Integrated stratigraphy, palaeontology and facies analysis of the Cenomanian – Turonian (Upper Cretaceous) Galala and Maghra El Hadida formations of the western Wadi Araba, Eastern Desert, Egypt

Dissertation zur Erlangung des
Naturwissenschaftlichen Doktorgrades
der Bayerischen Julius-Maximilans-Universität Würzburg

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WÜRZBURG, 2009

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Abstract

Four sections of the Galala and Maghra El Hadida formations on the footwalls of the slopes of the northern and southern Galala plateaus in Wadi Araba (Eastern Desert) have been measured and sampled in great detail. The Galala Formation is ranging in thickness from 55 to 95 meters. It unconformably overlies the Malha Formation which forms the base of the studied sections. The upper boundary of the Galala Formation is characterized by a major unconformity which separates it from the overlying the Maghra El Hadida Formation. The Galala Formation can be subdivided into five shallowing-upward cycles, each cycle starting with deep-lagoonal, marly-silty deposits at the base and grading into highly fossiliferous shallow-lagoonal limestones at the top. Only the basal part of the Galala Formation consists of unfossiliferous, greenish sandy siltstones intercalated with thin cross-bedded, bioturbated, fine- to medium-grained sandstones. Despite the lack of biostratigraphic markers in that lower part, its age can be assigned to the late Middle Cenomanian, since the conformably overlying strata contain the ammonite *Neolobites vibrayeanus* (D'ORBIGNY), the index marker of the early Upper Cenomanian which extends into the top of the formation. The measured thickness of the overlying Maghra El Hadida Formation is ranging from 59 to 118 meters. This formation starts with the Ghonima Member, introduced in this work to distinguish a brown, fine- to medium-grained calcareous sandstone unit in its lower part. The Ghonima Member is erosionally incised into the Galala Formation, explaining its strong lateral variability in thickness, ranging from 3 to 21 meters. It is mostly unfossiliferous except for irregular bioturbation in its upper part. The Ghonima Member is assigned to the middle Upper Cenomanian, based on its stratigraphic position between the lower Upper Cenomanian *Neolobites vibrayeanus* Zone and the overlying upper Upper Cenomanian *Metoicoceras geslinianum* and *Vascoceras cauvini* zones. This means that the lower part of the Maghra El Hadida Formation, about 20 – 30 m thick, accumulated during the latest Cenomanian and that the base of the formation does not coincide with the base of the Turonian as commonly believed. The overlying succession of the Maghra El Hadida Formation is characterized by an increase of carbonate content, represented by yellow, soft marls intercalated with fine-grained wacke- to packstones containing a highly fossiliferous ammonite assemblage of the upper Upper Cenomanian and Lower Turonian (zones of *Vascoceras proprium*, *Choffaticeras* spp., and *Wrightoceras munieri*). The Middle Turonian part of the Maghra El Hadida Formation consists of poorly fossiliferous, thick-bedded yellowish marls with upward-increasing silt content, showing occasional intercalations of medium- to coarse-grained sandstones with hummocky cross-stratification. The topmost part of the Maghra El Hadida Formation consists of brownish, medium-grained sandstones topped by fossiliferous marly limestones yielding the Upper Turonian zonal ammonite *Coilopoceras requienianum* (D'ORBIGNY).

Based on sequence stratigraphic analyses, four complete 3rd order depositional sequences and the lower part of a fifth one, each bounded by major unconformities, can be recognized: depositional sequence DS WA 1 (upper Middle – lower Upper Cenomanian) includes the entire Galala Formation, while the Maghra El Hadida Formation comprises all the overlying depositional sequences: DS WA 2 (upper Upper Cenomanian – Lower Turonian) reaches from the base of the *Metoicoceras geslinianum* Zone to the top of *Wrightoceras munieri* Zone, DS WA 3 and DS WA 4 comprise the Middle Turonian, while Upper Turonian sequence DS WA 5 is not complete. The stratigraphic positions of the recognized sequence boundaries SB WA 1 to SB WA 5 match well with contemporaneous sequence boundaries known from Europe and elsewhere.

The stacking pattern of the basic cycles and bundles of the Galala Formation (5:1) and the Maghra El Hadida Formation (4:1) strongly suggest an orbital forcing by MILANKOVITCH periodicities. The Galala Formation is composed of five 5th-order bundles which equal to ~500 kyr, each bundle equals to ~100 kyr (short eccentricity). Every bundle has five basic (6th-order) cycles, each one representing ~20 kyr (precession). Based on this precession-short eccentricity syndrome, the accumulation rate of the Galala Formation therefore accounts for about 19 cm/kyr. The rate of sea-level fall at sequence boundary SB WA 2 (equivalent to the quasi-global mid-Late Cenomanian SB Ce V) estimated is with 35 cm/kyr which can be explained only by glacio-eustasy. The Upper Cenomanian and Lower Turonian part of the Maghra El Hadida Formation is considered to equal to ~1200 kyr, based on the existence of three 4th-order bundles with an inferred duration of ~400 kyr for each bundle (long eccentricity of the MILANKOVITCH Band). Every bundle consists of four basic cycles with a duration of ~100 kyr. This means that the upper Cenomanian part of the Maghra El Hadida Formation is equivalent to ~400 kyr, while the Lower Turonian (consisting of the two upper bundles) lasted 800 kyr. This matches well with the recently proposed 785 kyr duration of the Early Turonian (SAGEMAN et al., 2006; VOIGT et al., 2008) and contradicts the 1300 kyr according to the standard time scale of GRADSTEIN et al. (2004). According to this temporal constrains, the accumulation rate of the Maghra El Hadida Formation is about 4.25 cm/kyr. In addition, based on the cyclostratigraphic analysis, the range of the Early Turonian genus *Choffaticeras* (HYATT) is equivalent to ~325 kyr and morphological changes within its lineage can be quantified.

The macrobenthos (bivalves, gastropods, echinoids) and cephalopods of the Galala and Maghra El Hadida formations were identified and illustrated in 24 figures. The ammonite taxonomy and palaeobiogeographic distribution is discussed in detail. Four genera and eight ammonite species are recorded from Egypt for the first time. The microfloral and -faunal assemblage identified in thin sections revealed two species of dasycladalean algae, two species of udoteacean algae, five species of benthic foraminifera, and two species of crustacean microcoprolites.

The six facies types of the upper Middle – Upper Cenomanian Galala Formation document largely open-lagoonal, warm water conditions, while the depositional environment of the Upper Cenomanian – Turonian Maghra El Hadida Formation (16 facies types) is suggested to range from a deep-subtidal to intertidal.

Key words: *Cenomanian, Turonian; biostratigraphy, sequence stratigraphy, cyclostratigraphy; macrobenthos, ammonites; facies analysis; Egypt.*

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PART I
GENERALITIES

1. Introduction

The Upper Cretaceous sediments are well exposed in the Wadi Araba area which is located in the northern part of the Eastern Desert of Egypt (Text-fig. 1.1). Some important works on litho- and biostratigraphy of the Cenomanian – Turonian successions in Wadi Araba area have already been published (e.g. FOURTAU, 1900, 1904, HUME 1911, ABDALLAH & ADINDANI 1963, AWAD & ABDALLAH 1966, and HEWAIDY et al. 2003). However, only a few detailed approaches have been included in these works and most attention has been paid to the eastern part of Wadi Araba area (close to the Gulf of Suez), where the successions are easily accessible.

Text-fig. 1.1. Geographic position of Egypt. The rectangle indicates the study area.

1.1. Aim of the study

This study aims to fill the gap of information on the western part of Wadi Araba (north Eastern Desert) and introduce more details on the Galala and Maghra El Hadida formations (Cenomanian – Turonian) in this area in order to enhance the knowledge on the lateral facies variability and age of the units by means of high-resolution integrated stratigraphy (ammonite biostratigraphy, lithostratigraphy, sequence stratigraphy, and cyclostratigraphy). Furthermore, the reconstruction of the depositional environments based on detailed bed-by-bed logging, sampling, and succeeding analysis of litho-, bio-, and microfacies is attempted.

1.2. Material and methods

Two sections from Wadi Ghonima area (northern slope of the Southern Galala Plateau in the western part of Wadi Araba) were measured in great detail, where the most complete Cenomanian – Turonian successions are well exposed. The Wadi Askhar section (southern slope of the Northern Galala Plateau) and the Saint Anthony section (northern slope of the

Southern Galala Plateau) are also included in the present study. The focus of this work is on the Wadi Ghonima sections, because the Wadi Askhar section is more faulted and not easy to reach, and the Cenomanian – Turonian sediments are much thinner at Saint Anthony. The macrofossils were collected bed-by-bed from the studied sections, cleaned, identified, described, discussed, and illustrated. The palaeobiogeographic distribution of the identified ammonites is discussed. The stratigraphic distribution of the identified ammonites was used for biostratigraphic classification of the studied successions. The description and interpretation of the various microfacies types is used to interpret the depositional environments. Furthermore, sequence- and cyclostratigraphy are used to recognize the depositional sequences and orbital forcing in order to enhance the stratigraphical resolution and the time scale for the Cenomanian – Turonian successions in the study area.

1.3. Previous studies

The history of stratigraphical and palaeontological investigations of the Upper Cretaceous of the north Eastern Desert started with FOURTAU (1900). He divided the Cretaceous beds on the southern slopes of the Northern Galala Plateau into: Nubian Sandstones of Early Cretaceous age, Cenomanian beds, and limestones with *Ostrea vesicularis* COQUAND of Campanian age. In 1904, he described the Cenomanian sequence of Wadi Askhar as marly sandstones characterized by *Neolobites fourtaui* PERVINQUIÈRE at the base followed by yellow marls and marly limestones with masses of *Ostrea africana* LAMARCK at the top. HUME (1911) described the Turonian sediments at Wadi Qena and neighbouring Wadi Abu Had, Tarfa and Hawashia (southern part of north Eastern Desert) as “Limestones rich in ammonites”. These limestones occur in many localities south of the Galala hills and are of Early Turonian age.

FAWZI (1959) considered the echinoid *Hemiaster cubicu*s DESOR as a index fossil for the Cenomanian beds in Wadi Araba. ABDALLAH & ADINDANI (1963) introduced the Galala Formation to describe the Cenomanian sediments at the Galala Massif, west Gulf of Suez. AWAD & ABDALLAH (1966) described the Cenomanian Galala Formation in Southern Galala as shale with fossiliferous marls at the base and limestones at the top, while the Turonian is characterized by dolomitic lithology, its lowermost part being highly fossiliferous and marked by the occurrence of an ammonite bed. EL AKKAD & ABDALLAH (1971) introduced the Maghra El Hadida Formation to described the Turonian sediments at Gebel Ataqa, Eastern Desert.

LUGER & GRÖSCHKE (1989) described the ammonite content of the Upper Cenomanian to Upper Campanian of Wadi Qena, Eastern Desert with comments of its stratigraphic distribution. The first biostratigraphic classification for the Cenomanian – Turonian successions of the southern part of the north Eastern Desert has been introduced by KASSAB (1991). According to KUSS (1992), the Cenomanian – Turonian strata of the Eastern Desert are dominated by carbonates in the northern areas and mixed siliciclastic limestones and sandstones in southern areas. After the work of FOURTAU (1900, 1904) on the west Wadi Araba, the only recent paper on the litho- and biostratigraphy of this area was published by HEWAIDY et al. (2003). They proposed one ammonite zone in the Cenomanian Galala Formation and five ammonite zones in the Turonian Maghra El Hadida Formation.

The most important lithostratigraphic works on the north Eastern Egypt (where the Cenomanian – Turonian sediments are exposed) are summarized in Table 1.1. The correlation between the rock units used in this study and those works will be discussed latter in chapter lithostratigraphy (Discussion part).

Despite the studies mentioned above, very little details are available about the facies, depositional environment, sedimentary sequences and cyclicity of the Cenomanian and Turonian successions of north Eastern Desert, in general, and west Wadi Araba, specifically.

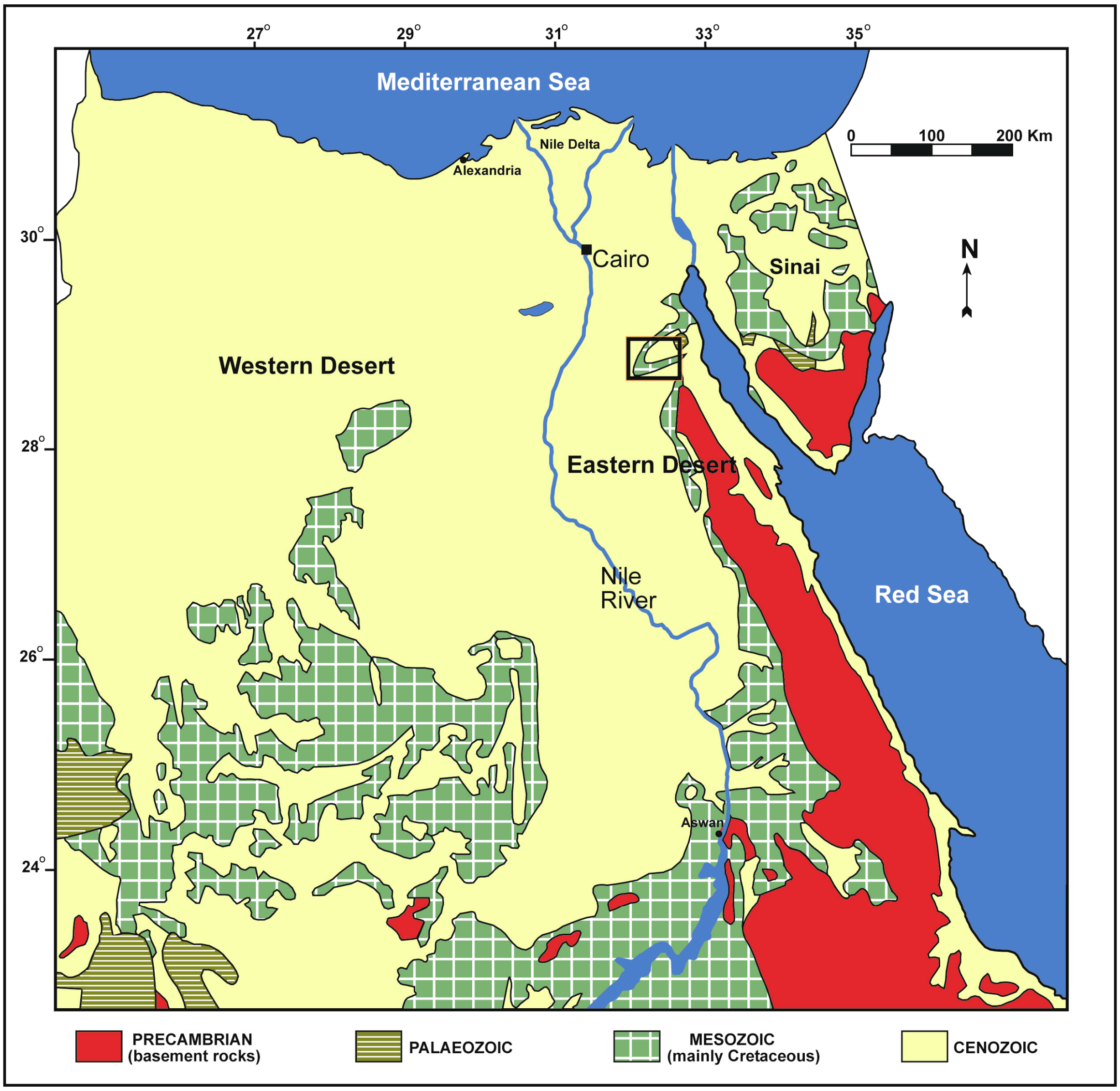
Table 1.1. Lithostratigrapahic classification used by different authors for the Cenomanian – Turonian of the north eastern Egypt.

	Age →	Turonian			Cenomanian		
	Previous studies	Upper	Middle	Lower	Upper	Middle	Lower
Sinai	Bartov et al. 1980	Gerofit Fm.		Ora Fm.	Hazera Fm.		
Sinai	Kora & Hamama 1987; Abdel-Gawad et al. 1992	Wata Fm.			Raha Fm.		
Sinai	Cherif et al. 1989; Orabi 1993	Wata Fm.		Abu Qada Fm.	Raha Fm.		
Sinai	Ziko et al. 1993	Wata Fm.			Galala Fm.		
Sinai	Kora & Genedi 1995	Wata Fm.		Abu Qada Fm.	Raha Fm.		
Sinai	Abdallah et al. 1996	Wata Fm.			Halal Fm.		
Sinai	Abed et al. 1996	Wata Fm.	Abu Qada Fm.		Halal Fm.		
Sinai	Abdel-Gawad 1999	Wata Fm.	Abu Qada Fm.		Raha Fm.		
Sinai	Issawi et al. 1999	Wata Fm.	Buttum Fm.	Abu Qada Fm.	Galala Fm.		
Sinai	Aly & Abdel-Gawad 2001	Wata Fm.	Buttum Fm.	Abu Qada Fm.	Raha Fm.		
Sinai	Bauer et al. 2001; 2002	Wata Fm.	Abu Qada Fm.		Raha Fm.		
North Eastern Desert	Ghorab 1961	Wata Fm.			Abu Qada Fm.	Raha Fm.	
North Eastern Desert	Abu Khadra et al. 1987	Wata Fm.			Galala Fm.		
North Eastern Desert	Ismail 1991	Wata Fm.	Abu Qada Fm.		Raha Fm.		
North Eastern Desert	Kassab 1996 (Galala Group)	Wata Fm.		Abu Qada Fm.	Raha Fm.		
North Eastern Desert	Galal et al. 2001	Umm Omeiyid Fm.	Wata Fm.	Abu Qada Fm.			Raha Fm.
North Eastern Desert	Elakkad & Abdallah 1971; Issawi et al. 1999; Hewaidy et al. 2003	Maghra El Hadida Fm.			Galala Fm.		

2. Geologic setting

Egypt lies in the northern part of the African-Arabian Plate and provides rocks from almost all geologic periods of earth history. The basement rocks are extensively developed on the eastern side of the country forming the mountain ranges known as the Reds Sea Hills (Text-fig. 2.1). They pass westward beneath a cover of Phanerozoic sediments to emerge again patchily at the surface in several massifs in the southern part of the Western Desert. Other exposures of the Basement complex are widely distributed in southern Sinai. The Basement complex of Egypt is a part of a huge ancient fold belt, forming the Arabian-Nubian Shield.

The regional distribution of the Palaeozoic strata in Egypt shows that there is a restricted thick sequence of these strata in the southwest, while a thinner sequence prevails in the eastern part of Egypt. The Mesozoic is represented by few outcrops of marine Triassic and Jurassic strata in north eastern Egypt, while Cretaceous rocks cover about 40% of the surface area of Egypt (Text-fig. 2.1). The Upper Cretaceous forms the bulk of these rocks and is well exposed in Sinai and the north Eastern Desert (where the study area is located). Tertiary rocks are the most widespread rocks in Egypt and represented by carbonate facies of Palaeogene and clastic facies of Neogene age. A geologic overview of Egypt is shown in Text-fig. 2.1.

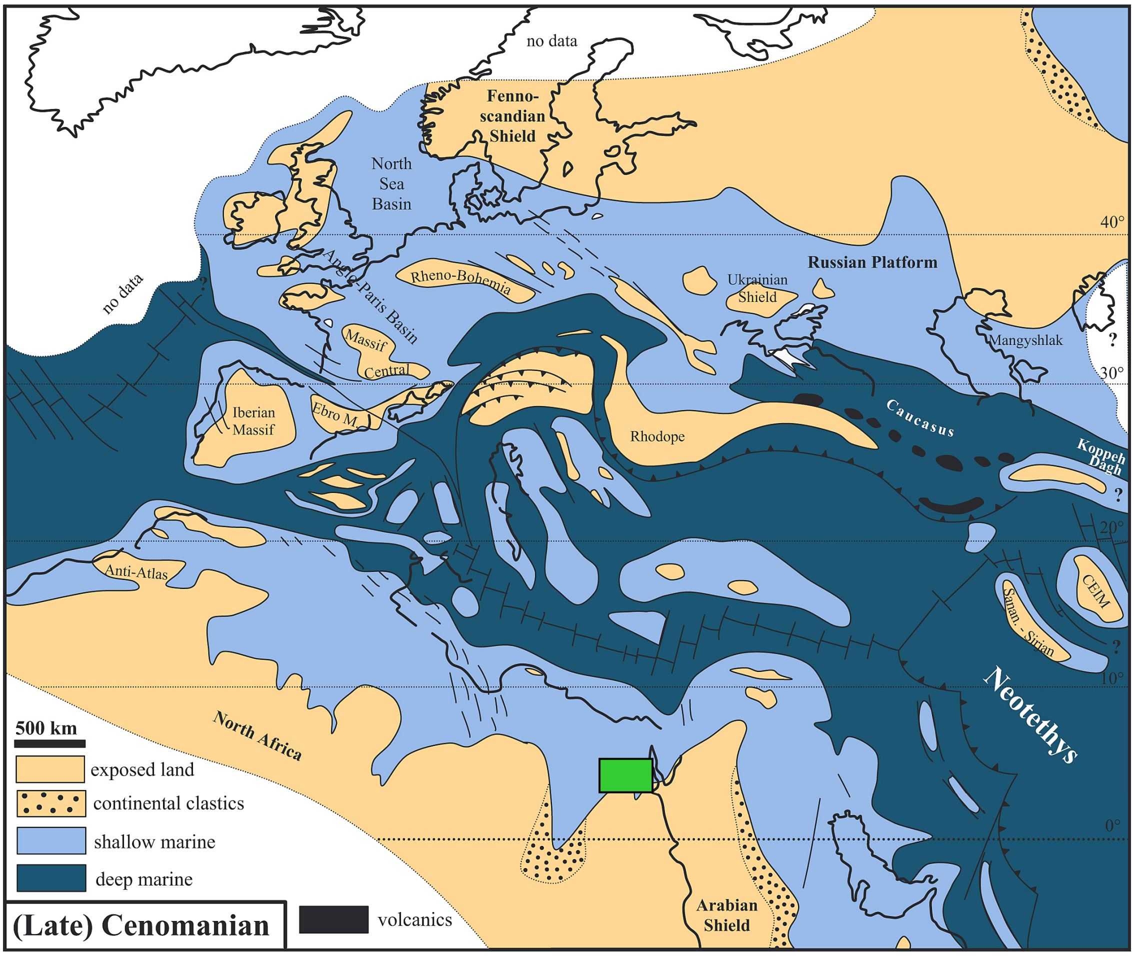


Text-fig. 2.1. Geological map of Egypt (modified after CONOCO, 1987). The rectangle indicates the study area.

2.1. Palaeogeography

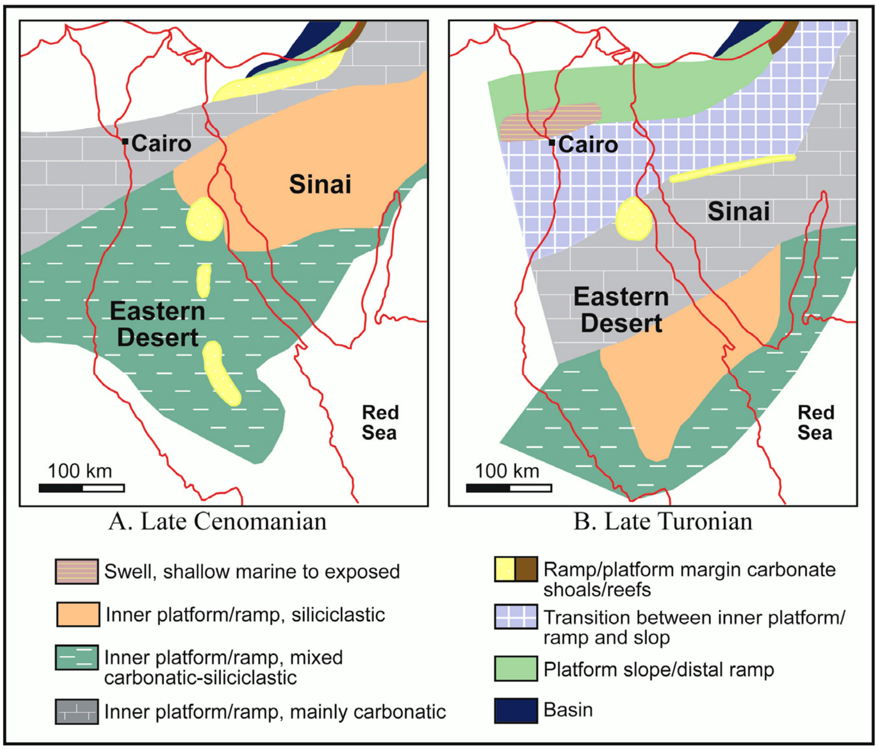
In Cretaceous times, Egypt was situated at the southern margin of the Neotethys Ocean (Text-fig. 2.2). The first major marine transgression in the Cretaceous occurred during the Aptian in response to a world-wide rise in sea-level (SAID, 1990). During the Early Cretaceous, only the northernmost edges of Egypt are covered by fluvio-deltaic sandstones, interfingering with shallow marine ramp deposits of Aptian age. The Albian sea encroached further south due to the rising of sea-level, resulting in conformable Aptian-Albian successions in northern Sinai, while in the south, the Albian sequences unconformably onlap Aptian and pre-Aptian siliciclastics (KUSS & BACHMANN, 1996).

During the Cenomanian, the ongoing rise of the sea-level corresponds to a Tethyan-wide highstand (PHILIP et al., 1993). As a consequence, Cenomanian strata cover extended areas in Egypt comprising marine siliciclastics, mixed with carbonates or interfingering with pure limestones (Text-fig. 2.3a). The Late Cenomanian shelf facies of the Eastern Desert and northern Sinai is characterized by a rich assemblage of benthic foraminifera and ammonites of the genera *Neolobites* and *Vascoceras* (KUSS & MALCHUS, 1989). During the following Early Turonian relative sea-level rise, the exposed areas were flooded, and large parts of the platform were drowned (Text-fig. 2.3b). This is documented by condensed deep-water deposits in the study area, which include ammonites and planktonic foraminifera. In the Eastern Desert, shallow-marine, siliciclastic and terrestrial conditions prevailed during the relative sea-level lowstand across the Turonian – Coniacian boundary (BAUER et al., 2003).



Text-fig. 2.2. Palaeogeographic map of the Late Cenomanian after PHILIP & FLOQUET (2000).
The green rectangle indicates the study area.

With the end of Coniacian, a slow regression of the sea took place and fine-grained clastic sedimentation was common. Thus, Upper Coniacian sediments are restricted to few northerly exposures in Egypt. The regression period during the Late Santonian resulted in spatially limited deposition in north Egypt. In Campanian times, an increasing subsidence is obvious, creating southward prograding onlap of siliciclastic shelf sediments and subordinate carbonates. These Campanian deposits are widely distributed into southern Egypt (KUSS & BACHMANN, 1996). By the end of the Cretaceous, during the Maastrichtian, the transgression reached further to the south and covered wide areas mostly with thick chalk-marl units, shale, and subordinate silts of deeper shelf origin (SAID, 1990).



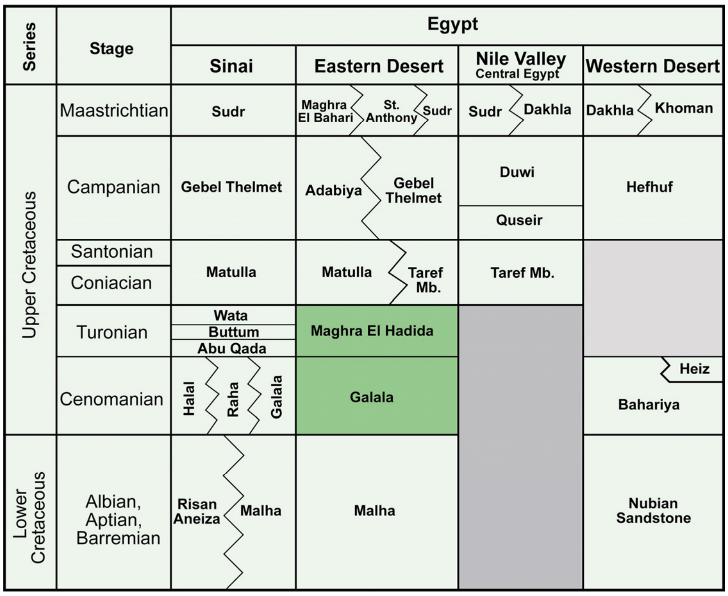
Text-fig. 2.3. Palaeogeographic maps for the Cenomanian – Turonian environments of deposition (after KUSS and BACHMANN, 1996).

2.2. Stratigraphy

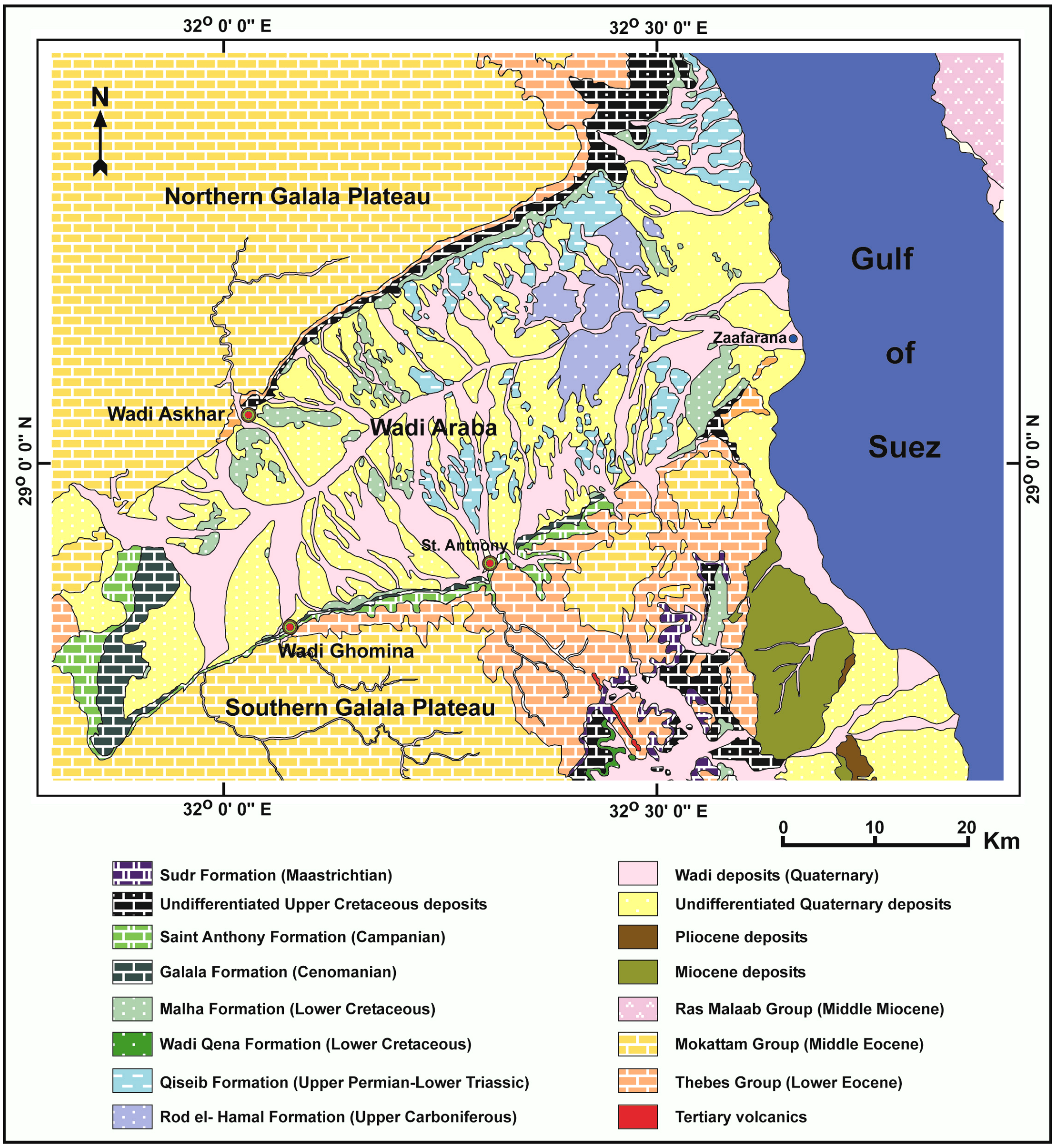
2.2.1. Lithostratigraphy

Pronounced facies changes during the Cretaceous are observed in Egypt as different successions are represented in different provinces. As a consequence, the Cretaceous sedimentary exposures of Egypt have been subdivided into several facies zones (SAID, 1962, 1990; ISSAWI et al., 1999). Each facies zone has characteristic rock units that differs in part from the adjacent facies zone, although some formations may be occur in two or more areas (Text-fig. 2.4).

In the north Eastern Desert (where the study area is located), the Cretaceous sediments characterize the area north of latitude 27° 25′ N and extends northward to 30° 19′ N (ISSAWI et al., 1999). In this stretch, about 300 km long, the Cretaceous rocks crop out at Southern Galala, Northern Galala, Gebel Ataqa, and Gebel Shabrawet, from south to north, respectively. The present work is focused on the southern part of this facies zone (Text-fig. 2.5). A brief description of the Cretaceous units exposed in the north Eastern Desert is given below.



Text-fig. 2.4. Stratigraphic framework of Cretaceous rocks in Egypt (modified after SAID, 1990 and ISSAWI et al., 1999). All rock units in formation rank. The present work deals with the Cenomanian – Turonian (Galala and Maghra formation) at the north Eastern Desert.

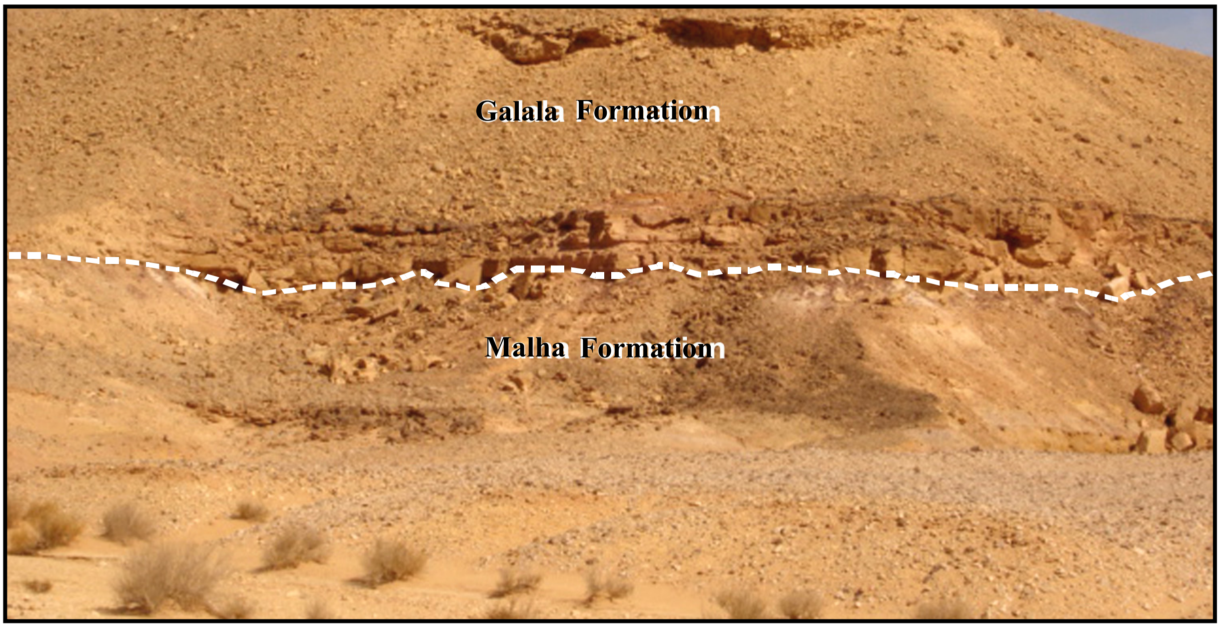


Text-fig. 2.5. Geological map of the study area (modified after CONOCO, 1987).

Malha Formation

The alluvial, hard to friable, varicoloured sandstone unit which overlies unconformably the Permo-Triassic or Jurassic sediments in the western coast of the Gulf of Suez and Sinai was named the Malha Formation by ABDALLAH & ADINDANI (1963). The thickness of this Formation varies greatly from place to place. It reaches 130 m in the Gulf of Suez area. The Malha Formation is non-fossiliferous although in Wadi Malha (Gulf of Suez region) and along the entrance of Wadi Qena, it is intercalated in its upper part by thin fossil-bearing marl beds of Albian age (SAID, 1990). The Malha Formation is exposed in the north Eastern Desert at Gebel Shabrawet, Northern Galala, Southern Galala, and along the upstream course of Wadi Qena.

In the study area, the Malha Formation constitutes the base of all studied sections and underlies the Galala Formation with no major break in sedimentation (Text-fig. 2.6). The exposed part of the Malha Formation is brownish, medium- to coarse-grained sandstone with bioturbation in its upper part.



Text-fig. 2.6. Malha Formation overlain by the Galala Formation, Wadi Askhar section.

Galala Formation

The Galala Formation consists of varicoloured, gypsiferous shale, marls and marly limestones of Cenomanian age and overlies the Malha Formation with no major break in sedimentation in the north Eastern Desert and central Sinai (ABDALLAH & ADINDANI, 1963). This unit is more calcareous in north Sinai and named Halal Formation, while it is more clastic in south Sinai and named Raha Formation (SAID, 1990). The thickness of this Formation varies greatly from one place to another and reaches up to 170 m in the Gulf of Suez area and 200 m in Sinai. The fauna collected from the Galala Formation assigns the formation to the Cenomanian (ISSAWI et al., 1999). The Galala Formation in the north Eastern Desert is characterized by sequences of compact limestones, marl, marly limestones and siliciclastics deposited in an inner shelf environment (AL AHWANI, 1982).

In the study area, the Galala Formation has been measured in all studied sections. It overlies the Malha Formation and underlies unconformably the Maghra El Hadida Formation. It attains 62 m at Wadi Ghonima section, 95 m at East Wadi Ghonima section, 85 m at Wadi Askhar section, and about 55 m at Saint Anthony section. Generally, the Galala Formation in the study area (Text-fig. 2.7) consists of siltstone with few sandstone intercalations in its lower part followed by repeated cycles of marly-silt sediments grading into shallow marine fossiliferous limestones.

Text-fig. 2.7. The Cenomanian Galala Formation at Wadi Ghonima section.

Maghra El Hadida Formation

The Turonian sediments are represented in the north eastern Egypt by three distinct formations: Abu Qada, Buttum, and Wata (ISSAWI et al., 1999). These formations are well represented in Sinai in and some parts of the north Eastern Desert, while, at the Galala plateaus, the three units are classified under the name Maghra El Hadida Formation (142 m thick) which consists of alternating limestone, marl and sandstone beds (EL AKKAD & ABDALLAH, 1971). The Turonian lithofacies and fossil content of this formation point to environments ranging from deep to shallow marine conditions (ISSAWI et al. 1999).

In the study area, the Maghra El Hadida Formation has been measured in all studied sections, albeit often incompletely. It overlies the Galala Formation and underlies the Matulla Formation. It attains about 82 m at Wadi Ghonima section (incomplete), 118 m at East Wadi Ghonima section (incomplete), 60 m at Wadi Askhar section, and about 59 m at Saint Anthony section. In general, the Maghra El Hadida Formation in the study area (Text-fig. 2.8) mainly consists of a sandstone unit at base, followed by argillaceous limestones intercalated with fossiliferous, hard limestones at the middle part, and a sequence of limestones and marls at the top, with some sandstone intercalations.

Text-fig. 2.8. Uppermost Cenomanian – Turonian Maghra El Hadida Formation, Wadi Ghonima section.

Matulla Formation

At the north Eastern Desert (Southern Galala Plateau and north Wadi Qena) the Coniacian – Santonian is represented by the Matulla Formation which was introduced by GHORAB (1961). It attains about 170 m thick in its type locality (Wadi Matulla, west-central Sinai). The Matulla Formation is made up of three units: a lower, 80 m thick unit of fluvial, cross bedded sandstones with thin argillaceous limestone and shale interbeds; a middle, 58 m thick unit of varicoloured glauconitic shale with thin limestone interbeds; and an upper, 32 m thick unit of chalky limestone with few glauconitic shale interbeds (SAID, 1990).

The sea urchins and oysters recoded in the Matulla Formation indicate deposition in littoral to inner neritic zones. This formation is well exposed in Sinai, where it overlies the Wata Formation in many exposures. In the north Eastern Desert, the Matulla Formation overlies unconformably the Maghra El Hadida Formation and underlies the Gebel Thelmet Formation. It is represented by few exposures in the northern part, while, in southern part, the facies changes to cross-bedded, dark-brown sandstone with intercalations of grey shale named Taref Member (ISSAWI et al. 1999).

Gebel Thelmet Formation

The yellow, argillaceous, highly fossiliferous limestones (partially dolomitic and phosphatic) with thin shale and sandstone interbeds which reach 225 m in thickness of Campanian age of the Thelmet area (Southern Galala) have been named Gebel Thelmet Formation by ABDALLAH & EISSA (1971). Further to the north, in the Ataqa area, the

Campanian strata consist of 235 m of poorly fossiliferous dolomites and limestones, named Adabiya Formation by EL AKKAD &ABDALLAH (1971).

Sudr Formation

The Maastrichtian deposits are widely distributed in north Egypt. They represented by snow-white, chalky limestones named Sudr Formation (GHORAB, 1961) in Sinai and the Southern Galala Plateau. In these areas, it overlies the Gebel Thelmet Formation and reaches up to 250 m in thickness. Further to the east, the Maastrichtian is represented by 190 m of chalky limestones, marl and sandstones at the monastery of Saint Anthony. This unit was named by BANDEL & KUSS (1987) as St. Anthony Formation. In the Ataqa area (north Eastern Desert), the Campanian Adabiya Formation is followed by Maghra El Bahari Formation of Maastrichtian age, consisting of 80 m of sandstones with minor marl, limestone and conglomerate bands (EL AKKAD &ABDALLAH, 1971).

2.2.2. Biostratigraphy

The Upper Cretaceous in north eastern Egypt is well exposed and fossiliferous. It yields a rich macrofauna at many localities in the Eastern Desert and Sinai. Most of the biostratigraphic works which have been published on these successions are based on bivalves, gastropods, and echinoids. The Cenomanian – Turonian ammonites have been reported in the general stratigraphic works of FOURTAU (1904), HUME (1911), DOUVILLÉ (1928), SAID (1962), ABDALLAH & ADINDANI (1963), AWAD & ABDALLAH (1966), and MAZHAR et al. (1979). In the last twenty years, numerous works used ammonites for biozonation of the Cenomanian – Turonian succession in the north eastern Egypt. The results of these works are summarized in Table 2.1.

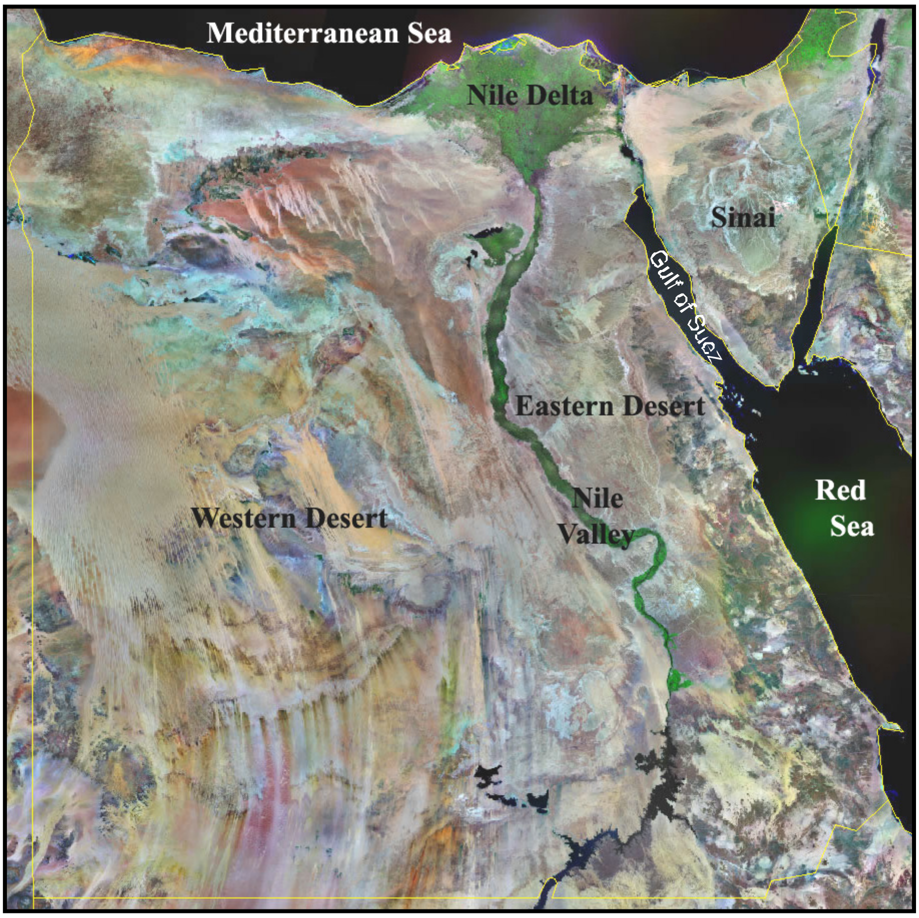
Table 2.1. Ammonite biostratigraphy used by different authors for the Upper Cenomanian – Turonian of north eastern Egypt.

Substage	S I N A I				N O R T H E A S T E R N D E S E R T				
	ALY & ABDEL-GAWAD (2001)	ABDALLAH et al. (2001)	KASSAB & OBAIDALLA (2001); EL-HEDENY (2002)	ABDEL-GAWAD et al. (2004a)	LUGER & GRÖSCHKE (1989)	KASSAB (1991)	KASSAB (1996)	HEWAIDY et al. (2003)	ABDEL-GAWAD et al. (2007)
Upper Turonian			*Coilopoceras requienianum*	*Coilopoceras requienianum*		*Coilopoceras requienianum*		*Coilopoceras requienianum*	*Coilopoceras requienianum*
Middle Turonian			?			?		*Hoplitoides ingens*	
Lower Turonian	*Mammites nodosoides* *Choffaticeras segne* *Pseudaspidoceras flexuosum*	*Choffaticeras segne* *P. flexuosum* / *Vacoceras proprium*	*Choffaticeras segne* *Vascoceras proprium* / *V. obesum*	*Choffaticeras sinaiticum* - *Thomasites rollandi* *Choffaticeras segne* - *Vascoceras harttii* *Choffaticeras quaasi* - *Ch. securiforme*	*Mammites* sp.- *Fagesia* cf. *supersies* *Vascoceras durandi*	*Choffaticeras segne* *Pseudaspidoceras flexuosum*	*P. flexuosum* - *V. proprium*	*Choffaticeras luciae* *Choffaticeras segne* *V. proprium* - *V. pioti*	*Choffaticeras segne*
Upper Cenomanian	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini* - *P. pseudonodosoides* - *Rubroceras alatum* *Neolobites vibrayeanus*	*Vascoceras cauvini*, *Vascoceras rumeai* *Vascoceras gamai* *Metengonoceras* cf. *acutum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Neolobites vibrayeanus*	*Vascoceras cauvini*

Despite all these attempts, the biostratigraphy of the Turonian in all those areas and the Cenomanian – Turonian biostratigraphy of Wadi Araba area is still not completely calibrated. Therefore, one of the aims of the present study is to enhance the knowledge about the Cenomanian – Turonian ammonite biostratigraphy of the north Eastern Desert and a correlation of the biozonation with the previous works in Egypt, neighbouring countries, and the standard ammonite zonation. This will be the topic of chapter biostratigraphy (Discussion part).

2.3. Geomorphology and structures

Egypt is subdivided into three major domains (Sinai, Eastern Desert, and Western Desert). The Nile valley crosses Egypt from south to north and separates the Eastern and Western deserts, while Sinai is separated from the Eastern Desert by the Gulf of Suez (Text-fig. 2.9). Geomorphologically, the Eastern Desert consists of high mountain ranges of igneous and metamorphic complexes parallel to the coast of Red Sea in the East. The sedimentary cover occurs mostly in the northern and western parts of the Eastern Desert and is characterized by some high plateaus separated by large numbers of dry valleys. Sinai is subdivided topographically into high igneous and metamorphic basement in the south, vast sedimentary plateaus in the central part, and widespread soft sand dunes in the north. The Western Desert mostly is low-lying and covered by Nubian sandstone facies in the south, morphologically rising Cretaceous to Eocene limestone in the centre, and low-lying gradually northward-sloping plateaus in the north (mainly formed by Miocene Marmarica limestones).



Text-fig. 2.9. Satellite-image of Egypt showing the major domains.

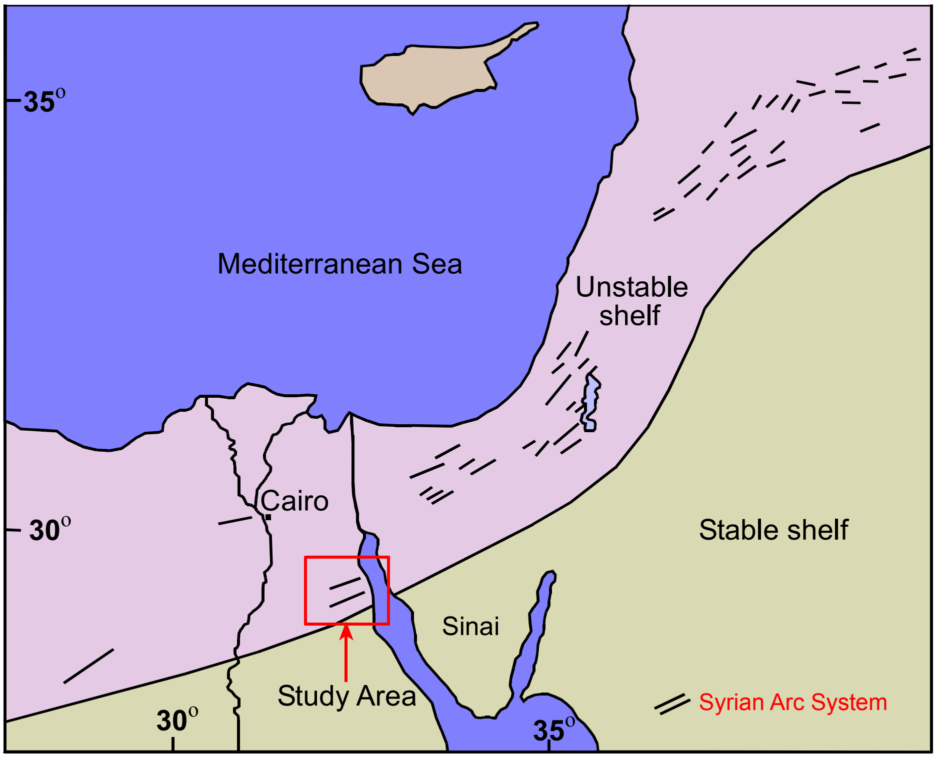
SAID (1962) subdivided the continental platform area of Egypt into two tectonic domains: a northern 'Unstable Shelf' and southern 'Stable Shelf' (Text-fig. 2.10). The Unstable Shelf comprises Sinai, north Eastern Desert and north Western Desert. In Sinai and the northern part of the Eastern Desert, the Mesozoic sediments are exposed and characterized by complex structures due to shear stress generated by the plate movements in the Tethyan Realm, while in the north Western Desert, these Mesozoic structures are masked by younger Tertiary sediments. The Stable Shelf is represented by the south of Egypt and mainly covered by incomplete continental successions belonging to the Palaozoic and Mesozoic with simple structural features (SAID, 1990).

The general tectonic setting of north Egypt played an important role in controlling the configuration of the depositional environments of the exposed sequences. The rapid lateral variation in the lithofacies of the different stratigraphic units, one of the most interesting features of the north Eastern Desert, could be due to synsedimentary structural control (SAID, 1990).

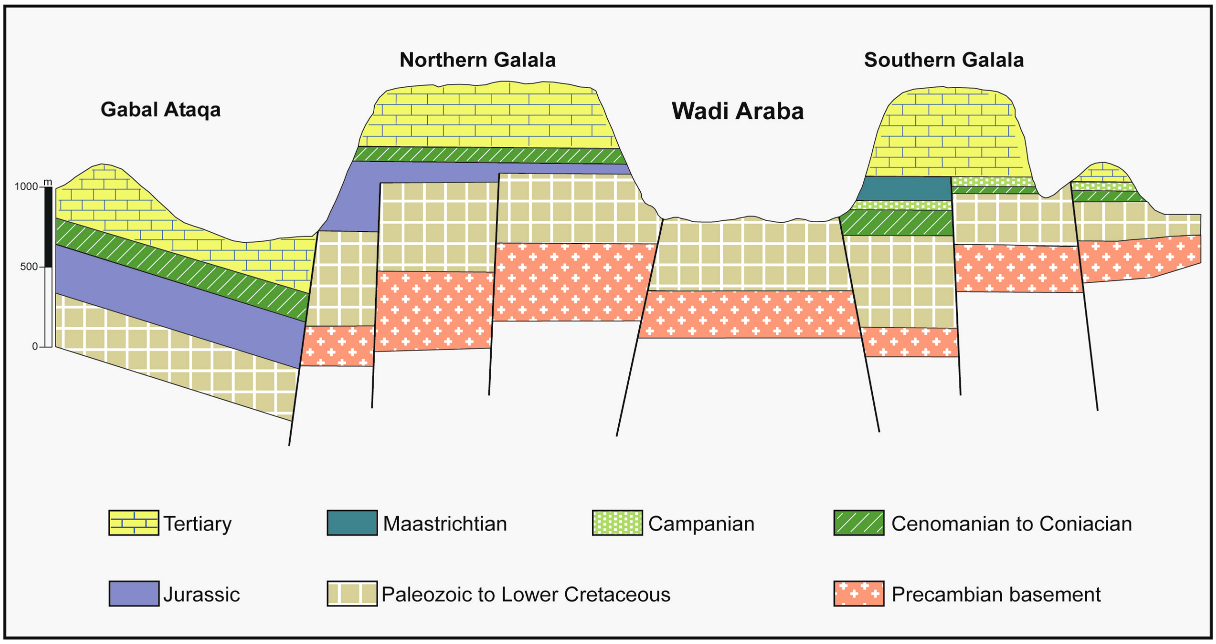
The Syrian Arc system is one of the best-kwon structural features in the Unstable Shelf. The complex uplifts and domal anticlines of the Syrian Arc Fold Belt were formed during the closure of the Neotethys (STAMPFLI et al., 1995), as a consequence of the convergence of the African and Eurasian plates. North eastern Egypt, situated at the northern edge of the African-Arabian Craton, was affected during the Late Cretaceous to early Tertiary times by east-northeast-oriented dextral wrench-faulting. This resulted in transpressive movements and the inversion of the Late Triassic – Liassic half-grabens that cut east-northeastward across the northern rim of the African-Arabian Plate (KUSS et al., 2000). The Syrian Arc can be traced from Syria to the central Western Desert of Egypt, via Sinai and the northern part of the Eastern Desert (Text-fig. 2.10). The Galala plateaus represent a major branch of the Syrian Arc in the Eastern Desert, characterized by Late Cretaceous uplift in the north and subsidence farther to the south. Folding and/or uplift of the Syrian Arc began in post-Cenomanian times (AAL & LELEK, 1994) and reached its acme during the Late Cretaceous (KUSS et al., 2000).

