-fig. 5.19.



Text-fig. 5.18. Distribution of life habits in the associations and assemblages of eastern Sinai. Numbers refer to associations (Text-fig. 5.13), letters to assemblages (Text-fig. 5.17).

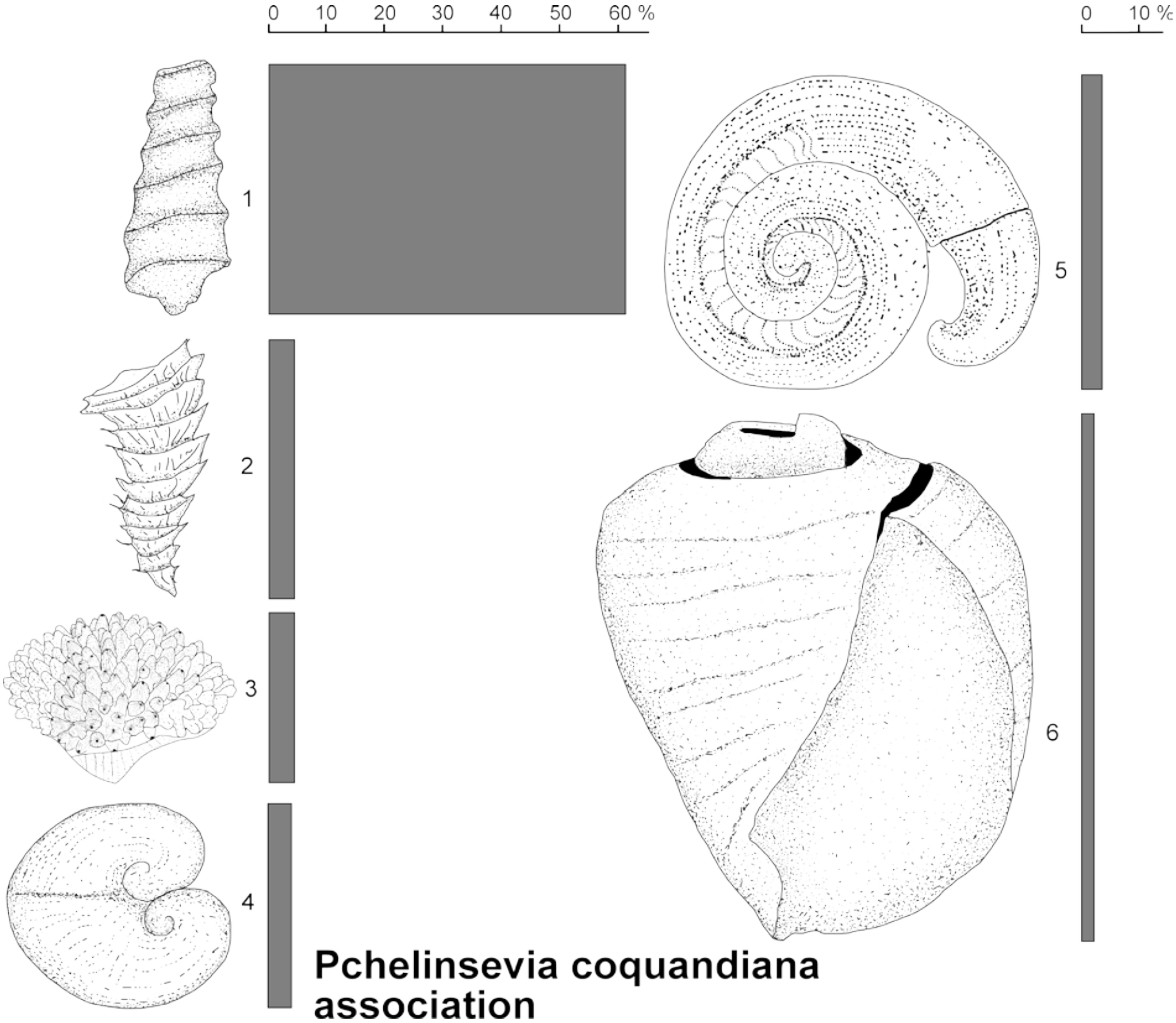


Text-fig. 5.19. Distribution of feeding modes in the associations and assemblages of eastern Sinai. Key as in Text-figs. 5.13 and 5.17.

Ten benthic associations and three assemblages have been recognized in the Cenomanian-Turonian succession of eastern Sinai. They are described in the following paragraphs.

5.6.1. *Pchelinsevia coquandiana* association

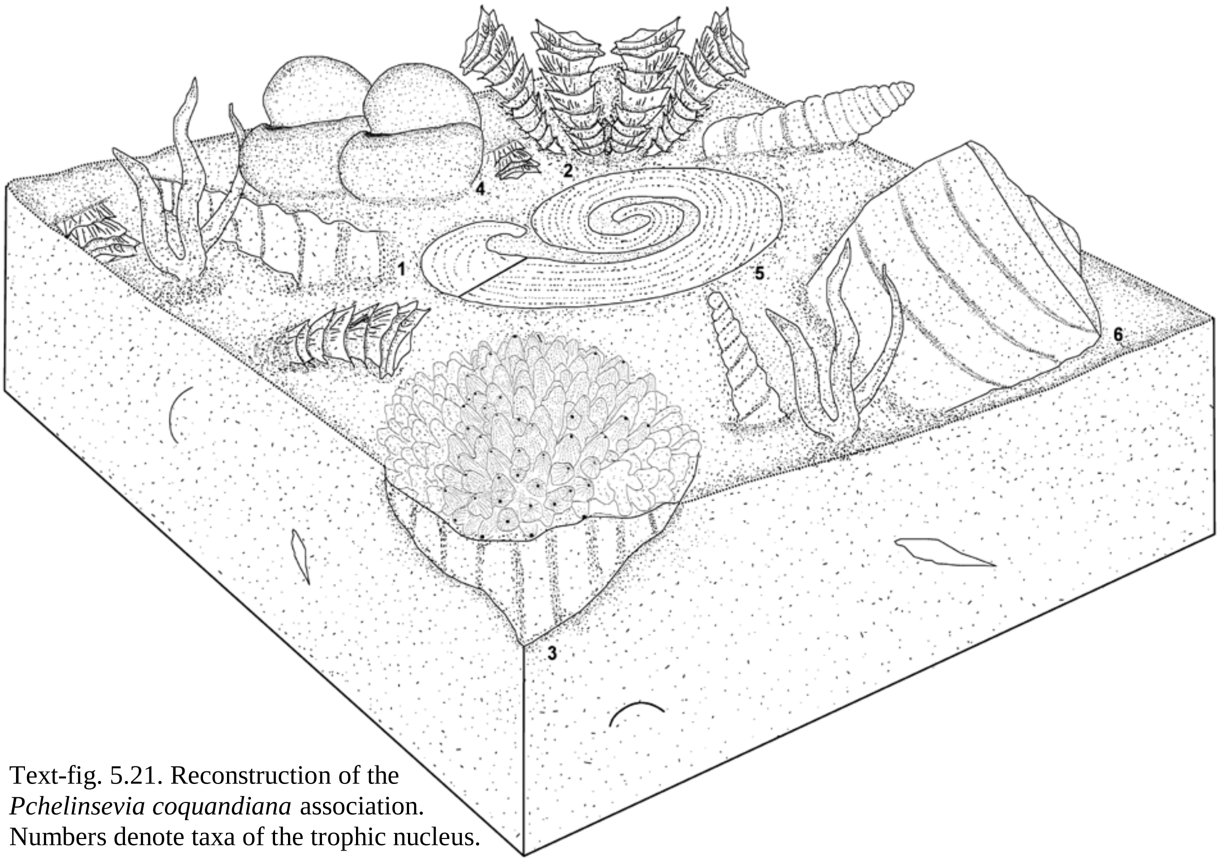
Description: The association is represented by 3 samples and 147 individuals. It consists of 23 species, six of which (*Pchelinsevia coquandiana*, *Praeradiolites* sp., *Tortoflabellum* sp., *Toucasia*? *matheroni*, *Ichthyosarcolites* sp., "*Strombus*" *incertus*) belong to the trophic nucleus (Text-fig. 5.20). The nerineoid *P. coquandiana* dominates the association with 62.6% (plus 10.19% other gastropod species). Additional taxa are bivalves (21%), corals (4.76%), and echinoids (1.36%). With respect to life habits, shallow-infaunal organisms prevail (69.38%), followed by epifauna (29.93%). No deep burrowing elements occur in the association. According to their feeding habits, suspension-feeders dominate the association with 85.04%, followed by microcarnivores and herbivores (together 8.84%), while carnivores and deposit-feeders are rare (2.72 and 1.36%, respectively). The feeding mode of 2.04% of the gastropods is difficult to determine. Because of the dominance of *Pchelinsevia coquandiana*, evenness values are low (ranging from 1.00 to 4.52; mean: 2.94) and the number of



Text-fig. 5.20. Trophic nucleus of the *Pchelinsevia coquandiana* association. 1. *Pchelinsevia coquandiana*, 2. *Praeradiolites* sp., 3. *Tortoflabellum* sp., 4. *Toucasia*? *matheroni*, 5. *Ichthyosarcolites* sp., 6. *"Strombus" incertus.* The width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

species ranges from 1 to 13 with a mean of 8.33. Nearly all gastropods are preserved as internal and composite moulds, while rudists and corals are mostly well preserved, showing their original shell fabrics. The association occurs predominantly in marly wackestones and marls.

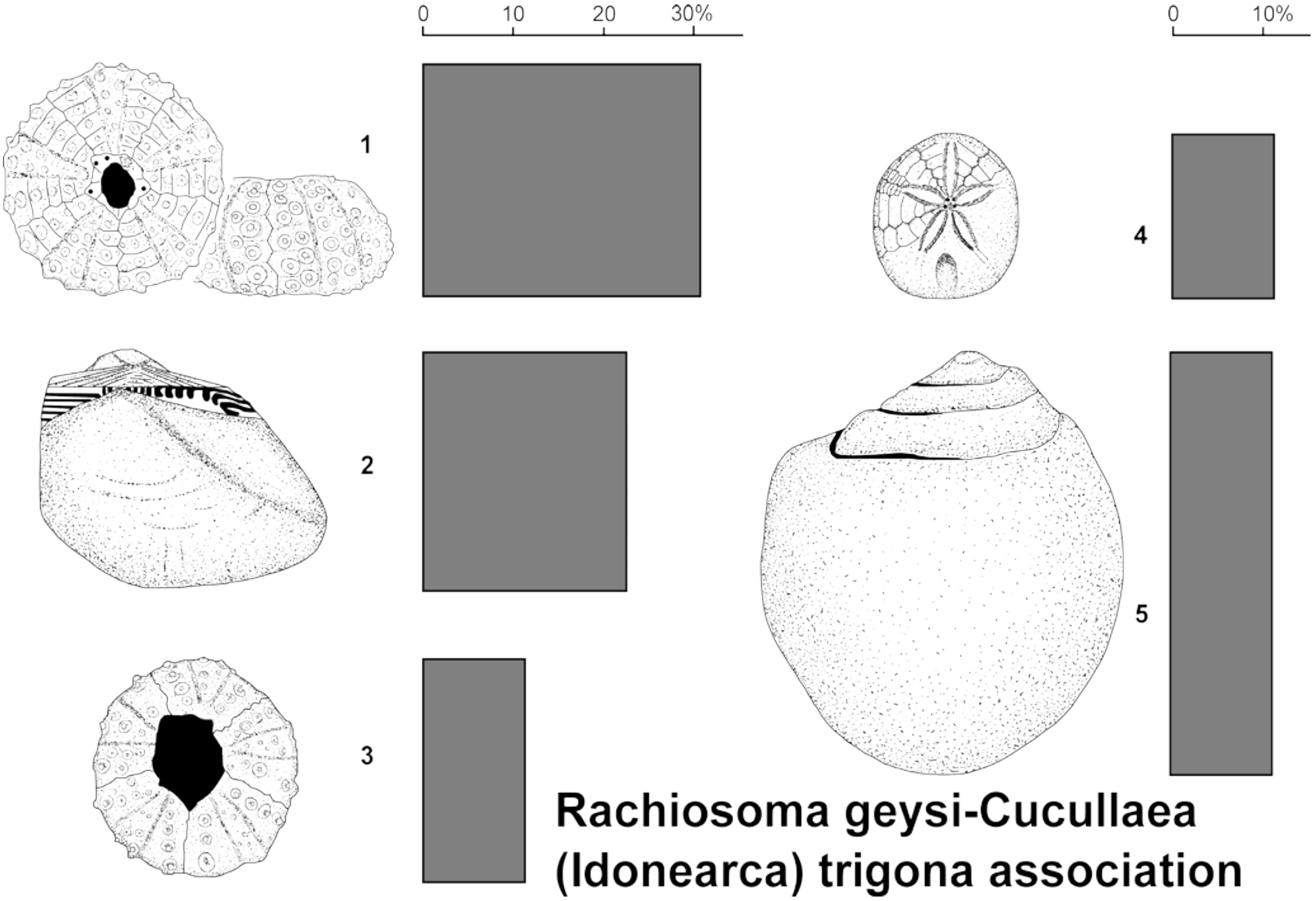
Interpretation: According to Sohl (1987) and Saul & Squires (2002), nerineoids are commonly an important element of Mesozoic carbonate faunas and form part of the subtropical to tropical Tethyan rudist-coral associations. In addition, corals and rudist bivalves co-exist on shallow carbonate platforms of the Tethyan realm during most of Cretaceous time (e.g. Coates, 1977; Carbone & Sirna, 1981; Gili et al., 1995; Schafhauser et al., 2003). Stenohaline corals and echinoids (together 6.12%) indicate euhaline conditions and a position probably within the photic zone. The latter is documented also by the presence of 4.08% herbivores. The dominance of shallow-infaunal nerineoids indicate that the substrate was soft. The few corals and rudists, which needed a hard substrate for fixation, probably used. The simple trophic structure with a dominance of nerineoids may indicate stress conditions. This interpretation is supported by the low values of evenness and species richness. However, the low diversity values as well as the lack of deep-infaunal elements may be related to the dissolution of aragonitic shells during early diagenesis. The rudist *Praeradiolites* sp. occurs as disarticulated and randomly oriented right valves (fragmented to some extent), while left valves are rare or entirely missing. These features indicate that the water energy was moderately high and the rare or entirely missing small left valves are evidence of sorting. Therefore, rudists in this association are parautochthonous and underwent some transport. The large and heavy gastropod “*Strombus*” *incertus* indicates a certain stability of the substrate. The widely arcuate form and large size of the caprinid *Ichthyosarcolites* sp. (recumbent rudist morphotype) prevented the organism to sink into an unstable, soft substrate (Steuber & Löser, 2000: 81) (Text-fig. 5.21).



Text-fig. 5.21. Reconstruction of the *Pchelinsevia coquandiana* association. Numbers denote taxa of the trophic nucleus.

5.6.2. *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association

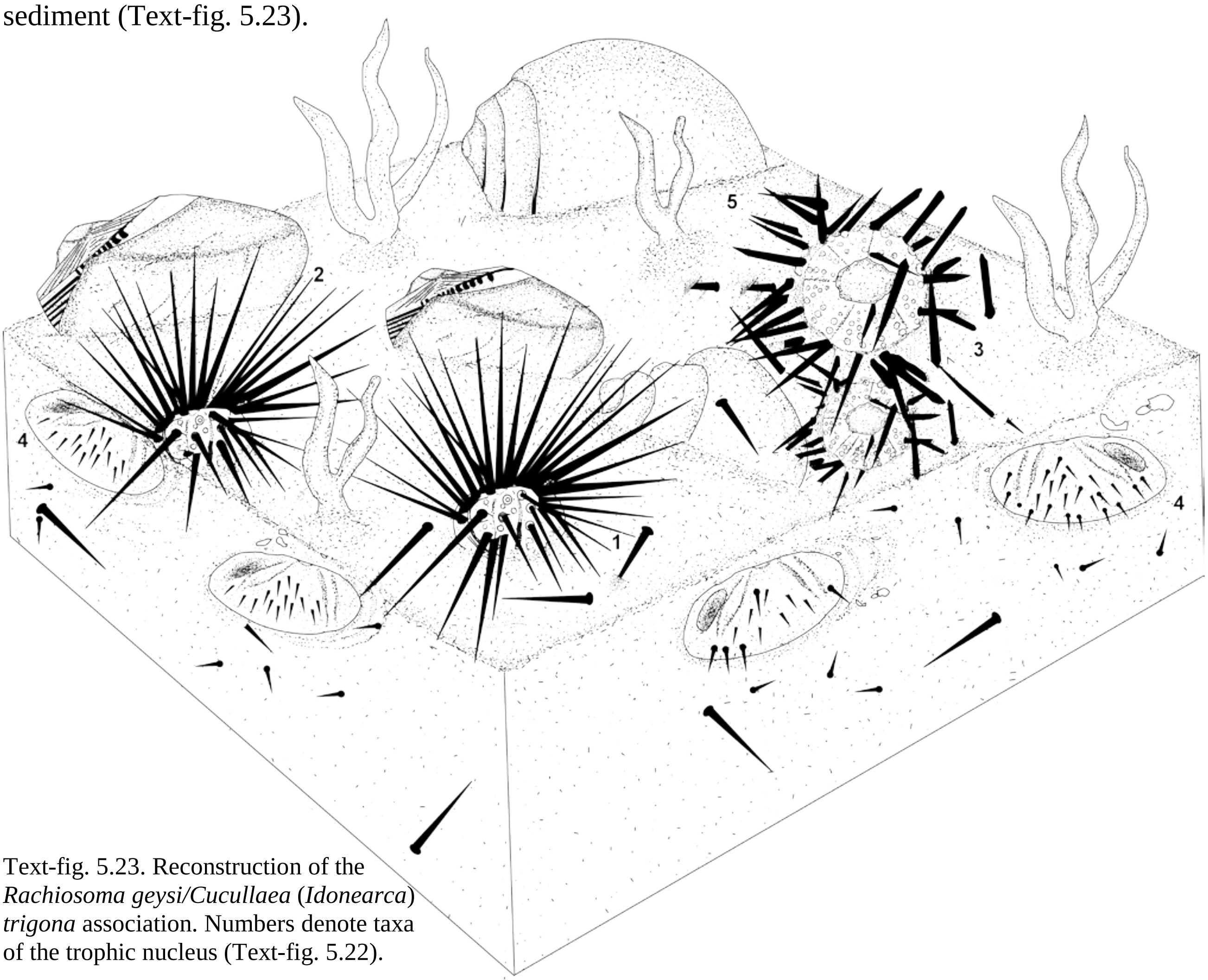
Description: Two samples with 157 individuals representing nine species have been grouped in this association. The trophic nucleus consists of five species, two epifaunal echinoids (*Rachiosoma geysi* and *Phymosoma abbatei*, together 42.67%), one shallow infaunal echinoid (*Petalobrissus* cf. *pygmaeus*, 11.46%), the shallow-infaunal bivalve *Cucullaea* (*Idonearca*) *trigona*, and the large shallow-infaunal gastropod *Tylostoma* (*Tylostoma*) *globosum* (Text-fig. 5.22). Echinoids are the most common faunal element (57.32%), followed by bivalves (31.84%), and gastropods (10.83%). With respect to life habits, epifaunal (45.85%) and shallow-infaunal (48.40%) organisms show nearly the same abundance, while deep-burrowing organisms are minor components (5.73%). Most epifaunal echinoids (Phymosomatoida) were predominantly grazers, feeding on encrusting or boring algae or plants such as sea grasses (herbivores, 42.67%). They were followed by suspension-feeding bivalves (31.85%), deposit-feeding echinoids (14.65%), and carnivorous gastropods (10.83%). Each sample in the *Rachiosoma geysi/Cucullaea* (*I.*) *trigona* association consists of six taxa with an average evenness of 3.52. All shallow-infaunal bivalves are preserved as composite and internal moulds of articulated specimens. In contrast, the epifaunal and infaunal echinoids mostly occur in shell preservation. Some of the epifaunal echinoid tests are broken into fragments. Large gastropods are preserved as internal moulds. The association occurs in greyish-white, moderately hard, marly wackestone.



Text-fig. 5.22. Trophic nucleus of the *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association. 1. *Rachiosoma geysi*, 2. *Cucullaea* (*Idonearca*) *trigona*, 3. *Phymosoma abbatei*, 4. *Petalobrissus* cf. *pygmaeus*, 5. *Tylostoma* (*Tylostoma*) *globosum.* The width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

Interpretation: The abundance of herbivorous echinoids probably indicates the presence of plant material; most likely the depositional environment was in the shallow photic zone. Stenohaline, epifaunal echinoids also indicate euhaline conditions. According to Smith (1984, 1995), Smith et al. (1988, 1995), Jagt (2000), and Saucède et al. (2003) all regular echinoids (e.g, *Rachiosoma geysi*, *Phymosoma abbatei*) wander across the sea floor in search of food as grazers and browsers. In comparison with irregular echinoids, they are generally much less particular types of substrate, although it is possible to infer, which species were adapted to shallow-water rocky bottoms. In the *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association, the presence of 14.65% deposit-feeders and nearly the same abundance of epifaunal (45.85%) and shallow infaunal (48.40%) organisms suggest that the substrate was not rocky but soft enough for shallow- and deep-infaunal organisms. In addition, the large and heavy semi-infaunal gastropod *Tylostoma* (*Tylostoma*) *globosum* indicates a certain stability of the substrate. The low values of evenness and species richness indicate that the association was subjected to stress conditions. The presence of echinoid fragments indicate a moderately high energy level. In agreement with Strathmann (1981) and Jagt (2000), the large spines of regular echinoids (e.g. Phymosomatoida) serve for defense against predators, for preventing structure damage (especially in turbulent currents), and for locomotion.

According to Smith (1984), each echinoid has a preferred habit and life style that is partially reflected by, and can be deduced from, the skeletal morphology. Thus, the large peristome of *Petalobrissus* cf. *pygmaeus* indicates that the animal fed by swallowing bulk sediment. The depressed shape of the test helped the animal to move easily inside the soft sediment (Text-fig. 5.23).



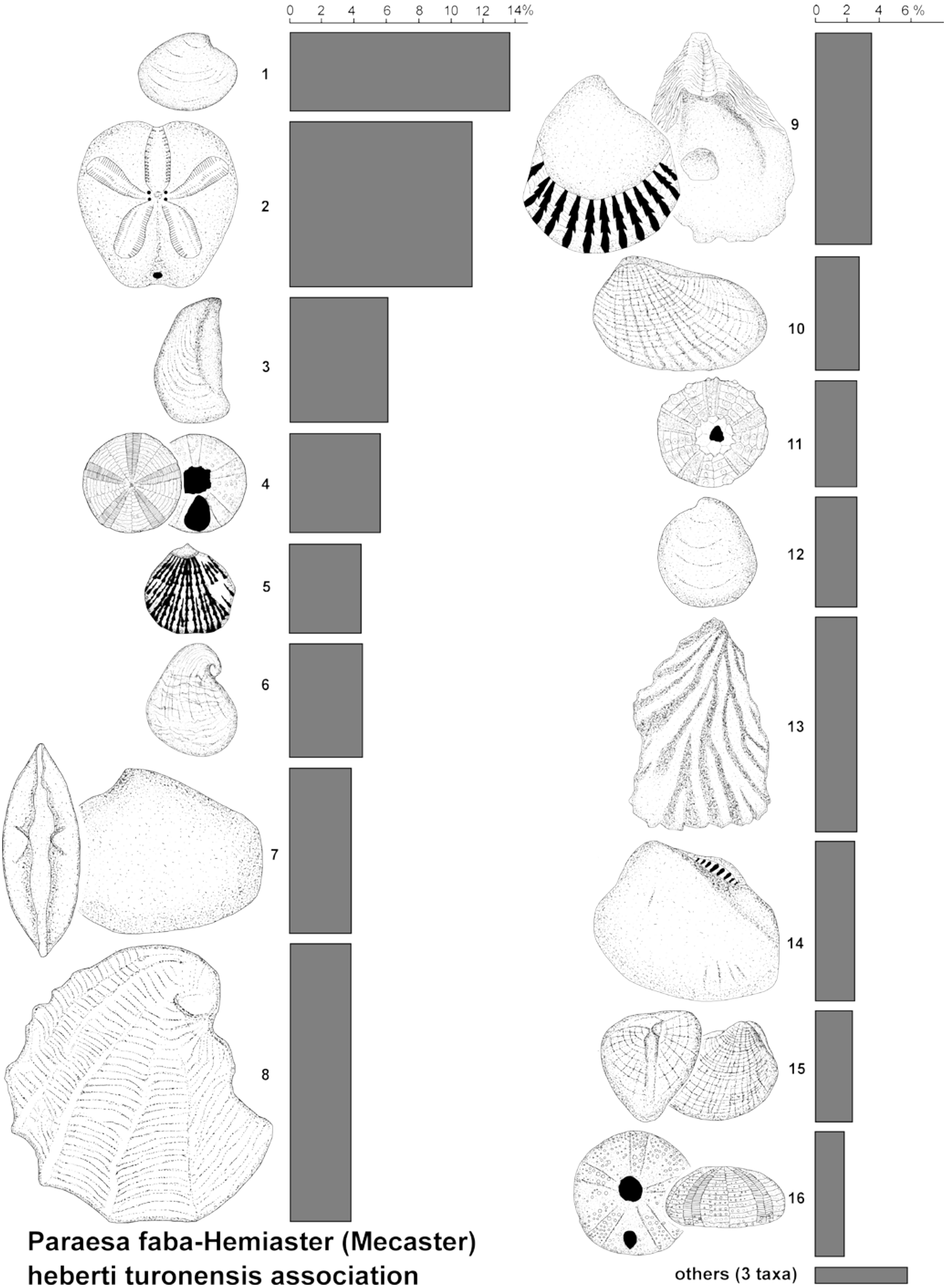
Text-fig. 5.23. Reconstruction of the *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association. Numbers denote taxa of the trophic nucleus (Text-fig. 5.22).

5.6.3. *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association

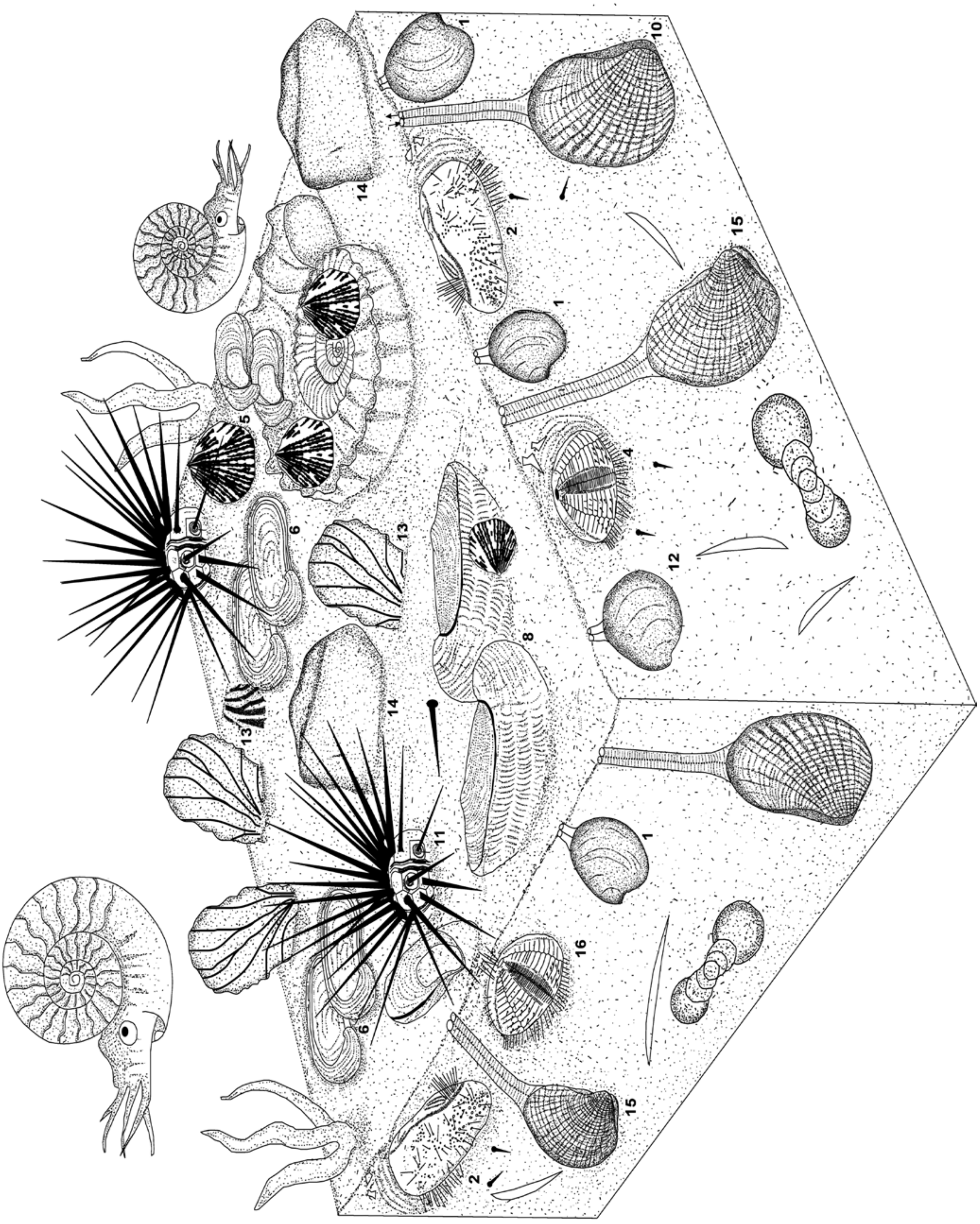
Description: This association has been defined on the basis of six samples, 762 individuals, and 51 species. Bivalves are the main benthic group representing 68.50% of the association, followed by echinoids (26.51%) and gastropods (4.33%). Corals are subordinate (0.70%). Nektonic elements are abundant and consist of ammonites, which are represented by Lower Turonian taxa, e.g, *Thomasites rollandi* and *Choffaticeras* (*Choffaticeras*) *segne* as well as by the lower Upper Turonian ammonite *Coilopoceras requienianum*. The trophic nucleus consists of 19 species dominated by the small, shallow-infaunal bivalve *Paraesa faba* (13.87%) and echinoids (11.26%) (Text-fig. 5.24). Other important benthic organisms in trophic nucleus are epifaunal oysters which are represented by four species: *Curvostrea rouvillei*, *Rhynchostreon suborbiculatum*, *Costagyra olisiponensis*, and *Gyrostrea* cf. *anubis* (together 18.06 %), plicatulids such as *Plicatula* (*Plicatula*) *ferryi* and *P.* (*P.*) *auressensis* (together 6.54 %), and the deep-infaunal *Pholadomya pedernalis* (2.75%) and *Ph. vignesi* (2.36 %) (Text-fig. 5.24). The association contains nearly equal abundances of epifaunal (43.70%) and shallow-infaunal organisms (49.47%), together with 5.52% of deep-burrowing bivalves. With respect to the feeding habits, suspension-feeders dominate (69.02%), followed by deposit-feeders (20.47%) and herbivores (6.16%). The other feeding groups such as microcarnivores, carnivores and omnivores occur subordinately (together 2.88%). The feeding mode of some gastropod species is difficult to determine (1.44%). All shallow-and deep-infaunal bivalves are preserved as internal and composite moulds of articulated specimens. In contrast, epifaunal and infaunal echinoids are preserved (with their shell), as are oysters and plicatulids. The species richness strongly varies from 8 to 23 (mean 13.50), and the evenness from 5.49 to 10.22 (mean 7.70). The association occurs mostly in marly and shaly interbeds and in marly limestones (wackestones).

Interpretation: The high diversity both in terms of evenness and species richness in this association indicates normal marine conditions and also suggests a low degree of environmental stress. In addition, the abundance of stenohaline groups such as ammonites and echinoids indicates euhaline conditions. FÜRSICH et al. (1995) pointed out that the genus *Pholadomya* is also a comparatively stenohaline taxon. According to the high percentage of suspension-feeders water energy must have been sufficient enough to keep nutrients in suspension (low to intermediate energy level). The nearly equal abundance of epifaunal and shallow-infaunal organisms together with the deep-burrowing bivalves indicates that the *Paraesa faba/Hemiaster* (*M.*) *heberti turonensis* association lived on a well oxygenated, moderately soft substrate. The epifaunal oyster *Costagyra olisiponensis* is thick, articulated and encrusted with plicatulids. Moreover, left valves of *Curvostrea rouvillei* occur far more abundantly than right ones (LV=35, RV= 15 in Wadi Quseib). The reason is that the cemented left valve is larger and thicker and therefore has a higher preservation potential. The right valve being much thinner (opercular) may be easily reworked and fragmented. Thus, the large abundance of left valves of *C. rouvillei* and the presence of articulated specimens of *C. olisiponensis* indicate that the fauna experienced slight reworking i.e., it is parautochthonous. The large and thick valves of oysters (e.g., *C. olisiponensis*) as well as encrusters such as plicatulids (e.g. *Plicatula* (*P.*) *ferryi*) may have protected these organisms from predators (e.g., ammonites and echinoids) and helped to stabilize them on unstable substrates.

Text-fig. 5.24. Trophic nucleus of the *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association. 1. *Paraesa faba*, 2. *Hemiaster* (*M.*) *heberti turonensis*, 3. *Curvostrea rouvillei*, 4. *Coenholectypus turonensis*, 5. *Plicatula* (*Plicatula*) *ferryi*, 6. *Rhynchostreon suborbiculatum*, 7. *Meretrix desvauxi*, 8. *Costagyra olisiponensis*, 9. *Gyrostrea* cf. *anubis*, 10. *Pholadomya pedernalis*, 11. *Goniopygus menardi*, 12. *Tenea delettrei*, 13. *Chondrodonta joannae*, 14. *Cucullaea* (*Idonearca*) *thevestensis*, 15. *Pholadomya vignesi*, 16. *Coenholectypus larteti*, others include three species: 17. *Plicatula* (*Plicatula*) *auressensis*, 18. *Pycnodonte* (*P.*) *vesicularis Vesiculosa*, and 19. *Hemiaster* (*Mecaster*) *fourneli.*



Paraesa faba-Hemiaster (Mecaster) heberti turonensis association

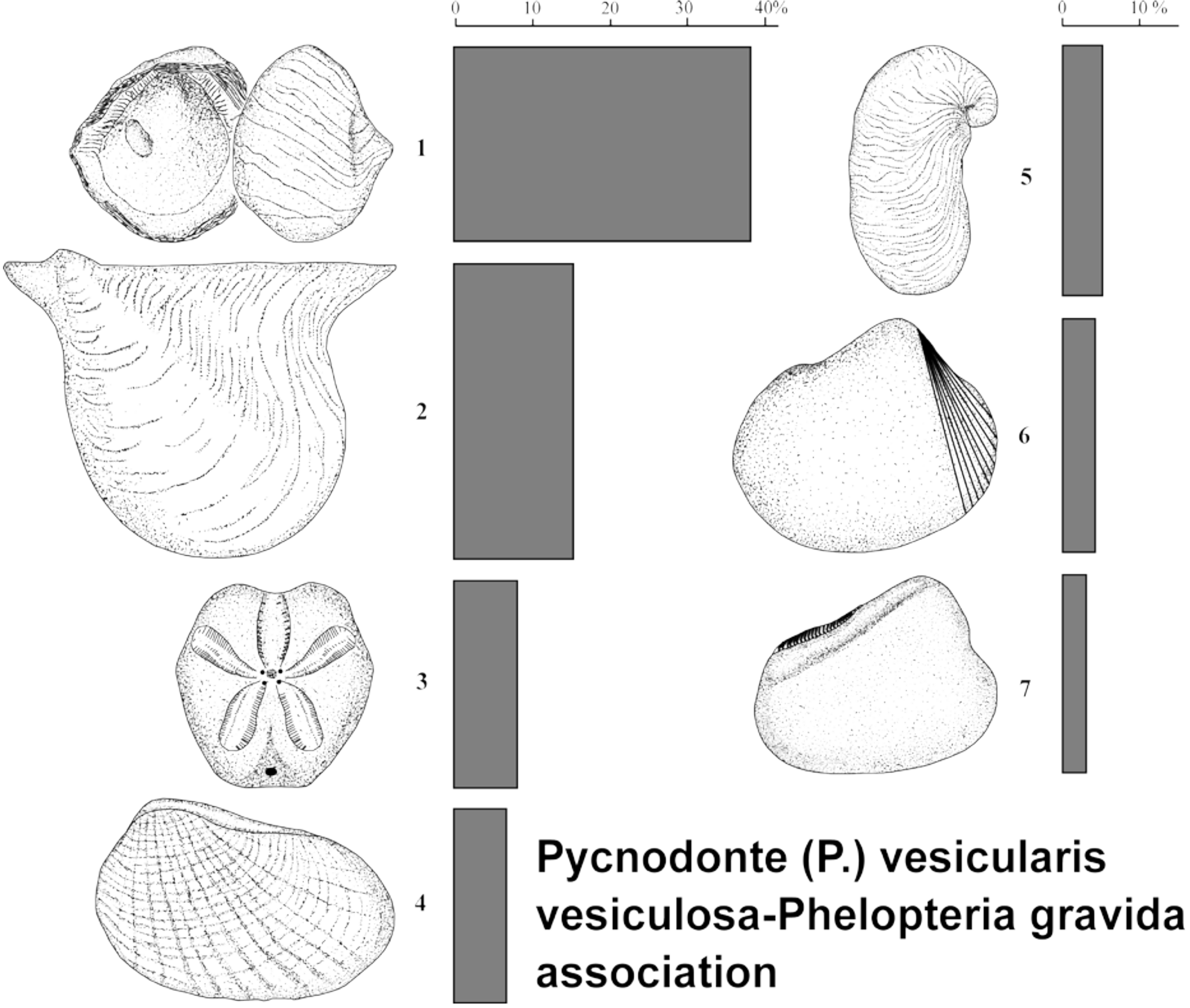


Text-fig. 5.25. Reconstruction of the *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association. Numbers denote taxa of the trophic nucleus (Text-fig. 5.24).

The heterodont bivalves such as *Paraesa faba* and *Tenea delettrei* are invariably infaunal suspension-feeders, and thus also protected from predators (Text-fig. 5.25).

5.6.4. *Pycnodonte* (*P.*) *vesicularis vesiculosa*/*Phelopteria gravida* association

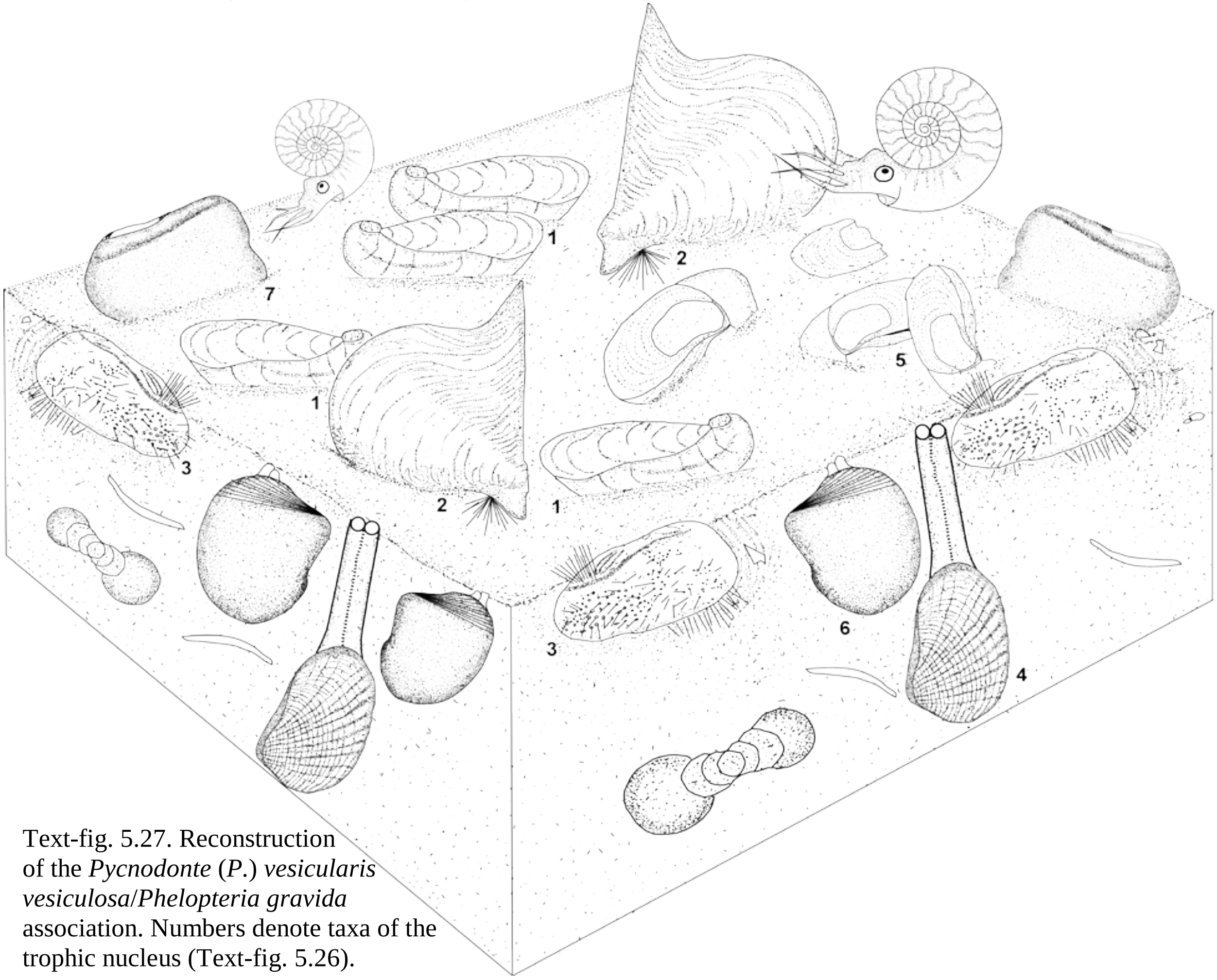
Description: Two samples with 196 individuals constitute the *Pycnodonte* (*P.*) *vesicularis vesiculosa*/*Phelopteria gravida* association. The dominant organisms of this association are bivalves (88.26%), whereas echinoids and gastropods are subordinate (together 11.74%). The trophic nucleus contains 7 species and is dominated by the epifaunal cemented bivalve *Pycnodonte* (*P.*) *vesicularis vesiculosa* (39.29%), followed by the epibyssate *Phelopteria gravida* (15.31%), and the shallow-infaunal echinoid *Hemiaster* (*Mecaster*) *fourneli* (7.65%) (Text-fig. 5.26). Other members of the trophic nucleus include the shallow-infaunal bivalves *Protocardia hillana* and *Cucullaea* (*Idonearca*) *trigona* (4.59% and 3.06% respectively), the deep-infaunal bivalve *Pholadomya pedernalis* (7.14%), and the oyster *Ilymatogyra africana* (5.10%). The ammonite *Thomasites rollandi* is also found in the association. With respect to life habits, epifaunal organisms prevail (72.90%), followed by shallow-infaunal (19.89%) and deep-infaunal organisms (7.14%). Suspension-feeders account for 88.26%, while deposit-feeders represent 7.65% of the total fauna.



Text-fig. 5.26. Trophic nucleus of the *Pycnodonte* (*Pycnodonte*) *vesicularis vesiculosa*/*Phelopteria gravida* association. 1. *Pycnodonte* (*P.*) *vesicularis vesiculosa*, 2. *Phelopteria gravida*, 3. *Hemiaster* (*Mecaster*) *fourneli*, 4. *Pholadomya pedernalis*, 5. *Ilymatogyra africana*, 6. *Protocardia hillana*, and 7. *Cucullaea* (*Idonearca*) *trigona*. The width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

The other feeding groups such as carnivores and herbivores occur subordinately (together 4.08%). Species richness, expressed by the number of taxa, varies between 10 and 11 (mean: 10.50); mean evenness is 4.87. Disarticulated *Pycnodonte* (*P.*) *vesicularis vesiculosa* is represented by small left valves showing mostly a convex-up orientation with a small attachment area. Some valves of this species are fragmented. Other oysters and echinoids (*Ilymatogyra africana* and *Hemiaster fourneli*) occur in shell preservation, while infaunal bivalves (e.g., *Pholadomya pedernalis*) are preserved as articulated internal moulds. Similarly, gastropods are also preserved as internal moulds. The association occurs in grey argillaceous wackestone and in sandy shale-wackestone alternations.

Interpretation: The percentage of epifaunal organisms (72.90%) suggests that the substrate was firm enough for colonization by byssate and cemented bivalves (Text-fig. 5.27). However, it must have been soft enough for burrowing organisms. Shallow-infaunal echinoids as well as ammonites (e.g., *Thomasites rollandi*) document euhaline conditions. The strong dominance of suspension-feeding epifauna (88.26%) refers to a nutrient-rich and well oxygenated water column. In addition, a relatively stable, low-stress environment is corroborated by intermediate diversity values. The dominance of cemented and byssate organisms indicates that the sedimentation rate cannot have been particularly high. According to Boucot et al. (1958), the degree of disarticulation is a reliable means of determining the relative amount of taphonomic reworking. Consequently, the oysters in this association rarely occur in situ, but commonly have been reworked (i.e., they are parautochthonous). This interpretation is also supported by the convex-up orientation of *Pycnodonte* (*P.*) *vesicularis vesiculosa* and by the presence of *Pycnodonte* fragments.

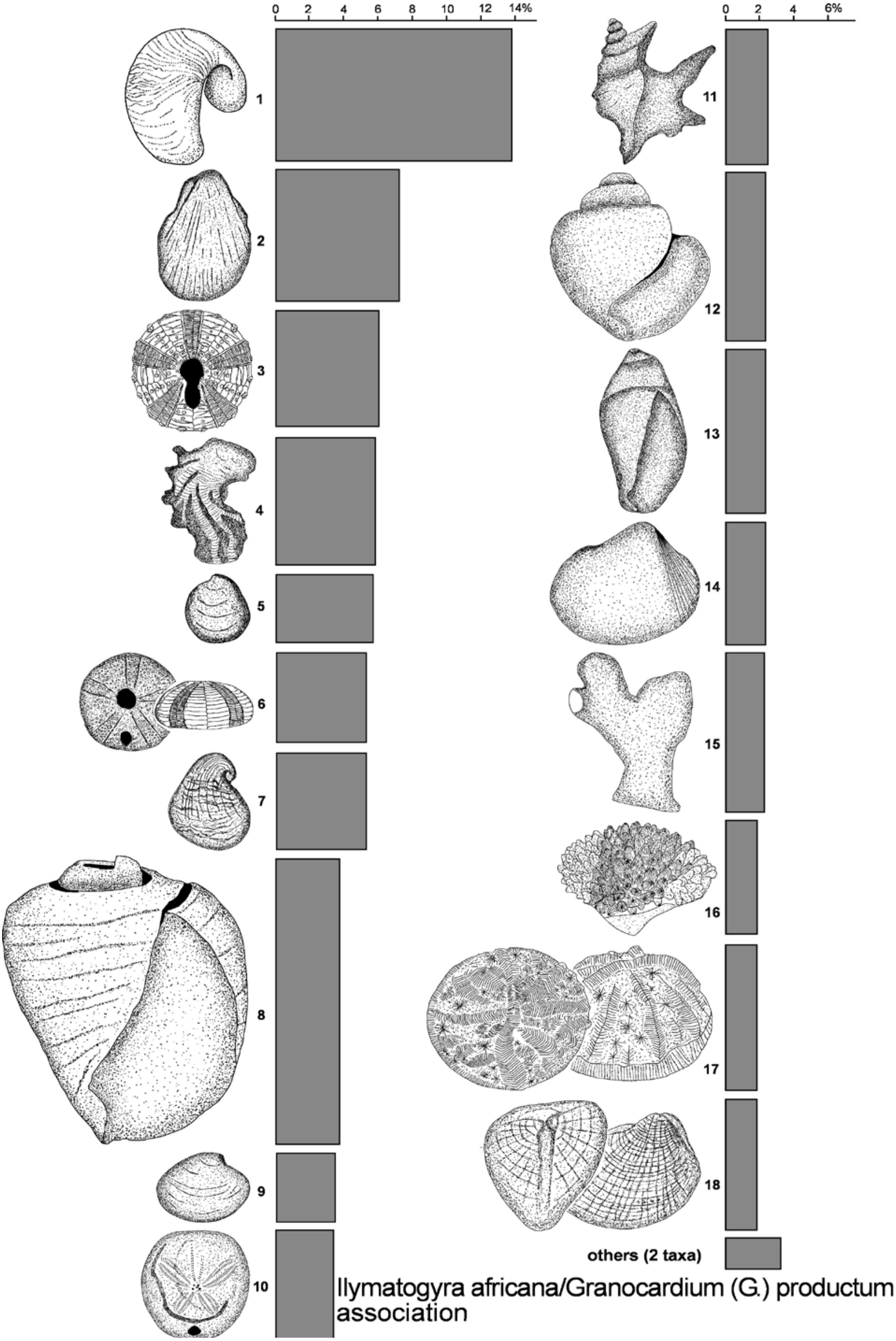


Text-fig. 5.27. Reconstruction of the *Pycnodonte* (*P.*) *vesicularis vesiculosa*/*Phelopteria gravida* association. Numbers denote taxa of the trophic nucleus (Text-fig. 5.26).