According to BANDEL & KUSS (1987), several structural units (blocks) can be differentiated in the study area (Text-fig. 2.11). The topography of Wadi Araba is strongly shaped by these blocks, also the drainage system is considerably affected by this faulting. The rise from the wadi floor to the tops of the plateaus is not gradational but abrupt and step-like.

Significant faulting of variable distance and displacements was detected associated with these blocks, paralleling in most cases the major scarps. Faulting on a minor scale is the most dominant structural feature noticed in Wadi Araba. Normal faults are the most widespread type. They constitute of series of step faults, minor grabens, minor horsts, or tilted blocks. Minor anticlines and synclines are recognized in Wadi Araba particularly in the Paleozoic rocks of the Rod El Hamal locality, East Wadi Araba (ABDALLAH et al., 1973).

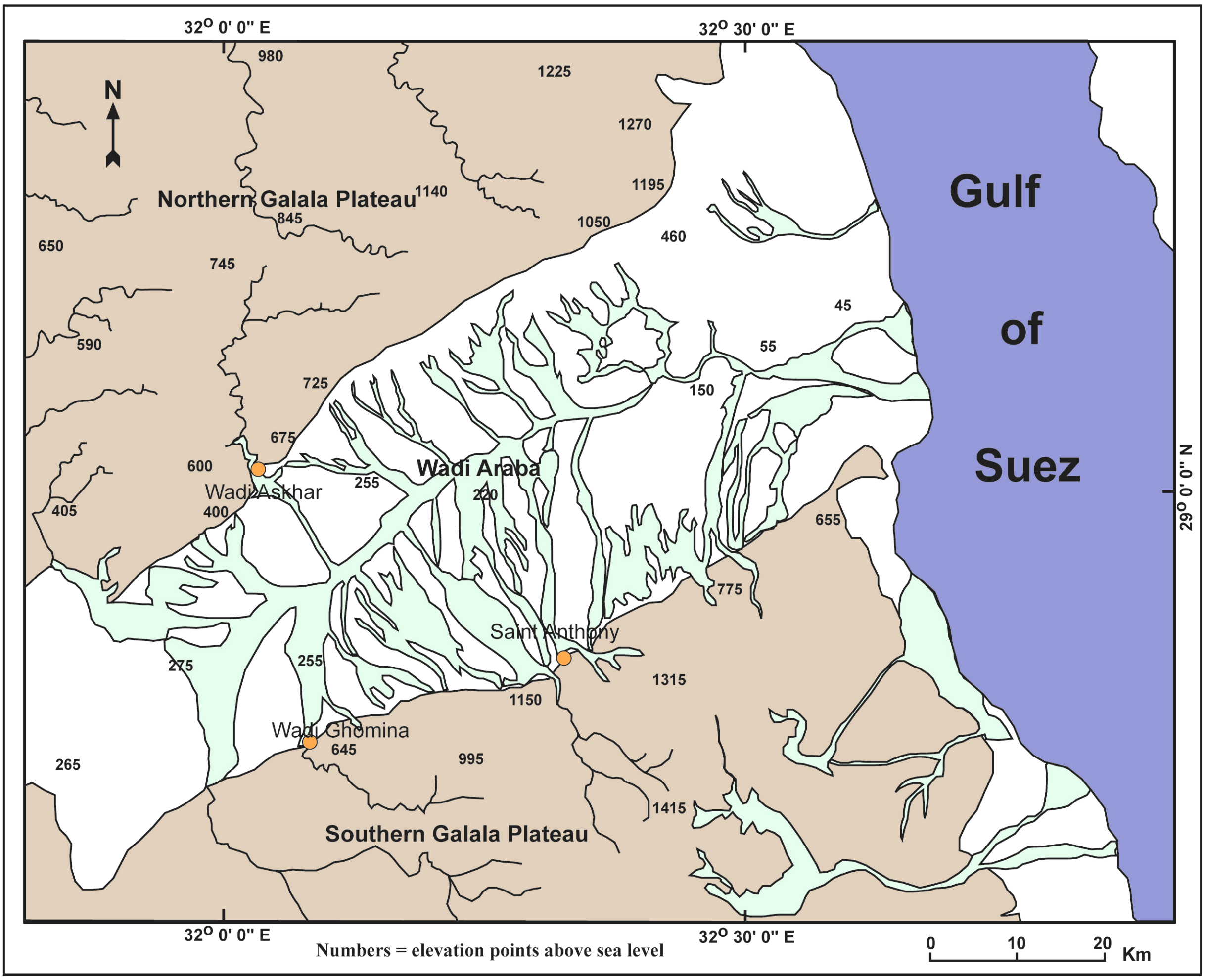


Text-fig. 2.10. The tectonic features in northeast Egypt showing the distribution of the Syrian Arc System (modified after KUSS et al., 2000).



Text-fig. 2.11. Sketch showing the geological situation in the Wadi Araba area (modified after KUSS, 1989).

These structural features control the geomorphology of the study area, where Wadi Araba is bounded in the north by the Northern Galala Plateau, in the south by the Southern Galala Plateau and in the east by the Gulf of Suez. Wadi Araba has NE – SW direction, following the direction of a regional Syrian Arc anticline structure. Wadi Araba is relatively low compared with the great heights of the surrounding plateaus (Text-fig. 2.12). It reaches 30 km width from north to south and extends westward to the central Eocene limestone plateau of the Eastern Desert. It is traversed by a large number of drainage lines (Text-fig. 2.12). Some of these drainage lines are shedding from the two Galalas (NW – SE and SE – NW), forming tributaries of the main WSW – ENE drainage line of Wadi Araba. Most of these drainage lines are filled with Plio – Pleistocene deposits (gravel or loose sands) that were transported from the limestone cliffs by the tributary branches.

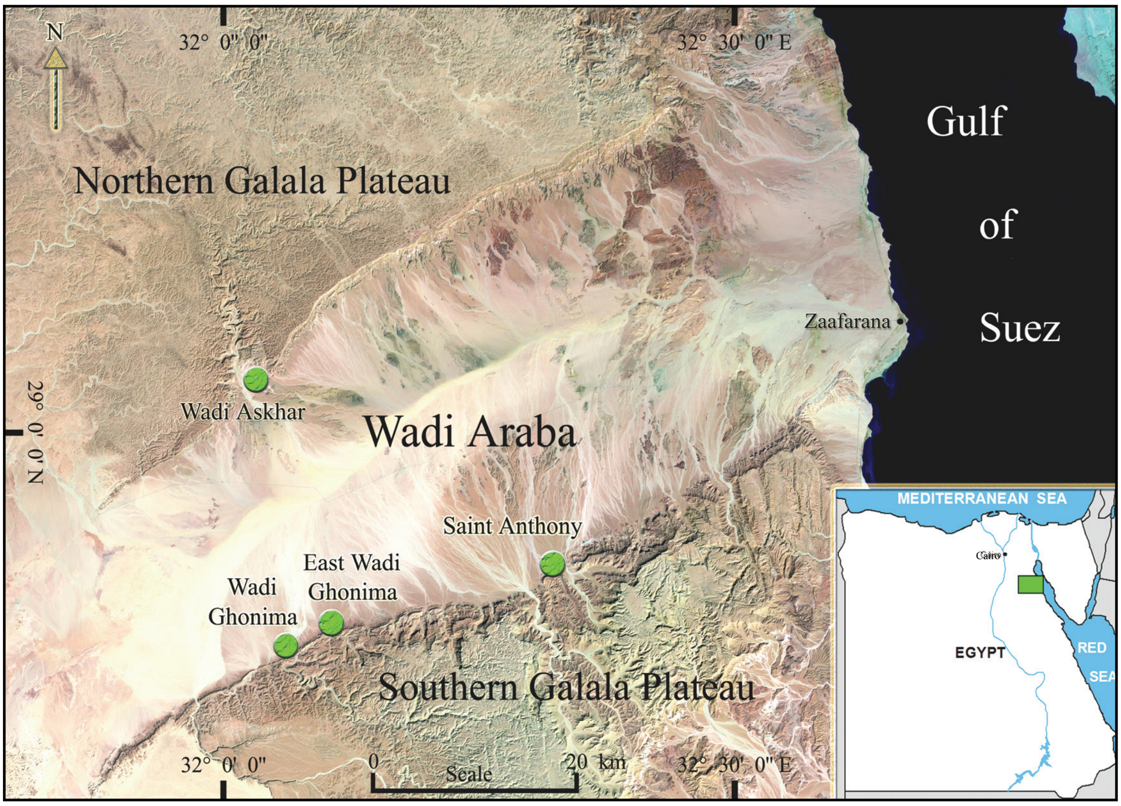


Text-fig. 2.12. The drainage system and elevation of Wadi Araba and the bounding Galala plateaus (modified after CONOCO, 1987).

PART II
RESULTS

3. Sections

Four sections have been measured in the Cenomanian – Turonian of the north Eastern Desert of Egypt. These sections are located on the footwalls of the slopes of the western extensions of the northern and southern Galala plateaus in the Wadi Araba (Text-fig. 3.1). Three of these sections (Wadi Ghonima, East Wadi Ghonima, and Saint Anthony) are situated at the southern Galala Plateau and one (Wadi Askhar section) at the northern Galala Plateau. All sections start with a non-marine sandstone unit (Malha Formation), followed by marine mixed, variable siliciclastics-carbonate successions of the Cenomanian – Turonian (Galala and Maghra El Hadida formations). The studied formations are overlain by a variable succession of Coniacian to Eocene formations (see chapter 2). The focus of this work is on the Wadi Ghonima and East Wadi Ghonima sections, where the Cenomanian – Turonian succession is mostly complete and well exposed. In the Wadi Askhar section, the succession is extensively faulted and at Saint Anthony, the thickness of the succession is strongly reduced.

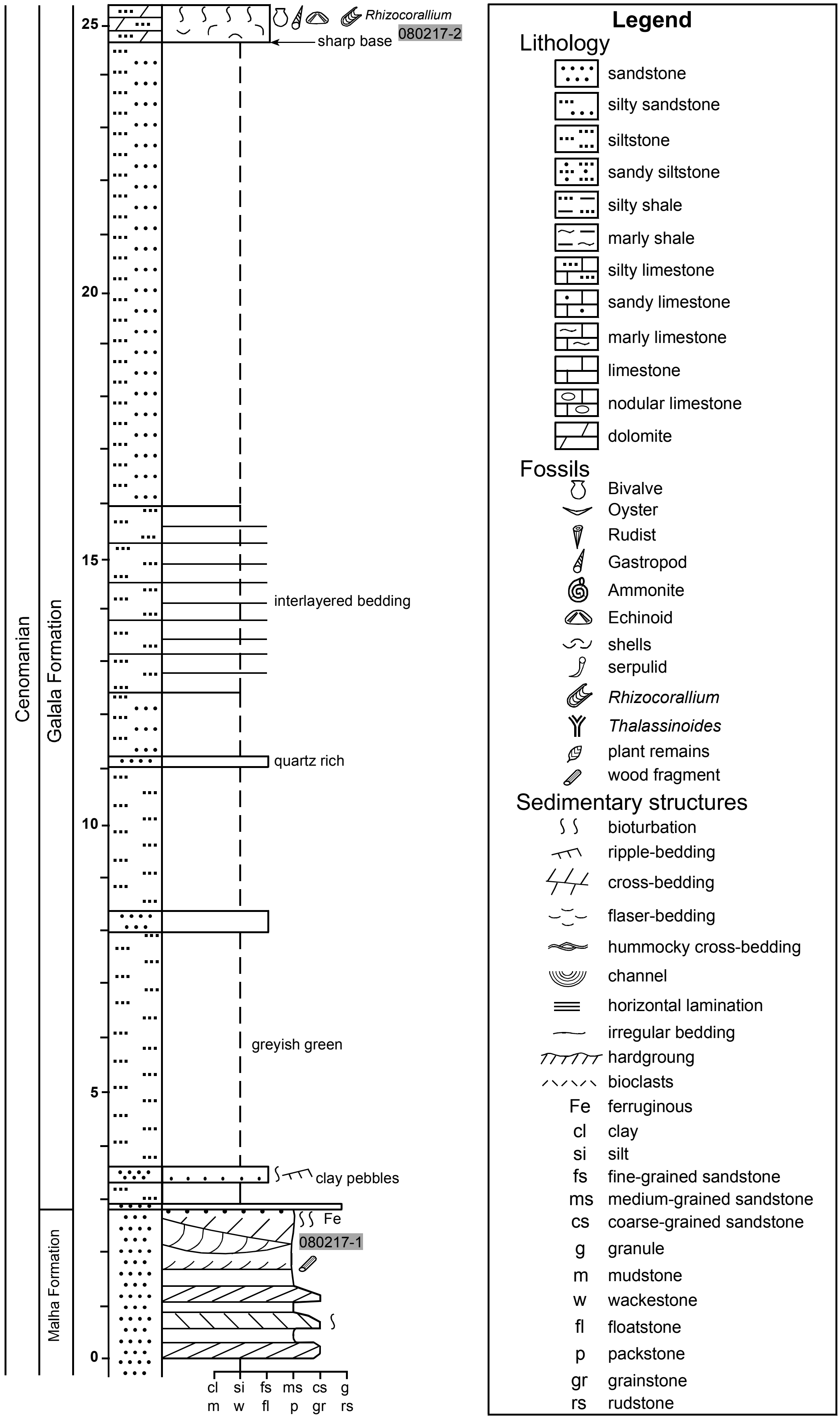


Text-fig. 3.1. Locality of sections measured for this study.

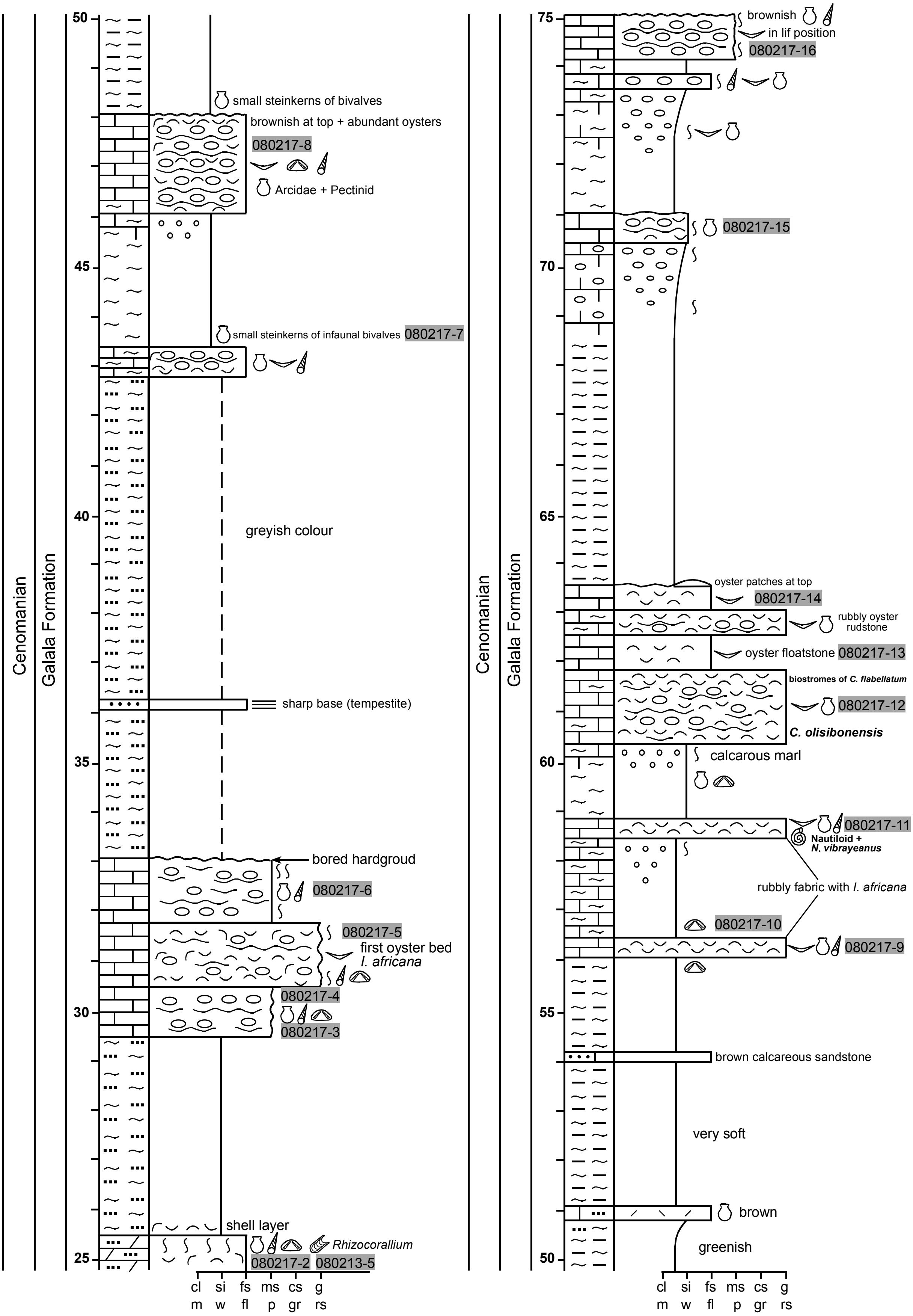
In the following, detailed descriptions of the measured sections are given, including thickness, lithology, colour, contact to the underlying unit, fossil content, sedimentary structures, and lateral changes.

3.1. East Wadi Ghonima section

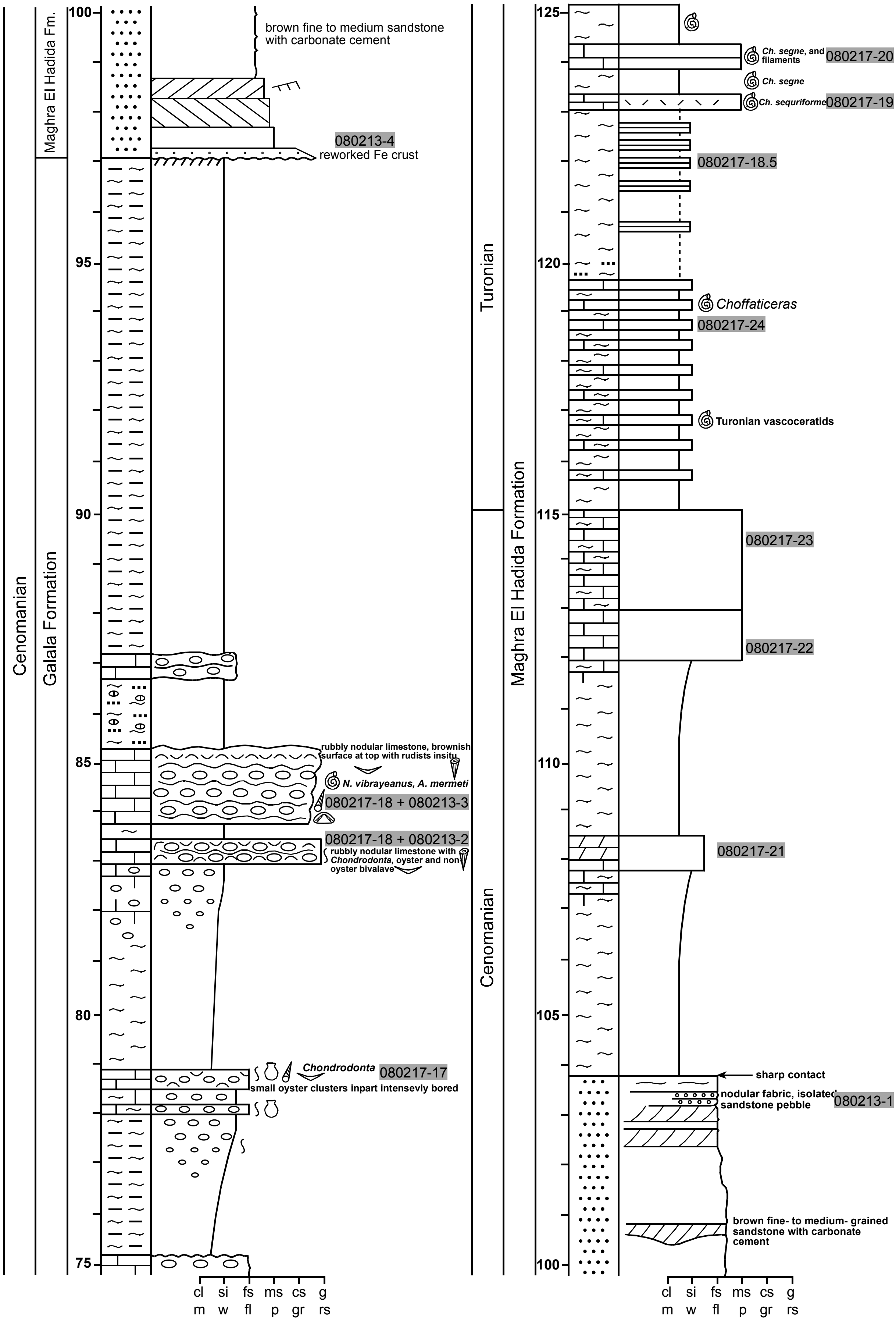
The East Wadi Ghonima section is located at the northern slope of the southern Galala Plateau (N 28^{o} 51\` 34\`\` E 32$^{o}$ 09\` 25\`\`). At this locality, the most complete upper Middle Cenomanian – Turonian succession is exposed. The total thickness of this section is 215 m (Text-fig. 3.2).



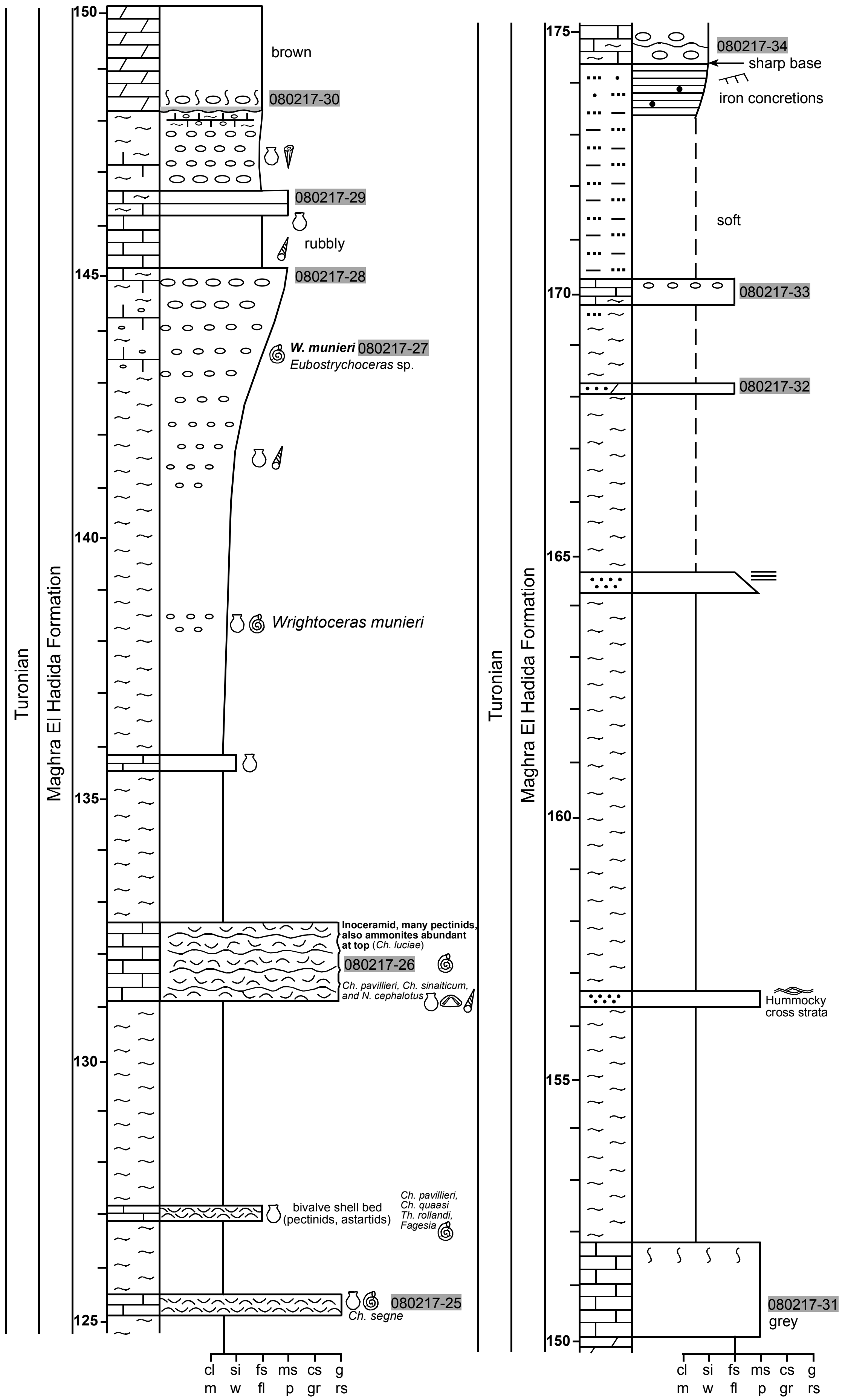
Text-fig. 3.2. East Wadi Ghonima section



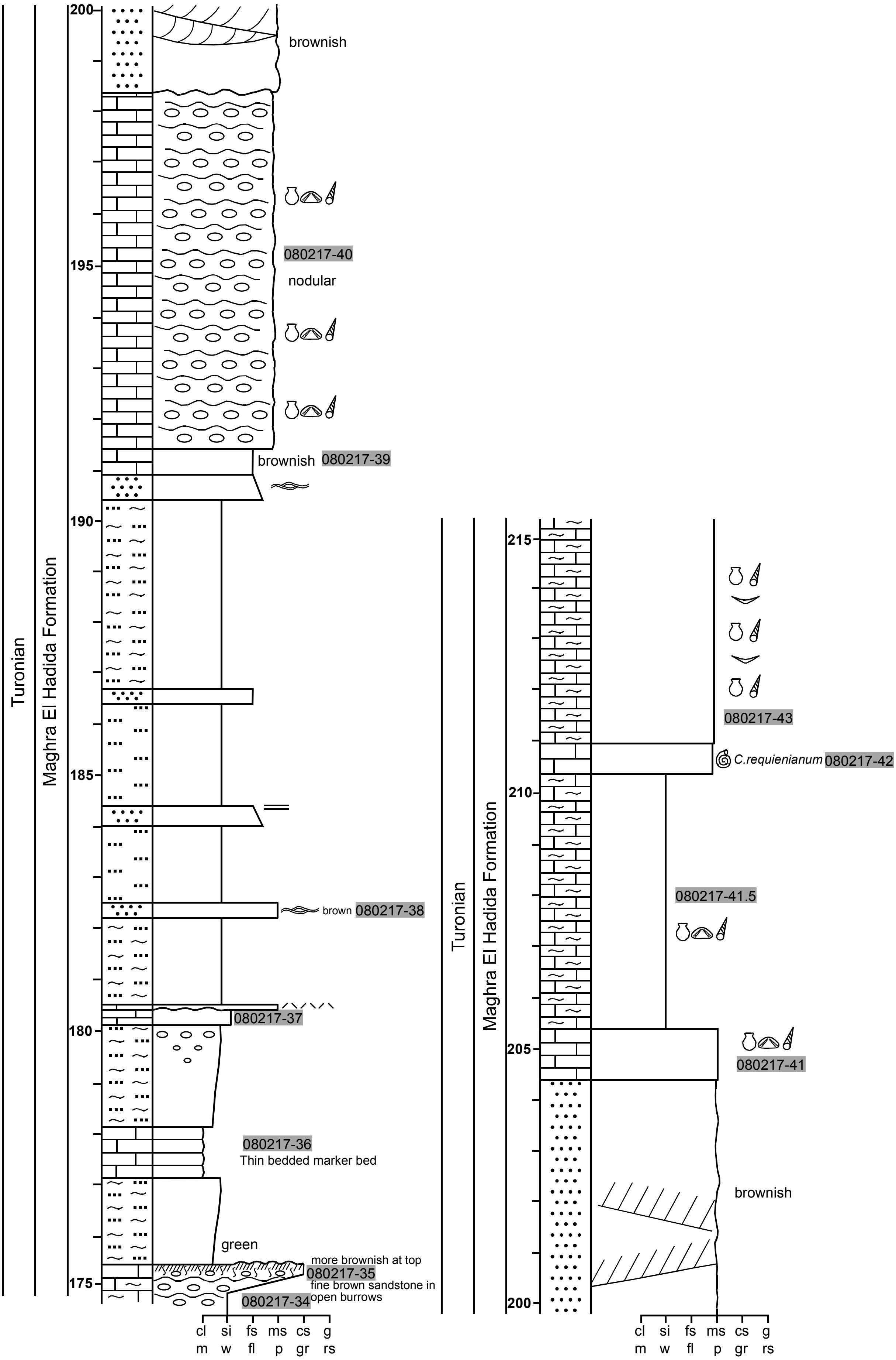
Cont. Text-fig. 3.2. East Wadi Ghonima section



Cont. Text-fig. 3.2. East Wadi Ghonima section



Cont. Text-fig. 3.2. East Wadi Ghonima section



Cont. Text-fig. 3.2. East Wadi Ghonima section

East Wadi Ghonima section starts with thick brownish, medium- to coarse-grained, cross-bedded sandstone belonging to the Malha Formation (Lower Cretaceous, maybe ranging into the Cenomanian). The measured thickness of the uppermost part of the Malha Formation is 4 m. The top of this unit is granule-grained; characterized by bioturbation (*Treptichnus*? isp.), wood fragments, and ferruginous colour. The bioturbation in the upper part of the Malha Formation indicates initial marine influence and a gradual interfingering of marine and non-marine deposits.

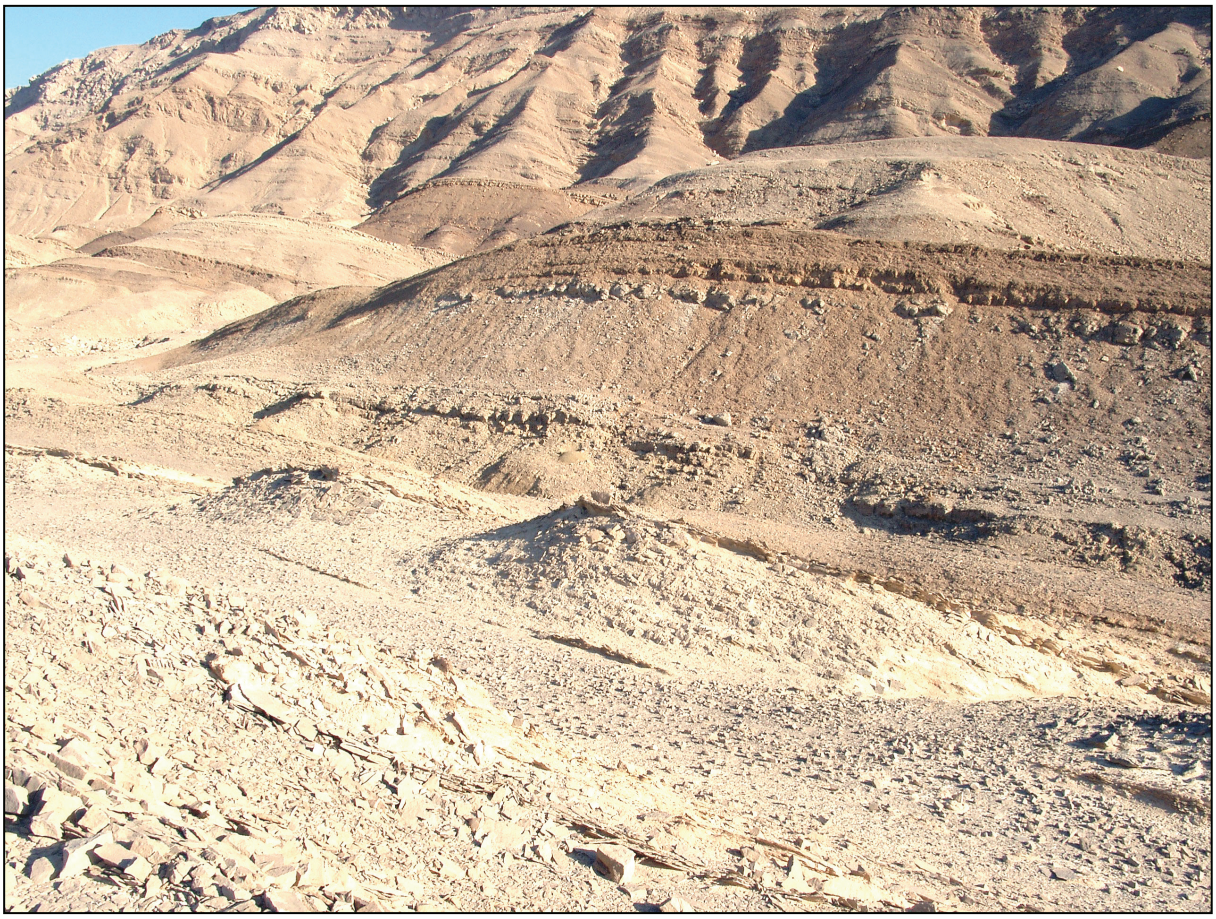
The basal sandstone unit (Malha Formation) is followed unconformably by silty marl intercalated with highly fossiliferous limestone (Galala Formation). This lithostratigraphic change can be easily recognizing in the field by the shift to pale colours and high fossil content, especially Cenomanian oysters. At East Wadi Ghonima section, the Galala Formation reaches a thickness of 95 m and can be divided into five shallowing-upward cycles, each cycle starting with marly-silty deposits at base and grading into fossiliferous limestone at top. The lower part of this formation starts with 22.5 m thick, greyish green, poorly exposed siltstone with fine-grained sandstone intercalations. The siltstones become sandy upward. A 1 m thick silty dolomite overlies the sandy siltstone with sharp base. This thin layer is highly fossiliferous with shell fragments of bivalves, gastropods, and echinoids and shows bioturbation (*Rhizocorallium*) in its upper part. The following 7.5 m can be differentiated into 4 m of well exposed, yellowish marly siltstone topped by 3.5 m of grey, nodular, highly fossiliferous limestone. The limestone unit can be divided into fossiliferous packstones in the lower and upper parts, while the middle part is composed of fossiliferous rudstone and considered as the first oyster bed of the Galala Formation. It yields abundant *Ilymatogyra africana* and *Rhynchostreon suborbiculatum*. Furthermore, gastropods (*Nerinea* sp., *Cimolithium tenouklense*) and echinoids (*Pedinopsis sinaica*, *Tetragramma variolare*, *Salina* sp.) occur, indicating a fully marine environment. The top surface of this limestone unit is marked by a brownish, bored hardground, representing the end of the first cycle in the Galala Formation. The second cycle consists of 15 m thick of greyish, poorly exposed marly siltstone followed by marl turning gradationally upward into brownish, nodular wackestone with abundant oysters. Its undulating upper surface indicates the end of this cycle. The next cycle consists of 16 m of shaley marl with intercalations of bioclastic float- and rudstones rich in bivalves (*Pycnodonte vesiculosa*, *Neithea* sp.) and gastropods (*Nerinea* sp., *Pyrazopsis* sp.) as well as rubbly limestone rich in oysters (*Costagyra olisiponensis*, *Ceratostreon flabellatum*, *Ilymatogyra africana*), nautiloids (*Angulithes mermeti*), ammonites (*Neolobites vibrayeanus*), and echinoids (*Hemiaster cubicus*), indicating a fully marine, shallow- to deep lagoonal environment. The following cycle is 22 m in thickness and can be divided into two parts. The lower part consists of 12 m of shaley marl grading into fossiliferous (mostly Upper Cenomanian oyster) nodular limestone, passing through bioturbated nodular marl. The upper part consists of 10 m of thin, shaley marl, nodular at the base, and changes into pure marl with intercalation of nodular rudstone containing rudist (*Eoradiolites liratus*) and *Chondrodonta*, suggesting a shallow-marine, warm water setting. This part is topped by fossiliferous nodular limestone containing abundant bivalves at the base and ammonites at the top (*Neolobites vibrayeanus*). The last cycle in the Galala Formation is not complete and constitutes the topmost part of this formation. It consists of 12 m thick of well exposed, poorly fossiliferous shaley marl.

The upper boundary of the Galala Formation is characterized by a major unconformity which separates lagoonal sediments from the deep subtidal- to shallow marine sediments of the Maghra El Hadida Formation above. The measured thickness of the Maghra El Hadida Formation at East Wadi Ghonima section is 118 m. This formation starts with the Ghonima Member, introduced in this work to distinguish a brown, fine- to medium-grained, calcareous sandstone unit in the lower part of the formation. The Ghonima Member appears to cut erosionally into the Galala Formation, explaining its strong lateral variation in thickness from 3 m at Saint Anthony section to about 21 m at Wadi Ghonima. It is mostly unfossiliferous except for irregular bioturbation in its upper part. The thickness of this member at East Wadi Ghonima section is 7 m. The following succession of the Maghra El Hadida Formation is characterized by an increase of carbonate content. The lower part consists of 44 m of yellow, soft marl intercalated with highly fossiliferous, fine-grained wackestone containing Late Cenomanian ammonites (*Metoicoceras geslinianum*, *Vascoceras cauvini*) and a rich Early Turonian ammonite assemblage (*Vascoceras proprium*, *Choffaticeras securiforme*, *Ch. segne*, *Ch. sinaiticum*, *Ch. luciae*, *Thomasites rollandi*, *Neoptychites cephalotus*). This succession is also intercalated with nodular limestone beds rich in bivalves (*Plicatula auressensis, Plicatula ferryi*, *Astarte tenuicostata*, and *Pholadomya pedernalis*), gastropods (*Tylostoma* sp.), and echinoids (*Phymosoma abbatei* and *Hemiaster fourneli*). The Lower Turonian succession is terminated by a prominent palaeo-karst horizon at 148.2 m. The overlying Middle and Upper Turonian part of the Maghra El Hadida Formation reaches 67 m in thickness at this locality. It starts with a thin, brown dolomite bed turning upward into grey limestone, with bioturbation in its upper part. Up-section, thick, yellowish marl, becoming silty upward, with occasional hummocky cross-bedded medium- to coarse-grained sandstone intercalations, suggest a deposition in a storm-influenced shelf setting. This part is capped by brownish, nodular wackestone. Its upper surface is characterized by an unconformity separating the Middle Turonian below and the Upper Turonian above. The topmost part of Maghra El Hadida Formation consists of brownish, medium-grained sandstone topped by marly, fossiliferous limestone yielding the ammonite *Coilopoceras requienianum* of Late Turonian age. Deposition is assumed in shallow subtidal conditions.

3.2. Wadi Ghonima section

The Wadi Ghonima section (Text-fig. 3.4) is located at the northern slope of the southern Galala Plateau (N 28° 51` 19`` E 32° 08` 48``). It is 3 km towards the west of the East Wadi Ghonima section. The measured thickness of this section is 145 m (from the base to the top of the Middle Turonian sediments of the Maghra El Hadida Formation). At this locality, the section starts with the Malha Formation. The measured part of this formation only includes the topmost 2 m of brownish sandstone rich in well rounded quartz grains with a few plant remains. The upper layers of this formation are characterized by cross-bedding and bioturbation, indicating the same environmental conditions for this formation as in East Wadi Ghonima section.

At this locality, the Galala Formation (62 m in thickness) unconformably overlies the Malha Formation. However, due to a gap in exposure ca. 30 m are missing so that a similar thickness as in East Wadi Ghonima can be inferred. The Galala Formation at Wadi Ghonima section starts with about 18 m of greenish, sandy siltstone changing upward into siltstone intercalated with thin, cross-bedded, bioturbated, fine- to medium-grained sandstone. Above, a 6 m thick estuarine channel fill, consisting of cross-bedded, bioturbated, medium-grained sandstone follows, characterized by flaser-bedding in the lower part and an erosional lower contact.

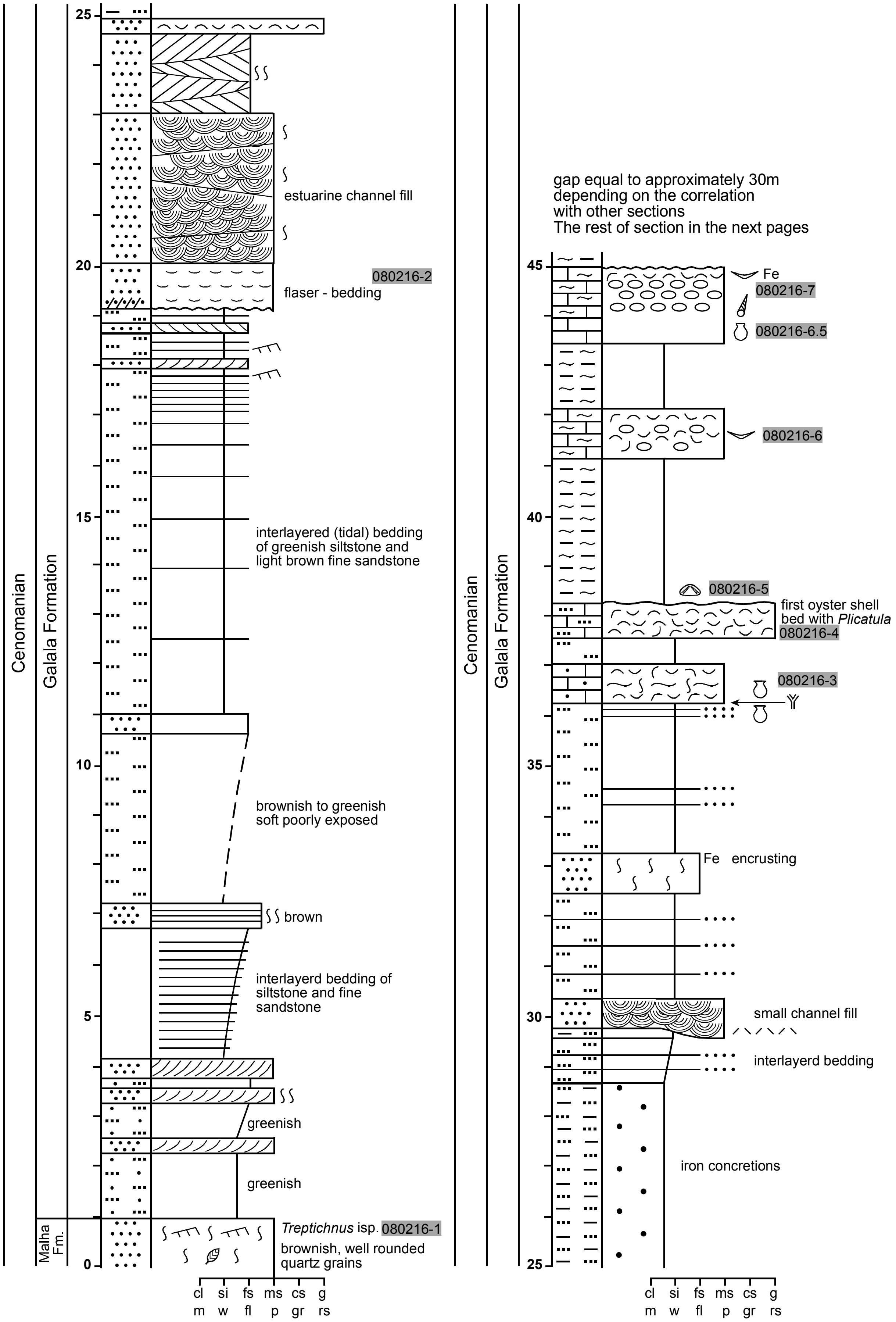


Text-fig. 3.3. General view of East Wadi Ghonima section.

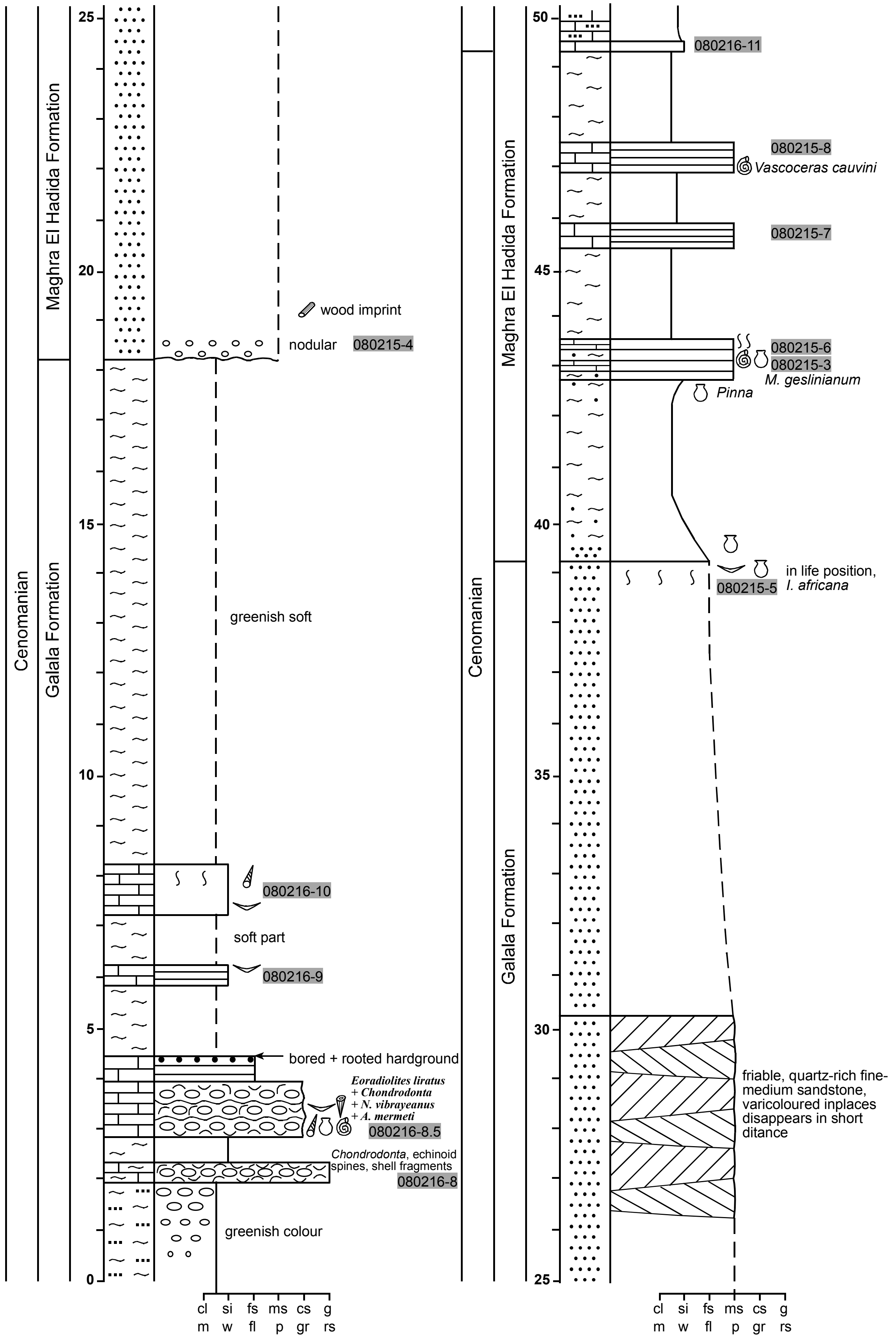
The following part is composed of 5.5 m of silty shales with iron concretions and interlayered bedding of siltstone and thin sandstones. This part is topped by a small channel fill of medium-grained sandstone. Up-section, 8 m of interlayered siltstone and very thin sandstones are topped by two limestone beds separated by ca. 50 cm of siltstone. The lower limestone bed is a fossiliferous sandy packstone yielding bivalves. The basal surface of this bed is marked by bioturbation with a dense network of *Thalassinoides* isp. The upper limestone bed is a silty rudstone and represents the first oyster bed of the Galala Formation. The increased grain size indicates shallow marine conditions with an open water circulation. The upper surface of this bed is undulating and forms the end of the first cycle of the Galala Formation at Wadi Ghonima section. The second cycle consists of 6.5 m of shaley marl capped by two nodular packstone layers. The fossil content of these layers consists of bivalves (*Ilymatogyra africana*, *Ceratostreon flabellatum*, *Pholadomya vignesi*), gastropods (*Pterocera incerta*, *Cimolithium tenouklense*, *Harpagodes heberti*) and echinoids (*Hemiaster cubicus*, *Coenholectypus larteti*). The upper surface of the last limestone bed is marked by an unconformity surface and forms the end of the second cycle. This surface is followed by a gap in exposure approximating to about 27 m (missing are the third and the lower part of the fourth cycle of the Galala Formation) based on the correlation with the complete East Wadi Ghonima section. The overlying part is considered as corresponding to the upper part of the fourth cycle and consists of 4.5 m of greenish silty marl capped by nodular fossiliferous limestone beds rich in shell fragments, *Chondrodonta* and *Eoradiolites liratus*, echinoid spines, nautiloids (*Angulithes mermeti*), and ammonites (*Neolobites vibrayeanus*). The fifth cycle, which constitutes the topmost part of the Galala Formation, is also incomplete and consists of 13.5 m of poorly exposed soft greenish marl intercalated with thin fossiliferous wackestone beds in the lower part. The upper boundary of the Galala Formation is represented by a major unconformity surface at the base of the overlying Maghra El Hadida Formation.

The total thickness of the measured part of Maghra El Hadida Formation at this locality is 82 m. The formation starts with the Ghonima Member, which reaches its maximum thickness (21 m) at this locality. The member consists of friable, quartz-rich medium-grained sandstone, varicoloured in places and with a nodular fabric at the base. Wood imprints, fining-upward and bioturbation at the top are further features. The Ghonima Member is erosionally incised into the Galala Formation with a sharp base whereas the top appears gradational.

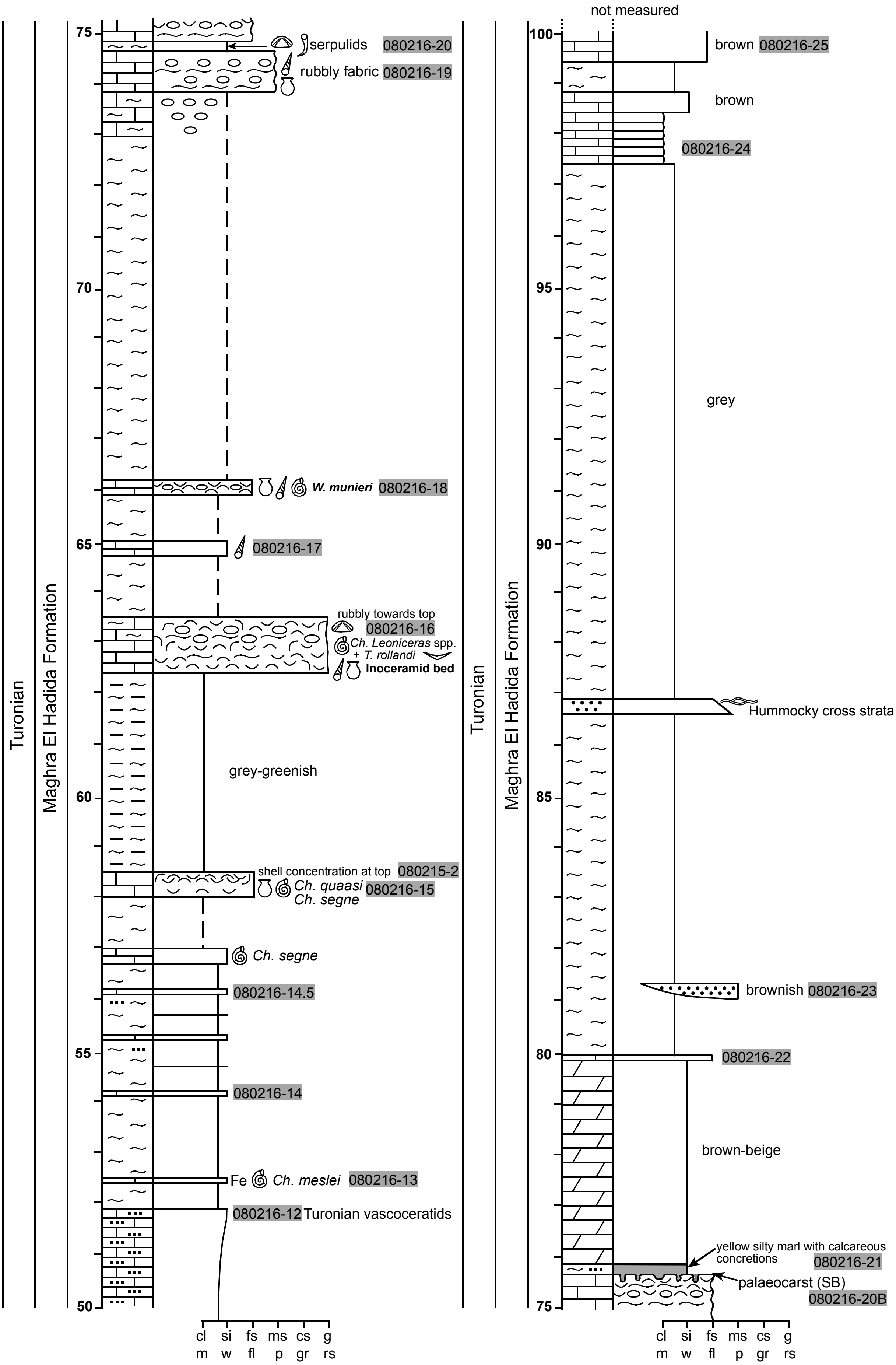
The succession of the Maghra El Hadida Formation above the Ghonima Member is characterized by an increase of carbonate content. It consists of 10 m of m-scale cycles of sandy marls at the base turning upwards into marl with limestones intercalations. These limestone beds are fossiliferous yielding Upper Cenomanian ammonites, *Metoicoceras geslinianum* at the base and *Vascoceras cauvini* at the top, representing the highest ammonite zones in the Cenomanian. The following part consists of 27 m of marl and thin, fine-grained wackestone intercalations. This interval is highly fossiliferous, containing abundant Lower Turonian ammonites (*Vascoceras proprium*, *Choffaticeras securiforme*, *Ch. segne*, *Ch. quaasi*, *Ch. luciae*, *Thomasites rollandi* and *Neoptychites cephalotus*). Some limestone beds of this interval are nodular and rich in bivalves (*Plicatula auressensis, Plicatula ferryi*, *Astarte tenuicostata*, *Pholadomya pedernalis*), gastropods (*Tylostoma* sp.) and echinoids (*Phymosoma abbatei*, *Hemiaster fourneli*). Also, two species of the family Inoceramidae (*Mytiloides kossmati*, *M. labiatus*) have been recorded from this interval and can be used to calibrate the Early Turonian age for these deposits as indicated by the ammonites. This succession is terminated by a prominent palaeo-karst horizon. The overlying strata consist of a 4 m thick, brown-beige dolomite bed followed by 20 m thick of yellow marlstone, with occasional hummocky cross-bedded medium- to coarse-grained sandstone intercalations, capped by a brown limestone bed. This part of the succession suggests deposition in a storm-influenced shelf setting.



Text-fig. 3.4. Wadi Ghonima section. For key of symbols see Text-fig. 3.2.



Cont. Text-fig. 3.4. Wadi Ghonima section



Cont. Text-fig. 3.4. Wadi Ghonima section

3.3. Wadi Askhar section

The Wadi Askhar section is located at the southern slope of the northern Galala Plateau (N 29^o 03` 04`` E 32$^o$ 01` 33``). The Cenomanian – Turonian succession at this section is faulted, less fossiliferous compared to the sections at the southern Galala Plateau, and not easy to reach. The measured thickness of this section is 150 m. At this locality, the section starts with the Malha Formation. The measured part of this formation is about 5 m thick, being characterized by non-marine deposits with gradual change to marine deposits towards the upper boundary. It generally consists of hard to friable, varicoloured medium-grained sandstone.

The Malha Formation is followed unconformably by 35 m thick lagoonal sediments of the lower Galala Formation. The formation is represented by pale, yellow, sandy siltstone intercalated with fossiliferous limestone beds towards the top. These limestone beds are rich in Upper Cenomanian fauna (bivalves: *Ilymatogyra africana*, *Ceratostreon flabellatum*; gastropods: *Nerinea* sp., *Pterocera incerta*; echinoids: *Hemiaster cubicus*). The following sediments of the Galala Formation consist of 30 m thick, yellowish green, silty shales with pale orange limestone intercalations. These limestone beds are fossiliferous, yielding *Eoradiolites liratus* in the basal limestones and *Angulithes mermeti* and *Neolobites vibrayeanus* in the upper limestones. The topmost part of the Galala Formation at Wadi Askhar section is represented by 20 m of fossiliferous, pale orange, marly limestone changing upward into fossiliferous yellowish marl which indicates shallow marine conditions. The total thickness of the Galala Formation is 85 m.

The Maghra El Hadida Formation unconformably overlies the Galala Formation and reaches 60 m at Wadi Askhar section. This formation starts with the Ghonima Member, consisting of 12 m of unfossiliferous, white, friable, fine- to medium-grained sandstone with sharp lower and upper boundaries. Up-section, the carbonate content tends to increase and the following succession is represented by 8 m of yellowish grey, compact dolomite followed by a 15 m thick, pale yellow, moderately compact, marly limestone bed. These carbonate beds are rich in Lower Turonian ammonites (*Vascoceras proprium*, *V. durandi*, *Choffaticeras segne*, *Ch. luciae*). The upper part of Maghra El Hadida Formation at this locality consists of 20 m of silty shale intercalated with fossiliferous limestones. The faunal content of this part includes bivalves (*Plicatula ferryi*, *Astarte tenuicostata*), gastropods (*Tylostoma* sp.), and echinoids (*Hemiaster turonensis*). The topmost part of this formation is represented by 5 m thick yellow, unfossiliferous silty marl.

3.4. Saint Anthony section

The Saint Anthony section is located on the northern slope of the southern Galala Plateau at the extreme eastern part of the study area (N 28^o 55` 16`` E 32$^o$ 20` 58``). At this locality, the Cenomanian – Turonian succession is thinner with a measured thickness of 116 m for the Galala and Maghra El Hadida formations. Furthermore, the ammonite content of this section is strongly reduced and only two zones in the Turonian are represented while the Cenomanian is barren of ammonites. Also at this locality, the succession starts with the Malha Formation. The exposed part of Malha Formation consists of 2 m of alluvial, friable, unfossiliferous yellowish brown medium-grained sandstone.

The Galala Formation overlies the Malha Formation with a thickness of 55 m. The lower 25 m consist of yellowish siltstone, becoming upward sandy, with intercalated thin, cross-bedded, bioturbated, fine-grained sandstones. The overlying part is represented by 20 m of yellowish-green, silty shale with shallow-marine limestone intercalations in the upper part. These limestone intercalations are fossiliferous, containing Upper Cenomanian bivalves (*Ilymatogyra africana*, *Ceratostreon flabellatum*) with a large number of shell fragments. The fragmentation of the fauna and concentrations of oyster are point to occasionally high water energy at Saint Anthony. The upper part of the Galala Formation consists of 10 m of greenish silty marl grading upward into greenish-yellow marl. The basal part of this interval is intercalated with fossiliferous limestone beds rich in shell fragments of *Chondrodonta* and *Eoradiolites liratus*, indicating a shallow-marine, warm water setting.

The shallow water sediments of the Galala Formation are followed unconformably by the Maghra El Hadida Formation. The total thickness of this formation at this locality is 59 m. The Maghra El Hadida Formation starts with the Ghonima Member, composed of 3 m of fine- to medium-grained, greyish-white calcareous sandstone. The top part of this sandstone grades into sandy siltstone and is topped by 3 m of shaley siltstone. Up-section, 10 m of greyish marly fossiliferous limestone follow, containing Lower Turonian ammonites (*Choffaticeras segne*) and some fragments of bivalves. The overlying part is represented by 25 m thick, silty shale with few and thin limestone intercalations, topped by a 3 m thick pale yellowish, hard dolomite. The topmost part of the Maghra El Hadida Formation at Saint Anthony consists of 15 m of marly shale with sandstone intercalations at the base, while the upper part is intercalated with fossiliferous limestone beds yielding Upper Turonian ammonites (*Coilopoceras requienianum*).

4. Macrobenthos

The Galala and Maghra El Hadida formations (Cenomanian – Turonian) of the study area are highly fossiliferous. 62 macrobenthos taxa (32 bivalves, 15 gastropods, and 15 echinoids) have been collected, identified, classified, and illustrated (Text-figs. 4.1 – 4.7). The complete list of these fauna is given below. The Bivalvia are arranged systematically according to AMLER et al. (2000), the Gastropoda according to BOUCHET & ROCROI (2005), and the Echinoidea according to SMITH & WRIGHT (1989, 1993, 1996, and 1999) and SMITH et al. (1995).

4.1. Class Bivalvia LINNÉ, 1758

Subclass Palaeotaxodonta KOROBKOV, 1954

Order Nuculoida DALL, 1889

Superfamily Nuculoidea GRAY, 1824

Family Nuculidae GRAY, 1824

Genus *Nucula* LAMARCK, 1799

Subgenus *Nucula* LAMARCK, 1799

Nucula (*Nucula*) *margaritifera* DOUVILLÉ, 1916 (Text-fig. 4.1A)

Order Arcoida STOLICZKA, 1871

Superfamily Arcoidea LAMARCK, 1809

Family Arcidae LAMARCK, 18f09

Subfamily Arcinae LAMARCK, 1809

Genus *Barbatia* GRAY, 1842

Subgenus *Barbatia* GRAY, 1842

Barbatia (*Barbatia*) *aegyptiaca* (FOURTAU, 1917) (Text-fig. 4.1B)

Text-fig. 4.1

A. *Nucula* (*Nucula*) *margaritifera* DOUVILLÉ, 1916, Upper Cenomanian Galala Formation. Articulated specimen; 1: side view of left valve, x2; 2: dorsal view, x2; WG-1.

B. *Barbatia* (*Barbatia*) *aegyptiaca* (FOURTAU, 1917), Upper Cenomanian Galala Formation. Articulated specimen; 1: side view of left valve, x1; 2: dorsal view, x1; WG-2.

C. *Cucullaea* sp., Turonian Maghra El Hadida Formation. Right valve; 1: external view, x1; 2: dorsal view, x1; WG-3.

D. *Mytiloides kossmati* (HEINZ, 1930), Lower Turonian Maghra El Hadida Formation. Left valve view, x1; 080216-16-1.

E. *Mytiloides labiatus* (SCHLOTHEIM, 1813), Lower Turonian Maghra El Hadida Formation. Left valve view, x1; 080216-16-2.

F. *Pycnodonte* (*Phygraea*) *vesicularis* (LAMARCK, 1806) *vesiculosa* (J. SOWERBY, 1823), Upper Cenomanian Galala Formation. Left valve; 1: external view, x1; 2: internal view, x1; WG-4.

G. *Costagyra olisiponensis* (SHARPE, 1850), Upper Cenomanian Galala Formation. Left valve; 1: external view, x1; 2: internal view, x1; 080217-12-1. – 3: external view, x1; 080217-12-2.

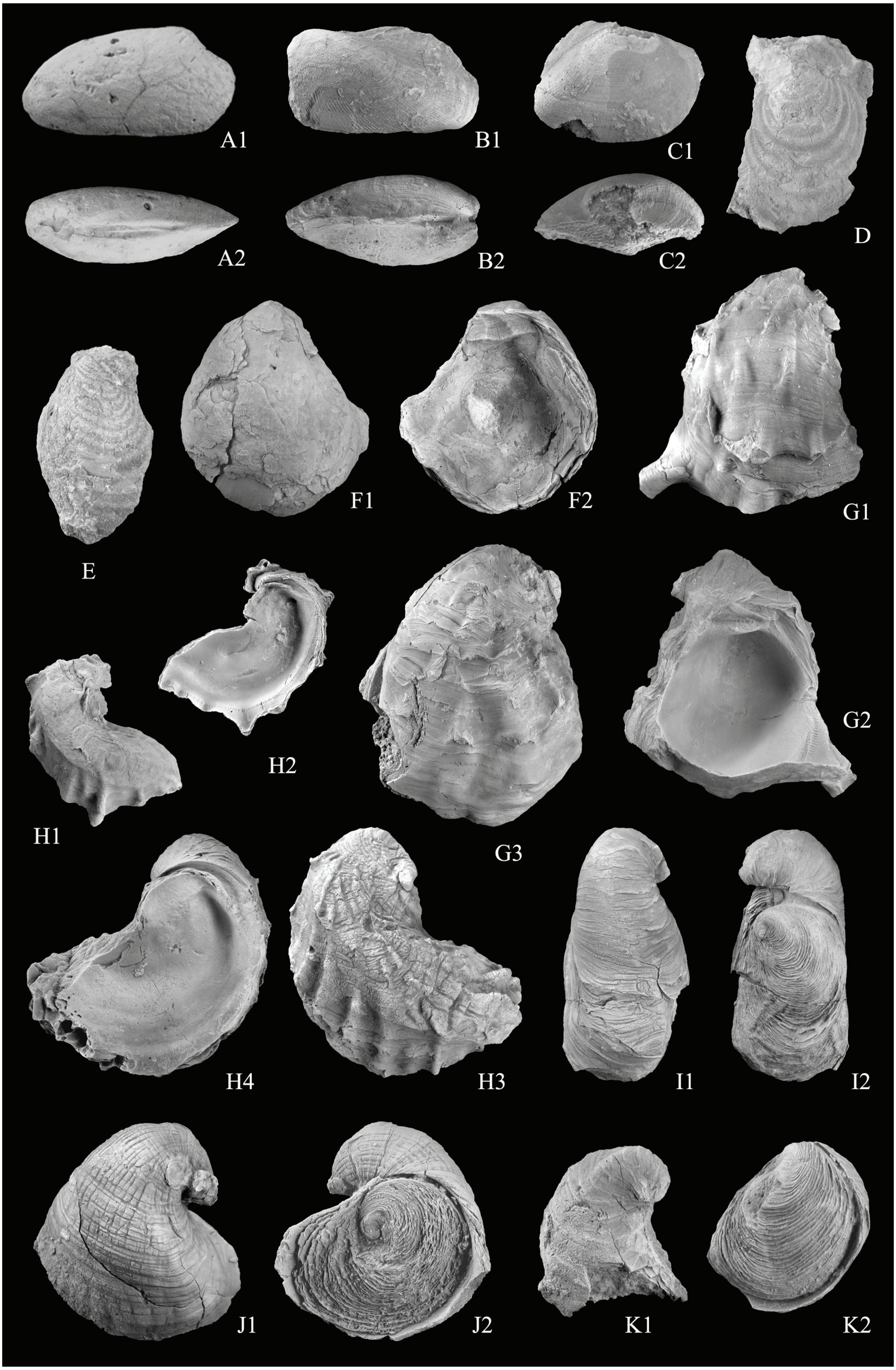
H. *Ceratostreon flabellatum* (GOLDFUSS, 1833), Upper Cenomanian Galala Formation. Left valve; 1: external view, x1; 2: internal view, x1; 080217-11-1. – 3: external view, x1; 4: internal view, x1; 080217-11-2.

I. *Ilymatogyra africana* (LAMARCK, 1801), Upper Cenomanian Galala Formation. Articulated specimen; 1: external view of left valve, x1; 2: external view of right valve, x1; 080217-11-3.

J. *Rhynchostreon suborbiculatum* (LAMARCK, 1801), Upper Cenomanian Galala Formation. Articulated specimen; 1: external view of left valve, x1; 2: external view of right valve, x1; 080217-5-1.

K. *Amphidonte conica* J. DE C. SOWERBY, 1813, Upper Cenomanian Galala Formation. Articulated specimen; 1: external view of left valve, x1; 2: external view of right valve, x1; WG-5.

Text-fig. 4.1



Family Cucullaeidae Stewart, 1930

Genus *Cucullaea* Lamarck, 1801

Cucullaea sp. (Text-fig. 4.1c)

Superorder Eupteriomorphia Boss, 1982

Order Pterioida Newell, 1965

Superfamily Pterioida Gray, 1847

Family Inoceramidae Giebel, 1852

Genus *Mytiloides* Brongniart, 1822

Mytiloides kossmati (Heinz, 1930) (Text-fig. 4.1d)

Mytiloides labiatus (Schlotheim, 1813) (Text-fig. 4.1e)

Order Ostreoida Férussac, 1822 (=Ostreina Waller, 1978)

Superfamily Ostreoidea Wilkes, 1810

Family Gryphaeidae Vyalov, 1936

Subfamily Pycnodonteinae Stenzel, 1959

Genus *Pycnodonte* Fischer de Waldheim, 1835

Subgenus *Phygraea* Vyalov, 1936

Pycnodonte (*Phygraea*) *vesicularis* (Lamarck, 1806) *vesiculosa* (J. de C. Sowerby, 1823) (Text-fig. 4.1f)

Subfamily Exogyrinae Vyalov, 1936

Tribe Exogyrini Vyalov, 1936

Genus *Costagyra* Vyalov, 1936

Costagyra olisiponensis (Sharpe, 1850) (Text-fig. 4.1g)

Genus *Ceratostreon* Bayle, 1878

Ceratostreon flabellatum (Goldfuss, 1833) (Text-fig. 4.1h)

Genus *Ilymatogyra* Stenzel, 1971

Ilymatogyra africana (Lamarck, 1801) (Text-fig. 4.1i)

Text-fig. 4.2

A. *Rastellum* cf. *carinatum* (Lamarck, 1806), Upper Cenomanian Formation. Left valve view, x1; WG-6.

B. *Plicatula auressensis* Coquand, 1862, Lower Turonian Maghra El Hadida Formation. Articulated specimen, external view of left valve, x1.5; 080217-26-1.

C. *Plicatula ferryi* Coquand, 1862, Lower Turonian Maghra El Hadida Formation. Articulated specimen; 1: external view of left valve, x1; 2: external view of right valve, x1; 080217-27-1.

D. *Neithea* sp., Upper Cenomanian Galala Formation. Right valve, x1; 080217-8.

E. *Pterotrigonia* (*Scabrotrigonia*) *scabra* (Lamarck, 1819), Upper Cenomanian Galala Formation. Articulated specimen, right valve view, x1.5; WG-7.

F. *Corbula parsura* Stoliczka, 1871, Lower Turonian Maghra El Hadida Formation. Articulated specimen; 1: Left valve view, x3; 2: dorsal view, x3; WG-8.

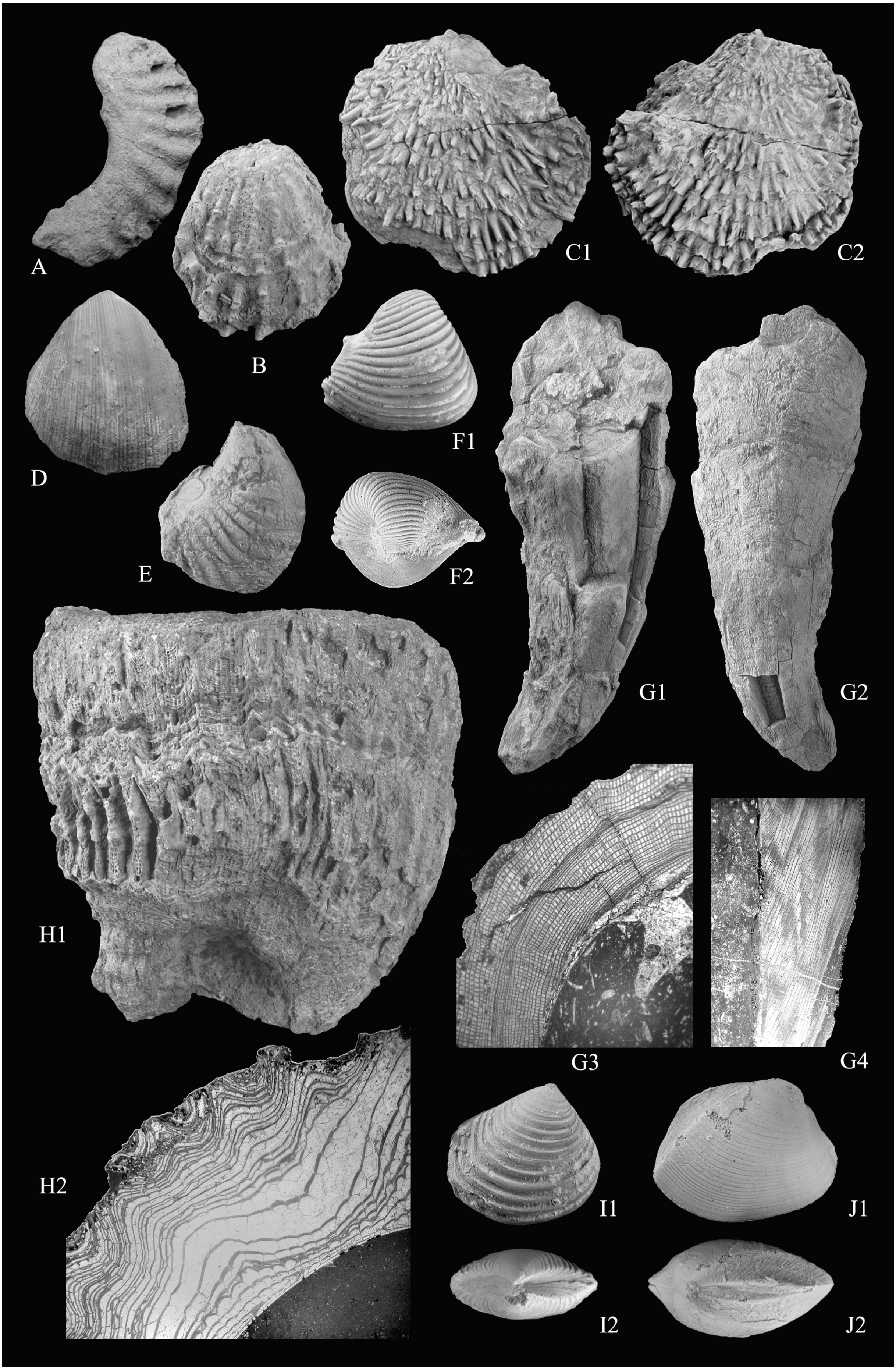
G. *Eoradiolites liratus* (Conrad, 1852), Upper Cenomanian Galala Formation. Right valve; 1, 2: right valve view, x1; 3: transverse section, x6; 4: longitudinal thin section, x12; 080217-18-1.

H. *Durania humei* Douvillé, 1913, Turonian Maghra El Hadida Formation. Right valve; 1: right valve view, x1; 2: transverse thin section, x12; WG-9.

I. *Astarte tenuicostata* Seguenza, 1882, Lower Turonian Maghra El Hadida Formation. Articulated specimen; 1: right valve view, x2; 2: dorsal view, x2; 080216-16-3.

J. *Crassatella matercula* Mayer-Eymar, 1896, Lower Turonian Maghra El Hadida Formation. Articulated specimen; 1: right valve view, x2; 2: dorsal view, x2; WG-10.

Text-fig. 4.2



Genus *Rhynchostreon* BAYLE, 1878

Rhynchostreon suborbiculatum (LAMARCK, 1801) (Text-fig. 4.1J)

Tribe Nanogyrini MALCHUS, 1990

Genus *Amphidonte* FISCHER DE WALDHEIM, 1829

Amphidonte conica J. DE C. SOWERBY, 1813 (Text-fig. 4.1K)

Family Ostreidae WILKES, 1810

Subfamily Lophinae VYALOV, 1936

Genus *Rastellum* FAUJAS-SAINT-FOND, 1799

Rastellum cf. *carinatum* (LAMARCK, 1806) (Text-fig. 4.2A)

Superfamily Plicatuloidea WATSON, 1930

Family Plicatulidae WATSON, 1930

Genus *Plicatula* LAMARCK, 1801

Plicatula auressensis COQUAND, 1862 (Text-fig. 4.2B)

Plicatula ferryi COQUAND, 1862 (Text-fig. 4.2C)

Order Pectinoida NEWELL & Boyd, 1995 (=Pectinina WALLER, 1978)

Superfamily Pectinoidea WILKES, 1810

Family Pectinidae WILKES, 1810

Subfamily Neitheinae SOBETSKIJ, 1960

Genus *Neithea* DROUET, 1824

Neithea sp. (Text-fig. 4.2D)

Text-fig. 4.3

A. *Granocardium productum* (J. DE C. SOWERBY, 1832), Upper Cenomanian Galala Formation. Articulated internal mould; 1: right valve view, x1; 2: anterior view, x1; WG-11.

B. *Protocardia hillana* (J. SOWERBY, 1813), Upper Cenomanian Galala Formation. Articulated specimen; 1: right valve view, x1; WG-12.

C. *Linearia aegyptiaca* EL QOT, 2006, Upper Cenomanian Galala Formation. Articulated specimen; 1: right valve view, x1; 2: dorsal view, x1; WG-13.

D. *Arctica picteti* (COQUAND, 1862), Upper Cenomanian Galala Formation. Articulated internal mould; 1: Left valve view, x1; WG-14-1. – 2: right valve view, 1x; 3: dorsal view, x1; WG-14-2.

E. *Tenea delettrei* (COQUAND, 1862), Upper Cenomanian Galala Formation. Articulated specimen; 1: left valve view, x1; 2: dorsal view, x1; WG-15.

F. *Glossus* sp., Upper Cenomanian Galala Formation. Articulated internal mould, left valve view, x1; WG-16.

G. *Parasea faba* (J. DE C. SOWERBY, 1827), Upper Cenomanian Galala Formation. Articulated specimen; 1: right valve view, x1.5; WG-17-1. – 2: dorsal view, x1.5; 3: right valve view, 1.5x; WG-17-2.

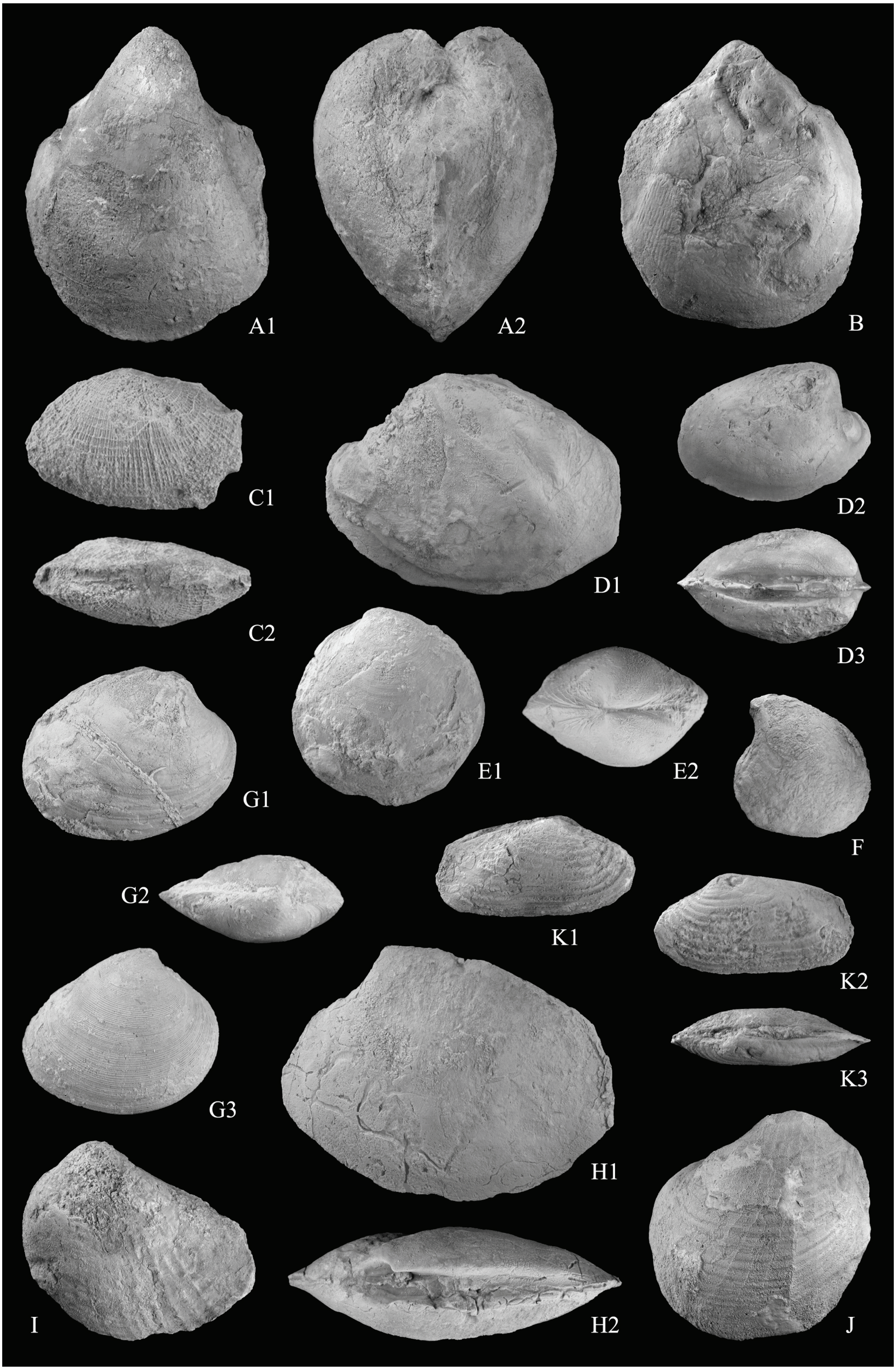
H. *Meretrix desvauxi* COQUAND, 1862, Upper Cenomanian Galala Formation. Articulated internal mould; 1: right valve view, x1; 2: dorsal view, x1; WG-18.

I. *Pholadomya* (*Pholadomya*) *pedernalis* ROEMER, 1852, Lower Turonian Maghra El Hadida Formation. Articulated internal mould, left valve view, x1; 080217-27-2.

J. *Pholadomya* (*Pholadomya*) *vignesi* LARTET, 1877, Upper Cenomanian Galala Formation. Articulated internal mould; 1: right valve view, x1; 080216-5.

K. *Plectomya humei* (FOURTAU, 1917), Upper Cenomanian Galala Formation. Articulated composite mould; 1: right valve view, x1; 2: left valve view, x1; 3: dorsal view, x1; WG-19.

Text-fig. 4.3



Subclass Heteroconchia HERTWING, 1895

Superorder Palaeoheterodonta NEWELL, 1965

Order Trigonioida DALL, 1889

Superfamily Trigonioidea LAMARCK, 1819

Family Trigoniidae LAMARCK, 1819

Genus *Pterotrigonia* VAN HOEPEN, 1929

Subgenus *Scabrotrigonia* DIETRICH, 1933

Pterotrigonia (*Scabrotrigonia*) *scabra* (LAMARCK, 1819)(Text-fig. 4.2E)

Superorder Heterodonta NEUMAYR, 1883

Order Myoida STOLICZKA, 1870

Suborder Myina STOLICZKA, 1870

Superfamily Myoidea LAMARCK, 1809

Family Corbulidae LAMARCK, 1818

Subfamily Corbulinae GRAY, 1823

Genus *Corbula* BRUGUIÈRE, 1933

Corbula parsura STOLICZKA, 1871 (Text-fig. 4.2F)

Order Hippuritoida NEWELL, 1965

Superfamily Hippuritoidea GRAY, 1848

Family Radiolitidae GRAY, 1848

Subfamily Radiolitinae GRAY, 1848

Genus *Eoradiolites* DOUVILLÉ, 1909

Eoradiolites liratus (CONRAD, 1852) (Text-fig. 4.2G)

Subfamily Sauvagesiinae DOUVILLÉ, 1908

Genus *Durania* DOUVILLÉ, 1908

Durania humei DOUVILLÉ, 1913 (Text-fig. 4.2H)

Order Veneroida H. ADAMS & A. ADAMS, 1856

Superfamily Crassatelloidea FÉRUSSAC, 1822

Family Astratidae D'ORBIGNY, 1844

Subfamily Astartinae D'ORBIGNY, 1844

Genus *Astarte* J. SOWERBY, 1816

Astarte tenuicostata SEGUENZA, 1882 (Text-fig. 4.2I)

Text-fig. 4.4

A. *Obirnella* sp., Upper Cenomanian Galala Formation. 1: apertural view, x1.5; 2: apical view, x1.5; WG-30.

B. Cerithiinae indet., Lower Turonian Maghra El Hadida Formation. 1: abapertural view, x1.5; 2: apertural view, x1.5; WG-22.

C. *Pyrazopsis* sp., Upper Cenomanian Galala Formation. abapertural view, x2; 080217-11-4.

D. *Turritella* Sp., Upper Cenomanian Galala Formation. Shell fragment: abapertural view, x2; 080217-11-6.

E. *Campanile ganesha* NOETLING, 1897, Upper Cenomanian Galala Formation. Internal mould, 1: apical view, x1; 2: abapertural view, x1; WG-20.

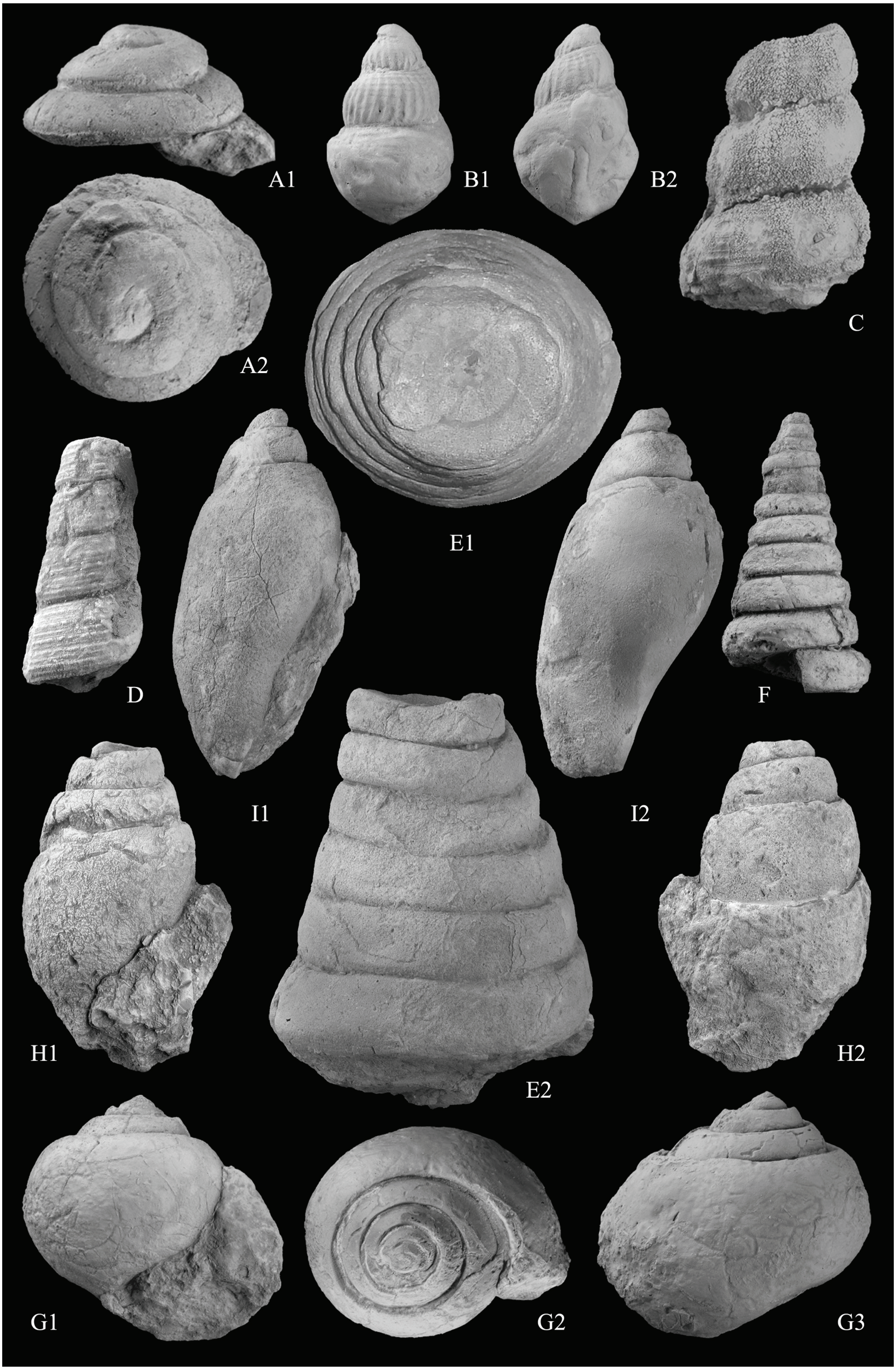
F. *Cimolithium tenouklense* (COQUAND, 1862), Upper Cenomanian Galala Formation. apertural view, x1; 080217-5-2.

G. *Ampullina* sp., Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: apical view, x1; 3: abapertural view, x1; 080217-27-3.

H. *Aporrhais* sp., Upper Cenomanian Galala Formation. 1: apertural view, x1; 2: abapertural view, x1; WG-35.

Fig. I. *Pterodonta deffisi* THOMAS & PERON, 1889, Cenomanian Galala Formation. 1: apertural view, x1; 2: abapertural view, x1; WG-27.

Text-fig. 4.4



Family Crassatellidae FERUSSAC, 1822

Subfamily Crassatellinae FERUSSAC, 1822

Genus *Crassatella* LAMARCK, 1799

Crassatella sp. (Text-fig. 4.2J)

Superfamily Cardioidea LAMARCK, 1809

Family Cardiidae LAMARCK, 1809

Subfamily Cardiinae LAMARCK, 1809

Genus *Granocardium* GABB, 1868

Subgenus *Granocardium* GABB, 1868

Granocardium productum (J. DE C. SOWERBY, 1832) (Text-fig. 4.3A)

Subfamily Protocardiinae KEEN, 1951

Genus *Protocardia* BEYRICH, 1845

Protocardia hillana (J. SOWERBY, 1813) (Text-fig. 4.3B)

Superfamily Tellinoidea BLAINVILLE, 1814

Family Tellinidae BLAINVILLE, 1814

Subfamily Tellininae BLAINVILLE, 1814

Genus *Linearia* CONRAD, 1860

Linearia aegyptiaca EL QOT, 2006 (Text-fig. 4.3C)

Superfamily Arcticoidea NEWTON, 1891

Family Arcticidae NEWTON, 1891

Genus *Arctica* SCHUMACHER, 1817

Arctica picteti (COQUAND, 1862) (Text-fig. 4.3D)

Genus *Tenea* CONRAD, 1870

Tenea delettrei (COQUAND, 1862) (Text-fig. 4.3E)

Superfamily Glossoidea GRAY, 1847

Family Glossidae GRAY, 1847

Genus *Glossus* POLI, 1795

Glossus sp. (Text-fig. 4.3F)

Superfamily Veneroidea RAFINESQUE, 1815

Family Veneridae RAFINESQUE, 1815

Subfamily Tapetinae ADAMS & ADAMS, 1857

Genus *Parasea* CASEY, 1952

Parasea faba (J. DE C. SOWERBY, 1827) (Text-fig. 4.3G)

Text-fig. 4.5

A. '*Pterocera*' *incerta* D'ORBIGNY, 1842, Upper Cenomanian Galala Formation. 1: apertural view, x0.5; 2: apical view, x0.5; 080216-7.

B. '*Harpagodes*' *heberti* (THOMAS & PERON, 1889), Upper Cenomanian Galala Formation. abapertural view, x1; WG-25.

C. *Pterodonta* sp., Upper Cenomanian Galala Formation. Apertural view, x1; WG-28.

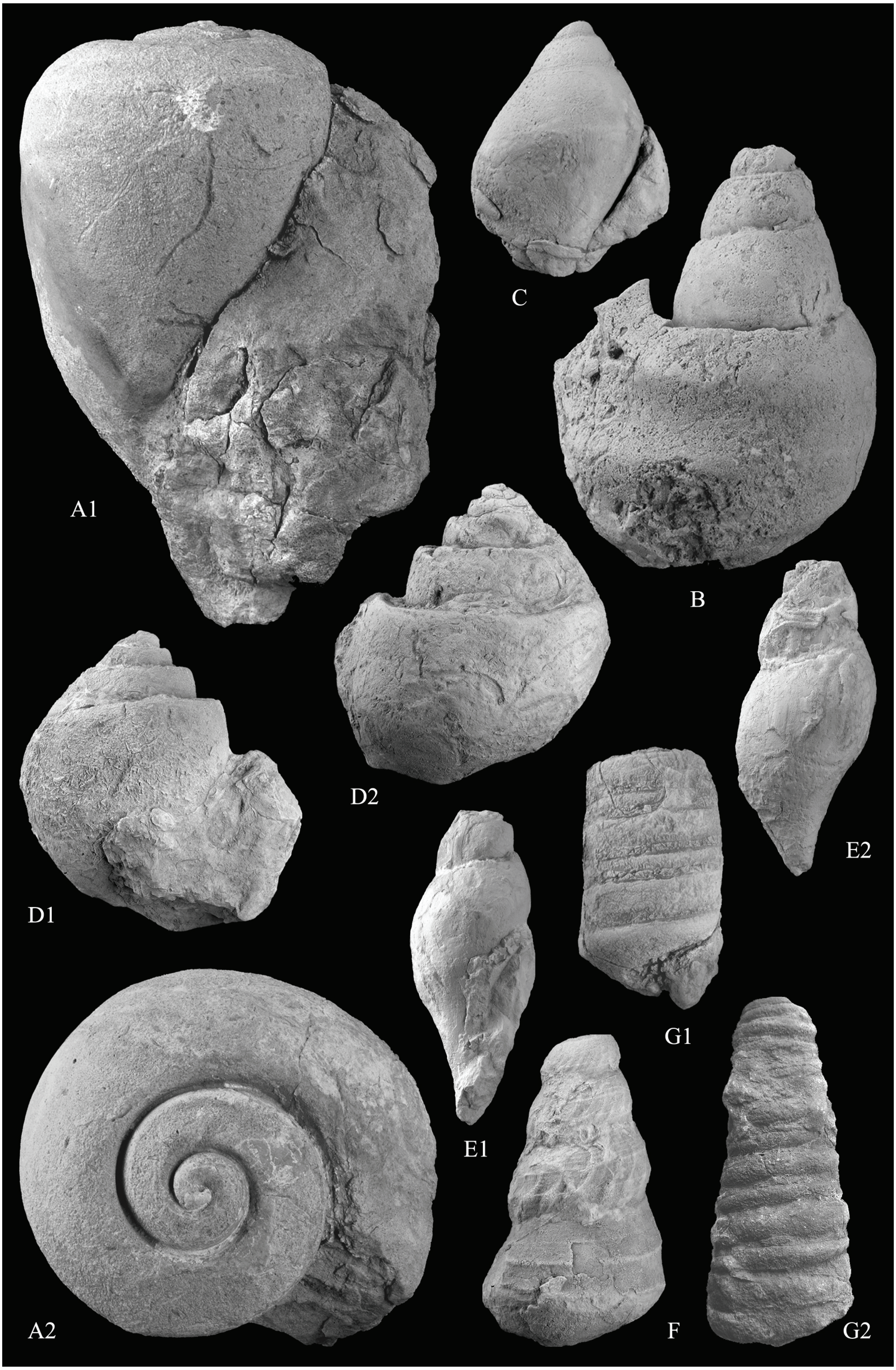
D. *Tylostoma* sp., Upper Cenomanian Galala Formation. 1: apertural view, x1; 2: abapertural view, x1; 080217-10-1.

E. *Volutoderma* sp., Upper Cenomanian Galala Formation. 1: apertural view, x2; 2: abapertural view, x2; WG-26- 2.

F. *Mrhilaia nerineaeformis* COQUAND, 1916, Upper Cenomanian Galala Formation. Abapertural view, x1; WG-29.

G. *Nerinea* sp. Upper Cenomanian Galala Formation. 1: apertural view, x1; 2: abapertural view, x1; 080217-3.

Text-fig. 4.5



Subfamily Meretricinae GRAY, 1847

Genus *Meretrix* LAMARCK, 1799

Meretrix desvauxi COQUAND, 1862 (Text-fig. 4.3H)

Superorder Anomalodesmata DALL, 1889

Order Pholadomyoida NEWELL, 1965

Superfamily Pholadomyoidea GRAY, 1847

Family Pholadomyidae GRAY, 1847

Genus *Pholadomya* J. DE C. SOWERBY, 1823

Subgenus *Pholadomya* J. DE C. SOWERBY, 1823

Pholadomya (*Pholadomya*) *pedernalis* ROEMER, 1852 (Text-fig. 4.3I)

Pholadomya (*Pholadomya*) *vignesi* LARTET, 1877 (Text-fig. 4.3J)

Superfamily Pandoroidea RAFINESQUE, 1815

Family Laternulidae HEDLEY, 1918

Genus *Plectomya* DE LORIOL, 1868

Plectomya humei (FOURTAU, 1917) (Text-fig. 4.3K)

4.2. Class Gastropoda CUVIER, 1797

Clade Caenogastropoda COX, 1960

Clade Vetigastropoda

Superfamily Pelurotomarioidea SWAINSON, 1840

Family Pelurotomariidae SWAINSON, 1840

Genus *Obornella* COX, 1959

Obornella sp. (Text-fig. 4.4A)

Clade Sorbeoconcha PONDER & LINDBERG, 1996

Superfamily Cerithioidea FLEMING, 1822

Family Cerithiidae FLEMING, 1822

Subfamily Cerithiinae FLEMING, 1822

Cerithiinae indet. (Text-fig. 4.4B)

Text-fig. 4.6

A. *Salenia* sp., Upper Cenomanian Galala Formation. 1: Adapical view, x2; 2: side view, x2; 080217-5-3.

B. *Orthopsis ovata* (COQUAND, 1862), Turonian Maghra El Hadida Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; 080216-26.

C. *Goniopygus menardi* (DESMAREST, 1825), Upper Cenomanian Galala Formation. 1: adapical view, x1.5; 2: side view, x1.5; WG-31.

D. *Pedinopsis sinaica* (DESOR, 1847), Upper Cenomanian Galala Formation. 1: adapical view, Side view, x1.5; 2: side view, x1.5; 080217-5-4.

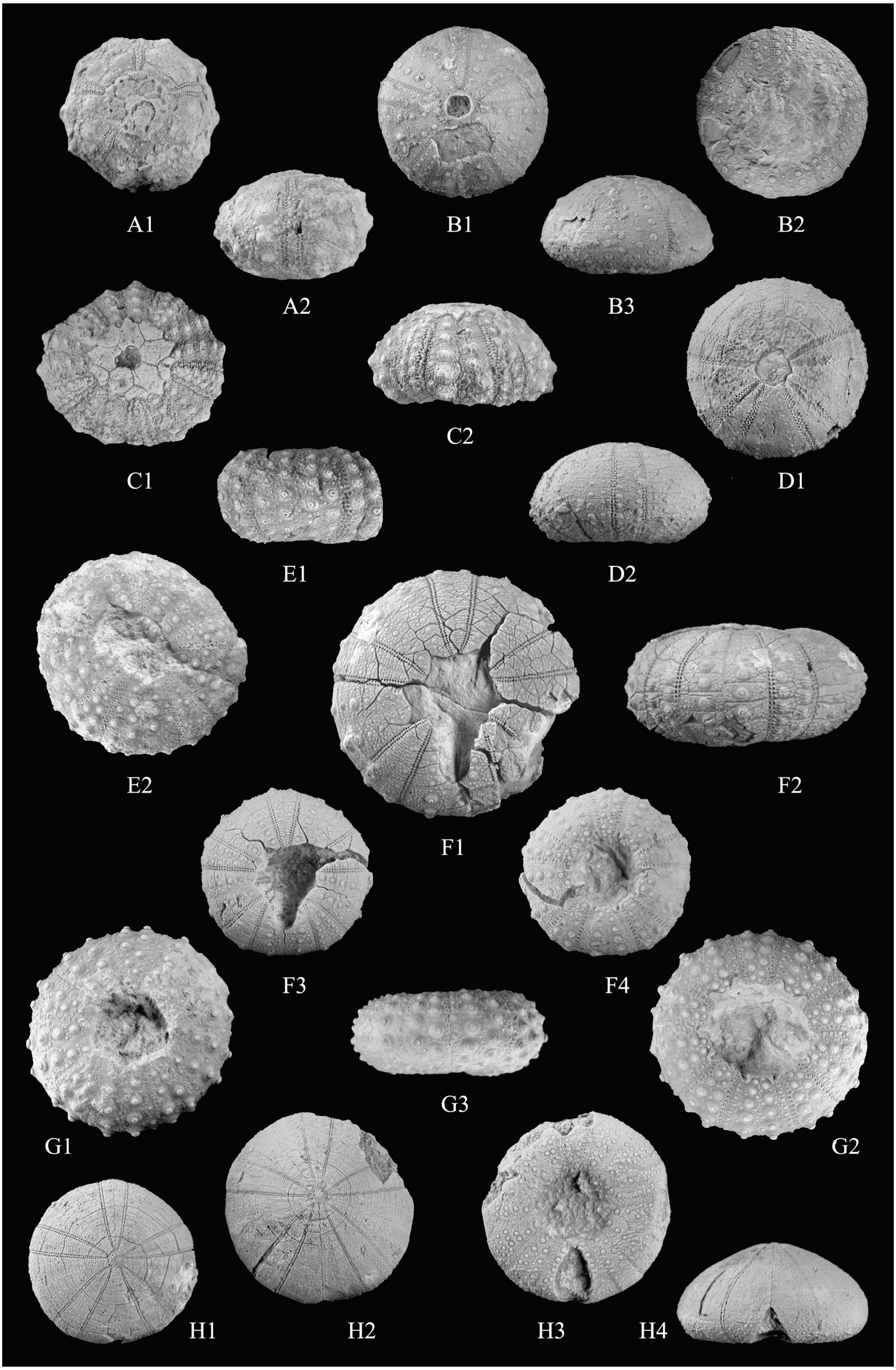
E. *Tetragramma variolare* (BRONGNIART, 1822), Upper Cenomanian Galala Formation. 1: side view, x1; 2: adoral view, x1; 080217-5-5.

F. *Heterodiadema libycum* (DESOR, 1846), Upper Cenomanian Galala Formation. 1: adapical view, x1; 2: side view, x1; 080217-10-2. – 3: adapical view, x1; 4: adoral view, x1; 080217-10-3.

G. *Phymosoma abbatei* (GAUTHIER, 1898), Turonian Maghra El Hadida Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; 080217-27-4.

H. *Coenholectypus excisus* (Desor, 1847), Upper Cenomanian Galala Formation. 1: adapical view, x1; 080217-5-6. – 2: adapical view, x1; 3: adoral view, x1; 4: side view, x1; 080217-5-7.

Text-fig. 4.6



Family Batillariidae THIELE, 1929 [= Pyrazidae HACOBJAN; 1972]

Genus *Pyrazopsis* AKOPJAN, 1972

Pyrazopsis sp. (Text-fig. 4.4C)

Family Turritellidae LOVÉN, 1847

Subfamily Turritellinae LOVEN, 1847

Genus *Turritella* LAMARCK, 1799

Turritella sp. (Text-fig. 4.4D)

Superfamily Campaniloidea DOUVILLÉ, 1904

Family Campanilidae DOUVILLÉ, 1904

Genus *Campanile* BAYLE, 1884

Subgenus *Campanile* BAYLE, 1884

Campanile ganesha Noetling, 1897 (Text-fig. 4.4E)

Family Uncertain

Genus *Cimolithium* COSSMANN, 1906

Cimolithium tenouklense (COQUAND, 1862) (Text-fig. 4.4F)

Family Ampullinidae COSSMANN, 1919

Subfamily Ampullininae COSSMANN**, 1919**

Genus *Ampullina* BOWDICH, 1822

Ampullina sp. (Text-fig. 4.4G)

Clade Hypsogastropoda PONDNER & LINDBERG, 1997

Clade Littorinimorpha GOLIKOV & STAROBOGATOV, 1975

Superfamily Stromboidea RAFINESQUE, 1815

Family Strombidae RAFINESQUE, 1815

Subfamily Strombinae RAFINESQUE, 1815

Genus *Pterocera* LAMARCK, 1799

'*Pterocera*' *incerta* d'ORBIGNY, 1842 (Text-fig. 4.5A)

Family Aporrhaidae GRAY, 1850

Subfamily Aporrhainae GRAY, 1850

Genus *Aporrhais* DA COSTA, 1778

Aporrhais sp. (COQUAND, 1862) (Text-fig. 4.4H)

Text-fig. 4.7

A. *Coenholectypus larteti* (COTTEAU, 1869), Upper Cenomanian Galala Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; 080217-10-4.

B. *Coenholectypus subpentagonalis* BLANCKENHORN, 1925, Upper Cenomanian Galala Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; 080217-5-8.

C. *Coenholectypus turonensis* (DESOR, 1847), Turonian Maghra El Hadida Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; WG-32.

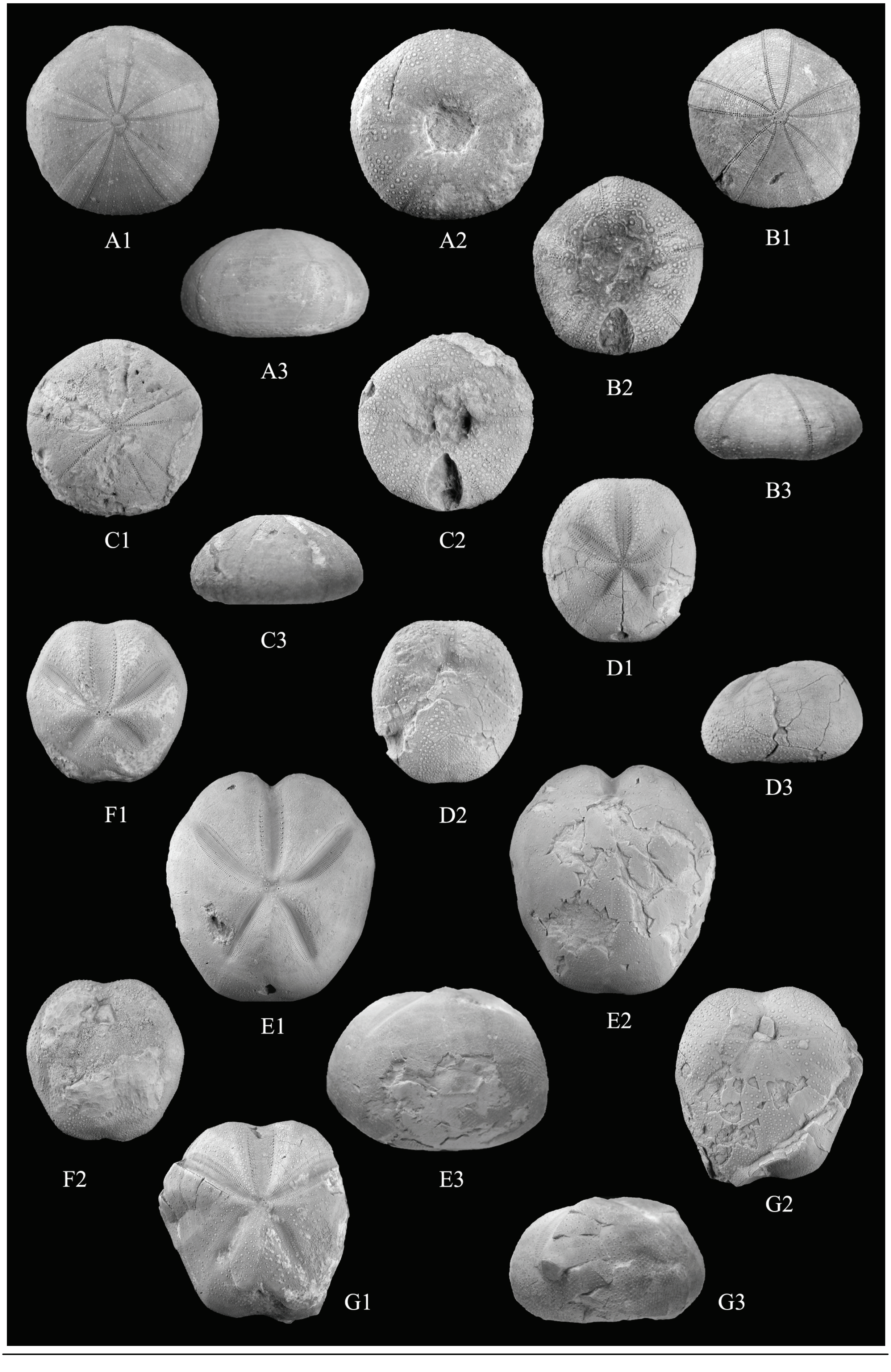
D. *Hemiaster batnensis* COQUAND, 1862, Turonian Maghra El Hadida Formation. 1: adapical view, x2; 2: adoral view, x2; 3: side view, x2; WG-33.