5.6.5. *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association

Description: Seven samples with 764 individuals have been grouped in this association. The trophic nucleus consists of 20 species dominated by cemented epifaunal bivalve *Ilymatogyra africana* and the shallow-infaunal *Granocardium* (*G.*) *productum* accounting together for 20.94% (Text-fig. 5.28). Other members of the trophic nucleus are the echinoids *Heterodiadema libycum* (6.02%), *Coenholectypus larteti* (5.37%), and *Hemiaster* (*H.*) *syriacus* (3.40%); gastropods such as "*Strombus*" *incertus*, "*Aporrhais*" *dutrugei*, *Tylostoma* (*T.*) *cossoni* (together 14.28%); the coral *Aspidiscus cristatus* (1.96%); and the coralline sponge *Actinostromarianena* sp.1 (2.23%). The most other important bivalvia taxa of the trophic nucleus are the shallow infaunal *Tenea delettrei*, *Paraesa faba*, *Protocardia hillana* (together 11.65%) and the deep infaunal *Pholadomya vignesi* (1.96%). Bivalves dominate the association with 58.90%, followed by gastropods (18.45%) and echinoids (16.50%). Corals and coralline sponges occur subordinately (together 6.14%). The ammonite *Neolobites vibrayeanus* and the nautiloid *Angulithes mermeti* represent the nektonic elements of this association. Epifaunal organisms represent 56.41% of the total benthic fauna, shallow infaunal ones 40.05%. The bivalves *Pholadomya vignesi* and *Lucina fallax* are the only deep-infaunal organisms (together 2.75%). With respect to the feeding habits, suspension-feeders dominate (63.87%), followed by deposit-feeders (10.07%) and herbivores (5.36%). The other feeding groups such as microcarnivores, carnivores, and omnivores as well as chemosymbiotic organisms are of minor importance (together 19.48%). The feeding mode of some gastropods is difficult to determine (1.17%). All infaunal bivalves are preserved as internal and composite moulds of articulated specimens. Epifaunal oysters such as *Ceratostreon flabellatum* and *Rhynchostreon suborbiculatum* occur as single-valves or articulated and are generally preserved with their original shell. Epifaunal and shallow-infaunal echinoids as well as corals are also well preserved, while coralline sponges are partially recrystallized. All gastropods and nektonic organisms are preserved as internal and composite moulds. Some epifaunal echinoid tests exhibit scratch marks of other organisms along the ambitus and an oral surface with small pores (Text-fig. 5.8D, E). Such marks were possibly left by grazing gastropods and the small pores by clionid sponges. In addition, a common epibiont on some echinoid tests such as *Heterodiadema libycum* as well as on moulds of the gastropod *Tylostoma* (*T.*) *cossoni* and on the plicatulid bivalve *Plicatula* (*P.*) *auressensis* is *Serpula* (*Cycloserpula*) sp. (Text-fig. 5.8F-H). As oyster shells are generally quite thick, borings are widely distributed in their shells. Thus, some of the oysters in this association are abundantly bored by clionid sponges producing the ichnogenus *Entobia,* less commonly by acrothoracican barnacles (e.g, LAMBERS & BOEKSCHOTEN 1986) and bivalves (*Gastrochaenolites*) (Text-fig. 5.8A-C). The *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association is limited to calcareous rocks and is found mostly in marls and marly pack- to floatstones from the Cenomanian Halal and Galala formations of the Gebel Areif El-Naqa and Wadi Quseib sections. The species richness strongly varies between 8 and 37 (mean 15.42), and the evenness from 4.10 to 15.70 (mean 8).

Text-fig. 5.28. Trophic nucleus of the *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association. 1. *Ilymatogyra africana*, 2. *Granocardium* (*G.*) *productum*, 3. *Heterodiadema libycum*, 4. *Ceratostreon flabellatum*, 5. *Tenea delettrei*, 6. *Coenholectypus larteti,* 7. *Rhynchostreon suborbiculatum*, 8. "*Strombus*" *incertus*, 9. *Paraesa faba*, 10. *Hemiaster* (*Hemiaster*) *syriacus*, 11. "*Aporrhais*" *dutrugei*, 12. *Tylostoma* (*Tylostoma*) *cossoni*, 13. *Pterodonta deffisi*, 14. *Protocardia hillana*, 15. *Actinostromarianena* sp.1, 16. *Tortoflabellum* sp., 17. *Aspidiscus cristatus*, 18. *Pholadomya vignesi*, others include two species: 19. *Harpagodes heberti*, and 20. *Pchelinsevia coquandiana.* Width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.


0
2
4
6
8
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12
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1
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9
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12
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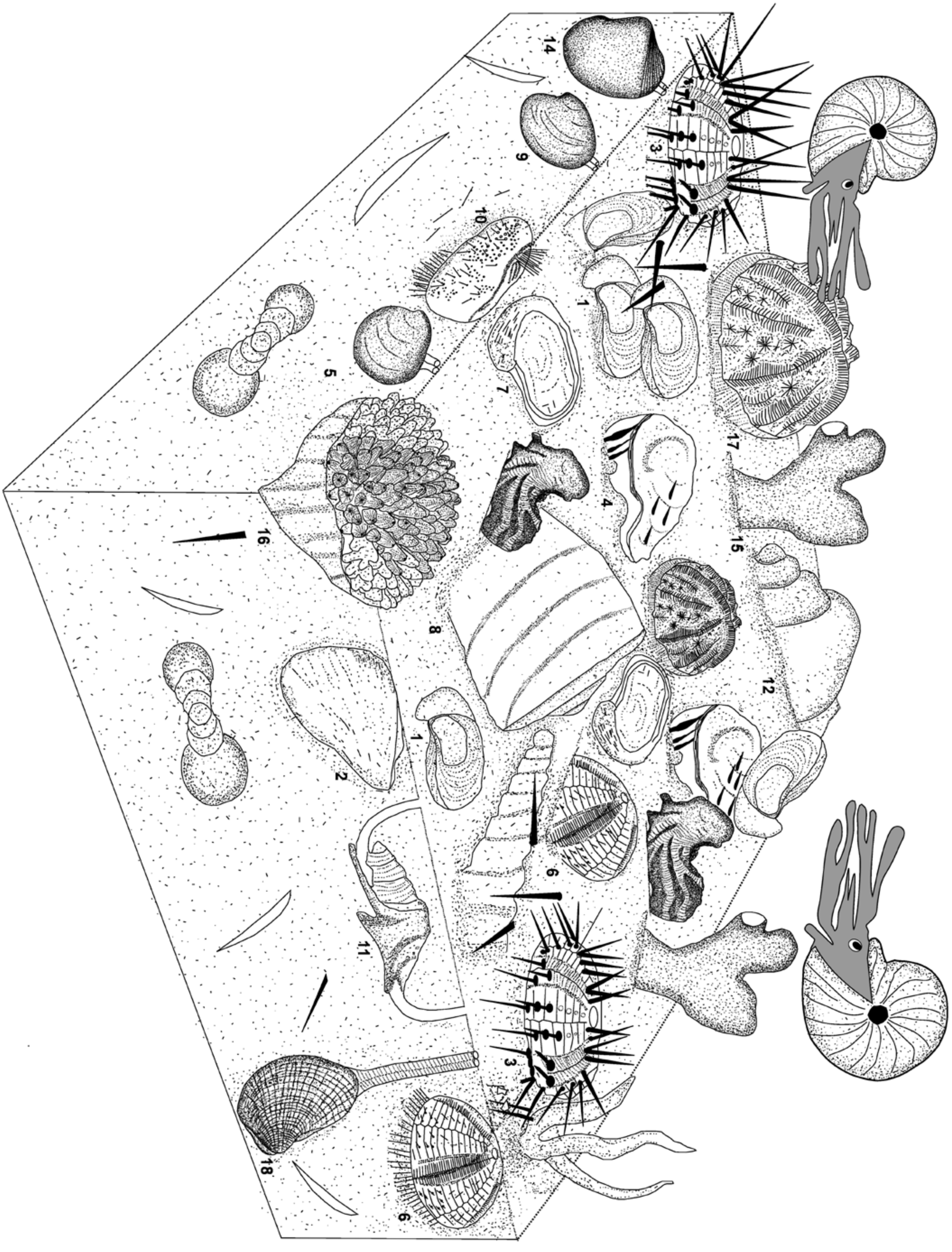
17
18
others (2 taxa)
Ilymatogyra africana/Granocardium (G.) productum association

Interpretation: The *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association is characterized by a high species richness and evenness, and thus it was subjected to a low degree of environmental stress. Oysters, which represent 27.35% of the total benthic fauna, are very tolerant organisms, able to withstand wide variations in temperature, salinity, and dissolved oxygen but the presence of stenohaline groups such as echinoids and ammonites indicate euhaline conditions. According to STENZEL (1971), BOTTJER (1981), and DHONDT et al. (1999), exogyrine oysters, such as *Ilymatogyra africana, Ceratostreon flabellatum* and *Rhynchostreon suborbiculatum*, lived in shallow to very shallow waters (i.e., in middle shelf environments; 25-50 m in depth). The presence of 56.41% epifaunal organisms and 40.05% shallow infauna together with 2.75% deep burrowing bivalves indicates that the association is adapted to life on a moderately soft substrate under well oxygenated, fully marine conditions. Large and heavy gastropods such as "*Strombus*" *incertus* and *Tylostoma* (*Tylostoma*) *cossoni* indicate a certain stability of the substrate. In addition, herbivorous gastropods probably indicate the presence of plants and thus deposition within the shallow photic zone. This interpretation is also supported by the presence of corals (Text-fig. 5.29). Boring organisms are widespread in most marine facies and are primary agents of shell destructions (e.g., DRISCOLL, 1970; BERTLING, 1992; CUTLER & FLESSA, 1995; RUBERTI, 1997). Moreover, a low sedimentation rate gives these bioeroders the chance to affect the oysters and echinoids prior to final burial, because when sediments input is high, a large amount of energy is required to clear blocked canals and tissues (KRAUTTER 1998; EL-HEDENY & EL-SABBACH 2007). In addition, the abundance of clionid sponges decreases with increasing water depth (HOBBIE et al. 1972). Most specimens of the coral *Aspidiscus cristatus* in the association are also highly bioeroded, both on upper and lower surfaces, and encrusted by oysters and serpulids (Text-fig. 5.8J). These features record phases of increased water energy, sufficient to dislodge the colonies. The oyster shells are well preserved but mostly disarticulated and convex-up orientated (60% convex-up and oblique, 40% convex-down). Fragmentation is uncommon. Consequently, the oysters in this association rarely occur in situ, but commonly have been reworked and possibly for a short distance under a moderately high energy regime. As the morphology of echinoids is closely related to the environment, they are excellent tools for reconstructing palaeoenvironments (KROH & NEBELSICK 2003). Thus, SMITH & BENGTSON (1991) noted that the poorly developed petals of the genus *Mecaster* (as in *Hemiaster* (*H.*) *syriacus*) indicate relatively warm water conditions. In addition, *Heterodiadema libycum* and *Tetragramma variolare* are good indicators of moderately shallow platform environments (NÉRAUDEAU & COURVILLE 1997). Some echinoid tests e.g., *H. libycum* and *C. larteti* exhibit scratch marks possibly produced by grazing gastropods. These bioeroders started their action after the death of the echinoids, because the echinoid tests were covered, during their life-times with tissue so that no bioeroding activity was possible. Also the presence of serpulids on the adoral surface of the echinoid *H. libycum* clearly indicates post-mortem encrustation.

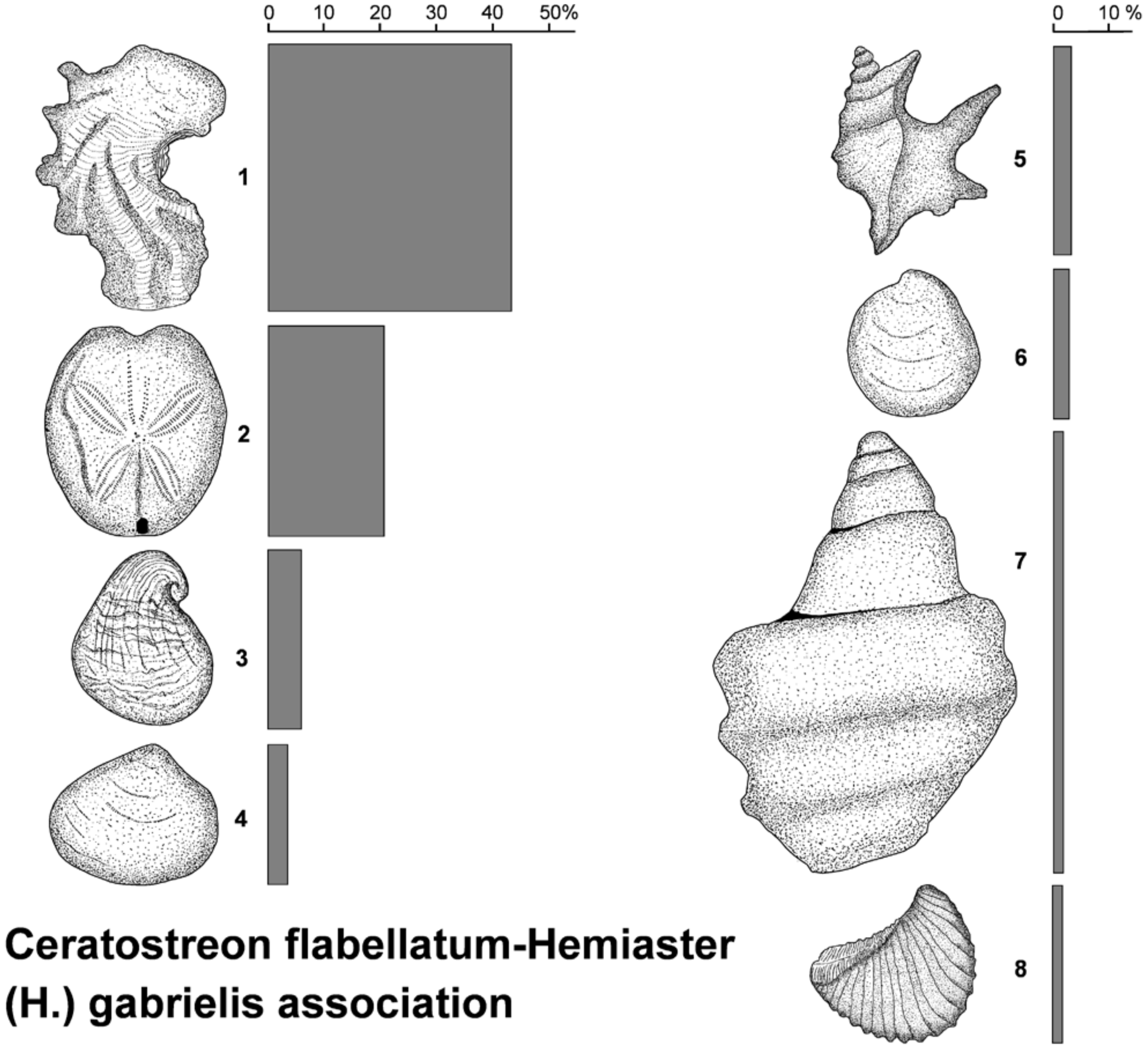
5.6.6. *Ceratostreon flabellatum*/*Hemiaster* (*Hemiaster*) *gabrielis* association

Description: The association consists of 5 samples with 34 taxa and 370 individuals. There are 8 species within the trophic nucleus, which is dominated by the epifaunal cemented bivalve *Ceratostreon flabellatum* (43.51%) and the shallow-infaunal echinoid *Hemiaster* (*Hemiaster*) *gabrielis* (20.54%) (Text-fig. 5.30). Other species of the trophic nucleus occur subordinately (Text-fig. 5.30). Bivalves are the most common faunal element (65.50%), followed by echinoids (22.64%), and gastropods (11.85%). The majority of bivalves are represented by oysters (67.64% of the total number of bivalves and 49.59% of the total fauna). The association contains a large number of epifaunal (55.80%) and shallow-infaunal organisms (43.39%).



Text-fig. 5.29. Reconstruction of the *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association. Numbers denote taxa of the trophic nucleus (Text-fig. 5.28).

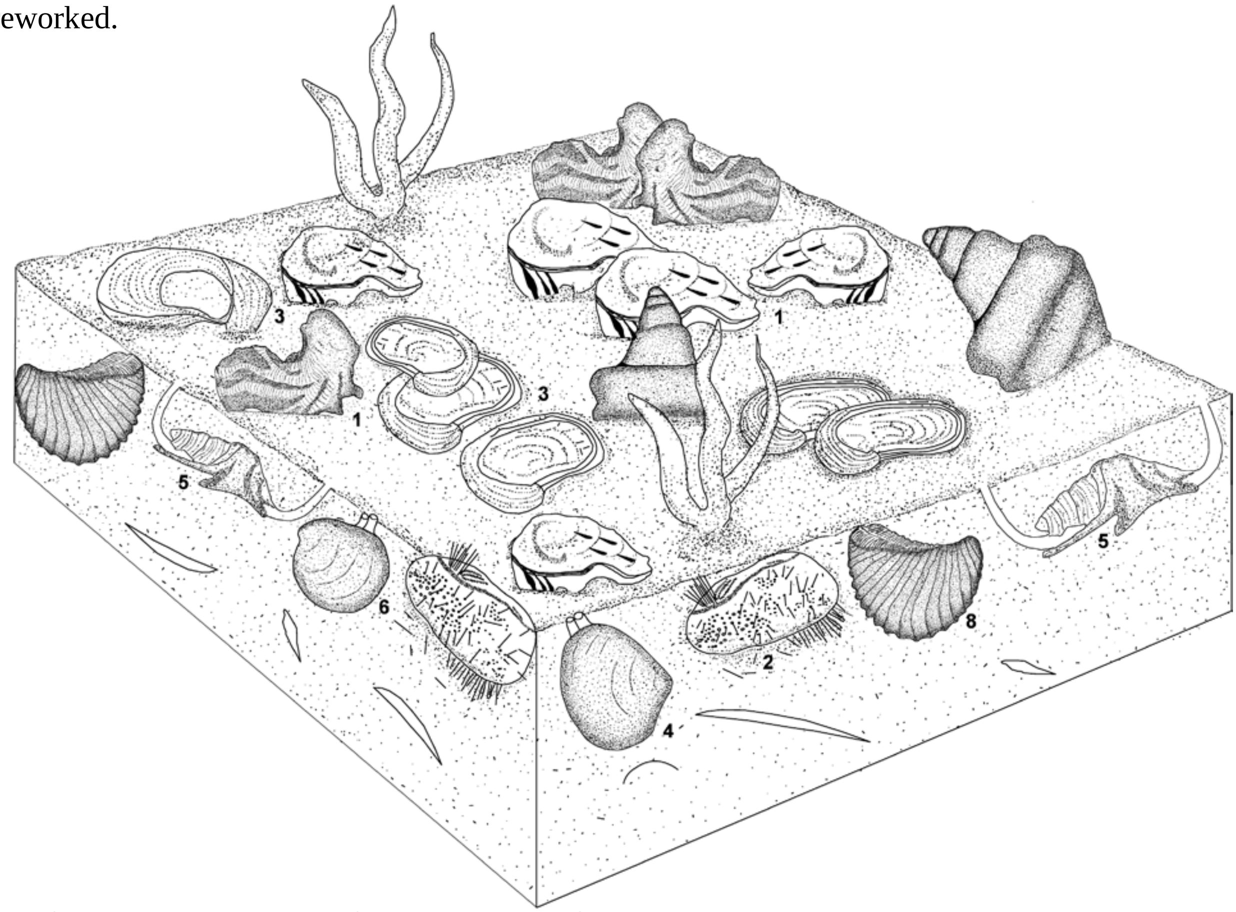
Deep-burrowing infauna is totally absent. Concerning feeding modes, suspension-feeders dominate (69.81%), followed by deposit-feeders (23.18%), while carnivores and herbivores are rare (together 4.84%). The feeding mode of some gastropods (2.15%) is difficult to determine. The preservation of the fauna is similar to that in the *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association. Infaunal bivalves such as *Meretrix orientalis* and *Tenea delettrei* and gastropods such as *Harpagodes heberti* and "*Aporrhais*" *dutrugei* are preserved as internal and composite moulds, whereas oysters and echinoids occur in shell preservation. The species richness varies strongly (3-23: mean 10). Because of the dominance of *Ceratostreon flabellatum* and *Hemiaster* (*H.*) *gabrielis* (together 64.05%) the evenness is low (2.11-4.5; mean 3.21). The association was found predominantly in green glauconitic marls and greyish-yellow marly limestones of the lower marly member of the Halal Formation of



Text-fig. 5.30. Trophic nucleus of the *Ceratostreon flabellatum/Hemiaster* (*Hemiaster*) *gabrielis* association. 1. *Ceratostreon flabellatum*, 2. *Hemiaster* (*Hemiaster*) *gabrielis*, 3. *Rhynchostreon suborbiculatum*, 4. *Meretrix orientalis*, 5. "*Aporrhais*" *dutrugei*, 6. *Tenea delettrei*, 7. *Harpagodes heberti*, and 8. *Pterotrigonia* (*S.*) *scabra*. Width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

Gebel Areif El-Naqa, less commonly in hard, fossiliferous rudist rudstone of the middle siliciclastic/carbonate member of the Cenomanian Galala Formation at Wadi Quseib section.

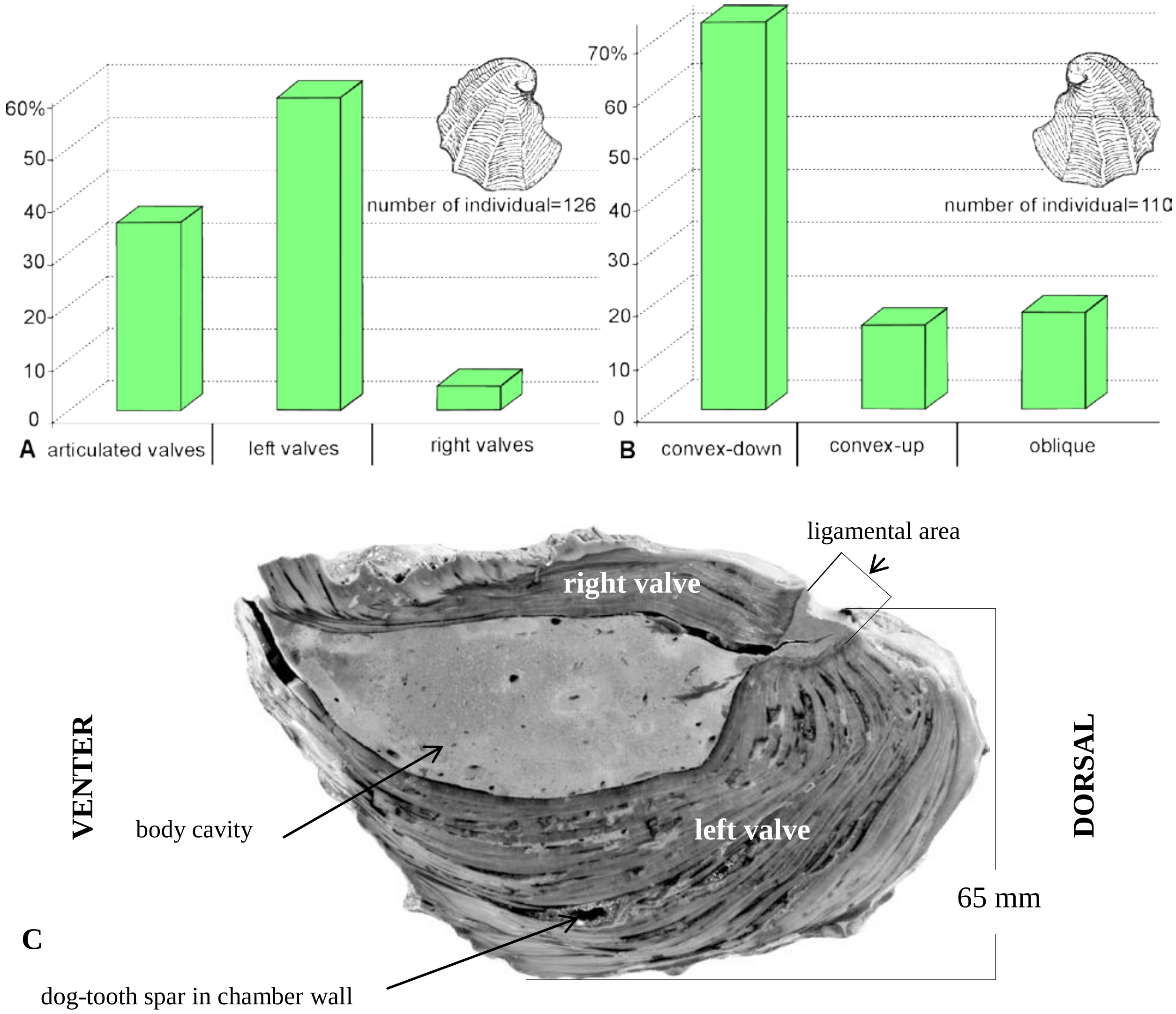
Interpretation: 43.39% shallow-infaunal organisms indicate that the substrate was soft during the deposition of *Ceratostreon flabellatum/Hemiaster* (*H.*) *gabrielis* association. Shells of the infauna probably served as hard substrate for the cemented epifauna (e.g., *Exogyra conica* and *Ceratostreon flabellatum*) (Text-fig. 5.31). Stenohaline shallow-infaunal echinoids (22.64%) document euhaline conditions. The very fine grain size of the lower marly member at Gebel Areif El-Naqa indicate a generally low sedimentation rate. In addition, the common presence of glauconite in this member suggests a low sedimentation rate in a shallow fully marine to nearshore environments (McRae, 1972). The high percentage of fixo-sessile oysters (*Ceratostreon flabellatum*) support also low sedimentation rates. A seasonal or episodic increase in surface water productivity may have caused an increase of particulate organic matter and thus of organic nutrients in the water column, which in turn may have caused episodic depletion of oxygen in the deeper layers of the substrate. Low oxygen conditions are confirmed by the lack of deep infaunal organisms and presence of dark sediments in the upper part of the lower marly member. Thick limestone beds with fragmented rudists and corals indicate episodic higher water energy. This is also supported by the abundant epifaunal suspension-feeders. Therefore water energy must have been sufficiently high to keep organic nutrients in suspension, but low enough to accumulate particulate organic matter being used by the deposit feeders (23.18%). Taphonomically, nearly all shallow-infaunal echinoids lack any sign of bioerosion, which suggests that they were not exhumed after death. In addition, epifaunal oysters in this association are well preserved but mostly disarticulated (single-valves) which indicate that they have been reworked.



Text-fig. 5.31. Reconstruction of the *Ceratostreon flabellatum/Hemiaster* (*Hemiaster*) *gabrielis* association. Numbers denote taxa of the trophic nucleus (Text-fig. 5.30).

5.6.7. *Costagyra olisiponensis*/*Ceratostreon flabellatum* association

Description: The association is documented by two samples and 179 individuals with 13 taxa. The trophic nucleus consists of two epifaunal suspension-feeders, *Costagyra olisiponensis* (70.39%) and *Ceratostreon flabellatum* (11.17%). Bivalves are the main benthic group in this association (92.73%), while gastropods and echinoids are rare (3.35% and 3.91% respectively). Shallow-infaunal elements account for 63.12% of all individuals, followed by epifauna (35.75%). *Pholadomya pedernalis* is the only deep-burrowing bivalve (1.11%). 93.85% of the faunal elements are suspension-feeders, 3.91% deposit-feeders, 1.67% herbivores (gastropods), and the rest carnivores. Most of the epifaunal oyster *Costagyra olisiponensis* are very large, variable in outline, thick, (L=25-104; H=33-130; C=33-75 mm), and articulated. Left valves are far more abundant than right valves (LV=59.52%; RV=4.76%, articulated valves=35.71%) being thicker and more robust (Text-fig. 5.32). The majority of juvenile individuals are disarticulated and more ornamented (spiny radial ribs) than the adult ones. Most of the oyster shells are encrusted and highly bioeroded with micro- and macro-borers *Entobia* is restricted to the commissural area of adult individuals of *C. olisiponensis*. The oysters are generally preserved with their shell.



Text-fig. 5.32. A-B. Preservational states (in %) of *Costagyra olisiponensis* (SHARPE, 1850) from the Cenomanian Galala Formation of East Themed. C. Dorsal-ventral cross-section through *Costagyra olisiponensis* showing the cup-shaped left valve and its excessive shell thickening in the dorsal region.

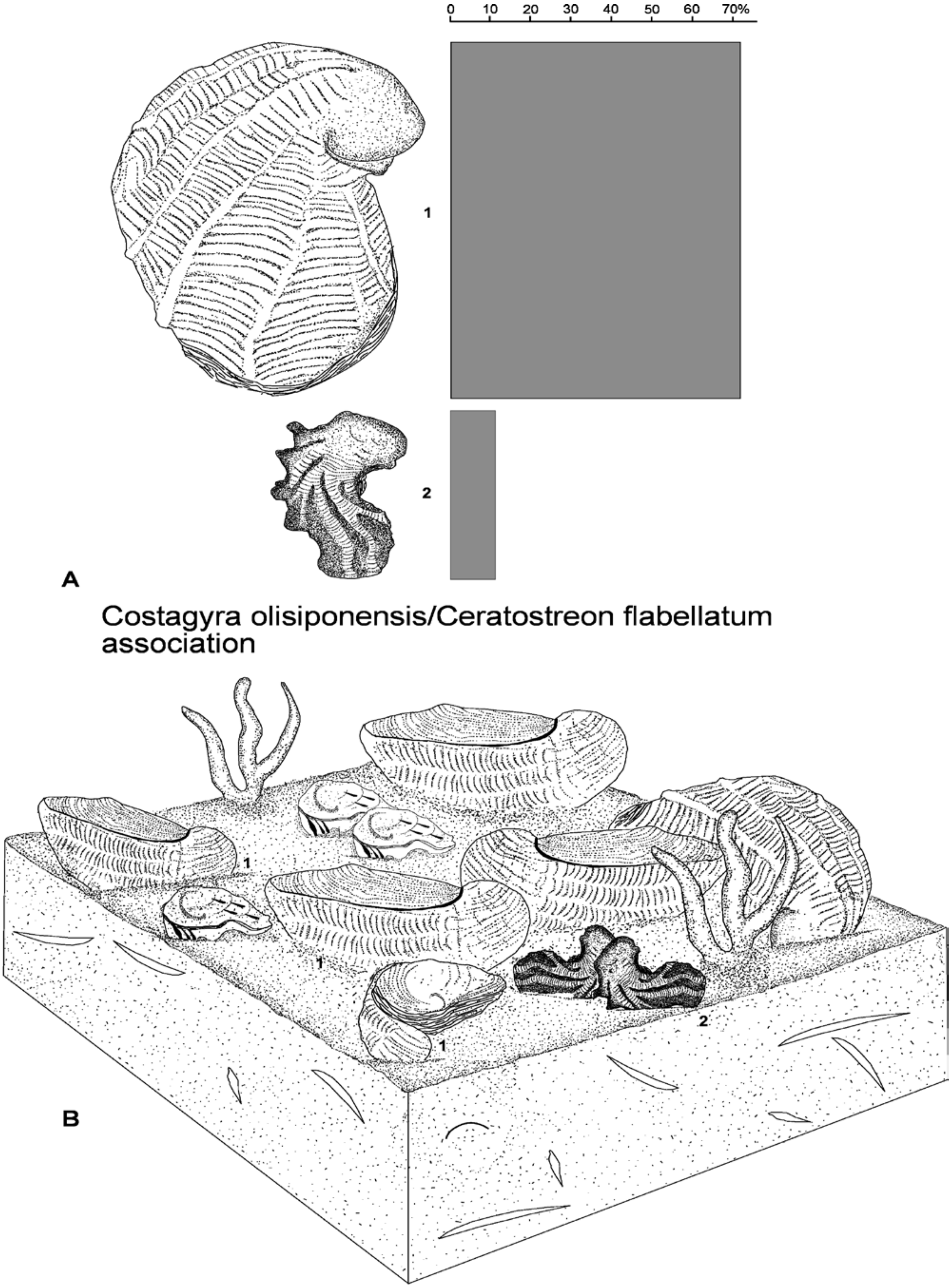
All gastropods are preserved as internal and composite moulds. Species richness (range: 5-9; mean: 7) and evenness (range: 1.78-2.04; mean: 1.99) are low. The association occurs in yellowish grey to yellowish green, glauconitic, moderately soft marls.

Interpretation: According to SEILACHER (1984: 217), the adhesion of organisms to the sediment may be increased by strong ornamentation (radial ribs, spines, concentric ribs). Therefore, the numerous spiny radial ribs in juvenile *Costagyra olisiponensis* serve to strengthen the attachment to the substrate and to protect themselves against predators. In addition, the excessive shell thickening and robust structure of adult individuals serve to increase stabilization on the soft substrate and indicate also that the water was relatively warm so that carbonate could be easily secreted (Text-fig. 5.33). The lenticular chambers, which are filled by sparry calcite (Text-fig. 5.32C), are considered here to have been produced to reduce the weight, in order to keeps the commissure above the sediment/water interface. In comparison to their modern representatives. Bivalves living in warm and high-energy environments tend to have thicker shells and more prominent growth lines than those living in quiet and cold water environments (MORRISON & BRAND 1986: 245). According to CRAIG & JONES (1966), VERMEIJ (1987), and BOND & SAUNDERS (1989), thick shells also strength-enhancing features that decrease the probability that a predator (such as ammonites) will be able to break the valves. The taphonomic features show that there is no evidence of reworking. For instance, the good preservation of the fauna, the presence of articulated valves, and high percentage of convex-down orientation (Text-fig. 5.32B) indicate that transport and reworking were insignificant. The low values of species richness and evenness are most probably a result of sample size effect (see rarefaction curve; Text-fig. 5.12). Low sedimentation rates can be inferred from the predominance of epifaunal cemented bivalves (91.62%), the great abundance of bioeroders, and the presence of glauconite.

5.6.8. *Rhynchostreon suborbiculatum* association

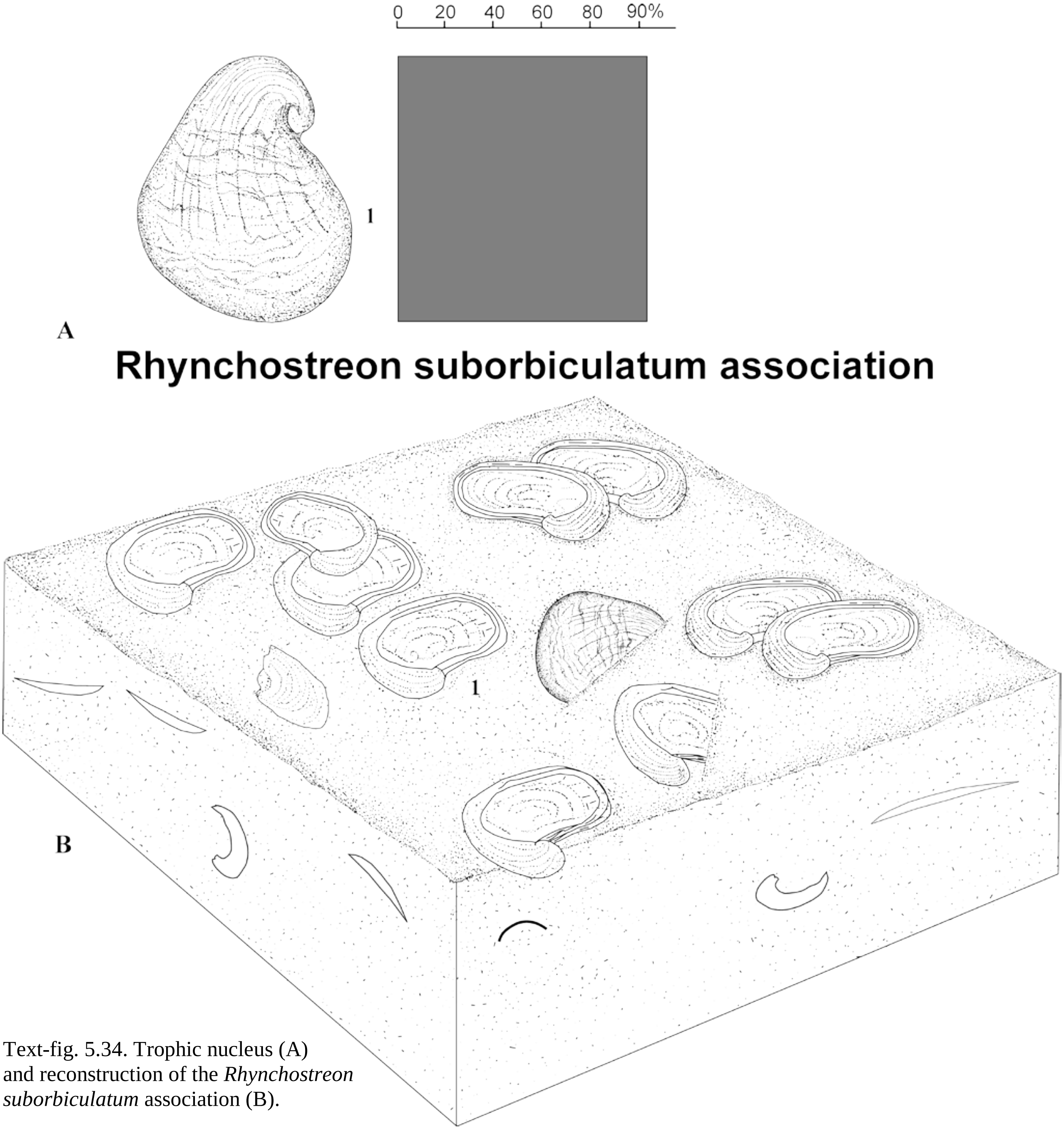
Description: Three samples with altogether 367 individuals and 10 taxa form this association. The trophic nucleus consists only of the oyster *Rhynchostreon suborbiculatum*, which represents 91.83% of the total macrobenthic fauna (Text-fig. 5.34). Bivalves are the most common faunal element (99.18%), while gastropods and echinoids are very rare. The *Rhynchostreon suborbiculatum* association is dominated by cemented oysters (98.63%) such as *Gyrostrea delettrei*, *Ceratostreon flabellatum*, and *Ilymatogyra africana*. Shallow-infaunal and deep-infaunal elements do not exceed 1.36% of the total fauna. Concerning the feeding modes, all benthic elements are suspension-feeders (99.18%). Because of the dominance of *Rhynchostreon suborbiculatum* (91.83%); the values of evenness (1 to 3.07; mean 1.90) and species richness (1 to 7; mean 4.66) are low. All oysters are preserved with their shell while gastropods are preserved as internal moulds. Oysters occur mostly disarticulated and fragmented. Some of them, especially *R. suborbiculatum*, are bored (*Entobia*). Stenohaline organisms are nearly absent. The association occurs predominantly in grey, hard, coarse-grained rudstones.

Interpretation: The dominance of cemented epifaunal oysters (91.83%) and the nearly complete lack of infaunal elements and gastropods in the *Rhynchostreon suborbiculatum* association indicates a firm substrate and a relatively low sedimentation rate. The latter is documented also by the presence of *Entobia*. The scarcity of infaunal organisms may be also due to early diagenetic dissolution of aragonitic shells. Low diversity values, combined with the dominance of a single taxon, indicate environmental stress conditions. However, the low diversity values and lack of stenohaline groups in this association are probably a result of sample size effect (see rarefaction curve; Text-fig. 5.12).



Text-fig. 5.33. Trophic nucleus (A) and reconstruction of the *Costagyra olisiponensis/Ceratostreon flabellatum* association (B). 1: *Costagyra olisiponensis*, 2: *Ceratostreon flabellatum*. The shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

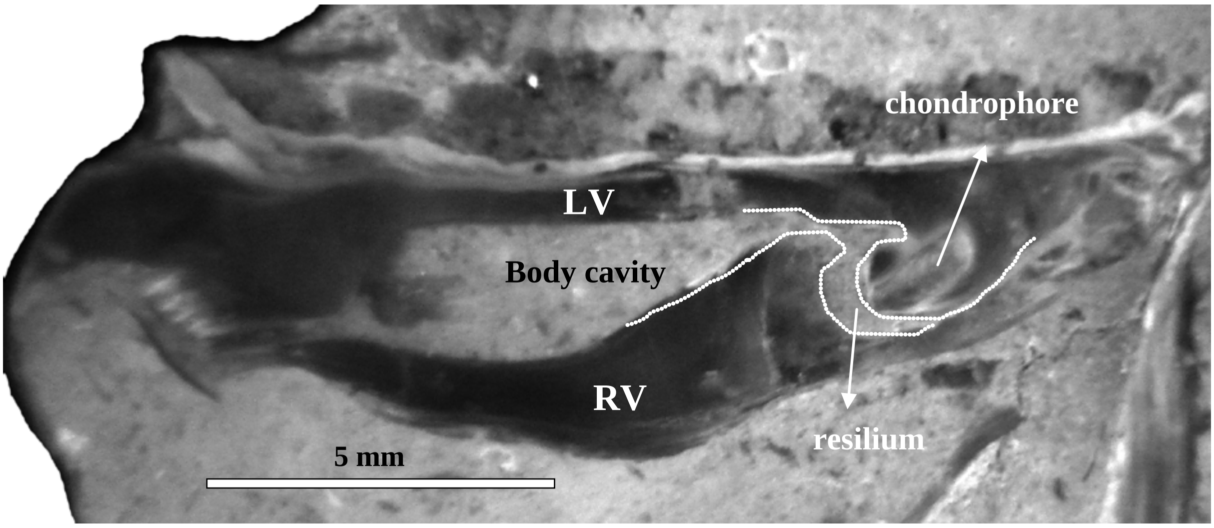
According to FÜRSICH & WERNER (1984: 89), the absence or scarcity of stenohaline organisms such as ammonites, echinoids, and corals possibly indicates deviating salinity values. The dominance of suspension-feeders (99.18%) indicates that the energy level was sufficiently high to keep food particles in suspension with low sedimentation rate. The high percentage of disarticulated shells indicates that reworking took place.



Text-fig. 5.34. Trophic nucleus (A) and reconstruction of the *Rhynchostreon suborbiculatum* association (B).

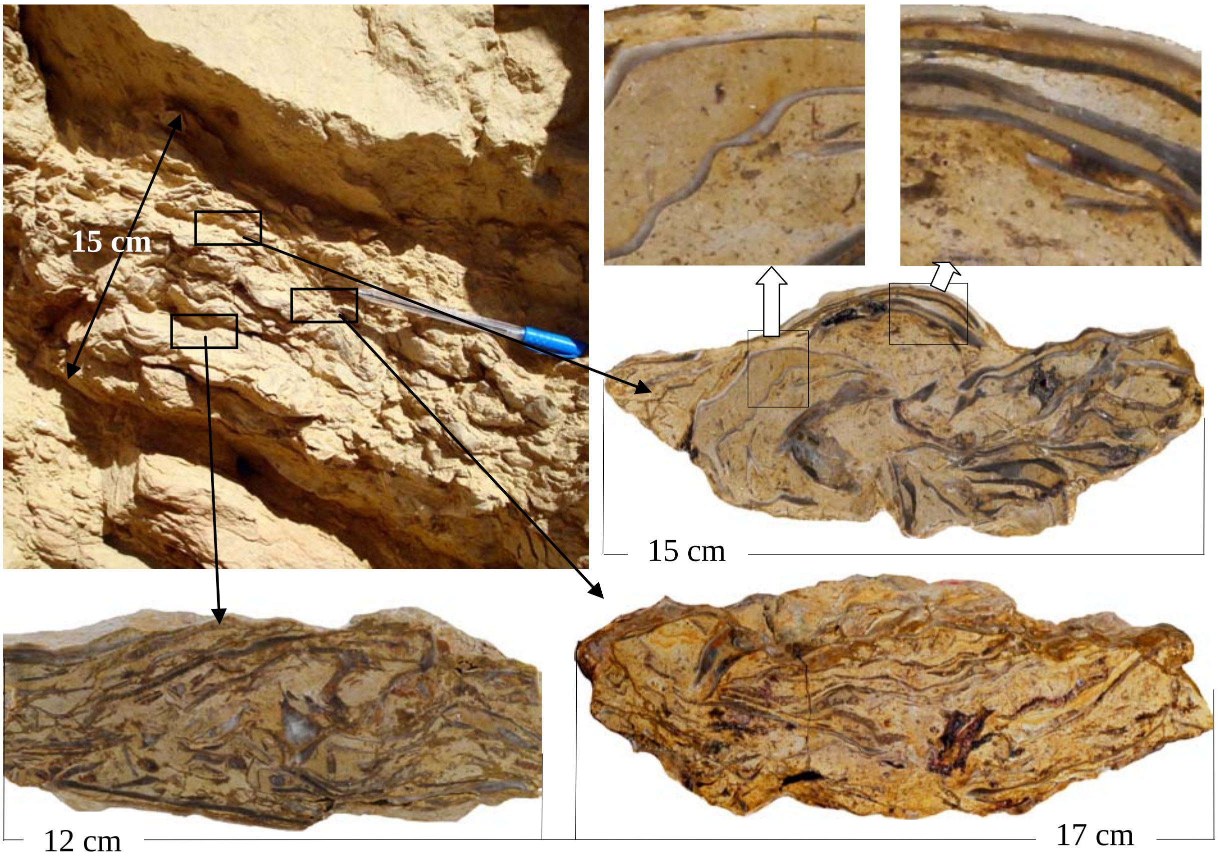
5.6.9. *Chondrodonta joannae* association

Description: The *Chondrodonta joannae* association is represented by 3 samples with 174 individuals. The trophic nucleus consists only of the oyster *Chondrodonta joannae* (91.95%) (Text-fig. 5.37A). Bivalves dominate the association (91.95), followed by the coral *Tortoflabellum* sp. (7.47%), while gastropods are very rare (0.60%). Epifaunal elements account for 99.42%, shallow-infauna for the rest. Deep-burrowing faunal elements are completely absent. Thus the association consists of mono- or near-monospecific accumulations of *Chondrodonta joannae* in different states of preservation. Most valves of *Chondrodonta* are strongly interlocked by a well developed and projecting chondrophore of the left and a corresponding socket of the right valve (Text-fig. 5.35). Therefore, the both valves normally remain articulated after post-mortem transport (DHONDT & DIENI 1993). They are concentrated in beds in the Cenomanian deposits with a preferred convex-up orientation. The shell concentrations vary in thickness from 12 to 20 cm. Polished slabs show that their valves occur in different states of preservation ranging from articulated specimens, to fragmented shells and shell debris but whereby articulated specimens dominate (Text-fig. 5.36). The lower part of the shell beds is more densely packed than the upper one. Stacking and imbrications of shells can be observed. Apart from the coral *Tortoflabellum* sp., which lived as a microcarnivore (7.47%), all other faunal elements are suspension-feeders (92.53%). Due to the dominance of *Ch. joanne*, the values of evenness and species richness are very low (mean evenness is 1.30). The association occurs in coarse-grained carbonate facies (*Chondrodonta* rudstone), locally also floatstone is developed in areas protected by shells (Text-fig. 5.36).



Text-fig. 5.35. Polished cross-section through an articulated specimen of *Chondrodonta joannae* showing the flat left valve and slightly convex right valve with a chondrophore. The chondrophore and its corresponding socket are strongly interlocked to prevent the lateral and/or vertical shear of valves.

Interpretation: In the *Chondrodonta joannae* association, shell accumulations represent high energy events (storms) leading to concentration of shells. This is documented by the densily packed, imbricated or stacked, randomly oriented, and highly fragmented *Chondrodonta* valves. The low values of species richness and evenness, combined with the dominance of a single taxon, may indicate also high stress conditions. In general, chondrodonts change their growth direction from an initial horizontal stage to a sub-vertical position and are cemented with their moderately convex right valves. In the term of functional morphology, the elongated shape can be regarded as indicative either of the mud-sticking habit (Text-fig. 5.37A-B). According to MACHALSKI (1998), such elevated growth probably related to the competition for space between specimen growing close to each other. Because no traces of contact with adjacent individuals, the elongated growth of the present material is regarded here as stick-shaped mud-stickers (SEILACHER, 1984). Vertical growth of mud-stickers is possible only when their shells are passively stabilized by surrounding sediments in high sedimentation rates. In contrast, recliners, with their commissure close to the sea floor, could have grown only under conditions of a much lower, or even nil sedimentation rates.