E. *Hemiaster cubicus* DESOR, 1847, Upper Cenomanian Galala Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; 080217-11-5.

F. *Hemiaster fourneli* DESHAYES, 1847, Turonian Maghra El Hadida Formation. 1: adapical view, x1.5; 2: adoral view, x1.5; 080217-27-5.

G. *Hemiaster heberti* (COQUAND, 1862) *turonensis* FOURTAU, 1921, Turonian Maghra El Hadida Formation. 1: adapical view, x1; 2: adoral view, x1; 3: side view, x1; WG-34.

Text-fig. 4.7



Subfamily Harpagodina PCHELINTSEV, 1963
Genus *Harpagodes* GILL, 1870
‘*Harpagodes*’ *heberti* (THOMAS & Peron, 1889) (Text-fig. 4.5B)
Family Colombellinidae P. FISCHER, 1884
Genus *Pterodonta* D’ORBIGNY, 1842
Pterodonta deffisi THOMAS & PERON, 1889 (Text-fig. 4.4I)
Pterodonta sp. (Text-fig. 4.5C)
Family Tylostomatidae STOLICZKA, 1868
Genus *Tylostoma* SHARPE, 1849
Tylostoma sp. (Text-fig. 4.5D)
Clade Neogastropoda
Superfamily Muricoidea RAFINESQUE, 1815
Family Pholidotomidae COSSMANN, 1896
Subfamily Volutodermatinae PILSBRY & OLSSON, 1954
Volutoderma sp. (Text-fig. 4.5E)
Clade Heterobranchia GRAY, 1840
Informal Group “Lower Heterobranchia” (=Allogastropoda PONDER, 1986)
Superfamily Acteonoidea D’ORBIGNY, 1843
Family Acteonellidae GILL, 1850
Subfamily Itieriinae COSSMANN, 1896
Genus *Mrhilaia* PERVINQUIÈRE, 1885
Mrhilaia nerineaeformis COQUAND, 1916 (Text-fig. 4.5F)
Superfamily Nerineoidea ZITTEL, 1873
Family Nerineidae ZITTEL, 1873
Subfamily Nerineinae ZITTEL, 1873
Genus *Nerinea* DESHAYES, 1827
Nerinea sp. (Text-fig. 4.5G)

4.3. Class Echinoidea LESKE, 1778

Order Cidaroida CLAUS, 1880
Family Cidaridae GRAY, 1825
Subfamily Cidarinae GRAY, 1825
Tribe Cidarini GRAY, 1825
Subtripe Cidarina GRAY, 1825
Genus *Cidaris* LESKE, 1778
Salenia sp. (Text-fig. 4.6A)
Infraclass Acroechinoidea SMITH, 1981
Order Orthopsida MORTENSEN, 1942
Family Orthopsidae DUNCAN, 1889
Genus *Orthopsis* COTTEAU, 1864
Orthopsis ovata (COQUAND, 1862) (Text-fig. 4.6B)
Order Arbacioida GREGORY, 1900
Suborder Arbaciina GREGORY, 1900
Family Acropeltidae, LAMBERT & THIÉRY, 1914
Genus *Goniopygus* AGASSIZ, 1838
Goniopygus menardi (DESMAREST, 1825) (Text-fig. 4.6C)

Order Phymosomatoida MORTENSEN, 1904

Family Diplopodiidae, SMITH & WRIGHT, 1993

Genus *Pedinopsis* COTTEAU, 1863

Pedinopsis sinaica (DESOR, 1847) (Text-fig. 4.6D)

Genus *Tetragramma* AGASSIZ, 1840

Tetragramma variolare (BRONGNIART, 1822) (Text-fig. 4.6E)

Family Heterodiadematidae, SMITH & WRIGHT, 1993

Genus *Heterodiadema* COTTEAU, 1846

Heterodiadema libycum (DESOR, 1846) (Text-fig. 4.6F)

Family Phymosomatidae POMEL, 1883

Genus *Phymosoma* HAIME in D'ARCHIAC & HAIME, 1853

Phymosoma abbatei (GAUTHIER, 1898) (Text-fig. 4.6G)

Order Holectypoida DUNCAN, 1889

Suborder Holectypina DUNCAN, 1889

Family Holectypidae LAMBERT, 1900

Subfamily Coenholectypinae SMITH & WRIGHT, 1999

Genus *Coenholectypus* POMEL, 1883

Coenholectypus excisus (DESOR, 1847) (Text-fig. 4.6H)

Coenholectypus larteti (COTTEAU, 1869) (Text-fig. 4.7A)

Coenholectypus subpentagonal BLANCKENHORN, 1925 (Text-fig. 4.7B)

Coenholectypus turonensis (DESOR, 1847) (Text-fig. 4.7C)

Order Spatangoida CLAUS, 1876

Family Hemiasteridae CLARK, 1917

Genus *Hemiaster* AGASSIZ, in AGASSIZ & DESOR, 1847

Subgenus *Hemiaster* AGASSIZ, in AGASSIZ & DESOR, 1847

Hemiaster cubicus DESOR, 1847 (Text-fig. 4.7D)

Hemiaster batnensis COQUAND, 1862 (Text-fig. 4.7E)

Hemiaster fourneli DESHAYES, 1847 (Text-fig. 4.7F)

Hemiaster heberti (COQUAND, 1862) *turonensis* FOURTAU, 1921 (Text-fig. 4.7G)

5. Cephalopod taxonomy

In the present study, 29 taxa (2 nautiloids and 27 ammonites) are identified, classified, described, and discussed in detail. 4 genera and 7 species of ammonites are recorded for the first time from Egypt. The studied ammonites are systematically arranged 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 (1996). In the case of the two nautiloid species, the systematic classification and terminology of WILMSEN (2000) was followed.

All linear dimensions, taken with a Vernier Caliper, are given in millimeters. The abbreviations that are used in the present work are: maximum diameter (D), whorl breadth (Wb), whorl height (Wh), breadth of umbilicus (U). Figures in parentheses refer to dimensions as a percentage of diameter.

Class Cephalopoda CUVIER, 1795
Order Nautilida DE BLAIVILLE, 1825
Suborder Nautilina DE BLAIVILLE, 1825
Superfamily Nautiloidea DE BLAIVILLE, 1825
Family Nautilidae DE BLAIVILLE, 1825
Genus *Angulithes* MONTFORT, 1808

Angulithes mermeti (COQUAND, 1862)

Text-figs. 5.1A-B, 5.2A

1862 *Nautilus Mermeti* sp. nov. – COQUAND: p. 166, pl. 2, figs. 1-2.
1907 *Nautilus Mermeti* COQUAND – PERVINQUIÈRE: p. 46.
1914 *Nautilus Mermeti* COQUAND – ECK: p. 183, pl. 9, fig. 1.
1960 *Angulithes* (*Angulithes*) *triangularis mermeti* (COQUAND) – WIEDMANN: p. 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.: p. 326, pl. 1, fig. 1.
2000 *Angulithes mermeti* (COQUAND) – WILMSEN: p. 35, pl. 5, fig. 3; text-fig. 5.
2002 *Angulithes* sp. – MEISTER & RHALMI: p. 768, pl. 5, figs. 1, 3; text-fig. 13b-c.
2004a *Angulithes mermeti* (COQUAND) – ABDEL-GAWAD et al.: pl. 1, fig. 1.
2006 *Angulithes mermeti* (COQUAND) – EL QOT: p. 114, pl. 24, figs. 1-2.

Material: Two moderately preserved complete internal moulds (080213-3-1,-2) from East Wadi Ghonima section (at 84m) and four complete and incomplete internal moulds (080216-8.5-1,-2 and WG-12-1,-2) from Wadi Ghonima section (from 15m below the top of Galala Formation). All specimens from the Upper Cenomanian *Neolobites vibrayeanus* Zone of the Galala Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-12-1	119.4 (100)	43.3 (36.2)	72.5 (60.7)	0.59	9.5 (7.9)
080213-3-1	161.9 (100)	57.8 (35.7)	113.1 (58.9)	0.51	8.1 (5.0)

Description: Involute, medium- to large-sized. Whorls strongly compressed, with triangular whorl section. Greatest width near to umbilicus. Walls slightly convex on the inner flank and relatively straight on the outer flank. Umbilicus small (about 8% of total diameter), shallow, with low and rounded umbilical walls. Venter angular due to strongly converging outer flanks. In some adult specimens the venter becomes slightly rounded at last whorl. Suture sinuous and very simple (Text-fig. 5.1A). Siphuncle located near dorsal (Text-fig. 5.1B).

Remarks: The compressed form, small umbilicus, and sinuous suture line are considered as the important characters of *Angulithes mermeti*. WIEDMANN (1960) considered *Angulithes mermeti* and *Angulithes triangularis* as conspecific and regarded *Angulithes mermeti* as a subspecies of *Angulithes triangularis*. However, WILMSEN (2000) recorded *A. triangularis* from the Middle Cenomanian of Spain and considered it differs from *A. mermeti* by its less compressed whorl section and less sinuous suture and mentioned that more material is needed to clarify if *A. mermeti* really falls into intraspecific variation with *A. triangularis*. WIEDMANN (1960) and WILMSEN (2000) regarded *Nautilus mermeti* COQUAND var. *munieri* CHOFFAT which has been recorded by ECK (1914) from Egypt, as a synonym of *Angulithes triangularis* MONTFORT. The present specimens are closely similar to *Angulithes mermeti* as described by COQUAND (1862) and WIEDMANN (1960). The more rounded venter in adult stage reported by WIEDMANN (1960) is also noted in the present material.

Occurrence: *Angulithes mermeti* has been recorded from the Upper Cenomanian of Tunisia (PERVINQUIÈRE, 1907; MEISTER & RHALMI, 2002), and Spain (WIEDMANN, 1960). In Egypt, it has been recorded from the Upper Cenomanian of the Eastern Desert (ECK, 1914) and Sinai (ABDEL-GAWAD et al., 1992; ABDEL-GAWAD et al., 2004a; EL QOT 2006). The present material has been collected from the lower Upper Cenomanian in association with *Neolobites vibrayeanus*.

Genus *Eutrephoceras* HYATT, 1894

Eutrephoceras sp.

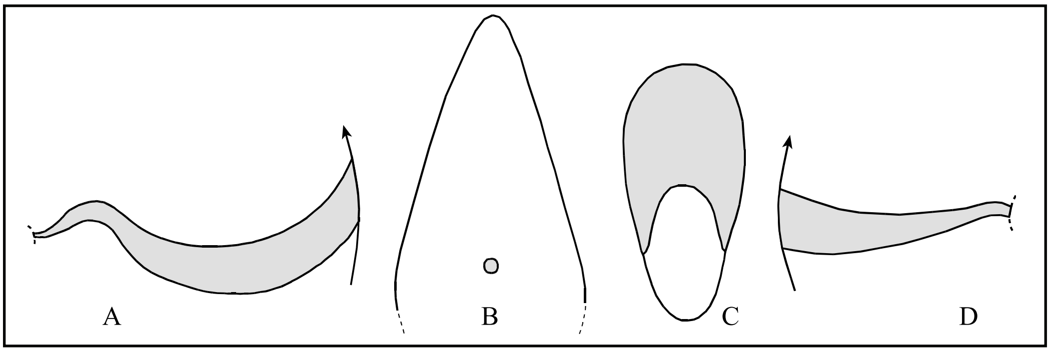
Text-figs. 5.1C-D, 5.2B

Material: Two poorly preserved complete and incomplete internal moulds (080217-11-1, -2) from the Upper Cenomanian *Neolobites vibrayeanus* Zone of the Galala Formation at East Wadi Ghonima section (at 58.5m).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-11-1	37.57 (100)	16.33 (43.4)	21.1 (56.1)	0.77	4.9 (13.0)

Description: Involute, small-sized. Whorls compressed, with maximum breadth at mid-flank. Whorl section is slightly higher than wide and with rounded venter (Text-fig. 5.1C-D). Flanks slightly convex. Umbilicus relatively small (13% of total diameter) and very shallow. Suture relatively straight with very shallow umbilical and ventral saddles. The position of the siphuncle is not seen.



Text-fig. 5.1. Suture lines and whorl sections of: A-B, *Angulithes mermeti* (COQUAND, 1862); C-D, *Eutrephoceras* sp. A, specimen 080213-3-1; B, specimen WG-12-2; C and D, specimen 080217-11-1. Not to scale

Occurrence: According to WILMSEN (2000), the genus *Eutrephoceras* has a wide range (Bajocian to Early Oligocene) and global distribution. In the study area, it has been recorded from the lower Upper Cenomanian in association with *Neolobites vibrayeanus*.

Order Ammonoidea ZITTEL, 1884
Suborder Ammontina HYATT, 1889
Superfamily Hoplitoidea DOUVILLÉ, 1809
? Family Engonoceratidae HYATT, 1900
Genus *Neolobites* FISCHER, 1882

Neolobites vibrayeanus (D'ORBIGNY, 1841)

Text-figs. 5.3, 5.4A

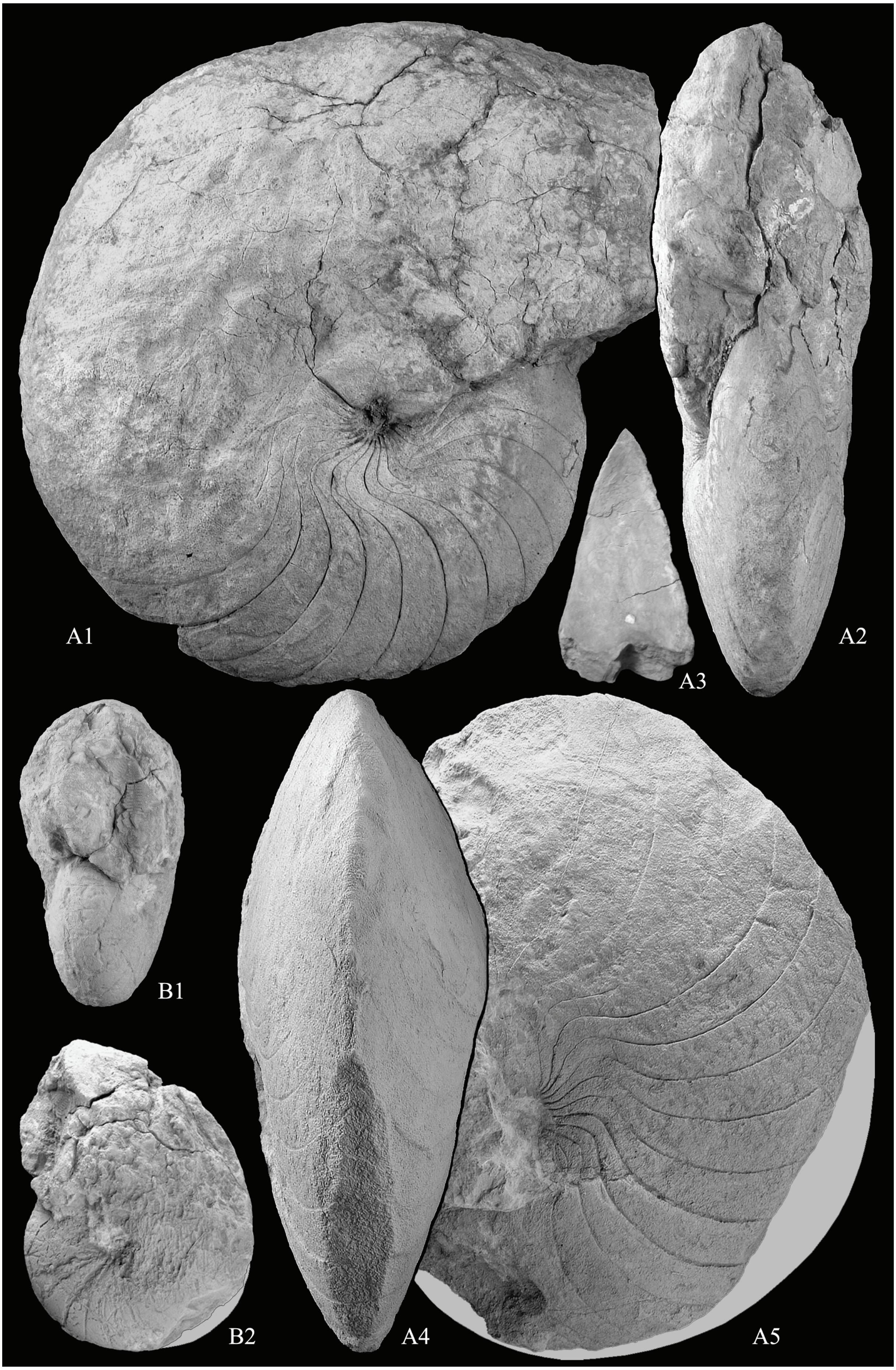
1841 *Ammonites vibrayeanus* sp. nov. – D'ORBIGNY: p. 322, pl. 96, figs. 1-3.
1889 *Neolobites Vibrayeanus* D'ORBIGNY – PERON: p. 16, pl. 18, figs. 1, 2.
1898 *Neolobites Vibrayeanus* D'ORBIGNY – CHOFFAT: p. 75, pl. 5, figs. 2-9.
1914 *Neolobites Schweinfurthi* sp. nov. – ECK: p. 186, pl. 11, fig. 1.
1914 *Neolobites Brancai* sp. nov. – ECK: p. 188, pl. 12.
1956 *Neolobites kummeli* BENAVIDES–CÁCERES: p. 486, pl. 66, figs. 5, 6.
1981 *Neolobites vibrayeanus* (D'ORBIGNY) – KENNEDY & JUIGNET: p. 23, figs. 3-4, 6a; text-fig. 5.
1989 *Neolobites vibrayeanus* (D'ORBIGNY) – LUGER & GRÖSCHKE: p. 366, pl. 39, fig. 3, text-fig. 5.
1991 *Neolobites vibrayeanus* (D'ORBIGNY) – KENNEDY & SIMMONS: p. 134, pl. 2, figs. d-g.
1992 *Neolobites vibrayeanus* (D'ORBIGNY) – MEISTER et al.: p. 60, figs. 1-4, 6; text-fig.8.
1994 *Neolobites vibrayeanus brancai* ECK – MEISTER et al.: p. 191, pl. 1, figs. 1-4; pl. 2, figs. 1, 2; text-fig. 4.
1996 *Neolobites vibrayeanus brancai* ECK – MEISTER & ABDALLAH: p. 7, pl. 2, fig. 2.

Text-fig. 5.2

A. *Angulithes mermeti* (COQUAND, 1862), Upper Cenomanian Galala Formation. 1: lateral view, x0.75; 2: apertural view, x0.75; 080213-3-1. – 3: front view, x1; WG-12-2. – 4: ventral view, x0.75; 5: lateral view, x0.75; WG-12-1.

B. *Eutrephoceras* sp., Upper Cenomanian Galala Formation. 1: apertural view, x1.5; 2: lateral view, x1.5; 080217-11-1.

Text-fig. 5.2



1996 *Neolobites vibrayeanus* (D'ORBIGNY) – KASSAB: pl. 1, figs. 1-3.
2001 *Neolobites vibrayeanus* (D'ORBIGNY) – ALY & ABDEL-GAWAD: p. 29, pl. 1, figs. 2-4; text-fig. 3a,b.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) – MEISTER & RHALMI: p. 763, pl. 1; pl. 2, fig. 5.
2002 *Neolobites vibrayeanus brancai* ECK – MEISTER & RHALMI: p. 764, pl. 2, figs. 1-3.
2002 *Neolobites vibrayeanus* (D'ORBIGNY) – EL-HEDENY: p. 401, fig. 3a-b, fig. 7d, fig. 8e.
2003 *Neolobites vibrayeanus* (D'ORBIGNY) – HEWAIDY et al.: p. 340, pl. 1, figs. 7-8.
2004a *Neolobites vibrayeanus* (D'ORBIGNY) – ABDEL-GAWAD et al.: pl. 1, fig. 2.
2005 *Neolobites vibrayeanus vibrayeanus* (D'ORBIGNY) – MEISTER & ABDALLAH: p. 123, pl. 1, figs. 3-6, 8; pl. 2, figs. 2, 3, 6.
2005 *Neolobites vibrayeanus brancai* ECK – MEISTER & ABDALLAH: p. 123, pl. 1, figs. 1, 2, 7; pl. 2, figs. 1, 5.
2005 *Neolobites vibrayeanus* (D'ORBIGNY) – WIESE & SCHULZE: p. 933, figs. 4-9.
2006 *Neolobites vibrayeanus* (D'ORBIGNY) – EL QOT: p. 116, pl. 24, figs. 4-5.
2008 *Neolobites vibrayeanus* (D'ORBIGNY) – ALY et al.: p. 46, pl. 3, figs. 2-3; text-fig. 3 (2).

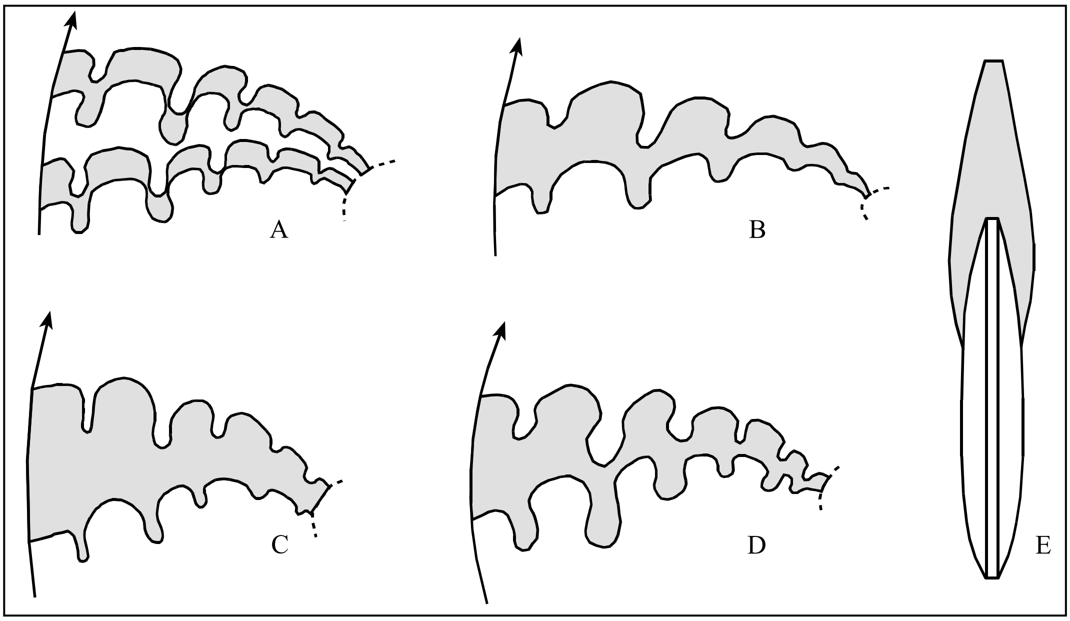
Material: 10 moderately preserved incomplete internal moulds (WG-10- 1–9 & 080216-8.5-3) from Wadi Ghonima section (15m below the top of Galala Formation), two moderately preserved incomplete internal moulds (080217-11-3 & 080213-3-3) from East Wadi Ghonima section (at 58.5m and 84m), and one incomplete internal mould (WA-9-1) from Wadi Askhar section (at 60m). All specimens have been collected from the lower Upper Cenomanian.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-10-1	69.6 (100)	23.3 (33.4)	46.4 (66.6)	0.50	6.4 (9.1)
WG-10-2	106.6 (100)	26.0 (24.3)	59.4 (55.7)	0.43	8.1 (7.5)

Description: Very involute, small- to medium-sized. Whorls strongly compressed, elevated, with lanceolate shape. Greatest breadth around mid-flank, with flat venter. Flank slightly convex with ventrolateral shoulders ornamented by delicate clavi, approximately 40 clavi/whorl in specimen WG-10-1. Umbilicus small (about 9% of total diameter), shallow, with low and rounded umbilical wall. Very week ribs are noted on the inner parts of flanks. The suture line (Text-fig. 5.3) has broad saddles, narrow and lanceolate lobes, with flattened ends of all suture elements. The lobes become shallower in the direction of the umbilicus. In addition, some specimens show overlapping suture lines.

Remarks: *Neolobites vibrayeanus* can be recognized depending on compressed whorls, distinctive suture line, flat venter and the small umbilicus. In the illustration of D'ORBIGNY (1841) for *Neolobites vibrayeanus*, the body chamber shows ornament with smooth broad ribs and a slightly concave, narrow flat venter with minute ventrolateral tubercles. In their redescription of the holotype of D'ORBIGNY, KENNEDY & JUIGNET (1981, p. 27) noted that the artist who produced the illustration has introduced several inaccuracies, for the inner whorls are entirely imaginary, as is the ventral ornament. BENAVIDES–CÁCERES (1965, p. 486) described *Neolobites kummeli* from Peru and differentiates between it and *N. vibrayeanus* by only the presence of ribs in the latter species. But in agreement with KENNEDY & JUIGNET (1981), *N. kummeli* is regarded as a synonym of *N. vibrayeanus*, as the presence or absence of ribs is related to postmortem conditions.



Text-fig. 5.3. Suture lines and whorl section of *Neolobites vibrayeanus* (D'ORBIGNY, 1841). A, specimen WG-10-1; B, specimen WG-10-3; C, specimen WG-10-6; D and E, specimen WG-10-2. Not to scale.

LUGER & GRÖSCHKE (1989, p. 366) considered their specimens, collected from Egypt, very close to the holotype as refigured by KENNEDY & JUIGNET (1981). However, the ornamentation of their specimens is slightly weaker and the umbilicus is a little narrower. KENNEDY & SIMMONS (1991, p. 136) described this species from the Upper Cenomanian of Oman and considered the small umbilicus, feeble ornamentation and the compressed whorls as characteristic for *N. vibrayeanus*. WIESE & SCHULZE (2005, p. 937) noted that their material, from the Middle East, shows a high morphological variation and recognized two morphotypes in *N. vibrayeanus*: small-umbilicus-morphotypes with weak ribbing and without tuberculation and large-umbilicus-morphotypes with subrectangular whorl section, stronger ribbing on the phragmocone and stronger ventrolateral clavi. Differences from other *Neolobites* species have been discussed by KENNEDY & JUIGNET (1981), LUGER & GRÖSCHKE (1989), and WIESE & SCHULZE (2005). In agreement with KENNEDY & JUIGNET (1981) and WIESE & SCHULZE (2005), *Neolobites brancai* and *Neolobites schweinfurthi* described by ECK (1914) from Egypt are regarded as *N. vibrayeanus* and the characters which were used to separate these species are considered as morphologic variation within one species. The specimen described by EL-HEDENY & NAFEE (2001, p. 119, pl. 1, fig. 1) and also the specimen figured by KORA et al. (2001, pl. 2, fig. 9, 10) from Egypt have suture lines which differ from the suture of *N. vibrayeanus* and also the venter of the latter authors' specimen seems to be sharp which is incompatible with the tabulate venter of *N. vibrayeanus*. Therefore, their specimens are not regarded here as *N. vibrayeanus*. Also, the suture line of the specimen figured by ABDEL-GAWAD et al. (2004b, pl. 6, fig. 1a,b) as *N. vibrayeanus* is completely different from the suture line of *N. vibrayeanus*, but it may be related to Acanthoceratidae. The studied specimens closely correspond to the holotype as figured by KENNEDY & JUIGNET (1981) and those specimens described by LUGER & GRÖSCHKE (1989) and are also similar to the morphotypes of WIESE & SCHULZE (2005). Most studied specimens lack ornament, but few specimens show delicate ventrolateral clavi and very weak ripping on the inner flanks. In addition, the studied specimens have considerable variation in the suture line due to postmortem conditions such as compaction.

Occurrence: According to KENNEDY & SIMMONS (1991, p.136), *Neolobites vibrayeanus* (D'ORBIGNY) is a widespread and characteristic lower Upper Cenomanian species, occurring commonly in western Europe (France, Spain, and Portugal), northern Africa and the Middle East (Morocco, Algeria, Tunisia, Egypt, Israel, Lebanon, Jordan, Syria, Saudi Arabia, and Oman), as well as South America (Bolivia, Colombia, Peru and Venezuela). So, this species tended to prefer lower latitudes and subtropical/ tropical areas. In Egypt, it has been recorded from the Upper Cenomanian of the north Eastern Desert (ECK, 1914; LUGER & GRÖSCHKE, 1989; HEWAIDY et al., 2003); from the Gulf of Suez region (KASSAB, 1996), and from Sinai (ALY & ABDEL-GAWAD, 2001; EL-HEDENY, 2002; ABDEL-GAWAD et al., 2004a; EL QOT, 2006). In the study area, *Neolobites vibrayeanus* is recorded from the lower Upper Cenomanian *Neolobites vibrayeanus* Zone that is equivalent to the standard ammonite Zone of *Calycoceras naviculare* (GRADSTEIN et al. 2004).

Superfamily Acanthoceratoidea GROOSSOUVRE, 1894

Family Acanthoceratidae GROOSSOUVRE, 1894

Subfamily Acanthoceratinae GROOSSOUVRE, 1894

Genus *Thomelites* WRIGHT & KENNEDY, 1973

Thomelites sp.

Text-figs. 5.4B, 5.6A-B

Material: One moderately preserved incomplete composite mould (WA-7-1) from the Upper Cenomanian of Galala Formation at Wadi Askhar section (at 50m).

Description: Medium-sized, with compressed whorl section (Text-fig. 5.6A-B). Maximum width at the umbilical shoulders. Venter tabulate, compressed, and relatively narrow. Umbilicus moderately wide with very strong umbilical tubercles. Ribs arise singly or in twos from umbilical tubercles and are intercalated. The ventrolateral shoulders have strong inner tubercles and outer clavi.

Occurrence: According to WRIGHT & KENNEDY (1981), the genus *Thomelites* is recorded from Upper Cenomanian of England, France, Israel, (?) southern India, Texas, South Dakota, and Brazil. This is the first record of the genus *Thomelites* from Egypt, it has been recorded from lower Upper Cenomanian (*Neolobites vibrayeanus* Zone).

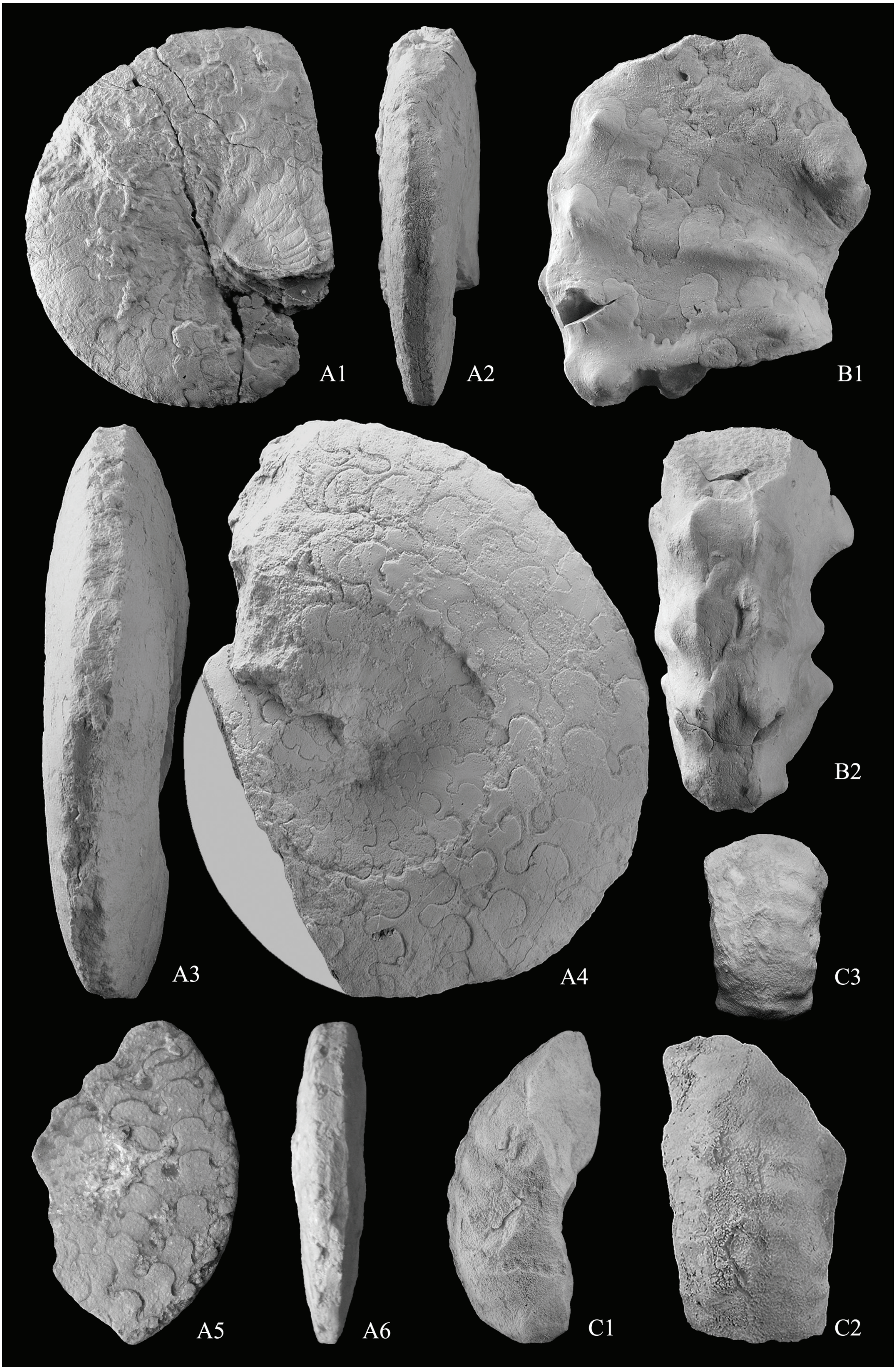
Text-fig. 5.4

A. *Neolobites vibrayeanus* (D'ORBIGNY, 1841), Upper Cenomanian Galala Formation. 1: lateral view, x1; 2: ventral view, x1; WG-10-1. – 3: ventral view, x0.75; 4: lateral view, x0.75; WG-10-2. – 5: lateral view, x1; 6: ventral view, x1; WG-10-3.

B. *Thomelites* sp., Upper Cenomanian Galala Formation. 1: lateral view, x1; 2: ventral view, x1; WA-7-1.

C. *Euomphaloceras septemseriatum* (CRAGIN, 1893), Upper Cenomanian Galala Formation. 1: lateral view, x1; 2: ventral view, x1; 080215-6-1. - 3: ventral view, x1; 080215-6-2.

Text-fig. 5.4



Subfamily Euomphaloceratinae COOPER, 1978
Genus *Euomphaloceras* SPATH, 1923b

Euomphaloceras septemseriatum (CRAGIN, 1893)

Text-figs. 5.4C, 5.6C

1893 *Scaphites septem-seriatum* sp. nov. – CRAGIN: p. 240.
1981 *Euomphaloceras septemseriatum* (CRAGIN) – WRIGHT & KENNEDY: p. 55, pl. 12, figs. 1-8; pl. 13, figs. 1-6; pl. 14, figs. 5-9 (with full synonymy).
1981 *Euomphaloceras septemseriatum* (CRAGIN) – KENNEDY & JUIGNET: p. 38, figs. 9b-d.
1984 *Euomphaloceras septemseriatum* (CRAGIN) – KENNEDY et al.: p. 36, figs. 3k, i.
1985 *Euomphaloceras* (*Kanabiceras*) *septemseriatum* (CRAGIN) – HOWARTH: p. 95, figs. 26-29.
1986 *Euomphaloceras septemseriatum* (CRAGIN) – KENNEDY et al.: p. 206, figs. 3c, d.
1988 *Euomphaloceras septemseriatum* (CRAGIN) – KENNEDY: p. 53, pl. 8, figs 1-6, 9; pl. 9, figs. 1-3, 5, 7, 9-12; pl. 22, fig. 3; text-figs. 10e, 1ld.
1990 *Euomphaloceras* cf. *septemseriatum* (CRAGIN) – ROBASZYNSKI et al.: p. 262, pl. 15, fig. 5.
1994 *Euomphaloceras* cf. *septemseriatum* (CRAGIN) – KENNEDY & JUIGNET: p. 492.
2003 *Euomphaloceras septemseriatum* (CRAGIN) – KENNEDY et al.: p. 10, pl. 2, figs. 9, 10, 13, 15, 18-23.

Material: Two poorly preserved incomplete composite moulds (080215-6-1, -2) from the Upper Cenomanian *Metoicoceras geslinianum* Zone of the Maghra El Hadida Formation at Wadi Ghonima section (24.7m above the base of the formation).

Description: Medium-sized, with subtrapezoidal, depressed whorl section (Text-fig. 5.6C). Maximum width at the position of the umbilical tubercles. Venter wide, with week keel and ornamented by weak siphonal tubercles equal in number to the ventrolateral tubercles. Flanks short, ornamented with weak ribs that curve forwards at the ventrolateral edge.

Remarks: The body chamber characteristics of this species are highly distinctive: it has a wide venter with siphonal tubercles and a row of ventrolateral tubercles on the two sides. WRIGHT & KENNEDY (1981) described material from chalk and limestone facies of England in detail. KENNEDY (1988) described much better preserved material of this highly variable species from Upper Cenomanian clays and concretions of Texas. *Euomphaloceras septemseriatum*, as recorded by KENNEDY et al. (2003), shows wide morphological and ontogenetic variations. However, the present material is too poorly preserved to comment on this, and most characters have been documented by previous authors.

Occurrence: *Euomphaloceras septemseriatum* has been recorded from the Upper Cenomanian of England (WRIGHT & KENNEDY, 1981), France (KENNEDY & JUIGNET, 1981; KENNEDY et al. 1984; KENNEDY et al. 1986; KENNEDY et al. 2003), Angola (HOWARTH, 1985), United States (KENNEDY, 1988), and Tunisia (ROBASZYNSKI et al. 1990). This is the first record of *Euomphaloceras septemseriatum* from Egypt; it has been recorded from the Upper Cenomanian in association with *Metoicoceras geslinianum*.

Genus *Kamerunoceras* REYMENT, 1954

Kamerunoceras turoniense (D'ORBIGNY, 1850)

Text-figs. 5.5A, 5.6D-E

1850 *Ammonites turoniensis* sp. nov. – D'ORBIGNY: p. 190.
1907 *Mammites* (*Pseudaspidoceras*) *salmuriensis* COURTILLER – PERVINQUIÈRE: p. 314, pl. 19, fig. 1; fig. A in explanation to plate (including var. *zerhalmensis*), text-fig. 120.
1907 *Mammites* (*Pseudaspidoceras*) *armatus* PERVINQUIÈRE: p. 317, pl. 19, figs. 2-4 (including var. *fraichichensis*).
1969 *Protexanites salmuriensis* (COURTILLER) – FREUND & RAAB: p. 69, pl. 5, figs. 4-6; text-fig. 14c-j.
1979a *Kamerunoceras turoniense* (D'ORBIGNY) – KENNEDY & WRIGHT: p. 1170, pl. 2, figs. 1-11; pl. 3, figs. 1-2; pl. 4, figs. 1-3; text-fig. 2-3 (with full synonymy).
1981 *Kamerunoceras turoniense* (D'ORBIGNY) – WRIGHT & KENNEDY: p. 57, pl. 14, figs. 1, 2, 10.
1982 *Pseudaspidoceras armatum* (PERVINQUIÈRE) – RENZ: p. 97, pl. 30, figs. 1-5.
1990 *Kamerunoceras turoniense* (D'ORBIGNY) – ROBASZYNSKI et al.: p. 262, pl. 15, figs. 1, 2.
1994 *Kamerunoceras turoniense* (D'ORBIGNY) – CHANCELLOR et al.: p. 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.
1997 *Kamerunoceras turoniense* (D'ORBIGNY) – WIESE: pl. 3, figs. 1-3.
1998 *Kamerunoceras turoniense* (D'ORBIGNY) – KÜCHLER: pl. 6, fig. 2; pl. 7, figs. 2-5; pl. 10, fig. 1.
2001 *Protexanites* cf. *salmuriensis* (COURTILLER) – GALAL et al.: pl. 5, figs. 8-9.
2004 *Kamerunoceras turoniense* (D'ORBIGNY) – BARROSO-BARCENILLA: p. 94, pl. 3, fig. 3.

Material: Three moderately preserved incomplete composite moulds (080217-26- 1–3) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at East Wadi Ghonima section (at 132m).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-26-1	118.21 (100)	42.74 (36.1)	54.15 (45.8)	0.78	43.56 (36.8)
080217-26-2	57.88 (100)	19.35 (33.4)	23.51 (40.6)	0.82	22.96 (39.6)

Description: Evolute, with large umbilicus, reaching up to 40% of total diameter. Medium- to large-sized, compressed, with greatest breadth at the outer ventrolateral tubercles. Flanks narrow, flatted with broadly rounded ventrolateral shoulders. Whorl section oval to subrectangular. Venter slightly convex with ridge marking the site of the siphuncle. Ornamentation consists of weak ribs, bearing strong and well developed inner and outer ventrolateral tubercles and weak tubercles near the umbilical shoulders. The smallest specimen (080217-26-2) has 7 ribs per half whorl. Suture line characterized by a narrow, deep external lobe, with a narrow, high external saddle, a broad asymmetrically bifid lateral saddle, a slightly wide, deep lateral lobe, and a low umbilical saddle with small branches (Text-fig. 5.6D-E).

Remarks: The wide and evolute coiling, flank ribbing with rows of tubercles on umbilical shoulder or on middle flank, inner and outer tubercles on ventrolateral shoulders, and the wide venter with ridge marking the site of the siphuncle are the characters that distinguish *Kamerunoceras turoniense*. The earliest name applied to this species is *Ammonites turoniensis* D'ORBIGNY (1850). PERVINQUIÈRE (1907), in the first revision of this species (as *Mammites* (*Pseudaspidoceras*) *salmuriensis*), described this species from Tunisia and introduced some varieties. These varieties and his species, *Mammites* (*Pseudaspidoceras*) *armatus*, were regarded later by different authors (e.g. FREUND & RAAB, 1969; KENNEDY & WRIGHT, 1979a and CHANCELLOR et al. 1994) as synonyms of *Kamerunoceras turoniense*. KENNEDY & WRIGHT (1979a) revised the abundant material of *Kamerunoceras turoniense* from Touraine in France. They described this species in details and discussed its relation with different other *Kamerunoceras* species. CHANCELLOR et al. (1994, p. 28) mentioned that *Kamerunoceras turoniense* extends well into the Middle Turonian, although they recorded it from a Lower Turonian zone (*Thomasites rollandi*). The studied specimens are identical with Tunisian material described by PERVINQUIÈRE (1907), ROBASZYNSKI et al. (1990), and CHANCELLOR et al. (1994). It co-occurs with *Thomasites rollandi* in the upper part of the *Choffaticeras* spp. Zone of the Lower Turonian.

Occurrence: According to WRIGHT & KENNEDY (1981): 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 Tunisia (PERVINQUIÈRE, 1907; ROBASZYNSKI et al. 1990; CHANCELLOR et al. 1994), Israel (FREUND & RAAB, 1969), France (KENNEDY & WRIGHT, 1979a), England (WRIGHT & KENNEDY, 1981), and Venezuela (RENZ, 1982). In Egypt, ABED et al. (1996) and BAUER et al. (2001) noted this species on their logs from the Lower Turonian of Sinai, but they didn't describe or illustrate it. In the present study, it has been recorded from the upper Lower Turonian.

Genus *Pseudaspidoceras* HYATT, 1903

Pseudaspidoceras sp.

Text-fig. 5.5B

Material: One poorly preserved incomplete composite mould (080215-6-3) from the Upper Cenomanian *Metoicoceras geslinianum* Zone of the Maghra El Hadida Formation at Wadi Ghonima section (24.7m above the base of the formation).

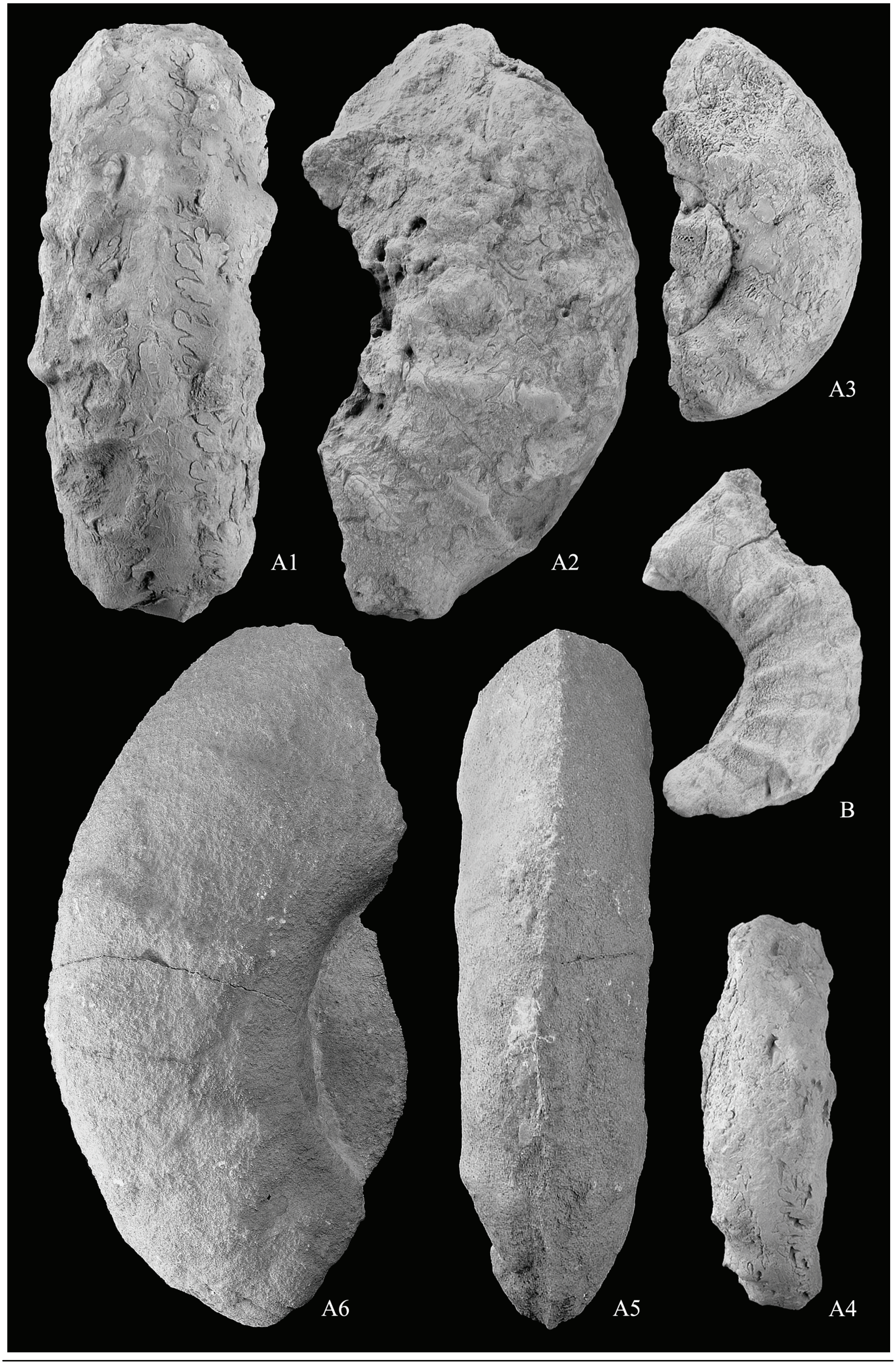
Description: Evolute, with large umbilicus. Medium-sized, with compressed whorl section. Maximum breadth at the outer ventrolateral tubercles. Flanks narrow, with flat sides. Ornamentation consists of weak ribs, bears weak inner and outer ventrolateral tubercles with umbilical bullae. Suture line not seen due to the poor preservation.

Text-fig. 5.5

A. *Kamerunoceras turoniense* (D'ORBIGNY, 1850), Lower Turonian Maghra El Hadida Formation. 1: ventral view, x1; 2: lateral view, x1; 080217-26-1. – 3: lateral view, x1; 4: ventral view, x1; 080217-26-2. – 5: lateral view, x0.75; 6: ventral view, x0.75; 080217-26-3.

B. *Pseudaspidoceras* sp., Upper Cenomanian Maghra El Hadida Formation. lateral view, x1; 080215-6-3.

Text-fig. 5.5



Remarks: The present specimen is similar to *Pseudaspidoceras paganum* REYMENT (1954) as described by ZABORSKI (1995, p. 63, figs. 15-16, 22-23) from Nigeria and by MEISTER & ABDALLAH (2005, p.127, pl. 6, fig. 2) from Tunisia. But unfortunately, the present specimen is too poorly preserved to ensure specific identification.

Occurrence: According to ZABORSKI (1995), the genus *Pseudaspidoceras* has a stratigraphical range from the Upper Cenomanian to Lower Turonian. It occurs in Texas, New Mexico, Arizona, Colorado, Mexico, Brazil, Germany, southern England, Portugal, Tunisia, Egypt, Algeria, Angola, Niger, Nigeria, Madagascar, southern India and (?) Japan. The present specimen is recorded from the Upper Cenomanian in association with *Metoicoceras geslinianum*.

Subfamily Mammitinae HYATT, 1900
Genus *Metoicoceras* HYATT, 1903

Metoicoceras geslinianum (D'ORBIGNY, 1850)

Text-figs. 5.6F, 5.7A

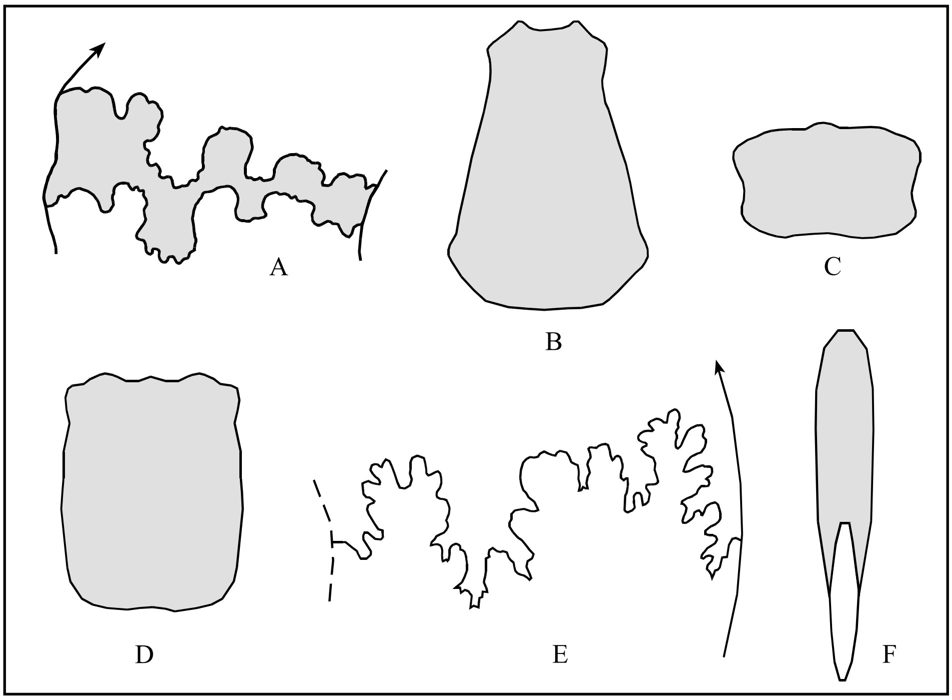
1850 *Ammonites geslinianus* sp. nov. – D'ORBIGNY: p. 146.
1981 *Metoicoceras geslinianum* (D'ORBIGNY, 1850) – WRIGHT & KENNEDY: p. 62, pl. 17, fig. 2; pl. 18, figs. 1, 2; pl. 19, figs. 1, 2; pl. 20, figs. 1-3; pl. 21, figs. 1, 2; text-figs. 19C-E, 20, 21A-D (with full synonymy).
1981 *Metoicoceras geslinianum* (D'ORBIGNY) – KENNEDY & JUIGNET: p. 39, text-figs. 7d-e, 8a-c, 9a, e, 10a.
1984 *Metoicoceras geslinianum* (D'ORBIGNY) – KENNEDY et al.: p. 37.
1988 *Metoicoceras geslinianum* (D'ORBIGNY) – KENNEDY: p. 58, pl. 9, fig. 8; pl. 10, figs. 25-27; pl. 22, figs. 16, 17; text-figs. 20-23.
1992 *Metoicoceras geslinianum* (D'ORBIGNY) – MEISTER et al.: p. 66, pl. 2, figs. 1, 3; text-fig. 11.
1994 *Metoicoceras geslinianum* (D'ORBIGNY) – KENNEDY & JUIGNET: p. 493, figs. 11a-d, f-h; 12a, f, g.
1996 *Metoicoceras geslinianum* (D'ORBIGNY) – KASSAB: pl. 1, figs. 4-6.
1999 *Metoicoceras geslinianum* (D'ORBIGNY) – LEHMANN: pl. 4, fig. 3.
?2001 *Metoicoceras geslinianum* (D'ORBIGNY) – ALY & ABDEL-GAWAD: p. 35, pl. 4, fig. 2.
2003 *Metoicoceras geslinianum* (D'ORBIGNY) – KENNEDY et al.: p. 11, pl. 3, figs. 1-9; pl. 5, figs. 4-9.
2004 *Metoicoceras geslinianum* (D'ORBIGNY) – BARROSO-BARCENILLA: p. 96, pl. 1, fig. 5; pl. 2, fig. 1.
2005 *Metoicoceras geslinianum* (D'ORBIGNY) – MEISTER & ABDALLAH: p. 128, pl. 8, fig. 1.

Material: Two poorly preserved composite moulds (080215-3-1, -2) from the Upper Cenomanian *Metoicoceras geslinianum* Zone of the Maghra El Hadida Formation at Wadi Ghonima section (24.7m above the base of the formation).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080215-3-1	50.2 (100)	11.2 (22.3)	25.8 (51.3)	0.43	9.1(18.1)

Description: Involute, small- to medium-sized. Whorls strongly compressed (Text-fig. 5.6F). Greatest breadth around mid-flank. Venter narrow, with ventrolateral shoulders. Umbilicus medium-sized, shallow, with low umbilical wall and rounded umbilical shoulder. Ornamentation consists of weak umbilical bullae giving rise to moderately strong and straight ribs with additional short intercalated ribs. All ribs bear slightly clavate ventrolateral tubercles. Suture line poorly preserved.



Text-fig. 5.6. Whorl section and suture line of: A-B, *Thomelites* sp.; C, *Euomphaloceras septemseriatum* (CRAGIN, 1893); D-E, *Kamerunoceras turoniense* (D'ORBIGNY, 1850); F, *Metoicoceras geslinianum* (D'ORBIGNY, 1850). A-B, specimen WA-7-1; C, specimen 080215-6-1; D-E, specimen 080217-26-1; F, specimen 080215-3-1. Not to scale.

Remarks: The studied specimens are closely similar the lectotype described by KENNEDY & JUIGNET (1981), but differs in having a narrower venter. The specimen described by ALY & ABDEL-GAWAD (2001) from Sinai has a more inflated whorl section and the height of whorls is very short, as well as the ornamentation on the ventrolateral shoulders is very weak or absent. Therefore, their specimen is placed here in synonymy with doubt.

Occurrence: *Metoicoceras geslinianum* has been recorded from the Upper Cenomanian of England (WRIGHT & KENNEDY, 1981), France (KENNEDY & JUIGNET, 1981; KENNEDY et al. 1984), United States (KENNEDY, 1988), Niger (MEISTER et al. 1992), and Germany (LEHMANN, 1999). In Egypt, it has been recorded from the Upper Cenomanian of the north Eastern Desert (KASSAB, 1991), Gulf of Suez region (KASSAB, 1996), and Sinai (ALY & ABDEL-GAWAD, 2001).

Family Vascoceratidae DOUVILLÉ, 1912

Genus *Vascoceras* CHOFFAT, 1898

Diagnosis: Involute to slightly evolute, compressed to depressed, with discoidal or subglobose to globose shape. Flanks short, with rounded or flattened venter, and steep-sided umbilicus. Early whorls ornamented with umbilical tubercles and fold-like ribs which cross the venter. This ornamentation mostly disappears during later growth stages and the last whorl is normally smooth. Suture line is irregular, with wide, shallow, feebly indented elements.

Discussion: FURON (1935) proposed *Paravascoceras* as a subgenus of *Vascoceras* to describe the compressed vascoceratids that are lacking umbilical tubercles. This subgenus has been used by different authors (e.g. COOPER, 1978; HOWARTH, 1985; MEISTER et al., 1992). Others (e.g. REYMENT, 1955; BARBER, 1957; FREUND & RAAB, 1969; SCHÖBEL, 1975; ZABORSKI, 1996) regarded it as a distinct genus. BERTHOU et al. (1985), however, regarded the presence or absence of umbilical tubercles in *Vascoceras* as an inadequate basis for generic and subgeneric diagnosis. BERTHOU's view was accepted by KENNEDY et al. (1987) and LUGER & GRÖSCHKE (1989), and the present work is in agreement with them. In the identified material, *Vascoceras adonense* CHOFFAT can be distinguished from other identified *Vascoceras* species by the asymmetric shape, rather evolute coiling in the late stage and strong umbilical border. *Vascoceras cauvini* CHUDEAU is the most compressed *Vascoceras* species, with elongate shape, rather higher than wide, narrow rounded venter, with vertical umbilical wall. *Vascoceras durandi* (THOMAS & PERON) is also compressed, but more depressed than *V. cauvini*, higher than wide, having a triangular outline in the last whorl, and a wider umbilicus, with distinctive rounded umbilical wall. *Vascoceras pioti* (PERON & FOURTAU) is also a compressed form, but with flat venter and small umbilicus. *Vascoceras proprium* (REYMENT) is distinguished from other identified *Vascoceras* species by its globose form, involute coiling until the last whorl, and the smallest umbilicus.

Vascoceras adonense CHOFFAT, 1898

Text-figs. 5.7B, 5.9A

1898 *Vascoceras adonense* sp. nov. – CHOFFAT: p. 59, pl. 9, fig. 3; pl. 21, fig. 12a, b.
1969 *Vascoceras* cf. *adonense* CHOFFAT – FREUND & RAAB: p. 32, pl. 5, fig. 1; text-fig. 7a-b.
2001 *Vascoceras adonense* CHOFFAT – KORA et al.: pl. 2, fig. 3.
2003 *Vascoceras adonense* CHOFFAT – HEWAIDY et al.: p. 343, pl. 1, figs. 14-15.

Material: Three poorly preserved complete internal moulds (WG-18- 1–3) from Wadi Ghonima section (33.5m above the base of Maghra El Hadida Formation) and one poorly preserved complete internal mould (WA-15-1) from Wadi Askhar section (at 106m). All specimens from the Lower Turonian *Vascoceras proprium* Zone of the Maghra El Hadida Formation.

Text-fig. 5.7

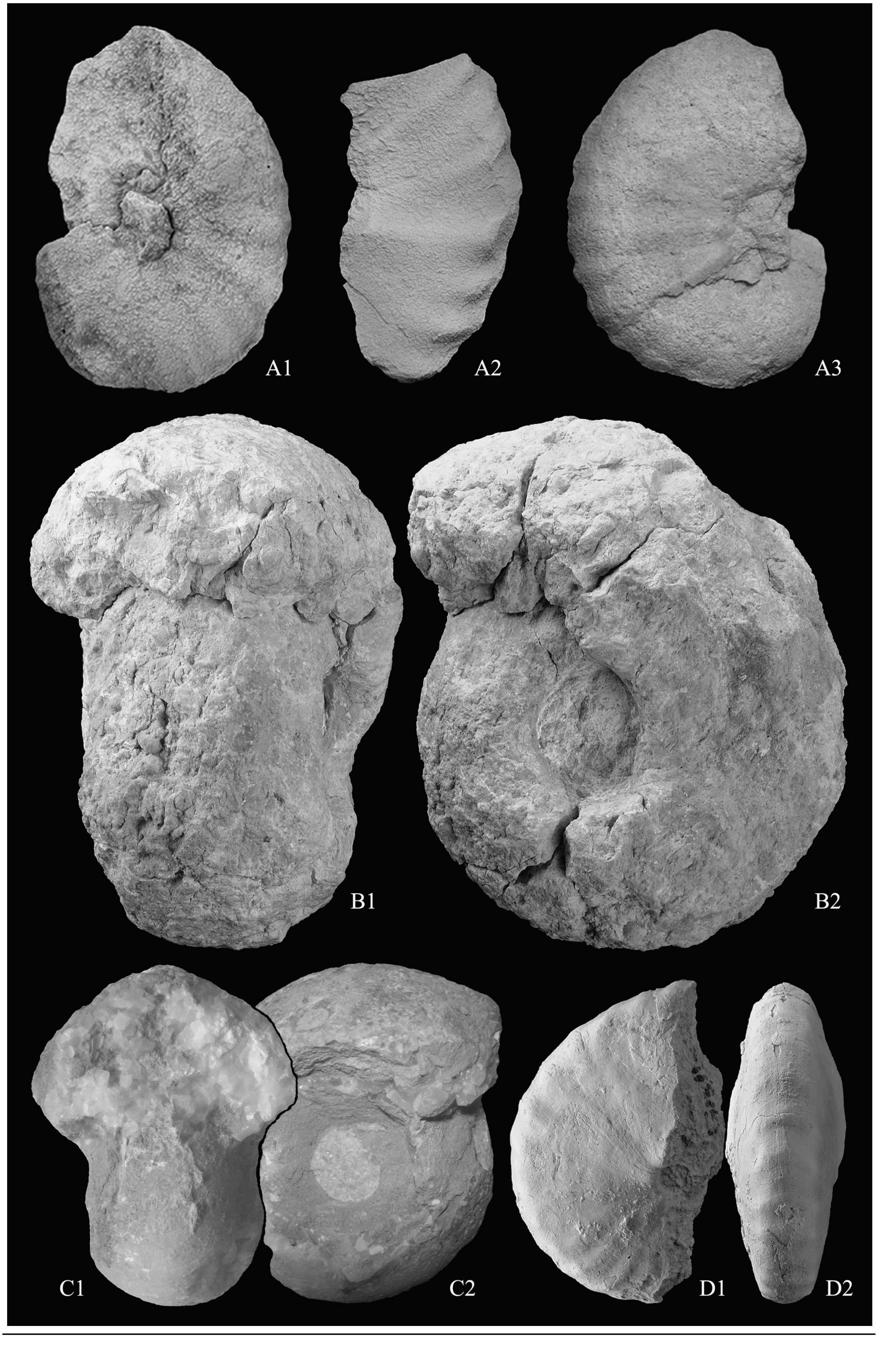
A. *Metoicoceras geslinianum* (D'ORBIGNY, 1850), Upper Cenomanian Maghra El Hadida Formation. 1, 3: lateral view, x1.5; 080215-3-1. - 2: lateral view, x1.5; 080215-3-2.

B. *Vascoceras adonense* CHOFFAT, 1898, Lower Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral view, x1; WG-18-1.

C. *Vascoceras durandi* (THOMAS & PERON, 1889), Lower Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral view, x1; WA-14-4.5.

D. *Vascoceras pioti* (PERON & FOURTAU 1904), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; WG-17-4.

Text-fig. 5.7



Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-18-1	101.4 (100)	69.9 (68.9)	35.1 (34.6)	1.99	29.4 (28.9)
WA-15-1	113.2 (100)	62.3 (55.0)	40.2 (35.5)	1.54	30.2 (26.6)

Description: Medium-sized, slightly inflated, asymmetrically distorted ammonites. Early whorls involute, later whorls more evolute. Whorl section rounded and semilunar (Text-fig. 5.9A). Umbilicus wide (about 29% of total diameter), relatively deep, with flat walls, inclined, and distinctive border. Venter wide, rounded, with moderately narrow flanks. Ornamentation and sutures absent due to poor preservation.

Remarks: FREUND & RAAB (1969) considered that their specimens are similar to the Portuguese holotype in dimensions, but have weaker umbilical tubercles. They considered the asymmetric shape of their specimens as original feature that cannot be a result of any deformation. The studied specimens closely correspond to those described by FREUND & RAAB (1969) from Israel. However, the studied specimens are smaller and the umbilical tubercles are not seen due to poor preservation.

Occurrence: *Vascoceras adonense* has been recorded from the Lower Turonian of Portugal (CHOFFAT, 1898) and from Israel (FREUND & RAAB, 1969). In Egypt, It has been recorded from the Lower Turonian of the north Eastern Desert (HEWAIDY et al., 2003) and the Gulf of Suez region (KORA et al., 2001).

Vascoceras cauvini CHUDEAU, 1909

Text-figs. 5.8A, 5.9B

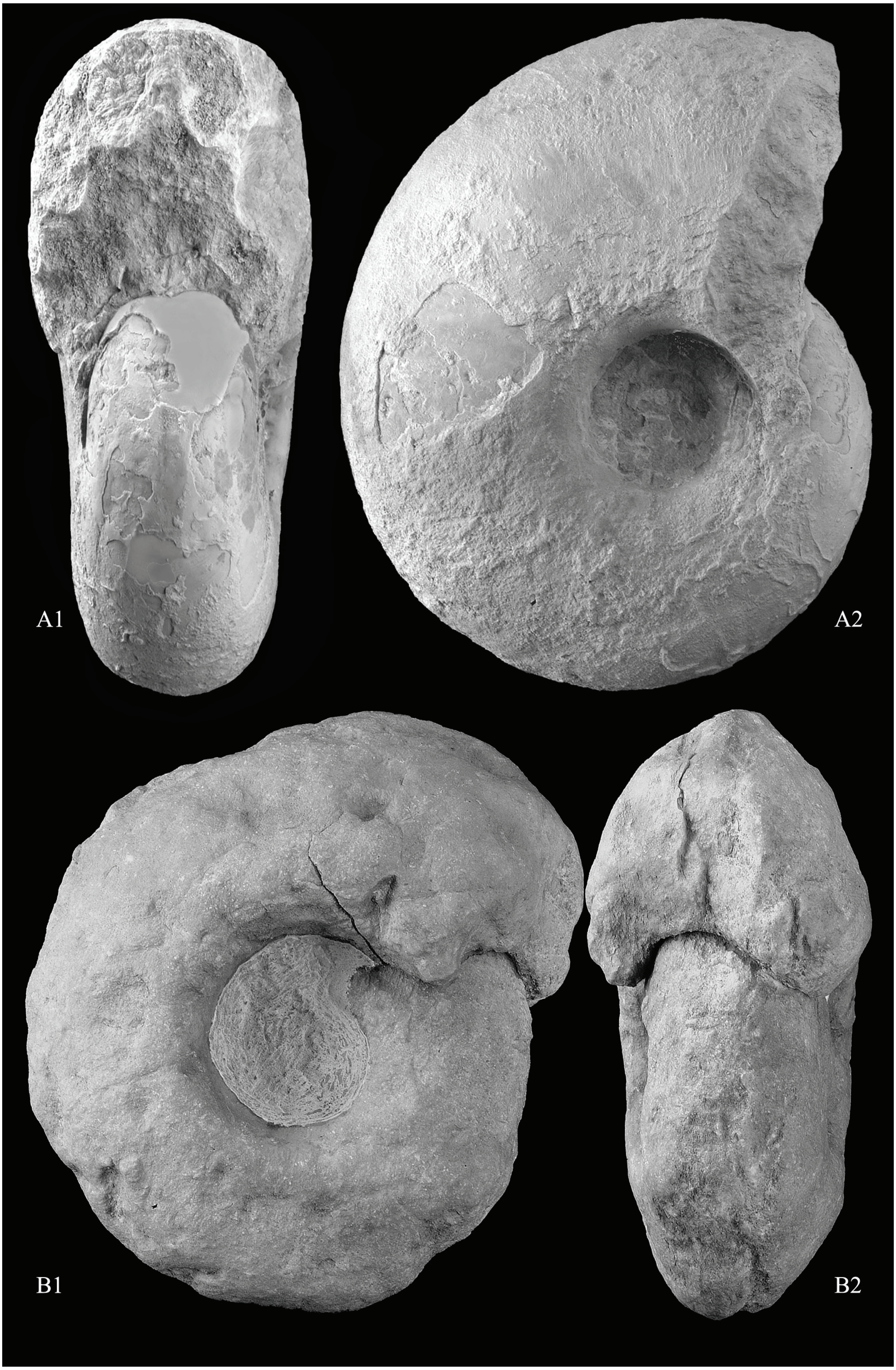
1909 *Vascoceras cauvini* sp. nov. – CHUDEAU: p. 67, pl. 1, figs. 1a, 2a; pl. 2, figs. 3, 5; pl. 3, figs. 1b, 2b, 4.
1969 *Paravascoceras cauvini* (CHUDEAU) – FREUND & RAAB: p. 20, pl. 3, figs. 1-3; text-fig. 5a-b.
1975 *Paravascoceras cauvini* (CHUDEAU) – SCHÖBEL: pl. 4, figs. 1-3, pl. 5, figs. 1-4.
1987 *Vascoceras cauvini* CHUDEAU – KORA & HAMAMA: pl. 1, fig. 6.
1989 *Vascoceras cauvini* CHUDEAU – LUGER & GRÖSCHKE: p. 374, pl. 40, figs. 3, 6, 8, 9; pl. 41, figs. 1-4; pl. 42, fig. 1; text-figs. 6g,h, 8c (with additional synonymy).
1996 *Vascoceras cauvini* CHUDEAU – KASSAB: pl. 2, figs. 1, 2.
1996 *Paravascoceras cauvini* (CHUDEAU) – ZABORSKI: p. 65, figs. 2-8.
2001 *Vascoceras cauvini* CHUDEAU – ALY & ABDEL-GAWAD: p. 40, pl. 5, fig. 3a-c.
2001 *Vascoceras cauvini* CHUDEAU – EL-HEDENY & NAFEE: p. 125, pl. 2, figs. 3-4.
2002 *Vascoceras cauvini* CHUDEAU – EL-HEDENY: p. 406, figs. 4b-c, 7f.
2003 *Vascoceras pioti* (PERON & FOURTAU) – HEWAIDY et al.: p. 344, pl. 2, figs. 2-5.
2004a *Vascoceras cauvini* CHUDEAU – ABDEL-GAWAD et al.: pl. 4, figs. 2-3, 5.

Text-fig. 5.8

A. *Vascoceras cauvini* CHUDEAU, 1909, Upper Cenomanian Maghra El Hadida Formation. 1: ventral view, x1; 2: lateral view, x1; WG-15-1.

B. *Vascoceras durandi* (THOMAS & PERON, 1889), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x0.75; 2: apertural view, x0.75; WA-14-4.

Text-fig. 5.8



2006 *Vascoceras cauvini* CHUDEAU – EL QOT: p. 117, pl. 25, figs. 2-3, 5.
2007 *Vascoceras cauvini* CHUDEAU – ABDEL-GAWAD et al.: pl. 2, fig. 4.
2008 *Vascoceras cauvini* CHUDEAU – ALY et al.: p. 47, pl. 4, figs. 3-4; text-fig. 3 (3).

Material: Four moderately preserved incomplete internal moulds (WG-15- 1–3 & 080215-8-1) from the Upper Cenomanian *Vascoceras cauvini* Zone of the Maghra El Hadida Formation at Wadi Ghonima section (29m above the base of the formation).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080215-8-1	116.0 (100)	42.0 (36.2)	59.1 (50.9)	0.71	21.5 (18.5)
WG-15-1	127.1 (100)	49.0 (38.5)	64.7 (50.9)	0.75	26.3 (20.6)

Description: Involute, medium-sized. Whorl section compressed (Text-fig. 5.9B), higher than wide, with slightly inclined flanks and maximum breadth close to the umbilical shoulder. Umbilicus relatively wide (about 22.5% of total diameter), deep, with feebly rounded shoulders and vertical walls. Venter well rounded. Ornamentation consists of faint, weak marginal ribs crossing the venter. Sutures not preserved.

Remarks: SCHÖBEL (1975) pointed out that *Vascoceras cauvini* CHUDEAU varies in the degree of compression and ornamentation. LUGER & GRÖSCHKE (1989) considered their specimens closely resembling the type material in size, shape, and suture line, but differing in their very weak ornamentation. They separated individuals with depressed whorl as *Vascoceras* cf. *cauvini*. ZABORSKI (1996) regarded *Nigericeras gadeni* (CHUDEAU) as a synonym of *Vascoceras cauvini*. He also considered the medium-sized whorls of *Vascoceras cauvini* that were described by LEWY et al. (1984) from Israel and the *Vascoceras* cf. *cauvini* that were described by COOPER (1978) from Angola as *Nigericeras*. The studied specimen fits with material of LUGER & GRÖSCHKE (1989) from the Egyptian Eastern Desert, but the studied specimens are larger in size and the suture line is not preserved. They are similar to the material of FREUND & RAAB (1969) from Israel, but, the umbilicus of the studied specimens is larger and the ornamentation weaker. However, all these differences are small and considered as intraspecific variability.

Occurrence: According LUGER & GRÖSCHKE (1989, p.375), *Vascoceras cauvini* is widely known from Upper Cenomanian strata of central and northern Africa, the Middle East, and Peru. Also, it has been recorded from the Upper Cenomanian of Nigeria by ZABORSKI (1996). In Egypt, It has been recorded from the Upper Cenomanian of the north Eastern Desert (LUGER & GRÖSCHKE, 1989; EL-HEDENY & NAFEE, 2001; ABDEL-GAWAD et al., 2007), Sinai (ALY & ABDEL-GAWAD, 2001; EL-HEDENY, 2002; ABDEL-GAWAD et al., 2004a; EL QOT, 2006), and the Gulf of Suez region (KASSAB, 1996). In the study area, *Vascoceras cauvini* is recorded from strata of latest Cenomanian age. The *Vascoceras cauvini* Zone is equivalent to *Neocardioceras juddii* Zone in the standard ammonite zonation by GRADSTEIN et al. (2004).

Vascoceras durandi (THOMAS & PERON, 1889)

Text-figs. 5.7C, 5.8B, 5.9C

1889 *Pachydiscus Durandi* sp. nov. – THOMAS & PERON: p. 27, pl. 18, figs. 5-8.

1907 *Vascoceras Durandi* (THOMAS & PERON) – PERVINQUIÈRE: p. 332, pl. 21, fig. 1; text-fig. 125.

1928 *Vascoceras* sp. DOUVILLÉ: p. 15, pl. 1, fig. 6.

1969 *Vascoceras durandi* (THOMAS & PERON) – FREUND & RAAB: p. 29, text-fig. 6h-i.

1989 *Vascoceras durandi* (THOMAS & PERON) – LUGER & GRÖSCHKE: p. 376, pl. 43, figs. 1, 2, text-fig. 8a.

1991 *Vascoceras durandi* (THOMAS & PERON) – KENNEDY & SIMMONS: p. 138, pl. 5a, b.

1994 *Vascoceras durandi* (THOMAS & PERON) – CHANCELLOR et al.: p. 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 (see for further synonymy).

1996 *Vascoceras* (*Paravascoceras*) aff. *durandi* (THOMAS & PERON) – MEISTER & ABDALLAH: p. 10, pl. 4, fig.1; pl. 5, fig. 2; fig. 5c.

2003 *Vascoceras durandi* (THOMAS & PERON) – HEWAIDY et al.: p. 343, pl. 2, figs. 1-2.

2004a *Vascoceras* cf. *durandi* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 4, figs. 4.

2005 *Vascoceras durandi* (THOMAS & PERON) – MEISTER & ABDALLAH: p. 135, pl. 14, fig. 1; pl. 26, fig. 1; pl. 27, fig. 1.

2006 *Vascoceras* cf. *durandi* (THOMAS & PERON) – EL QOT: p. 118, pl. 25, fig. 4; pl. 26, fig. 1a-b.

Material: Two moderately preserved complete internal moulds (WA-14-4, -4.5) from the Lower Turonian Maghra El Hadida Formation of Wadi Askhar section (at 105m).

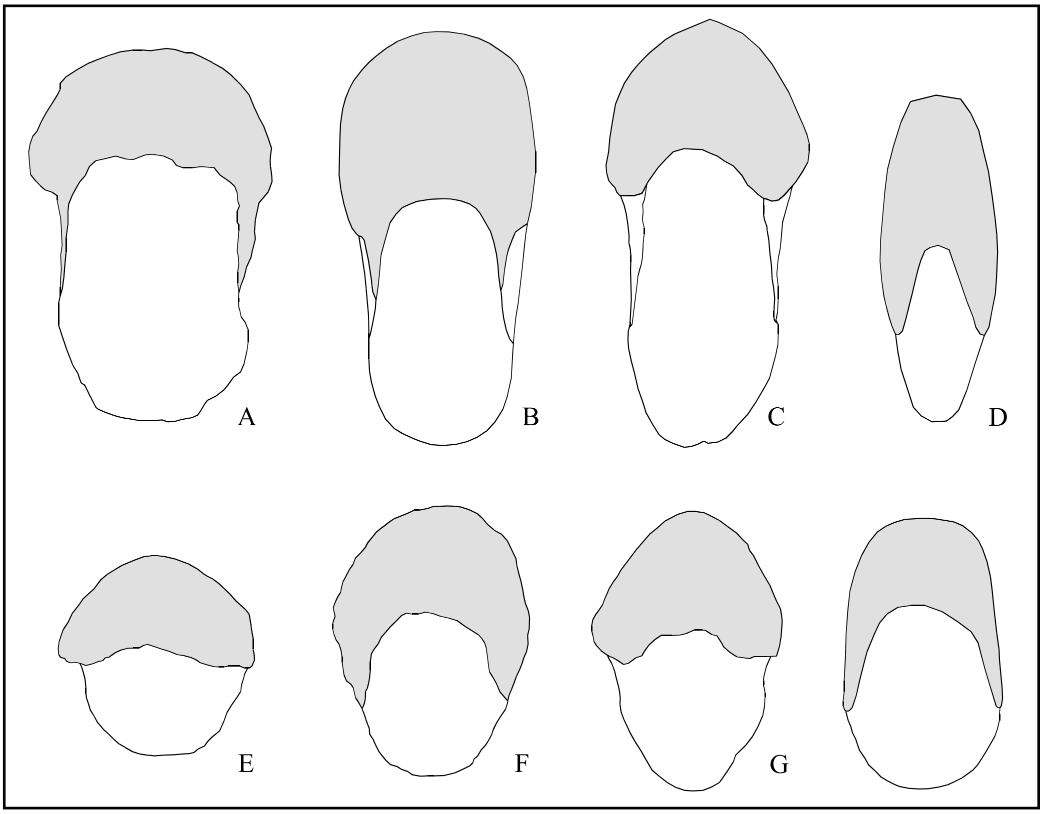
Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WA-14-4	126.1 (100)	56.6 (44.8)	61.3 (48.6)	0.92	38.1 (30.2)

Description: Involute, medium-sized, and compressed. Whorl higher than wide, body chamber large, and whorl section becomes triangular at the body chamber (Text-fig. 5.9C). Flanks narrow and slightly convex. Umbilicus wide (about 30% of total diameter) and moderately deep, with rounded shoulders and vertical walls. Venter narrowly rounded. Ornamentation and sutures absent due to poor preservation.

Remarks: *Vascoceras durandi* can be distinguished by its large-size, absence of umbilical tubercles, and subtriangular whorl section at maturity. BERTHOU et al. (1985) revised CHOFFAT's *Vascoceras* from Portugal, and concluded that *Vascoceras douvillei* CHOFFAT, and *Vascoceras amieirensis* CHOFFAT were synonyms of *Vascoceras durandi* (THOMAS & PERON), in agreement with CHANCELLOR et al. (1994). Also, they discussed the differences between *Vascoceras durandi* and other Portuguese species. In addition, they interpreted the presence or absence of umbilical tubercles in the earlier growth stages of *Vascoceras durandi* as being related to geographical variation. The studied specimens correspond to those described by FREUND & RAAB (1969) from Israel and to those described by LUGER & GRÖSCHKE (1989) from the north Eastern Desert, Egypt. However, in the studied specimens the ornamentation is not preserved but this does not prevent specific determination.

Occurrence: *Vascoceras durandi* has been recorded from the Upper Cenomanian to Lower Turonian of Portugal (BERTHOU et al., 1985) and from the Lower Turonian of Israel (FREUND & RAAB, 1969). Furthermore, it is known from Spain, Algeria, Tunisia, (?) Angola, Japan, Mexico, and Brazil (BERTHOU et al., 1985). In Egypt, it has been recorded from the Lower Turonian of the north Eastern Desert (LUGER & GRÖSCHKE, 1989; HEWAIDY et al., 2003), and from Sinai (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).



Text-fig. 5.9. Whorl sections of: A, *Vascoceras adonense* CHOFFAT, 1898; B, *Vascoceras cauvini* CHUDEAU, 1909; C, *Vascoceras durandi* (THOMAS & PERON, 1889); D, *Vascoceras pioti* (PERON & FOURTAU, 1904); E-H, *Vascoceras proprium* (REYMENT, 1954). A, specimen WG-18-1; B, specimen WG-15-1; C, specimen WA-14-4; D, specimen WG-17-4; E, specimen WG-17-1; F, specimen WG-17-2; G, specimen WG-17-3; H, specimen WA-14-1. Not to scale.

Vascoceras pioti (PERON & FOURTAU, 1904)

Text-figs. 5.7D, 5.9D

1904 *Ammonites pioti* sp. nov. – PERON & FOURTAU in FOURTAU: p. 275, pl. 1, figs. 4-5.

1969 *Vascoceras pioti* (PERON & FOURTAU) – FREUND & RAAB: p. 28, pl. 4, figs. 1-9; text-fig. 6d-g.

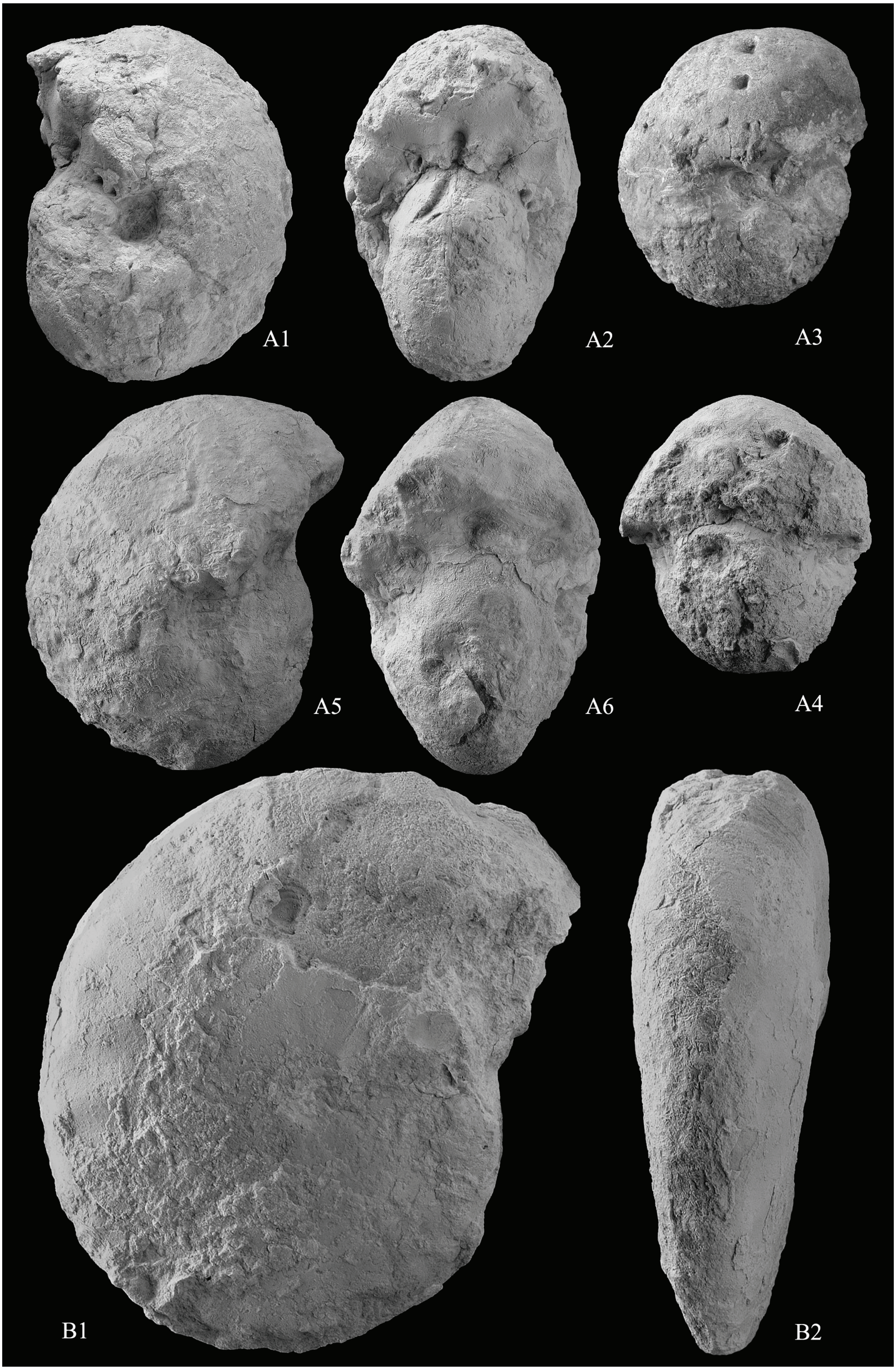
Material: One well preserved incomplete shell (WG-17-4) and one poorly preserved incomplete internal mould (WG-17-5) from the Lower Turonian Maghra El Hadida Formation of Wadi Ghonima section (at 32m).

Text-fig. 5.10

A. *Vascoceras proprium* (REYMENT, 1954), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: apertural view, x1; WG-17-2. – 3: lateral view, x1; 4: apertural view, x1; WG-17-1. – 5: lateral view, x1; 6: apertural view, x1; WG-17-3.

B. *Neoptychites cephalotus* (COURTILLER, 1860), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; WG-23-1.

Text-fig. 5.10



Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-17-4	47.6 (100)	17.2 (36.1)	30.0 (63.0)	0.57	4.7 (9.8)
WG-17-5	57.1 (100)	22.4 (39.2)	36.3 (63.5)	0.61	5.6 (9.8)

Description: Very involute, relatively small. Whorls strongly compressed (Text-fig. 5.9D). Maximum thickness near the umbilicus. Walls vertical with well-defined borders. Venter flat to slightly convex, clearly separated from the flanks. Umbilicus small (about 10% of diameter). The body chamber occupies almost one complete whorl. Ornamentation consists of numerous ribs, weak at the umbilicus and strong at the middle and outer flanks, each rib forming small clavi at the ventrolateral shoulder. Sutures not seen in the present specimen.

Remarks: FREUND & RAAB (1969) considered their specimens identical with the holotype as described and figured by PERON & FOURTAU (in FOURTAU 1904: p. 275, pl. 1, figs. 4-5). They also noted the similarity between the body chambers of this species with *Thomasites rollandi*. The specimens described by HEWAIDY et al. (2003, p. 344, pl. 2, figs. 2-5) as *Vascoceras pioti* have completely rounded venters, without ventrolateral shoulders, and with wide, deep umbilicus, while *Vascoceras pioti* as described by PERON & FOURTAU (1904) and FREUND & RAAB (1969) has a flat venter, clearly separated from the flanks, with very small and shallow umbilici. Therefore, their specimen are not considered here as *Vascoceras pioti*, but may be related to *Vascoceras cauvini*. The studied material is very close to that described by FREUND & RAAB (1969) from Israel.

Occurrence: *Vascoceras pioti* has been recorded from the Lower Turonian of Israel (FREUND & RAAB, 1969). In the study area, it is also recorded from the Lower Turonian.

Vascoceras proprium (REYMENT, 1954)

Text-figs. 5.9E-H, 5.10A

1954 *Pachyvascoceras proprium* sp. nov. – REYMENT: p. 258, pl. 5, fig. 1; text-fig. 3d.
1957 *Vascoceras globosum proprium* (REYMENT) – BARBER: p. 25, pl. 7, fig. 3; pl. 28, figs. 6, 7.
1987 *Vascoceras proprium* (REYMENT) – KENNEDY et al.: p. 46, pl. 4, figs. 1-15, 18-19; pls. 5-6; text-figs. 8a-c, 9 (with full synonymy).
1994 *Vascoceras proprium* (REYMENT) – KASSAB: p. 120, fig. 5 (1-4).
1994 *Vascoceras proprium* (REYMENT) – KASSAB & ISMAEL: p. 226, fig. 2 (10-12).
1996 *Vascoceras proprium* (REYMENT) – KASSAB: pl. 2, figs. 5-7.
2001 *Vascoceras proprium* (REYMENT) – ALY & ABDEL-GAWAD: p. 39, pl. 5, fig. 4a-c.
2001 *Vascoceras proprium* (REYMENT) – KORA et al.: pl. 2, fig. 3.
2002 *Vascoceras proprium* (REYMENT) – EL-HEDENY: p. 407, figs. 5a-b, 7c.
2003 *Vascoceras proprium* (REYMENT) – HEWAIDY et al.: p. 344, pl. 2, figs. 3-5.
2008 *Vascoceras proprium* (REYMENT) – ALY et al.: p. 49, pl. 5, figs. 1-2; text-fig. 3 (4).

Material: Three moderately preserved incomplete internal moulds (WA-14- 1–3) from Wadi Askhar section (at 104m), three moderately preserved complete internal moulds (WG-17- 1–3) from Wadi Ghonima section (31m above the base of Maghra El Hadida Formation), and two poorly preserved incomplete internal moulds (080217-23.5- 1–2) from East Wadi

Ghonima section (at 117m). All specimens from the Lower Turonian *Vascoceras proprium* Zone of the Maghra El Hadida Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WA-14-1	71.3 (100)	41.8 (58.6)	36.6 (51.3)	1.14	15.6 (21.8)
WA-14-2	83.5 (100)	48.5 (58.0)	41.5 (49.7)	1.16	24.6 (29.4)
WA-14-3	62.8 (100)	32.6 (51.9)	27.5 (43.7)	1.18	13.6 (21.6)
WG-17-1	50.8 (100)	44.3 (87.2)	28.6 (56.2)	1.54	7.1 (13.9)
WG-17-2	66.6 (100)	47.8 (71.7)	35.0 (52.5)	1.36	11.8 (17.7)
WG-17-3	69.3 (100)	46.5 (48.2)	40.0 (57.7)	1.16	7.7 (11.1)

Description: Involute, medium-sized, and slightly compressed to inflated. Whorl section varies from slightly rounded to triangular (Text-fig. 5.9E-H). Umbilical width ranges from 11% to 29% of diameter, relatively deep, with vertical to slightly undercut walls and well rounded umbilical shoulder. Venter varies from broadly arched to fairly narrow. Flanks short and convex. Ornamentation and suture line absent due to poor preservation.

Remarks: *Vascoceras proprium* (REYMENT) was discussed in detail by KENNEDY et al. (1987). They studied a large number of specimens from a single horizon and the same locality and concluded that their intermediate specimens match well with the holotype of REYMENT (1954). They placed a range of associated forms separated by REYMENT (1954, 1955) and BARBER (1957) in the synonymy of this species. The present material has variations in whorl section, but there is no big difference in the main characters to separate them as different species. Therefore, the studied material supports the opinion of KENNEDY et al. (1987) that there is a high variation in this species.

Occurrence: *Vascoceras proprium* has been recorded from the Lower Turonian of Jordan (ALY et al., 2008), Nigeria (BARBER, 1957), northern Mexico and Texas (KENNEDY et al., 1987). In Egypt, it has been recorded from the Lower Turonian of the north Eastern Desert (KASSAB, 1994; HEWAIDY et al., 2003), Gulf of Suez region (KASSAB, 1996; KORA et al., 2001), and from Sinai (KASSAB & ISMAEL, 1994; ALY & ABDEL-GAWAD, 2001; EL-HEDENY, 2002).

Genus *Neoptychites* KOSSMAT, 1895

Neoptychites cephalotus (COURTILLER, 1860)

Text-figs. 5.10B, 5.11A-B, 5.12A

1860 *Ammonites cephalotus* sp. nov. – COURTILLER: p. 248, pl. 2, figs. 1-4.

1889 *Pachydiscus africanus* sp. nov. – PERON: p. 28, pl. 17, figs. 9-10.

1907 *Neoptychites cephalotus* (COURTILLER) – PERVINQUIÈRE: p. 393, pl. 27, figs. 1-4, text-fig. 152.

1969 *Neoptychites cephalotus* (COURTILLER) – FREUND & RAAB: p. 48.

1979b *Neoptychites cephalotus* (COURTILLER) – KENNEDY & WRIGHT: p. 670, pl. 82, figs. 3-5; pl. 83, figs. 1-3; pl. 84, fig. 3; pl. 85, figs. 1-5; pl. 86, figs. 4-5; text-fig. 2 (with full synonymy).

1979b *Neoptychites xetriformis* PERVINQUIÈRE – KENNEDY & WRIGHT: p. 679, pl. 84, figs. 1-2; pl. 86, figs. 1-3.
1982 *Neoptychites xetriformis* PERVINQUIÈRE – RENZ: p. 88, pl. 26, fig. 19, text-fig. 67.
1990 *Neoptychites cephalotus* (COURTILLER) – ROBASZYNSKI et al.: p. 266, pl. 20, figs. 2-3; pl. 21, fig. 3.
1994 *Neoptychites cephalotus* (COURTILLER) – CHANCELLOR et al.: p. 70, pl. 16, figs. 1-9; pl. 17, figs. 1-5; pl. 18, figs. 1-3; pl. 26, figs. 2-4.
1994 *Neoptychites xetriformis* PERVINQUIÈRE – KASSAB: p. 121, fig. 5 (8).
2001 *Neoptychites cephalotus* (COURTILLER) – ALY & ABDEL-GAWAD: p. 39, pl. 6, fig. 1.
2005 *Neoptychites* gr. *cephalotus* (COURTILLER) – MEISTER & ABDALLAH: p. 136, pl. 15, figs. 1, 2; pl. 16, fig. 1; pl. 20, fig. 1.
2008 *Neoptychites cephalotus* (COURTILLER) – ALY et al.: p. 49, pl. 6, fig. 1a-b.
2009 *Neoptychites cephalotus* (COURTILLER) – BARROSO-BARCENILLA & GOY: p. 34, fig. 9 (4-6), fig. 10 (1-3); see for complete synonymy.

Material: Three moderately preserved complete internal moulds (WG-23- 1–3) and two well preserved incomplete shells (WG-23- 4–5) from Wadi Ghonima section (44m above the base of Maghra El Hadida Formation) and two poorly preserved incomplete internal moulds (080217-26- 3–5) from East Wadi Ghonima section (at 132m). All specimens from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-23-1	110.3 (100)	32.7 (29.6)	54.1 (49.0)	0.60	6.4 (5.8)
WG-23-2	96.6 (100)	55.1 (57.0)	53.5 (55.3)	1.02	9.3 (9.6)
WG-23-3	109.2 (100)	60.9 (55.7)	48.1 (44.0)	1.26	10.2 (9.3)
WG-23-4	93.3 (100)	43.1 (46.1)	47.0 (50.3)	0.91	9.6 (10.2)
WG-23-5	95.2 (100)	---	45.9 (48.2)	---	10.6 (10.7)

Description: There are two forms of *Neoptychites cephalotus* in the studied material, compressed and depressed ones (Text-fig. 5.11A-B). In the compressed form, coiling is involute, medium-sized, whorls are strongly compressed, with rectangular whorl section, umbilicus small (about 6% of total diameter), shallow, with low and rounded umbilical shoulder. Whorl walls are vertical on the inner flank and slightly convex on the outer flank, venter narrowly rounded. Ornamentation consists of weak folding on the outer flank. In the depressed form, coiling is also involute, medium-sized, but whorls are depressed, with rounded whorl section, the umbilicus is wider (up to about 10.5% of diameter), walls convex, venter more widely rounded. Ornamentation consists of strong folding on the outer flank. Suture lines not seen in the two forms.

Remarks: PERVINQUIÈRE (1907) and KENNEDY & WRIGHT (1979b) considered *Pachydiscus africanus* PERON (1889) as a juvenile of *Neoptychites cephalotus* and the present work is in agreement with them. KENNEDY & WRIGHT (1979b) revised different forms of *Neoptychites* from Touraine, France, and recognized two species, *Neoptychites cephalotus* and *Neoptychites xetriformis* and considered the latter species different by having stronger ribs. In agreement with CHANCELLOR et al. (1994, p. 72), *Neoptychites xetriformis* is the microconch and a junior synonym of *Neoptychites cephalotus*. KENNEDY & WRIGHT (1979b, p. 674) demonstrate that *Neoptychites cephalotus* passes though three distinctive ontogenetic stages depending on the size. The third stage is well represented in the studied specimens, where compressed, smooth depressed, and ribbed depressed forms have been recorded. The compressed form (Text-fig. 10B) is identical to the material of KENNEDY & WRIGHT (1979b, Pl. 83) and CHANCELLOR et al. (1994, Pl. 18). Also, the depressed form (Text-fig. 5.12A) is identical with specimens of KENNEDY & WRIGHT (1979b, Pl. 86, Fig. 1, 2).

Occurrence: According to CHANCELLOR et al. (1994, p. 72), the total range of *Neoptychites cephalotus* is mid-Lower Turonian to lower Middle Turonian, with records from France, northern Spain, Morocco, Algeria, Tunisia, Israel, Syria, Cameroon, Madagascar, southern India, the Western Interior of the United States, northern Mexico, Trinidad, Venezuela, Colombia, Brazil, Niger and Nigeria. Recently, it has been recorded from Jordan (ALY et al., 2008). In Egypt, it has been recorded from the Lower Turonian of Sinai (ALY & ABDEL-GAWAD, 2001).

Genus *Fagesia* PERVINQUIÈRE, 1907

Fagesia cf. *peroni* PERVINQUIÈRE, 1907

Text-figs. 5.11C, 5.12B

cf.1907 *Fagesia Peroni* sp. nov. – PERVINQUIÈRE: p. 329, pl. 20, figs. 7-8.
cf.1994 *Fagesia peroni* PERVINQUIÈRE – CHANCELLOR et al.: p. 64, pl. 14, figs. 6-10.

Material: Two poorly preserved incomplete internal moulds (080217-25.5- 1–2) from East Wadi Ghonima section (at 127m) and one poorly preserved complete internal mould (WG-24-1) from Wadi Ghonima section (at 39.5m above the base of Maghra El Hadida Formation). All specimens from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation.

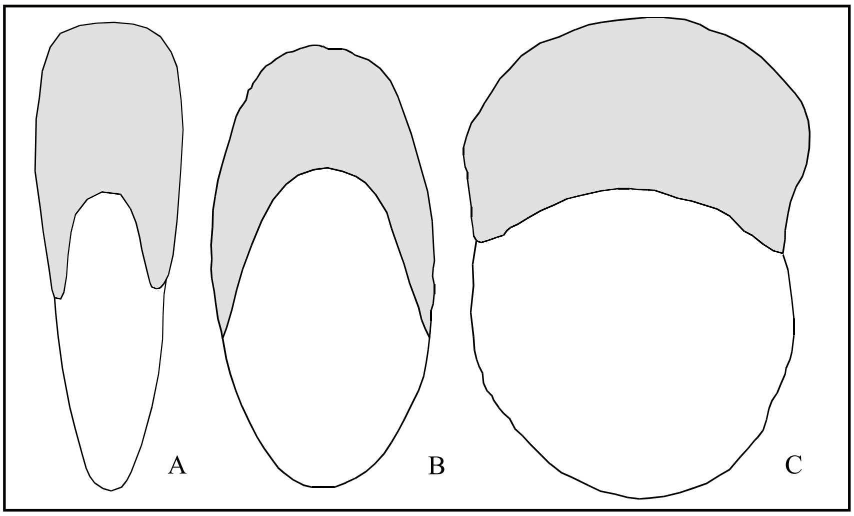
Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-24-1	123.1 (100)	89.1 (72.3)	56.2 (45.6)	1.58	38.9 (31.6)

Description: Involute, large-sized, and inflated. Whorl section (Text-fig. 5.11C) very depressed (Wb/Wh= 1.58), with very narrow flanks. Umbilicus wide (31.6% of total diameter), fairly deep, with distinctive rounded umbilical shoulder and traces of umbilical tubercles. Venter broadly rounded. Ornamentation and suture line absent due to poor preservation.

Remarks: The present specimen is very similar to the lectotype of PERVINQUIÈRE (1907) as described and refigured by CHANCELLOR et al. (1994, pl. 14, figs. 7, 8, 10). However, the studied specimen is larger and the ornamentation not visible due to poor preservation.

Occurrence: *Fagesia peroni* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994). According to CHANCELLOR et al. (1994), there are further records from Romania, Colombia and the former Soviet Central Asia. This is the first record of *Fagesia peroni* from Egypt.



Text-fig. 5.11. Whorl sections of: A-B, *Neoptychites cephalotus* (COURTILLER, 1860); C, *Fagesia* cf. *peroni* PERVINQUIÈRE, 1907. A, specimen WG-23-1; B, specimen WG-23-2; C, specimen WG-24-1. Not to scale.

Family Pseudotissotiidae HYATT, 1903

Subfamily Pseudotissotiinae HYATT, 1903

Genus *Thomasites* PERVINQUIÈRE, 1907

Thomasites rollandi (THOMAS & PERON, 1889)

Text-figs. 5.12C, 5.13A, 5.14A-D

1889 *Pachydiscus Rollandi* sp. nov. – THOMAS & PERON: p. 25, pl. 17, figs. 1-3.

1907 *Thomasites Rollandi* (THOMAS & PERON) and varieties – PERVINQUIÈRE: p. 341, pl. 22, figs. 1-7, text-figs. 127-130.

1907 *Thomasites Meslei* sp. nov. – PERVINQUIÈRE: p. 345, pl. 22, figs. 8, 9; text-fig. 131.

1907 *Thomasites Jordani* sp. nov. – PERVINQUIÈRE: p. 347, pl. 22, figs. 10-13; text-figs. 132, 133 (with varieties).

?1928 *Mammites incertus* sp. nov. – DOUVILLÉ: p. 11, pl. 2, fig. 2; text-fig. 2.

?1928 *Mammites* sp. – DOUVILLÉ: p. 12, pl. 2, fig. 1.

1928 *Thomasites egyptiacus* sp. nov. – DOUVILLÉ: p. 16, pl. 2, fig. 3.

1928 *Thomasites Lefevrei* sp. nov. – DOUVILLÉ: p. 16, pl. 2, fig. 4.

1928 *Thomasites Jordani* PERVINQUIÈRE – DOUVILLÉ, p. 17, pl. 2, figs. 5,6.

1969 *Thomasites rollandi* (THOMAS & PERON) and varieties of PERVINQUIÈRE – FREUND & RAAB: p. 43, text-fig. 9f-k.

1969 *Thomasites jordani* and varieties of PERVINQUIÈRE – FREUND & RAAB: p. 45, text-figs. 10a-c.

1990 *Thomasites rollandi* (PERON) – ROBASZYNSKI et al.: p. 267, pl. 22, figs. 1a-b, 4a-b.

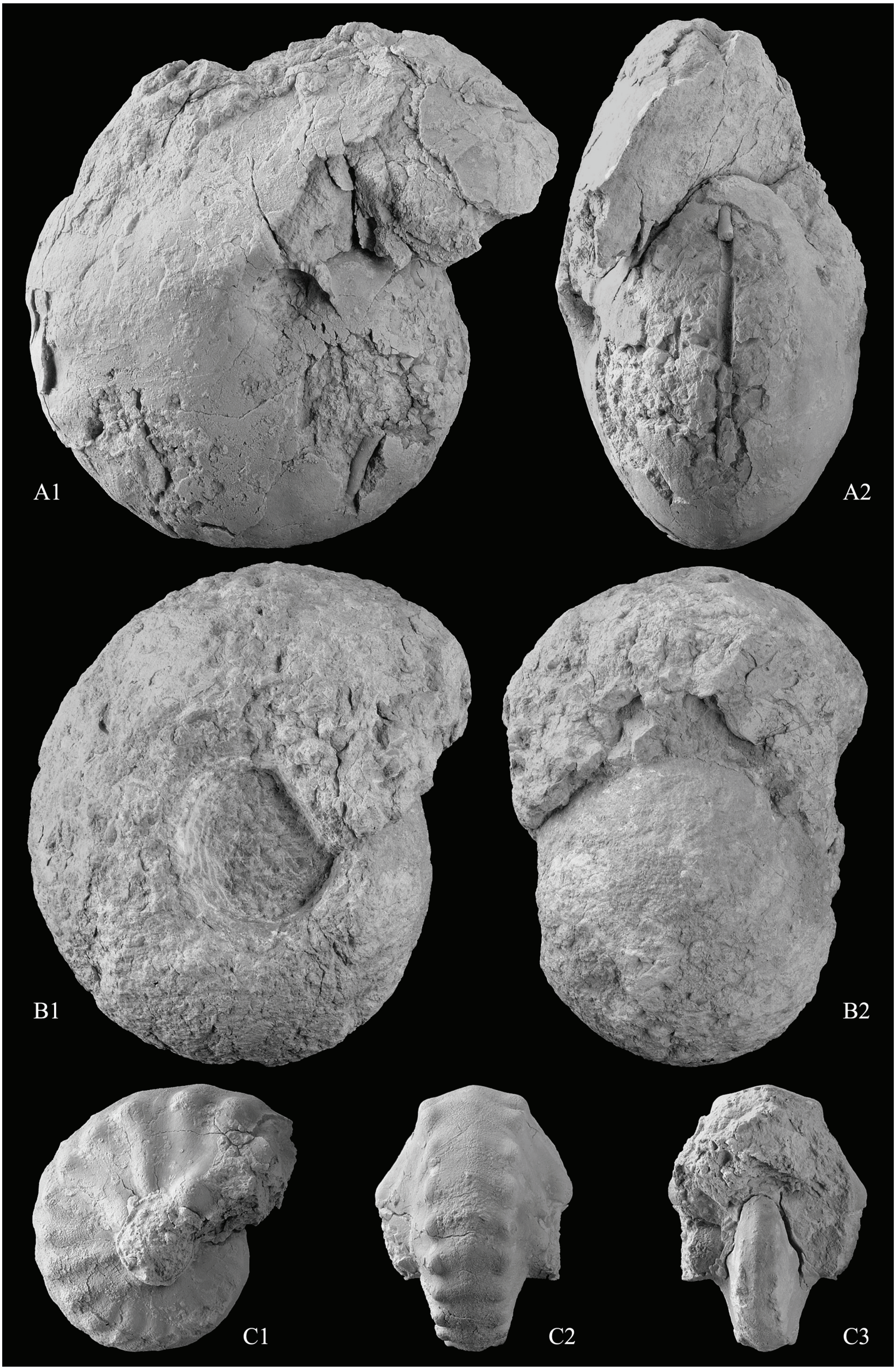
Text-fig. 5.12

A. *Neoptychites cephalotus* (COURTILLER, 1860), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: apertural view, x1; WG-23-2.

B. *Fagesia* cf. *peroni* PERVINQUIÈRE, 1907, Lower Turonian Maghra El Hadida Formation. 1: lateral view, x0.75; 2: apertural view, x0.75; WG-24-1.

C. *Thomasites rollandi* (THOMAS & PERON, 1889), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; 3: apertural view, x1; WG-23-6.

Text-fig. 5.12



1990 *Thomasites jordani* PERVINQUIÈRE – ROBASZYNSKI et al.: p. 268, pl. 22, fig. 3 a-b.

1994 *Thomasites rollandi* (THOMAS & PERON) – CHANCELLOR et al.: p. 75, pl. 19, figs. 1-2; pl. 20, figs. 1-12; pl. 21, figs. 1-9; pl. 22, figs. 1-6; pl. 23, figs. 1-9; text-fig. 14a-f (see for complete synonymy).