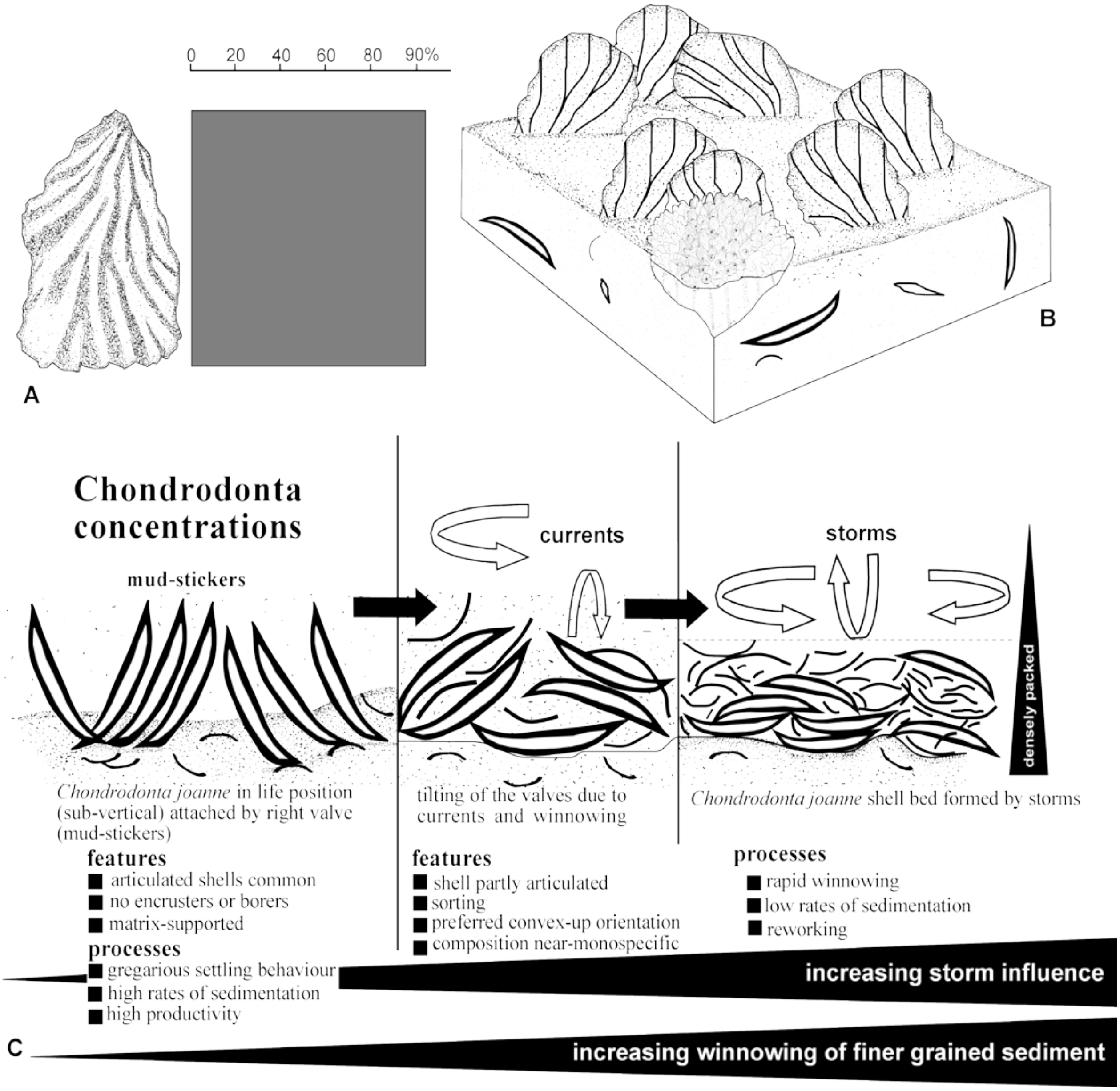


Text-fig. 5.36. *Chondrodonta joanne* shell bed from the middle siliciclastic/carbonate member of the Cenomanian Galala Formation of Wadi Quseib. Shells are densely packed in the lower part of bed. The fine-grained sediment in some parts has been trapped by the valves.

In such more or less elevated life position, strong currents can easily produce closely packed shell beds (more or less parallel to the bedding plane). The compressed and broad valves of *Chondrodonta* (flat left valve and slightly convex right valves with small body cavity, Text-fig. 5.35) are easier to tilt than other reclining oysters. Therefore, they are prone to form shell beds and became secondary hard substrates for other epifaunal organisms such as rudists (DHONDT & DIENI 1993). During storms, the loose, fine-grained sediment was winnowed away, while *Chondrodonta* shells were concentrated in rudstones. The association is probably a parautochthonous or autochthonous, formed by in-situ reworking and winnowing by currents. Text-fig. 5.37C shows the formation of a *Chondrodonta* shell bed by storm action. The strong dominance of suspension-feeding epifaunal organisms (92.53%) refers also to a low sedimentation rate and nutrient-rich community. The presence of stenohaline corals (7.47%) indicates a normal marine condition.

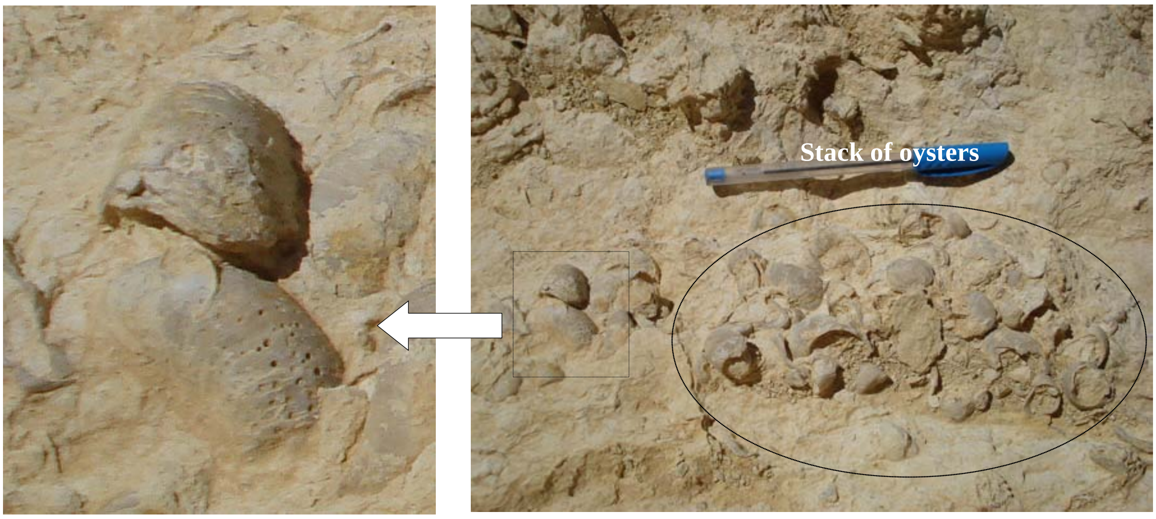
5.6.10. *Ilymatogyra africana* association

Description: The *Ilymatogyra africana* association is documented by 5 samples and 1055 individuals with 19 taxa. The trophic nucleus contains only the oyster *Ilymatogyra africana* (84.83%) (Text-fig. 5.40). Bivalves are the main macrobenthic element in the association (98.19) while gastropods and echinoids are rare (1.50% and 0.30% respectively). With respect to life habits, epifauna dominates the association (96.30%), while shallow-infauna and deep-nfauna are rare (3.50% and 0.20%, respectively).



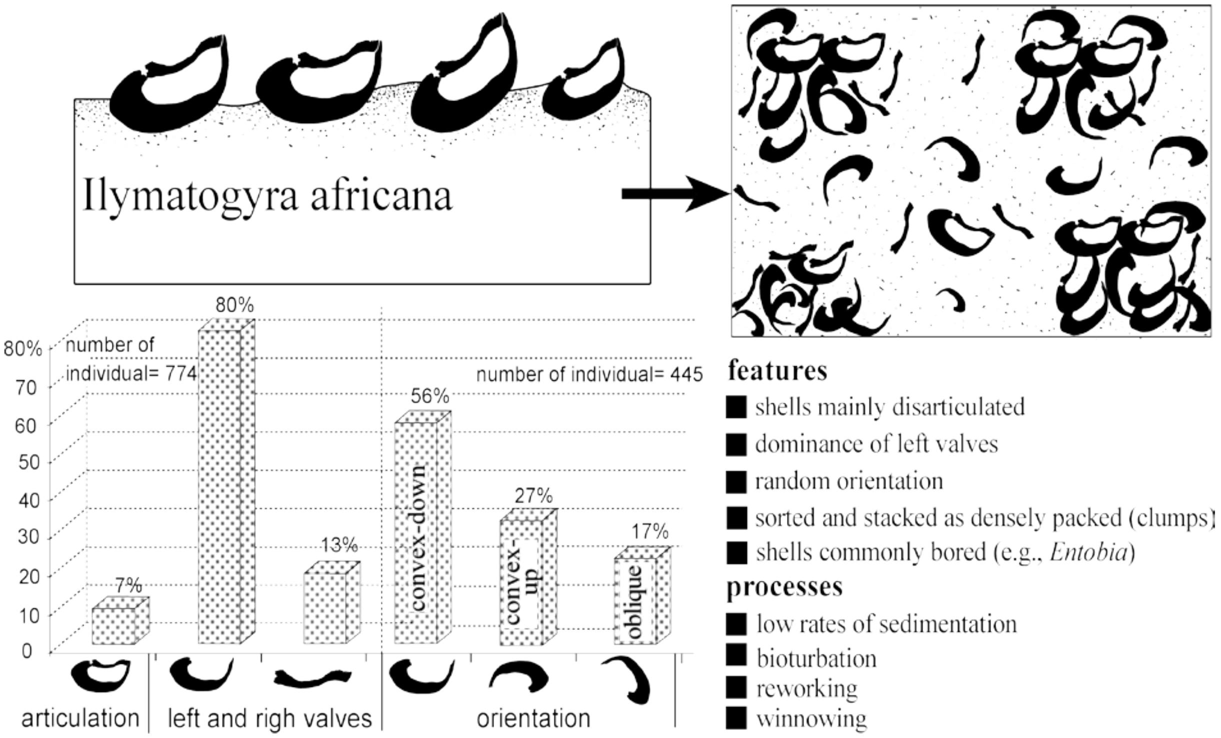
Text-fig. 5.37. Trophic nucleus (A) and reconstruction of the *Chondrodonta joannae* association (B). C. Taphonomic model of the formation of *Chondrodonta* shell beds. The shaded area (A) is a semi-quantitative measure of its biovolume.

The association is strongly dominated by suspension-feeders (98.19%). Herbivores, carnivores, and omnivores are very rare and account for the rest. The *Ilymatogyra africana* association exhibits a fairly low diversity, species richness varying between 2 and 11 (mean: 5.6) and evenness values between 1.17 and 1.63 (mean: 1.39). Most of epifaunal oysters are disarticulated (80% left valves, 13% right valves, 7% articulated, Text-fig. 5.39) and are generally preserved with their shell. They are well sorted and stacked as densely packed shells (clumps, Text-fig. 5.38) in some parts and scattered in others. 56% of valves are convex-down oriented when scattered (Text-fig. 5.39). Highly fragmented shells are generally lacking. Some valves are abundantly bored by clionid sponges particularly on the convex side of the left valves. The *Ilymatogyra africana* association occurs mainly in coarse-grained carbonate rocks (floatstone and rudstone), and occasionally in shale/marl interbeds.



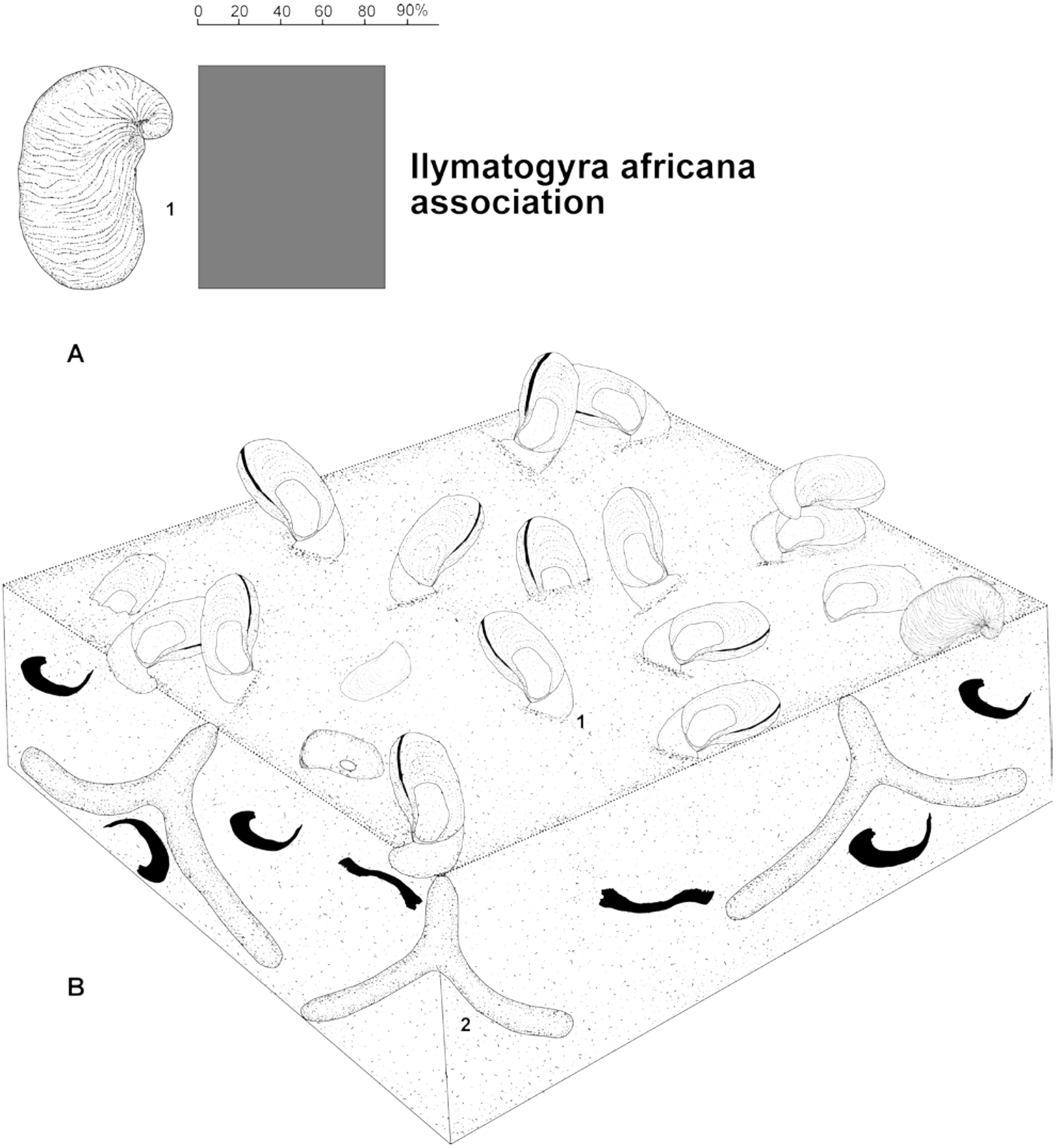
Text-fig. 5.38. Field photograph showing clumps of *Ilymatogyra africana* from the Cenomanian Galala Formation of East Themed. The enlarged photograph (left) shows the sponge boring *Entobia* on the left valve.

Interpretation: The low diversity values (especially the evenness values), combined with the dominance of a single taxon, probably indicate certain stress conditions. The high degree of disarticulation (only 7% are articulated) and high concentration of *Ilymatogyra africana* (as clumps) suggests that reworking took place for short distance or in-situ under a variable current intensity. Usually left valves are far more abundant than right valves (Text-fig. 5.39). The reason is that the right valves are much thinner and lighter than the cemented left valves and are easily removed and fragmented by currents. These large abundance of left valves (80%) and the presence of right ones (13%) suggest also that shells were reworked for a short distance (e.g. they are autochthonous to parautochthonous). Therefore, the depositional environment of the *Ilymatogyra africana* association was probably above storm wave-base.



Text-fig. 5.39. Features of, and processes leading to, *Ilymatogyra africana* concentrations (as clumps) in the Upper Cenomanian Galala Formation of the East Themed section. The histograms refer to the percentage of articulated valves, right and left valves, and the orientation pattern of single valves.

According to Fürsich & Oschmann (1986b: 72), the spiral shape of *Ilymatogyra* is characteristic of a higher sedimentation rate and enabled the oyster to live on soft substrate. The nearly complete lack of infaunal elements and gastropods might be due to a substrate.



Text-fig. 5.40 Trophic nucleus (A) and reconstruction of the *Ilymatogyra africana* association (B). 1. *Ilymatogyra africana*, 2. *Thalassinoides* sp.

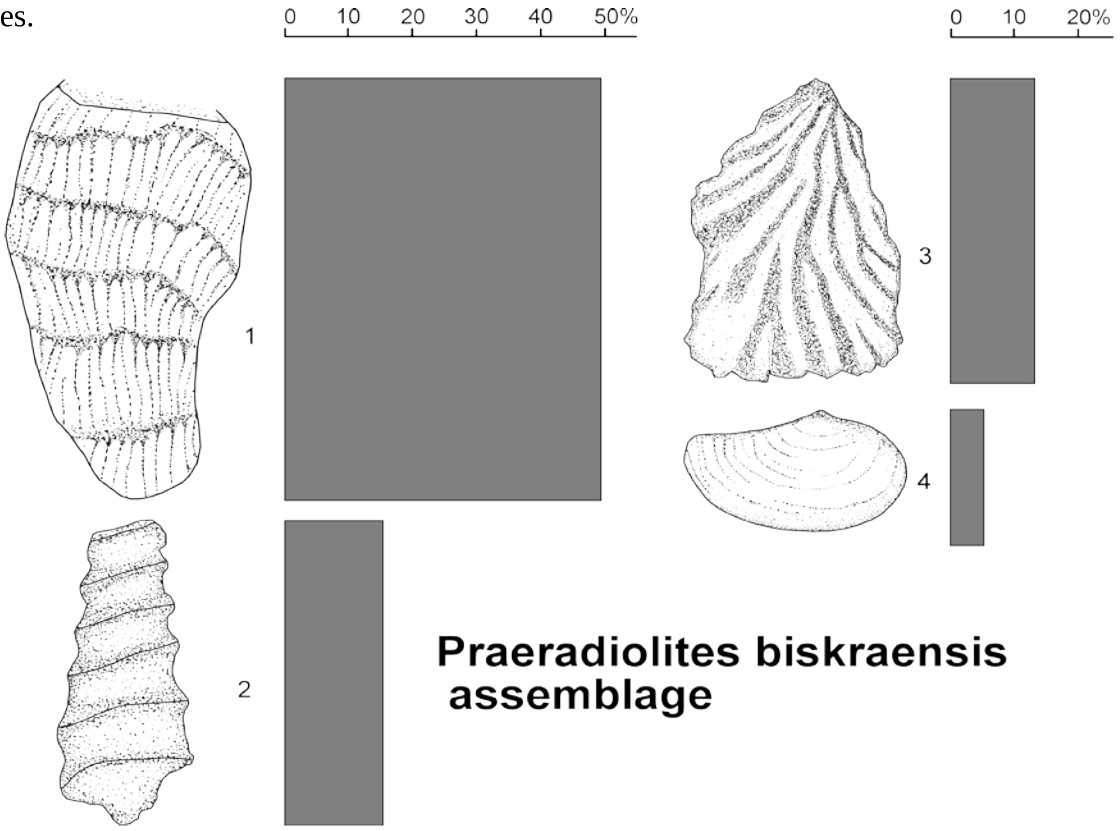
5.7. Macrobenthic assemblages

Apart from the macrobenthic associations described above, three assemblages can be recognised in the Cenomanian-Turonian rocks of eastern Sinai. The assemblages differ from the associations described above in that they have been encountered only once and might be the result of transport, faunal mixing, and diagenetic distortion. They are either dominated by bivalves or gastropods (Text-figs. 5.17).

5.7.1. *Praeradiolites biskraensis* assemblage

Description: Represented by only one sample with 159 individuals and 14 taxa. The trophic nucleus consists of four species. The rudist *Praeradiolites biskraensis* (49.06%) dominates, followed by the nerineid *Pchelinsevia coquandiana* (15.72%), and the bivalves *Chondrodonta joannae* (13.12%) and *Nucula* (*N.*) *margaritifera* (5.03%) (Text/fig. 5.41). Bivalves are the dominant group (77.35%), followed by gastropod (20.12%). Coralline sponges are subordinate (2.51%). Epifaunal elements represent 70.45% and consist mainly of the bivalve *Praeradiolites biskraensis*, whereas shallow infaunal organisms represent 28.93% and consist mainly of *P. coquandiana*. With respect to feeding modes, suspension-feeders strongly prevail (90.56%), followed by deposit-feeders and herbivores (5.03% and 2.51%, respectively). Other feeding groups such as carnivores are rare. All rudists occur in shell preservation but are mostly disarticulated, randomly oriented, and fragmented. In contrast, gastropods and shallow infaunal bivalves are preserved as internal and composite moulds. The nerineids lie parallel to the bedding surface but do not show any preferred orientation. The *Praeradiolites biskraensis* assemblage was found in about three meters of hard carbonate facies (dolomitic in some parts) of the Cenomanian Galala Formation of the East Themed and Wadi Quseib sections.

Interpretation: The distribution of rudist bivalves (superfamily Hippuritoidea) is often considered as a good indicator of a tropical, shallow marine environment and carbonate platform facies (Tethyan Realm) in Cretaceous time (e.g., Kauffman, 1973; Sohl, 1987; Dhondt & Dieni, 1992; Masse, 1992; Johnson et al., 1996). Most of the Late Cenomanian rudist assemblages are associated with other bivalves such as *Chondrodonta joannae*. The latter species definitely lived in the rudist framework and some rudists even grew on its valves.



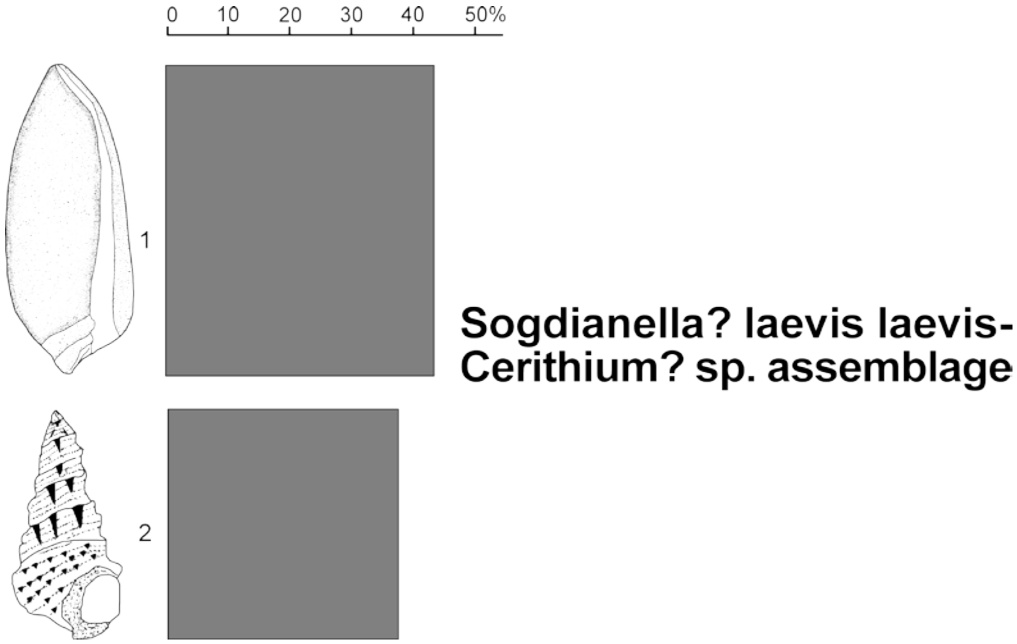
Text-fig. 5.41. Trophic nucleus of the *Praeradiolites biskraensis* assemblage. 1. *Praeradiolites biskraensis*, 2. *Pchelinsevia coquandiana*, 3. *Chondrodonta joannae*, 4. *Nucula* (*Nucula*) *margaritifera.* The width of the columns indicates the relatively abundance (in %) of taxa, the shaded area is a semi-quantitative measure of their biovolume. All specimens are drawn in their relative natural size.

The rudists were rarely preserved in life position because strong currents removed the surrounding finer sediment fractions and caused the toppling of the valves and subsequent accumulation as small clusters. The rare or entirely missing left valves are evidence of sorting. Therefore, rudists in this assemblage are parautochthonous having undergone some transport. Most nerineacean genera were able to settle only on stable substrates characterized by a low sedimentation rate (WIECZOREK, 1979). Therefore, the high turbulence, unstable substrate, and high sedimentation rate are unfavourable condition for nerineid gastropods.

5.7.2. *Sogdianella*? *laevis laevis*/*Cerithium*? sp. assemblage

Description: The assemblage consists of one sample with 5 taxa and 133 individuals. Two species belong to the trophic nucleus, *Sogdianella*? *laevis laevis* (43.61%) and *Cerithium*? sp. (37.60%) (Text-fig. 5.42). Gastropods are the dominant group (82.70%), followed by bivalves (15.03%) and echinoids (2.25%). The assemblage is strongly dominated by epifaunal organisms (81.20%), the rest belonging to shallow infaunal taxa (18.80%). Deep-burrowing infaunal organisms are completely absent. Concerning feeding habits, carnivores are the dominant group (45.11%), followed by herbivores (37.60%) and suspension-feeders (15%). Deposit-feeders subordinately occur. All gastropods and bivalves are preserved as internal and composite moulds, while echinoids occur in shell preservation.

Interpretation: According to KOLLMANN & SOHL (1979: A1) and SQUIRES & SAUL (2002: 43), representatives of the nerineacean family Itieriidae (e.g., *Sogdianella*) occur widely in the shallow, warm-water faunas of the Tethyan or marginal Tethyan province of most areas during Middle Jurassic to Late Cretaceous times. The rudstone composition of the sediment indicates an agitated environment. The very narrow aperture of the genus *Sogdianella* (as described by KOLLMANN & SOHL, 1979) helped the organism to resist the unstable condition. If the aperture becomes too large, the protective function is limited (ANDREWS, 1974). The high-spired form of the gastropods (*Cerithium*? sp.) is also a protective function, enabling the gastropod to withdraw deeply into the shell when under attack by predators (VERMEIJ, 1989; ABERHAN et al., 2006). In addition, tiny individuals of *Cerithium* and *Sogdianella* may have developed in response to the unstable sediment, which might have clogged their feeding mechanism and subsequently inhibited growth.



Text-fig. 5.42. Trophic nucleus of the *Sogdianella*? *laevis laevis*/*Cerithium*? sp. assemblage. 1. *Sogdianella*? *laevis laevis*, 2. *Cerithium*? sp.

5.7.3. *Gyrostrea* cf. *anubis* assemblage

Description: This assemblage includes 5 species with 29 individuals. Bivalves are the most abundant macrobenthic group (93.10%). Gastropods account for the rest. Three species (*Gyrostrea* cf. *anubis*, *Pycnodonte* (*P.*) *vesicularis Vesiculosa*, *Gyrostrea delettrei*) belong to the trophic nucleus (Text-fig. 5.43A). The assemblage is strongly dominated by epifaunal organisms (93.10%), while infaunal elements are comparatively rare. With respect to feeding modes, suspension-feeders strongly dominate (93.10%), followed by carnivores (6.89%). The *G. anubis* assemblage was found in yellowish-green, moderately hard marl. The majority of *G. anubis* specimens are attached to left valves of the same species, thereby forming clusters. They are disarticulated and variable in outline, from elongated to fan-shaped and rounded, and there is no preferred shell orientation.

Interpretation: Oysters are a bivalve group that has become sessile mostly on rocks or other hard substrates, hence abandoning a mobile mode of life (KOMATSU et al., 2002). However, *Gyrostrea anubis* returned to soft substrates. SEILACHER (1982) called such groups secondary soft-bottom dwellers. *G. anubis* employed two adaptive strategies to overcome problems associated with life on marly substrate. Firstly the individuals successively attached themselves to other oyster shells and formed clusters (Text-fig. 5.43B). The large clusters helped the organisms to keep their position above the surface of the soft sediment and prevented them from sinking into it. The second strategy is an elongation of the shell to keep the living part above the mud (HUDSON & PALMER, 1976; CHINZEI, 1986). In terms of functional morphology, the fan shape can be regarded as indicative either of a mud-sticking habit or of competition for space between specimens growing close to each other (MACHALSKI, 1998). The presence of large attachment areas in most individuals indicates that individuals remained cemented during their post-larval life. This suggests a horizontal life position (Text-fig. 5.43B). The high frequency of disarticulated specimens suggests that the assemblage was associated with medium to high energy events.

5.8. Environmental parameters controlling the faunal distribution

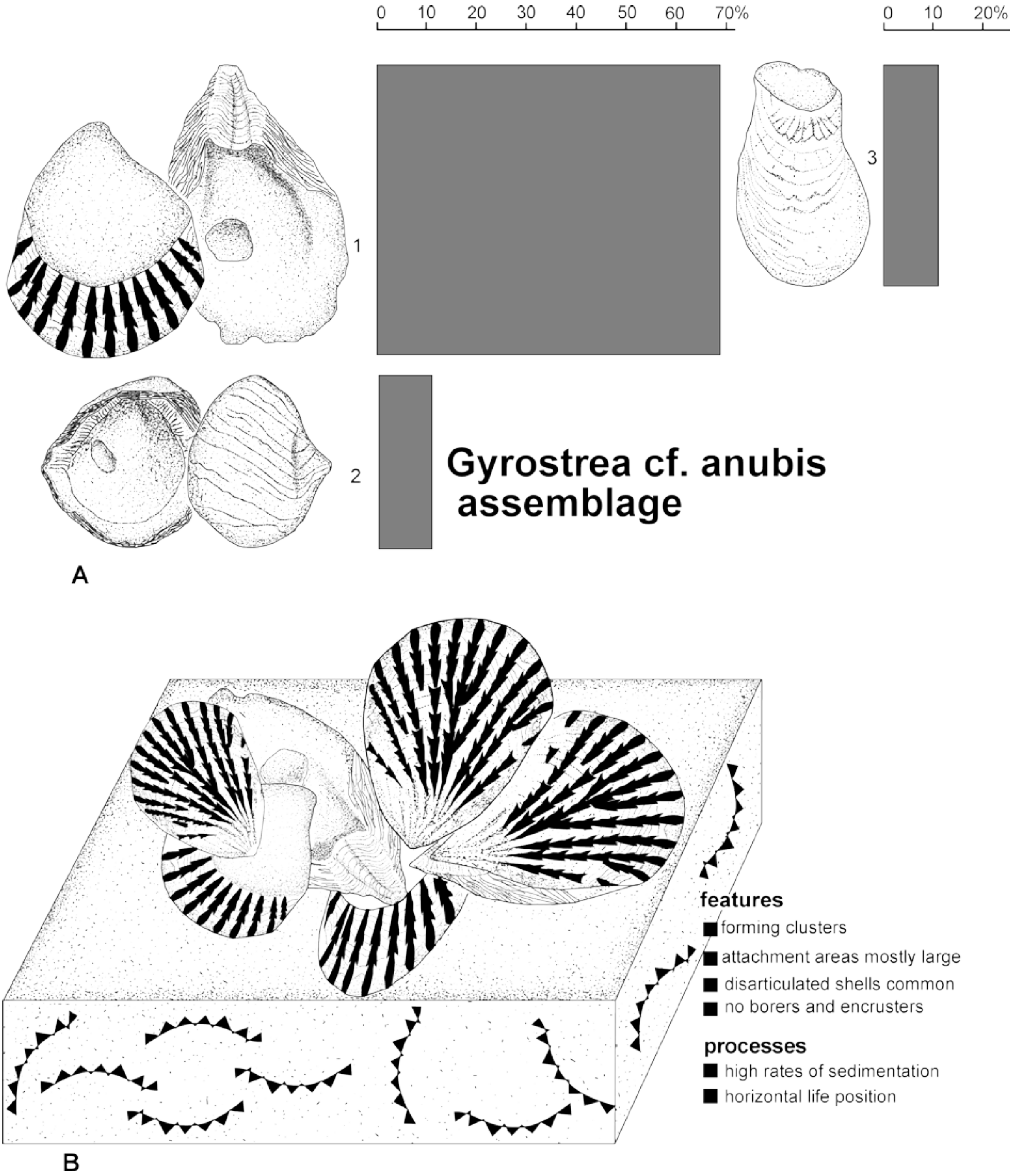
The distribution of the benthic fauna is primarily controlled by environmental parameters. The main physical parameters are substrate, energy level, salinity and temperature variations, light intensity, and nutrient supply. According to FÜRSICH (1976: 343), only substrate is directly available to the palaeoecologists and from it certain inferences about other factors such as sedimentation rate and water energy can be drawn. The major environmental parameters that governed the distribution of individual taxa and finally also of macrobenthos associations in eastern Sinai are briefly discussed in the following paragraphs.

5.8.1. Substrate

5.8.1.A. Associations and substrate

All the benthic associations of the studied sections occur in mixed siliciclastic/carbonate and carbonate facies, four of them come from marls and shaly marls, while the other six associations occur in carbonates facies (marly and sandy wackestone, marly floatstone, and rudstone; Text-fig. 5.44). This indicates that the different benthic faunal elements prefer particular types of substrate.

Substrate consistency (soft, firm, or hard) influences in particular the distribution of epifaunal and infaunal organisms. The distribution of life habits is largely controlled by the firmness and stability of substrate. Text-fig. 5.44 summarises the distribution of life habits and feeding modes in different facies types. For instance, the oyster-dominated *Ilymatogyra*



Text-fig. 5.43. A. Trophic nucleus of the *Gyrostrea* cf. *anubis* assemblage. 1. *Gyrostrea* cf. *anubis.* B. *Pycnodonte* (*P.*) *vesicularis Vesiculosa*. C. *Gyrostrea delettrei*. B. Reconstruction of life position of *G. anubis* from the lower member of the Lower Turonian Abu Qada Fromation of Gebel Areif El-Naqa.

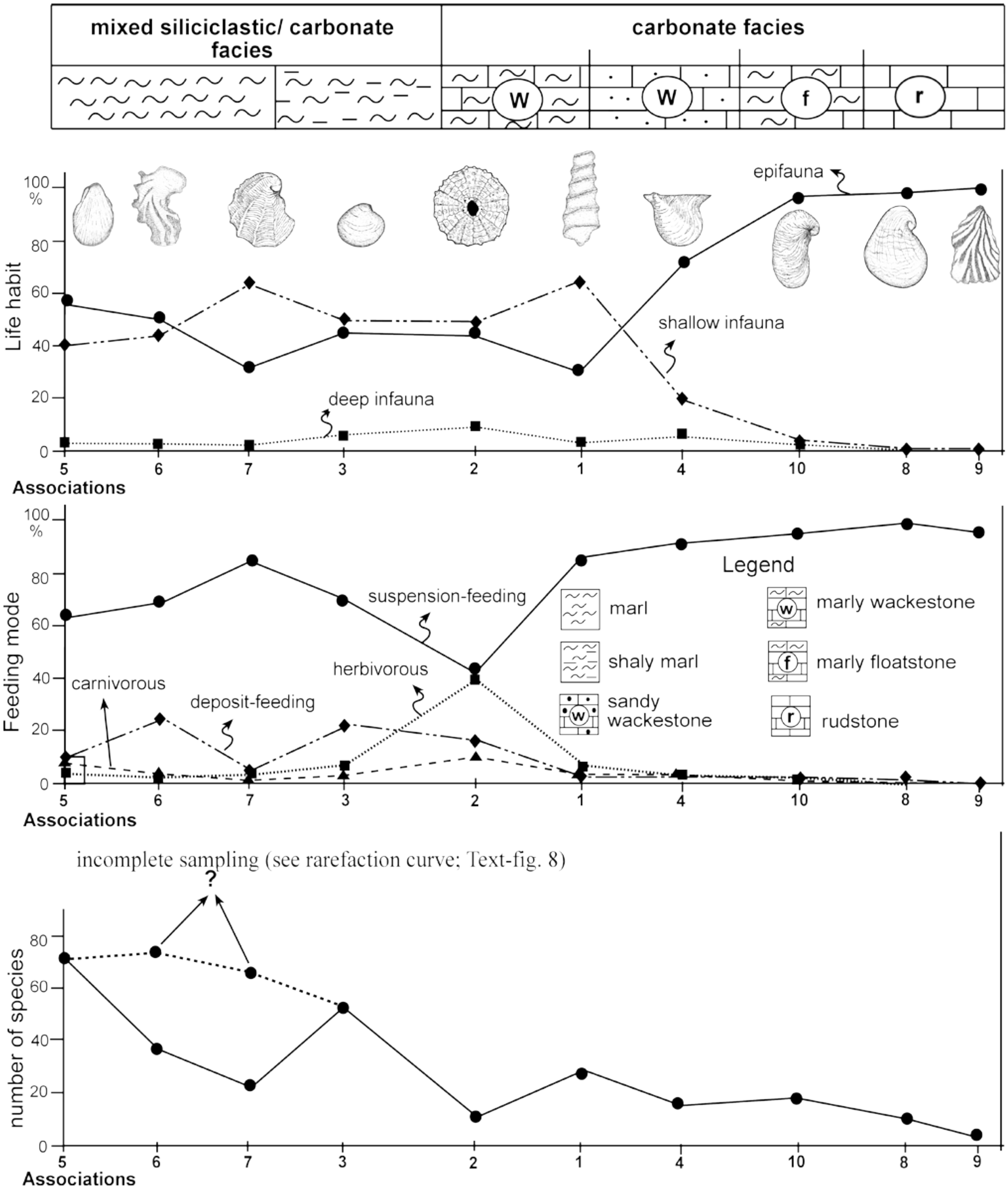
africana association (10), *Rhynchostreon suborbiculatum* association (8) and *Chondrodonta joannae* association (9) with their high amount of epifauna (ranging from 96% to 99%) indicate a firm substrate. They occur in marly floatstone and rudstone. In addition, the complete absence of infaunal organisms in the latter associations might be due to a somewhat hardened substrate. However, oysters occur also in marly facies (e.g., associations 6 and 7). Therefore, epifaunal oysters in the present study are found in nearly all substrate types. On unstable substrates they adapt themselves by changing their morphology. In soft substrate, small, shallow infaunal and deep infaunal burrowers are more abundant than in firm substrate.

For example, the *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association (association 3), which commonly occurs in mixed-siliciclastic/carbonate facies (marly facies), consists of 49.47% shallow-infauna and 5.52% deep-infauna with 21% deposit-feeders. Other associations such as the *Ceratostreon flabellatum/Hemiaster* (*Hemiaster*) *gabrielis* association and the *Rachiosoma geysi/Cucullaea* (*Idonearca*) *trigona* association, which also occur in from marls and marly wackestones, contain nearly the same abundance of epifaunal and infaunal organisms because the soft substrate contained secondary hard substrates in form of shells. With respect to feeding modes, suspension-feeders occur in coarse-grained carbonate rocks where they account for 93% to 99% of the total fauna (e.g., associations 8, 9, 10). Deposit-feeders, in contrast, increase in the mixed siliciclastic/carbonate facies and are completely absent in coarse-grained sediments. Other feeding groups such as carnivores and herbivores depend on the presence of other organisms. Therefore, the type of substrate (e.g., grain-size) as well as water energy exhibit considerable control over the type of feeding mode. Under high energy conditions deposit feeders, which feed on settling larvae of suspension-feeders, are replaced by suspension-feeders (adult-larval interaction WOODIN, 1976).

The diversity values of the associations (expressed by number of species) in various substrates have been plotted and compared (Text-fig. 5.44). A high diversity is found in the mixed siliciclastic/carbonate facies as well as in marly wackestones (Text-fig. 5.44), in the coarse-grained facies (e.g., floatstone and rudstone) diversity is low. The reason for the low diversity may be the result of transport, sorting, and selective destruction of thin shell under high water energy. Therefore, the skeletons of epifaunal organisms are usually thicker than infaunal ones be able to live in high energy environments. The high diversity values in the marly facies (associations 5, 6, 7) are quiet obviously the result of stable and predictable environments which, for the most part, were free of physical stress. In this case, the members of these associations seem to have followed a k-strategy. They can regarded as biologically accommodated communities characterized by a relatively long time span with low disturbances, a relatively low reproduction rate, and a high level of speciation (MACARTHUR & WILSON, 1967; SANDERS, 1968).

5.8.1.B. Functional morphology and adaptation of some taxa to different types of substrate

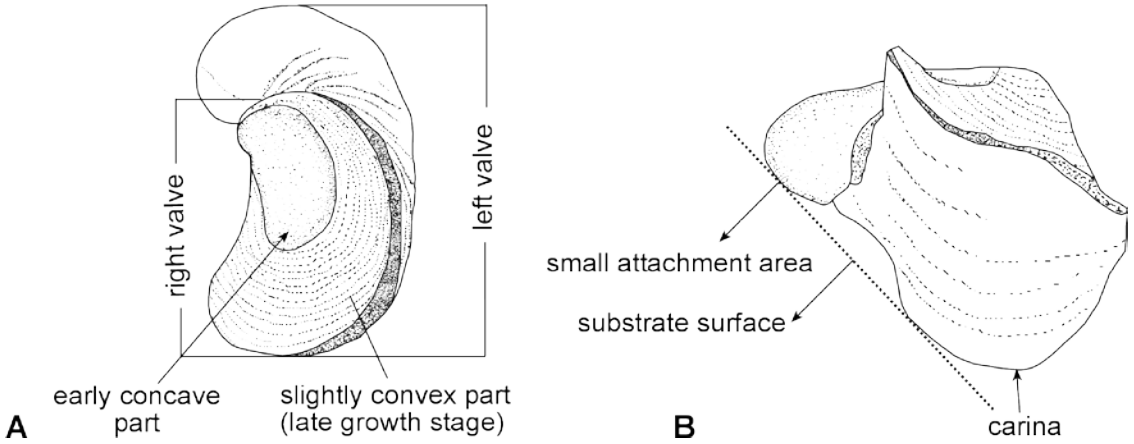
Oysters: The investigated exogyrine oysters, such as *Ilymatogyra africana*, *Ceratostreon flabellatum*, *Rhynchostreon suborbiculatum*, and *Costagyra olisiponensis* are morphologically highly variable. The great variability of these species led many palaeontologists to split them into different species and varieties. In fact, most of the morphological variations (e.g., shell thickness, ornamentation) are most likely related to ecological parameters such as water energy and consistency of substrate. According to SEILACHER (1984), the outlines of cemented shells, which tend to be irregular and highly variable, are controlled by the nature of substrate. In the following, two oyster species are discussed as examples to illustrate the relationship between substrate and functional morphology.



Text-fig. 5.44. Relationships between the macrobenthic associations (life habits and feeding modes), their species richness, and facies.

Ilymatogyra africana

MALCHUS (1990) distinguished two varieties of *Ilymatogyra africana*, which he named "forma typica" and "forma crassa". The two forms of *I. africana* are tied to different facies types, forma typica (strongly convex, helicospiral) occurs in marls, whereas forma crassa (large, less convex, and elongated) comes from coarse-grained carbonate facies (floatstone and rudstone). In both forms, the posterior flank is more steeply raised than the anterior flank, which may be entirely resting on the ground (Text-fig. 5.45B).



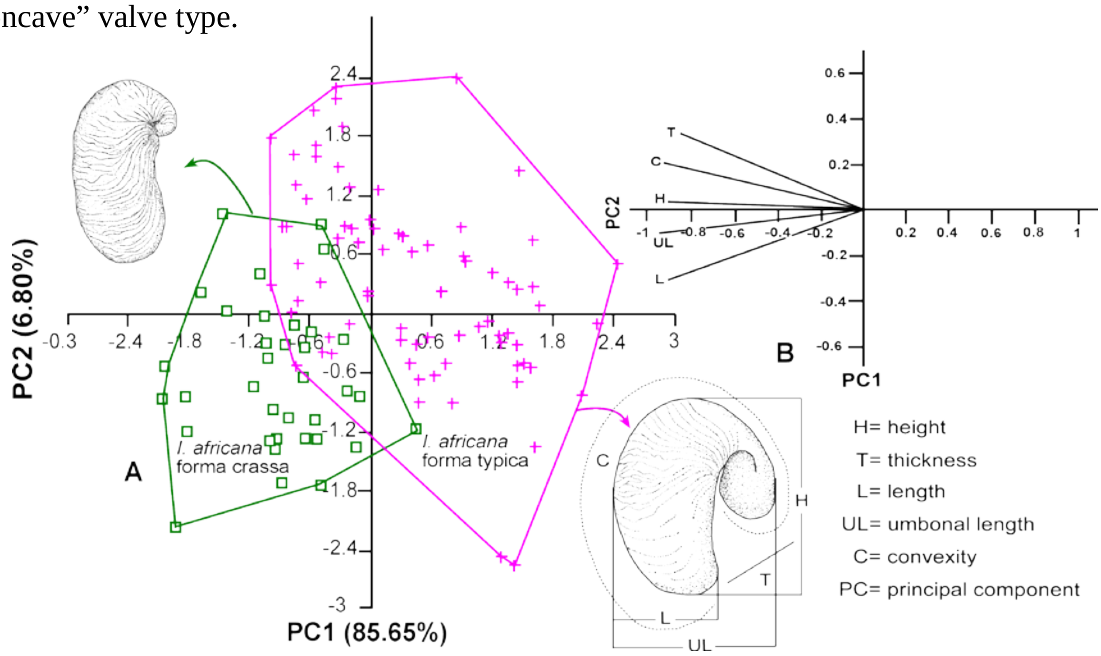
Text-fig. 5.45. Sketch of the external features of the two valves of *Ilymatogyra africana*.

A principal components analysis (PCA) was performed to clarify the morphological relationship between forma typica and forma crassa. The PCA was performed in PAST (version 2) on a variance-covariance matrix of the following log-transformed variables: height, thickness, length, umbonal length, and convexity. The first principal component (PC1) accounted for 85.65% of the variation in the data while PC2 accounted for 6.80% (Table 2). All five of the original variables displayed a strong negative correlation with PC1, therefore, individuals with low PC1 scores have a large body size and vice versa (Text-fig. 5.46B) Length is negatively correlated with PC2, while thickness is positively correlated with it. Therefore, individuals with a high PC2 score would have a smaller length and larger thickness for a given size. When PC1 and PC2 of scores individual specimens are plotted by growth form one can see that forma typica and forma crassa are indeed different, but overlap; suggesting that they represent two forms of the same species (Text-fig. 5.46A). Forma typica is characterized by a smaller body size (higher PC1 score) and a more variable morphology in terms of relative length and thickness (more variable PC2 scores) in comparison with forma crassa.

Table 3. Percent of variation explained by PCA of body size variables of *I. africana*.

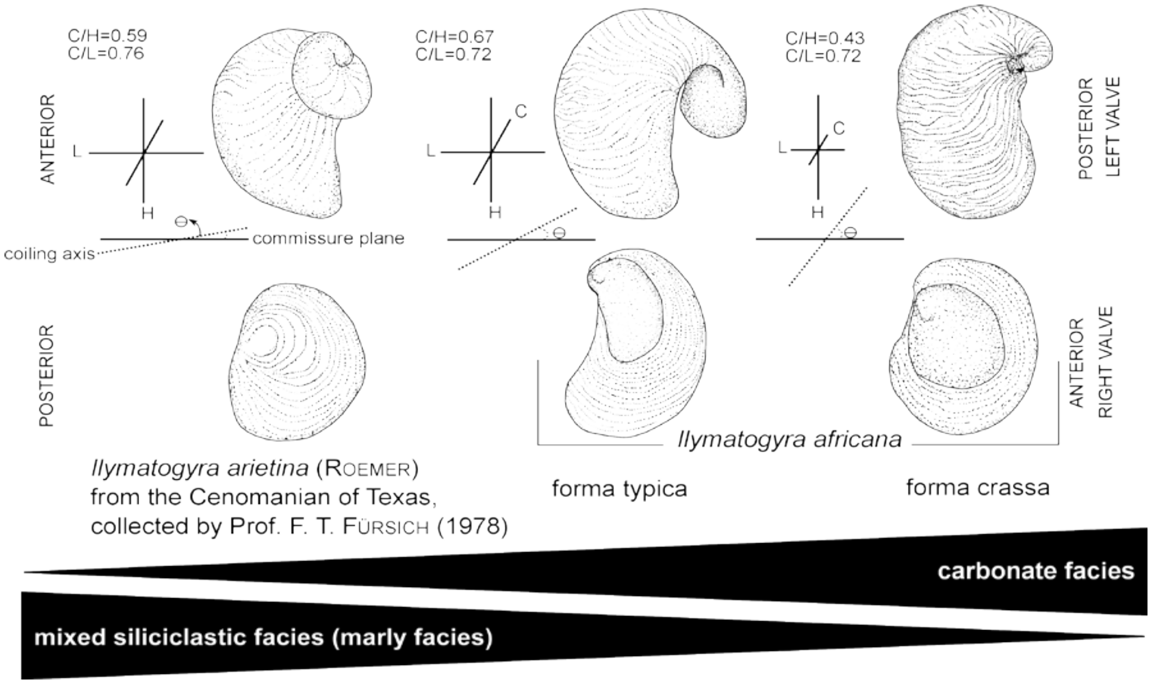
PC	% Variance
PC1	85.65
PC2	6.80
PC3	4.97
PC4	1.74
PC5	0.82

The right valves of the species are extremely thin except along the dorsal side (about 3 mm thick). In the early growth stage and around the body cavity, it is extremely thin, less than 2 mm, and concave (Text-fig. 5.45A). This concave part is larger in forma crassa than in forma typica. In a later stage, the right valve becomes thick and convex (growth lamellae are strongly bent upward parallel to the shell margin). MALCHUS (1990: 94) called this “convex-concave” valve type.



Text-fig. 5.46. Principal component analysis (PCA) of forma crassa and forma typica of *Ilymatogyra africana* using PAST (HAMMER et al., 2001). A. Scatter plot of PC1 and PC2, B. Loadings chart for PC1 and PC2 on variance-covariance matrix.

In *Ilymatogyra arietina* (ROEMER) from the Cenomanian of Texas, the right valve is more convex than in *I. africana* and lacks the early concave part of right valve. *I. arietina* has also a strongly coiled umbo (spiral) with high vertical increments of the dorsal region. In addition, the coiling axis of the left valve lies nearly parallel to the commissure plane in *I. arietina* (strongly coiled form), while in both forms of *I. africana* it is steeper (Text-fig. 5.47).