1996 *Thomasites rollandi* (THOMAS & PERON) s.s., forme *jordani* and forme *meslei* of PERVINQUIÈRE – MEISTER & ABDALLAH: p. 12, 13, pl. 7, figs. 1, 2; pl. 11, fig. 2; pl. 6, fig. 2; pl. 8, figs. 1-3; pl. 9, fig. 2; pl. 10, fig. 2; text-figs. 5h-k, 6a-d.

2004a *Thomasites rollandi* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 3, fig. 1.

2005 *Thomasites rollandi rollandi* (THOMAS & PERON), forme *jordani*, and forme *meslei* – MEISTER & ABDALLAH: p. 137, 138, pl. 17, fig. 1-3, 5-7; pl. 18, figs. 1, 3.

2006 *Thomasites rollandi* (THOMAS & PERON) – EL QOT: p. 122, pl.27, figs. 4,5; pl. 28, fig.1.

2007 *Thomasites rollandi* (THOMAS & PERON) – ABDEL-GAWAD et al.: pl. 3, fig. 1.

Material: 9 complete and incomplete, moderately to well preserved shells and internal moulds (WG-23- 6–14) from Wadi Ghonima section (at 44m) and three moderately preserved incomplete internal moulds (080217-25.5- 3–5) from East Wadi Ghonima section (at 127m). All specimens from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-23-6	38.8 (100)	28.7 (73.9)	20.6 (53.0)	1.93	11.6 (29.8)
WG-23-7	56.1 (100)	37.1 (66.1)	32.6 (58.1)	1.13	7.1 (12.6)
WG-23-8	48.7 (100)	39.8 (81.7)	31.1 (63.8)	1.27	6.8 (13.9)
WG-23-9	51.4 (100)	33.6 (65.3)	30.4 (59.1)	1.10	7.4 (14.3)
WG-23-10	37.1 (100)	27.0 (72.7)	18.8 (50.6)	1.43	5.7 (15.3)
WG-23-11	92.0 (100)	54.2 (58.9)	50.9 (55.3)	1.06	10.3 (11.1)
WG-23-12	60.7 (100)	41.4 (68.2)	36.1 (59.4)	1.14	7.5 (12.3)
WG-23-13	55.6 (100)	29.0 (52.1)	31.2 (56.1)	0.92	5.4 (9.7)
WG-23-14	51.7 (100)	29.9 (57.8)	30.3 (58.6)	0.98	7.2 (13.9)
080217-25.5-3	52.1 (100)	22.2 (42.6)	27.5 (52.7)	0.80	5.1 (9.7)

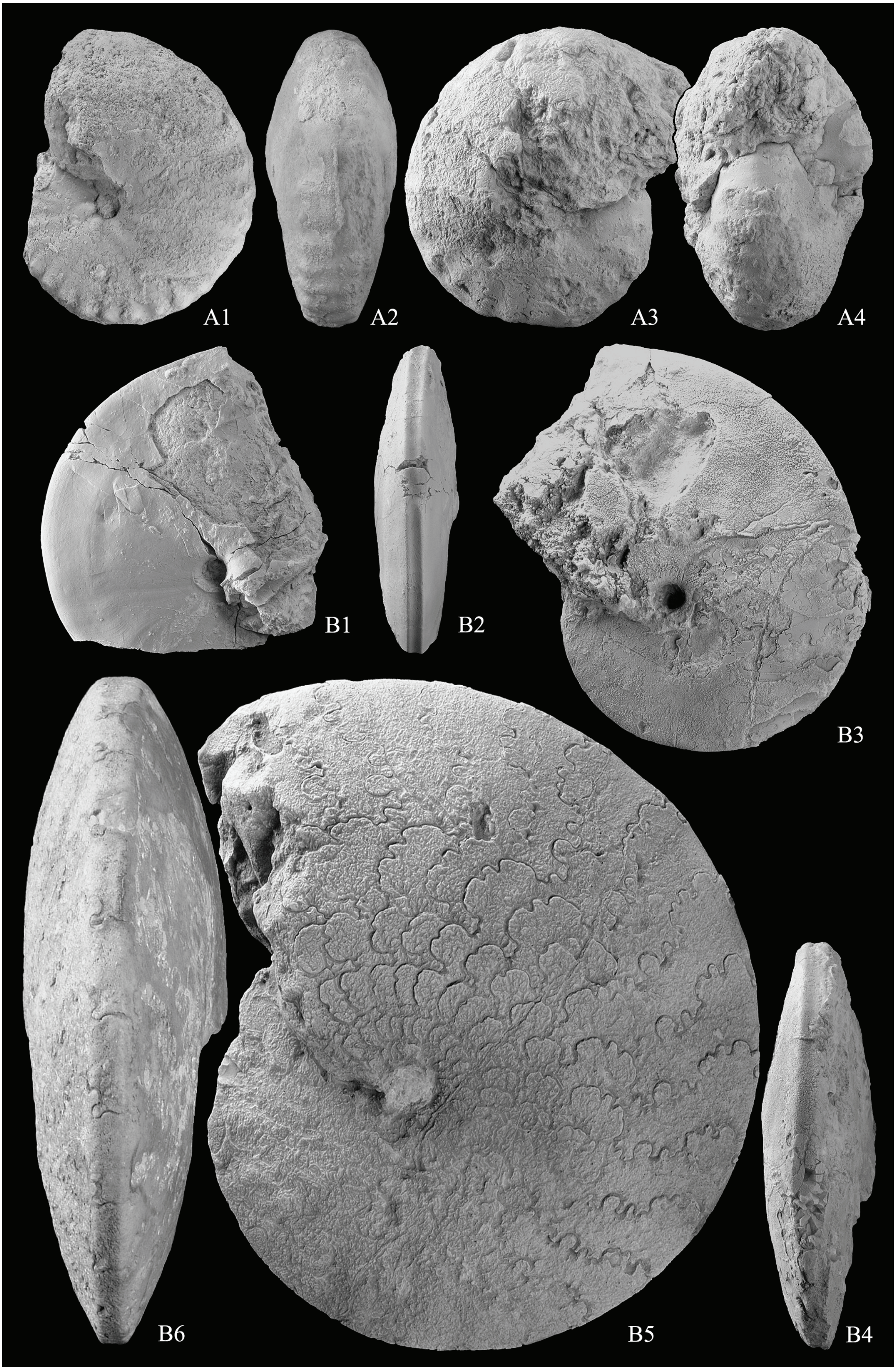
Description: Medium-sized, very involute. Whorl section compressed to globose and inflated. Umbilicus moderately wide to small (about 30% to 10% of total diameter), deep, with a high subvertical wall; umbilical shoulder narrowly rounded, with distinctive tubercles. Greatest width at the umbilical shoulder. The inner flanks are strongly inflated, but the outer flanks are flattened and convergent. The ventrolateral shoulders are rounded, with a row of small bullae on each side (19 bullae/whorl in specimen WG-23-6) which form coarse, blunt ribs that are strong on the outer flank and weaker on the inner flank. Venter rounded to nearly flat. Suture line composed of four saddles, the first one being the broadest (Text-fig. 5.14A-D).

Text-fig. 5.13

A. *Thomasites rollandi* (THOMAS & PERON, 1889), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; 080217-25.5-3. – 3: lateral view, x1; 4: apertural view, x1; WG-23-13.

B. *Wrightoceras munieri* (PERVINQUIÈRE, 1907), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; 080216-18-2. – 3: lateral view, x1; 4: ventral view, x1; 080216-18-1. – 5: lateral view, x1; 6: ventral view, x1; 080216-18-3.

Text-fig. 5.13



Remarks: PERVINQUIÈRE (1907) erected the genus *Thomasites* and noted that there is a difficulty in distinguishing mature specimens of this genus from mature specimens of genus *Neoptychites*. According to CHANCELLOR et al. (1994, p. 69), *Thomasites* retain their ventrolateral shoulder ornament throughout ontogeny and rarely develop the rounded venter of *Neoptychites*. Furthermore, *Thomasites* has blunt umbilical tubercules from which very weak ribs arise in twos or threes and strengthen into tubercles at a moderately distinct ventrolateral shoulder, then flex forwards and may extend across a flat venter. *Neoptychites*, on the other hand, has ribs or a smooth shell bearing only sparse constrictions and associated collar-like ribs that are strongest over the venter. BASSE (1940) restudied the PERVINQUIÈRE collection and considered *Thomasites meslei* PERVINQUIÈRE and *T. jordani* PERVINQUIÈRE as synonyms of *T. rollandi*. CHANCELLOR et al. (1994, p. 78) examined PERON's and PERVINQUIÈRE's types plus 150 other specimens of *Thomasites* from Tunisia. They concluded that only one species is required to embrace the variation in these collections. In agreement with FREUND & RAAB (1969) and CHANCELLOR et al. (1994), *T. egyptiacus*, *T. lefevrei* and the 'race' *T. jordani sinaitica* of DOUVILLÉ (1928) are considered as *T. rollandi*. Also, the *Mammites incertus* and *Mammites* sp. of DOUVILLÉ (1928) may be *Thomasites*. MEISTER & ABDALLAH (1996) separated *T. jordani* PERVINQUIÈRE and *T. meslei* PERVINQUIÈRE as forms from *T. rollandi*. These forms are regarded here as *T. rollandi* because the figured material matches well with that of CHANCELLOR et al. (1994) and the studied specimens. The differences between these forms are considered as intraspecific variability. In the studied specimens, all forms of *T. rollandi* were recorded and the fauna is very similar to the Tunisian material.

Occurrence: *Thomasites rollandi* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; ROBASZYNSKI et al., 1990; CHANCELLOR et al., 1994; MEISTER & ABDALLAH, 1996), Israel (FREUND & RAAB, 1969), and from England (WRIGHT & KENNEDY, 1981). According to CHANCELLOR et al. (1994, p. 81), it is known from France, Spain, Algeria, Jordan, Syria, Lebanon, (?) Colombia and (?) Tadzhikistan. In Egypt, it has been recorded from the Lower Turonian of Sinai (DOUVILLÉ, 1928; ABDEL-GAWAD et al., 2004a; EL QOT, 2006) and the Eastern Desert (ABDEL-GAWAD et al., 2007).

Genus *Wrightoceras* REYMENT, 1954

Wrightoceras munieri (PERVINQUIÈRE, 1907)

Text-figs. 5.13B, 5.14E-F

1907 *Hoplitoides Munieri* sp. nov. – PERVINQUIÈRE: p. 217, pl. 10, figs. 1, 2; text-fig. 83.

1956 *Hoplitoides inca* sp. nov. – BENAVIDES–CÁCERES: p. 475, pl. 63, figs. 6-11; text-fig. 54.

1982 *Hoplitoides munieri* PERVINQUIERE – RENZ: p. 100, pl. 31, figs. 3-6, 11.

1982 *Wrightoceras* cf. *munieri* (PERVINQUIÈRE) – CHANCELLOR: p. 119, figs. 60-63; text-figs. 2H.

1987 *Wrightoceras munieri* (PERVINQUIERE) – KENNEDY et al., p. 58, pl. 10, figs. 9-11; text-fig. 2e.

1994 *Wrightoceras munieri* (PERVINQUIÈRE) – CHANCELLOR et al.: p. 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.

1997 *Wrightoceras munieri* (PERVINQUIERE) – WIESE: pl. 3, figs. 4, 5.

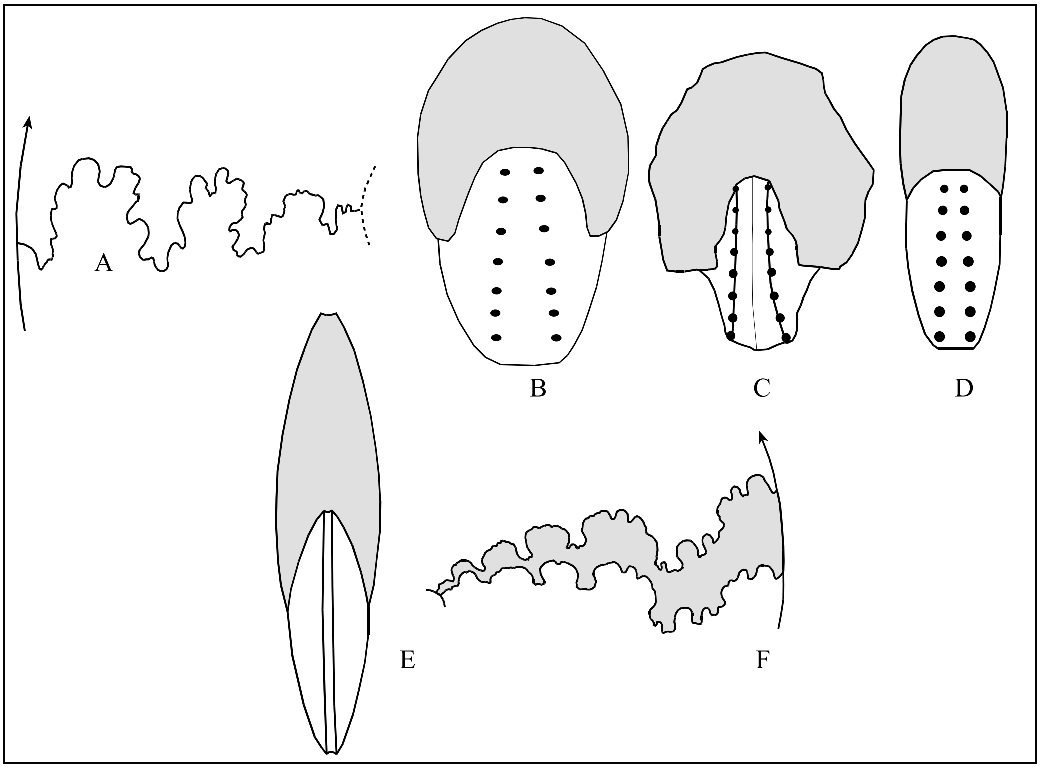
2007 *Wrightoceras munieri* (PERVINQUIÈRE) – BARROSO-BARCENILLA & GOY: p. 480, fig. 10(3, 4) (see for further synonymy).

Material: Two well preserved incomplete shells (080216-18- 1–2) and five well preserved complete and incomplete internal moulds (080216-18- 3–7) from Wadi Ghonima section (at 47m) and four moderately preserved incomplete internal moulds (080217-27- 1–4) from East Wadi Ghonima section (at 143.5m respectively). All specimens from the Lower Turonian *Wrightoceras munieri* Zone of the Maghra El Hadida Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080216-18-1	74.7 (100)	22.1 (29.5)	45.3 (60.6)	0.48	5.4 (7.2)
080216-18-3	121.9 (100)	39.4 (32.3)	76.4 (62.6)	0.51	7.9 (6.4)

Description: Very involute, medium-sized. Whorls very compressed. Umbilicus small, umbilical shoulder very narrowly rounded. Maximum width at umbilical shoulder. Whorl walls slightly convex. Venter narrow, concave, edges developed into sharp keels. All specimens lack ornamentation. The suture line is well preserved, the first lateral saddle is the highest and the widest one and is also divided by accessory lobes (Text-fig. 5.14E-F).



Text-fig. 5.14. Whorl sections and suture lines of: A-D, *Thomasites rollandi* (THOMAS & PERON, 1889); E-F, *Wrightoceras munieri* (PERVINQUIÈRE, 1907). A, D, specimen 080217-25.5-3; B, WG-23-13; C, specimen WG-23-6; E, F, specimen 080216-18-3. Not to scale.

Remarks: Some *Hoplitoides* lose the bicarinate venter at late stages; therefore, REYMENT (1954) proposed the subgenus *Wrightoceras* for *Pseudotissotia* of PERON (1897) to include these forms. KENNEDY et al. (1979) separated *Wrightoceras* as a distinct genus, stating that *Pseudotissotia* are smooth and tricarinate during the first ontogenetic stages, in contrast to the members of *Wrightoceras*. KENNEDY et al. (1987, p. 58) and CHANCELLOR et al. (1994, p.

100) regarded *Hoplitoides inca* BENAVIDES–CÁCERES (1956, p. 475, pl. 63, fig. 6-11) as a synonym of *Wrightoceras munieri* (PERVINQUIÈRE, 1907). In addition, RENZ (1982) showed that it is probably closely related, if not identical, to *Wrightoceras munieri*. KENNEDY et al. (1987) considered the Colombian species *Imlayiceras washbournei* LEANZA (1967, p. 198, pl. 4, figs. 1-4; pl. 6, figs. 1, 4-6) and *Imlayiceras ralphimlayi* ETAYO-SERNA (1979, p. 88, pl. 13, fig. 3; text-fig. 8a) closely resembling *Wrightoceras munieri*. The studied specimens closely correspond to the holotype as figured by PERVINQUIÈRE (1907) and those described by KENNEDY et al. (1987) as well as the Tunisian material of CHANCELLOR et al. (1994).

Occurrence: According to CHANCELLOR et al. (1994, p. 100), *Wrightoceras munieri* is known from the Lower Turonian of Tunisia, Niger, Nigeria, (?) Morocco, Spain, Peru, Venezuela, Colombia, Texas, and Mexico. This is the first record of *Wrightoceras munieri* from Egypt, it has been recorded from the upper Lower Turonian.

Genus *Choffaticeras* HYATT, 1903

Diagnosis: Small- to large-sized, compressed to inflated with lanceolate or subtriangular whorl sections, reaching their greatest width close to the umbilical margins or on the inner flanks. Coiling involute with small and deep umbilici. Narrow, sharp or rounded venters with continuous siphonal keels, occasionally flanked by two keels consisting of feeble ventrolateral tubercles. The first whorls may show fine ornamentation consisting of dense ribbing and weak umbilical and ventrolateral tubercles that disappear quite soon during ontogeny. The adult specimens are smooth and range from medium to large sizes. Very variable suture lines that maintain certain resemblance to that of *Pseudotissotia*, PERON (1897). First lateral saddle deeply indented, others with minor incisions.

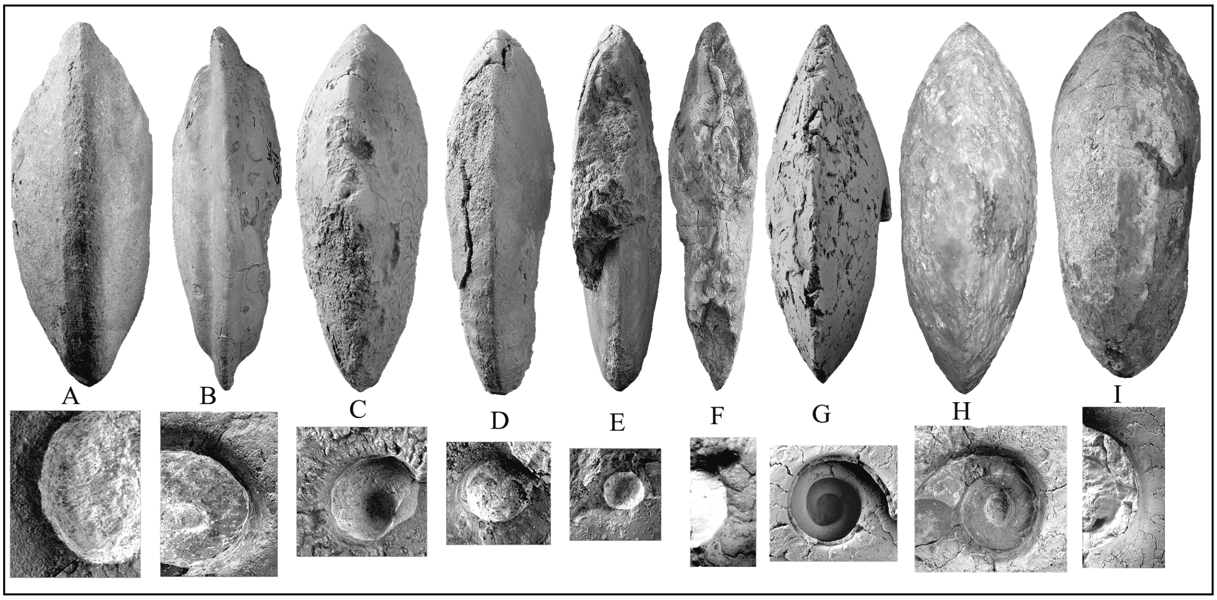
Discussion: HYATT (1903) introduced the genus *Choffaticeras* to describe the more involute and compressed forms of *Pseudotissotia*. PERVINQUIÈRE (1907) included this genus in *Pseudotissotia* as a subgenus and distinguished two groups characterised by tricarinate and by monocarinate species. REYMENT (1955) redefined the genus on the basis of the observations of PERVINQUIÈRE, dividing the group into tricarinate, *Choffaticeras* (*Choffaticeras*), and monocarinate, *Choffaticeras* (*Leoniceras*), forms. This systematic proposal was already accepted by WRIGHT in MOORE (1957) and subsequently by KENNEDY (1994), CHANCELLOR et al. (1994), WRIGHT et al. (1996) and BARROSO-BARCENILLA & GOY (2007). Also the present work adopts this view. The limits between the numerous species assigned to the genus *Choffaticeras* are hard to set, as among many of them a constant morphological variability can be observed. Therefore, KASSAB (1991: p. 29) and KASSAB & OBAIDALLA (2001: p. 109) proposed *Ch. luciae*, *Ch. pavillieri*, *Ch. schweinfurthi*, *Ch. securiforme* and, *Ch. quaasi* as synonyms of *Ch. segne*. But, in agreement with BARROSO-BARCENILLA & GOY (2007), they assigned to *Ch. segne* some non contemporary species with very different morphologies that are even attributable to different subgenera. According to many authors (e.g. FREUND & RAAB, 1969; KENNEDY, 1994; CHANCELLOR et al., 1994; BARROSO-BARCENILLA & GOY, 2007) it can be separated to different species depending on different morphological features. In the present study, the following species can be identified in this genus and the two subgenera.

***Choffaticeras* (*Choffaticeras*)**: *Ch.* (*Ch.*) *meslei*, the oldest tricarinate species, is characterized by fairly broad, convex venter with three blunt keels (Text-fig. 5.15A). *Ch.* (*Ch.*) *securiforme* shows strong ventrolateral grooves with relatively wide umbilicus and strong umbilical shoulder (Text-fig. 5.15B). A continuous series consisting of the species *Ch.* (*Ch.*) *quaasi*, *Ch.* (*Ch.*) *segne*, and *Ch.* (*Ch.*) *pavillieri* can be identified. In agreement with BARROSO-BARCENILLA & GOY (2007), *Ch.* (*Ch.*) *segne* would include those specimens with a more depressed whorl section (Text-fig. 5.15C) whose breadth exceeds two thirds of its height, and which have a relatively broad umbilicus. Slightly more compressed specimens (width is not wider than two thirds of the whorl breadth) with a bit narrower umbilicus whose would be included within *Ch.* (*Ch.*) *quaasi* (Text-fig. 5.15D). In this continuous series, the most compressed specimens with the narrowest umbilicus would be grouped in *Ch.* (*Ch.*) *pavillieri* (Text-fig. 5.15E). *Ch.* (*Ch.*) *sinaiticum* has the most compressed whorl section in the tricarinate group (Text-fig. 5.15F). In agreement with BARROSO-BARCENILLA & GOY (2007), *Ch.* (*Ch.*) *sinaiticum* apparently belongs to the tricarinate group but, in fact, it acts as a transitional form between the tricarinate and monocarinate members of the genus.

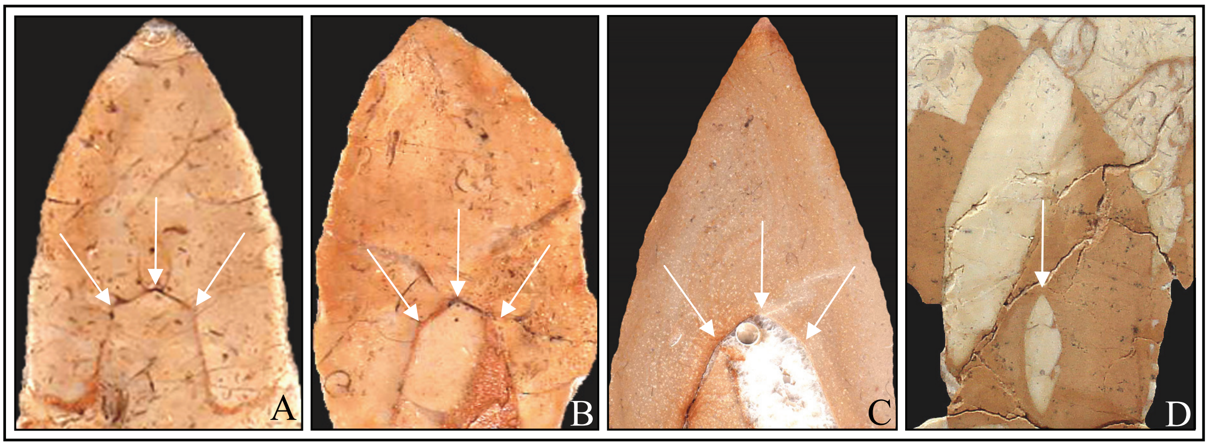
The tricarinate character of the subgenus *Choffaticeras* cannot be observed in some adult specimens of *Ch.* (*Ch.*) *segne* and *Ch.* (*Ch.*) *sinaiticum*. Therefore, polished sections through the early whorls (Text-fig. 5.16A-C) are used here to confirm the inclusion of these taxa to the subgenus *Choffaticeras*.

***Choffaticeras* (*Leoniceras*)**: Among the monocarinate taxa, another continuous series consisting of *Ch.* (*L.*) *barjonai* and *Ch.* (*L.*) *luciae* can be identified. In agreement with BARROSO-BARCENILLA & GOY (2007), the proportions of the umbilical width and the whorl breadth widen in a continuous manner. *Ch.* (*L.*) *luciae* would include those specimens with a more compressed whorl section and small and deep umbilici in both juveniles and adult individuals (Text-fig. 5.15G). Specimens which have wide umbilici (in small and large size) and more depressed forms would be grouped in *Ch.* (*L.*) *barjonai* (Text-fig. 5.15H). *Ch.* (*L.*) *philippii* groups the most depressed forms with strongly convex flanks, wider umbilici, and more complex suture line in adult specimens and even in juveniles (Text-fig. 5.15I).

The monocarinate character of subgenus *Leoniceras* can be observed in small and large individuals. The adult specimens of *Ch.* (*L.*) *philippii* show a wide and slightly rounded venter. Therefore, polished sections through early whorls (Text-fig. 5.16D) are used here to confirm the affinity of this taxon to the subgenus *Leoniceras*.



Text-fig. 5.15. Whorl section and umbilici of: A, *Choffaticeras* (*Choffaticeras*) *meslei*; B, *Ch.* (*Ch.*) *securiforme*; C, *Ch.* (*Ch.*) *segne*; D, *Ch.* (*Ch.*) *quaasi*; E, *Ch.* (*Ch.*) *pavillieri*; F, *Ch.* (*Ch.*) *sinaticum*; G, *Ch.* (*Leoniceras*) *luciae*; H, *Ch.* (*L.*) *barjonai*, and I, *Ch.* (*L.*) *philippii*. Not to scale.



Text-fig. 5.16. Cross section showing the early whorls in some adult specimens of genus *Choffaticeras*. A-B, *Choffaticeras* (*Choffaticeras*) *segne*; C, *Ch.* (*Ch.*) *sinaticum*; D, *Ch.* (*Leoniceras*) *philippii*. Arrows indicate ventral carination. Not to scale.

Subgenus *Choffaticeras* DOUVILLÉ, 1911

Choffaticeras (*Choffaticeras*) *meslei* (PERON, 1897)

Text-figs. 5.17A, 5.23A-B

1897 *Pseudotissotia meslei* sp. nov. – PERON: p. 33, pl. 14(1), fig. 1; pl. 15(2), figs. 1, 2; pl. 16(3), fig. 2; pl. 11(17), fig.1.

1969 *Choffaticeras meslei* (PERON) – FREUND & RAAB: p. 53, pl. 9, fig. 2; text-fig. 10i.

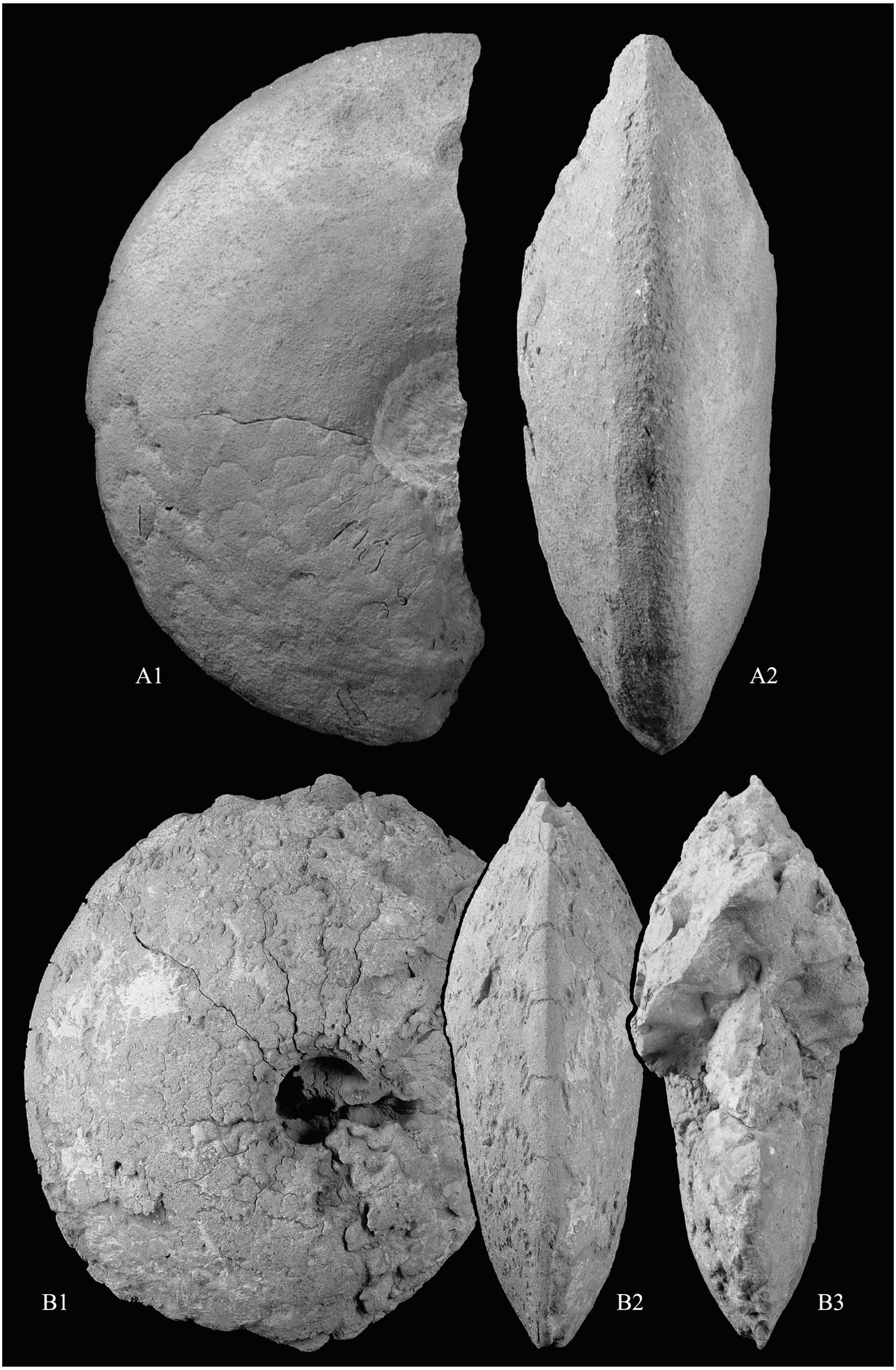
1994 *Choffaticeras* (*Choffaticeras*) *meslei* (PERON) – CHANCELLOR et al.: p. 84, pl. 24, figs. 1-2; pl. 25, figs. 4-6 ; pl. 27, figs. 3, 5; text-fig. 15C, E.

Text-fig. 5.17

A. *Choffaticeras* (*Choffaticeras*) *meslei* (PERON, 1897), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x0.75; 2: ventral view, x0.75; 080216-13-1.

B. *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER, 1903), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x0.75; 2: ventral view, x0.75; 3: apertural view, x0.75; 080216-15-1.

Text-fig. 5.17



Material: Two poorly preserved incomplete internal moulds (080216-13- 1-2) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at Wadi Ghonima section (34m above the base of Maghra El Hadida Formation).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080216-13- 1	180.2 (100)	46.3 (25.6)	94.4 (52.3)	0.49	36.7 (20.3)

Description: Coiling involute, large-sized. Whorl section trigonal (Text-fig. 5.23A-B), with convex flanks. Greatest whorl breadth below mid-flank (about 25% of total diameter). Venter relatively broad, convex with three blunt keels. Umbilicus medium-sized (about 20% of total diameter), deep, with narrow and low rounded umbilical shoulder. No ornament visible. The suture line consists of four saddles, the first one is high, wide, and has unequal branches.

Remarks: As recorded by FREUND & RAAB (1969), *Choffaticeras* (*Choffaticeras*) *meslei* has been recorded in the study area from the lower part of the *Choffaticeras* interval. CHANCELLOR et al. (1994) demonstrated that there is a wide variation in this taxon in terms of whorl section, ornament, and especially umbilical width. The studied specimens are similar to the large form of the Tunisian material described by CHANCELLOR et al. (1994), but differ in having higher whorls. Furthermore, the ornament is only represented by three keels in the ventral area, which is considered as the most diagnostic character of this species.

Occurrence: *Choffaticeras* (*Choffaticeras*) *meslei* has been recorded from the Lower Turonian of Israel (FREUND & RAAB, 1969) and Tunisia (CHANCELLOR et al., 1994). The *Choffaticeras* (*Choffaticeras*) *meslei* from the Lower Turonian of the study area represent the first record of this species from Egypt.

Choffaticeras (*Choffaticeras*) *quaasi* (PERON, 1904)

Text-figs. 5.18A, 5.23C

1904 *Schloenbachia quaasi* sp. nov. – PERON: p. 255, pl. 1, figs. 1-3.
1907 *Pseudotissotia* (*Choffaticeras*) *segnis* SOLGER – PERVINQUIÈRE: p. 351, pl. 23, fig. 2.
1907 *Pseudotissotia* (*Choffaticeras*) *segnis* varieties *discoidalis* PERVINQUIÈRE: p. 352, pl. 23, fig. 3a, b.
1914 *Schloenbachia Quaasi* FOURTAU – ECK: p. 212, pl. 13, figs. 3-7; pl. 14, figs. 2-5, 8.
1928 *Leoniceras Quaasi* (PERON) – DOUVILLÉ: p. 21, pl. 3, figs. 2-7.
1969 *Choffaticeras quaasi* (PERON) – FREUND & RAAB: p. 56, pl. 9, figs. 5-6; text-figs. 10m, 11a.

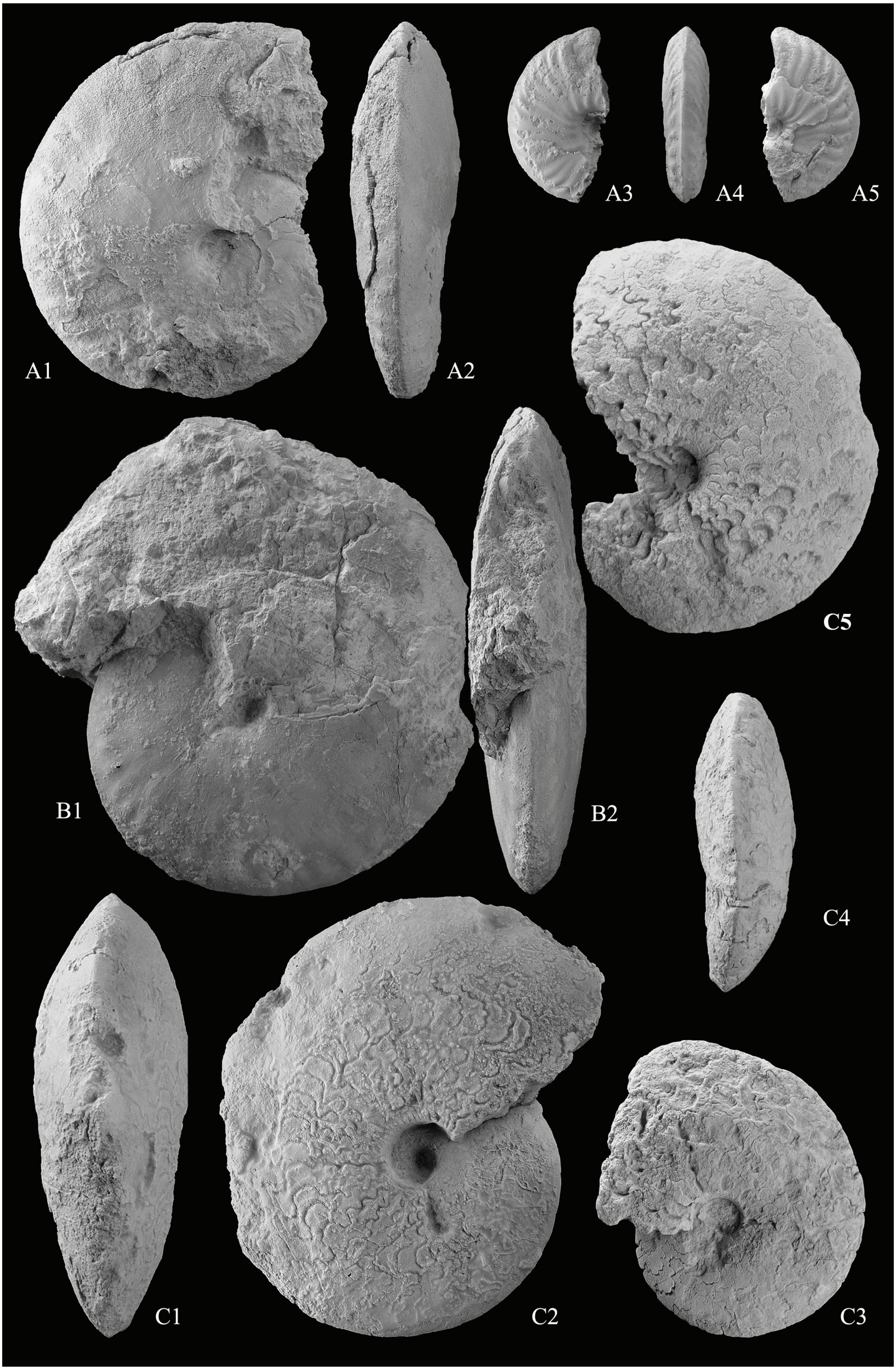
Text-fig. 5.18

A. *Choffaticeras* (*Choffaticeras*) *quaasi* (PERON, 1904), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; WG-19-1. – 3, 5: lateral view, x2; 4: ventral view, x2; WG-19-2.

B. *Choffaticeras* (*Choffaticeras*) *pavillieri* PERVINQUIÈRE, 1907, Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: apertural view, x1; 080217-26-6. – 3: lateral view, x1; 080217-26-7.

C. *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER, 1903), Lower Turonian Maghra El Hadida Formation. 1: ventral view, x1; 2: lateral view, x1; 080216-15-2.- 3: lateral view, x1; 4: ventral view, x1; 080216-25-1. – 5: lateral view, x1; 080216-20-1.

Text-fig. 5.18



1994 *Choffaticeras* (*Choffaticeras*) *quaasi* (PERON) – CHANCELLOR et al.: p. 88, pl. 28, figs. 5-7.

1998 *Choffaticeras quaasi* (PERON) – KÜCHLER: pl. 9, fig. 8.

2001 *Choffaticeras quaasi* (PERON) – ALY & ABDEL-GAWAD: p. 43, pl. 2, fig. 3.

2004a *Choffaticeras quaasi* (PERON) – ABDEL-GAWAD et al.: pl. 3, fig. 3.

2006 *Choffaticeras* (*Choffaticeras*) *quaasi* (PERON) – EL QOT: p. 124, pl. 28, fig. 3.

2007 *Choffaticeras* (*Choffaticeras*) *quaasi* (PERON) – BARROSO-BARCENILLA & GOY: p. 464, figs. 4(4,5), 5(1).

Material: Five moderately preserved complete and incomplete shells (WG-19- 1–2, WG-20-1–3) from Wadi Ghonima section (38.5m above the base of the Maghra El Hadida Formation) and two poorly preserved incomplete internal moulds (WA-16- 1–2) from Wadi Askhar section (at 107m). All specimens from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-19-1	68.28 (100)	20.1 (29.4)	40.5 (59.3)	0.49	8.1 (11.8)
WG-19-2	16.3 (100)	5.13 (31.4)	9.1 (55.8)	0.56	2.3 (14.1)

Description: Small- to medium- sized. Coiling slightly evolute in juveniles and very involute in adult specimens, oxycone. Whorls compressed, with ogival shape (Text-fig. 5.23C). Maximum thickness near to umbilical shoulder. Walls slightly convex, with sharp venter. Umbilicus small (about 14% of total diameter), deep, with narrow and low rounded umbilical shoulder. Ornament consists of weak umbilical tubercles giving rise to sinuous ribs in juveniles and straight ones in adults, each rib bearing a distinct ventrolateral clavus, which form ventrolateral keels. The costal density ranges from 23 to 29 ribs per half whorl. These ribs become rare in the last whorls of adult specimens. Sutures not seen in the present specimens.

Remarks: *Pseudotissotia* (*Choffaticeras*) *segnis* varieties *discoidalis* described by PERVINQUIÈRE (1907) as a variety including the most compressed forms of *Pseudotissotia segnis*, was considered a mere synonym of *Ch.* (*Ch.*) *quaasi* by FREUND & RAAB (1969) and many other subsequent authors, such as CHANCELLOR et al. (1994) and BARROSO-BARCENILLA & GOY (2007).

Occurrence: *Choffaticeras* (*Choffaticeras*) *quaasi* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994), Israel (FREUND & RAAB, 1969) and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it has been recorded from Sinai (ECK, 1914; DOUVILLÉ, 1928; ALY & ABDEL-GAWAD, 2001; ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Choffaticeras (*Choffaticeras*) *pavillieri* (PERVINQUIÈRE, 1907)

Text-figs. 5.18B, 5.23D

1907 *Pseudotissotia* (*Choffaticeras*) *pavillieri* sp. nov. – PERVINQUIÈRE: p. 353, pl. 23, figs. 4-6; text-fig. 134.

?1914 *Pseudotissotia segnis* SOLGER, var. *discoidalis* PERVINQUIÈRE – ECK: p. 207, pl. 14, fig. 7; pl. 15, fig. 1; text-figs. 7-9.

1928 *Leoniceras Quaasi* (PERON) – DOUVILLÉ: p. 21, pl. 4, fig. 1, 2.

?1928 *Leoniceras carinifer* sp. nov. – DOUVILLÉ: p. 25, pl. 4, fig. 3a.

1969 *Choffaticeras pavillieri* (PERVINQUIÈRE) – FREUND & RAAB: p. 56, pl. 9, figs. 3, 4; text-fig. 11b-d.

1994 *Choffaticeras* (*Choffaticeras*) *pavillieri* (PERVINQUIÈRE) – CHANCELLOR et al.: p. 87, pl. 26, figs. 6-7, 9-12; text-fig. 15b, d.

1997 *Choffaticeras pavillieri* (PERVINQUIÈRE) – WIESE: pl. 1, figs. 2-3.

2001 *Choffaticeras pavillieri* (PERVINQUIÈRE) – ALY & ABDEL-GAWAD: p. 42, pl. 7, fig. 2.

2007 *Choffaticeras* (*Choffaticeras*) *pavillieri* (PERVINQUIÈRE) – BARROSO-BARCENILLA & GOY: p. 467, figs. 5(2-4).

Material: Seven moderately preserved complete and incomplete shells (080217-25.5- 6–9 & 080217-26- 6–8) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at East Wadi Ghonima section (at 127m and 132m, respectively).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-26-6	88.3 (100)	15.9 (18.0)	56.1 (63.5)	0.28	4.9 (5.5)

Description: Coiling completely involute, small- to medium-sized. Whorls strongly compressed, with subogival whorl section (Text-fig. 5.23D). Greatest breadth close to the middle part of the flank. Walls almost flat, with narrow and sharp venter. Umbilicus very small (about 5.5% of total diameter). Ornament consists of weak, relatively straight ribs, bearing weak ventrolateral tubercles. The ornament disappears in large specimens. Sutures not seen in the present specimens.

Remarks: *Pseudotissotia segnis* SOLGER, var. *discoidalis* PERVINQUIÈRE as described by ECK (1914) has a very small umbilicus and a more compressed whorl section. Therefore, this form is regarded as *Ch.* (*Ch.*) *pavillieri* by BARROSO-BARCENILLA & GOY (2007) and the present work is in agreement with them. *Leoniceras carinifer* of DOUVILLÉ (1928) is considered as synonym of *Ch.* (*Ch.*) *pavillieri* by many authors (FREUND & RAAB, 1969; CHANCELLOR et al., 1994; BARROSO-BARCENILLA & GOY, 2007) depending on its dimensions, general appearance, narrow umbilicus, high whorl section, and its ventrolateral shape. This view is accepted in this work.

Occurrence: *Choffaticeras* (*Choffaticeras*) *pavillieri* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; CHANCELLOR et al., 1994), Israel (FREUND & RAAB, 1969) and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it has been recorded from Sinai (DOUVILLÉ, 1928; ALY & ABDEL-GAWAD, 2001).

Choffaticeras (*Choffaticeras*) *securiforme* (ECK, 1909)

Text-figs. 5.19, 5.20A, 5.23H-I

1909 *Tissotia securiformis* sp .nov. – ECK: p. 187, figs. 9-13.

1914 *Tissotia securiformis* ECK – ECK: p. 216, pl. 19, fig. 3.

?1914 *Pseudotissotia segnis* SOLGER – ECK: p. 204, pl. 16, figs. 1-2.

?1928 *Leoniceras segne* (SOLGER) – DOUVILLÉ: p. 26, pl. 5.
1969 *Choffaticeras securiforme* (ECK) – FREUND & RAAB: p. 60, pl. 9, fig. 1; text-fig. 11i-k.
1996 *Choffaticeras* gr. *securiforme* (ECK) – MEISTER & ABDALLAH: p. 15, pl. 9, fig. 1; text-fig. 6g.
2003 *Choffaticeras segne* (SOLGER) – HEWAIDY et al.: p. 351, pl. 3, figs. 1,3.
2004a *Choffaticeras securiforme* (ECK) – ABDEL-GAWAD et al.: pl. 3, figs. 4.
2006 *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK) – EL QOT: p. 124, pl. 28, figs. 4.

Material: Five moderately preserved incomplete internal moulds (080217-19- 1–5) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at East Wadi Ghonima section (at 123m).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-19-1	169.4 (100)	47.5 (28.0)	75.4 (44.5)	0.62	40.4 (23.8)
080217-19-2	140.0 (100)	48.1 (34.5)	63.3 (45.2)	0.75	30.1 (21.5)

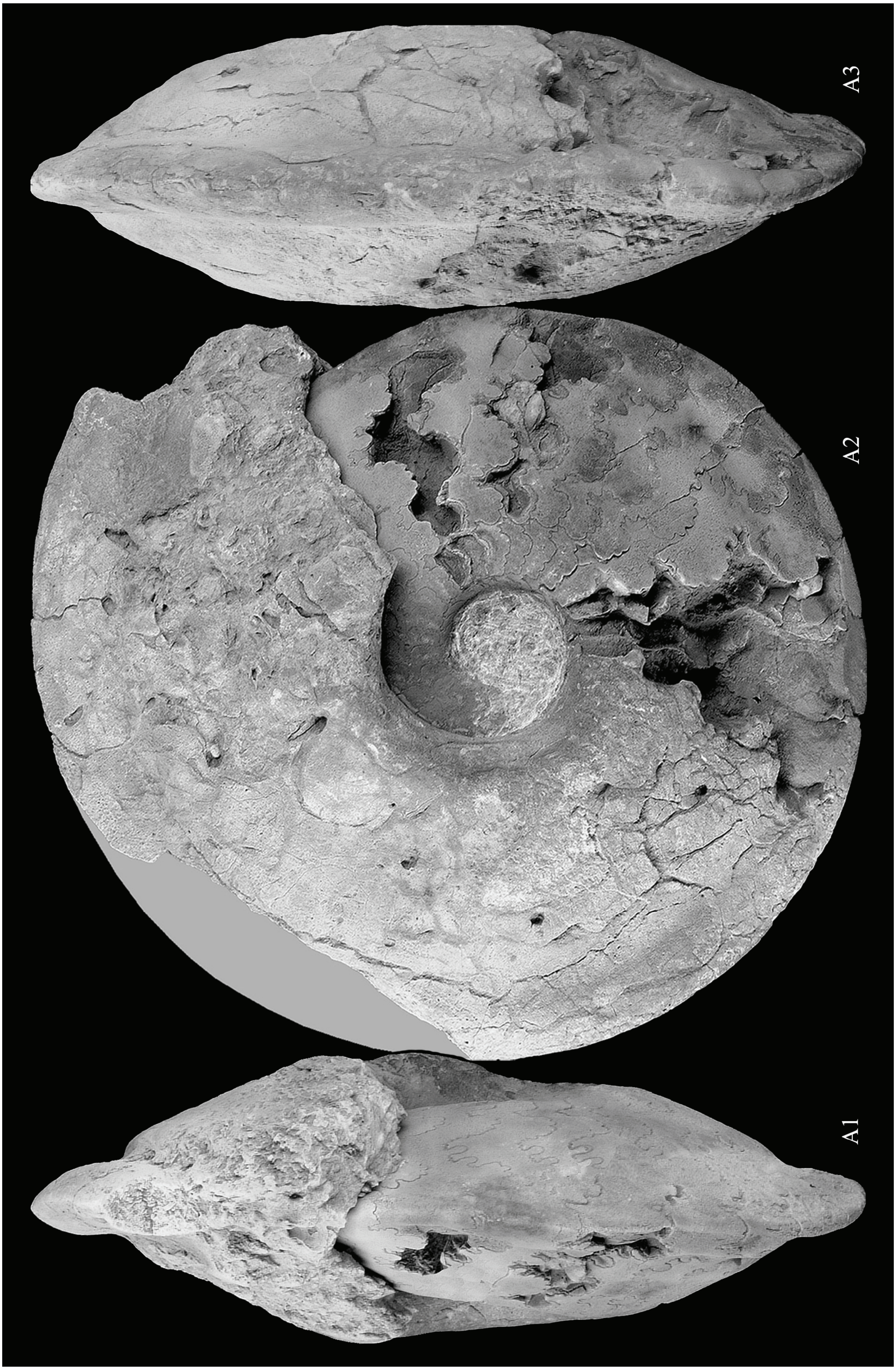
Description: Involute, large-sized. Whorls compressed, with lanceolate shape. Maximum width at the umbilical shoulder. Walls oblique, with very strong ventrolateral shoulder. Venter narrow, with a median, obtuse keel. Umbilicus wide and fairly deep, with vertical walls and distinct border. Ornamentation consists of growth lines, which are rursiradiate on the umbilical wall, prorsiradiate on the flank, bend backwards in the spiral groove and again forwards crossing the rounded keel. The suture line consists of four saddles. The lateral saddle is high and divided by accessory lobes into unequal parts. The other three saddles are shallow and each one is divided by one or two lobes into secondary saddles (Text-fig. 5.23H-I).

Remarks: According to FREUND & RAAB (1969), *Tissotia securiformis* of ECK does not belong to the genus *Tissotia* as its umbilicus is too large and its saddles are not entire. Thus, this taxon should be included in *Choffaticeras*. They suggested that *Leoniceras* gr. *segne* of ROMAN & MAZERAN (1913, p. 28, pl. 3, fig.3), *Pseudotissotia segnis* of ECK (1914, p. 204, pl. 6, figs. 1-2), and *Leoniceras segne* of DOUVILLÉ (1928, p. 27, pl. 5) are closely resembling *Ch*. *securiforme* because they have ventrolateral grooves. In contrast, BARROSO-BARCENILLA & GOY (2007, p. 469) regarded these taxa with doubt as *Ch*. (*Ch*.) *segne* depending on its narrower umbilicus than *Ch*. *securiforme*. The present work supports the view of FREUND & RAAB (1969), where all forms of subgenus *Choffaticeras* with ventrolateral grooves are regarded here as *Ch*. *securiforme*. FREUND & RAAB (1969) differentiated between *Ch*. *securiforme* (ECK) and *Ch*. *luciae* (PERVINQUIÈRE), which have ventrolateral grooves in some specimens, by the single keel, the shallow spiral groove, and the flat umbilical walls of *Choffaticeras luciae*. The specimen figured by GALAL et al. (2001) from the Egyptian Eastern Desert as *Ch*. *securiforme* has a convex venter without ventrolateral groove and with low and rounded umbilical shoulder. Therefore, it regarded here as *Ch*. *segne*.

Text-fig. 5.19

A. *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK, 1909), Lower Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral view, x1; 3: ventral view, x1; 080217-19-2.

Text-fig. 5.19



Occurrence: *Choffaticeras* (*Choffaticeras*) *securiforme* has been recorded from Lower Turonian of Israel (FREUND & RAAB, 1969) and Tunisia (MEISTER & ABDALLAH, 1996). In Egypt, it has been recorded from Lower Turonian of Sinai (ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Choffaticeras (*Choffaticeras*) *segne* (SOLGER, 1903)

Text-figs. 5.17B, 5.18C, 5.23E-G

1903 *Pseudotissotia segnis* sp. nov. – SOLGER: p. 77, pl. 4, figs. 1-2; text-figs. 16-21.
1907 *Pseudotissotia* (*Choffaticeras*) *segnis* SOLGER – PERVINQUIERE: p. 351, pl. 23, figs. 1-2 [non pl. 23, fig. 2 (*Ch*. [*Ch*.] *quaasi*)].
1911 *Leoniceras segnis* (SOLGER) – DOUVILLÉ: p. 313, text-fig. 49.
1914 *Pseudotissotia segnis* SOLGER – ECK: p. 204, pl. 16. figs. 3.
1969 *Choffaticeras segne* (SOLGER) – FREUND & RAAB: p. 54, text-fig. 10j-i (see for further synonymy).
1987 *Choffaticeras segne* (SOLGER) – KORA & HAMAMA: pl. 1, fig. 7.
1992 *Choffaticeras segne* (SOLGER) – ABDEL-GAWAD et al.: p. 330, pl. 1, figs. 6-7.
1994 *Choffaticeras segne* (SOLGER) – KASSAB & ISMAEL: p. 228, figs. 3 (4-7).
1994 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – CHANCELLOR et al.: p. 88.
2001 *Choffaticeras segne* (SOLGER) – ALY & ABDEL-GAWAD: p. 41, pl. 7, fig. 1.
2001 *Choffaticeras segne* (SOLGER) – GALAL et al.: pl. 4, figs. 5-8.
2001 *Choffaticeras securiforme* (ECK) – GALAL et al.: pl. 4, figs. 3-4.
2001 *Choffaticeras segne* (SOLGER) – KORA et al.: pl. 2, figs. 1, 2.
2002 *Choffaticeras segne* (SOLGER) – EL-HEDENY: p. 410, figs. 5c-d, figs. 8c.
2003 *Choffaticeras segne* (SOLGER) – HEWAIDY et al.: p. 351, pl. 2, figs. 9-10; pl. 3, fig. 2.
2004a *Choffaticeras segne* (SOLGER) – ABDEL-GAWAD et al.: pl. 3, figs. 2, 6.
2006 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – EL QOT: p. 124, pl. 28, figs. 2, 6.
2007 *Choffaticeras segne* (SOLGER) – ABDEL-GAWAD et al.: pl. 3, figs. 4, 6.
2007 *Choffaticeras* (*Choffaticeras*) *segne* (SOLGER) – BARROSO-BARCENILLA & GOY: p. 468, figs. 5(5), 6(1-3).
2008 *Choffaticeras segne* (SOLGER) – ALY: p. 50, pl. 2, figs. A-f; pl. 6, fig. 2a-b; pl. 7, fig. 1c; text-fig. 3 (5).

Material: 7 poorly to moderately preserved complete and incomplete internal moulds (080216-15- 1–4 & 080216-16- 1–3) from Wadi Ghonima section (38m and 42.5 above the base of the Maghra El Hadida Formation), 5 moderately preserved incomplete internal moulds (080217-20- 1–2 & 080217-25- 1–3) from East Wadi Ghonima section (at 124m and 125.5m), 5 moderately preserved complete and incomplete internal moulds (WA-17- 1–7) from Wadi Askhar section (at 115m), and two poorly preserved internal moulds (St.A-1- 1–2) from Saint Anthony section. All specimens from the Lower Turonian *Choffaticeras* ssp. Zone of the Maghra El Hadida Formation.

Text-fig. 5.20

A. *Choffaticeras* (*Choffaticeras*) *securiforme* (ECK, 1909), Lower Turonian Maghra El Hadida Formation. 1: ventral view, x0.90; 2: lateral view, x0.90; 080217-19-1.

B. *Choffaticeras* (*Choffaticeras*) *sinaiticum* (DOUVILLÉ, 1928), Lower Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral, x1; 080217-26-9.

Text-fig. 5.20

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080216-15-1	176.4 (100)	64.8 (36.7)	88.1 (49.9)	0.73	28.3 (16.0)
080216-15-2	79.8 (100)	27.9 (34.9)	41.2 (51.6)	0.67	10.2 (12.7)
080217-20-1	71.1 (100)	25.4 (35.7)	38.1 (53.5)	0.66	7.5 (10.5)
080216-25-1	53.5 (100)	22.7 (42.4)	34.0 (63.5)	0.66	6.7 (12.5)

Description: More evolute in small-sized, and more involute in large-sized specimens. Whorls slightly compressed, with lenticular shape (Text-fig. 5.23E-G). Greatest breadth at the umbilical shoulder. Different growth stages varying from juveniles to adults are recorded: Umbilicus wide and moderately deep, with rounded walls and rounded umbilical shoulders. Walls convex, with venter fairly sharp in the first stages and narrowly rounded in adult whorls. Only the small specimens are ornamented by very weak ventrolateral tubercles that disappear during ontogeny. The suture line is well preserved in all specimens and shows variability. It consists of four to five saddles on the flank and two on the umbilical wall. The first one is high, wide, and divided into three to four unequal branches. The other three saddles are shallower and each one is divided by one or two lobes into secondary saddles. The first lateral lobe is quite shallow.

Occurrence: *Choffaticeras* (*Choffaticeras*) *segne* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907), Israel (FREUND & RAAB, 1969), Jordan (ALY et al. 2008) and from Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it has been recorded from the Lower Turonian of the north Eastern Desert (GALAL et al., 2001; HEWAIDY et al., 2003: ABDEL-GAWAD et al., 2007), from the Gulf of Suez region (KORA et al., 2001), and from Sinai (KORA & HAMAMA, 1987; KASSAB & ISMAEL, 1994; ABDEL-GAWAD et al., 1992; ALY & ABDEL-GAWAD, 2001; EL-HEDENY, 2002; ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Choffaticeras (*Choffaticeras*) *sinaiticum* (DOUVILLÉ, 1928)

Text-figs. 5.20B, 5.23J-K

1928 *Leoniceras sinaiticum* sp. nov. – DOUVILLÉ: p. 25, pl. 4, fig. 4; text-fig. 15.
1969 *Choffaticeras sinaiticum* (DOUVILLÉ) – FREUND & RAAB: p. 58, text-fig. 11e-h (see for more synonymy).
1996 *Choffaticeras sinaiticum* (DOUVILLÉ) – MEISTER & ABDALLAH: p. 15, pl. 10, fig. 1; text-fig. 6e.
? 2003 *Choffaticeras sinaiticum* (DOUVILLÉ) – HEWAIDY et al.: p. 351, pl. 4, fig. 7.
2004a *Choffaticeras sinaiticum* (DOUVILLÉ) – ABDEL-GAWAD et al.: pl. 3, fig. 5.
2005 *Choffaticeras sinaiticum* (DOUVILLÉ) – MEISTER & ABDALLAH: p. 139, pl. 21, fig. 1,2, text-fig. 27.
2006 *Choffaticeras* (*Choffaticeras*) *sinaiticum* (DOUVILLÉ) – EL QOT: p. 126, pl. 28, fig. 5.
2007 *Choffaticeras* (*Choffaticeras*) *sinaiticum* (DOUVILLÉ) – BARROSO-BARCENILLA & GOY: p. 470, figs. 6(4, 5), 7(1).
2008 *Choffaticeras sinaiticum* (DOUVILLÉ) – ALY et al.: p. 51, pl. 9, fig. 1a-c.

Material: Three poorly preserved, incomplete internal moulds (080217-26- 9–11) from the Lower Turonian *Choffaticeras* spp. Zone of Maghra El Hadida Formation at East Wadi Ghonima section (at 132.5m).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-26-9	142.9 (100)	30.2 (21.1)	73.6 (51.5)	0.41	18.8 (13.1)

Description: Coiling involute, medium-sized, with strongly compressed whorl section (Text-fig. 5.23J-K). Maximum width on the inner flank with slightly convex walls that meet at a sharp venter. Umbilicus relatively small, with rounded shoulder and low umbilical walls. No ornament visible due to poor preservation. The suture line consists of four to five saddles, the first one is high, wide, and has unequal branches.

Remarks: FREUND & RAAB (1969) considered the small specimen of *Choffaticeras segne discoidalis* of GRECO (1915, pl. 19, figs. 2-3) similar to their juvenile *Choffaticeras sinaiticum*. They also pointed out that the differences between *Choffaticeras pavillieri* and *Choffaticeras sinaiticum* are small and there are transitional forms between them. The studied specimens are closely similar in most characters to those described by FREUND & RAAB (1969). However, the more compressed form with less ventrolateral tuberculation of *Choffaticeras sinaiticum* are used here to separate it from *Choffaticeras pavillieri*.

Occurrence: *Choffaticeras sinaiticum* has been recorded from the Lower Turonian of Israel (FREUND & RAAB, 1969), Jordan (ALY et al. 2008), Tunisia (MEISTER & ABDALLAH, 1996) and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it has been recorded from the Lower Turonian of the north Eastern Desert (HEWAIDY et al., 2003) and Sinai (DOUVILLÉ, 1928; ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Subgenus *Leoniceras* HYATT, 1903

Choffaticeras (*Leoniceras*) *barjonai* (CHOFFAT, 1898)

Text-figs. 5.21A, 5.23L-M

1898 *Pseudo-tissotia Barjonai* sp. nov. – CHOFFAT: p. 73, pl. 3; pl. 18, fig. 3; pl. 22, figs. 40-42.

2007 *Choffaticeras* (*Leoniceras*) *barjonai* (CHOFFAT) – BARROSO-BARCENILLA & GOY: p. 474, figs. 7(5, 6), 9(1-4) (with additional synonymy).

Material: Two moderately preserved incomplete internal moulds (080217-26.5- 1–2) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at East Wadi Ghonima section (at 133m).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080217-26.5-1	122.4 (100)	42.8 (34.9)	59.5 (48.6)	0.71	31.1 (25.4)

Description: Relatively evolute, medium-sized, with slightly compressed, sublanceolate whorl section (Text-fig. 5.23L-M). Maximum thickness at the inner third of the flank. Walls convex and becoming relatively flat at the ventrolateral area, meeting at the sharp venter. Umbilicus wide (about 25% of total diameter), with vertical walls. No ornament preserved on the flanks. The suture line consists of four saddles and three lobes on the flank and one lobe on the umbilical shoulder. The saddles are wider than the lobes. The first lateral saddle and lobe are wide and subdivided into branches.

Remarks: In agreement with BARROSO-BARCENILLA & GOY (2007), *Choffaticeras* (*Leoniceras*) *barjonai* could have arisen from *Ch*. (*L*.) *luciae* by the differences in the whorl section and the degree of involution, as well as by simplification of the suture line. CHOFFAT (1898) collected this species in Portugal in the same bed with *Inoceramus labiatus* and this is consistent with this study, where *Mytiloides labiatus* was collected in the Wadi Ghonima section from the same horizon as *Ch*. (*L*.) *barjonai*.

Occurrence: *Choffaticeras* (*Leoniceras*) *barjonai* (CHOFFAT) has been recorded from the Lower Turonian of Portugal (CHOFFAT, 1898) and Spain (BARROSO-BARCENILLA & GOY, 2007). This is the first record of this species from Egypt.

Choffaticeras (*Leoniceras*) *luciae* (PERVINQUIÈRE, 1907)

Text-figs. 5.21B, 5.23N-O

1907 *Pseudotissotia* (*Choffaticeras*) *luciae* sp. nov. – PERVINQUIÈRE: p. 354, pl. 24, figs. 1-2; text-figs. 135-137.
1969 *Choffaticeras luciae trisellatum* subsp. nov. – FREUND & RAAB: p. 59, pl. 9, figs. 7, 8; text-figs. 12i-q, 13a-h.
1981 *Leoniceras luciae* (PERVINQUIERE) – AMARD et al.: p. 57, pl. 10, fig. 6a, b.
1990 *Choffaticeras luciae* (PERVINQUIERE) – ROBASZYNSKI et al.: p. 268, pl. 23, fig. 1; pl. 24, fig. 1.
1992 *Choffaticeras luciae* (PERVINQUIÈRE) – THOMEL: p. 234, pl. 127, figs. 1, 2.
1994 *Choffaticeras* (*Leoniceras*) *luciae* (PERVINQUIÈRE) – CHANCELLOR et al.: p. 91, pl. 25, figs. 1-3.
1996 *Choffaticeras luciae* (PERVINQUIÈRE) – MEISTER & ABDALLAH: p. 15, pl. 13, figs. 1-3.
? 2001 *Choffaticeras luciae* (PERVINQUIERE) – GALAL et al.: pl. 4, figs. 1-2.
2003 *Choffaticeras luciae* (PERVINQUIERE) – HEWAIDY et al.: p. 347, pl. 3, figs. 4-5.
2005 *Choffaticeras luciae* (PERVINQUIERE) – MEISTER & ABDALLAH: p. 140, pl. 22, fig. 2; pl. 23, figs. 1-3.
2007 *Choffaticeras* (*Leoniceras*) *luciae* (PERVINQUIERE) – BARROSO-BARCENILLA & GOY: p. 472, figs. 7(2-4).
2008 *Choffaticeras luciae* (PERVINQUIERE) – ALY et al.: p. 51, pl. 8, figs. 1-2.

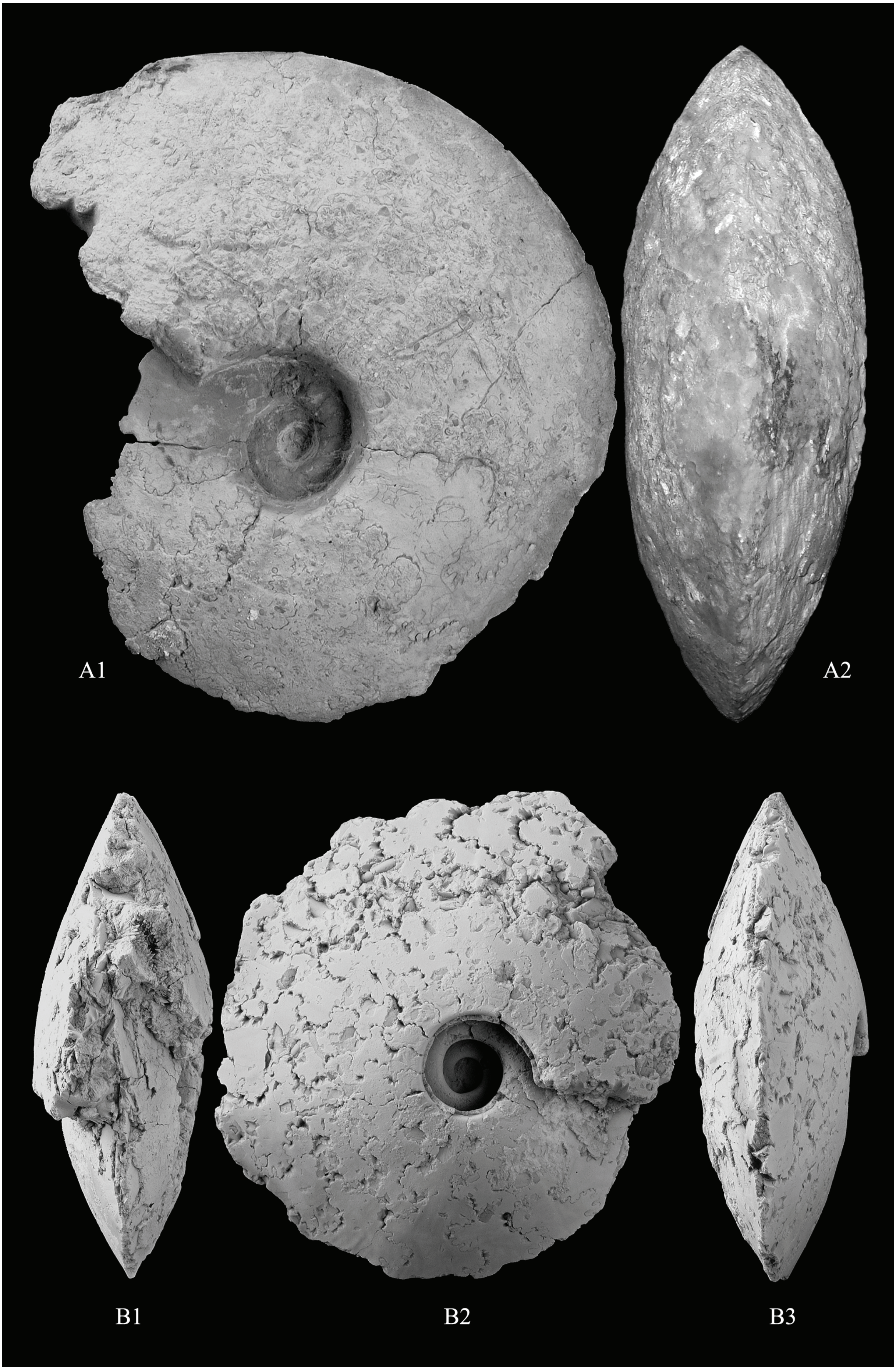
Material: Two poorly preserved incomplete internal moulds (080216-16.5- 3-4) from Wadi Ghonima section (45m above the base of Maghra El Hadida Formation) and one moderately preserved complete internal mould (WA-18-1) from Wadi Askhar section (at 120m). All specimens from the Lower Turonian *Choffaticeras* ssp. Zone of the Maghra El Hadida Formation.

Text-fig. 5.21

A. *Choffaticeras* (*Leoniceras*) *barjonai* (CHOFFAT, 1898), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x1; 2: ventral view, x1; 80217-26.5-1.

B. *Choffaticeras* (*Leoniceras*) *luciae* (PERVINQUIÈRE, 1907), Lower Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral view, x1; 3: ventral view, x1; WA-18-1.

Text-fig. 5.21



Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WA-18-1	89.3 (100)	32.7 (36.6)	53.6 (60)	0.61	12.7(14.2)

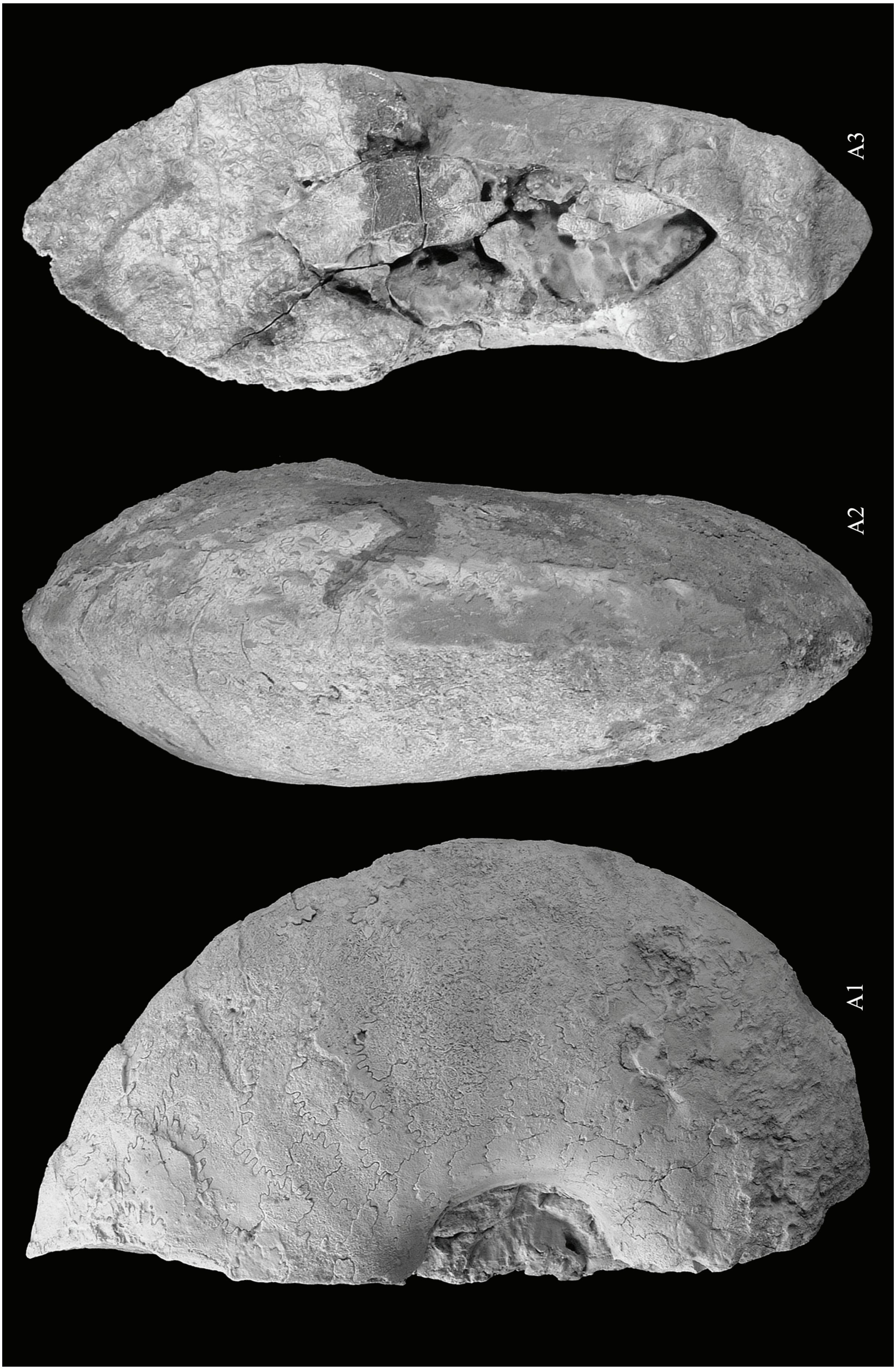
Description: Involute, oxycone, medium-sized. Whorls compressed, with lanceolate shape. Maximum thickness near the umbilicus. Walls slightly convex, meeting at the sharp venter. Umbilicus small (about 14% of total diameter) and very deep, with vertical walls. No ornament preserved on the flanks. The suture line is very close to that of the *Choffaticeras luciae* illustrated by PERVINQUIÈRE (1907). The first lateral lobe is the deepest, with large and oblique accessory saddle in its external side. Also, the first saddle is the deepest and the widest (Text-fig. 5.23N-O).

Remarks: PERVINQUIÉRE (1907) described and illustrated the holotype of *Choffaticeras* (*Leoniceras*) *luciae*. FREUND & RAAB (1969) considered their subspecies (*Ch. luciae trisellatum*) as intermediate form between the compressed *Ch. luciae* PERVINQUIÉRE (1907) and the more inflated *Ch. barjonai* CHOFFAT (1898). However, ROBASZYNSKI et al. (1990) regarded the subspecies of FREUND & RAAB (1969) as a synonym of *Ch. luciae*. They compared the type of *Ch. luciae* with the illustrations of *Ch. barjonai* and suggested a close affinity between the two species, showing that the most significant difference is the slightly greater thickness of *Ch. barjonai*. In the same time, their material is not sufficient to demonstrate the existence of a continuous sequence from moderately compressed variants (*Ch. luciae*) to thicker variants (*Ch. barjonai*). In agreement with BARROSO-BARCENILLA & GOY (2007), the main distinguishing features of *Choffaticeras* (*Leoniceras*) *luciae* are the relatively broad umbilicus, the vertical umbilical wall, the subtriangular whorl section and the shallow ventrolateral groove existing on the outer extreme of the flanks. Some members of *Ch.* (*L.*) *luciae*, such as the specimens of PERVINQUIÉRE (1907: pl. 24, figs. 2), AMARD et al. (1981: pl. 10, fig. 6a, b), ROBASZYNSKI et al. (1990: pl. 24, fig. 1a, b) and MEISTER & ABDALLAH (1996: pl. 13, figs. 1a, b, 3; 2005, pl. 23, fig. 3), may show a marked ventrolateral groove. BARROSO-BARCENILLA & GOY (2007) mentioned that this was probably caused by post mortem deformation. However, in this work, this feature is considered as an original character feature of *Ch.* (*L.*) *luciae* because of the symmetry of the ventrolateral groove in all illustrated specimens. In fact, this may cause confusion with *Ch.* (*Ch.*) *securiforme* which has also ventrolateral grooves. However, it can be differentiated between both species by means of the strong ventrolateral groove, obtuse venter, oblique flanks, wide umbilicus, and oblique umbilical walls in all specimens of *Ch.* (*Ch.*) *securiforme*. On the other hand, *Ch.* (*L.*) *luciae* is characterized by weak ventrolateral grooves (only in some specimens), sharp venter, convex flanks, narrow umbilici, and vertical umbilical walls. *Ch. luciae* recorded by GALAL et al. (2001) from the Egyptian Eastern Desert has a very wide umbilicus with low and rounded umbilical shoulder. Therefore, and due to poor preservation, their identification is questionable. The studied specimens closely correspond to the holotype and also the material described by BARROSO-BARCENILLA & GOY (2007) from Spain.

Text-fig. 5.22

A. *Choffaticeras* (*Leoniceras*) *philippii* (SOLGER, 1904), Lower Turonian Maghra El Hadida Formation. 1: lateral view, x0.75; 2: ventral view, x0.75; 3: apertural view, x0.75; 80216-14-1.

Text-fig. 5.22



Occurrence: *Choffaticeras* (*Leoniceras*) *luciae* has been recorded from the Lower Turonian of Tunisia (PERVINQUIÈRE, 1907; ROBASZYNSKI et al., 1990; CHANCELLOR et al., 1994; MEISTER & ABDALLAH, 1996, 2005), Algeria (AMARD et al., 1981), Israel (FREUND & RAAB, 1969), Jordan (ALY et al. 2008), France (THOMEL, 1992) and Spain (BARROSO-BARCENILLA & GOY, 2007). In Egypt, it has been recorded from the Lower Turonian of the north Eastern Desert (HEWAIDY et al. 2003).

Choffaticeras (*Leoniceras*) *philippii* (SOLGER, 1904)

Text-figs. 5.22, 5.23P-Q

1904 *Pseudotissotia philippii* sp. nov. – SOLGER: p. 162, pl. 4, fig. 7; text-fig. 52.

Material: Three moderately preserved incomplete internal moulds (080216-14- 1-3) from the Lower Turonian *Choffaticeras* spp. Zone of the Maghra El Hadida Formation at Wadi Ghonima section (35.5m above the base of Maghra El Hadida Formation).

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
080216-14-1	208.1 (100)	98.1 (47.1)	95.2 (45.7)	1.03	51.8 (24.8)
080216-14-2	137.5 (100)	62.9 (45.7)	61.3 (44.5)	1.02	32.6 (23.7)

Description: Coiling relatively evolute. Whorls narrow depressed, with lanceolate shape and large-size. Maximum width near the umbilicus. Umbilicus relatively wide (about 25% of total diameter), deep, with strong rounded shoulder and high umbilical walls. Walls straight on the inner flank and strongly convex on the outer flank, meeting at a moderately shape venter in early whorls which turns to blunt in late whorls. No ornament visible. The suture line is complex and consists of four to five saddles, all saddles and lobes have unequal branches, the first lateral saddle is the highest one and the second lateral lobe is the deepest and widest one (Text-fig. 5.23P-Q).

Remarks: This species differs from other species of the subgenus *Leoniceras* in having a more depressed whorl section, strongly convex flanks, wide and deep umbilici, with strong rounded umbilical shoulders, and a complicated suture line.

Occurrence: *Choffaticeras* (*Leoniceras*) *philippii* has so far only been recorded from the Lower Turonian of Cameroon (SOLGER, 1904). This is the first record of this species from Egypt.

Text-fig. 5.23
(Not to scale)

A-B. *Choffaticeras* (*Choffaticeras*) *meslei* (PERON, 1897); 020816-13-1.

C. *Ch.* (*Ch.*) *quaasi* (PERVINQUIÈRE, 1904); WG-19-1.

D, *Ch.* (*Ch.*) *pavillieri* (PERVINQUIÈRE, 1907); 080217-26-6.

E-G. *Ch.* (*Ch.*) *segne* (SOLGER, 1903); E-F, 080216-15-2; G, 080216-15-1.

H-I. *Ch.* (*Ch.*) *securiforme* (ECK, 1909); 080217-19-1.

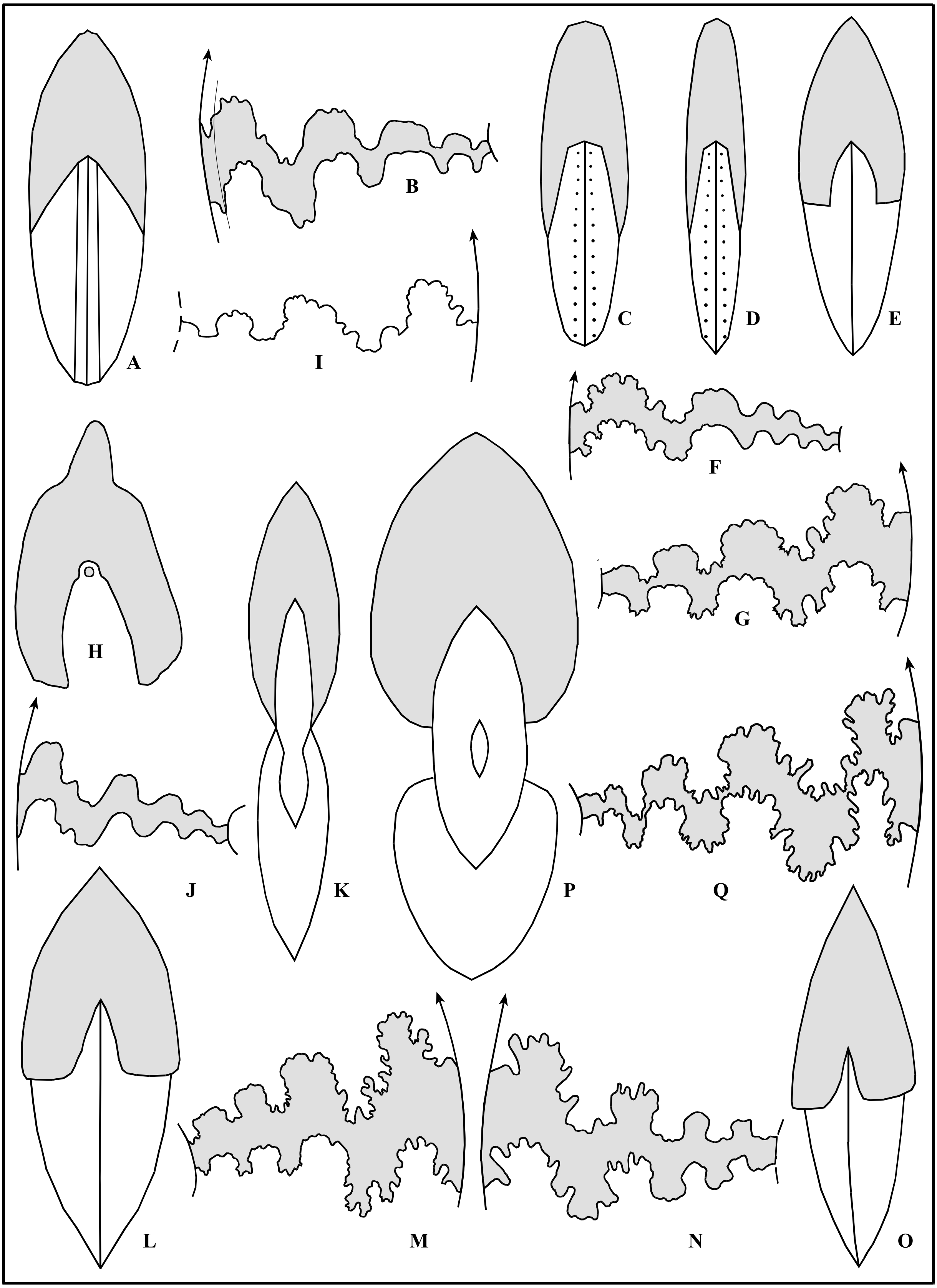
J-K. *Ch.* (*Ch.*) *sinaiticum* (DOUVILLÉ, 1928); 080217-26-9.

L-M. *Ch.* (*Leoniceras*) *barjonai* (CHOFFAT, 1898); 080216-14-1.

N-O. *Ch.* (*L.*) *luciae* (PERVINQUIÈRE, 1907); 080217-26.5-1.

P-Q. *Ch.* (*L.*) *philippii* (SOLGER, 1904); WA-18-1.

Text-fig. 5.23



Family Coilopoceratidae HYATT, 1903

Genus *Coilopoceras* HYATT, 1903

Coilopoceras africanum PERVINQUIÈRE, 1910

Text-figs. 5.24, 5.25A-B

1910 *Coilopoceras africanum* sp. nov. – PERVINQUIÈRE: p. 72, figs. 35, 36; pl. 3, figs. 11-18.

1984 *Coilopoceras africanum* PERVINQUIÈRE – KENNEDY & WRIGHT: pl. 37, figs. 1-2, 8-12.

Material: Two moderately preserved incomplete composite moulds (WG-33- 1–2) from the Lower Upper Turonian (Lower part of *Coilopoceras requienianum* Zone) of the Maghra El Hadida Formation at Wadi Ghonima section.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-33-1	101.7 (100)	26.4 (25.9)	55.5 (54.5)	0.47	8.2 (8.0)

Description: Involute in the early stages but more evolute later on. Medium-sized. Whorl section high and strongly compressed. Umbilicus small (8% of diameter), with low and rounded shoulder. Wall straight to slightly convex. Venter fastigate and acute. The maximum width at the middle of the flanks. Ornamentation consists of numerous fine ribs on the outer flank. The suture line is composed of six saddles, each one divided into two or three small saddles (Text-fig. 5.25A-B).

Remarks: PERVINQUIÈRE (1910) recorded *Coilopoceras africanum* from the Cenomanian of Algeria. In contrast, KENNEDY & WRIGHT (1984) mentioned that there is no strong evidence for the occurrence of *Hoplitoides* or *Coilopoceras* before the Middle Turonian and the material of PERVINQUIÈRE from the Cenomanian of Algeria was misdated. The view of KENNEDY & WRIGHT (1984) is supported by this study as the studied specimens were recorded from the lower Upper Turonian.

Occurrence: *Coilopoceras africanum* has so far only been recorded from Algeria (PERVINQUIÈRE, 1910). Recording of *Coilopoceras africanum* from the Upper Turonian of the study area represents the first record of this species from Egypt.

Coilopoceras requienianum (D'ORBIGNY, 1841)

Text-figs. 5.25C-D, 5.26, 5.27A

1841 *Ammonites requienianum* sp. nov. – D'ORBIGNY: p. 315, pl. 93, figs. 1-4.

1984 *Coilopoceras requienianum* (D'ORBIGNY) – KENNEDY & WRIGHT: p. 282, pls. 35-36, text-figs. 1-5 (see for further synonymy).

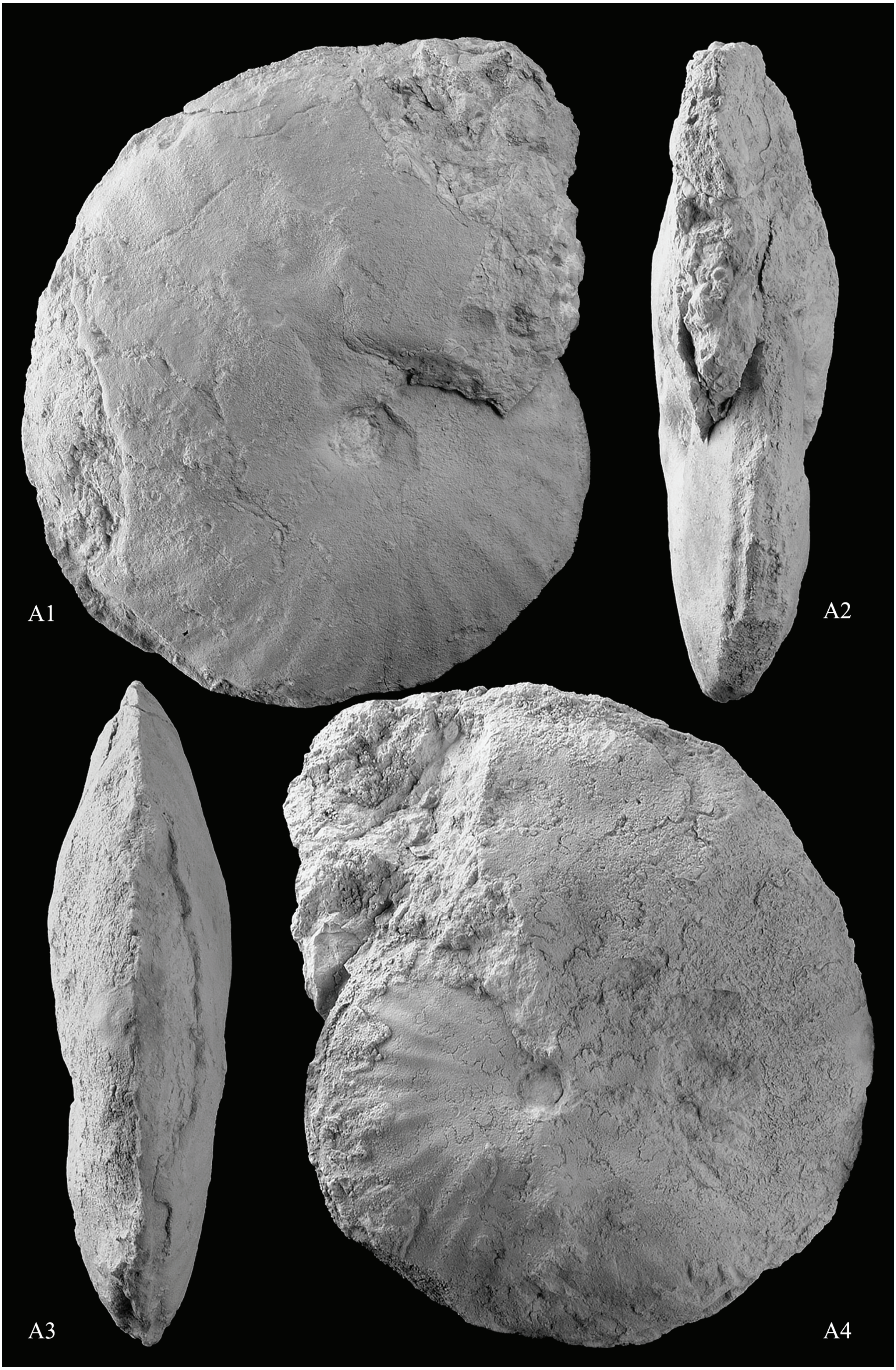
1989 *Coilopoceras requienianum* (D'ORBIGNY) – LUGER & GRÖSCHKE: p. 388, pl. 46, text-figs. 6a,e, 11, 12, 13a-c.

1987 *Coilopoceras requienianum* (D'ORBIGNY) – KORA & HAMAMA: pl. 1, fig. 9.

Text-fig. 5.24

A. *Coilopoceras africanum* PERVINQUIÈRE, 1910, Upper Turonian Maghra El Hadida Formation. 1, 3: lateral view, x1; 2: apertural view, x1; 4: ventral view, x1; WG-33-1.

Text-fig. 5.24



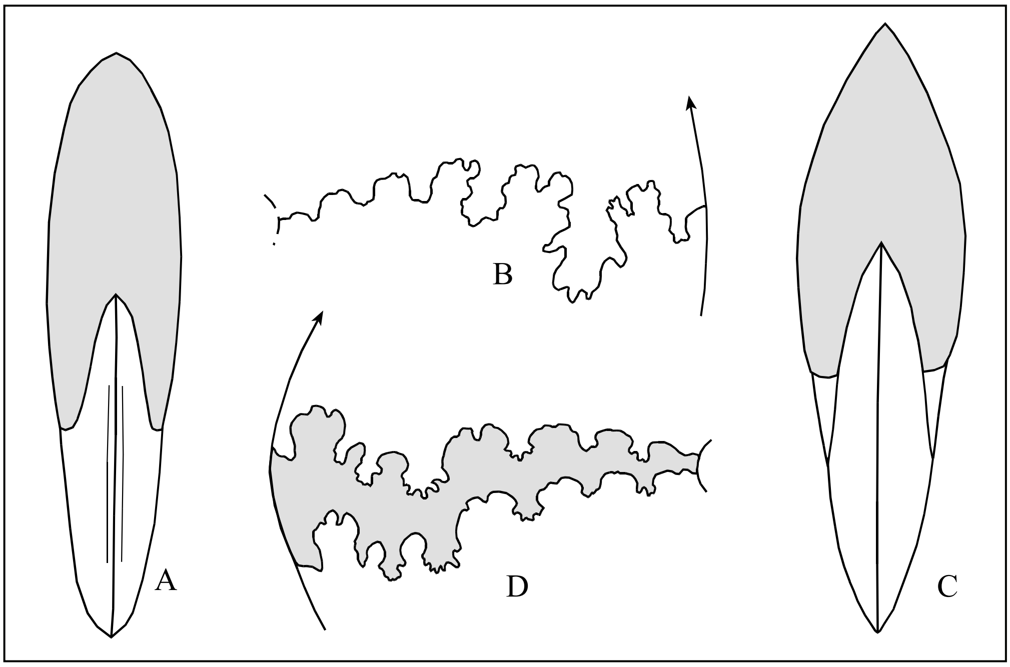
1997 *Coilopoceras requienianum* (D'ORBIGNY) – WIESE: pl. 6, fig. 3.
2001 *Coilopoceras requienianum* (D'ORBIGNY) – KORA et al.: pl. 2, figs. 11, 12.
2003 *Coilopoceras requienianum* (D'ORBIGNY) – HEWAIDY et al.: p. 354, pl. 6, figs. 4-5.
2004a *Coilopoceras requienianum* (D'ORBIGNY) – ABDEL-GAWAD et al.: pl. 1, figs. 3, 5.
2006 *Coilopoceras requienianum* (D'ORBIGNY) – EL QOT: p. 128, pl. 29, figs. 1a-b, 2-3.
2007 *Coilopoceras requienianum* (D'ORBIGNY) – ABDEL-GAWAD et al.: pl. 3, figs. 2, 7.

Material: Two complete and three incomplete, moderately preserved internal moulds (WG-37- 1–5) and one moderately preserved, incomplete shell (WG-37-6) from Wadi Ghonima section, one complete, poorly preserved internal mould (080217-42-1) from East Wadi Ghonima section (at 210.5m), and one incomplete, moderately preserved internal mould (St.A-2-1) from Saint Anthony section.

Measurements:

Specimen No.	D	Wb	Wh	Wb/Wh	U
WG-37-1	140.2 (100)	43.9 (39.4)	85.6 (61.0)	0.51	6.9 (4.9)
WG-37-2	125.5 (100)	38.3 (30.5)	79.8 (63.5)	0.47	unavailable
WG-37-6	111.2 (100)	36.5 (32.8)	75.7 (68.0)	0.48	6.6 (5.9)

Description: Very involute, oxycone, medium-sized. Whorls compressed, with lanceolate shape. Nearly vertical walls, with rounded shoulders and sharpened venter. Maximum width tends to be situated at the middle of the flanks. Very narrow umbilicus, with low and rounded shoulders. Ornament of a few weak ribs on the early whorls only on specimen WG-37-1, other specimens are smooth. The suture line (Text-fig. 5.25C-D) shows a broad and shallow external lobe, and a very broad, open and bifid lateral lobe.



Text-fig. 5.25. A-B, *Coilopoceras africanum* PERVINQUIÈRE, 1910; C-D, *Coilopoceras requienianum* (D'ORBIGNY, 1841). A-B, specimen WG-33-1; C-D, specimen WG-37-6. Not to scale.

Text-fig. 5.26

A. *Coilopoceras requienianum* (D'ORBIGNY, 1841), Upper Turonian Maghra El Hadida Formation. 1: apertural view, x1; 2: lateral view, x1; 3: ventral view, x1; WG-37-1.

Text-fig. 5.26

Remarks: COBBAN & HOOK (1980) documented that some species of the genus *Coilopoceras* display sexual dimorphism. This agrees with the redescription of the type-material of *Coilopoceras requienianum* (D'ORBIGNY) by KENNEDY & WRIGHT (1984), where they suggested the existence of sexual dimorphism in *Coilopoceras requienianum* (D'ORBIGNY) shown by smooth and ribbed forms. LUGER & GRÖSCHKE (1989) considered their specimens very similar to the type-material as redescribed by KENNEDY & WRIGHT (1984). They also referred both *Coilopoceras sinaiense* and *Coilopoceras multicostatum* of LEWY (1975) to *Coilopoceras requienianum* (D'ORBIGNY) with doubts because of the poor preservation of the figured specimens. The studied specimens closely correspond to the type-material (see KENNEDY & WRIGHT, 1984) and also to those described by LUGER & GRÖSCHKE (1989). However, the studied specimens are more inflated and the smooth morphotype is dominant.

Occurrence: *Coilopoceras requienianum* has been recorded from the Upper Turonian of Madagascar (COLLIGNON, 1965), North and South America (COBBAN & HOOK, 1980), and from Western Europe (KENNEDY & WRIGHT, 1984). In Egypt, it has been recorded from the Upper Turonian of the north Eastern Desert (LUGER & GRÖSCHKE, 1989; HEWAIDY et al., 2003), the Gulf of Suez region (KORA et al., 2001), and from the Upper Turonian of Sinai (KORA & HAMAMA, 1987; ABDEL-GAWAD et al., 2004a; EL QOT, 2006).

Suborder Ancyloceratina WIEDMANN, 1966
Superfamily Turrilitoidea GILL, 1871
Family Nostoceratidae HYATT, 1894
Genus *Eubostrychoceras* MATSUMOTO, 1967

Eubostrychoceras sp.

Text-fig. 27B

Material: One moderately preserved, incomplete composite mould (080217-27-1) from the Lower Turonian *Wrightoceras munieri* Zone of the Maghra El Hadida Formation at East Wadi Ghonima section (at 143.5 m).

Description: Small-sized, with tight coiling. Whorl section rounded. Ornamentation consists of simple ribs, without tuberculation.

Remarks: The present specimen is similar to *Eubostrychoceras saxonicum* but differs in having coarser ribs. It also resembles *Eubostrychoceras matsumotoi* (see COBBAN, 1987; KÜCHLER, 1998), but differs in having finer ribs. The rib density and size of the present specimen is considered as intermediate between *E. saxonicum* and *E. matsumotoi*.

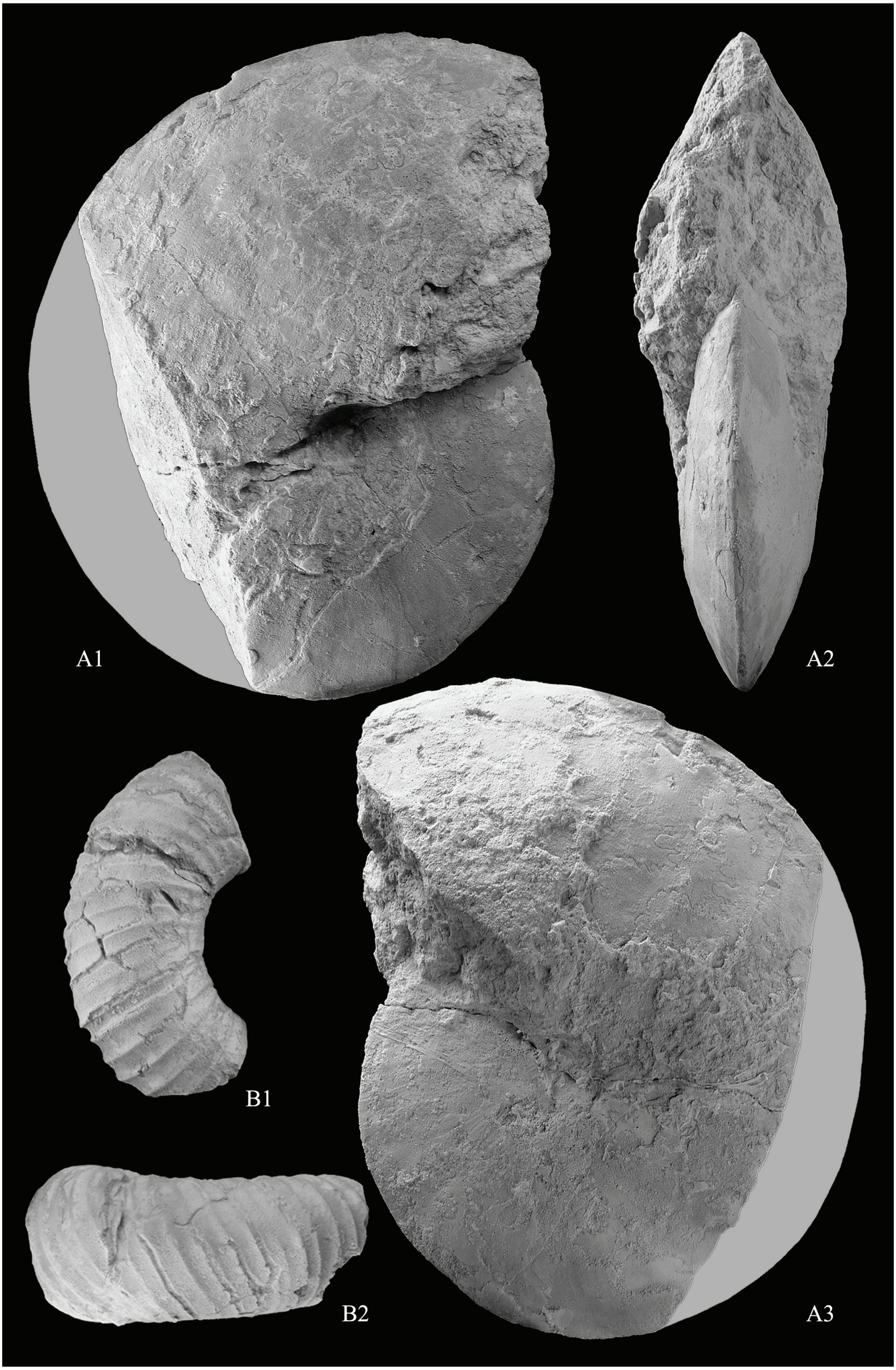
Occurrence: According to WRIGHT et al. (1996), the genus *Eubostrychoceras* has been recorded from Turonian – Santonian of western Europe, northern Africa, Madagascar, southern India, Japan, New Mexico, and Texas. Recording of the genus *Eubostrychoceras* from the Lower Turonian of the study area represents the first record of the genus from Egypt.

Text-fig. 5.27

A. *Coilopoceras requienianum* (D'ORBIGNY, 1841), Upper Turonian Maghra El Hadida Formation. 1, 3: lateral view, x1; 2, 3: apertural view, x1; WG-37-6.

B. *Eubostrychoceras* sp., Lower Turonian Maghra El Hadida Formation. 1, 2, x1; 080217-27.

Text-fig. 5.27



Palaeobiogeography

The geographic distribution of the identified ammonites that are discussed in details above are summarized in Table 5.1. This distribution confirms the strong affinity of the studied taxa to the Mediterranean province of the Tethyan Realm and their distribution in different parts of the Tethyan regions suggest open marine connection between Egypt and the other Tethyan regions during Late Cenomanian – Early Turonian times, related to the general sea-level high-stand during that interval.

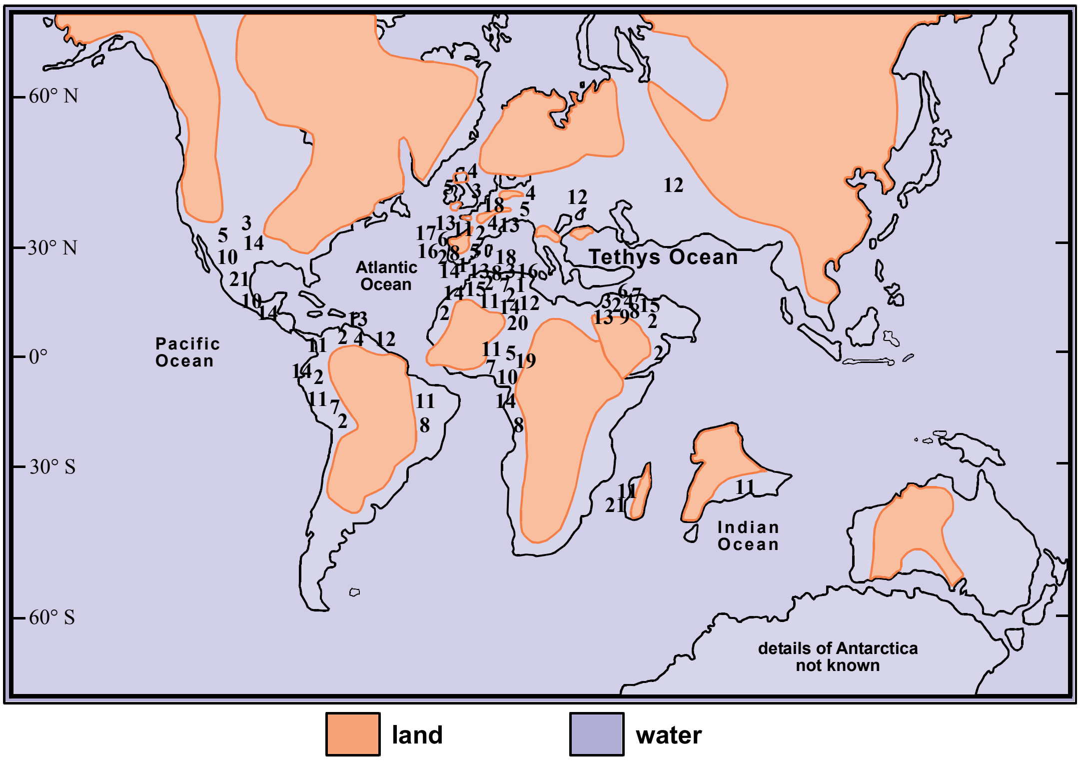
Table 5.1. Summary of the geographic distribution of the studied Cenomanian – Turonian ammonites outside Egypt. (+) recorded.

No. of the map		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Locality	Species	***Anguilithes mermeti***	***Neolobites vibrayeanus***	***Euomphaloceras septemseriatum***	***Kamerunoceras turoniense***	***Metoicoceras geslinianum***	***Vascoceras adonense***	***Vascoceras cauvini***	***Vascoceras durandi***	***Vascoceras pioti***	***Vascoceras proprium***	***Neoptychites cephalotus***	***Fagesia cf. peroni***	***Thomasites rollandi***	***Wrightoceras munieri***	***Choffaticeras (Ch.) meslei***	***Choffaticeras (Ch.) securiforme***	***Choffaticeras (Ch.) quaasi***	***Choffaticeras (Ch.) pavillieri***	***Choffaticeras (Ch.) segne***	***Choffaticeras (Ch.) sinaticum***	***Choffaticeras (L.) barjonai***	***Choffaticeras (L.) luciae***	***Choffaticeras (L.) philippii***	***Coilopoceras africanum***	***Coilopoceras requienianum***
Middle East	Oman		+																							
	Saudi Arabia		+																							
	Jordan		+											+												
	Syria		+									+		+												
	Lebanon		+											+												
	Israel		+		+		+	+	+	+		+		+		+	+	+	+	+	+		+			
N. Africa	Tunisia	+	+	+	+			+	+			+	+	+	+	+	+	+	+	+	+		+			
	Algeria		+						+			+		+									+		+	
	Morocco		+									+			+											
W. Africa	Niger					+						+			+											
	Nigeria							+			+	+			+											
	Cameroon											+														
	Angola			+					+															+		
	Madagascar											+														+
Europe	Romania												+													
	Germany					+																				
	England			+	+	+								+												
	France		+	+	+	+						+		+									+			
	Spain	+	+						+			+		+	+		+	+	+	+	+	+	+			
	Portugal		+				+		+													+				
N. Am-erica	United States			+		+					+	+			+											+
	Mexico								+		+	+			+											
South America	Venezuela		+		+							+			+											
	Colombia		+									+	+	+	+											
	Trinidad											+														
	Peru		+					+							+											
	Brazil								+			+														
	Bolivia		+																							
Asia	Russia												+													
	India											+														
	Japan								+																	

Text-fig. 5.28 represents the distribution of the studied ammonite taxa during Late Cenomanian – Turonian times. This composite map is based on the reconstruction of CHANCELLOR (1982) and SKELTON (2003). The connection between the Tethyan regions and West Africa via the Trans-Saharan epicontinental sea is supported by this work and has been documented by many authors (e. g., COLLIGNON & LEFRANC, 1974; REYMENT & CHANCELLOR, 1978; KASSAB, 1994; MEISTER & ABDALLAH, 1996; ABDALLAH & MEISTER, 1997). It seems likely that this connection has been established during the Late Cenomanian *Neolobites vibrayeanus* Zone and the earliest Turonian (this interval represents a 2^{nd}-order eustatic highstand; HARDENBOL et al. 1998; WILMSEN, 2003). *Neolobites vibrayeanus* is a typical Tethyan ammonite of wide distribution, having been recorded from the Middle East, the Saharan Platform, Portugal, Spain, and from Niger (WIESE & SCHULZE, 2005).