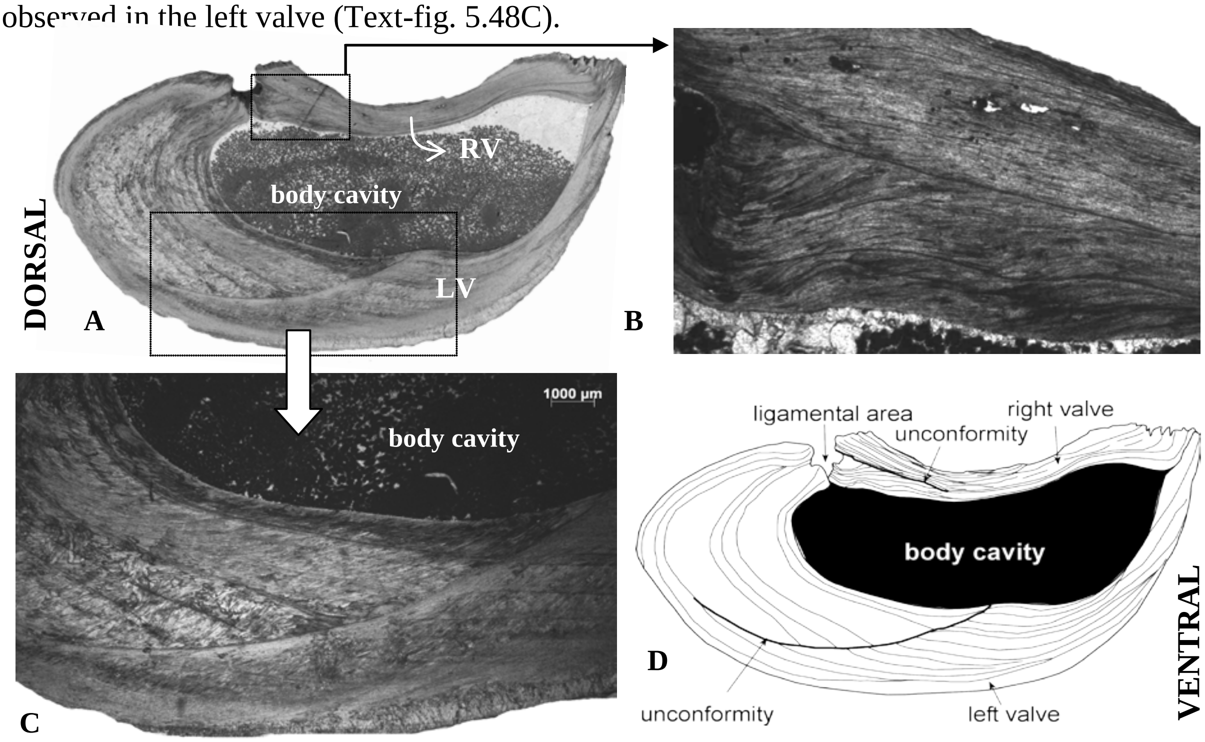


Text-fig. 5.47. Different types of umbonal coiling of left valve and effects on general shell morphology of right valve. Plane of commissure approximately parallel to the coiling axis in strongly coiled forms. L=length, H=height, C=thickness.

According to MALCHUS (1990), the coiling intensity and direction of the umbo have considerable influence on the general phenotypic appearance of shell. Therefore, the type of coiling and the shape of left valve influenced the convexity of the right valve (Text-fig. 5.47).

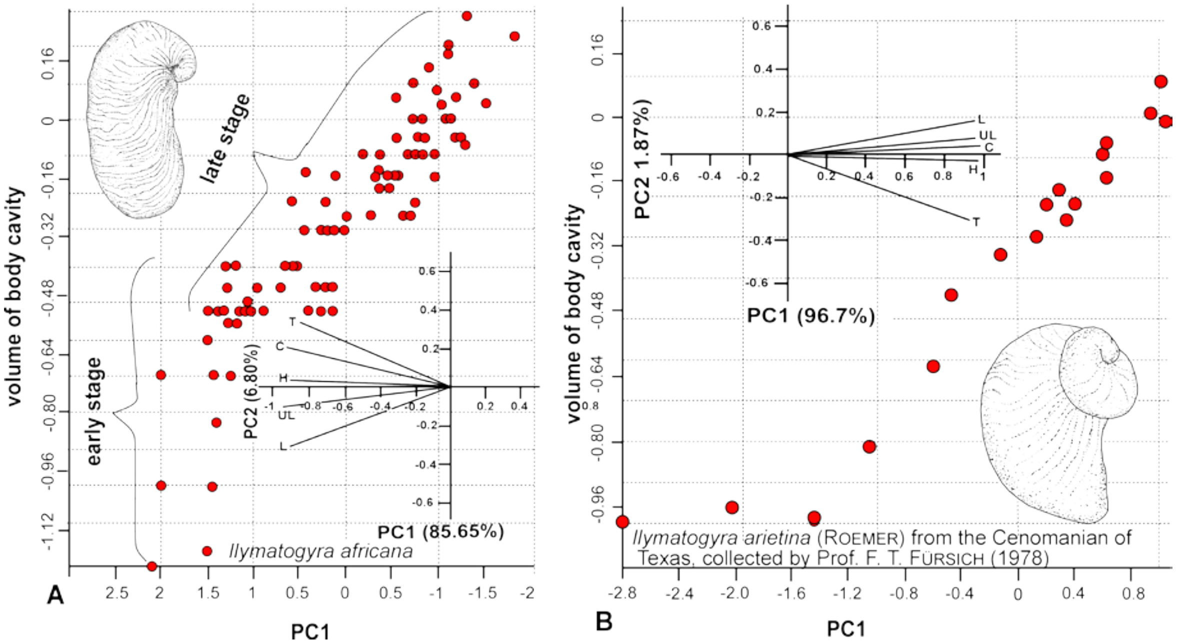
All these features can be explained as consequences of the adaptation of *I. africana* to life on a soft substrate. FÜRSICH & OSCHMANN (1986b) pointed out that a possible pathway for ostreids to survive on soft substrates is to grow in a three-dimensional spiral, especially when suitable hard substrates for attachment are rare. Therefore, the three-dimensional spiral growth and high vertical increment of the strongly convex left valve protected the organisms from the danger of burial in soft sediment and from clogging of their gills. The lack of an attachment area (some individuals have a tiny attachment area) in forma typica of *I. africana* is also found in *I. arietina*, which grows from its earliest larval stage onwards without ever becoming attached to the substrate (STENZEL, 1971: N995).

The dorso-ventral section through both valves of *I. africana* shows that the right valve is composed simply of a thin foliated layer, except in the umbonal region. Sheets of foliated material are slightly oblique to the outer surface of valve (Text-fig. 5.48A-B). The left valve is more complex and the lamellae are more oblique. Growth discontinuities are generally observed in the left valve (Text-fig. 5.48C).



Text-fig. 5.48. A. Dorso-ventral cross-section through the both valves of *Ilymatogyra africana*. B-C. Enlargement of the unconformity of the right and left valves respectively- D. Sketch showing the unconformity in the middle part of the both valves.

The large unconformity in the middle part of left valve probably indicates rapid and episodic growth of the organism. In the early growth stages (seen in the far dorsal region), the layers are apparently conformable, and they become unconformable in the latter growth stages. The large unconformity in *I. africana* is interpreted to indicate thickening of the dorsal region of the left valve (Text-fig. 5.48A). RHOADS & LUTZ (1980) pointed out that the mollusc populations living on mud might have disturbance lines (unconformities) within their internal growth pattern than those living on other facies such as sand. In addition, some aspects of shell microstructure have been attributed to environmental influences (DAVIES & SAYRE, 1970; LUTZ & RHOADS, 1977). Therefore, the substrate type and its stability probably influenced the internal structure of valve. Text-fig. 5.49A shows that the smallest individuals of *I. africana* display a wide variation in relative body cavity volume, whereas larger individuals (approximately PC1 scores of 1 to -2) display a log-linear relationship between body cavity volume and overall body size. In *I. arietina*, in contrast, the body cavity volume displays a log-linear relationship with overall body size even in the smallest individuals (Text-fig. 5.49B). Thus *I. africana* exhibits a more complex growth pattern.



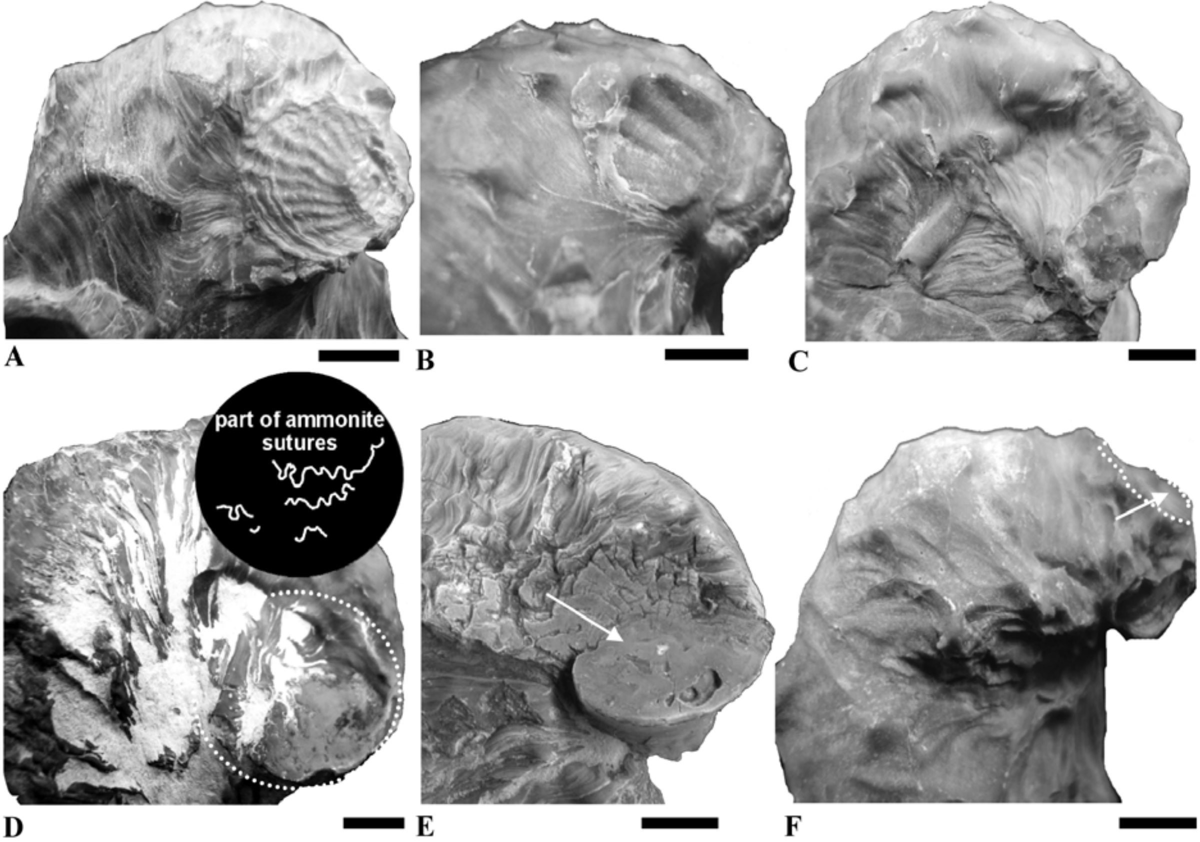
Text-fig. 5.49. Relationships between body cavity and body size variables (PC1) in *I. africana* (A) and *I. arietina* (B).

In general, the species grew rapidly in the early stages to maximize its surface area on relatively soft sediment. This is supported by the thin and concave right valve interpreted to have primarily grown laterally rather than in thickness. At a latter stage, when the valve was wide enough to ensure a stable position, the oysters could grow convexly to increase valve thickness and body cavity volume. According to CHINZEI (1995: 224), the mantle margin responsible for the shell accretion is situated very close to the surface of the mud, and probably suffered a constant stimulus from the mud. Thus the growth vector of the margin directed away from the mud surface, and accordingly produces an extremely thick dorsal margin (in the latter stage) to keep the commissure above the water-sediment interface.

The space between the comparatively widely spaced laminae of the left valve (above the unconformity surface, Text-fig. 5.48C) might have had originally a different microstructure, possibly composed of a kind of "chalky" material, which is generally associated with rapid dorsal growth and low shell density (RHOADS & LUTZ, 1980; CHINZEI, 1995). Such "chalky" material is observed in some Cretaceous oysters. The variation in the shell microstructure is largely biologically controlled. Its function is related to the thickening of the dorsal side of the left valve to keep the oyster's commissure above the sediment-water interface or to push the soft body into a more ventral position. Some individuals have small empty chambers within the growth layers. These hollow structures have an important role in maintaining the position of the oysters on soft sediment and are advantageous for quick growth (CHINZEI 1995). Without this characteristic feature the oysters would have been unable to expand their habitat to the soft bottom.

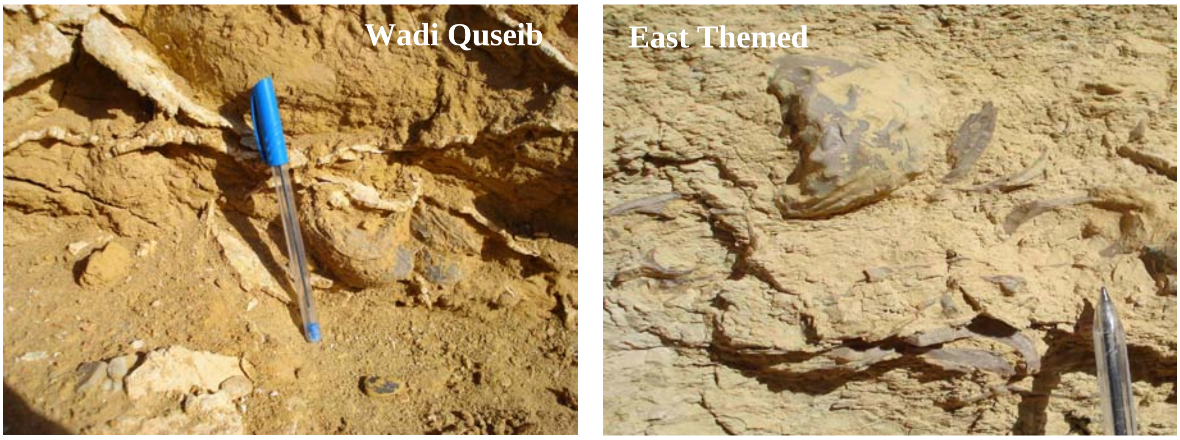
Costagyra olisiponensis

C. olisiponensis is another very common oyster of the Upper Cenomanian (Halal, Galala, and Raha formations) of the Eastern Desert and Sinai Peninsula. The species is abundant in the mixed siliciclastic/carbonate facies and associated with other macrobenthos such as bivalves and gastropods. The species is highly variable, well preserved, articulated, very thick (in the dorsal part, Text-fig. 5.32C), and helicospiral with variable-sized attachment areas. The features of the attachment areas indicate that the oysters cemented themselves to different objects after their planktonic larval stage. Some of them were cemented to plicatulids and ammonites, others to the interior of other oyster species (Text-fig. 5.50). Few attachment areas were smooth and lacked any information on the nature of the substrate. This indicates that the substrate was rich in shell fragments, which probably result from predation and occasional high-energy events (Text-fig. 5.51). On unstable sediments and under elevated rates of sedimentation, the oysters initially grew straight upwards before spiral growth set in, which helped the organisms to maintain its commissure above the sediment/water interface and to prevent them from sinking into the soft sediment (Text-fig. 5.50F).



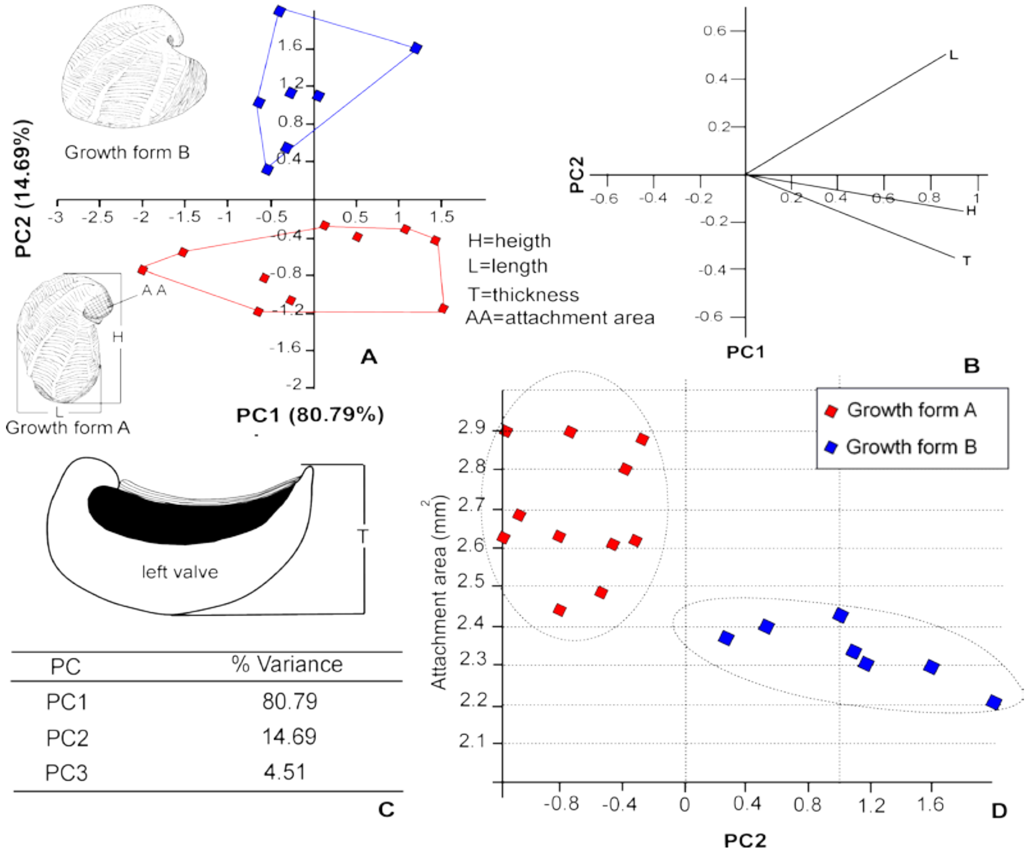
Text-fig. 5.50. Attachment areas and substrates of *Costagyra olisiponensis* (SHARPE, 1850) from the Cenomanian Galala Formation of the Wadi Quseib and East Themed sections. A-B. Substrates are valves of *Plicatula*, either *Plicatula* (*P.*) *ferryi* (A) or possibly the internal side of ?*Plicatula* (*P.*) *auressensis* (B). C. Shell fragments of other oysters. D. Imprint of ammonite sutures, possibly the suture of *Neolobites* (large ammonitic substrate). E. Large smooth attachment area which lacks any information of the substrate except that it was smooth. F. Small attachment area (? internal side of oyster valve) and expanded umbonal region in the early growth stage. Scale= 10 mm.

A principal component analysis (PCA) was carried out to clarify the morphological variations between the two forms (growth forms A and B) of *C. olisiponensis*. Three log-transformed variables were used in this analysis based on a variance-covariance matrix: height, length, and thickness. The first principal component analysis (PC1) accounted for



Text-fig. 5.51. Juveniles of *Costagyra olisiponensis* (SHARPE, 1850) from the Cenomanian Galala Formation at Wadi Quseib and East Themed in disturbed life position.

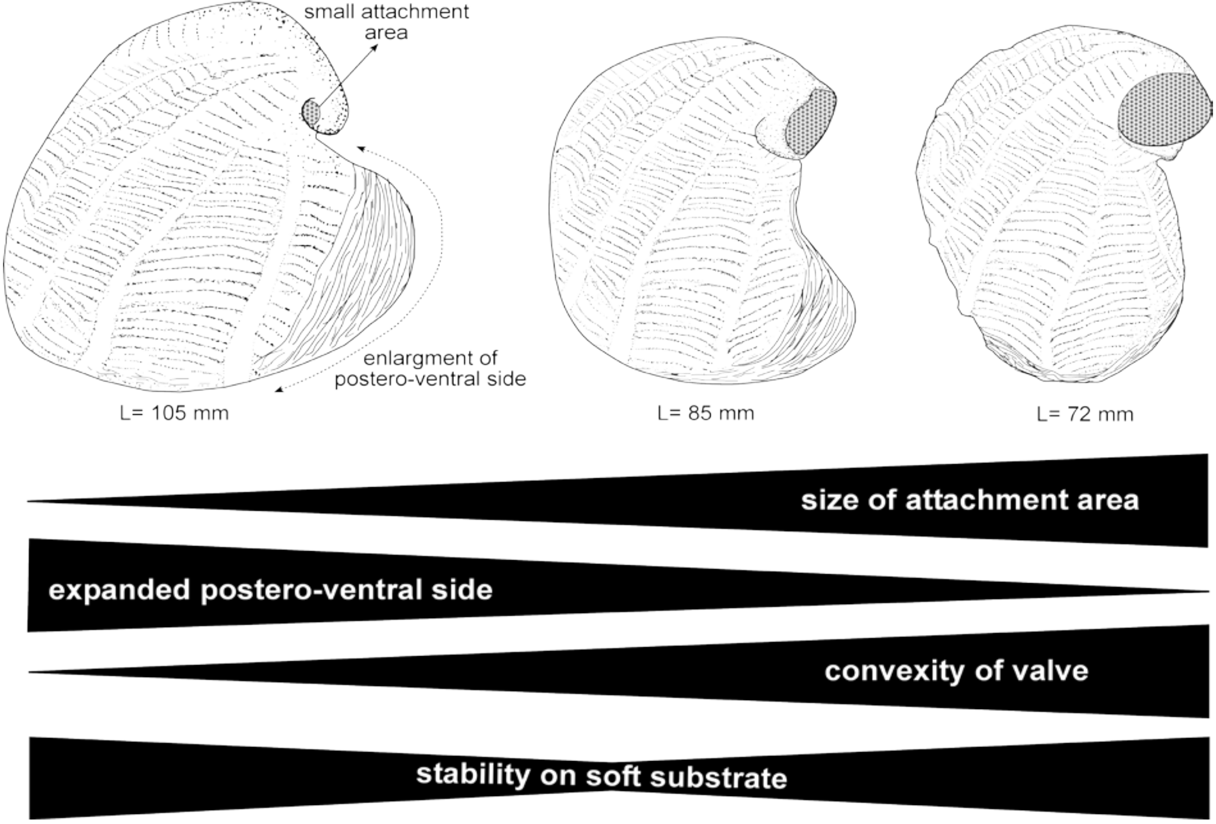
80.79% of the variation in the data, while PC2 accounted for 14.69% (Text-fig. 5.52C). PC1 scores are ideal indices of body size as they are derived from many measures of size. In this case, the three variables displayed a strong positive correlation with PC1. Therefore, individuals with high PC1 scores are of large body size. In addition, length is positively correlated with PC2, while height and thickness are negatively correlated with PC2 (Text-fig. 5.52B). Thus, individuals with a high PC2 score would be longer and less thick and high for a given size. When PC1 and PC2 scores of individual specimens are plotted by growth form it becomes obvious that the two forms are indeed different (Text-fig. 5.52A).



PC	% Variance
PC1	80.79
PC2	14.69
PC3	4.51

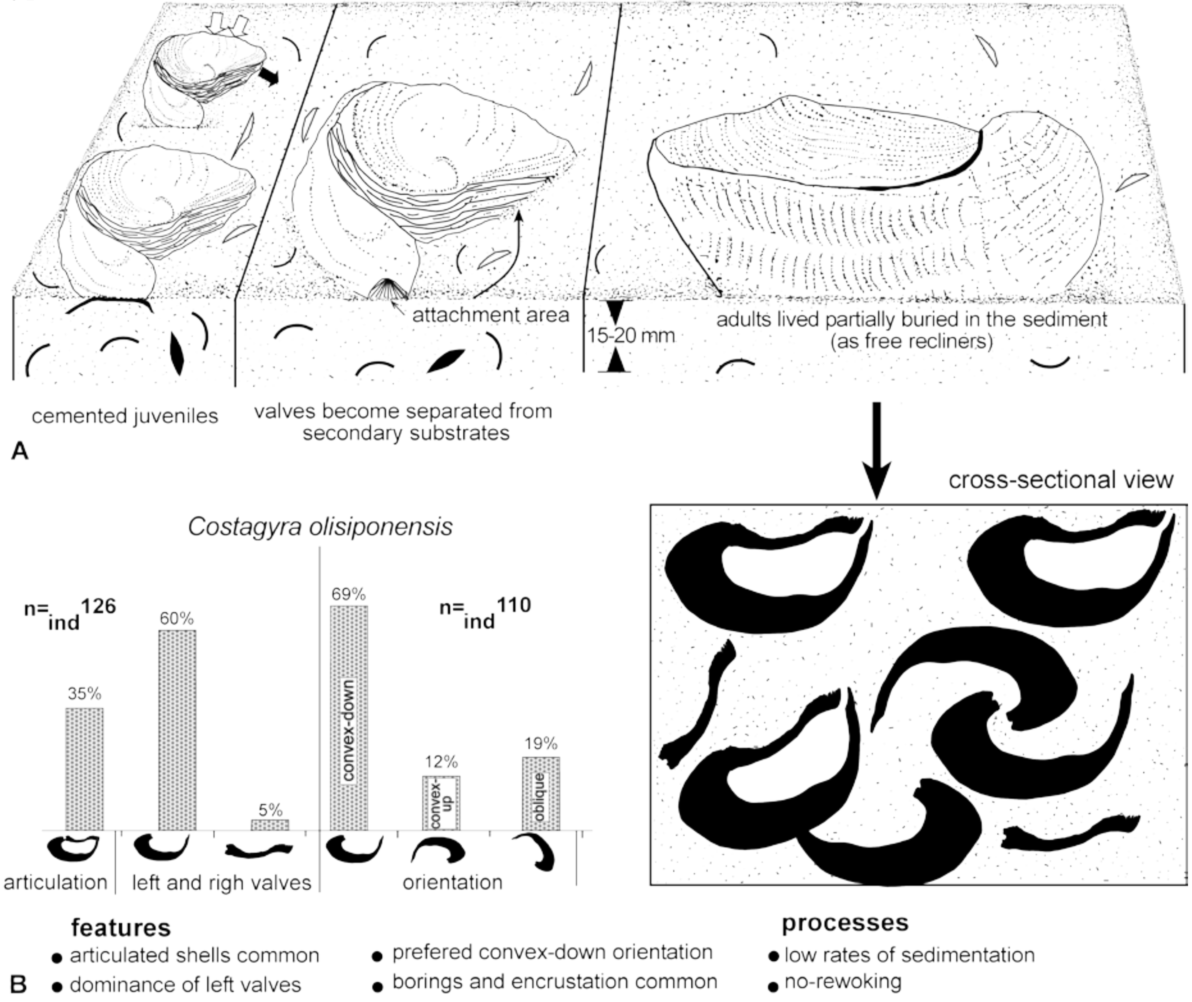
Text-fig. 5.52. Principal component analysis (PCA) of the two forms (form A and form B) of *Costagyra olisiponensis* using PAST (HAMMER et al., 2001). A. Scatter plot of PC1 and PC2, B. Loadings chart for PC1 and PC2 on variance-covariance matrix. C. Percent of variation explained by PCA of body size variables. D. Relationship between PC2 and size of attachment area.

MALCHUS (1990) observed that nearly all long and narrow species of *C. olisiponensis* have no or only a small attachment area, whereas the wider and shorter forms have a large to very largeattachment area. His observation cannot be verified with the present material. The principal component analysis often reflects differences in shape (PC1 having removed most of variance related to size) (HUNTLEY in press). Therefore, PC2 reflects the difference of the shell outline of *C. olisiponensis*. Text-fig. 5.52D shows that growth form B, which has a great length (positively correlated with PC2), has a small attachment area, while growth form A with a small length (more elongated individuals) has a large attachment area. Thickness and height are negatively correlated with PC2 and thus growth form A is more convex and more elongated than growth form B. In conclusion, there exists a relationship between the size of attachment area and shell outline and the convexity of valves; a small attachment area occurs in individuals with a wide postero-ventral part (oval-shape, growth form B) and less convex valves and a large attachment area in more elongated shells (H/L=1.62, growth form A) with strongly convex valves (Text-fig. 5.53). The expanded postero-dorsal margin of *C. olisiponensis* is interpreted as an adaptation to increase the surface area to prevent the shell from sinking into soft sediment. At the same time the high convexity of adult individuals serves to increase stability on the substrate. *C. olisiponensis* can be interpreted as cup-shaped recliner (SEILACHER 1984: 215; text-fig. 4). The latter author stated that the excessive shell thickening in the dorsal part of gryphaeids (as in the present species) serves to keep the organism in the right position.). The taphonomic features show that there is no evidence of reworking. For instance, the good preservation of the fauna, the presence of articulated valves (35%), and high percentage of convex-down orientation (69%) (Text-fig. 5.54B) indicate that transport and reworking were insignificant. However, significant transport of the left valves seems less likely, but the currents led to a re-orientation of shells in a hydrodynamically-stable position.



Text-fig. 5.53. Variations in outline and stability on soft substrate of *Costagyra olisiponensis* with respect to size of attachment area, expansion of the postero-ventral margin, and convexity of valve.

FÜRSICH & OSCHMANN (1986b) pointed out that fine-grained substrates (clay-silt and marl-micrite) are a good indicator for a free living mode of life of oysters on soft substrate. The excessive shell thickening of *C. olisiponensis* in the dorsal region (C>70 mm) serves to stabilize the shell on soft substrate (functioning as a keel to keep the individual upright). Individuals of *C. olisiponensis* were cemented for stabilization when settling after the planktonic larval stage, but as adults they lived partially buried in the sediment as free recliners (Text-fig. 5.54). For the reclining adults, it was necessary to keep their commissure above the sediment/water interface for feeding and respiration purposes. The invariably strongly convex left valve served this purpose. The occurrence of sponge boring (*Entobia*) restricted to the commissural area of adult individuals support this mode of life. Helicospiral growth is another good indicator for a free-reclining mode of life. Therefore, the Upper Cenomanian *C. olisiponensis* apparently followed two life habit strategies, cemented to secondary hard substrates as juveniles, and subsequently free reclin as adults (similar to *Gryphaea*) (Text-fig. 5.54A).

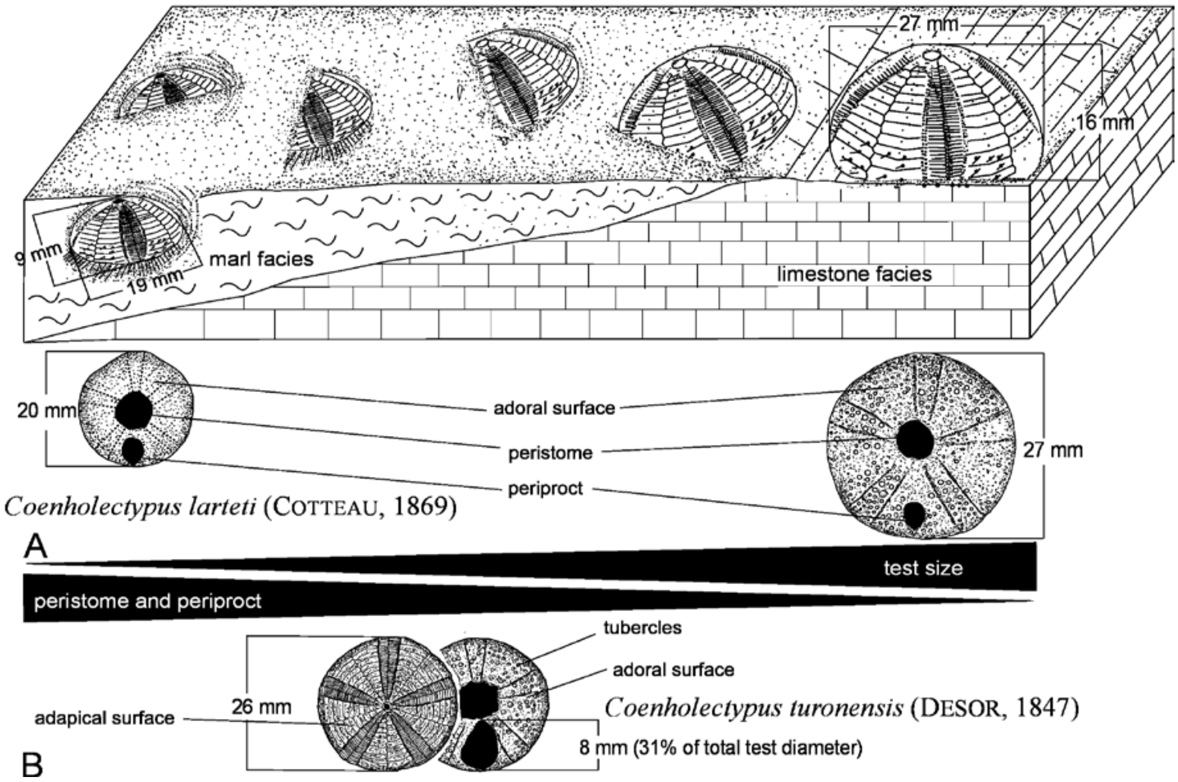


Text-fig. 5.54. A. The two life habit strategies of *Costagyra olisiponensis* (SHARPE, 1850), cemented in the juvenile stage and a freely reclining in the adult stage. B. Features of, and processes leading to, *C. olisiponensis* association in the Upper Cenomanian Galala Formation of the East Themed and Wadi Quseib sections. The histograms refer to the percentage of articulated valves, right and left valves.

Echinoids: According to SMITH (1984), SMITH et al. (1988) and SMITH & BENGTSON (1991), echinoids are a conspicuous and an important element of Upper Cretaceous faunas and can be good palaeoenvironmental indicators, because they are often highly facies restricted. In addition, each taxon has a preferred habit and life style that is partially reflected by, and can be deduced from, the skeletal characters. The nature of substrate plays also an important role in the change of skeletal morphology of regular and irregular echinoids (BARRAS, 2008). These skeletal characters include (1) general test morphology; (2) peristome with surrounding phyllodal pores; (3) size of periproct; (4) tubercle morphology and density; and (5) tube feet morphology deduced from ambulacral pores. Therefore, the functional morphology of some irregular and regular echinoid species and their adaptations on different facies types will be discussed in the following paragraphs.

The genus *Coenholectypus* is represented in the present study by three species, *C. larteti*, *C. portentosus*, and *C. turonensis*. Most of the *Coenholectypus* species have a low ambitus, broad base, and low-domed apical surface. In the firm substrate (carbonate facies), *C. larteti* is, on average, larger and higher (with numerous oral tubercles) than its representatives in soft substrate (e.g., marl). SMITH (1995) thought that the highly inflated *C. inflatus* (COTTEAU & GAUTHIER, 1895) may have reverted to a primary epifaunal mode of life below the fair-weather wave-base. Also NEJBERT (2007) pointed out that the test height decreases with increasing clay or sand content in the substrate. This interpretation is generally accepted. NÉRAUDEAU & MOREAU (1989) suggested that *C. excisus* is small and flattened in fine-grained sandstone and becomes large and flattened in limestone facies, while *C. cenomanensis* becomes globular and large in limestone facies. Therefore, the high domal and large test of *C. larteti* from carbonate facies might be a sign of an epifaunal mode of life, while the small and flattened test is an adaptation to live within soft sediment as a shallow-burrowers (Text-fig. 5.55). SMITH (1981, 1984) interpreted the reduction in size and the increase in number of tubercles as an adaptation of the first irregular echinoids to an infaunal mobile life-style in soft bottom environments. In addition a broad and flat base, low profile, low ambitus, and a domed apical surface of the genus *Coenholectypus*, has been interpreted as an adaptation for more efficient locomotion and probably enhanced the stability on unconsolidated sediment under stronger currents and/or wave action (SMITH 1984; SMITH et al., 1988; RADWAŃSKA 2005). The periproct is variable in shape, size, and position. It can be large and drop-shaped (about 31% of test diameter; Text-fig. 5.55B)) as in *C. turonensis*, or small, inframarginal, and ovate as in *C. larteti*. However, the periproct as well as the peristome of *C. larteti* in the marly facies is larger than in carbonate facies. The large periproct of *C. turonensis* as well as of *C. larteti* indicates that the volume of faecal material was great and that ingested particles were relatively large, probably as a result of a sediment-rich diet.

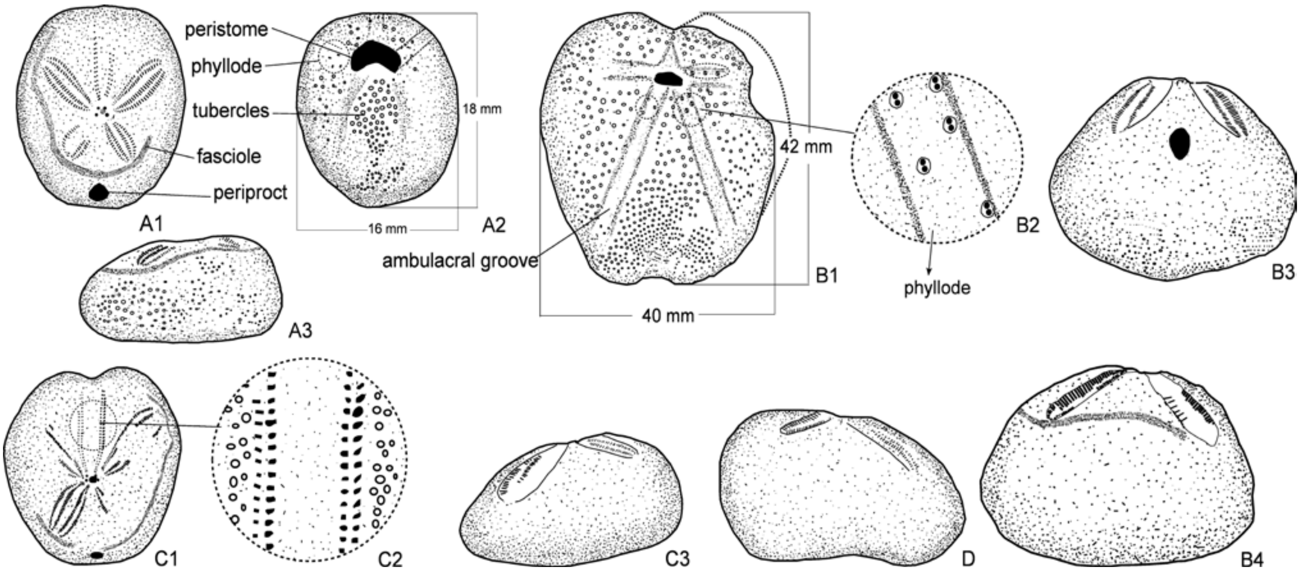
Five species of *Hemiaster* have been identified and most of them have been collected from marl. Most of these species have wedge-shaped tests e.g., *Hemiaster* (*H.*) *syriacus*, but others are globular in outline e.g., *H.* (*Mecaster*) *heberti turonensis* (Text-fig. 5.56). They have relatively deep and petaloid petals, well developed non-conjugated ambulacral pores as well as peristomal pores (phyllodal pores), and lack a real frontal sulcus. The pores of ambulacrum III are separated and circular, and are almost certainly associated with adapically funnel-building tube-feet (SMITH 1980; SMITH et al. 1988). Many authors e.g., SMITH & BENGTSON (1991), SMITH (1995), and BARRAS (2008) pointed out that many spatangoids are infaunal deposit-feeders, burrowing relatively deeply within the sediment (of different grain size), and picking up suitable particles from the floor of the burrow by the penicillate tube-feet around the peristome (phyllodal pores).



Text-fig. 5.55. A. Mode of life and relationship between the size of test, periproct, and peristome of *Coenholectypus larteti* (COTTEAU, 1869) and sediment type. B. Large periproct and peristome of *C. turonensis* (DESOR, 1847) from mixed siliciclastic/carbonate facies of the *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association.

The number of phyllodal pores in some *Hemiaster* species such as *H.* (*Mecaster*) *heberti turonensis* of association 3 is relatively high. They are circular, single to paired isopores (Text-fig. 5.48B2). The penicillate tube foot in *Hemiaster* species is ideally suited for picking up very small, mud-sized particles, and each tube foot can pick up a disc-full of fine sediment particles by mucous adhesion (SMITH 1980; BARRAS 2008). Thus the presence of such pores indicates that the substrate was soft and rich in food particles. Moreover, the presence of frontal well-developed pores (in ambulacrum III) indicates that the species lived in relatively poorly permeable, rather fine-grained sediment and that they were also used in burrowing or food transport (JAGT 2000; VILLIER et al. 2004). The lack of the frontal groove in some species such as *H.* (*H.*) *syriacus* indicates that all food particles were derived from within the sediment and not from the sediment-water interface. In this case, phyllode tubes pick up the food particles from the sediment and transfer them to the mouth. It appears that the presence of well-developed ambulacrum III pores as well as phyllodal pores are adaptations for feeding in soft sediments.

The type of spine and its position on the test are clearly correlated with the mode of life (SMITH, 1980). Spines of echinoids are outer body appendages mainly involved in the passive and active defense of echinoids (DUBIOS & AMEYE 2001). The size and density of tubercles (base of spines) on both the oral and aboral surfaces differ in shape, size, and density. In the present material the tubercles on the oral surface (oral spines) are coarser than on the opposite surface (Text-fig. 5.56A-B). They were used to excavate the sediment so that the animal sank shallowly into the substrate. The anterior spines (in front of the mouth) are used for forward motion and for loosening grains from the front side of the animal, while the numerous and strong spines posterior of the mouth are used to push the animal within the moderately hard marly sediments. At the same time, the spines within fascioles produced current that drew water into the burrow for respiration, especially in low permeable sediments. Thus the presence of fascioles is a strong indication that the echinoid lives infaunally, as fascioles play an important role for respiration.



Text-fig. 5.56. Some morphological characters of *Hemiaster* species. A, D. *Hemiaster* (*H.*) *syriacus* (CONRAD, 1852); B. *H.* (*Mecaster*) *heberti* (COQUAND, 1862) *turonensis* FOURTAU, 1921; C. *Hemiaster* (*Hemiaster*) *gabrielis* PERON & GAUTHIER, 1878.

The outline (profile) of the echinoid test is known to be sensitive to environmental variations (NÉRAUDEAU, 1995). In several Cretaceous *Hemiaster* the shape of the test is related to the grain size of the sediment (more gibbous in finer-grained sediment), to the depth of burrowing, and to water depth (SMITH & PAUL 1985; NÉRAUDEAU & MOREAU 1989). For instance, the wedge-shaped profile of *H. (H.) bufo* (BRONGNIART 1822) and *H. nasutulus* (SORIGNET 1850) suggests that they were excellent burrowers, well adapted for moving through more compact layers (SMITH et al. 1988). This applies also to species such as *H.* (*H.*) *syriacus*, *H.* (*M.*) *fourneli*, and *H.* (*M.*) *pseudofourneli*. In addition, the heart-shaped test of *H.* (*M.*) *heberti turonensis* indicates that they lived infaunally, within relatively poorly permeable, rather fine-grained sediment (SMITH 1995). It is here suggested that the different *Hemiaster* species lived semi-infaunally (up to the ambitus) or shallow infaunally (slightly above the ambitus) in marly facies. In summary, four significant features, i.e. change in tubercle density, well-developed phyllodal pores as well as ambulacrum III pores, change of test shape, and presence of a peripetalous fasciole provide strong evidence for adaptation to inhabiting relatively poorly permeable sediment (marly facies) as semi-infaunal organisms (up to the ambitus or slightly above the ambitus).

5.8.2. Energy level

From the above discussion it seems that the substrate conditions are closely related to the water energy, because it controls the distribution of sediments as well as of organisms. For instance, coarse-grained substrates (e.g. of association 8) deposited under high water energy are mostly poor in fossils (Text-fig. 33). In contrast, the deposit-feeders in the marly facies must have lived under low-energy conditions, otherwise nutrients could not have accumulated in the sediment. Obviously, the water energy under which the associations and assemblages lived varied. In the present study, three energy levels have been recognized; low, medium, and high. Associations 3, 5, 7 reflect low energy conditions, because of the dominance of small, shallow-infaunal bivalves such as *Paraesa faba* and *Tenea delettrei*. This is also supported by the soft, fine-grained substrates, without signs of regular reworking events (FÜRSICH et. al., 2004). The presence of deposit-feeders in the sediment (e.g., 21% in association 3) indicates also a relatively low energy level. The water energy in the *Ceratostreon flabellatum* − *Hemiaster* (*H.*) *gabrielis* association was medium and sufficiently high to keep organic nutrients in suspension, but low enough to accumulate particulate organic matter in the sediment being used by deposit feeders (23.18%). Similarly, the energy level in the *Pycnodonte* (*P.*) *vesicularis vesiculosa* − *Phelopteria gravida* association was sufficiently high for the epibyssate suspension-feeding *Phelopteria gravida* (15.31%), but low enough for organic matter accumulation (7.65% of deposit-feeding *Hemiaster* (*M.*) *fourneli*). According to FÜRSICH et. al. (2004), intermediate energy levels often exhibit signs of winnowing, but large-scale transport of fauna is not the rule. The *Chondrodonta* concentrations represent high energy events (storms) leading to concentration of shells. This is documented by the densily packed, imbricated or stacked, randomly oriented, and highly fragmented *Chondrodonta* valves. However, the *Chondrodonta joannae* association surely lived in a comparatively low-energy environment, and the association was produced by the final processes, i.e. in-situ reworking and winnowing by intermediate to strong currents.

5.8.3. Salinity

The presence of stenohaline organisms such as ammonites, echinoids, and corals of the *Paraesa faba* − *Hemiaster* (*M.*) *heberti turonensis* association and *Ilymatogyra africana* − *Granocardium* (*G.*) *productum* association with high values of species richness and evenness indicate that the associations lived in fully marine environments. The complete absence of stenohaline organisms and low values of species richness and evenness, in contrast suggest a lowered salinity. However, one has to keep in mind that these features were, at least in some cases, a diagenetic product caused by chemical sorting.

CONCLUSIONS

1. The Cenomanian-Turonian sedimentary successions of north and central East Sinai (Egypt) has been studied in three detailed sections. They are, from north to south, Gebel Areif El-Naqa, East Themed area, and Wadi Quseib. The present study is mainly concerned with lithostratigraphy, biostratigraphy, taxonomy, taphonomy and palaeoecology.

2. The Cenomanian-Turonian succession of Gebel Areif El-Naqa is 457 m thick and has been subdivided into three formations, which from older to younger are the Halal Formation (Upper Albian-Cenomanian) (301 m), the Abu Qada Formation (Lower-?Middle Turonian) (96 m), and the Wata Formation (Upper Turonian) (60 m). The Halal Formation has been subdivided into three informal members. The lower part of the Halal Formation has been assigned to the Upper Albian based on ammonite *Knemiceras deserti* Zone and the inoceramid *Mytiloides concentricus* Total Range Zone. In the East Themed section, the Cenomanian-Turonian succession is 239 m thick and has been subdivided into four formations which, from older to younger are Galala (Middle-lower Upper Cenomanian), Abu Qada (Upper Cenomanian-Lower Turonian), Buttum (Middle Turonian), and Wata formations (Upper Turonian). The basal part of the Cenomanian Galala Formation is not exposed. Three formations have been recognized in the third section (Wadi Quseib) which are the Galala (Cenomanian) (143 m), Abu Qada (Lower-?Middle Turonian) (100 m), and Wata formations (upper Middle-Upper Turonian) (91 m). The Galala Formation has been subdivided into three informal members. The Cenomanian Galala/Halal Formation of the studied sections is rich in macrobenthos except for the lower shale member of Wadi Quseib. The latter member consists mainly of ochre shale with intercalations of fine- to coarse-grained sandstone, thin reddish clay horizons, and lacks any macrobenthic fauna. This facies represents a marginal-marine environment with a semi-arid to arid climate. The area was affected by small-scale sea-level fluctuations with lowstands causing subaerial exposure as documented by thin paleosoils. These unfavourable ecological conditions explain the complete absence of marine macrofossils in the lower shale member. From the lithostratigraphic correlation, the mixed siliciclastic-carbonate rocks increase in abundance towards the south at the expense of carbonates, while the total thickness gradually decreases (East Themed and Wadi Quseib sections). In contrast, carbonates increase in abundance toward the north (deep carbonate facies as in Gebel Areif El-Naqa). The Buttum Formation (Middle Turonian) of the East Themed section was found to be 40 m thick, consisting mainly of variegated gypsum/claystone intercalations. This formation indicates very shallow lagoonal or sabkha deposits of a tidal flat (regressive phase linked with a climate change to arid conditions). The gypsum layers are avoid of a nodular and chicken wire structure typical of a sabkha facies, but show instead a laminated fabric. They are therefore interpreted to have been precipitated subaqueously in a lagoonal environment.

3. The Cenomanian-Turonian rocks of the studied sections yield associations of bivalves, gastropods, ammonites, echinoids, and corals. 144 taxa are taxonomically discussed in details. The stratigraphic and palaeogeographic distribution are taken in consideration. Due to diagenetic processes, the preservation of the faunal elements is, in general, poor. Aragonitic faunal elements are usually preserved as steinkerns or moulds. The only faunal elements with well-preserved shell structures are calcitic taxa such as infaunal and epifaunal echinoids and epifaunal, thick-shelled oysters and plicatulid bivalves.

Bivalves: 67 bivalve species belonging to 50 genera and 28 families have been identified and described. Six of the species are recorded from Egypt for the first time. As the structure of the outer shell layers of rudists together with other related skeletal characters (e.g., development of the ligament ridge, radial bands, ornamentation) are important in taxonomy, the internal microstructure of rudist has been illustrated. The presence of compact layers in the outer shell layer of *Eoradiolites liratus* is probably due to the continuous growth and continuous stacking of lamellae.

Gastropods: 34 gastropod species belong to 25 genera and 19 families have been identified. Eight of the species are recorded from Egypt for the first time. The genus *Sogdianella* DJALILOV is the first record from the Lower Turonian of Egypt and North Africa. Three nerineid genera were identified in the present study, two of these, namely *Neoptyxis* and *Pchelinsevia* LISENKO & ALIYEV, 1987, can easily be classified because they exhibit a characteristic fold pattern (columellar, parietal, labial and basal folds). The third genus *Diozoptyxis* is not well preserved.

Cephalopods: 14 species (13 ammonites and one nautilid), which belong to 12 genera and 6 families, are described from the uppermost part of the Cenomanian Halal/Galala Formation and Turonian Abu Qada/Wata Formation.

Echinoids: 26 echinoid species belonging to 16 genera, 14 families, and 8 orders are taxonomically discussed. *Gentilia syriensis* KIER is the first record of the species from Egypt. The taxonomy and palaeoecology of the Upper Cretaceous echinoids of the present sections has been published by EL QOT et al. (2009).

Coral: *Aspidiscus cristatus* (LAMARCK), *Tortoflabellum* sp., and *Cladocora* sp. are described and illustrated from three coral-bearing horizons of the Cenomanian sedimentary succession of Wadi Quseib.

4. Five biozones based on ammonites, two on echinoids, two on bivalves, and one on corals have been established in the present study. The oldest ammonite zone is the *Knemiceras deserti* Zone (Upper Albian) from the Halal Formation. The lower Upper Cenomanian zone is identified as the *Neolobites vibrayeanus* Zone. In addition, three Turonian ammonite zones have been recorded in the Abu Qada and Wata formations, (1) the Lower Turonian *Choffaticeras* (*Ch.*) *segne* Zone, (2) the upper Lower Turonian *Wrightoceras munieri* Zone, and (3) the lower Upper Turonian *Coilopoceras requienianum* Zone. The Cenomanian-Turonian boundary in the studied sections is drawn in the lower part of the Abu Qada Formation between the extinction of the upper Cenomanian oysters and the first appearance of upper Lower Turonian ammonites such as *Choffaticeras (Ch.) segne.* Typical upper Upper Cenomanian ammonites such as *Metoicoceras geslinianum* (D'ORBIGNY) and *Vascoceras cauvini* CHUDEAU and lower Lower Turonian ammonites such as *V. proprium* (REYMENT) and *P. flexuosum* POWELL are completely absent in the present study. Thus, the first appearance of the upper Lower Turonian ammonites above the Cenomanian deposits indicates a hiatus between the Cenomanian and Turonian deposits due either to erosion or non-deposition.

5. In order to reconstruct the benthic association, all rare and allochthonous individuals were removed from the database of the three sections, and the remaining 41 statistical samples were subjected to a cluster analysis. The samples were grouped into ten associations and three assemblages, which turned out to be a useful tool for reconstructing the different depositional environments. The dominating macrobenthic groups are bivalves, followed by gastropods and echinoids. Oysters are the most common element in the studied sections, especially in the Cenomanian deposits. In contrast, the abundance of oysters rapidly decreases towards the Cenomanian-Turonian boundary and remains at low levels throughout the Turonian. The generally low abundances of oysters in the Turonian deposits document a regional deterioration of their living conditions, most likely caused by the global sea-level rise at the Cenomanian-Turonian boundary drowned the oyster habitats below optimum water depth. With respect to feeding mode, most of the benthic associations are strongly dominated by suspension-feeders followed by deposit-feeders. The distribution of associations and

assemblages is mainly controlled by the environmental parameters substrate, water energy, and salinity.
6. A high species diversity is found in the mixed siliciclastic/carbonate facies and in marly wackestones. In the coarse-grained facies (e.g., floatstone and rudstone) diversity is low. The high diversity values in the marly facies are obviously the result of stable and predictable environments which, for the most part, were free of physical stress. In this case, the members of these associations seem to have followed a k-strategy. They can be regarded as biologically accommodated communities characterized by a relatively long time span with low disturbances, a relatively low reproduction rate, and a high level of speciation. In addition, the water energy is closely related to the substrate because it controls the distribution of sediments as well as of organisms.

7. A principal components analysis (PCA) was performed to clarify the morphological relationship between forma typica and forma crassa of *Ilymatogyra africana*. When PC1 and PC2 scores of individual specimens are plotted by growth form forma typica and forma crassa indeed differ but overlap.Thus suggests that they represent two morphotypes of the same species. By comparing *I. africana* with *I. arietina* (ROEMER) from the Cenomanian of Texas, the type of coiling and the shape of the left valve influenced the convexity and outline of right valve. In addition, the species grew rapidly in the early stages to maximize its surface area on relatively soft sediment. This is supported by the thin and concave right valve interpreted to have primarily grown laterally rather than in thickness. At a latter stage, when the valve was wide enough to ensure a stable position, the oysters could grow convexly to increase valve thickness and body cavity volume. The dorso-ventral section through both valves of *I. africana* shows a large unconformity in the middle part of the left valve indicating rapid and episodic growth of the organism. The large unconformity is interpreted to indicate thickening of the dorsal region of the left valve, which resulted in the re-orientation of the organisms, thereby protecting them from the danger of burial in soft sediment and from clogging of their gills.

8. The principal component analysis (PCA) also reflects the variation of the individual’s outline (PC1 having removed most of variance related to size). The morphometric analysis between two growth forms of *Costagyra olisiponensis* (A and B) confirms that there exists a relationship between the size of attachment area, shell outline, and the convexity of valves. A small attachment area occurs in individuals with a wide postero-ventral part and less convex valves. In contrast, a large attachment area occurs in more elongated shells (H/L=1.62, growth form A) with strongly convex valves. In the present study, *C. olisiponensis* apparently followed two life habit strategies, cemented to secondary hard substrates as juveniles, and adopting a freely reclining mode of life as adults (similar to *Gryphaea*). The excessive shell thickening in the dorsal region (C>70 mm) served to stabilize the shell on soft substrate.

9. The nature of substrate plays an important role in the change of skeletal morphology of regular and irregular echinoids. For instance, the high domal and large test of *Coenholectypus larteti* from carbonate facies might be a sign of an epifaunal mode of life, while small and flattened tests of the same species is interpreted as an adaptation to live within soft sediment as a shallow-burrowers.

10. Five species of *Hemiaster* have been identified and most of them have been collected from the marly facies. Four significant features, i.e. change in tubercle density, well-developed phyllodal pores as well as ambulacrum III pores, change of test shape, and presence of a peripetalous fasciole provide strong evidence for adaptation to inhabiting relatively poorly permeable sediment (marly facies) as semi-infaunal organisms (up to the ambitus or slightly above the ambitus).

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REFERENCES

ABBASS, H.L. 1962. A monograph on the Egyptian Cretaceous pelecypods. – Geological Survey and Mineral Research Department, Monographs of the Geological Museum, Palaeontological Series **1**: 224pp.

ABBASS, H.L. 1963. A monograph on the Egyptian Cretaceous gastropods. – Geological Survey and Mineral Research Department, Monographs of the Geological Museum, Palaeontological Series **2**: 146pp.

ABBASS, H.L. 1973. Some British Cretaceous gastropods belonging to the families Procerithiidae, Cerithiidae and Cerithiopsidae (Cerithiacea). – Bulletin of the British Museum (Natural History) **23**: 107-170.

ABDALLAH, A. M. & ADINDANI, A. 1963. Notes on the Cenomanian-Turonian contact in the Galala Plateau, Eastern Desert, Egypt. – Egyptian Journal of Geology, United Arab Republic **7**: 67-70.

ABDALLAH, A.M. & ABOU-KHADRAH A. M. 1977. Remarks on the geomorphology of the Sinai Peninsula and its associated rocks. – Colloquium on the Geology of Aegean Region, Athens **4**: 509-516.

ABDALLAH, A.M., ABDEL-GAWAD, G.I. & MEKAWY, M.S. 2001. Stratigraphy of the Cenomanian and Turonian sequence of El-Giddi Pass, northwest Siani, Egypt. – Proceedings of the 6th International Conference, Geology of Sinai for Development: 211-229.

ABDEL-GAWAD, G.I. 1986. Maastrichtian non-cephalopod mollusks (Scaphopoda, Gastropoda, and bivalvia) of the Middle Vistula Valley, central Poland. – Acta Geologica Polonica **36**: 1-224.

ABDEL-GAWAD, G.I. 1995. Late Cenomanian fauna from Jardas Al Abid area, NW Jabal Al Akhdar, Libya. – Middle East Research Center, Ain Shams University, Earth Science Series **9**: 161-172.

ABDEL-GAWAD, G.I. 1999. Biostratigraphy and facies of the Turonian in west central Sinai, Egypt. – Annals of the Geological Survey of Egypt **22**: 99-114.

ABDEL-GAWAD, G.I. 2000. Coniacian gastropods from Sinai, Egypt. – 5th International Conference on the Geology of the Arab World **3**: 1509-1526.

ABDEL-GAWAD, G.I. & GAMEIL, M. 1992. Cenomanian gastropods from the Gebel Nezzazat area, west central Sinai, Egypt. – Middle East Research Center, Ain Shams University, Earth Sciences Series **6**: 69-85.

ABDEL-GAWAD, G.I. & GAMEIL, M. 1995. Cretaceous and Palaeocene coral faunas in Egypt and Greece. – Coral Research Bulletin **4**: 1-36.

ABDEL-GAWAD, G.I. & GAMEIL, M. 2002. Bivalvia taxonomy of the Cenomanian-Turonian strata of Gabal Nezzazat, west central Sinai, Egypt. – Journal of Faculty of Science of United Arab Emirates **124**: 70-107.

ABDEL-GAWAD, G.I. & ZALAT, A. 1992. Some Upper Cretaceous macroinvertebrates from Gebel El-Hamra and Gebel Um Heriba, Mitla Pass, west central Sinai. – Proceedings of the first International Conference on the Geology of the Arab World, Cairo University: 333-344.

ABDEL-GAWAD, G.I., ABOUL ELA, N.M. & GAMEIL, M. 1992. Molluscan biostratigraphy of the Cenomanian-Turonian strata of Gebel Nezzazat area, west central Sinai, Egypt. – Proceedings of the first International Conference on the Geology of the Arab World, Cairo University: 321-332.

ABDEL-GAWAD, G.I., EL-SHEIKH, H.A., ABDELHAMID, M.A., EL-BESHTAWY, M.K., ABED, M.M., FÜRSICH, F.T. & EL QOT, G.M. 2004a. Stratigraphic studies on some Upper Cretaceous successions in Sinai, Egypt. – Egyptian Journal of Paleontology **4**: 263-303.

ABDEL-GAWAD, G.I., ORABI, O.H. & AYOUB, W.S. 2004b. Macrofauna and biostratigraphy of the Cretaceous section of Gebel El-Fallig area, northwest Sinai, Egypt. – Egyptian Journal of Paleontology **4**: 305-333.

ABDEL-GAWAD, G.I., EL QOT, G.M. & MEKAWY, M.S. 2007. Macrobiostratigraphy of the Upper Cretaceous succession from southern Galala, Eastern Desert, Egypt. – Second International Conference on the Geology of the Tethys, Cairo University: 329-349.

ABDELHAMID, M.A.M. 1999. Parasitism, abnormal growth and predation on Cretaceous echinoids from Egypt. – Revue de Paléobiologie **18**: 69-83.

ABDELHAMID, M.A.M. & EL QOT, G.M. 2001. Cenomanian-Santonian echinoids from Gebel El-Hamra and El-Minsherah, north and west central Sinai, Egypt. – Middle East Research Center, Ain Shams University, Earth Science Series **15**: 1-20.

ABDELHAMID, M.A.M. & EL QOT, G.M. 2002. Some Upper Cretaceous bivalves from Gabal El-Minsherah and Gabal El-Hamra, north and west central Sinai, Egypt. – Egyptian Journal of Paleontology **2**: 259-288.

ABDEL KHALEK, M.L., ABDEL WAHED, M. & SEHIM, A.A. 1992. Gravitational tectonics in the northwestern part of the Gulf of Aqaba, Sinai, Egypt. – Geology of the Arab World, Cairo University: 395-416.

ABDEL KHALEK, M.L., ABDEL WAHED, M. & SEHIM, A.A. 1993. Wrenching deformation and tectonic setting of the northwestern part of the Gulf of Aqaba. – Geological Scoiety of Egypt, Special Publication **1**: 409-444.

ABED, M.M., AYYAD, S.N. & ABU-ZIED, R.H. 1996. Stratigraphic classification of Triassic-Cretaceous rocks of Gebel Arif El-Naga, northeastern Sinai, Egypt. – Newsletters on Stratigraphy **33**: 117-131.

ABDELHAMID, M.A.M. & AZAB, M.M. 2003. Aptian-Cenomanian echinoids from Egypt. – Revue de Paléobiologie **22**: 851-876.

ABERHAN, M. 1992. Palökologie und zeitliche Verbreitung benthischer Faunengemeinschaften im Unterjura von Chile. – Beringeria **5**: 3-174.

ABERHAN, M. 1993a. Benthic invertebrate associations on a carbonate-clastic ramp in segments of the Early Jurassic Backarc Basin of northern Chile (26-29˚S). – Revista Geológica de Chile **2**: 105-136.

ABERHAN, M. 1993b. Faunal replacement in the Early Jurassic of northern Chile: Implications for the evolution in Mesozoic benthic shelf ecosystems. – Palaeogeography, Palaeoclimatology, Palaeoecology **103**: 155-177.

ABERHAN, M. 1994. Guild-structure and evolution of Mesozoic benthic shelf communities. – Palaios **9**: 516-545.

ABERHAN, M. & FÜRSICH, F.T. 1997. Diversity analysis of Lower Jurassic bivalves of the Andean Basin and the Pliensbachian-Toarcian mass extinction. – Lethaia **29**: 181-195.

ABERHAN, M., KIESSLING, W. & FÜRSICH, F.T. 2006. Testing the role of biological interactions in the evolution of mid-Mesozoic marine benthic ecosystems. – Paleobiology **32**: 259-277.

ABOUL ELA, N.M., ABDEL-GAWAD, G.I. & ALY, M.F. 1991. Albian fauna of Gebel Manzour, Maghara area, north Sinai, Egypt. – Journal of African Earth Sciences **13**: 201-221.

ABU KHADRAH, A.M., DARWISH, M., EL-AZABI, M.H. & ABDEL FATTAH, M.A. 1987. Lithostratigraphy of the Upper Cretaceous-Tertiary succession in the Gulf of Suez (southern Galala Plateau), Egypt. – In: MATHEIS, G. & SCHANDELMEIER, H. (eds.), Current Research in African Earth Sciences: 171-176, Rotterdam (Balkema).

ACCORDI, G., CARBONE, F. & SIRNA, G. 1982. Relationships among tectonic setting, substratum and benthonic communites in the Upper Cretaceous of northeastern Matese (Molise, Italy). – Geologica Romana **21**: 755-793.

AGAH, A. 1981. Structural map and plate reconstruction of the Gulf of Suez, Sinai area, Egypt. – Internal Report, Conoco Oil Company, Houston, Texas, USA.

AGASSIZ, L. 1840. Catalogus systematicus ectyporum echinodermatum fossilium musei Neocomiensis. – 20pp., Petitpierre, Neuchâtel.

AGASSIZ, L. & DESOR, E. 1846-1847. Catalogue raisonné des familles des genres et des espèces de la classe des Echinodermes. – Annales des Sciences Naturelles, Zoologie **3**: 6-8.

AHMAD, F. & AL-HAMMAD, A. 2002. Oysters and echinoids from the Naur Formation (Late Aptian-Early Cenomanian) of Central Jordan. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **2002**: 449-464.

AKARISH, A.I.M. 1999. Microfacies analysis of the Cenomanian-Paleocene exposures of Taba-Nuweiba area, East Sinai. – Middle East Research Center, Ain Shams University, Earth Science Series **13**: 135-152.

ALBANESI, C. & BUSSON, G. 1974. Gastéropodes du Crétacé Supérieur de l'extrème-sud tunisien et de la région du Tinrhert (Sahara Algérien). – Rivista Italiana di Paleontologia e Stratigrafia **80**: 251-342.

ALI, M.S.M. 1989. Late Cretaceous echinoids from Gebel El Rowdah, Hatta area, U.A.E. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **177**: 393-412.

ALI, M.S.M. 1990. Cenomanian echinoids from Ras Al Khaimah, United Arab Emirates. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **179**: 97-116.

ALI, M.F. & ABDEL-GAWAD, G.I. 2001a. Upper Cenomanian-Lower Turonian ammonites from north and central Sinai, Egypt. – El-Minia Science Bulletin **13**: 17-60.

ALI, M.F. & ABDEL-GAWAD, G.I. 2001b. Early Cretaceous ammonites of Gebel Lagama, North Sinai, Egypt. – Palaeontographica A**262**: 25-52.

ALI, M.F., SABER, S.G., ABDEL-GAWAD, G.I. & FERIEG, Y.F. 2005. Cenomanian-Turonian rudist buildups of northern Sinai, Egypt. – Egyptian Journal of Paleontology **5**: 253-286.

ALI, M.F., SMADI, A. & ABU AZZAM, H. 2008. Late Cenomanian-Early Turonian ammonites of Jordan. – Revue de Paléobiologie **27**: 43-71.

ALLOITEAU, J. 1952. Madréporaires post-paléozoiques. – In: PIVETEAU, J. (ed.), Traité de Paléontologie **1**; Paris (MASSON et CIE.): 539-684.

ALSHARHAN, A.S. & SALAH, M.G. 1996. Geologic setting and hydrocarbon potential of North Sinai, Egypt. – Bulletin of Canadian Petroleum Geology **44**: 615-631.

AMARD, B., COLLIGNON, M. & ROMAN, J. 1981. Etude stratigraphique et paléontologique du Crétacé supérieur et Paléocéne du Tinhert-W et Tademait-E (Sahara Algérien). **–** Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon, Hors Série **6**: 15-173.

AMLER, M., FISCHER, R. & ROGALLA, N. 2000. Muscheln. – 214pp., Enke-Verlag, Stuttgart.

ANDRADE, E. DE J., SEELING, J., BENGTSON, P. & SOUZA-LIMA, W. 2004. The bivalve *Neithea* from the Cretaceous of Brazil. – Journal of South American Earth Sciences **17**: 25-38.

ANDREWS, H. E. 1974. Morphometrics and functional morphology of *Turritella mortoni*. – Jounal of Paleontology **48**: 1126-1140.

AVNIMELECH, M. 1947. A new species of *Aspidiscus* from the Middle Cretaceous of Sinai and remarks on this genus in general. – Mémoires de la Société paléontologique Suisse (= Abhandlungen der Schweizerischen Paläontologischen Gesellschaft) **40**: 294-299.

AWAD, G.H. 1952. The Nerineas of Sinai (with a note on the mode of these extinct gastropods). – Bulletin de l'Institut du Désert d'Egypte **2**: 23-29.

AWAD, G.H. 1961. Note on fauna of interest encountered in the western side of the Gulf of Suez. – Journal of the Geological Society of Egypt **5**: 73-75.

AYYAD, S.N., ABED, M.M. & ABU ZIED, R. H. 1996. Biostratigraphy and correlation of Cretaceous rocks in Gebel Arif El-Naga, northeastern Sinai, Egypt, based on planktonic foraminifera. – Cretaceous Research **17**: 263-291.

BACHMANN, M. & KUSS, J. 1998. The middle Cretaceous carbonate ramp of the northern Sinai: sequence stratigraphy and facies distribution. In: WRIGHT, V.P.& BURCHETTE, T.P. (eds.), Carbonate ramps. – Geological Society of London, Special Publication **149**: 253-280.

BANDEL, K. & GEYS, J.F. 1985. Regular echinoids in the Upper Cretaceous of the Hashemite Kingdom of Jordan. – Annales de la Société Géologique du Nord **104**: 97-115.

BANDEL, K. & KIEL, S. 2003. Relationships of Cretaceous Neritimorpha (Gastropoda, Mollusca), with description of seven new species. – Bulletin of the Czech Geological Survey **78**: 53-63.

BANDEL, K., KUSS, J. & MALCHUS, N. 1987. The sediments of Wadi Qena (Eastern Desert, Egypt). – Journal of African Earth Science **6**: 427-455.

BARBER, W. 1958. Upper Cretaceous Mollusca from north-eastern Nigeria. – Records of the Geological Survey of Nigeria Bulletin: 14-46.

BARKER, M.J. 1990. The palaeobiology of Nerineacean gastropods. – Historical Biology **3**: 249-264.

BARON-SZABO, R. C.; SCHAFHAUSER, A.; GÖTZ, S. & STINNESBECK, W. 2006. Scleractinian corals from the Cardenas Formation (Maastrichtian), San Luis Potosí, Mexico. – Journal of Paleontology 80: 1033-1046.

Baron-SzaBO, R. C. 2002. Scleractinian corals of the Cretaceous. – 539pp., Knoxville, TN (BARON-SZABO).

BARONI, C., INCITTI, L., OLIVERI, A. & VIOLA, V. 1953. Revisione della fauna neocretacica della Libia: Pinnidae, Mytilidae, Limidae, Nuculidae, Ledidae, Arcidae, Cyprinidae, Astartidae, Crassatellidae, Veneridae, Cardiidae, Lucinidae, Aloididae, Thraciidae, Chamidae. – Annali del Museo Libico di Storia Naturale **4**: 11-110.

BARRAS, C.G. 2008. Morphological innovation associated with the expansion of atelostomate irregular echinoids into fine-grained sediments during the Jurassic. – Palaeogeography, Palaeoclimatology, Palaeoecology **263**: 44-57.

BARROSO-BARCENILLA, F. & GOY, A. 2007. Revision and new data of the ammonite family Pseudotissotiidae in the Iberian Trough, Spain. – Geobios **40**: 455-487.

BARROSO-BARCENILLA, F. & GOY, A. 2009. The ammonite genera *Fagesia* and *Neoptychites* (family Vascoceratidae) in the Iberian Trough, Spain. – Geobios **42**: 17-42.

BARTOV, Y. & STEINITZ, G. 1977. The Judea and Mount Scopus groups in the Negev and Sinai with trend surface analysis of the thickness data. – Israel Journal of Earth Sciences **26**: 119-148.

BARTOV, Y., LEWY, Z., STEINITZ, G. & ZAK, I. 1980a. Mesozoic and Tertiary stratigraphy, paleogeography and structural history of Gebel Areif En Naqa area, eastern Sinai. – Israel Journal of Earth Sciences **29**: 114-139.

BARTOV, Y., STEINITZ, G., EYAL, M. & EYAL, Y. 1980b. Sinistral movement along the Gulf of Aqaba - its age and relation to the opening of the Red Sea. – Nature **285**: 220-222.

BASSE, É. 1955. Invertébrés jurassiques. – In: BASSE, É., KARRENBERG, H., LEHMAN, J.P., ALLOTTEAU, J. & LEFRANCE, J.P. Fossiles du jurassique supérieur et des “Grès de Nubie” de la région de Sana (Yémen). – Bulletin de la Société géologique de France 4: 663-673.

BATALLER, J. R. 1937. La fauna Corallina del Cretacic de Catalunya i regions limitrofes. – Arxius Escole Sup. Agriculture, n.s. **3**(1): 1-310.

BAUER, J., MARZOUK, A.M., STEUBER, T. & KUSS, J. 2001. Lithostratigraphy and biostratigraphy of the Cenomanian-Santonian strata of Sinai, Egypt. – Cretaceous Research **22**: 497-526.

BAUER, J., KUSS, J. & STEUBER, T. 2003. Sequence architecture and carbonate platform configuration (Late Cenomanian-Santonian), Sinai, Egypt. – Sedimentology **50**: 387-414.

BENGSTON, P., 1996. The Turonian stage and substage boundaries. – In: RAWSON, P.F., DHONDT, A.V., HANCOCK, J.M. & KENNEDY, W.J. (eds.). Proceedings of the Second International Symposium on Cretaceous Stage Boundaries, Brussels. – Bulletin de l’Institut Royal des Sciences Naturelles de Belgique **66**: 69-79.

BERNDT, R. 2002. Palaeoecology and taxonomy of the macrobenthic fauna from the Upper Cretaceous Ajlun Group, southern Jordan. – Unpublished Ph.D thesis, Würzburg University, Germany: 1-221.

BERNDT, R. 2003. Cenomanian echinoids from Southern Jordan. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **2003**: 73-90.

BERTHOU, P.Y., CHANCELLOR, G.R. & LAUVERJAT, J. 1985. Revision of the Cenomanian-Turonian Ammonite *Vascoceras* CHOFFAT, 1898 from Portugal. – Comunicações dos Serviços Geológios de Portugal **171**: 55-79.

BERTLING, M. 1992. *Arachnostega* n. ichnog. - burrowing traces in internal moulds of boring bivalves (Late Jurassic, northern Germany). – Paläontologische Zeitschrift **66**: 177-185.

BIRKELUND, T., HANCOCK, J.M., HART, M.B., RAWSON, P.F., REMANE, J., ROBASZYNSKI, F., SCHMID, F. & SURLYK, F. 1984. Cretaceous stage boundaries - Proposal. – Bulletin of the Geological Society of Denmark **33**: 3-20.

BLANCKENHORN, M. 1890. Beiträge zur Geologie Syriens: Die Entwickelung des Kreidesystems in Mittel- und Nord-Syrien mit besonderer Berücksichtigung der paläontologischen Verhältnisse nebst einem Anhang über den jurassischen Glandarienkalk. – Cassel: 135pp.

BLANCKENHORN, M. 1925. Die Seeigelfauna der Kreide Palästinas. – Palaeontographica **67**: 83-113.

BLANCKENHORN, M. 1927. Die fossilen Gastropoden und Scaphopoden der Kreide von Syrien-Palästina. – Palaeontographica **69**: 111-186.

BLANCKENHORN, M. 1934. Die Bivalven der Kreideformation von Syrien-Palästina nebst einem ergänzenden Anlang über Brachiopoden, Gastropoden und Pteropoden und einem Überblick über die gesamte Molluskenfauna. – Palaeontographica A**81**: 161-296.

BOEHM, G., 1895. Beiträge zur Kenntniss der Kreide in den Südalpen. I. Die Schiost- und Callonghe-Fauna. – Palaeontographica **41**: 81-148.

BOLLI, H.M. 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. – Association Venezolana de Geologia, Mineria y Petroleo, Boletin Informativo **9**: 1-32.

BONANNO, S. & SIRNA, G. 1995. Revision of some species of Cenomanian caprinid rudists instituted by G. G. GEMMELLARO in 1865. – Revista Mexicana de Ciencias Geológicas **12**: 135-144.

BOND, P.N. & SAUNDERS, W.B. 1989. Sublethal injury and shell repair in Upper Mississippian ammonoids. – Paleobiology **15**: 414-428.

BOREHAM, A.U.E. 1959. Cretaceous fossils from the Chatham Islands. – Transactions of the Royal Society of New Zealand **86**: 119-125.

BOSWORTH, W., GUIRAUD, R. & KESSLER, L.G. 1999. Late Cretaceous (ca. 84 Ma) compressive deformation of the stable platform of the northeast Africa (Egypt): Far-field stress effects of the “Santonian Event” and origin of the Syrian Arc deformation belt. – Geology **27**: 633-636.

BOTTJER, D.J. 1981. Structure of Upper Cretaceous chalk benthic communities, southwestern Arkansas. – Palaeogeography, Palaeoclimatology, Palaeoecology **34**: 225-256.

BOUCHET, P. & ROCROI, J.P. 2005. Classification nomenclator of gastropod families. – International Journal of Malacology, Malacologia **47**: 1-397.

BOUCOT, A.J., BRACE, W. & DEMAR, R. 1958. Distribution of brachiopod and pelecypod shells by currents. – Journal of Sedimentary Petrology **28**: 321-332.

BÖHM, J. 1900. Über cretaceische Gastropoden vom Libanon und vom Karmel. – Zeitschrift der Deutschen Geologischen Gesellschaft **52**: 189-236.

BÖTTCHER, R. 1982. Die Abu Ballas Formation (Lingula Shale) (Apt.?) der Nubischen Gruppe Südwest-Ägyptens. Eine Beschreibung der Formation under besonderer Berücksichtigung der Paläontologie. – Berliner geowissenschaftliche Abhandlungen A **39**: 1-145.

BRONGNIART, A. 1822. Sur quelque terrains des Craie hors du Basin de Paris. – In: CUVIER, G. & BRONGNIART, A. (eds.). Description géologique des couches des environs des Paris (**1**): 80-101.

BROMLEY, G.R. & D'ALESSANDRO, A. 1984. The ichnogenus *Entobia* from the Miocene, Pliocene, and Pleistocene of southern Italy. – Rivista Italiana di Paleontologia e Stratigrafia **90**: 227-296.

BUSSON, G., DHONDT, A., AMÉDRO, F., NÉRAUDEAU, D. & CORNÉE, A. 1999. La grande transgression du Cénomanien supérieur-Turonien inférieur sur la Hamada de Tinrhert (Sahara algérien): datations biostratigraphiques, environnement de dépôt et comparaison d'un témoin épicratonique avec les séries contemporaines à matiére organique du Maghreb. – Cretaceous Research **20**: 29-46.

CAMION, G. 1983. Plates-formes carbonatées et recifs à rudistes du Crétacé de Sicile. – Travaux du Laboratoire de Géologie Historique et de Paléontologie **13**: 1-244.

CARBONE, F & SIRNA, G. 1981. Upper Cretaceous reef models from Rocca di Cave and adjacent areas in Latium, Central Italy. In: TOOMEY, D.F. (ed.), European Fossil Reef Models. – The Society of Economic Paleontologists and Mineralogists, Special Publication **30**: 427-445.

CARON, M. 1985. Cretaceous planktonic foraminifera. – In: BOLLI, H.M., SAUNDERS, J.B. & PERCH-NIELSEN, K. (eds.): Plankton stratigraphy: 17-87 (Cambridge University Press, Cambridge).

CESTARI, R. & SARTORIO, D. 1995. Rudists and facies of the Periadriatic Domain. – 207pp. DONATO MILANESE (AGIP), San Donato Milanes, Milano.

CESTARI, R., PONS, J.M. & SIRNA, G. 1998. Undescribed *Ichthyosarcolites* from Sicily, belonging to Gemmellaro's collection. – Geobios **31**: 69-73.

CHAIMOV, T.A., BARAZANGI, M., AL-SAAD, D., SAWAF, T. & GEBRAN, A. 1992. Mesozoic and Cenozoic deformation inferred from seismic stratigraphy in the southwestern intracontinental Palmyride fold-thrust belt, Syria. – Geological Society of America Bulletin **104**: 702-715.

CHANCELLOR, G.R., KENNEDY, W.J. & HANCOCK, J.M. 1994. Turonian ammonite faunas from central Tunisia. – Special Papers in Palaeontology **50**: 1-111.

CHARRIÈRE, A., ANDREU, B., CISZAK, R., KENNEDY, W.J., ROSSI, A. & VILA, J.M. 1998. La transgression du Cénomanien supérieur dans la Haute Moulouya et le Moyen Atlas méridional, Maroc. – Geobios **31**: 551-569.

CHERIF, O.H., AL-RIFAIY, I.A., AL-AFIFI, F.I. & ORABI, O.H. 1989a. Foraminiferal biostratigraphy and paleoecology of some Cenomanian-Turonian exposures in the west central Sinai (Egypt). – Revue de Micropaléontologie **31**: 243-262.

CHERIF, O.H., AL-RIFAIY, I.A., AL-AFIFI, F.I. & ORABI, O.H. 1989b. Planktonic Foraminifera and chronostratigraphy of Senonian exposures in west central Sinai, Egypt. – Revue de Micropaléontologie **32**: 167-184.

CHEVALIER J.P. 1987. Ordre des Scléractiniaires (Systématique with Beauvais L). – In GRASSÉ P.P. (ed.), Traité de Zoologie III Cnidaires, Anthozoaires **3**: 403-764, Paris.

CHINZEI, K. 1986. Shell structure, growth, and functional morphology of an elongated Cretaceous oyster. – Palaeontology **29**: 139-154.

CHINZEI, K. 1995. Adaptive significance of the lightweight shell structure in soft bottom oysters. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **195**: 217-227.

CHOFFAT, P. 1886-1902. Recueil d'études paléontologiques sur la faune crétacique du Portugal. – Comunicaçoes dos Serviços geologicos de Portugal **1**: 1-171.

COATES, A.G. 1977. Jamaican Cretaceous coral assemblages and their relationship to rudist frameworks. – In: Deuxième Symposium international sur les coraux et les récifs corallienes fossiles. - Mémoires du Bureau de Recherches Géologiques et minières **89**: 336-341.

COBBAN, W.A. & HOOK, S.C. 1980. The Upper Cretaceous (Turonian) ammonite family Coilopoceratidae HYATT in the Western Interior of the United States. - United States Geological Survey Professional Paper **1192**: 1–28.

COBBAN, W.A., SKELTON, P.W. & KENNEDY, W.J. 1991. Occurrence of the rudistid *Durania cornupastoris* (DES MOULINS, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado. – Bulletin of the United States Geological Survey, 1985-D: D1-D8.

COHEN, Z., KAPTSAN, V. & FLEXER, A. 1990. The tectonic mosaic of the southern Levant: Implications for hydrocarbon prospects. – Journal of Petroleum Geology **13**: 437-462.

COLLIGNON, M. 1971. Gastéropodes et Lamellibranches du Sahara. – Annales de Paléontologie (Invertébrés) **57**: 143-202.

CONRAD, T.A. 1852. Description of the fossils of Syria, collected in the Palestine expedition. – In: LYNCH, W.F. (ed.), Official report of the United States expedition to explore the Dead Sea and the River Jordan: 235pp., Murphy and Co, Baltimore.

COQUAND, M.H. 1854. Déscription géologique de la province de Constantine. – Mémoires de la Société Géologique de France 2(**5**): 140-154.

COQUAND, M.H. 1862. Géologie et Paléontologie de la région sud de la Province de Constantine. – Memoires de la Société d'Emulation de la Provence **2**: 1-341.

COQUAND, M.H. 1869. Monographie du genre "*Ostrea*". – Terrain crétacé: 215pp. (Baillière et fils, Paris).

COQUAND, H. 1880. Etudes supplémentaires sur paléontologie algerienne faisant à la déscription géologique et paléontologique de la region sud de la province de Constantine. – Bulletin de l'Académie d'Hippone **15**: 1-451.

COSSMANN, M. 1906. Essais de paléoconchologie comparé **7**: 1-261, Paris.

COTTEAU, G. 1861-1867. Paléontologie française. Déscription des animaux invertébrés commencée par ALCIDE D' ORBIGNY, Terrain Crétacé **7**, Echinides réguliers: 1-892.

COTTEAU, G. 1869: Notice sur les échinides fossiles recueillis par M. LOUIS LARTET en Syrie et en Idumée, pendant son voyage avec le duc de Luynes. – Bulletin de la Société géologique de France **2**(26): 533-538.

COTTEAU, G., PERON, P. & GAUTHIER, V. 1876-1881. Echinides fossiles de l'Algérie. – **1**: pt. 3 (1876), Etage Urgo-Aptien et Albien: 1-90; pt. 4 (1878), Etage Cenomanien: 1-144; pt. 5 (1879), Etage Cenomanien: 145-234; **2**: pt. 6 (1879), Etage Turonien: 1-110; pt. 7 (1881), Etage Senonien: 1-118, Paris.

COURTILLER, M.A. 1860. Déscription de trois nouvelles espéces d'ammonites du terrain crétacé des environs de Saumur et des Ammonites *Carolinus* et *Fleuriausianus* a l' état adulte. – Mémoires de la Société impériale d'agriculture, sciences et arts d'Angers **3**: 246-252.

COURTILLER, M.A. 1867. Les ammonites du Tuffeau. – Annales de la Société Linnéenne du de Maine-et-Loire Angers **9**: 1-8.

COX, L.R. 1949. On the genotype of *Nerinea*; with a new subgeneric name *Eunerinea*. – Proceedings of the Malacological Society of London **27**: 248–250.

COX, L.R. 1960. General characteristics of gastropods. – In: MOORE, R.C. (ed.). Treatise on Invertebrate Paleontology, Part 1(Mollusca 1): L249-L251. – Boulder (Geological Society of America), and Lawrence (University of Kansas Press).

COX, L.R. 1969. Morphological terms applied to bivalve shells and soft parts affecting shell. – In: MOORE, R.C. (ed.). Treatise on Invertebrate Paleontology, Part N (Mollusca 6, Bivalvia): N1-N489. – Boulder (Geological Society of America), and Lawrence (University of Kansas Press).

CRAIG, G.Y. & JONES, N.S. 1966. Marine benthos, substrate and palaeoecology. KLITZSCH, E., GRÖSCHKE, M. & HERRMANN-DEGEN, W. 1990. Wadi Qena: Paleozoic and Pre-Campanian Cretaceous Strata Paleontology **9**: 30-38.

CRAME, J.A. 1979. The occurrence of the bivalvia *Inoceramus concentricus* on Dundee Island, Joinville Island Group. – Bulletin of the British Antarctic Survey **49**: 283-288.

CUTLER, A.H. & FLESSA, K.W. 1995. Bioerosion, dissolution and precipitation as taphonomic agents at high and low latitudes. – Senckenbergiana Maritima **25**: 115-121.

DARWISH, M. 1994. Cenomanian-Turonian sequence stratigraphy, basin evolution and hydrocarbon potentialities of Northern Egypt. – 2nd International Conference of Geology of the Arab World, Cairo University: 261-303.

DAVIES, T.T. & SAYRE, J.G. 1970. The effect of environmental stress on pelecypod shell ultrastructure. – Geological Society of America, Abstract, Southeastern Section: 204-205.

DE CASTRO, P. & SIRNA, G. 1996. The *Durania arnaudi* biostrome of El-Hassana, Abu Roash area (Egypt). – Geologica Romana **32**: 69-91.

DELPEY, G. 1939. Les Gastéropodes Mésozoiques de la Région Libanaise. – Notes et Mémoires de la Section d’Études géologiques du Haut-Commissariat de la République Française en Syrie et au Liban: 292pp.

DELPEY, G. 1941. Gastéropodes marines, paléontologie-stratigraphie. – Mémoires de la Société Géologique de France (nouv. sér.) **43**: 1-144.

DE RIDDER, C. & LAWRENCE, J.M. 1982. Food and feeding mechanism: Echinoidae. – In: JANGOUX, M. & LAWRENCE, J.M. (eds.), Echinoderm Nutrition: 57-115, Rotterdam (Balkema).

DESMAREST, A. 1825. Oursins. – In LEVRAULT, F.G. (ed.). Dictionnaire des Sciences Naturelles **37**: 59-104.

DHONDT, A.V. 1973. Systematic revision of the subfamily Neitheinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. – Institut Royal des Sciences Naturelles de Belgique Mémoire **176**: 5-101.

DHONDT, A.V. 1982. Some Spanish Cretaceous bivalves. – Cuadernos de Geologia Ibérica **8**: 847-865.

DHONDT, A.V. 1985. Late Cretaceous bivalves from the A10 exposures in northern Aquitaine. – Cretaceous Research **6**: 33-74.

DHONDT, A.V. 1987. Bivalves from the Hochmoos Formation Group, (Gosau Oberösterreich, Austria). – Annalen des Naturhistorischen Museums Wien **88**: 41–101.

DHONDT, A.V. & DIENI, I. 1992. Non rudistid bivalves from Cretaceous rudist formations. – Geologica Romana **28**: 211-218.

DHONDT, A.V. & DIENI, I. 1993. Non-rudistid bivalves from Late Cretaceous rudist limestones of NE Italy (Col dei Schiosi and Lago di S. Croce areas). – Memorie Scienze Geologiche **45**: 165–241.

DHONDT, A.V., MALCHUS, N., BOUMAZA, L. & JAILLARD, E. 1999. Cretaceous oysters from North Africa: origin and distribution. – Bulletin de la Société Géologique de France **170**: 67-76.

DJALILOV, M.R. 1972. [Systematics of actaeonellids (gastropods)]: Paleontologicheskiy Zhurnal, 1972, **1**: 16–23. (In Russian; English translation published by American Geological Institut: Paleontological Journal **6**: 13-19).

DOMINIK, W. 1985. Stratigraphie und Sedimentologie (Geochemie, Schwermineralanalyse) der Oberkreide von Bahariya und ihre Korrelation zum Dakhla-Becken (Western Desert, Ägypten). – Berliner Geowissenschaftliche Abhandlungen A**62**: 1-173.

DOUVILLÉ, M.H. 1910. Études sur les rudistes. Rudistes de Sicile, d’Algérie, d’Egypte, du Liban et de la Perse. – Mémoires de la Société géologique de France (Paléontologie) **41**: 1-83.

DOUVILLÉ, M.H. 1913. Description des rudistes de l’Egypte. – Mémoires présentés a l’Institut Egyptien **6**: 237-256.

DOUVILLÉ, M.H. 1916. Les terrains secondaires dans le massif du Moghara, à l’est de l’isthme de Sues, d’après les explorations de COUYAT-BARTHOUX. – Mémoires de l’Académie des Sciences de l’Institut de France **55**: 1-184.

DOUVILLÉ, M.H. 1926. Description de quelques fossiles crétacés de l'Afghanistan. – Records of the Geological Survey of India **58**: 345-348.

DOUVILLÉ, M.H. 1928. Les Ammonites de la Craie supérieure en Égypte et au Sinai. – Mémoires de l'Académie des Sciences de l' Institut de France **60**: 1-41.

DRISCOLL, E.G. 1970. Selective bivalve destruction in marine environments, a field study. – Journal of sedimentary Petrology **40**: 898-905.

DUBOIS, P. & AMEYE, L. 2001. Regeneration of spines and pedicellariae in echinoderms. – Microscopy Research and Technique **55**: 427-437.

DUFF, K.L. 1975. Palaeoecology of a Bituminous Shale: The Lower Oxford Clay of central England. – Palaeontology **18**: 443-482.

DURHAM, J.W. & WAGNER, C.D. 1966. Glossary of morphological terms applied to echinoids. – In: MOORE, R.C. (ed.), Treatise on Invertebrate Paleontology, Part U, Echinodermata **3**(1): U251-256, Boulder (Geological Society of America) and Lawrence (Kansas University Press).

DURHAM, J. W., CASTER, K.E., EXLINE, H., FELL, H. B., FISCHIER, A. G., FRIZZELL, D.L., KESLING, R.V., KIER, P. M., MELVILLE, R. V., MOORE, R.C., PAWSON, D.L. REGNÉLL, G., SPENCER, W.K., UBACHS, G., WAGNER, C.D. & WRIGHT, C.W. 1966. Echinoids. – In: MOORE, R. C. (ed.), Treatise on Invertebrate Paleontology, Part U, Echinodermata **3**(1): U368-U695, (Boulder Geological Society of America) and Lawrence (Kansas University Press).

ECK, O. 1909. Bemerkungen über drei neue Ammoniten aus der oberen aegyptischen Kreide. – Sitzungsberichte der Gesellschaft der naturforschenden Freunde zu Berlin **3**: 179-191.

ECK, O. 1914. Die Cephalopoden der Schweinfurthschen Sammlung aus der Oberen Kreide Ägyptens. – Zeitschrift der Deutschen Geologischen Gesellschaft **66**: 179-216.

EL-AKKAD, S.E. & ISSAWI, B. 1963. Geology and phosphate deposits of Wasif-Safaga area. – Geological Survey of Egypt **1**: 21-42.

ELDER, W.P. 1990. *Tibiaporrhais*, a new Late Cretaceous genus of Aporrhaidae resembling *Tibia* Röding. – The Veliger **33**: 293-298.

EL-HEDENY, M.M. 2002. Cenomanian-Coniacian ammonites from the west-central Sinai, Egypt, and their significance in biostratigraphy. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **2002**: 397-425.

EL-HEDENY, M.M. 2006. *Pterotrigonia* (*Scabrotrigonia*) *scabra* (LAMAECK, 1819), a polymorphic bivalve from the Upper Cretaceous (Coniacian-Santonian) of Egypt. – Revue de Paléobiologie, Genéve **25**: 709-722.

EL-HEDENY, M.M. 2007. New taxonomic and biostratigraphic data on the ?Upper Cenomanian-Turonian Radiolitidae (Bivalvia: Hippuritoidea) of Abu Roash, Western Desert, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **244**: 79-98.

EL-HEDENY, M.M. & EL-SABBAGH, A.M. 2005. *Eoradiolites liratus* (Bivalvia, Radiolitidae) from the Upper Cenomanian Galala Formation at Saint Paul, Eastern Desert (Egypt). – Cretaceous Research **26**: 551-566.

EL-HEDENY, M.M. & EL-SABBAGH, A.M. 2007. Macro-borings on Late Cretaceous oysters of Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **244**: 273-286.

EL-HEDENY, M.M., ABDEL AAL, A.A., MAREE, M. & SEELING, J. 2001. Plicatulid bivalves from the Coniacian-Santonian Matulla Formation, Wadi Sudr, western Sinai, Egypt. – Cretaceous Research **22**: 295-308.

EL QOT, G.M. 2006. Late Cretaceous macrofossils from Sinai, Egypt. – Beringeria **36**: 3-163.

EL QOT, G.M. 2008. Upper Cenomanian-Lower Santonian ammonites from Galala Plateaux, north Eastern Desert, Egypt: A systematic paleontology. – Egyptian Journal of Paleontology **8**: 247-289.

EL QOT, G.M., FÜRSICH, F.T., ABDEL-GAWAD, G.I. & AYOUB-HANNAA, W.S. 2009. Taxonomy and palaeoecology of Cenomanian-Turonian (Upper Cretaceous) echinoids from eastern Sinai, Egypt. – Beringeria **40**: 55-98.

EL-SABBAGH, A.M. & EL-HEDENY, M.M. 2003. Upper Turonian Radiolitidae (Rudist bivalves) from the *Acteonella* Series, El-Hassana Dome, Abu Roash, Egypt. – Egyptian Journal of Paleontology **3**: 243-269.

EL-SHEIKH, H.A., ABDELHAMID, M.A. & EL QOT, G.M. 1998. Macrofossils and foraminiferal biostratigraphy and paleoecology of some Cenomanian-Santonian sequences in north and west central Sinai, Egypt. – Egyptian Journal of Geology **42**: 471-495.

FAWZI, M.A. 1963. La faune Cènomanienne d' Egypte. – Geological Survey of Egypt, Monograph **2**: 1-133.

FELIX, J. 1914. Anthozoa Cretacea. - Fossilium Catalogus, (1: Animalia) **5-7**: 273 pp.

FISCHER, P. 1884. Manuel de Conchyliologie et de Paléontologie Conchyliologique: 609-688, Paris.

FORBES, E. 1846. Report on the fossil Invertebrata from southern India, collected by Mr. KAYE & Mr. CUNLIFFE. – Transactions of the Geological Society of London (2)**7**: 97−174.

FOURTAU, R. 1898. Révision des echinides fossiles de l’Egypte. – Mémoires de l’ Institut Egyptien **3**: 612-633.

FOURTAU, R. 1901. Note sure les echinides fossiles de l’Egypte, 2. – Bulletin de l’ Institut Egyptien **4**: 131-147.

FOURTAU, R. 1904. Contribution à l’étude de la faune Crétacique d’Egypte. – Bulletin de l’ Institut Egyptien **4**: 231-249.

FOURTAU, R. 1906. Contribution à l’étude des echinides fossiles de la craie supérieure. – Bulletin de l’ Institut Egyptien **4**: 139-175.

FOURTAU, R. 1909. Description des echinides fossiles recueillis par W. F. HUME et J. BALL dans le désert Libyque et le nord du désert Arabique. – Mémoires de l’ Institut Egyptien **6**: 93-175.

FOURTAU, R. 1912. Notes sur les echinides fossiles de l’ Egypte. – Bulletin de l’ Institut Egyptien **5**: 137-176.

FOURTAU, R. 1914. Catalogue des invertébrés fossiles de l' Egypte. Terrains Crètacès, 1, Èchinodermes. – Geological Survey of Egypt, Palaeontological Series **2**: 1-109.

FOURTAU, R. 1917. Catalogue des Invertébrés fossiles de l'Egypte repésentés dans les collections du Musée de Géologie au Caire. Terrains Crétacés 2me Partie: Mollusques Lamellibranches. – Geological Survey of Egypt, Palaeontological Series **3**:1-108.

FOURTAU, R. 1921. Catalogue des invertébrés fossiles de l' Egypte. Terrains Crétacés, 3, Èchinoderms (Supplément). – Geological Survey of Egypt, Palaeontological Series **5**: 1-101.

FRAAS, O. 1878. Aus dem Orient II. Geologische Beobachtungen am Libanon: 1-136.

FRENEIX, S. 1960. Lamellibranches du Crétacé supérieur de France (Protobranches, Prionodontes, Dysodontes). – Congrès de la Société Savojarde Dijon 1959, Section des Sciences, Sous-Section de Géologie, Colloque sur la Crétacé Supérieur français: 174-284.

FRENEIX, S. 1972. Le bassin cotier de Tarfaya (Maroc méridional). – Notes et Mémoires du Service Géologique **228**: 1-255.

FRENEIX, S. 1982. Disparité microstructurale du test entre Gryphaeostrea et Gryostrea (huitres du Crétacé-Miocène). Nouvelle classification des genres. – Annales de Paléontologie **68**: 223-240.

FRENEIX, S. & LEFÉVRE, R. 1968. Deux espèces nouvelles de *Chondrodonta* et *Neithea* (Bivalves) du Sénonien du Taurus Lycien (Turquie). – Bulletin de la Société Géologique de France **7**(9): 762-776.

FREUND, R. & RAAB, M. 1969. Lower Turonian ammonites from Israel. – Special Papers in Palaeontology **4**: 1-79.

FÜRSICH, F.T. 1976. Fauna-substrate relationships in the Coralline of England and Normandy. - Lethaia **9**: 343-356.

FÜRSICH, F.T. 1977. Corallian (Upper Jurassic) marine benthic associations from England and Normandy. – Paleontology **20**: 337-385.

FÜRSICH, F.T. 1978. The influence of faunal condensation and mixing on the preservation of fossil benthic communities. – Lethaia **11**: 243-250.

FÜRSICH, F.T. 1980. Preserved life positions of some Jurassic bivalves. - Paläontologische Zeitschrift **54**: 289-300.

FÜRSICH, F.T. 1981. Salinity-controlled benthic associations from the Upper Jurassic of Portugal. – Lethaia **14**: 203-223.

FÜRSICH, F.T. 1982. Upper Jurassic bivalves from Milne Land, East Greenland. – Grønlands Geologiske Undersøgelske, Bulletin **144**: 1-126.

FÜRSICH, F.T. 1984. Palaeoecology of boreal invertebrate faunas from the Upper Jurassic of central eastern Greenland. – Palaeogeography, Palaeoclimatology, Palaeoecology **48**: 309-346.

FÜRSICH, F.T. 1994. Palaeoecology and evolution of Mesozoic salinity-controlled benthic macroinvertebrate associations. – Lethaia **26**: 327-346.

FÜRSICH, F.T. & ABERHAN, M. 1990. Significance of time-averaging for palaeocommunity analysis. – Lethaia **23**: 143-152.

FÜRSICH, F.T. & OSCHMANN, W. 1986a. Storm shell beds of *Nanogyra virgula* in the Upper Jurassic of France. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **172**: 141-161.

FÜRSICH, F.T. & OSCHMANN, W. 1986b. Autecology of the Upper Jurassic oyster *Nanogyra virgula* (DEFRANCE). – Paläontologische Zeitschrift **60**: 65-74.

FÜRSICH, F.T. & WERNER, W. 1984. Salinity zonation of benthic associations in the Upper Jurassic of the Lusitanian Basin (Portugal). – Geobios Mémoire Spécial **8**: 85-92.

FÜRSICH, F.T. & WERNER, W. 1986. Benthic associations and their environmental significance in the Lusitanian Basin (Upper Jurassic, Portugal). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **172**: 271-329.

FÜRSICH, F.T. & WERNER, W. 1991. Palaeoecology of coralline sponge-coral meadows from the Upper Jurassic of Portugal. – Paläontologische Zeitschrift **65**: 35-69.

FÜRSICH, F.T., BERNDT, R., SCHEUER, T. & GAHR, M. 2001. Comparative ecological analysis of Toarcian (Lower Jurassic) benthic fauns from southern France and east-central Spain. – Lethaia **43**: 169-199.

FÜRSICH, F.T., FREYTAG, S., RÖHL, J. & SCHMID, A. 1995. Palaeoecology of benthic associations in salinity-controlled marginal marine environments: examples from the Lower Bathonian (Jurassic) of the Causses (southern France). – Palaeogeography, Palaeoclimatology, Palaeoecology **113**: 135-172.

FÜRSICH, F.T., OSCHMANN, W., JAITLY, A.K. & BIR SINGH, I. 1991. Faunal response to transgressive-regressive cycles: example from the Jurassic of western India – Palaeogeography, Palaeoclimatology, Palaeoecology **85**: 149-159.

FÜRSICH, F.T., OSCHMANN, W., PANDEY, D.K., JAITLY, A.K., SINGH, I.B. & LIU, C. 2004. Palaeoecology of middle to lower Upper Jurassic macrofaunas of the Kachchh Basin, western India: an overview. – Journal of the Palaeontological Society of India **49**: 1-26.

FÜRSICH, F.T., SINGH, I.B., JOACHIMSKI, M., KRUMM, S., SCHLIRF, M. & SCHILRF, S. 2005. Palaeoclimate reconstructions of the Middle Jurassic of Kachchh (western India): an integrated approach based on palaeoecological, oxygen isotopic, and clay mineralogical data. – Palaeogeography, Palaeoclimatology, Palaeoecology **217**: 289-309.

GALAL, G. & NAFAE, S. 2003. Middle Cenomanian-Early Turonian foraminiferal zones at the Galala Plateaus, Eastern Desert, Egypt. – Egyptian Journal of Paleontology **3**: 91-108.

GALAL, G., EL-HEDENY, M. & NAFAE, S. 2001. Biostratigraphy of the Cenomanian-Turonian sequence of Wadi El-Tarfa, Eastern Desert, Egypt, based on foraminifers and ammonites. – 2nd International Conference of the Geology of Africa **1**: 557-588.

GALLO MARESCA, M. 1994. Aspetti tassonomici e biostratigrafici delle Radiolitidae albiane delle Murge e del Gargano (Puglia, Italia Meridionale). – Palaeopelagos **4**: 223-232.

GARFUNKEL, Z. 1970. The tectonics of the western margins of the southern Arava. A contribution to the understanding of rifting. – Unpublished Ph.D Thesis, Hebrew University, Jerusalem (in Hebrew, English abstract).

GAUTHIER, V. 1889. Descriptions des echinides fossiles receuillis en 1885 et 1886 dans la région sud des hauts plateaux de la Tunisie par M. PHILIPPE THOMAS. – In: Exploration Scientifique de la Tunisie: 1-116.

GEYS, J.F. 1989: Hemicidaroid echinoids from Upper Cretaceous deposits in Wadi Qena area (Eastern Desert, Egypt). – Bulletin de l’Institut Royal des Science Naturelles de Belgique **59**: 127-135.

GEYS, J.F. 1992: Regular echinoids, other than Hemicidaroida from Upper Cretaceous deposits in the Wadi Qena area (Eastern Desert, Egypt). – Bulletin de l’Institut Royal des Science Naturelles de Belgique **62**: 139-154.

GHORAB, M.A. 1961. Abnormal stratigraphic features in Ras Gharib oil Fields. – Third Arab Petroleum Congress, Alexandria, Egypt: 10pp.

GILI, E., SKELTON, P.W., VICENS, E. & OBRADOR, A. 1995. Corals to rudists - an environmentally induced assemblage sequence. – In: PHILIP, J. & SKELTON, P.W. (eds.), Palaeoenvironmental models for the benthic associations of Tethyan Cretaceous carbonate platforms. – Palaeogeography, Palaeoclimatology, Palaeoecology **119**: 127-136.

GILL, G.A. & CHIKHI, F. 1991. Remarks on new occurrences of *Aspidiscus*, a Cenomanian scleractinian coral, in the Persian Gulf and in Algeria. – Lethaia **24**: 349-350.

GILL, G.A. & LAFUSTE, J. 1987. Structure, répartition et signification paléogéographique d'*Aspidiscus*, hexacoralliaire cénomanien de la Téthys. – Bulletin de la Société géologique de France **3**: 921-934.

GOLDFUSS, A. 1833. Petrefacta Germaniae. Lamellibranchia **2**: 1-68 (Arnz & Co., Düsseldorf).

GRADSTEIN, F.M., OGG, J.G., SMITH, A.G., AGTERBERG, F.P., BLEEKER, W., COOPER, R.A., DAVYDOV, V., GIBBARD, P., HINNOV, L.A., HOUSE, M.R., LOURENS, L., LUTERBACHER, H.P., MCARTHUR, J., MELCHIN, M.J., ROBB, L.J., SHERGOLD, J., VILLENEUVE, M., WARDLAW, B.R., ALI, J., BRINKHUIS, H., HILGEN, F.J., HOOKER, J., HOWARTH, R.J., KNOLL, A.H., LASKAR, J., MONECHI, S., POWELL, J., PLUMB, K.A., RAFFI, I., ROHL, U., SANFILIPPOO, A., SCHMITZ, B., SHACKLETON, N.J., SHIELDS, G.A., STRAUSS, H., VAN DAM, J., VEIZER, J., VAN KOLFSCHOTENTH, & WILSON, D. 2004. - A Geological Time Scale 2004. - 384pp., Cambridge (Cambridge University Press).

GRATELOUP, A. DE. 1836. Mémoire de géo-zoologie sur les oursins fossiles (Échinides), qui se recontrent dans les terrains calcaires des environs des Dax (département des Landes). – Actes de la Société Linnéen de Bordeaux **8**: 1-89.

GRECO, B. 1916. Fauna cretacea dell'Egitto raccolta dal Figari Bey. Parte seconda. Gastropoda. – Palaeontographica Italica, Memorie di Palaeontologia **22**: 103-170.

GRECO, B. 1918. Fauna cretacea dell’Egitto raccolta dal Figari Bey Parte terza: Lamellibranchiata (cont. e fine). Fasc. 2 Lamellibranchi del Turoniano e del Cenomaniano. – Palaeontographica Italica, Memorie di Palaeontologia **24:** 1–58.

GREGORY, J.W. 1906. Fossil Echinoidea from Sinai and Egypt. – Geological Magazine **5**: 216-227.

GUIRAUD, R. 1998. Mesozoic rifting and basin inversion along the northern African Tethyan margin: an overview. – Petroleum Geology of North Africa, Geological Society of London, Special Publication **132**: 217-229.

GUIRAUD, R. & BOSWORTH, W. 1997. Senonian basin inversion and rejuvenation of rifting in Africa and Arabia: synthesis and implications to plate-scale tectonics. – Tectonophysics **282**: 39-82.

HAMLIN, C.E. 1884. Results of an examination of Syrian Molluscan fossils, chiefly from the Range of Mount Lebanon. – Memoirs of the Museum of Comparative Zoology **10**: 1-68.

HAMMER, Ø. & HARPER D.A.T. 2005. Paleontological Data Analysis. Malden (Massachusetts): Blackwell, 351pp.

HAMMER, Ø., HARPER, D.A.T. & RYAN, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. – Palaeontologia Electronica **4(1)** (URL: http://palaeo-electronica.org/2001_1/past/issue1_01.htm).

HANCOCK, J.M. 1991. Ammonite scales for the Cretaceous system. – Cretaceous Research **12**: 259-291.

HANCOCK, J.M. 1993. Sea-level changes around the Cenomanian-Turonian boundary. – Cretaceous Research **14**: 553-562.

HAQ, B.U., HARDENBOL, J. & VAIL, P.R. 1987. Chronology of fluctuating sea levels since the Triassic. – Science **235**: 1156-1167.

HARPER, E.M., PALMER, T.J. & HUDSON, J.D. 2002. The Middle Jurassic bivalve '*Cuspidaria*' *ibbetsoni*: A corbulid not a septibranch. – Palaeontology **45**: 759-769.

HATABA, H. & AMMAR, G. 1990. Comparative stratigraphic study on the Upper Cenomanian-Lower Senonian sediments between the Gulf of Suez and Western Desert, Egypt. – Proceedings 10th Petroleum Exploration and Production Conference: 1-16.

HEWAIDY, A.A., AZAB, M.M. & FAROUK, S. 2003. Ammonite biostratigraphy of the Upper Cretaceous succession in the area west of Wadi Araba, north Eastern Desert, Egypt. – Egyptian Journal of Paleontology **3**: 331-359.

HILDEBRAND, N., SHIRAV (SCHWARTZ), M. & FREUND, R. 1974. Structure of the western margin of the Gulf of Elat (Aqaba) in the Wadi El-Quseib, Wadi Haimur area, Sinai. – Israel Journal of Earth Sciences **23**: 117-130.

HOBBIE, J.E., HOLM-HANSEN, O., PACKARD, T.T., POMEROY, L.R., SHELDON, R.W., THOMAS, J.P. & WIEBE, W.J. 1972. A study of the distribution and activity of micro-organisms in ocean water. – Limnology and Oceanography **17**: 244-555.

HOMBRES-FIRMAS, L.A.D. 1838. Recueil de mémoires et d'observations de physique, de météorologie, d'agriculture et d'histoire naturelle. – Ballivet et Fabre, Nismes: 278pp.

HONG-FU, Y. & YOCHELSON, E.L. 1983. Middle Triassic gastropoda from Qingyan, Guizhou Province, China: 1-Pleurotomariacea and Murchisoniacea. – Journal of Paleontology **57**: 162-187.

HUDSON, J.D. & PALMER, T.J. 1976. A euryhaline oyster from the Middle Jurassic and the origin of the true oysters. – Palaeontology **19**: 79-93.

HUNTLEY, J.W. (in press). Exploratory multivariate techniques and their utility for understanding ancient ecosystems. – In: LAFLAMME, M., SCHIFFBAUER, J.D. & DORNBOS, S.Q. (eds.), Quantifying the early evolution of life: numerical and technological approaches to the study of fossils and ancient ecosystems. - Topics in Geology, Springer.

ISMAIL, A. 2000. Upper Cretaceous stratigraphy and micropaleontology of the western part of the Gulf of Aqaba, East Sinai, Egypt. – Middle East Research Center, Ain Shams University, Earth Science Series **14**: 239-261.

ISSAWI, B., OSMAN, R., FRANCIS, M., EL HINNAWI, M., BAGORI, Y., MAZHAR, A. & LABIB, S. 1998. Contributions to the geology of East Sinai. – Annals, Geological Survey of Egypt **22**: 55-88.

ISSAWI, B., EL HINNAWI, M., FRANCIS, M. & MAZHAR, A. 1999.The Phanerozoic geology of Egypt, a geodynamic approach. – The Egyptian Geological Survey, Special Publication **76**: 1-462.

JACKSON, J.B.C., BUDD, A.F. & PANDOLFI, J.M. 1996. The shifting balance of natural communities. – In: JABLONSKI, D., ERWIN, D.H. & LIPPS, J.H. (eds.), Evolutionary Biology: 89-122, Chicago (The University of Chicago Press).

JAGT, J.W.M. 2000. Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium-Part 6, Conclusions. – Scripta Geology **121**: 505-571.

KANAZAWA, K. 1992. Adaption of test shape for burrowing and locomotion in spatangoid echinoids. – Palaeontology **35**: 733-750.

KASSAB, A.S. 1991a. Statistical analysis of a Cretaceous oyster from Egypt. - Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **191**: 239-254.

KASSAB, A.S. 1991b. Cenomanian-Coniacian biostratigraphy of the northern Eastern Desert, Egypt, based on ammonites. – Newsletters on Stratigraphy **25**: 25-35.

KASSAB, A.S. 1994. Upper Cretaceous ammonites from the El-Sheikh Fadl-Ras Gharib Road, Northeastern Desert, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **1994**: 108-128.

KASSAB, A.S. 1996. Cenomanian-Turonian boundary in the Gulf of Suez region, Egypt: towards an interregional correlation, based on ammonites. – The Geological Society of Egypt, Special Publication **2**: 61-98.

KASSAB, A.S. & ISMAEL, M.M. 1994. Upper Cretaceous invertebrate fossils from the area northeast of Abu Zuneima, Sinai, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **191**: 221-249.

KASSAB, A.S. & OBAIDALLA, N. A. 2001. Integrated biostratigraphy and inter-regional correlation of the Cenomanian-Turonian deposits of Wadi Feiran, Sinai, Egypt. – Cretaceous Research **22**: 1-11.

KASSAB, A.S. & ZAKHERA, M.S. 2002. Upper Cretaceous oysters from the northern part of the Eastern Desert, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **224**: 1-30.

KAUFMANN, E.G. 1973. Cretaceous Bivalvia. – In: HALLAM, A. (ed.), Atlas of Paleobiogeography: 353-383, Amsterdam (Elsevier).

KENNEDY, W.J. & COBBAN, W.A. 1991. Stratigraphy and interregional correlation of the Cenomanian-Turonian transition in the Western Interior of the United States near Pueblo, Colorado, a potential boundary stratotype for the base of the Turonian stage. – Newsletters on Stratigraphy **24**: 1-33.

KENNEDY, W.J. & JUIGNET, P. 1981. Upper Cenomanian ammonites from the environs of Saumur, and the provenance of the types of *Ammonites vibrayeanus* and *Ammonites geslinianus*. – Cretaceous Research **2**: 19-49.

KENNEDY, W.J. & SIMMONS, M.D. 1991. Mid-Cretaceous ammonites and associated microfossils from the central Oman Mountains. – Newsletters on Stratigraphy **25**: 127-154.

KENNEDY, W.J. & WRIGHT, C.W. 1979a. On *Kamerunoceras* REYMENT, 1954 (Cretaceous: Ammonoidea). – Journal of Paleontology **53**: 1165-1178.

KENNEDY, W.J. & WRIGHT, C.W. 1979b. Vascoceratid ammonites from the type Turonian. – Palaeontology **22**: 665-683.

KENNEDY, W.J., COOPER, M.R. & WRIGHT, C.W. 1979. On Ammonites *galliennei* D'ORBIGNY, 1850. - Bulletin of the Geological Institutions of the University of Uppsala NS **8**: 5-15.

KENNEDY, W.J., WRIGHT, C.W. & HANCOCK, J.M. 1987. Basal Turonian ammonites from west Texas. – Palaeontology **30**: 27-74.

KHALIL, H. & MASHALY, S. 2004. Stratigraphy and stage boundaries of the Upper Cretaceous-Lower Paleogene succession in Gabal Musaba Salama area, southwestern Sinai, Egypt. – Egyptian Journal of Paleontology **4**: 1-38.

KIEL, S. & BANDEL, K. 2002. About some aporrhaid and strombid gastropods from the Late Cretaceous. – Paläontologische Zeitschrift **76**: 83-97.

KIEL, S. & BANDEL, K. 2004. The Cenomanian Gastropoda of the Kassenberg quarry in Mülheim (Germany, Late Cretaceous). – Paläontologische Zeitschrift **78**: 103-126.

KIEL, S. & PERRILLIAT, M.C. 2001. New gastropods from the Maastrichtian of the Mexcala Formation in Guerrero, southern Mexico, 1. Stromboidea. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **222**: 407-426.

KIER, P.M. 1962. Revision of the cassiduloid echinoids. – Smithsonian Miscellaneous collections **144**: 1-262.

KIER, P.M. 1974. Evolutionary trends and their functional significance in the post-Paleozoic echinoids. – Journal of Paleontology **48**: 1-95.

KLITZSCH, E., GRÖSCHKE, M. & HERRMANN-DEGEN, W. 1990. Wadi Qena: Paleozoic and Pre-Campanian Cretaceous Strata. – In: SAID, R. (ed.), The Geology of Egypt: 321-327, Rotterdam (Balkema).

KOLLMANN, H.A. 1965. Actaeonellen (Gastropoda) aus der ostalpinen Oberkreide. – Annalen des Naturhistorischen Museums **68**: 243-262.

KOLLMANN, H.A. 1985. Upper Cretaceous gastropods from excavations for the highways A10 (Charente, France). – Cretaceous Research **6**: 85-111.

KOLLMANN, H.A. 1987. Eine cenomane Gastropodenfauna aus Nea Nikopolis bei Kozani (Mazedonien, Griechenland). – Annalen des Naturhistorischen Museums **89**: 37-56.

KOLLMANN, H.A. & SOHL, N.F. 1979. Western hemisphere Cretaceous Itieriidae gastropods. – Geological Survey of United States, Professional Paper **1125** A: A1-A15.

KOLLMANN, H.A., DECKER, K. & LEMONE, D. 2003. Facies control of Lower Cretaceous gastropod assemblages, southwestern United States. – In: SCOTT, R. W. (ed.), Gulf

Coast Section, Society of Economic Palaeontologists and Mineralogists Foundation. - Special Publication in Geology **1**: 101-146.

KOMATSU, T., CHINZEI, K., ZAKHERA, M.S. & MATSUOKA, H. 2002. Jurassic softbottom oyster *Crassostrea* from Japan. – Palaeontology **45**: 1037-1048.

KORA, M. & HAMAMA, H. 1987. Biostratigraphy of the Cenomanian-Turonian succession of Gabal Gunna, Southeastern Sinai, Egypt. – Mansoura Science Bulletin **14**: 289-301.

KORA, M., SHAHIN, A. & SEMIET, A. 1993. Stratigraphy and macrofauna of the Cenomanian exposures in west central Sinai, Egypt. – Mansoura Science Bulletin **20**: 227-260.

KORA, M., KHALIL, H. & SOBHY, M. 2001. Cenomanian-Turonian macrofauna from the Gulf of Suez region: biostratigraphy and paleobiogeography. – Egyptian Journal of Geology **45**: 441-462.

KORA, M., HAMAMA, H. & SALLAM, H. 2002. Senonian macrofauna from west-central Sinai: biostratigraphy and paleobiogeography. – Egyptian Journal of Paleontology **2**: 235-258.

KOWALKE, V.T. & BANDEL, K. 1996. Systematik und Paläoökologie der nordalpinen Brandenberg-Gosau (Oberconiac/Untersanton) mit einem Vergleich zur Gastropodenfauna des Maastrichts des Trempbeckens (Südpyrenäen, Spanien). – Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie **36**: 15-17.

KRAUTTER, M. 1998. Ecology of siliceous sponges – Application to the environmental interpretation of the Upper Jurassic sponge facies (Oxfordian) from Spain. – Cuadernos de Geología Ibérica **24**: 223-239.

KREBS, C.J. 1989. Ecological methodology. – 654pp, New York, HARPER & ROW (1989).

KRENKEL, E. 1924. Der syrische Bogen. – Centralblatt für Mineralogie, Geologie und Paläontologie, Abhandlungen B**9**: 274-281; **10**: 301-313.

KROH, A. & NEBELSICK, J.H. 2003. Echinoid assemblages as a tool for palaeoenvironmental reconstruction – an example from the Early Miocene of Egypt. - Palaeogeography, Palaeoclimatology, Palaeoecology **201**: 157-177.

KUNOW, R., BAUER, J., BACHMANN, M. & KUSS, J. 1998. Verteilungsmuster benthischer Foraminiferen und Tonmineralassoziationen im Oberapt des Sinai. – Zentralblatt der Geologie und Paläontologie, Teil **I**: 353-371.

KUSS, J. 1987. Interpretation of Upper Cretaceous and Lower Tertiary facies patterns from limestone-dominated sequences of Northeastern Egypt. – In: MATHEIS, G. & SCHANDELMEIER, H. (eds.), Current Research in African Earth Sciences: 195-198, Rotterdam (Balkema).

KUSS, J. 1989. Facies and paleogeographic importance of the pre-rift limestones from NE-Egypt/Sinai. – Geologische Rundschau **78**: 487-498.

KUSS, J. & BACHMANN, M. 1996. Cretaceous paleogeography of Sinai Peninsula and neighboring areas. – Comptes Rendus de l'Academie des Sciences de Paris **322**: 915-933.

KUSS, J. & SCHLAGINTWEIT, F. 1989. Facies and stratigraphy of Early to Middle Cretaceous (Late Aptian-Early Cenomanian) strata from the northern rim of the African Craton (Gebel Maghara-Siani, Egypt). – Facies **19**: 77-96.

LAMARCK, J.B.P. 1801. Système des animaux sans vertèbres. – 432pp., Paris (Deterville).

LAMARCK, J.B.P. 1806. Sur les fossils des environs de Paris. – Annales du Musée d'Histoire Naturelle: 156-166.

LAMARCK, J.B.P. 1818-1819. Histoire Naturelle des animaux sans Vertèbres, présentant les caractères généraux et particuliers de ces animaux. – Les Conchifères **5**: 411-612 (1818), **6**: 1-228 (1819), Paris (Deterville).

LAMBERS, P. & BOEKSCHOTEN. J. 1986. On fossil and recent borings produced by acrothoracic cirripeds. – Geologie en Mijnbouw **65**: 257-268.

LAMBERT, J. 1919-1922. Echinides fossiles des environs de Santander. – Annals de la Société linnéenne Lyon **66**: 1-61.

LAMBERT, J. 1931-1932. Etude sur les echinides fossiles du nord de l'Afrique. – Mémoires de la Société Géologique de France **16**: 1-228.

LAMBERT, J. 1933. Echinides fossiles du Maroc. – Notes et Mémoires de Service Géologique du Maroc **27**: 1-79.

LAMBERT, J. & THIÈRY, P.P. 1909-1925. Essai de nomenclature raisonée des échinides. – Libraire Septime Ferriere, Chaumont: 1-607.

LARTET, L. 1873. Essai sur la Géologie de la Palestine et des contrées avoisinantes telles que l'Egypte et l'Arabie. Deuxième Partie. Paléontologie. – Annales de Science de Géologie (Pelecypods): 49-71.

LARTET, L. 1880. Exploration géologique de la Mer Morte de la Palestine et de l'Idumée, II. – Paléontologie: 112-159.

LEVINTON, J.S. 1970. The paleoecological significance of opportunistic species. – Lethaia **3**: 69-78.

LEWY, Z., 1975. The geological history of southern Israel and Sinai during the Coniacian. – Israel Journal of Earth Science **24**: 37-43.

LEWY, Z., 1989. Correlation of lithostratigraphic units in the upper Judea Group (Late Cenomanian-Late Coniacian) in Israel. – Israel Journal of Earth Sciences **38**: 19-43.

LEWY, Z., 1996. The approximate position of the Middle-Upper Cenomanian substage boundary in Israel. – Israel Journal of Earth Sciences **45**: 193-199.

LEWY, Z., KENNEDY, W.J. & CHANCELLOR, G. 1984. Co-occurrence of *Metoicoceras geslinianum* (D'ORBIGNY) and *Vascoceras cauvini* CHUDEAU (Cretaceous Ammonoidea) in the southern Negev (Israel) and its stratigraphic implications. – Newsletters on Stratigraphy **13**: 67-76.

LLUECA, G. 1932. Noticia sobre el hallazgo del *Aspidiscus cristatus* LAMARCK en el Cenomaniense de España. – Boletin del Instituto geológico y minero de España **52**: 347-348.

LUGER, P. & GRÖSCHKE, M. 1989. Late Cretaceous ammonites from the Wadi Qena area in the Egyptian Eastern Desert. – Palaeontology **32**: 355-407.

LUTZ, R.A. & RHOADS, D.C. 1977. Anaerobiosis and a theory of growth line formation. – Science **198**: 1222-1227.

LYNCH, W.F. 1852. Official report of the United States expedition to explore the Dead Sea and the River Jordan: 235 pp., Baltimore (J. Murphy).

LÜNING, S., KUSS, J., BACHMANN, M., MARZOUK, A.M. & MORSI, A.M.1998a. Sedimentary response to basin inversion: Mid Cretaceous-Early Tertiary pre-to syndeformational deposition at the Areif El- Naqa anticline (Sinai, Egypt). – Facies **38**: 103-136.

LÜNING, S., MARZOUK, A.M., MORSI, A.M. & KUSS, J. 1998b. Sequence stratigraphy of the Upper Cretaceous of central-east Sinai, Egypt. – Cretaceous Research **19**: 153-195.

MACARTHUR, R.H. 1972. Geographical ecology. Patterns in the distribution of species: 269pp.

MACARTHUR, R.H. & WILSON, E.O. 1967. The theory of Island Biogeography. – Princeton: 203pp., Princeton (University Press, Princeton).

MACHALSKI, M. 1998. Oyster life positions and shell beds from the Upper Jurassic of Poland. – Acta Palaeontologica Polonica **43**: 609-634.

MAHMOUD, I.G.E. 1955. Etudes paléontologiques sur la fauna Cretacique du Massif du Moghara (Sinaï-Egypte). – Publications de L'Institut du Desert D'Egypte: 192pp., Egypte.

MALCHUS, N. 1990. Revision der Kreide-Austern (Bivalvia-Pteriomorpha) Ägyptens (Biostratigraphie, Systematik). – Berliner geowissenschaftliche Abhandlungen A**125**: 1-231.

MASSE, J.P. 1992. Les rudistes de l'Aptien inférieur d'Italie continentale: aspects systématiques, stratigraphiques et paléobiogéographiques. – Geologica Romana **28**: 243-260.

MASSE, J.P., MARESCA, M.G. & SINNI, E.L. 1998. Albian rudist faunas from southern Italy: taxonomic, biostratigraphic and palaeobiogeographic aspects. – Geobios **31**: 47-59.

MAXIA, C. 1941. Molluschi Maestrichtiani della Tripolitania (Generi *Cryptorhytis, Bernaya, Eocypraea, Solarium, Natica, Nerita, Dentalium*). – Bolletino della Societá Geologica Italiana **60**: 176-191.

MCDOWELL, S.B. & BOGERT, C. M. 1954. The systematic position of *Lanthanotus* and the affinities of the anguinomorphan lizards. – Bulletin of the American Museum of Natural History **105**:1–142.

MCRAE, S. G. 1972. Glauconites. - Earth Science Review **8**: 397-440.

MEISTER, C. & ABDALLAH, H. 1996. Les ammonites du Cénomanien supérieur et du Turonien inférieur de la région de Gafsa-Chotts, Tunisie du centre-sud. - Geobios **29**: 3-49.

MEISTER, C. & ABDALLAH, H. 2005. Précision sur les successions du Cénomanien-Turonien dans la région de Gafsa, Tunisie du centre-sud. – Revue de Paléobiologie **24**: 111-199.

MEISTER, C. & RHALMI, M. 2002. Quelques ammonites du Cénomanien-Turonien de la région d'Errachidia-Boudnid-Erfoud (partie méridionale du Haut Atlas Central, Maroc). – Revue de Paléobiologie **21**: 759-779.

MEISTER, C., ALZOUMA, K., LANG, J. & MATHEY, B. 1992. Les ammonites du Niger (Afrique occidentale) et la transgression transsaharienne au cours du Cénomanien-Turonien. – Geobios **25**: 55-100.

MEKAWY, M.S. 2007a. Gastropods of the Cenomanian-Santonian sequence from north Eastern Desert, Egypt. – Egyptian Journal of Geology **51**: 149-176.

MEKAWY, M.S. 2007b. Upper Cretaceous bivalves from Galala Plateaux, north Eastern Desert, Egypt: A systematic paleontology. - Egyptian Journal of Paleontology **7**: 197-243.

MEKAWY, M.S. & ABU-ZIED, H. 2008. Lower Cretaceous Molluscan fauna from North Sinai, Maghara area, Egypt. – Egyptian Journal of Paleontology **8**: 291-334.

MENGE, B.A. & SUTHERLAND, J.P. 1976. Species diversity gradients synthesis of the roles of predation, competition, and temporal heterogeneity. – American Naturalist **110:** 351-369.

MOUSTAFA, A.R. & KHALIL, M.H. 1990. Structural characteristics and tectonic evolution of north Sinai fold belts. – In: SAID, R. (ed.), The Geology of Egypt: 381-389, Rotterdam (Balkema).

MOUSTAFA, A.R., KHALIL, M.H., 1994. Rejuvenation of the eastern Mediterranean passive continental margin in northern and central Sinai: New data from the Themed fault. – Geological Magazine **131**: 435-448.

MORRISON, J.O. & BRAND, U. 1986. Geochemistry of Recent marine invertebrates. – Geoscience Canada **13**: 237-254.

MORYCOWA, E. & RONIEWICZ, E. 1995. Microstructural disparity between Recent fungiine and Mesozoic microsolenine scleractinians. – Acta Palaeontologica Polonica **40**: 361-385.

NEEV, D. 1975. Tectonic evolution of the Middle East and Levantine Basin (easternmost Mediterranean). – Geology **3**: 683-686.

NEJBERT, D.O. 2007. Late Cretaceous (Turonain-Coniacian) irregular echinoids of western Kazakhstan (Mangyshlak) and southern Poland (Opole). – Acta Geologica Polonica **57**: 1-87.

NEYMAN, A.A. 1967. Limits to the application of the trophic group concept in benthic studies. – Oceanology **7**: 149-155.

NOETKING, F. 1897. Fauna of Baluchistan: The fauna of the Upper Cretaceous (Maastrichtian) beds of the Mari. – Palaeontologica Indica, series 16, **1**, part 3: 1-79.

NÉRAUDEAU, D. 1995. Diversité des échinides fossiles et reconstitutions paléoenvironnementales. – Geobios, Mémoire Spécial **18**: 337-345.

NÉRAUDEAU, D. & COURVILLE, P. 1997. Cenomanian and Turonian echinoids from Nigeria. – Géobios **30**: 835-847.

NÉRAUDEAU, D. & MOREAU, P. 1989. Paléoécologie et paléobiogéographie des faunes d'échinides du Cénomanien nord-aquitain (Charente-Maritime, France). – Géobios **22**: 293-324.

NÉRAUDEAU, D., BUSSON, G. & CORNEE, A. 1993. Les échinides du Cénomanian supérieur et du Turonien inférieur du Tinrhert oriental central (Sahara algérien). – Annales de Paléontologie **79**: 273-313.

NÉRAUDEAU, D., DAVID, B. & AL MUALLEM, M.S. 1995. Cretaceous echinoids from Saudi Arabia. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **197**: 399-424.

NÉRAUDEAU, D., DAVID, B. & MADON, C. 1998. Tuberculation in spatangoid fascioles: delineating plausible homologies. – Lethaia **31**: 323-334.

NÜTZEL, A. 1998. Über die Stammesgeschichte der Ptenoglossa (Gastropoda). – Berliner Geowissenschaftliche Abhandlungen **26**: 1-229.

ORABI, O.H. 1993. Biostratigraphy and paleoecology of some Cenomanian-Early Turonian exposures of Wadi Watir and Wadi Taba, southeastern Sinai, Egypt. – Egyptian Journal of Geology **37**: 231-246.

ORBIGNY, A. DE. 1840-1842. Paléontologie française. Terrains Crétacés. **1**. Céphalopodes: 662pp., Paris (1840).

ORBIGNY, A. DE. 1842-1843. Paléontologie francaise. Description des mollusques et rayonnés fossiles. – Terrains Crétacés. **2**. Gastropodes: 5-456, Paris (1842).

ORBIGNY, A. DE. 1843-1847. Paléontologie francaise. Description des mollusques et rayonnés fossils de France. – Terrains Crétacés. **3**. Lamellibranches: 807pp., Paris (1843), Paris (1843).

ORBIGNY, A. DE. 1850. Prodrome de Paléontologie stratigraphique universelle des animaux Mollusques et rayonnés **2**. – 427pp., Paris (Masson).

OSCHMANN, W. 1988. Upper Kimmeridgian and Portlandian marine macrobenthic associations from southern England and northern France. – Facies **18**: 49-84.

OSMAN, R.A. 1999. Stratigraphy and facies of the Upper Cretaceous sequence in East Sinai, Egypt. – Annals, Geological Survey of Egypt **5**: 65-78.

PANDEY, D.K., FÜRSICH, F.T. & HEINZE, M. 1996. Contributions to the Jurassic of Kachchh, Western India. **V**. The bivalve fauna. Part II. Subclass Anomalodesmata. – Beringeria **18**: 51-87.

PARKINSON, J. 1819. Remarks on the fossils collected by Mr. PHILLIPS near Dover and Folkestone. – Transactions of the Geological Society of London **1**: 52-59.

PARNES, A. 1987. Radiation of species of the genus *Radiolites* from the Upper Turonian at Gebel Er-Risha (NE Sinai, Egypt). – Israel Journal of Earth Sciences **36**: 133-153.

PARONA, C.F. 1909. *Radiolites liratus* (CONRARD) e *Apricardia Nötlingi* (BLANCKENHORN) nel Cretaceo superiore della Siria. – Atti Della Reale Accademia delle Scienze di Torino **44**: 491-495.

PARONA, C.F. 1912. Fossili neocretacei della Conca Anticolana. – Bollettino del Regio Comitato geologico d'Italia **43**: 1-17.

PERRILLIAT, M.C., AHMAD, F. & VEGA, F.J. 2006. Upper Cretaceous (Cenomanian-Turonian) bivalves from northern Jordan, Middle East. – Revista Mexicana de Ciencias Geológicas **23**: 96-106.

PERRON, F.E. 1978. Seasonal burrowing behavior and ecology of *Aporrhais occidentalis* (Gastropoda: Strombacea). – Biological Bulletin **154**: 463-471.

PERVINQUIÈRE, L. 1907. Ètudes de paléontologie tunisienne. I. Céphalopodes des terrains secondaires. – Carte Géologique de la Tunisie: 438pp., Paris.

PERVINQUIÈRE, L. 1912. Études de paléontologie tunisienne II. Gastropodes et Lamellibranches des Terrains Crétacés. Carte géologique de la Tunisie: 352pp., Paris.

PETITOT, M.L. 1961. Contribution à l'étude des échinides fossiles du Maroc (Jurassique et Crétacé). – Notes et Mémoires du Service géologique du Maroc **146**: 1-183.

PÉRON, A. 1877. Observations sur la faune des Calcaires à Echinides de Rennes-les-Bains et sur quelques fossiles du terrain crétacé supérieur. - Bulletin de la Société Géologique de France **3**(5): 499-535.

PÉRON, A. 1889-91. Déscription des mollusques fossiles des terrains crétacés de la région sud des Hauts-Plateaux de la Tunisie recueillis en 1885 et 1886 par THOMAS, M. P. – In: Exploration Scientifique de la Tunisie: 405pp., Paris.

PHILIP, J., FLOQUET, M. et al. (11 co-authors). 2000. Late Cenomanian. - In: DERCOURT, J., GAETANI, M. et al. (eds.), Atlas Peri-Tethys, Palaeogeographical Maps. – map 14, Paris.

PICTET, F.J. & ROUX, W. 1847-1853. Déscription des mollusques fossils qui se trouvent dans le Grés Verts des environs de Genéve. – 558pp., Genève.

PICTET, F.J. & CAMPICHE, G. 1861-1864. Déscription des fossils du terrain crétacé des environs de Saint-CROIX (2 partie): Gastéropodes. – Materiaux pour la Paléontologie, Suisse **3**: 1-752.

PLENIČAR, M. 1973. Radiolites from the Cretaceous beds of Slovenia. Part 1. – Geologija **16**: 187-226.

POLŠAK, A. 1967. Macrofaune crétacée de l'Istrie méridionale (Yougoslavie). – Palaeontologia Jugoslavica **8**: 1-219.

PONS, J.M. & SIRNA, G. 1992. Upper Cretaceous rudists distribution in the Mediterranean Tethys: Comparison between platforms from Spain and south central Italy. – Geologica Romana **28**: 341-349.

PONS, J.M. & VICENS, E. 2008. The structure of the outer shell layer in radiolitid rudists, a morphoconstructional approach. – Lethaia **41**: 219-234.

PONS, J.M., VICENS, E., CHIKHI-AOUIMEUR, F. & ABDALLAH, H. 2010. Albian *Eoradiolites* (Bivalvia: Radiolitidae) from Jabal Naïmia, Gafsa region, Tunisia, with revisional studies on the Albian forms of the genus. – Journal of Palaeontology **84**: 321-331.

POPENOE, W.P. 1937. Upper Cretaceous Mollusca from southern California. – Journal of Paleontology **11**: 379-402.

PRATURLON, A. & SIRNA, G. 1976. Ulteriori dati sul margine cenomaniano della piattaforma carbonatica laziale-abruzzese. – Geologica Romana **15**: 83-111.

PULTENEY, R. 1813. Catalogues of the birds, shells and some of the more rare plants of Dorsetshire from the new enlarged edition of Mr. HUTCHIN's history of that county: 108pp., London.

QUAAS, A. 1902. Beitrag zur Kenntniss der Fauna der obersten Kreidebildungen in der libyschen Wüste (Overwegischichten und Blätterthon). – Palaeontographica **30**: 153-336.

RADWAŃSKA, U. 2005. Callovian and Oxfordian echinoids of Zalas. – Volumina Jurassica **3**: 63-74.

RENZ, C. 1930. Neue mittelkretazische Fossilvorkommen in Griechenland. – Mémoires de la Société paléontologique Suisse (=Abhandlungen der Schweizerischen Paläontologischen Gesellschaft) **49**(5): 1-10.

RENZ, O. 1982. The Cretaceous ammonites of Venezuela. – In: MARAVEN, B. (ed.), Petroleos de Venezeula S.A.: 132 pp., Basel (Birkhäuser).

REUSS, A.E. 1845-1846. Die Versteinerungen der Böhmischen Kreideformation. – 1845: **1**: 1-58; 1846: **2**: 1-148, Stuttgart.

REYMENT, R.A. 1954. New Turonian (Cretaceous) ammonite genera from Nigeria. – Colonial Geology and Mineral Resources, London **4**: 149-164.

REYMENT, R.A. 1955. The Cretaceous Ammonoidea of southern Nigeria and the southern Cameroons. – Bulletin of the Geological Survey of Nigeria **25**: 1-112.

RHOADS, C. & LUTZ, R. 1980. Skeletal records of environmental change. - In: RHOADS, C. & LUTZ, R. (eds.), Skeletal growth of aquatic organisms, biological records of environmental change. – 750pp., New York (Plenum Publishing Corporation).

ROBASZYNSKI, F. & CARON, M. 1979. Atlas de foraminifères planctoniques du Crétacé moyen (mer boréale et Téthys). – Cahiers de Micopaléontologie **1**: 1-185.

ROBASZYNSKI, F., CARON, M., DUPUIS, C., AMÉDRO, F., GONZALEZ DONOSO, J-M., LINARES, D., HARDENBOL, J., GARTNER, S., CALANDRA, F. & DELOFFRE, R. 1990. A tentative integrated stratigraphy in the Turonian of Central Tunisia: formations, zones and sequential stratigraphy in the Kalaat Senan area. - Bulletin des Centres de Recherches, Exploration-Production Elf-Aquitaine **14**: 213-284.

ROEMER, F. A. (1839). Die Versteinerungen des Norddeutschen Oolithen-Gebirges – Ein Nachtrag: 1-59.

ROEMER, F. A., 1852. Die Kreidebildungen von Texas und ihre organischen Einschlüsse. – 100pp., Bonn (A. Marcus).

ROSENTHAL, E., WEINBERGER, G., ALMOGI-LABIN, A. & FLEXER, A. 2000. Late Cretaceous-Early Tertiary development of depositional basins in Samaria as a reflection of eastern Mediterranean tectonic evolution. – American Association of Petroleum Geologists Bulletin **84**: 997-1014.

ROSS, D.J. & SKELTON, P.W. 1993. Rudist formations of the Cretaceous: a palaeoecological, sedimentological and stratigraphical review. – In: WRIGHT, V.P. (ed.), - Sedimentology Review. – 73-91, Oxford (Blackwell Scientific Publications).

RÖHL, H., RÖHL, A. S. & OSCHMANN, W. 2001. The Posidonia Shale (Lower Toarcian) of SW-Germany: an oxygen-depleted ecosystem controlled by sea level and palaeoclimate. – Palaeogeography, Palaeoclimatology, Palaeoecology **165**: 27-52.

RUBERTI, D. 1997. Facies analysis of an Upper Cretaceous high-energy rudist-dominated carbonate ramp (Matese Mountains, central-southern Italy): subtidal and peritidal cycles. – Palaeogeography, Palaeoclimatology, Palaeoecology **113**: 81-110.

RUTSCH, R.F. & SALVADOR, A. 1954. Mollusks from the Cogollo and La Luna formations (Cretaceous) of the Chejendé area, western Venezuela. – Journal of Paleontology **28**: 417-426.

SADOONI, F.N. 2005. The nature and origin of Upper Cretaceous basin-margin rudist buildups of the Mesopotamian Basin, southern Iraq, with consideration of possible hydrocarbon stratigraphic entrapment. – Cretaceous Research **26**: 213-224.

SAID, R., 1962. The Geology of Egypt. – 337pp., Amsterdam-New York (Elsevier).

SAID, R. 1971. Explanatory notes to accompany the geological map of Egypt. – Geological Survey of Egypt **56**: 1-123.

SAID, R. 1990. The Geology of Egypt. –734pp., Rotterdam (Schlische).

SAID, R. & BARAKAT, M. G. 1957. Cenomanian foraminifera from Gebel Asagil, northern Sinai, Egypt. – Egyptian Journal of Geology **1**: 65-83.

SANDERS, H.L. 1968. Marine benthic diversity: a comparative study. – American Naturalist **102**: 243-282.

SANDERS, H.L. 1969. Benthic marine diversity and time-stability hypothesis. In: Diversity and stability in ecological system. – Brookhaven Symposia on Biology **22**: 71-81.

SAUL, L.R. 1998. Eight aporrhaid gastropod species from the Cretaceous of the Pacific slope of North America and classification of the type species of *Perissoptera*. – The Nautilus **111**: 119-142.

SAUL, L.R. & SQUIRES, R.L. 2002. Added nerineoid gastropod evidence for a warm Turonian sea in southern California. – Journal of Paleontology **76**: 386-390.

SAUCÉDE, T., MOOI, R. & DAVID, B. 2003. Combining embryology and paleontology: origins of the anterio-posterior axis in echinoids. – Comptes Rendus Palevol **2**: 399-412.

SAUCÉDE, T., MOOI, R. & DAVID, B. 2007. Phylogeny and origin of Jurassic irregular echinoids (Echinodermata: Echinoidea). – Geological Magazine **144**: 333-359.

SÁNCHEZ, B.E.B & TINAJERO, Y.L. 1995. Mollusk gastropods in a Lower Cretaceous rudist-bearing Formation of Jalisco, west central Mexico. – Revista Mexicana de Ciencias Geológicas **12**: 157-168.

SCHAFHAUSER, A., GÖTZ, S., BARON-SZABO, R. & STINNESBECK, W., 2003. Depositional environment of coral-rudist associations in the Upper Cretaceous Cardenas Formation (Central Mexico). – Geologia Croatica **56**: 187-198.

SCHOLZ, A., SCHWEIGERT, G. & DIETL, G. 2008. Bivalves from the Nusplingen lithographic limestone (Upper Jurassic, Southern Germany). – Palaeodiversity **1**: 111-131.

SCHUBERT, R.F. 1903. Über einige Bivalven des istrodalmatinischen Rudistenkalkes. I. *Vola lapparenti* CHOFF. und *Chondrodonta joannaemunsoni*. – Jahrbuch der kaiserlich königlichen Geologischen Reichsanstalt **52**: 265-276.

SCOTT, R.W. 2002. Albian caprinid rudists from Texas re-evaluated. – Journal of Paleontology **76**: 408-423.

SEELING, J. & BENGTSON, P. 1999. Cenomanian oysters from the Sergipe Basin, Brazil. – Cretaceous Research **20**: 747-765.

SEELING, J. & BENGTSON, P. 2003. The bivalve *Pinna cretacea* (SCHLOTHEIM, 1813) from the Cretaceous of Brazil. – Acta Palaeontologica Polonica **48**: 475–480.

SEGUENZA, G. 1882. Studi geologici e paleontologici sul Cretaceo medio dell'Italia meridionale. – Atti della Accademia Nazionale dei Lincei (serie **3**): 65-214.

SEILACHER, A. 1982. Adaptational strategies of bivalves living as infaunal secondary soft bottom dwellers: **1**. Introduction. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **164**: 229-230.

SEILACHER, A. 1984. Constructional morphology of bivalves: Evolutionary pathways in primary versus secondary soft-bottom dwellers. – Palaeontology **27**: 207-237.

SHAHAR, J. 1994. The Syrian Arc system: an overview. – Palaeogeography, Paleoclimatology, Paleoecology **112**: 125-142.

SHANNON, C.E. & WEAVER, W. 1949. The mathematical theory of communication. – Urbana, IL., (University of Illinois Press).

SHARPE, D. 1849. On *Tylostoma*, a proposed genus of gasteropodous mollusks. – Quarterly Journal of the Geological Society **5**: 376-380.

SHARPE, D. 1850. On the secondary district of Portugal which lies on the north of the Tagus. – Quarterly Journal of the Geological Society **6**: 135-195.

SHATA, A.A. 1956. Structural development of the Sinai Peninsula, Egypt. – Bulletin de l'Institut du Désert d'Égypte **6**: 117-157.

SHATA, A.A. 1960. The geology and geomorphology of El Qusaima area (northern Sinai, Egypt). – Bulletin of the Society of Geography **33**: 95-145.

SHIKAMA, T., YUI, S. 1973. On some nerineid gastropoda in Japan (preliminary report). - Science Reports, University of Yokohama, Section **2** (20): 9–55.

SIRNA, G. 1995. The nerineids: taxonomy, stratigraphy and palaeoecology with particular references to Italian examples. – Geologica Romana **31**: 285-305.

SIRNA, G. & MASTROIANNI, F. 1993. Jurassic-Cretaceous nerineids of Campoli Appennino (Latium). – Geologica Romana **29**: 139-153.

SKELTON, P.W. 1974. Aragonitic shell structures in the rudist *Biradiolites* and some palaeobiological inferences. – Géologie Méditerranéenne **1**: 63-74.

SKELTON, P.W. & GILI, E. 1991. Palaeoecological classification of rudist morphotypes. – Proceedings of the 1st International Conference of Rudists, Belgrad 1988, Serbian Geological Society, Special Publication: 265-287.

SLIŠKOVIC, T. 1966. Zwei neue Arten der Gattung *Ichthyosarcolites* aus der Oberkreide (Ablagerungen der Südherzegowina). – Conseil des Académies des Sciences et des Arts de la RSF de Yougoslavie, Bulletin scientifique A**12**: 177-178.

SLOBODKIN, L.B & SANDERS, H.L. 1969. On the contribution of environmental predictability to species diversity. In: Diversity and stability in ecological system. – Brookhaven Symposia on Biology **22**: 82-95.

SMITH, A.B. 1981. Implications of lantern morphology for the phylogeny of post-Palaeozoic echinoids. – Palaeontology **24**: 779-801.

SMITH, A.B. 1984. Echinoid palaeobiology. - 190 pp., London (George Allen and Unwin).

SMITH, A.B. 1995. Late Campanian-Maastrichtian echinoids from the United Arab Emirates-Oman border region. – Bulletin of Natural History Museum **51**: 121-240.

SMITH, A.B. & BENGSTON, P. 1991. Cretaceous echinoids from north-eastern Brazil. – Fossils and Strata **31**: 1-88.

SMITH, A.B. & PAUL, C.R.C. 1985. Variation in the irregular echinoid *Discoides* during the Early Cenomanian. – In: COPE, J.C.W. & SKELTON, P.W. (eds.), Evolutionary case histories from the fossil record. - Palaeontology, Special Papers **33**: 29-37.

SMITH, A.B. & WRIGHT, C.W. 1989. British Cretaceous echinoids. Part 1, General introduction and Cidaroida. – Palaeontographical Society Monographs **141**: 1-101, i-vi.

SMITH, A.B. & WRIGHT, C.W. 1990. British Cretaceous echinoids. Part 2, Echinothurioida, Diadematoida and Stirodonta (1, Calycina). – Palaeontographical Society Monographs **143**: 101-198, i-iv.

SMITH, A.B. & WRIGHT, C.W. 1993. British Cretaceous echinoids. Part 3, Stirodonta 2 (Hemicidaroida, Arbacioida and Phymosomatoida, Part 1). – Palaeontographical Society Monographs **147**: 199-267, i-ii.

SMITH, A.B. & WRIGHT, C.W. 1996. British Cretaceous echinoids. Part 4, Stirodonta 3 (Phymosomatoidae, Pseudodiadematidae) and Camarodonta. – Palaeontographical Society Monographs **150**: 268-341.

SMITH, A.B. & WRIGHT, C.W. 1999. British Cretaceous echinoids. Part 5, Holectypoida, Echinoneoida. – Palaeontographical Society Monographs **153**: 343-390.

SMITH, A.B. & WRIGHT, C.W. 2000. British Cretaceous echinoids. Part 6, Neognathostomata (Cassiduloids). – Palaeontographical Society Monographs, London **154**: 391-439, i-ii.

SMITH, A.B., PAUL, C.R. C., GALE, A.S. & DONOVAN, S.K. 1988. Cenomanian and Lower Turonian echinoderms from Wilmington, south-east Devon, England. – Bulletin of the British Museum (Natural History) **42**: 1-245.

SMITH, A.B., SIMMONS, M.D. & RACEY, A. 1990. Cenomanian echinoids, larger foraminifera and calcareous algae from the Natih Formation, central Oman Mountains. – Cretaceous Research **11**: 29-69.

SMITH, A.B., MORRIS, N.J., GALE, A.S. & ROSEN, B.R. 1995. Late Cretaceous (Maastrichtian) echinoid-mollusc-coral assemblages and palaeoenvironments from a Tethyan carbonate platform succession, northern Oman Mountains. – Palaeogeography, Palaeoclimatology, Palaeoecology **119**: 155-168.

SOHL, N.D. 1964. Neogastropoda, Opisthobranchia and Basommatophora from the Ripley, Owl Creek, and Prairie Bluff formations. – Geological Survey Professional Paper **331**: 1-344.

SOHL, N.D. 1987. Cretaceous gastropods: contrasts between Tethys and temperate provinces. – Journal of Paleontology **61**: 1085-1111.

SOLGER, F. 1903. Über die Jugendentwicklung von *Sphenodiscus lenticularis* OWEN und seine Beziehungen zur Gruppe der Tissotien. – Zeitschrift der Deutschen Geologischen Gesellschat **55**: 69-84.

SOWERBY, J. 1835. In: SEDGWICK, A. & MURCHISON, R. A sketch of the structure of the Eastern Alps; with sections through the newer formations on the northern flanks of the chain, and through the Tertiary deposits of Styria. – Transactions of the Geological Society of London **2**: 301-420.

SOWERBY, J. & SOWERBY, J. DE C. 1812-1846. The mineral Conchology of Great Britain or coloured figures and descriptions of those remains of testaceous animals or shells which have been preserved at various times and depths in the earth, 7 vols.; 803pp., pls. 1-383 by J. SOWERBY (1812-1822); 558pp., pls. 384-648 by J. DE C. SOWERBY (1823-1846), London.

SQUIRES, R.L., & SAUL, L.R. 2002. New early Late Cretaceous (Cenomanian) mollusks from east-central Oregon. – Journal of Paleontology **76**: 43-51.

STANLEY, S.M. 1970. Relation of shell form to life habits of the bivalvia (Mollusca). – The Geological Society of America Memoir **125**: 1-296.

STANTON, T.W. 1901. *Chondrodonta,* a new genus of ostreiform mollusks from the Cretaceous, with descriptions of the genotype and a new species. – Proceedings of the United States National Museum **24**: 301-307

STANLEY, S.M. 1972. Functional morphology and evolution of byssally attached bivalve mollusks. – Journal of Paleontology **46**: 165-212.

STENZEL, H.B. 1971. Oysters. – In: MOORE, R. C. (ed.), Treatise on Invertebrate Paleontology, Part N, Mollusca 6(3), Bivalvia: N953-N1224, Boulder (Geological Society of America), and Lawrence (University of Kansas Press).

STEUBER, T. 1996. Stable isotope sclerochronology of rudist bivalves: Growth rates and Late Cretaceous seasonality. – Geology **24**: 315-318.

STEUBER, T. 1999. Cretaceous rudists of Boeotia, central Greece. – Special Papers in Palaeontology **61**: 5-205.

STEUBER, T. & BACHMANN, M. 2002. Upper Aptian-Albian rudist bivalves from northern Sinai, Egypt. – Palaeontology **45**: 725-749.

STEUBER, T. & LÖSER, H. 2000. Species richness and abundance patterns of Tethyan Cretaceous rudist bivalves (Mollusca: Hippuritacea) in the central-eastern Mediterranean and Middle East, analysed from palaeontological database. – Palaeogeography, Palaeoclimatology, Palaeoecology **162**: 75-104.

STILWELL, J.D. & HENDERSON, R.A. 2002. Description and paleobiogeographic significance of a rare Cenomanian molluscan faunule from Bathurst Island, Northern Australia. – Journal of Paleontology **76**: 447-471.

STILWELL, J.D. & ZINSMEISTER, W.J. 2002. A new, large acteonid gastropod (Mollusca) from the latest Cretaceous of Antarctica. – Journal of Paleontology **76**: 1102-1105.

STOLICZKA, F. 1865. Eine Revision der Gastropoden der Gosauschichten in den Ostalpen. – Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse **52**: 104-223.

STOLICZKA, F. 1870-71. Cretaceous fauna of southern India: The Pelecypoda, with a review of all known genera of this class, fossil and recent. – Paleontologica Indica **6**(3): 1-557.

STRATHMANN, R. 1981. The role of spines in preventing structural damage to echinoid tests. – Paleobiology **7**: 400-406.

TELFORD, M. & MOOI, R. 1996. Podial particle picking in *Cassidulus caribaearum* (Echinodermata: Echinoidea) and the phylogeny of sea urchin feeding mechanisms. – Biological Bulletin **191**: 209-233.

THOMAS, H.D. & OMARA, S. 1957. The Cenomanian compound coral, *Aspidiscus cristatus* (LAMARCK), from Nezzazat, western Sinai. – Geological Magazine **94**: 151-155.

THOMSON, M.R. & WILLEY, L.E. 1972. Upper Jurassic and Lower Cretaceous *Inoceramus* (Bivalvia) from south-east Alexander Island. – Bulletin of the British Antarctic Survey **29**: 1-19.

TONI, R.T. 1969. Campanian-Maastrichtian mollusca from Gebel El-Rokham, Eastern Desert, Egypt. – Bulletin of the Faculty of Science, Alexandria University **9**: 527-554.

TOUCAS, A. 1908. Etudes sur la classification et l'évolution des radiolitidés: *Sphaerulites* et *Radiolites*. – Mémoires de la Société géologique de France, Paléontologie **36**: 47-78.

TREVISAN, L. 1937. La fauna ei giacimenti del Cenomaniano di facies africana della Sicilia occidentale. – Mémoire dell'Istituto Geologico della Universita di Padova **12**: 1-132.

VAUGHAN, T.W. & WELLS, J.W. 1943. Revision of the suborders, families and genera of the Scleractinia. **–** Geological Society of America, Special Papers **44**: 1-363.

VERNEUIL, E. DE & LORIÈRE, G. DE 1868. Descriptions des fossiles du Néocomien supérieur d'Utrillas et ses environs (Province de Teruel). – 30pp., Le Mans (Monnoyer).

VERMEIJ, G.J. 1987. Evolution and escalation: An ecological history of life. – 527pp., Princeton (Princeton University Press).

VERMEIJ, G.J. 1989. Interoceanic differences in adaptation: Effects of history and productivity. – Marine Ecology Progress Series **57**: 293-305.

VILLIER, L., NÉRAUDEAU, D., CLAVEL, B., NEUMANN, C. & DAVID, B. 2004. Phylogeny of Early Cretaceous spatangoids (Echinodermata: Echinoidea) and taxonomic implications. – Palaeontology **47**: 265-299.

VOKES, H. E. 1941. Contributions to the paleontology of the Lebanon Mountain, Republic of Lebanon. Part 1. A Cenomanian pelecypod fauna from Hajula. – American Museum Novitates **1145**: 1-13.

VOKES, H. E. 1946. Contributions to the paleontology of the Lebanon Mountains, Republic of Lebanon. Part 3. The pelecypod fauna of the "Olive Locality" (Aptian) at Abeih. – Bulletin of the American Museum of Natural History **87**: 139-216.

WAITE, R., WETZEL, A., MEYER, C.A. & STRASSER, A. 2008. The palaeoecological significance of nerineid mass accumulations from the Kimmeridgian of the Swiss Jura Mountains. – Palaios **23**: 548-558.

WALLEY, C.D. 1998. Some outstanding issues in the geology of Lebanon and their importance in the tectonic evolution of the Levantine region. – Tectonophysics **298**: 37-62.

WELLS, J.W. 1956. Scleractinia. – In: MOORE, R.C., (ed.). Treatise on Invertebrate Paleontology, Part F, Coelenterata: F328-F444, Lawrence and New York (University of Kansas Press and Geological Society of America).

WENZ, W. 1938-1944. Teil 1: Allgemeiner Teil und Prosobranchia. – In: SCHINDEWOLF, O. H. (ed.), Handbuch der Paläozoologie, Band **6**, Gastropoda. – 1639pp., Berlin (Borntraeger).

WIECZOREK, J. 1979. Upper Jurassic nerineacean gastropods from the Holy Cross MTS (Poland). – Acta Palaeontologica Polonica **24**: 299-350.

WIEDMANN, J. 1960. Zur Systematik jungmesozoischer Nautiliden under besonderer Berücksichtigung der iberischen Nautilinae D'ORB. – Palaeontographica A**115**: 144-206.

WIESE, F. & SCHULZE, F. 2005. The Upper Cenomanian (Cretaceous) ammonite *Neolobites vibrayeanus* (D'ORBIGNY, 1841) in the Middle East: taxonomic and palaeoecologic remarks. – Cretaceous Research **26**: 930-946.

WIGNALL, P.B. 1989. Sedimentary dynamics of the Kimmeridge Clay: Tempests and earthquakes. – Journal of the Geological Society of London **145**: 273-284.

WIGNALL, P.B. 1990. Benthic palaeoecology of the Late Jurassic Kimmeridge Clay of England. – Special Paper in Palaeontology **43**: 5-74.

WIGNALL, P.B. (1993). Distinguishing between oxygen and substrate control in fossil benthic assemblages. – Journal of the Geological Society of London **150**: 193-196.

WILMSEN, M. 2000. Late Cretaceous nautilids from northern Cantabria, Spain. – Acta Geologica Polonica **50**: 29-43.

WILMSEN, M. & VOIGT, T. 2006. The Middle-Upper Cenomanian of Zilly (Sachsen-Anhalt, northern Germany) with remarks on the *Pycnodonte* Event. – Acta Geologica Polonica **56**: 17-31.

WILMSEN, M., NIEBUHR, B., WOOD, C.J. & ZAWISCHA, D. 2007. Fauna and palaeoecology of the Middle Cenomanian *Praeactinocamax primus* Event at the type locality, Wunstorf quarry, northern Germany. – Cretaceous Research **28**: 428-460.

WOODS, H. 1899-1903. A monograph of the Cretaceous lamellibranchia of England. Vol. 1. – Monographs of the Palaeontographical Society, 1899: 1-72, 1900: 73-112, 1901: 113-144, 1902: 145-196, 1903: 197-232, London.

WOODS, H. 1904-1912. A monograph of the Cretaceous lamellibranchia of England. Vol. 2. – Monographs of the Palaeontographical Society,1904: 1-56, 1905: 57-96, 1906: 97-132, 1907: 133-180, 1908: 181-216, 1909: 217-260, 1910: 261-284, 1911: 285-340. 1912: 341-473, London.

WOOD, R. 1987. Biology and revision systematics of some Late Mesozoic stromatoporoids. – Special Paper in Palaeontology **37**: 5-87.

WOODIN, S.A. 1976. Adult-larval interactions in dense infaunal assemblages. – Journal of Marine Research **34**: 25-41.

WRIGHT, R.P. 1974. Jurassic bivalves from Wyoming and South Dakota: A study of feeding relationships. – Journal of Paleontology **48**: 425-433.

WRIGHT, C.W. & KENNEDY, W.J. 1981. The Ammonoidea of the Plenus Marls and the Middle Chalk. - Monographs Palaeontolographical Society **134**: 1-148.

WRIGHT, C.W., CALLOMON, J.H. & HOWARTH, M.K. 1996. Cretaceous Ammonoidea. – In: KAESLER, R.L. (ed.), Treatise on Invertebrate Paleontology, Part L, Mollusca **4**(4): 362pp., Boulder (Geological Society of America) and Lawrence (University of Kansas).

YONGE, C.M. 1937. The biology of *Aporrhais pespelicani* (L.) and *A. serresiana* (MICH.). – Journal of the Marine Biological Association of the UK **21**: 687-703.

ZABORSKI, P.M.P. 1987. Lower Turonian (Cretaceous) ammonites from southeast Nigeria. – Bulletin of the British Museum of Natural History (Geology) **41**: 31-66.

ZABORSKI, P.M.P. 1996. The Upper Cretaceous ammonite *Vascoceras* CHOFFAT, 1898 in north-eastern Nigeria. – Bulletin of Natural History Museum **52**: 61-89.

ZAKHERA, M.S. 2001. Cenomanian-Turonian mollusks (bivalves, gastropods and ammonites) from Gebel Musabaa Salama, west central Sinai, Egypt. – 2nd International Conference on the Geology of Africa **2**: 445-466.

ZAKHERA, M.S. 2002. Upper Cretaceous (Cenomanian-Maastrichtian) gastropods from west of the Gulf of Suez, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **225**: 297-336.

ZAKHERA, M.S. & KASSAB, A.S. 1999. New species of ostreid bivalves from the Upper Cretaceous (Santonian-Maastrichtian) of Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **1999**: 385-396.

ZAKHERA, M.S. & KASSAB, A.S. 2002a. Integrated macrobiostratigraphy of the Cenomanian-Turonian transition, Wadi El-Siq, west-central Sinai, Egypt. – Egyptian Journal of Paleontology **2**: 219-233.

ZAKHERA, M.S. & KASSAB, A.S. 2002b. Functional morphology and shell microstructure of some Upper Cretaceous oysters from the Eastern Desert of Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **2002**: 257-272.

ZIKO, A., DARWISH, M. & EWEDA, S. 1993. Late Cretaceous-Early Tertiary stratigraphy of the Themed area, East Central Sinai, Egypt. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte **1993**: 135-149.

ZITTEL, K.A. 1865-1866. Die Bivalven der Gosaugebilde in den nordöstlichen Alpen. – Denkschriften der Akademie der Wissenschaften Wien, Mathematisch-Naturwissenschaftliche Klasse **1**: Dimyaria **24**(1): 105-177 (1865), **25**(2): 77-198 (1866).

ZITTEL, K.A. 1883. Beiträge zur Geologie und Paläontologie der Libyschen Wüste. – Palaeontographica **30**: 1-147.

ZITTEL, K.A. 1885. Handbuch der Palaeozoologie **2**, Mollusca und Arthropoda. – 893pp., München and Leipzig (Oldenbourg).

Appendix A. Distribution of macrobenthos in the studied sections. The Buttum Formation (Middle Turonian) in the East Themed area lacks any macrofauna. H1: lower marly member, H2: middle carbonate member, H3: upper marly carbonate member of the Halal Formation; A1: lower member, A2: middle member, A3: Upper member of the Abu Qada Formation at Gebel Areif El-Naqa; G1: lower shale member G2: middle siliciclastic/carbonate member, G3: upper carbonate member of the Galala Formation of the Wadi Quseib section.

Taxa	**Gebel Areif El-Naqa**							**East Themed**			**Wadi Quseib**				
	Halal Fm			Abu Qada Fm			Wata Fm	Galala Fm	Abu Qada Fm	Wata Fm	Galala Fm			Abu Qada Fm	Wata Fm
	H1	H2	H3	A1	A2	A3					G1	G2	G3		
Bivalvia															
Nucula (*N*) *margaritifera*	●							●							
Nuculana (*Nuculana*) sp.		●						●							
Mytilus cf. *bussoni*						●									
Inoperna flagellifera	●														
Modiolus (*M.*) *aequalis*	●	●						●				●		●	
Cucullaea (*I.*) *diceras*												●			
Cucullaea (*I.*) *trigona*									●	●				●	
Cucullaea (*I.*) *thevestensi*									●						●
Cucullaea? cf. *favrei*			●												
Mytiloides concentricus	●														
Phelopteria atra													●	●	●
Phelopteria gravida						●		●	●						●
Nayadina gaudryi		●						●					●		
Pinna (*Pinna*) sp.	●														
Pseudolima itieriana								●	●		●			●	
Pycnodonte (*P.*) *vesiculosa*						●			●		●				
Exogyra conica	●	●							●			●			
Costagyra olisiponensis									●			●	●		
Ceratostreon flabellatum	●	●	●					●	●			●			
Ilymatogyra africana	●	●						●	●			●			
R. suborbiculatum	●	●	●						●		●	●			
Curvostrea rouvillei	●								●			●			
Gyrostrea delettrei	●					●						●			
Gyrostrea cf. *anubis*						●			●					●	●
Ambigostrea pseudovillei												●			

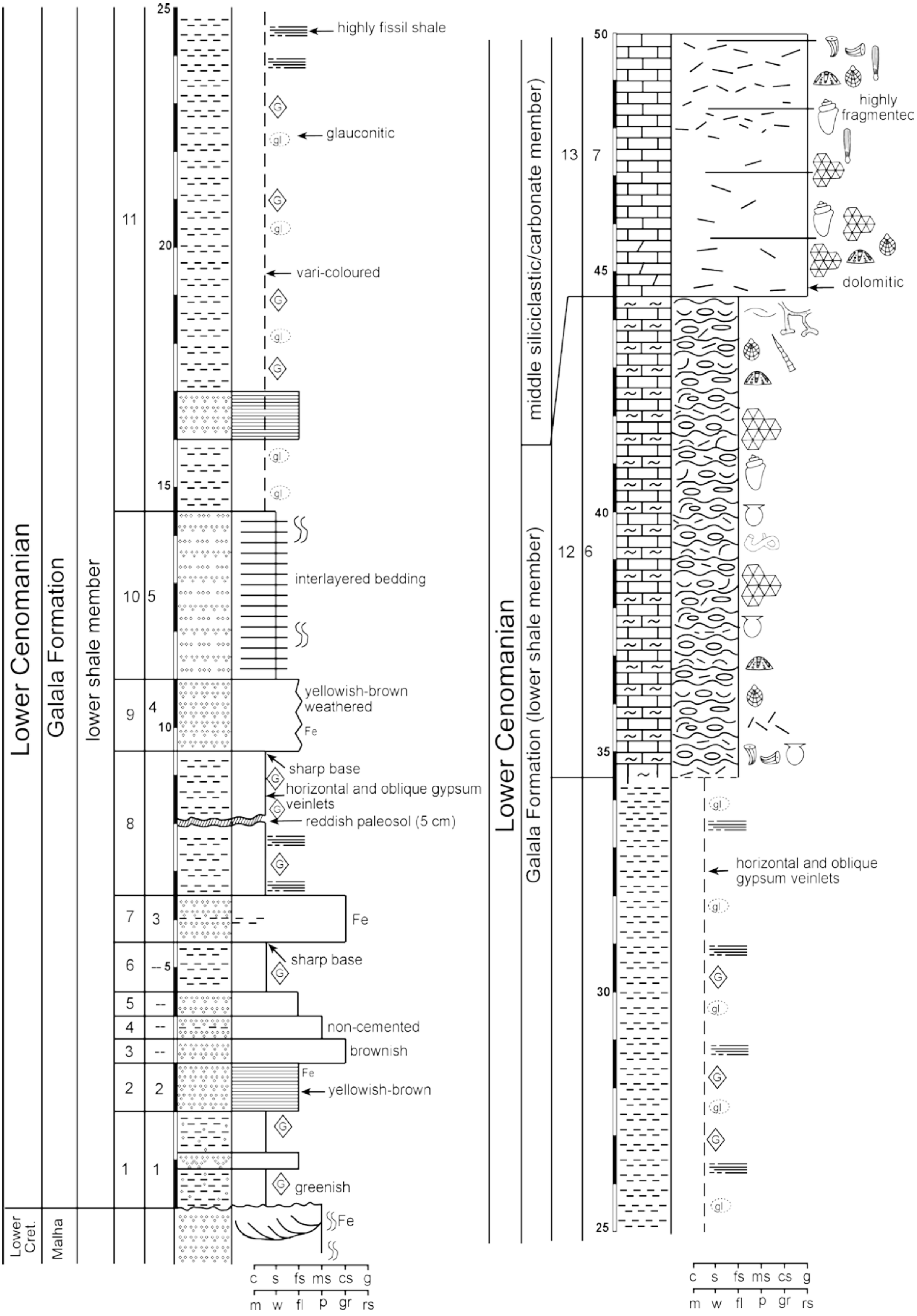
Lopha syphax	●														
Rastellum carinatum													●		
Chondrodonta joannae			●					●			●	●	●		
Plicatula (*P.*) *aurессensis*		●							●			●	●	●	
Plicatula (*P.*) *ferryi*			●						●					●	
Neithea (*N.*) *coquandi*									●						
Neithea (*N.*) *dutrugei*			●					●				●	●		
Neithea (*N.*) *quinquecostata*	●								●						
Neithea (*N.*) sp.												●			
Pterotrigonia (*S.*) *scabra*	●							●							
Corbula (*Corbula*) sp.								●							
Ichthyosarcolites sp.												●			
Toucasia? matheroni												●			
Radiolites sauvagesi			●							●			●	●	
Eoradiolites liratus	●		●									●			
Praeradiolites biskraensis								●							
Praeradiolites sp.												●			
Durania arnaudi							●								
Lucina fallax		●													
Clisocolus corrugatus		●							●			●			
Cardita? *nicaisei*												●			
Venericardia? *forgemoli*	●	●							●						
Granocardium carolinum		●								●					
Granocardium desvauxi												●			
Granocardium productum	●	●						●	●		●	●	●		
Protocardia hillana		●						●	●			●	●		
Protocardia? *regulare*		●													
Protocardia sp.	●														
Arctica? *rostrata*	●														
Arctica? *inornata*		●						●							
Arctica? *Picteti*	●														
Tenea delettrei	●	●						●	●			●			
Veniella cf. *trapezoidalis*									●					●	●
Glossus aquilinus	●							●					●		
Paraesa faba	●	●						●	●			●	●	●	●
Meretrix desvauxi									●				●	●	

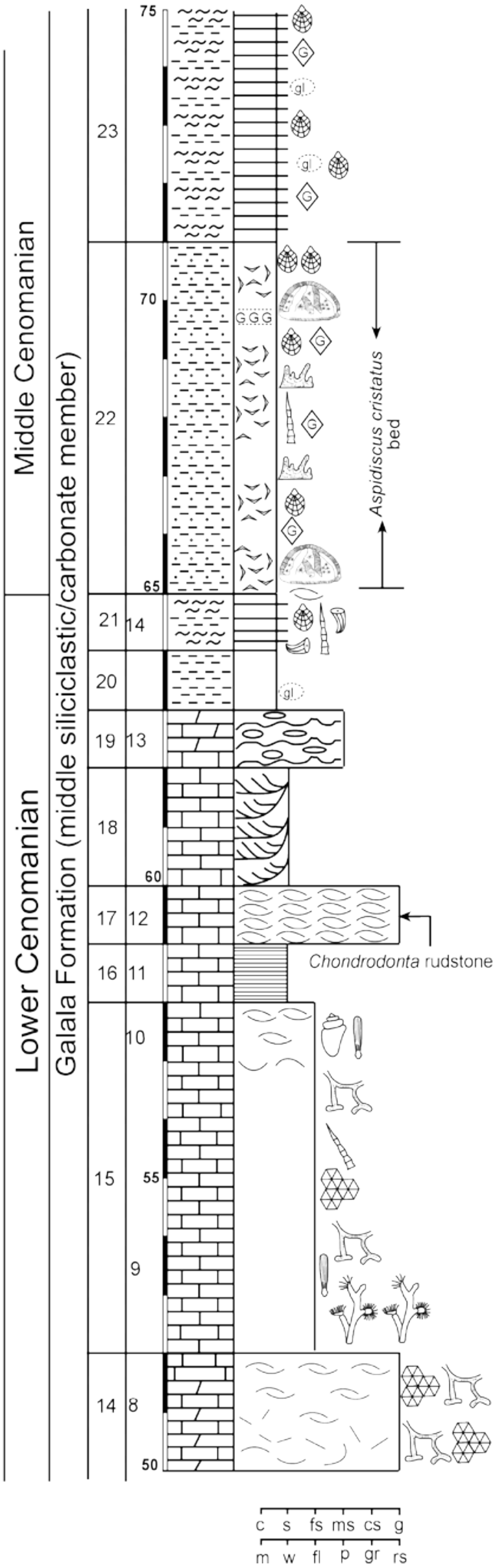
Meretrix orientalis		●													
bivalve gen. et sp. indet.		●													
Pholadomya fabrina															●
Pholadomya pedernalis									●	●					●
Pholadomya vignesi									●				●		
Osteomya sp.		●													
Poromya? *ligeriensis*												●			
Gastropoda															
Calliomphalus orientalis													●		
Neritopsis sp.								●							
Cerithium cf. *mogharense*		●													
Cerithium? sp.															●
Pyrazus valeriae		●							●			●			
Turritella cf. *difficilis*		●													
Campanile (*C.*) *ganesha*												●	●		
Cimolithium tenouklense	●	●										●		●	
Ampullina (*A.*) *abeihensis*		●										●			
Ampullina (*A.*) cf. *quaasi*	●								●						
Coronatica cf. *ornata*															
“Strombus” incertus	●	●	●					●	●			●			
“Aporrhais” dutrugei	●	●	●					●					●		
“Aporrhais” sp.1				●											
“Aporrhais” sp.2														●	
Harpagodes heberti	●	●	●					●				●			
Columbellina fusiformis	●								●						
Pterodonta deffisi	●	●	●					●			●	●			
Pterodonta cf. *subinflata*												●			
?*Pterodonticeras germeri*		●	●												
Tylostoma (*T.*) *cossoni*	●	●				●			●		●	●			●
Tylostoma (*T.*) *globosum*				●					●	●				●	●
Tylostoma (*T.*) *pallaryi*	●	●						●							
Fasciolaria tournoueri									●						
Palaeatractus cf. *figarii*				●											
Caricella sp.		●													
Gastropod indet.								●							
Acteon? sp.	●														
Globiconcha cf. *rotundata*	●														

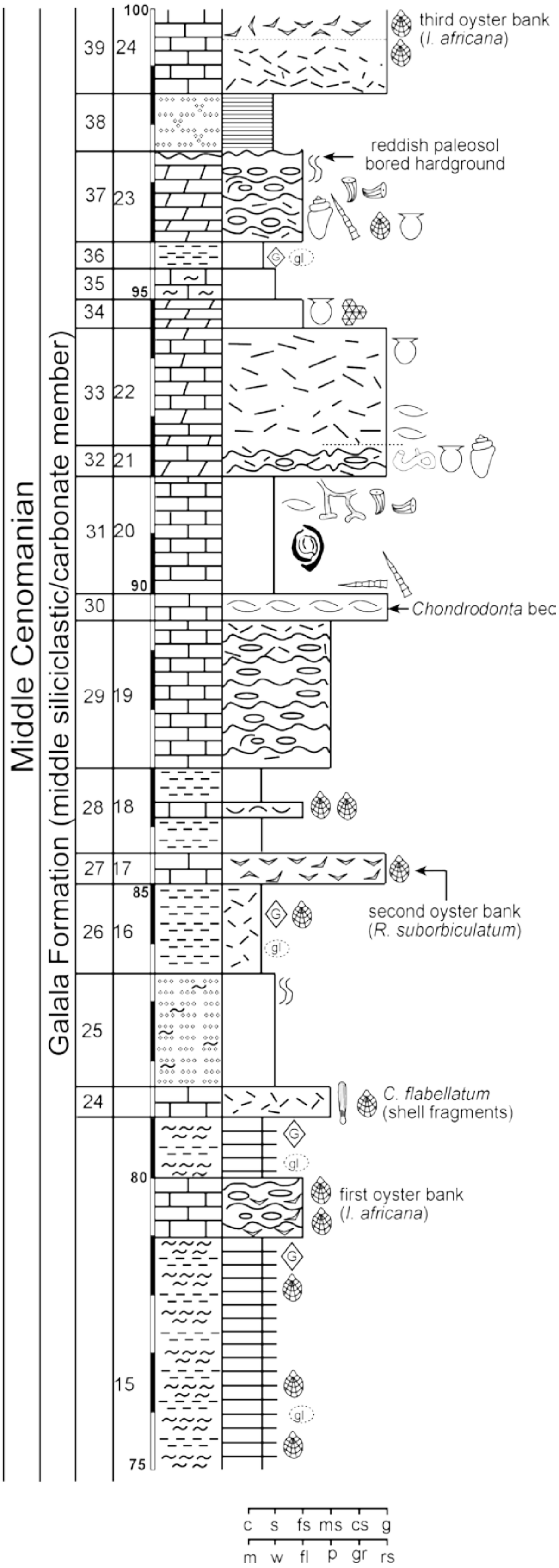
Sogdianella? *laevis laevis*														●	
Neoptyxis olisiponensis											●	●	●		
Pchelinsevia coquandiana			●					●				●			
Diozoptyxis? *blancheti*												●			
Akera thevestensis								●							
Cephalopoda															
Angulithes mermeti								●				●			
Knemiceras deserti	●														
Neolobites vibrayeanus								●				●			
Kamerunoceras turoniense				●					●						
Vascoceras durandi									●					●	
Vascoceras sp.									●					●	
Neoptychites cephalotus				●					●						
Fagesia cf. *peroni*									●						
Thomasites rollandi				●					●					●	
Wrightoceras munieri									●						
Choffaticeras securiforme									●					●	
Choffaticeras (*Ch.*) *segne*				●					●					●	
Hemitissotia sp.															●
Coilopoceras requienianum															●
Echinoids															
Sinaecidaris cf. *gauthieri*												●			
Micropedina olisiponensis													●		
Orthopsis ovata									●					●	
Goniopygus menardi													●		
Goniopygus cf. *peroni*							●								
Codiopsis sp.											●				
Pedinopsis desori		●													
Tetragramma variolare		●													
Heterodiadema libycum		●						●				●		●	
Phymosoma abbatei				●						●					●
Phymosoma sinaeum														●	
Rachiosoma geysi										●					●
Rachiosoma irregulare															●
Coenholectypus larteti		●										●	●	●	
Coenholectypus portentosus	●	●													

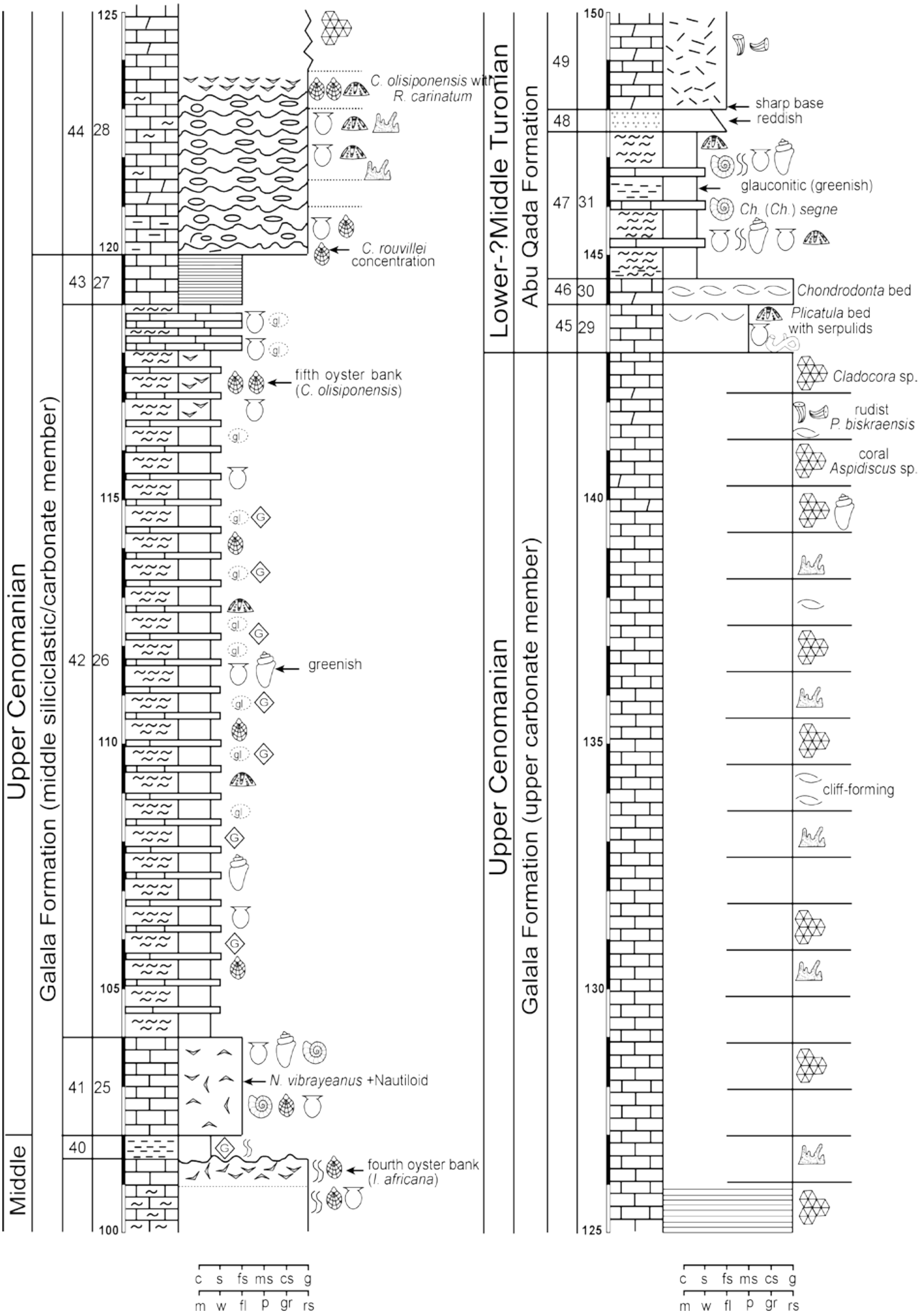
Coenholectypus turonensis									●					●	
Anorthopygus orbicularis											●				
Petalobrissus cf. *pygmaeus*										●				●	
Pygurus cf. *subproductus*	●														
Gentilia syriensis													●		
Hemiaster (*H.*) *syriacus*	●	●						●				●			
Hemiaster (*H.*) *gabrielis*	●														
Hemiaster (*M.*) *fourneli*							●		●					●	●
Hemiaster (*M.*) cf. *newtoni*											●				
Hemiaster pseudofourneli												●			
Hemiaster (*M.*) *heberti turonensis*				●			●		●	●				●	●
Corals															
Aspidiscus cristatus												●			
Tortoflabellum sp.											●	●			
Cladocora sp.													●		

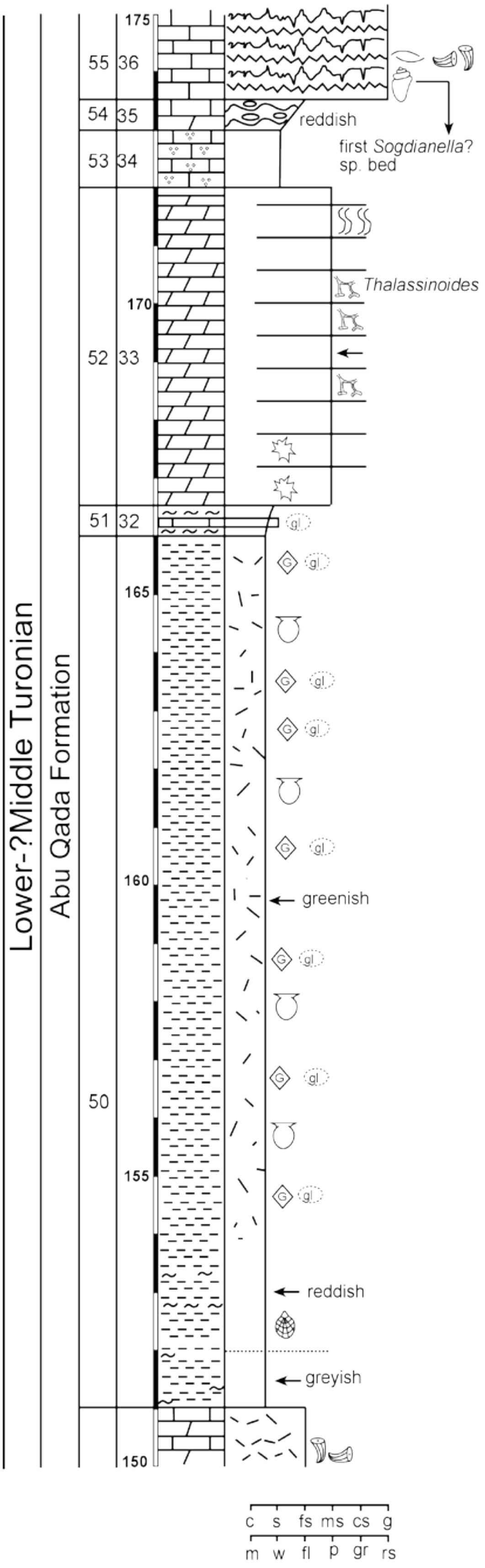
Appendix B. Detailed sections, Wadi Quseib

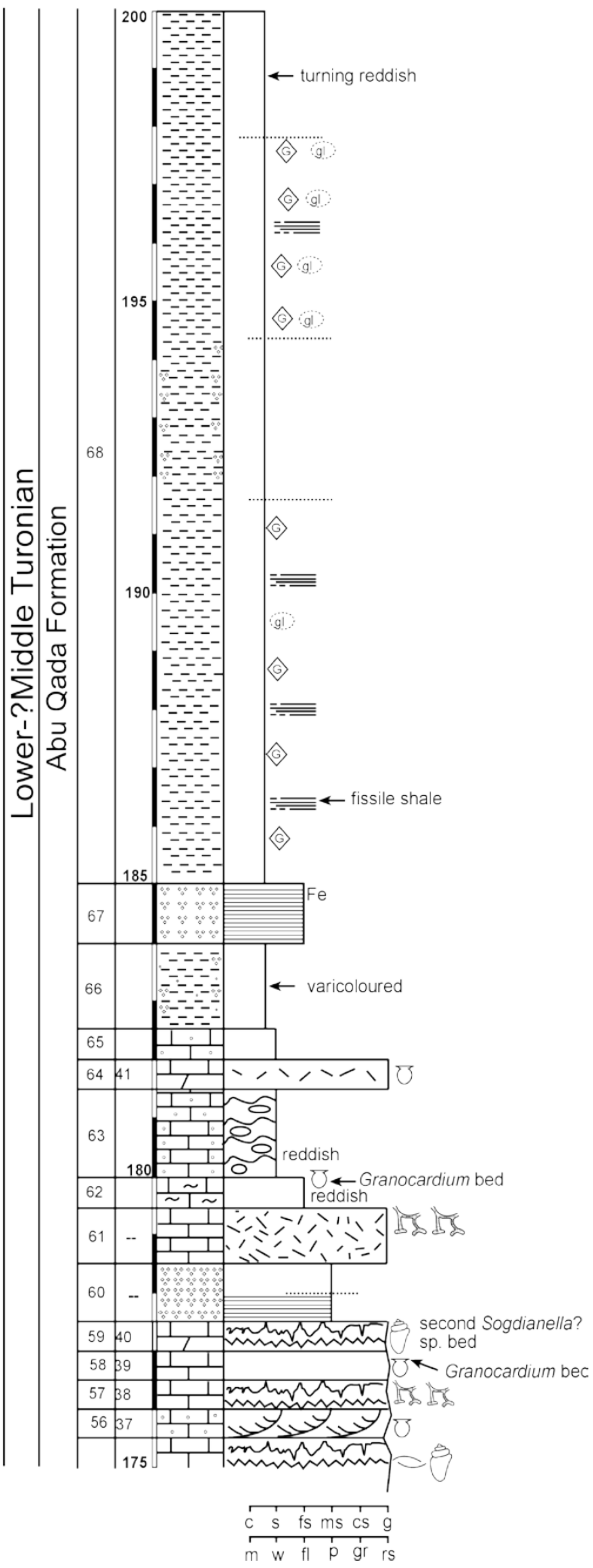


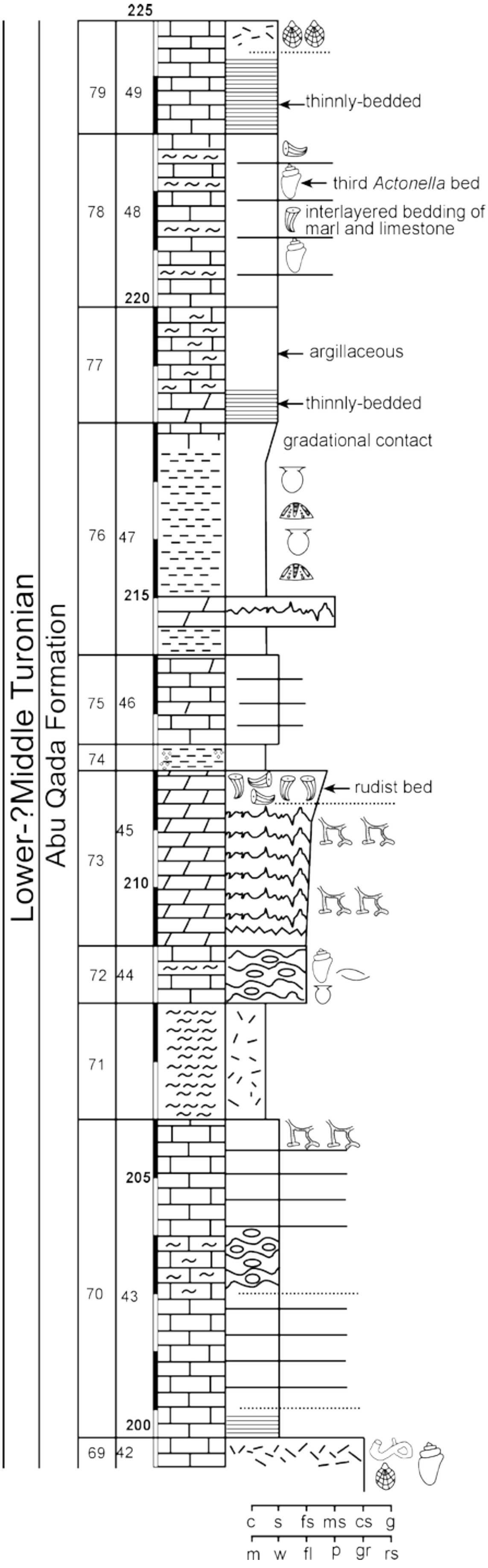

Middle Cenomanian
Lower Cenomanian
Galala Formation (middle siliciclastic/carbonate member)
23
22
21
20
19
18
17
16
15
14
14
13
12
11
10
9
8
75
70
65
60
55
50
gl
G
GGG
Aspidiscus cristatus bed
Chondrodonta rudstone
c s fs ms cs g
m w fl p gr rs

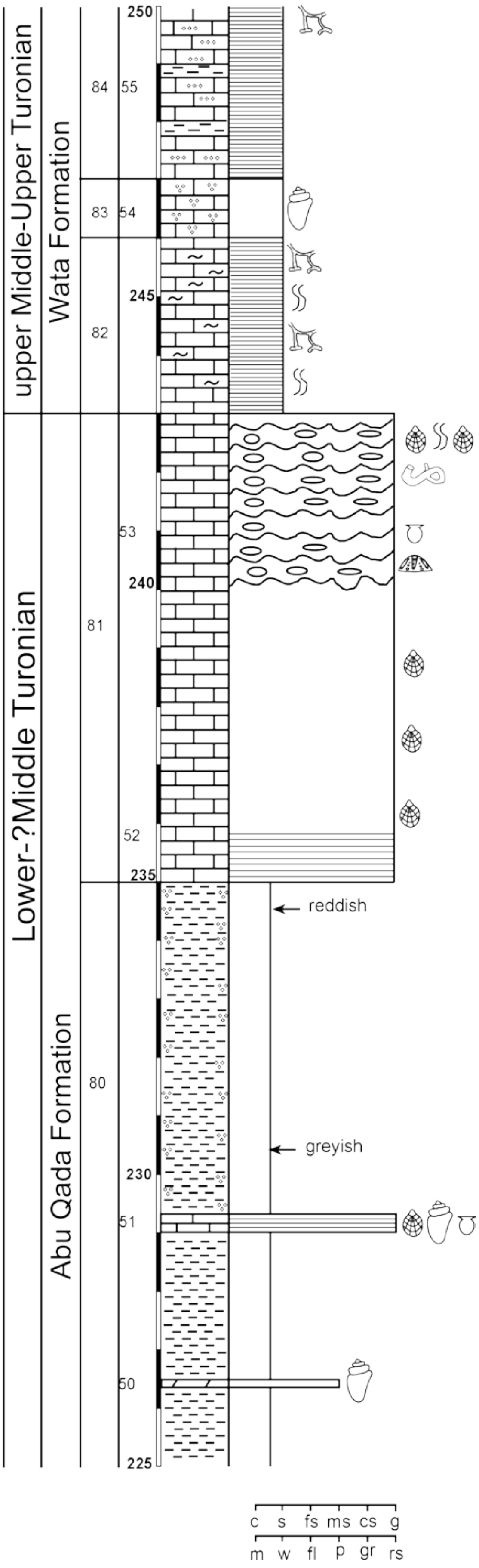

Middle Cenomanian
Galala Formation (middle siliciclastic/carbonate member)
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
24
23
22
21
20
19
18
17
16
15
100
95
90
85
80
75
third oyster bank
(I. africana)
reddish paleosol
bored hardground
Chondrodonta bec
second oyster bank
(R. suborbiculatum)
C. flabellatum
(shell fragments)
first oyster bank
(I. africana)
G
gl
c s fs ms cs g
m w fl p gr rs

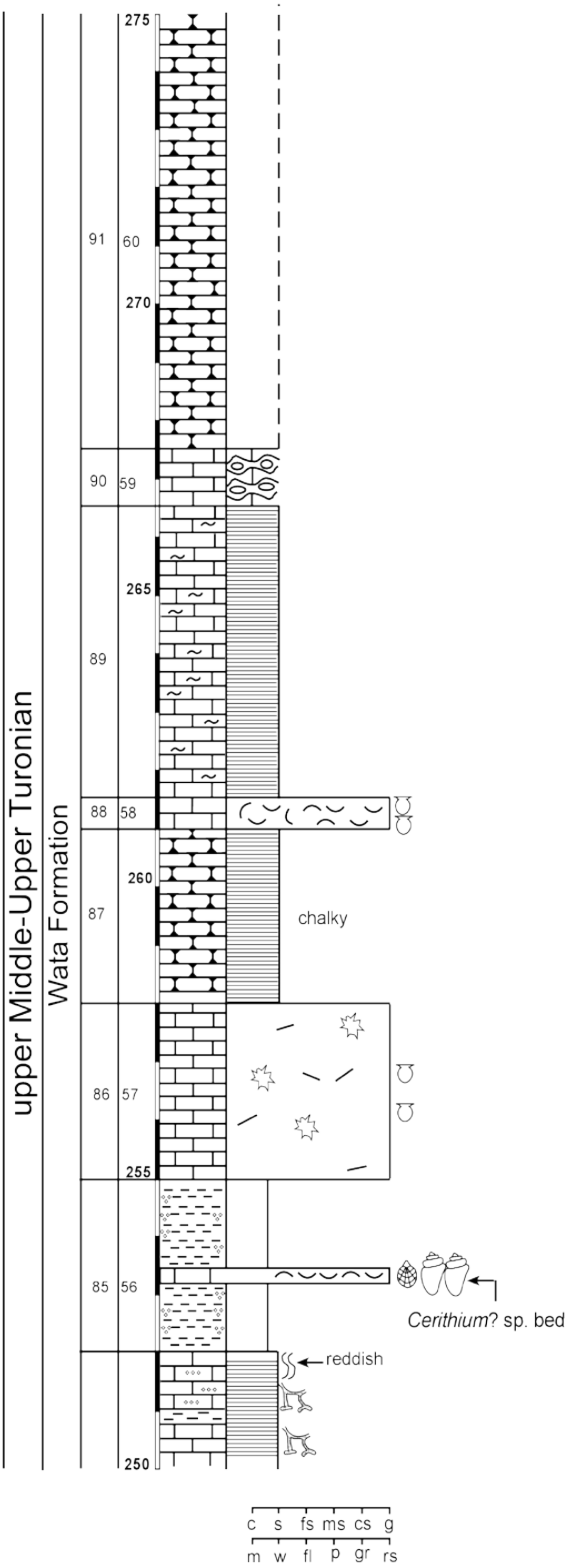

Upper Cenomanian
Galala Formation (middle siliciclastic/carbonate member)
Middle
44
28
43
27
42
26
41
25
40
125
120
115
110
105
100
C. olisiponensis with R. carinatum
C. rouvillei concentration
gl.
G
fifth oyster bank (C. olisiponensis)
greenish
N. vibrayeanus +Nautiloid
fourth oyster bank (I. africana)
Lower-?Middle Turonian
Abu Qada Formation
Upper Cenomanian
Galala Formation (upper carbonate member)
49
48
47
31
46
30
45
29
150
145
140
135
130
125
sharp base
reddish
glauconitic (greenish)
Ch. (Ch.) segne
Chondrodonta bed
Plicatula bed with serpulids
Cladocora sp.
rudist P. biskraensis
coral Aspidiscus sp.
cliff-forming
c s fs ms cs g
m w fl p gr rs
c s fs ms cs g
m w fl p gr rs

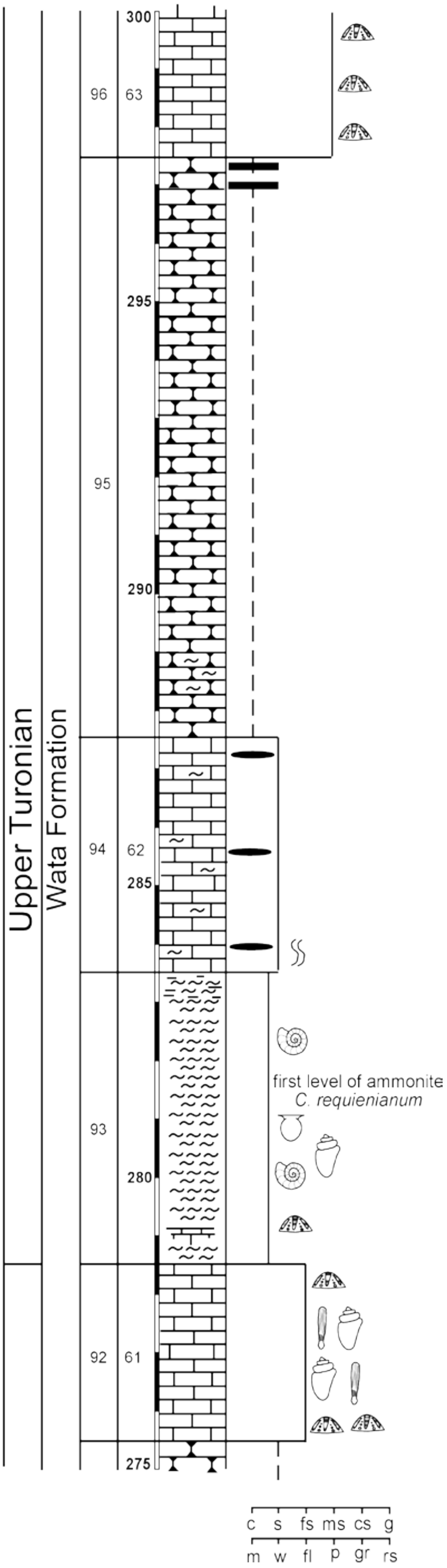

Lower-?Middle Turonian
Abu Qada Formation
175
55 36
54 35
reddish
first Sogdianella? sp. bed
53 34
Thalassinoides
170
52 33
51 32
gl
G
165
160
greenish
50
155
reddish
greyish
150
c s fs ms cs g
m w fl p gr rs

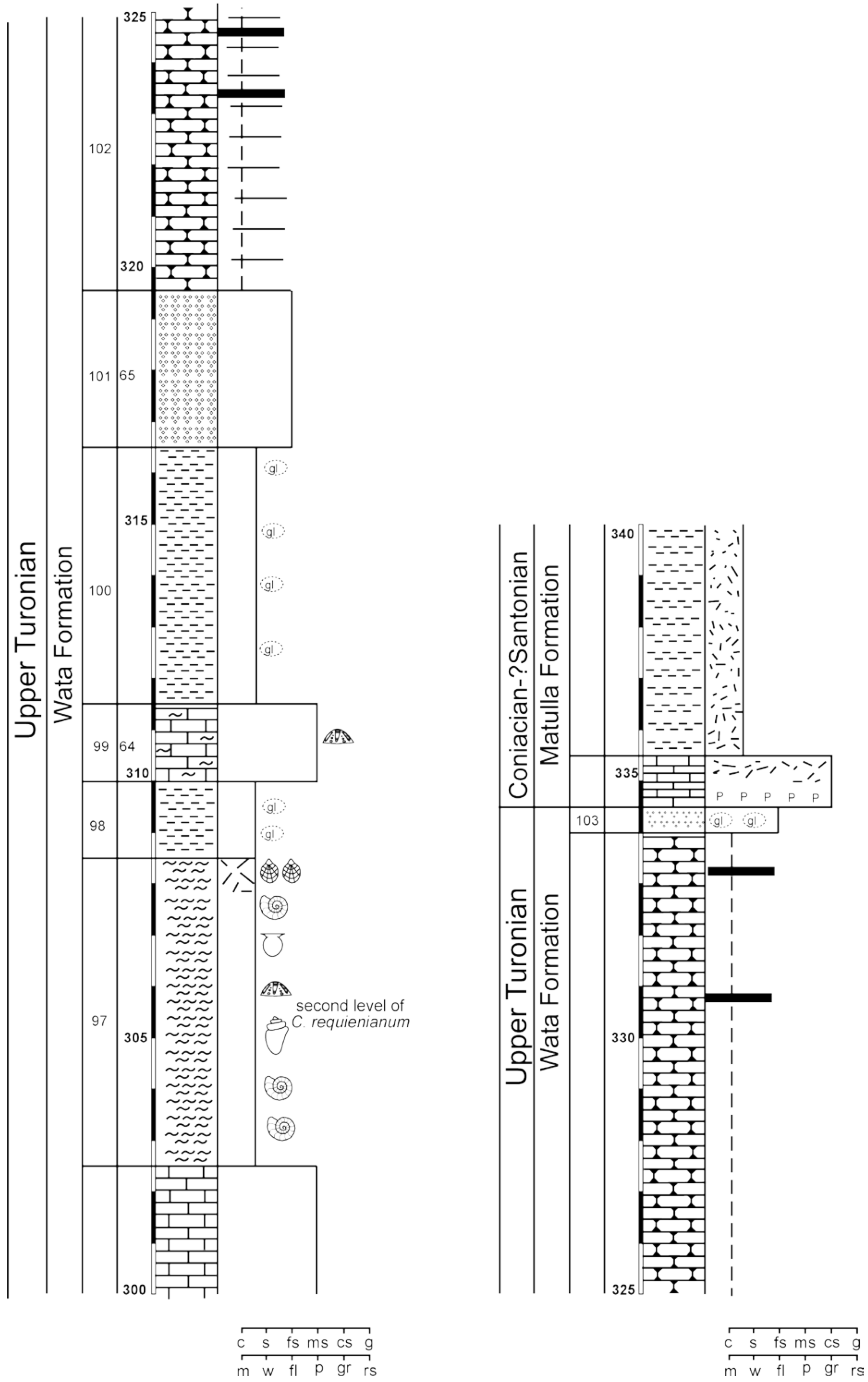

Lower-?Middle Turonian
Abu Qada Formation
200
turning reddish
G
gl
195
68
190
fissile shale
185
67
Fe
66
varicoloured
65
64 41
63
reddish
180
62
Granocardium bed
reddish
61 --
60 --
59 40
second Sogdianella? sp. bed
58 39
Granocardium bec
57 38
56 37
175
c s fs ms cs g
m w fl p gr rs


Lower-?Middle Turonian
Abu Qada Formation
225
79
49
thinnly-bedded
78
48
third *Actonella* bed
interlayered bedding of marl and limestone
220
77
argillaceous
thinnly-bedded
gradational contact
76
47
215
75
46
74
73
45
rudist bed
210
72
44
71
70
43
205
200
69
42
c s fs ms cs g
m w fl p gr rs

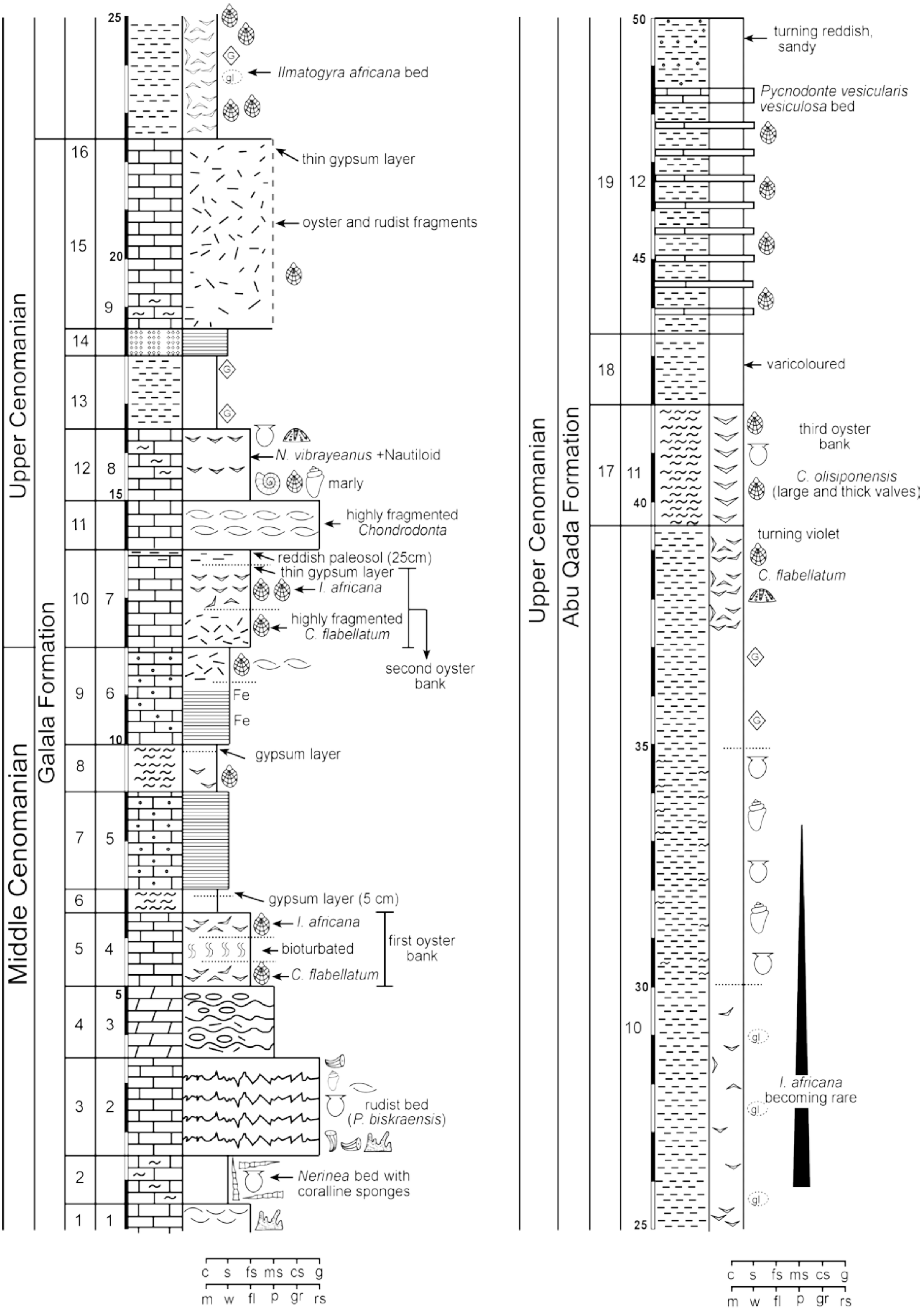

upper Middle-Upper Turonian
Wata Formation
250
84
55
83
54
245
82
Lower-?Middle Turonian
Abu Qada Formation
81
53
240
52
235
reddish
80
greyish
230
51
50
225
c s fs ms cs g
m w fl p gr rs

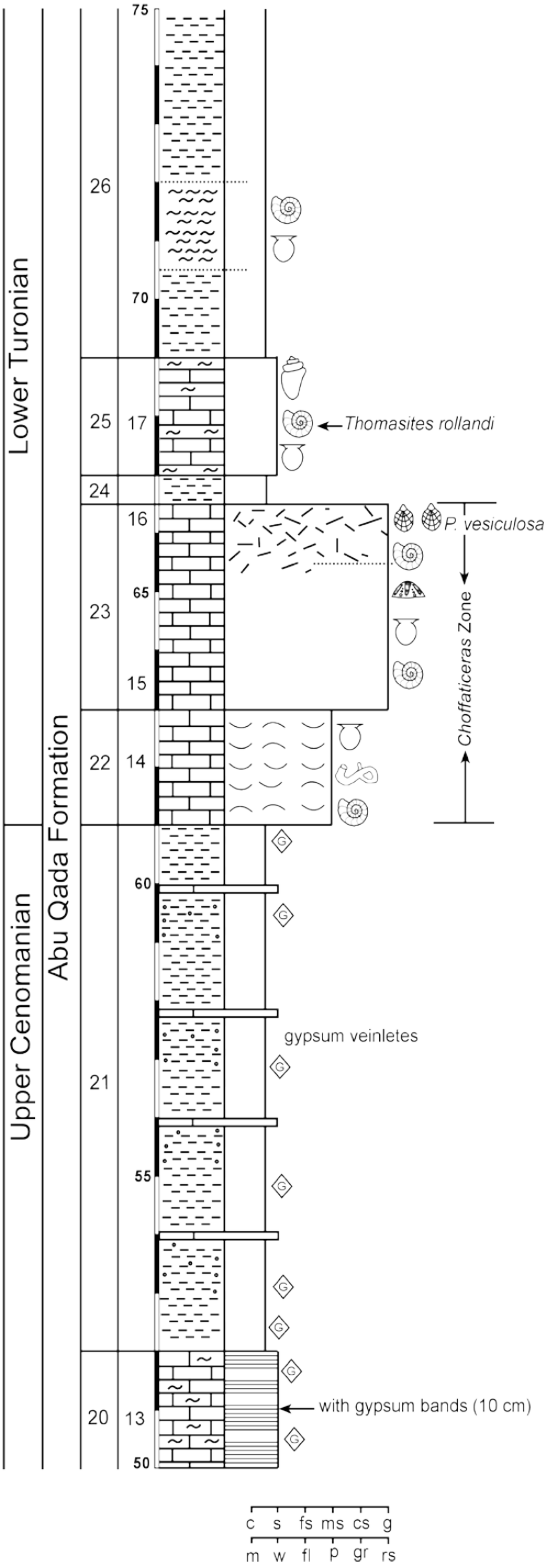

upper Middle-Upper Turonian
Wata Formation
275
91
60
270
90
59
265
89
88
58
260
87
chalky
86
57
255
85
56
Cerithium? sp. bed
reddish
250
c s fs ms cs g
m w fl p gr rs

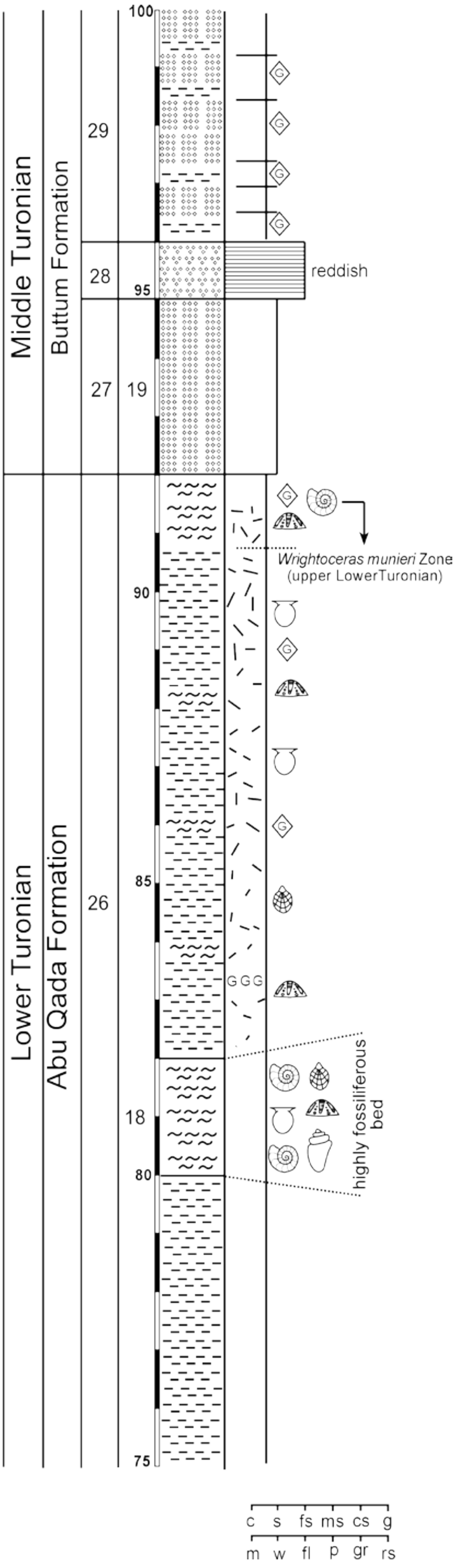

Upper Turonian
Wata Formation
300
96
63
295
95
290
94
62
285
first level of ammonite
C. requienianum
93
280
92
61
275
c s fs ms cs g
m w fl p gr rs

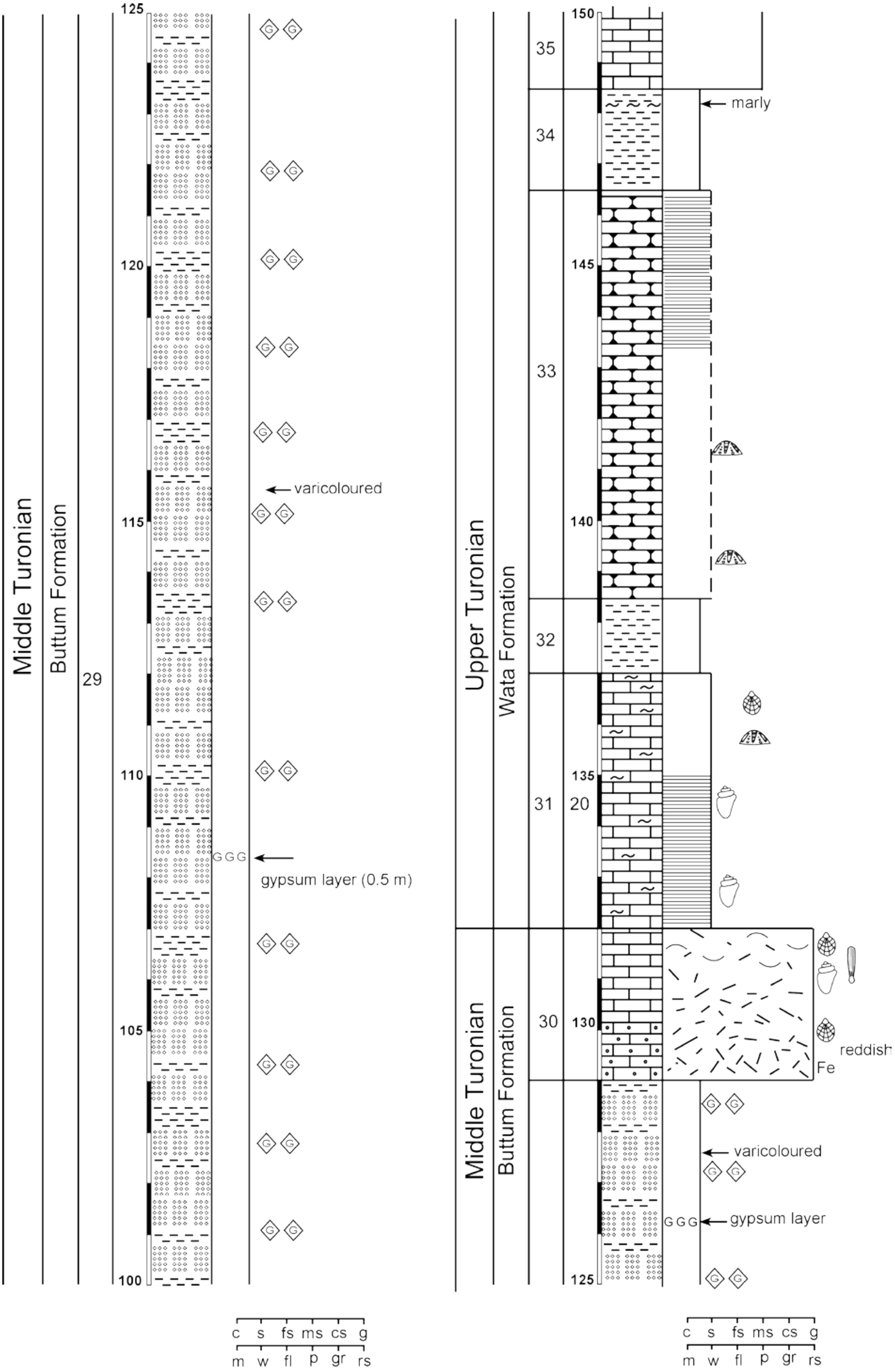

Upper Turonian
Wata Formation
102
101
65
100
99
64
98
97
325
320
315
310
305
300
gl
second level of
C. requienianum
c s fs ms cs g
m w fl p gr rs
Coniacian-?Santonian
Matulla Formation
Upper Turonian
Wata Formation
103
340
335
330
325
P P P P P
gl gl
c s fs ms cs g
m w fl p gr rs

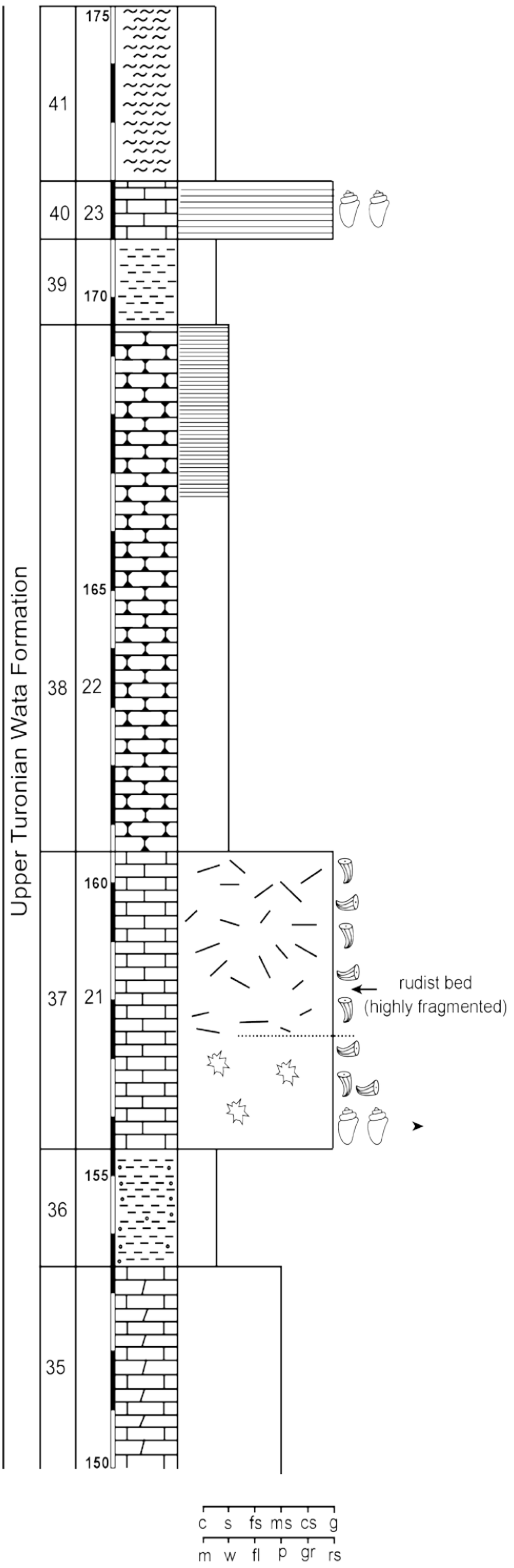
Appendix C. Detailed sections, East Themed

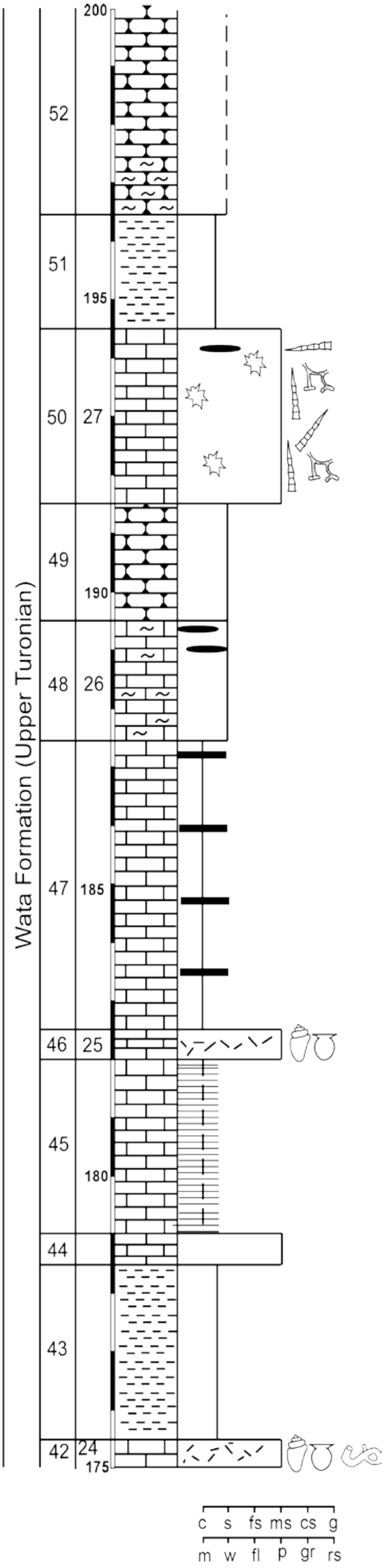


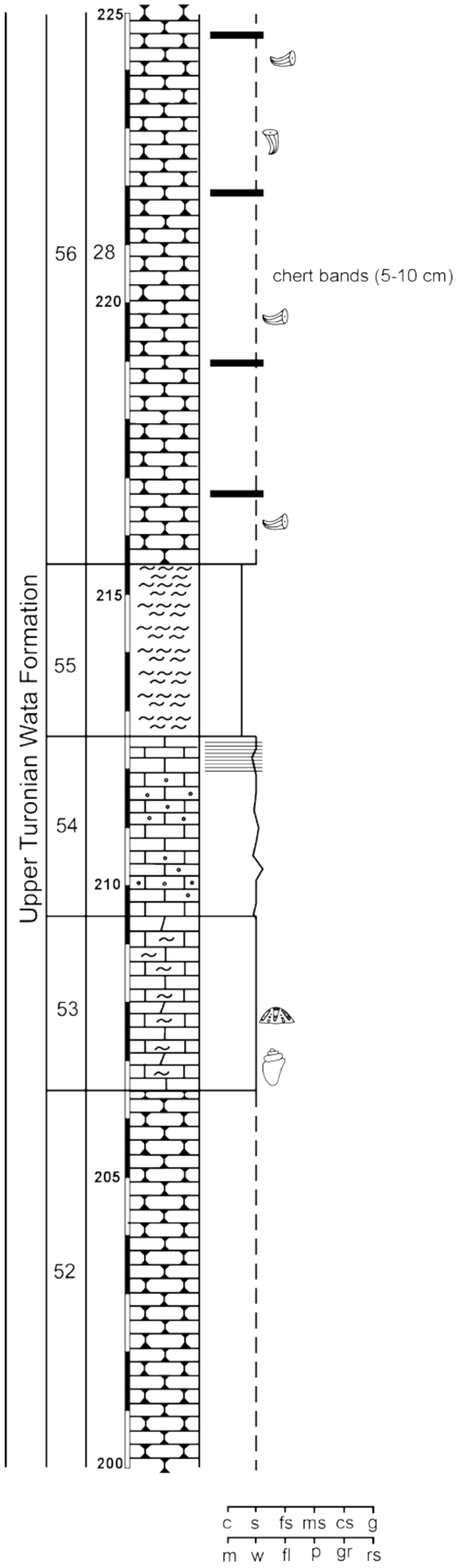

Lower Turonian
Upper Cenomanian
Abu Qada Formation
26
25
24
23
22
21
20
17
16
15
14
13
75
70
65
60
55
50
Thomasites rollandi
P. vesiculosa
Choffaticeras Zone
gypsum veinletes
with gypsum bands (10 cm)
c s fs ms cs g
m w fl p gr rs

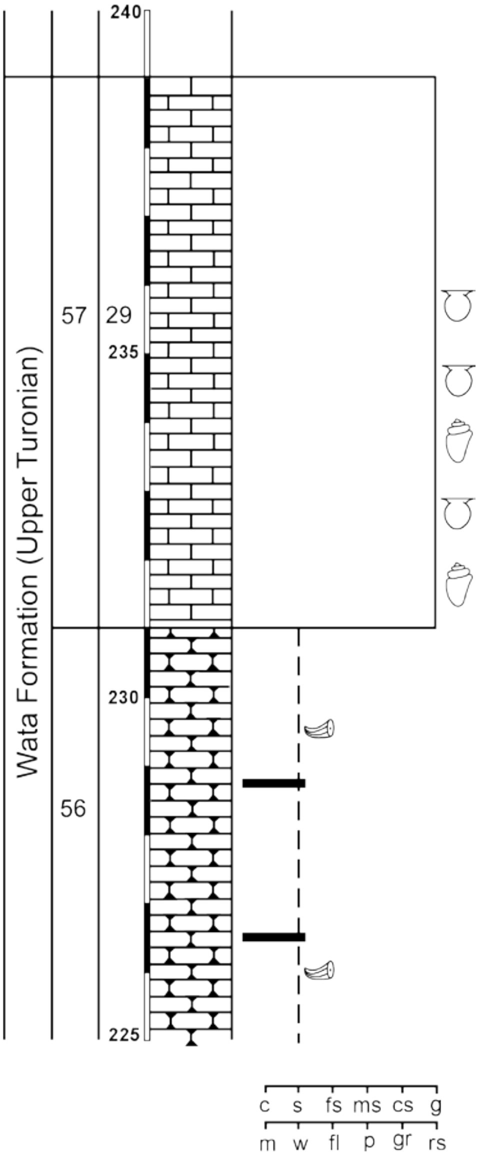

Middle Turonian
Buttum Formation
Lower Turonian
Abu Qada Formation
29
28
27
26
19
18
100
95
90
85
80
75
reddish
Wrightoceras munieri Zone
(upper LowerTuronian)
GGG
highly fossiliferous bed
c s fs ms cs g
m w fl p gr rs


Middle Turonian
Buttum Formation
29
125
120
115
110
105
100
varicoloured
GGG
gypsum layer (0.5 m)
c s fs ms cs g
m w fl p gr rs
Upper Turonian
Wata Formation
Middle Turonian
Buttum Formation
35
34
33
32
31
20
30
150
145
140
135
130
125
marly
reddish
Fe
varicoloured
GGG
gypsum layer
c s fs ms cs g
m w fl p gr rs


Upper Turonian Wata Formation
41
175
40
23
39
170
38
22
165
37
21
160
rudist bed
(highly fragmented)
36
155
35
150
c s fs ms cs g
m w fl p gr rs


Wata Formation (Upper Turonian)
200
52
51
195
50
27
49
190
48
26
47
185
46
25
45
180
44
43
42
24
175
c s fs ms cs g
m w fl p gr rs


Upper Turonian Wata Formation
56
28
55
54
53
52
225
220
215
210
205
200
chert bands (5-10 cm)
c s fs ms cs g
m w fl p gr rs


Wata Formation (Upper Turonian)
57
29
56
240
235
230
225
c s fs ms cs g
m w fl p gr rs

Appendix D

Relative abundance and presence percentage of the ten macrobenthic associations from the Cenomanian-Turonian successions of the eastern Sinai, Egypt. Taxa marked with an asterisk belong to the trophic nucleus; rel. abund=relative abundance; pres. %=presence percentage.

(1) *Pchelinsevia coquandiana* **association**
3 samples, 147 individuals, 23 taxa

species	**Rel. abund.%**	**Pres.%**
**Pchelinsevia coquandiana*	62.59	100
**Praeradiolites* sp.	4.76	33.33
**Tortoflabellum* sp.	4.76	33.33
**Toucasia*? *matheroni*	4.08	33.33
*“*Ichthyosarcolites*” sp.	3.40	33.33
**“Strombus” incertus*	2.04	33.33
Tylostoma (*T.*) *cossoni*	1.36	33.33
?*Pterodonticeras germeri*	1.36	33.33
Pterodonta deffisi	1.36	33.33
Ampullina (*Ampullina*) *abeihensis*	1.36	33.33
Coenholectypus larteti	1.36	33.33
Eoradiolites liratus	1.36	33.33
Neithea (*Neithea*) *dutrugei*	1.36	33.33
Plicatula (*Plicatula*) *ferryi*	1.36	33.33
Chondrodonta joannae	1.36	33.33
Cucullaea? cf. *favrei*	1.36	33.33
Harpagodes heberti	0.68	33.33
“*Aporrhais*” *dutrugei*	0.68	33.33
Campanile (*Campanile*) *ganesha*	0.68	33.33
Pyrazus valeriae	0.68	33.33
Granocardium (*G.*) *desvauxi*	0.68	33.33
Clisocolus corrugatus	0.68	33.33
Neithea (*Neithea*) sp.	0.68	33.33

(2) ***Rachiosoma geysi/Cucullaea*** **(*Idonearca*)** ***trigona*** **association**
2 samples, 157 individuals, 9 taxa

species	**Rel. abund.%**	**Pres.%**
**Rachiosoma geysi*	31.21	100
**Cucullaea* (*Idonearca*) *trigona*	22.29	50
**Phymosoma abbatei*	11.46	100
**Petalobrissus* cf. *pygmaeus*	11.46	50
**Tylostoma* (*Tylostoma*) *globosum*	10.83	100
Pholadomya pedernalis	5.73	50
Hemiaster (*M.*) *heberti turonensis*	3.18	50
Curvostrea rouvillei	3.18	50
Granocardium (*G.*) *carolinum*	0.64	50

(3) *Paraesa faba/Hemiaster* (*Mecaster*) *heberti turonensis* association
6 samples, 762 individuals, 51 taxa

species	**Rel. abund.%**	**Pres. %**
**Paraesa faba*	13.87	100
**Hemiaster* (*M.*) *heberti turonensis*	11.26	100
**Curvostrea rouvillei*	6.02	16.66
**Coenholectypus turonensis*	5.63	50
**Plicatula* (*Plicatula*) *ferryi*	4.58	33.33
**Rhynchostreon suborbiculatum*	4.58	16.66
**Meretrix desvauxi*	3.93	33.33
**Costagyra olisiponensis*	3.93	16.66
**Gyrostrea* cf. *anubis*	3.53	33.33
**Pholadomya pedernalis*	2.75	50
**Goniopygus menardi*	2.62	16.66
**Tenea delettrei*	2.62	16.66
**Chondrodonta joannae*	2.62	16.66
**Cucullaea* (*Idonearca*) *thevestensis*	2.49	50
**Pholadomya vignesi*	2.36	16.66
**Coenholectypus larteti*	1.96	16.66
**Plicatula* (*Plicatula*) *auressensis*	1.96	33.33
**Pycnodonte* (*P.*) *vesicularis Vesiculosa*	1.96	33.33
**Hemiaster* (*Mecaster*) *fourneli*	1.83	33.33
Phymosoma abbatei	1.83	33.33
Radiolites sauvagesi	1.57	16.66
Campanile (*Campanile*) *ganesha*	1.31	33.33
Glossus aquilinus	1.18	16.66
Phelopteria gravida	1.18	33.33
Rastellum carinatum	1.05	16.66
Tylostoma (*Tylostoma*) *cossoni*	0.92	33.33
Phelopteria atra	0.92	33.33
Cucullaea (*Idonearca*) *trigona*	0.92	16.66
Granocardium (*G.*) *productum*	0.79	33.33
Cladocora sp.	0.65	16.66
Columbellina (*C.*) *fusiformis*	0.65	16.66
Neithea (*Neithea*) *dutrugei*	0.65	16.66
Pseudolima itieriana	0.52	33.33
Neoptyxis olisiponensis	0.39	16.66
Rachiosoma irregulare	0.39	16.66
Phymosoma sinaeum	0.39	16.66
Pholadomya fabrina	0.39	16.66
Veniella cf. *trapezoidalis*	0.39	33.33
Protocardia hillana	0.39	16.66
Nayadina (*Nayadina*) *gaudryi*	0.39	16.66
Modiolus (*M.*) *aequalis*	0.39	33.33
Fasciolaria tournoueri	0.26	16.66
Tylostoma (*Tylostoma*) *globosum*	0.26	16.66
"*Aporrhais*" *dutrugei*	0.26	16.66
Calliomphalus orientalis	0.26	16.66
Rachiosoma geysi	0.26	16.66
Orthopsis ovata	0.26	33.33
Exogyra conica	0.26	16.66
Heterodiadema libycum	0.13	16.66
Micropedina olisiponensis	0.13	16.66
Clisocolus corrugatus	0.13	16.66

(4) *Pycnodonte* (*Pycnodonte*) *vesicularis vesiculosa*/*Phelopteria gravida* association

2 samples, 196 individuals, 16 taxa

species	Rel. abund.%	Pres. %
**Pycnodonte* (*P.*) *vesicularis Vesiculosa*	39.29	100
**Phelopteria gravida*	15.31	100
**Hemiaster* (*Mecaster*) *fourneli*	7.65	50
**Pholadomya pedernalis*	7.14	100
**Ilymatogyra africana*	5.10	50
**Protocardia hillana*	4.59	50
**Cucullaea* (*Idonearca*) *trigona*	3.06	100
Gyrostrea cf. *anubis*	3.06	50
Plicatula (*P.*) *auressensis*	2.55	100
Pseudolima itieriana	2.55	50
Tylostoma (*Tylostoma*) *globosum*	2.04	50
“Strombus” incertus	2.04	50
Meretrix desvauxi	2.04	50
Curvostrea rouvillei	1.53	50
Rhynchostreon suborbiculatum	1.53	50
Veniella cf. *trapezoidalis*	0.51	50

(5) *Ilymatogyra africana*/*Granocardium* (*G.*) *productum* association

7 samples, 764 individuals, 63 taxa

species	Rel. abund.%	Pres. %
**Ilymatogyra africana*	13.74	100
**Granocardium* (*G.*) *productum*	7.20	71.43
**Heterodiadema libycum*	6.02	42.85
**Ceratostreon flabellatum*	5.89	28.57
**Tenea delettrei*	5.76	42.85
**Rhynchostreon suborbiculatum*	5.37	57.14
**Coenholectypus larteti*	5.37	28.57
**“Strombus” incertus*	3.80	28.57
**Paraesa faba*	3.53	42.85
**Hemiaster* (*Hemiaster*) *syriacus*	3.40	28.57
*“*Aporrhais*” *dutrugei*	2.49	28.57
**Tylostoma* (*Tylostoma*) *cossoni*	2.36	42.85
**Pterodonta deffisi*	2.36	57.14
**Protocardia hillana*	2.36	42.85
**Actinostromarianena* sp.1	2.23	28.57
**Tortoflabellum* sp.	1.96	14.28
**Aspidiscus cristatus*	1.96	14.28
**Pholadomya vignesi*	1.96	14.28
**Pchelinsevia coquandiana*	1.96	42.85
**Harpagodes heberti*	1.70	28.57
Pseudolima itieriana	1.57	28.57
Modiolus (*Modiolus*) *aequalis*	1.44	42.85
Chondrodonta joannae	1.31	28.57
Tylostoma (*Tylostoma*) *pallaryi*	1.05	28.57
Lucina fallax	0.79	14.28
Ichthyosarcolites sp.	0.79	28.85
Cimolithium tenouklense	0.65	14.28
Arctica? *inornata*	0.65	28.57
Praeradiolites biskraensis	0.65	14.28
Toucasia? *matheroni*	0.65	28.57
Plicatula (*P.*) *auressensis*	0.65	14.28
Curvostrea rouvillei	0.65	14.28
Ampullina (*Ampullina*) *abeihensis*	0.52	28.57
Venericardia? *forgemoli*	0.52	14.28

Nayadina (*Nayadina*) *gaudryi*	0.52	28.57
Phelopteria gravida	0.52	14.28
Pyrazus valeriae	0.39	14.28
Hemiaster (*Mecaster*) *pseudofourneli*	0.39	14.28
Tetragramma variolare	0.39	14.28
Praeradiolites sp.	0.39	14.28
Caricella? sp.	0.26	14.28
Turritella cf. *difficilis*	0.26	14.28
Sinaecidaris cf. *gauthieri*	0.26	14.28
Clisocolus corrugatus	0.26	14.28
Ambigostrea pseudovillei	0.26	14.28
Phelopteria atra	0.26	14.28
Nucula (*Nucula*) *margaritifera*	0.26	14.28
Neoptyxis olisiponensis	0.13	14.28
?*Pterodonticeras germeri*	0.13	14.28
Cerithium cf. *mogharense*	0.13	14.28
Hemiaster (*Mecaster*) cf. *newtoni*	0.13	14.28
Anorthopygus orbicularis	0.13	14.28
Coenholectypus portentosus	0.13	14.28
Pedinopsis desori	0.13	14.28
Codiopsis sp.	0.13	14.28
bivalve gen. et. sp. ind.	0.13	14.28
Glossus aquilinus	0.13	14.28
Protocardia? *regulare*	0.13	14.28
Granocardium (*G.*) *carolinum*	0.13	14.28
Corbula (*Corbula*) sp.	0.13	14.28
Exogyra conica	0.13	14.28
Nuculana (*Nuculana*) sp.	0.13	14.28

(6) *Ceratostreon flabellatum/Hemiaster* (*Hemiaster*) *gabrielis* association

5 samples, 370 individuals, 34 taxa

Species	Rel. abund.%	Pres.%
**Ceratostreon flabellatum*	43.51	100
**Hemiaster* (*Hemiaster*) *gabrielis*	20.54	80
**Rhynchostreon suborbiculatum*	5.14	60
**Meretrix orientalis*	3.24	20
*“*Aporrhais*” *dutrugei*	2.97	40
**Tenea delettrei*	2.16	60
**Harpagodes heberti*	1.89	20
**Pterotrigonia* (*S.*) *scabra*	1.89	20
“Strombus” incertus	1.35	20
Hemiaster (*H.*) *syriacus*	1.35	20
Paraesa faba	1.35	20
Inoperna flagellifera	1.35	20
Tylostoma (*Tylostoma*) *pallaryi*	1.08	20
Columbellina (*C.*) *fusiformis*	1.08	40
Exogyra conica	1.08	20
Acteon ? sp.	0.81	20
Cimolithium tenouklense	0.81	20
Arctica? *Picteti*	0.81	20
“*Ichthyosarcolites*” sp.	0.81	20
Modiolus (*M.*) *aequalis*	0.81	20
Globiconcha cf. *rotundata*	0.54	20
Tylostoma (*T.*) *cossoni*	0.54	20
Pterodonta deffisi	0.54	20
Coenholectypus larteti	0.54	20
Glossus aquilinus	0.54	40
Venericardia? *forgemoli*	0.54	20
Praeradiolites sp.	0.54	20
Nucula (*N.*) *margaritifera*	0.54	40

Ampullina (*Ampullina*) cf. *quaasi*	0.27	20
Coenholectypus portentosus	0.27	20
Arctica? *rostrata*	0.27	20
Granocardium (*G.*) *productum*	0.27	20
Neithea (*Neithea*) *quinquecostata*	0.27	20
Pinna (*Pinna*) sp.	0.27	20

(7) *Costagyra olisiponensis/Ceratostreon flabellatum* association
2 samples, 179 individuals, 13 taxa

species	Rel. abund.%	Pres.%
**Costagyra olisiponensis*	70.39	100
**Ceratostreon flabellatum*	11.17	50
Plicatula (*P.*) *auressensis*	5.59	50
Hemiaster (*H.*) *syriacus*	3.35	50
“Strombus” incertus	1.68	50
Paraesa faba	1.68	50
Curvostrea rouvillei	1.68	50
Harpagodes heberti	1.12	50
Pholadomya pedernalis	1.12	50
Pterodonta cf. *subinflata*	0.56	50
Gentilia syriensis	0.56	50
Cardita? *nicaisei*	0.56	50
Neithea (*N.*) *coquandi*	0.56	50

(8) *Rhynchostreon suborbiculatum* association
3 samples, 367 individuals, 10 taxa

species	Rel. abund.%	Pres.%
**Rhynchostreon suborbiculatum*	91.83	100
Gyrostrea delettrei	4.90	66.66
Ceratostreon flabellatum	1.36	66.66
Mytiloides concentricus	0.27	33.33
Ilymatogyra africana	0.27	33.33
Lopha syphax	0.27	33.33
Osteomya sp.,	0.27	33.33
Pygurus cf. *subproductus*	0.27	33.33
Hemiaster (*Hemiaster*) *syriacus*	0.27	33.33
Tylostoma (*Tylostoma*) *pallaryi*	0.27	33.33

(9) *Chondrodonta joannae* association
3 samples, 174 individuals, 3 taxa

species	Rel. abund.%	Pres.%
**Chondrodonta joannae*	91.95	100
Tortoflabellum sp.	7.47	66.66
Neoptyxis olisiponensis	0.57	33.33

(10) *Ilymatogyra africana* association
5 samples, 1055 individuals, 19 taxa

species	Rel. abund.%	Pres.%
**Ilymatogyra africana*	84.83	100
Ceratostreon flabellatum	5.78	80
Paraesa faba	2.84	20
Rhynchostreon suborbiculatum	1.61	60

Pyrazus valeriae	1.23	20
Tenea delettrei	0.47	20
Ambigostrea pseudovillei	0.47	20
Curvostrea rouvillei	0.47	20
Exogyra conica	0.38	20
Heterodiadema libycum	0.28	20
Coronatica cf. *ornate*	0.19	20
Poromya? *ligeriensis*	0.19	20
Neithea (*Neithea*) *quinquecostata*	0.19	20
Gyrostrea delettrei	0.19	20
Pycnodonte (*P.*) *vesicularis*	0.19	20
Vesiculosa	0.19	20
Pseudolima itieriana	0.19	20
Phelopteria gravida	0.19	20
Arca (*Idonearca*) *diceras*	0.19	20
Ampullina (*Ampullina*) *abeihensis*	0.09	20

Composition of assemblages from the Cenomanian-Turonian succession of eastern Sinai, Egypt

(A) *Praeradiolites biskraensis* assemblage

1 sample, 159 individuals, 14 taxa

species	Rel. abund.%
**Praeradiolites biskraensis*	49.06
**Pchelinsevia coquandiana*	15.72
**Chondrodonta joannae*	13.21
**Nucula* (*Nucula*) *margaritifera*	5.03
Glossus aquilinus	4.40
Actinostromarianena sp.2	2.52
Neithea (*Neithea*) *dutrugei*	2.52
Pyrazus valeriae	1.89
Ceratostreon flabellatum	1.89
Pterodonta deffisi	1.26
Akera thevestensis	0.63
Neritopsis sp.	0.63
Venericardia? *Forgemoli*	0.63
Pterotrigonia (*S.*) *scabra*	0.63

(B) *Sogdianella*? sp. /*Cerithium*? sp. assemblage

1 sample, 133 individuals, 5 taxa

species	Rel. abund.%
**Sogdianella*? sp.	43.61
**Cerithium*? sp.	37.60
Granocardium (*G.*) *productum*	15.03
Coenholectypus larteti	2.25
Tylostoma (*Tylostoma*) *globosum*	1.50

(C) *Gyrostrea* cf. *anubis* assemblage

1 sample, 29 individuals, 5 taxa

species	Rel. abund.%
**Gyrostrea* cf. *anubis*	68.96
**Pycnodonte* (*P.*) *vesicularis Vesiculosa*	10.35
**Gyrostrea delettrei*	10.35
Tylostoma (*Tylostoma*) *cossoni*	6.89
Phelopteria gravida	3.44