BÖSE (1920) recognized that the North American fauna belonged to a distinctive Mediterranean facies typified by vascocerastid ammonites and the genus *Pseudaspidoceras*, which are dominant in the Turonian. He though that this facies was distributed throughout northern and central Africa and in Portugal. This view is supported here by records of vascoceratids in the studied ammonite collection. BOBKOVA & LUPPOV (1964) took the presence of tuberculate vascoceratids in Turkestan as evidence of a connection with the Mediterranean via Iran and Syria, at peak transgression. WIEDMANN (1964) and COLLIGNON (1966) have augmented the links between Mexico and the Western Tethys. These links apply especially to *Mammites*, *Pseudaspidoceras*, *Neoptychites*, and *Spathites*.

CHANCELLOR (1982, p.122) pointed out that the vascoceratids described by MATSUMOTO & MURAMOTO (1978) from Japan seem to share the Japanese fauna with Mexico, France, Middle East, and India. In northwest Europe and North America, the most common vascoceratids encountered are forms closely comparable to the Mexican *Fagesia*. The genus *Fagesia* spread northwards though the Western Interior of northern America and up the Pacific coast to what is now almost the Canadian border. The genera *Mammites*, *Pseudaspidoceras*, *Vascoceras*, *Neoptychites*, *Pseudotissotia*, and *Wrightoceras* all point to connections between Mexico and Nigeria, Brazil, Angola and the Congo. All the above mentioned genera, with the exception of *Neoptychites*, are also known from the Pacific coast of South America (BENAVIDES–CÁCERES, 1956 and ETAYO-SERNA, 1979). This supports a direct connection between Mexico and the Pacific via the Caribbean during the mid-Cretaceous (CHANCELLOR, 1982). These genera, which are recorded also from the study area, show the connection between the different places mentioned above and Egypt.



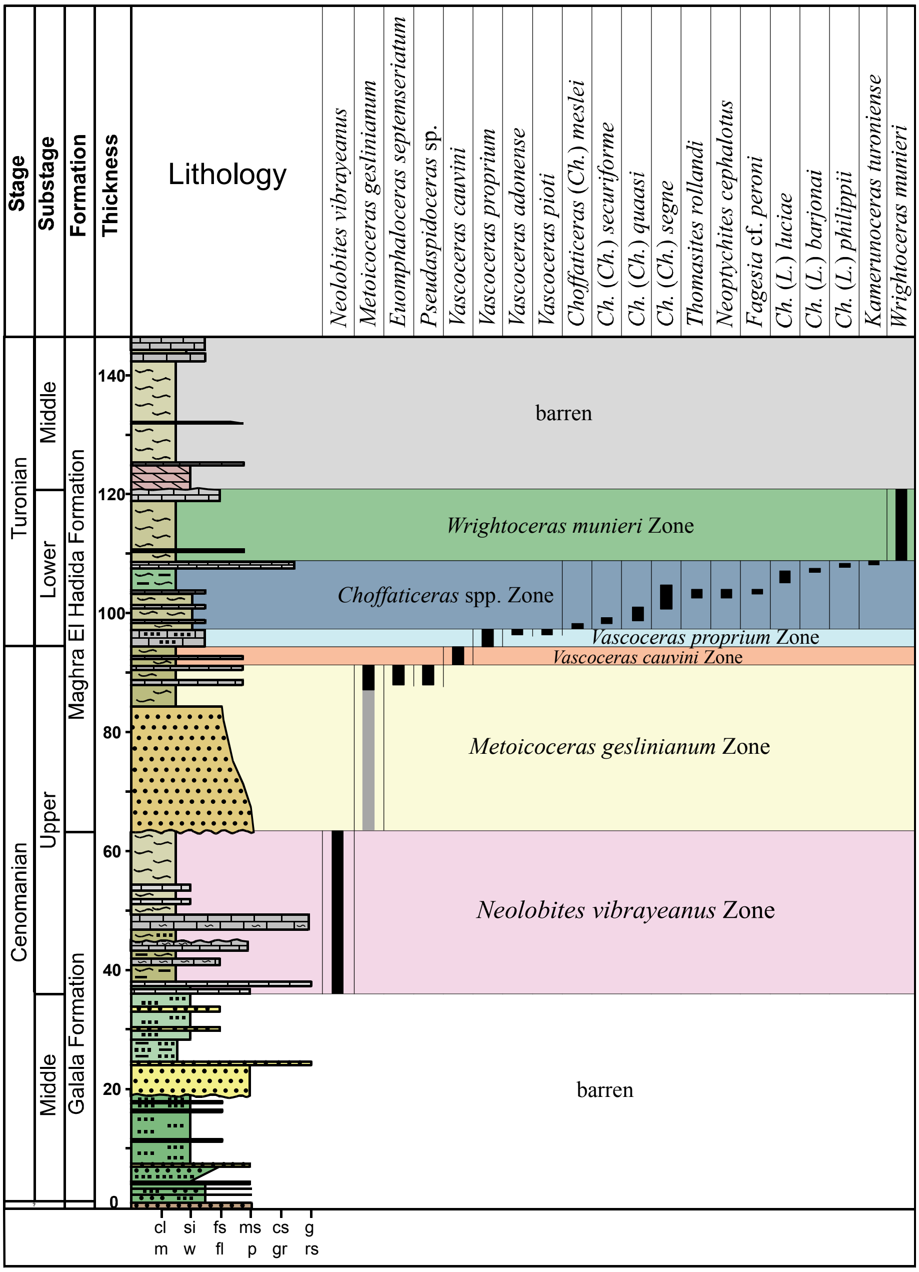
Text-fig. 5.28. Palaeogeographic affinity of the studied ammonites taxa.
Numbers refer to the taxa listed in Table 5.1. Map after CHANCELLOR (1982) and SKELTON (2003).

PART III
DISCUSSIONS

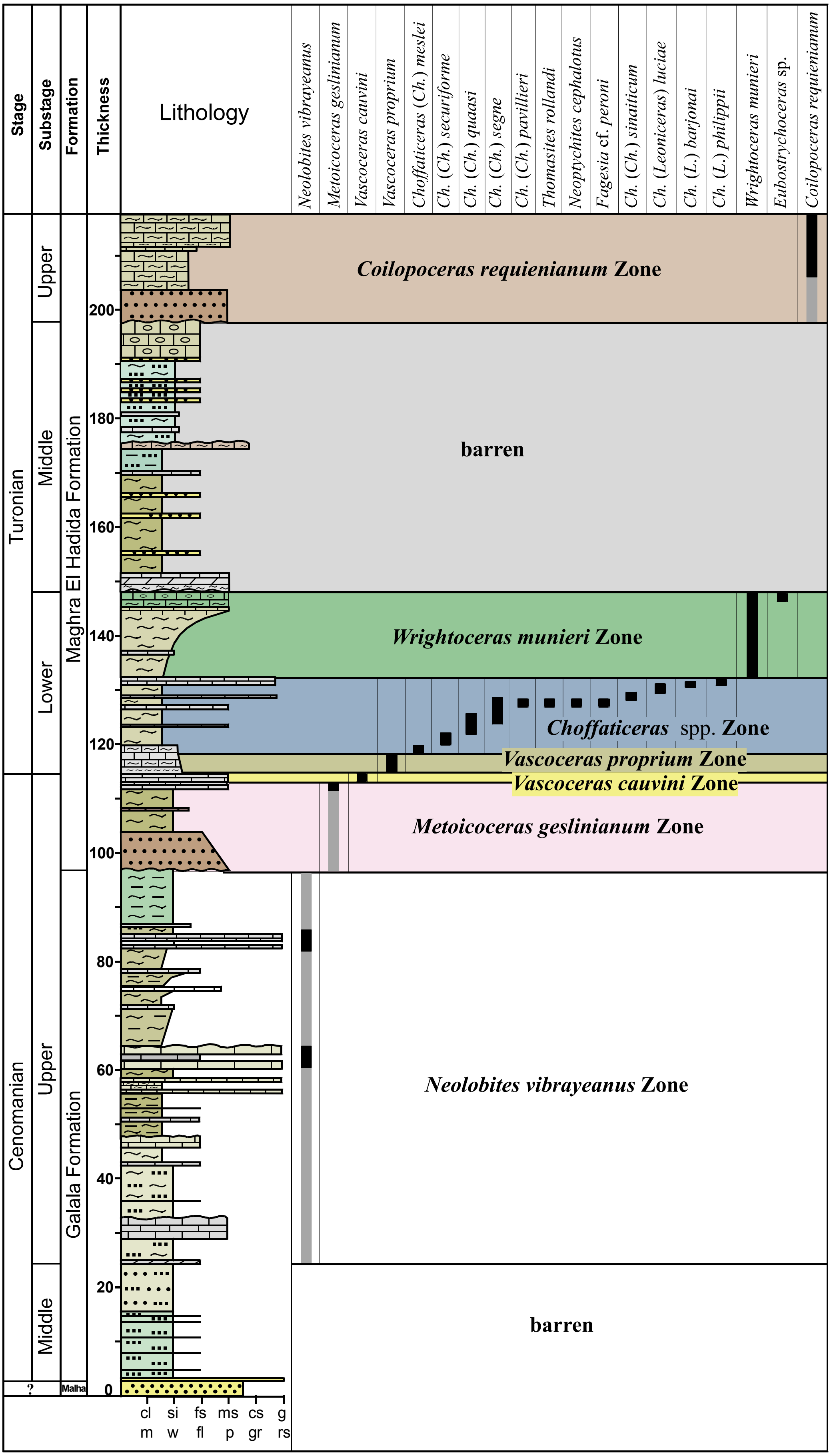
6. Biostratigraphy

The Upper Cenomanian – Turonian successions of the study area are rich in ammonites. The identified ammonites include many index taxa which allow establishing a good biostratigraphic dating of the studied sections which is consequently used for chronostratigraphic correlations of the successions. The stratigraphic distribution of the identified ammonite taxa in the studied sections is illustrated in Text-figs. 6.1, 6.2, and 6.3.

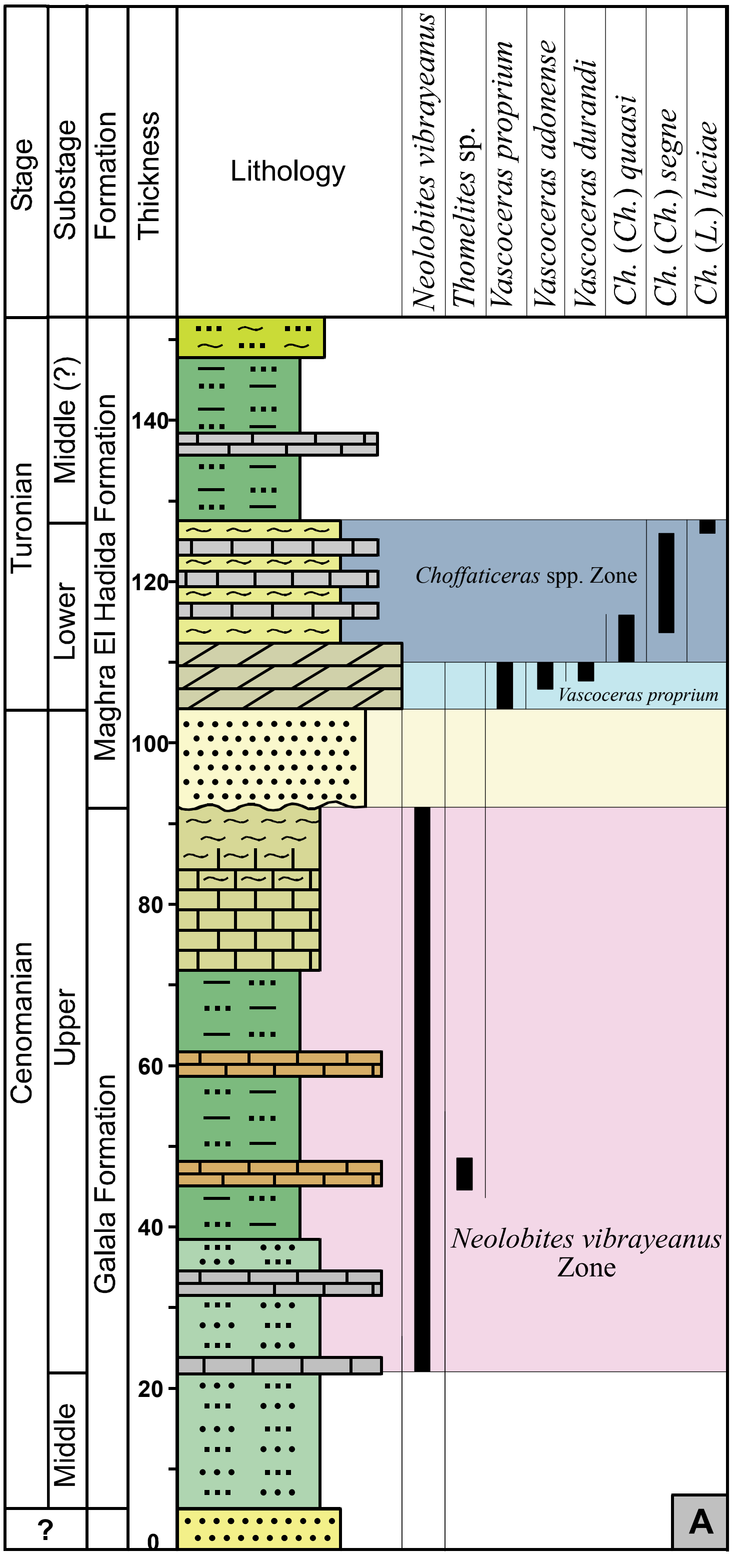
Three zones were recognized in the Upper Cenomanian, from base to top, the *Neolobites vibrayeanus*, *Metoicoceras geslinianum*, and *Vascoceras cauvini* zones. Three zones were recognized in the Lower Turonian, these are, *Vascoceras proprium*, *Choffaticeras* spp., and *Wrightoceras munieri*. The Middle Turonian is barren of ammonites, while the Upper Turonian is represented by the *Coilopoceras requienianum* zone. In addition, two inoceramid zones (*Mytiloides kossmati* and *M. labiatus*) are recorded from the Lower Turonian.

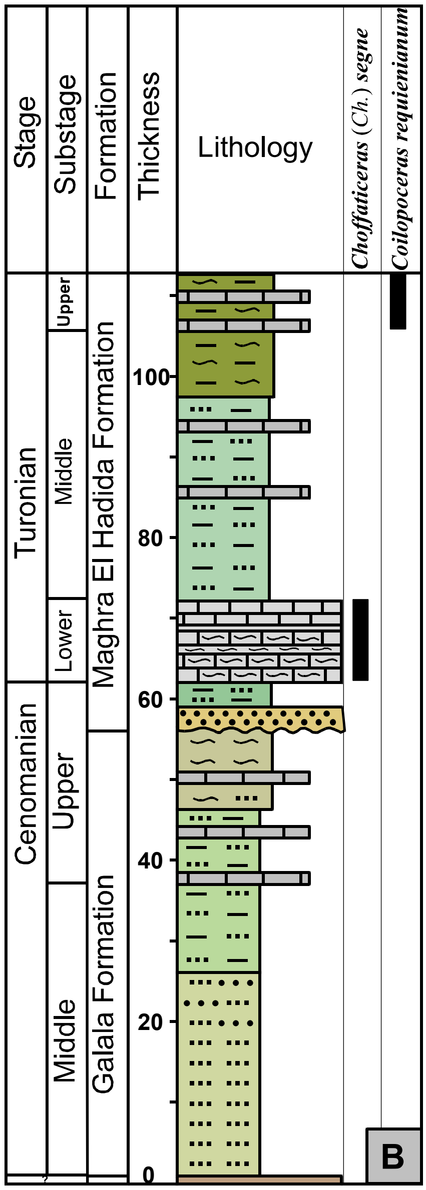


Text-Fig. 6.1. Stratigraphic distribution of the identified ammonite taxa at Wadi Ghonima section. Grey-shaded ranges are inferred from other stratigraphic data (see chapters 9, 10).



Text-Fig. 6.2. Stratigraphic distribution of the identified ammonite taxa at East Wadi Ghonima section. Grey-shaded ranges are inferred from other stratigraphic data (see chapters 9, 10).





Text-fig. 6.3.

Stratigraphic distribution of the identified ammonite taxa at:

A. Wadi Askhar section.

B. Saint Anthony section.

Description of the established biozones

The description of the proposed biozones in the study area (Table 6.1) is given below from older to younger. The ammonite sketches shown in this section are not to scale and are only used to show the most important morphological features of the zonal indices.

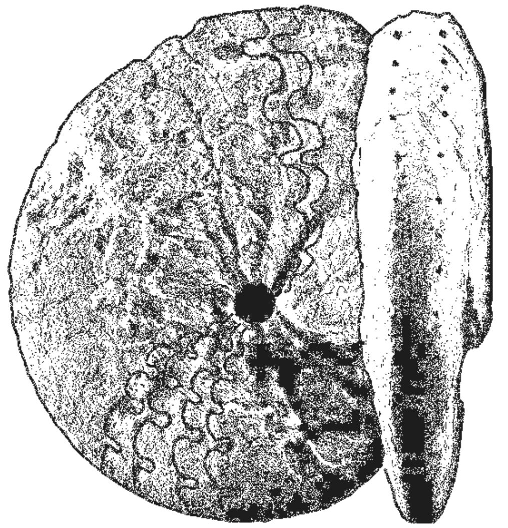
Table. 6.1. The proposed biozones for the Upper Cenomanian – Turonian in the study area.

<table>
<tr><th>Substage</th><th colspan="2">Ammonite biozones</th><th>Inoceramid</th></tr>
<tr><td>Upper Turonian</td><td colspan="2">Coilopoceras requienianum</td><td rowspan="2">barren</td></tr>
<tr><td>Middle Turonian</td><td colspan="2">barren</td></tr>
<tr><td rowspan="7">Lower Turonian</td><td colspan="2">Wrightoceras munieri</td><td rowspan="2">Mytiloides labiatus</td></tr>
<tr><td rowspan="5">Choffaticeras spp.</td><td>Ch. (Leoniceras) luciae</td></tr>
<tr><td>Ch. (Ch.) sinaiticum</td><td rowspan="3">Mytiloides kossmati</td></tr>
<tr><td>Ch. (Ch.) segne</td></tr>
<tr><td>Ch. (Ch.) quaasi</td></tr>
<tr><td>Ch. (Ch.) securiforme - Ch. (Ch.) meslei</td><td rowspan="5">barren</td></tr>
<tr><td colspan="2">Vascoceras proprium</td></tr>
<tr><td rowspan="3">Upper Cenomanian</td><td colspan="2">Vascoceras cauvini</td></tr>
<tr><td colspan="2">Metoicoceras geslinianum</td></tr>
<tr><td colspan="2">Neolobites vibrayeanus</td></tr>
</table>

6.1. *Neolobites vibrayeanus* Zone

Definition: The *Neolobites vibrayeanus* Zone is defined by the total range of *Neolobites vibrayeanus* (D'ORBIGNY, 1841) (Text-fig. 6.4).

Description: This zone is the oldest ammonite zone recognized in the study area and characterizes the lower Upper Cenomanian. The index is recorded from two different levels in the upper part of the Galala Formation and commonly associated with rudstone beds. The total thickness of this zone is about 27 m at Wadi Ghonima section, 72 m at East Wadi Ghonima section, and 70 m at Wadi Askhar section. It is missing at Saint Anthony section which is interpreted as being related to more shallow conditions dominating in the eastern part of the study area during this time.



Text-fig. 6.4. *Neolobites vibrayeanus* (D'ORBIGNY, 1841).

Associated fauna: *Neolobites vibrayeanus* is associated with other ammonites: *Thomelites* sp.; nautiloids: *Angulithes mermeti* (COQUAND), *Eutrephoceras* sp.; bivalves: *Pycnodonte vesicularis* (LAMARCK) *vesiculosa* (J. DE C. SOWERBY), *Costagyra olisiponensis* (SHARPE), *Ceratostreon flabellatum* (GOLDFUSS), *Ilymatogyra africana* (LAMARCK), *Rhynchostreon suborbiculatum* (LAMARCK), *Amphidonte conica* J. DE C. SOWERBY, *Eoradiolites liratus* (CONRAD); Gastropods: *Campanile ganesha* NOETLING, *Pyrazopsis* sp., *Cimolithium tenouklense* (COQUAND) *Pterocera incerta* D'ORBIGNY, *Harpagodes heberti* (THOMAS & PERON), *Pterodonta deffisi* THOMAS & PERON; Echinoids: *Goniopygus menardi* (DESMAREST), *Heterodiadema libycum* (DESOR), *Coenholectypus excisus* (DESOR), *Coenholectypus larteti* (COTTEAU), and *Hemiaster cubicus* DESOR.

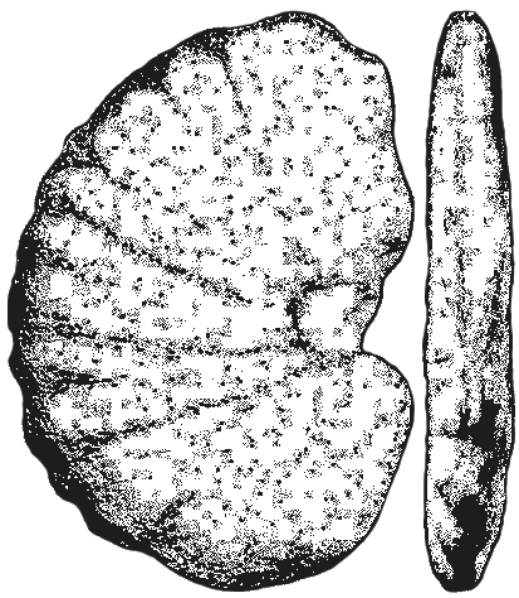
Equivalent biozones: In Egypt, the *Neolobites vibrayeanus* Zone is equivalent to the *Neolobites vibrayeanus* Zone of LUGER & GRÖSCHKE (1989), KASSAB (1991, 1996), HEWAIDY et al. (2003) and ABDEL-GAWAD et al. (2007) in the north Eastern Desert; ALY & ABDEL-GAWAD (2001), ABDALLAH et al. (2001), KASSAB & OBAIDALLA (2001), EL-HEDENY (2002), and ABDEL-GAWAD et al. (2004a) in Sinai. Outside Egypt, this zone is equivalent to the *Neolobites vibrayeanus* Zone of ALY et al. (2008) in Jordan; LEWY et al. (1984) in Israel; CHANCELLOR et al. (1994) and ABDALLAH et al. (2000) in Tunisia; AMARD et al. (1981) in Algeria; CHARRIERE et al. (1998) in Morocco. In addition, this zone is equivalent to the *Eucalycoceras* interval Zone of ROBASZYNSKI et al. (1990) in Tunisia and to the European and North American *Calycoceras guerangeri* Zone on the basis of the occurrence of *Neolobites vibrayeanus* in the latter zone in France (KENNEDY & JUIGNET, 1981). Furthermore, the *Neolobites vibrayeanus* Zone is equivalent to the *Calycoceras naviculare* Zone in the standard ammonite Zonation of GRADSTEIN et al. (2004).

Remarks: The lower Upper Cenomanian *Neolobites vibrayeanus* Zone is situated between a barren interval below and the *Metoicoceras geslinianum* Zone above. This barren interval forms the base of the Galala Formation. It is considered in this work as late Middle Cenomanian age depending on the conformably overlying strata contains the *Neolobites vibrayeanus* Zone. This interval attains about 37m at Wadi Ghonima section, 25m at East Wadi Ghonima section, and 22m at Wadi Askhar section.

6.2. *Metoicoceras geslinianum* Zone

Definition: The *Metoicoceras geslinianum* Zone is defined by the total range of *Metoicoceras geslinianum* (D'ORBIGNY, 1850) (Text-fig. 6.5). This Zone is situated between the *Neolobites vibrayeanus* Zone below and the *Vascoceras cauvini* Zone above.

Description: This zone is considered as an upper Upper Cenomanian zone. It is recorded from the wacke- to packstone beds of the lowermost part of the Maghra El Hadida Formation. The total thickness of this zone is about 28 m at Wadi Ghonima section and 10 m at East Wadi Ghonima section. On the other hand, this zone is not recorded from Wadi Askhar and Saint Anthony sections due to the absence of sedimentation during this time at these sections.



Text-fig. 6.5. *Metoicoceras geslinianum* (D'ORBIGNY, 1850).

Associated fauna: *Metoicoceras geslinianum* is associated with the ammonites *Euomphaloceras septemseriatum* (CRAGIN) and *Pseudaspidoceras* sp.

Equivalent biozones: In Egypt, the *Metoicoceras geslinianum* Zone is equivalent to the *Metoicoceras geslinianum* Zone of KASSAB (1991, 1996) in the north Eastern Desert and ALY & ABDEL-GAWAD (2001) in Sinai. Furthermore, this zone is equivalent to the *Metengonoceras* cf. *acutum* and *Vascoceras gamai* zones of LUGER & GRÖSCHKE (1989) in the north Eastern Desert. Outside Egypt, this zone is equivalent to the *Kanabiceras* sp. Zone of LEWY et al. (1984) in Israel; the *Metoicoceras geslinianum* Zone of CHANCELLOR et al. (1994) in Tunisia and of BARROSO-BARCENILLA & GOY (2007) in Spain. Furthermore, the *Metoicoceras geslinianum* Zone is one of the standard zones in the Upper Cenomanian for the Tethyan region in the standard ammonite Zonation of GRADSTEIN et al. (2004).

6.3. *Vascoceras cauvini* Zone.

Definition: The *Vascoceras cauvini* Zone is defined by the total range of *Vascoceras cauvini* CHUDEAU, 1909 (Text-fig. 6.6).

Description: This zone is the latest Cenomanian zone recognized in the study area. It is recorded from wacke- to packstone beds of the lower part of the Maghra El Hadida Formation at the Wadi Ghonima and East Wadi Ghonima sections and attains about 3 m and 2 m in thickness, respectively. This zone is obviously missing at the Wadi Askhar and Saint Anthony sections due to the absence of sedimentation during this time at these sections.

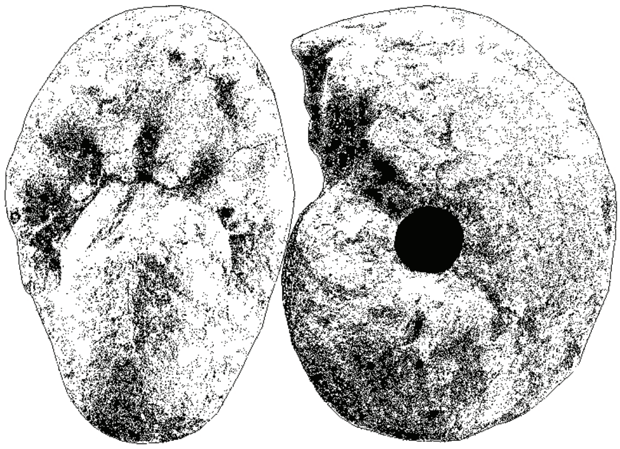
Text-fig. 6.6. *Vascoceras cauvini* CHUDEAU, 1909.

Equivalent biozones: In Egypt, the *Vascoceras cauvini* Zone is equivalent to the *Vascoceras cauvini* Zone of KASSAB (1991, 1996) and ABDEL-GAWAD et al. (2007) in the north Eastern Desert; ALY & ABDEL-GAWAD (2001), KASSAB & OBAIDALLA (2001), and EL-HEDENY (2002) in Sinai. Furthermore, this zone is equivalent to the *Vascoceras cauvini* and *Vascoceras rumeaui* Zone of LUGER & GRÖSCHKE (1989) in the north Eastern Desert and equivalent to the *Vascoceras cauvini*-*Pseudaspidoceras pseudonodosoides*-*Rubroceras alatum* Zone of ABDEL-GAWAD et al. (2004a) in Sinai. Outside Egypt, this zone is equivalent to the *Vascoceras cauvini* Zone of LEWY et al. (1984) in Israel, MEISTER et al. (1992) in Niger, BUSSON et al. (1999) in Algeria, ALY et al. (2008) in Jordan. In addition, this zone is equivalent to the standard *Neocardioceras juddii* Zone of GRADSTEIN et al. (2004). LEWY et al. (1984) suggested this correlation based on the occurrence of *Pseudaspidoceras pseudonodosoides* in the *Vascoceras cauvini* Zone as recoded from Israel and in association with the *Neocardioceras juddii* Zone as recorded by HOOK & COBBAN (1981) from Texas, which provides an indirect link between the *Neocardioceras juddii* Zone and *Vascoceras cauvini* Zone.

Remarks: The upper boundary of the *Vascoceras cauvini* Zone is marked by the disappearance of the zonal index and appearance of *Vascoceras proprium* which considered as the Cenomanian – Turonian boundary in the study area.

6.4. *Vascoceras proprium* Zone

Definition: The *Vascoceras proprium* Zone is defined by the total range of *Vascoceras proprium* (REYMENT, 1954) (Text-fig. 6.7). The first appearance of *Vascoceras proprium* is considered as the marker for the base of the Turonian in the study area.



Text-fig. 6.7. *Vascoceras proprium* (REYMENT, 1954).

Description: This zone defines the lowermost Turonian in the study area. It is recorded from wackestone in the lower part of the Maghra El Hadida Formation at all sections except Saint Anthony section due to the absence of sedimentation during this time at this locality. It attains about 2 m thickness at Wadi Ghonima section, 3 m at East Wadi Ghonima section and about 4 m at Wadi Askhar section.

Associated fauna: The zonal index is only associated with the ammonites *Vascoceras durandi* (THOMAS & PERON) and *Vascoceras pioti* (PERON & FOURTAU).

Equivalent biozones: In Egypt, the zonal index occurs together with *Pseudaspidoceras flexuosum* in several sections (KASSAB, 1991; ALY & ABDEL-GAWAD, 2001) and also in Jordan (ALY et al., 2008). Therefore, the *Vascoceras proprium* Zone is equivalent to the *Pseudaspidoceras flexuosum* Zone of KASSAB (1991), the *Pseudaspidoceras flexuosum-Vascoceras proprium* Zone of KASSAB (1996) and the *Vascoceras proprium-Vascoceras pioti* Zone of HEWAIDY et al. (2003) in the Eastern Desert, and to the *Vascoceras proprium* Zone of KASSAB & OBAIDALLA (2001) and EL-HEDENY (2002), the *Pseudaspidoceras flexuosum* Zone of ALY & ABDEL-GAWAD (2001) in Sinai. Outside Egypt, this zone is equivalent to the *Vascoceras pioti* Zone of LEWY et al. (1984) in Israel, the *Pseudaspidoceras flexuosum* Zone of ROBASZYNSKI et al. (1990), CHANCELLOR et al. (1994) and ABDALLAH et al. (2000) in Tunisia, the *Vascoceras durandi-Pseudaspidoceras flexuosum* Zone of CHARRIERE et al. (1998) in Morocco, and the North American *Pseudaspidoceras flexuosum* Zone of HANCOCK et al. (1993). In the standard ammonite zonations of GRADSTEIN et al. (2004), this zone is equivalent to the standard *Watinoceras devonense* Zone in the Tethyan region and the standard *Pseudaspidoceras flexuosum* Zone in the Western Interior of North America on the basis of the occurrence of *Vascoceras durandi* (THOMAS & PERON) and *Vascoceras pioti* (PERON & FOURTAU) in both standard zones.

Remarks: BIRKELUND et al. (1984) recommended the use of *Vascoceras proprium* as the zonal index for the lowermost Turonian instead of *Pseudaspidoceras flexuosum*, because of the wide distribution of Vascoceratidae, which extended from South America, West and North Africa, Madagascar, Japan to Boreal Europe. BENGTSON (1996) proposed that the Cenomanian – Turonian boundary at the Rock Canyon anticline west of Pueblo, Colorado, United States, could be placed at the first occurrence of the ammonite *Watinoceras devonense* which is also equivalent to *Vascoceras proprium* in Egypt (KASSAB, 1991; ALY & ABDEL-GAWAD, 2001; EL-HEDENY, 2002), Jordan (ALY et al., 2008) and in Niger (MEISTER et al., 1992). Therefore, the first appearance of *Vascoceras proprium* is considered as the index for the base of the Turonian in the study area.

6.5. *Choffaticeras* spp. Zone

Definition: This zone is defined by the total range of representatives of the genus *Choffaticeras*.

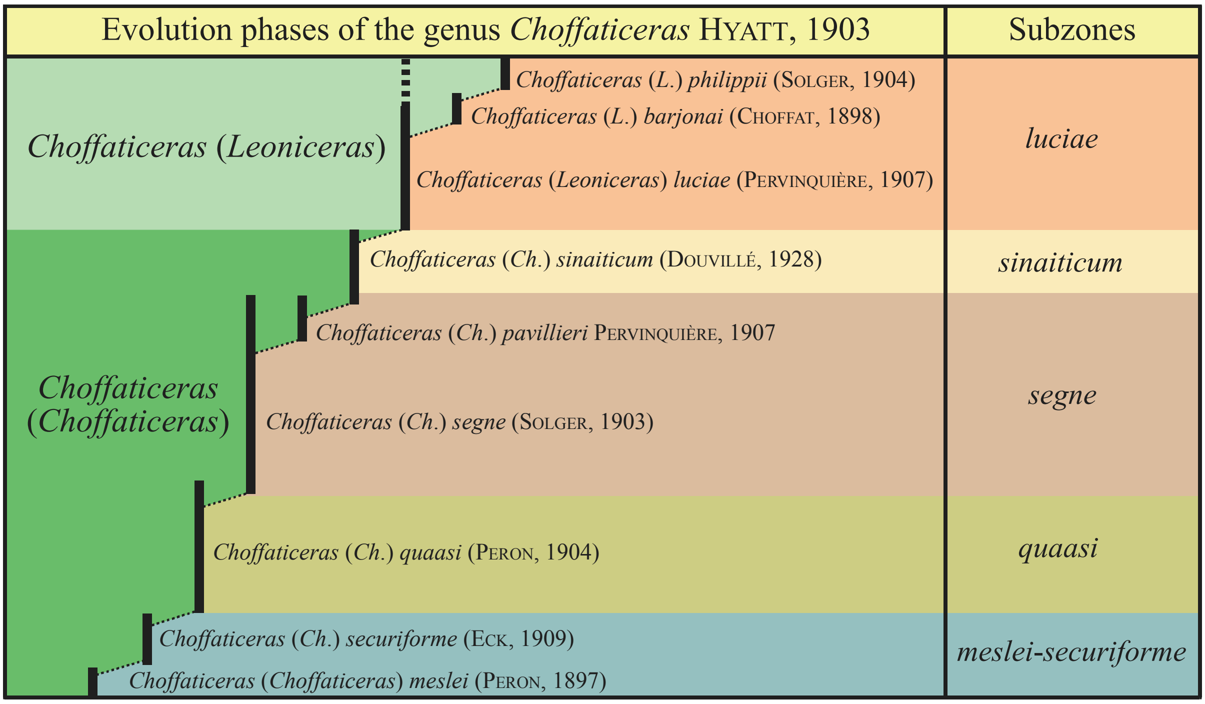
Description: The *Choffaticeras* spp. Zone is the middle ammonite zone recognized in the Lower Turonian. It is recorded from marly wacke- to rudstone in the lower part of the Maghra El Hadida Formation in all studied sections and attains about 12 m in thickness at Wadi Ghonima, 14 m at East Wadi Ghonima, 17 m at Wadi Askhar, and about 9 m thickness at Saint Anthony.

Associated fauna: The *Choffaticeras* interval is characterized by a high fossil content. The most important taxa are: ammonites: *Kamerunoceras turoniense* (D'ORBIGNY), *Fagesia* cf. *peroni* PERVINQUIÈRE, *Neoptychites cephalotus* (COURTILLER), *Thomasites rollandi* (THOMAS & PERON); bivalves: *Cucullaea* sp., *Mytiloides kossmati* (HEINZ), *Mytiloides labiatus* (SCHLOTHEIM), *Plicatula auressensis* COQUAND, *Plicatula ferryi* COQUAND, *Granocardium productum* (J. DE C. SOWERBY), *Parasea faba* (J. DE C. SOWERBY), *Durania humei* DOUVILLÈ, *Astarte tenuicostata* SEGUENZA, and *Crassatella materculla* MAYER-EYMAR; gastropods: *Ampullina* sp., *Tylostoma* sp.; echinoids: *Orthopsis ovata* (COQUAND), *Phymosoma abbatei* (GAUTHIER), *Coenholectypus turonensis* (DESOR), *Hemiaster heberti* (COQUAND).

Equivalent biozones: In Egypt, this zone is equivalent to the *Choffaticeras segne* Zone of KASSAB (1991) and ABDEL-GAWAD et al. (2007) in the north Eastern Desert, and to the eponymous zone of ALY & ABDEL-GAWAD (2001), ABDALLAH et al. (2001), KASSAB & OBAIDALLA (2001) and EL-HEDENY (2002) in Sinai. Outside Egypt, this zone is equivalent to the two zones of *Choffaticeras* (*Ch.*) *quaasi* and *Spathites* (*Ingridella*) *malladae* from Spain (BARROSO-BARCENILLA & GOY, 2007), the *Choffaticeras* interval of ROBASZYNSKI et al. (1990), and the *Thomasites rollandi* Zone of CHANCELLOR et al. (1994) in Tunisia. The *Choffaticeras* spp. Zone is equivalent to the upper part of the standard *Watinoceras devonense* Zone and maybe extended to the lower part of *Mammites nodosoides* Zone.

Remarks: The *Choffaticeras* spp. Zone is highly fossiliferous and considered as the most fossiliferous interval in the Cenomanian – Turonian succession of the study area. This zone comprises most identified species of the genus *Choffaticeras* which allow establishing the evolution phases of this genus (Text-fig. 6.8) and also subdividing the *Choffaticeras* spp.

Zone into five subzones depending on successive different *Choffaticeras* species. These subzones, from base to top, are: *Choffaticeras* (*Ch.*) *meslei*-*Ch.* (*Ch.*) *securiforme*, *Ch.* (*Ch.*) *quaasi*, *Ch.* (*Ch.*) *segne*, *Ch.* (*Ch.*) *sinaiticum* and *Ch.* (*Leoniceras*) *luciae*.



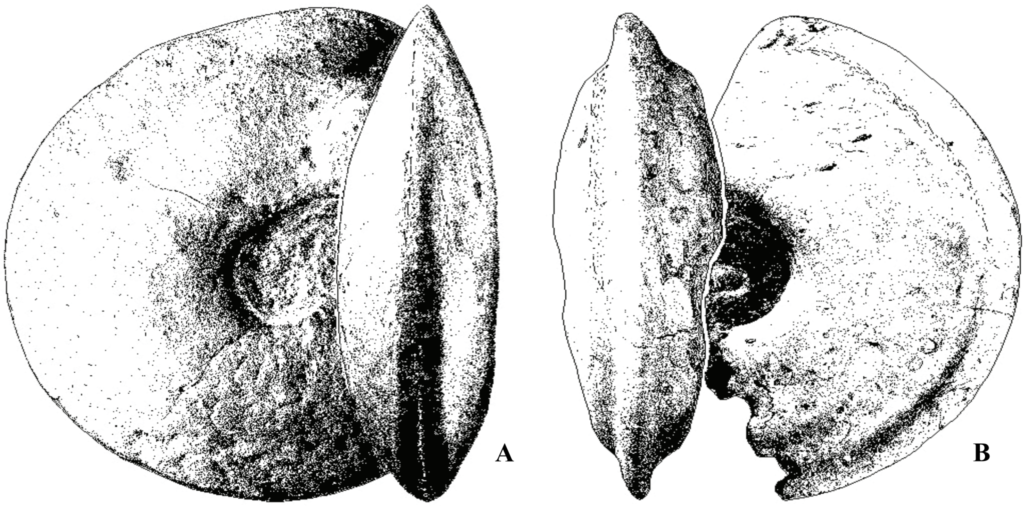
Text-fig. 6.8. The evolution phases of the genus *Choffaticeras* (HYATT, 1903) and its subzones divisions.

6.5.1. *Choffaticeras* (*Choffaticeras*) *meslei*-*Choffaticeras* (*Choffaticeras*) *securiforme* Subzone

Definition: The lower boundary of this subzone is defined by the first appearance of *Ch.* (*Ch.*) *meslei* (PERON, 1897) (Text-fig. 6.9A), while the upper boundary is marked by the last appearance *Ch.* (*Ch.*) *securiforme* (ECK, 1909) (Text-fig. 6.9B).

Description: This subzone forms the lower part of the *Choffaticeras* spp. Zone of the Maghra El Hadida Formation. The thickness of this subzone reaches 2 m in Wadi Ghonima and 3 m at East Wadi Ghonima, while it is missing at Wadi Askhar and Saint Anthony.

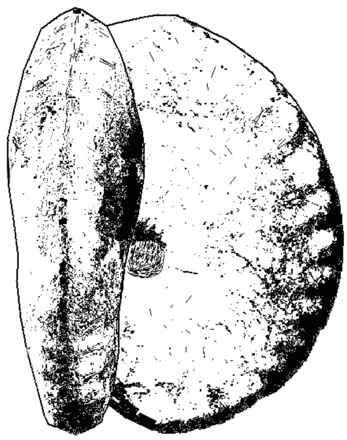
Equivalent biozones: In Egypt, the *Ch.* (*Ch.*) *meslei*-*Ch.* (*Ch.*) *securiforme* Subzone is equivalent to the lower part of *Choffaticeras quaasi*-*Choffaticeras securiforme* Zone of ABDEL-GAWAD et al. (2004a) in Sinai. Outside Egypt, this subzone is equivalent to the *Choffaticeras securiforme* Zone of LEWY et al. (1984) in Israel and the lower part of the *Choffaticeras quaasi* Zone of BARROSO-BARCENILLA & GOY (2007) in Spain.



Text-fig. 6.9. A, *Choffaticeras* (*Ch.*) *meslei* (PERON, 1897); B, *Choffaticeras* (*Ch.*) *securiforme* (ECK, 1909).

6.5.2. *Choffaticeras* (*Choffaticeras*) *quaasi* Subzone

Definition: This subzone is defined by the interval between the first appearance of the *Choffaticeras* (*Ch.*) *quaasi* (PERON, 1904) (Text-fig. 6.10) and the first appearance of the *Ch.* (*Ch.*) *segne* (SOLGER, 1903).



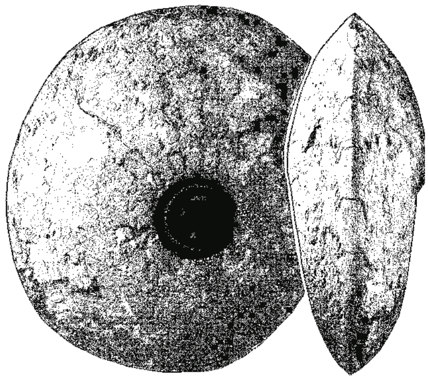
Text-fig. 6.10. *Choffaticeras* (*Ch.*) *quaasi* (PERON, 1904).

Description: The *Ch.* (*Ch.*) *quaasi* Subzone represents the second subzone in the *Choffaticeras* spp. Zone of the lower part of the Maghra El Hadida Formation. It attains about 3 m in thickness at Wadi Ghonima, 4 m at East Wadi Ghonima, and about 5 m at Wadi Askhar.

Equivalent biozones: In Egypt, the *Choffaticeras* (*Ch.*) *quaasi* Subzone is equivalent to the upper part of *Choffaticeras quaasi*-*Choffaticeras securiforme* Zone of ABDEL-GAWAD et al. (2004a) in Sinai. Outside Egypt, this subzone is equivalent to the *Choffaticeras quaasi* Zone of LEWY et al. (1984) in Israel and the upper part of the *Choffaticeras quaasi* Zone of BARROSO-BARCENILLA & GOY (2007) in Spain.

6.5.3. *Choffaticeras* (*Choffaticeras*) *segne* Subzone

Definition: This subzone is defined by the total range of *Choffaticeras* (*Ch.*) *segne* (SOLGER, 1903) (Text-fig. 6.11).



Text-fig. 6.11. *Choffaticeras* (*Ch.*) *segne* (SOLGER, 1903).

Description: This subzone is considered as the most widely distributed subzone in the *Choffaticeras* spp. Zone where it is recorded from the lower part of the Maghra El Hadida Formation in all studied sections. It attains about 4 m in thickness at Wadi Ghonima, 4 m thickness at East Wadi Ghonima, 6 m thickness at Askhar, and 9 m at Saint Anthony. This subzone is highly fossiliferous and most of the associated fauna of the *Choffaticeras* interval occurs in this subzone.

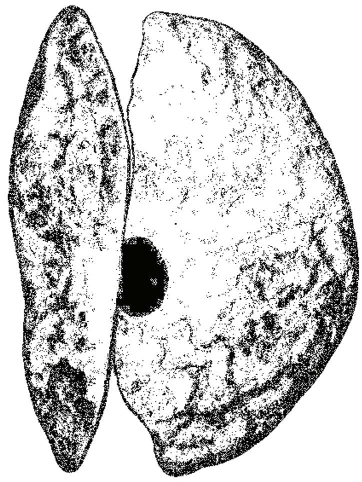
Equivalent biozones: In Egypt, the *Choffaticeras* (*Ch.*) *segne* Subzone is equivalent to the upper part of *Choffaticeras segne-Vascoceras harttii* Zone of ABDEL-GAWAD et al. (2004a) in Sinai. Outside Egypt, this subzone is equivalent to the *Spathites* (*Ingridella*) *malladae* Subzone of BARROSO-BARCENILLA & GOY (2007) in Spain.

6.5.4. *Choffaticeras* (*Ch.*) *sinaiticum* Subzone

Definition: This subzone is defined by the interval between the last appearance of the *Choffaticeras* (*Ch.*) *segne* (SOLGER, 1903) and the last appearance of the *Ch.* (*Ch.*) *sinaiticum* (DOUVILLÉ, 1928) (Text-fig. 6.12).

Description: The *Choffaticeras* (*Ch.*) *sinaiticum* Subzone is recoded from the lower part of the Maghra El Hadida Formation at East Wadi Ghonima with 2 m thickness. So far it has not been recognized in the other sections.

Equivalent biozones: In Egypt, the *Choffaticeras* (*Ch.*) *sinaiticum* Subzone is equivalent to the *Choffaticeras sinaiticum-Thomasites rollandi* Zone of ABDEL-GAWAD et al. (2004a) in Sinai.



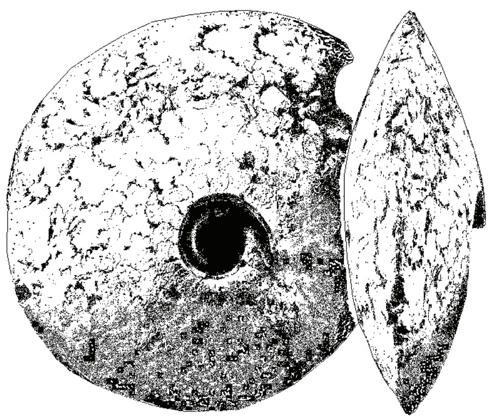
Text-fig. 6.12. *Choffaticeras* (*Ch.*) *sinaiticum* (DOUVILLÉ, 1928).

6.5.5. *Choffaticeras* (*Leoniceras*) *luciae* Subzone

Definition: This subzone is defined by the total range of *Choffaticeras* (*Leoniceras*) *luciae* (PERVINQUIÉRE, 1907) (Text-fig. 6.13).

Description: This subzone is considered as the uppermost subzone of the *Choffaticeras* interval of the Maghra El Hadida Formation. It attains about 3 m in thickness at Wadi Ghonima, 3 m at East Wadi Ghonima, and about 2 m at Wadi Askhar.

Associated fauna: *Choffaticeras* (*Leoniceras*) *luciae* is associated with *Choffaticeras* (*L.*) *barjonai* (CHOFFAT) and *Choffaticeras* (*L.*) *philippii* (SOLGER) which are common in the upper part of the subzone.



Text-fig. 6.13. *Choffaticeras* (*L.*) *luciae* PERVINQUIÉRE, 1907.

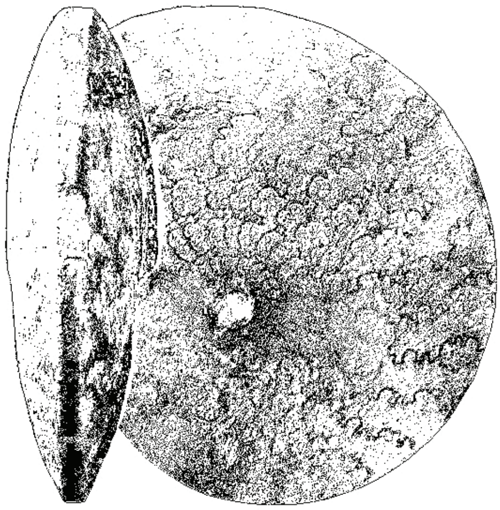
Equivalent biozones: In Egypt, the *Choffaticeras* (*L.*) *luciae* Subzone is equivalent to the *Choffaticeras luciae* Zone of HEWAIDY et al. (2003) in the north Eastern Desert. Outside Egypt, this subzone is equivalent to the *Choffaticeras luciae trisellatum* Zone of LEWY et al. (1984) in Israel and the *Choffaticeras* (*L.*) *luciae* Subzone [*Spathites* (*Ingridella*) *malladae* Zone] of BARROSO-BARCENILLA & GOY (2007) in Spain.

6.6. *Wrightoceras munieri* Zone

Definition: This zone is defined by the total range of *Wrightoceras munieri* (PERVINQUIÈRE, 1907) (Text-fig. 6.14).

Description: The *Wrightoceras munieri* Zone was recorded from marly wacke- to packstone of the upper Lower Turonian of the Maghra El Hadida Formation. This zone attains about 11 m in thickness at Wadi Ghonima and 11.5 m at East Wadi Ghonima, while it is missing at Wadi Askhar and Saint Anthony sections due to the absence of sedimentation during this time at these localities.

Associated fauna: *Wrightoceras munieri* is associated with the ammonite: *Eubostrychoceras* sp.; bivalves: *Plicatula auressensis* COQUAND, *Corbula parsura* STOLICZKA, *Pholadomya pedernalis* ROEMER; and the echinoid: *Hemiaster fourneli* DESHAYES.



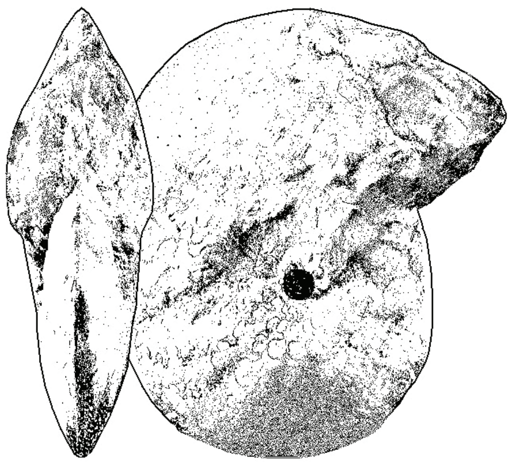
Text-fig. 6.14. *Wrightoceras munieri* (PERVINQUIÈRE, 1907).

Equivalent biozones: In Egypt, this zone is equivalent to the upper part of the *Mammites nodosoides* Zone of ALY & ABDEL-GAWAD (2001) in Sinai. Outside Egypt, this zone is equivalent to the *Wrightoceras munieri* Subzone of BARROSO-BARCENILLA & GOY (2007) in Spain and to the upper part of the standard *Mammites nodosoides* Zone (GRADSTEIN et al. 2004). The lower part of the *M. nodosoides* Zone is represented in the study area by the uppermost part of the *Choffaticeras* spp. Zone.

6.7. *Coilopoceras requienianum* Zone

Definition: This zone is defined by the total range of *Coilopoceras requienianum* (D'ORBIGNY, 1841) (Text-fig. 6.15).

Description: This zone is the only ammonite zone recognized in the lower Upper Turonian of the study area. It is recorded from packstone of the upper part of the Maghra El Hadida Formation. The thickness of the zone is 16 m at East Wadi Ghonima and 6 m at Saint Anthony.



Text-fig. 6.15. *Coilopoceras requienianum* (D'ORBIGNY, 1841).

Equivalent biozones: In Egypt, this zone is equivalent to the *Coilopoceras requienianum* Zone of KASSAB (1991) and HEWAIDY et al. (2003) in the north Eastern Desert as well as KASSAB & OBAIDALLA (2001) and EL-HEDENY (2002) in Sinai. Outside Egypt, this zone is equivalent to the *Coilopoceras requienianum* Zone of LEWY et al. (1984) in Israel and the standard *Subprionocyclus neptuni* Zone.

Inoceramid biozones:

Two inoceramid biozones were recognized in the Lower Turonian of the study area, they are:

A. ***Mytiloides kossmati* Zone**: This zone is equivalent to the middle part of the ammonite *Choffaticeras* spp. Zone [*Ch*. (*Ch*.) *quaasi*, *Ch*. (*Ch*.) *segne* and *Ch*. (*Ch*.) *sinaiticum* subzones]. It attains 8 m thickness at Wadi Ghonima and 9 m at East Wadi Ghonima.

B. ***Mytiloides labiatus* Zone**: This zone represents the upper part of the Lower Turonian. It is equivalent to the upper part of *Choffaticeras* spp. Zone [*Ch*. (*L*.) *luciae* Subzone] and *Wrightoceras munieri* Zone. The thickness of this zone reaches to 14 m at Wadi Ghonima and East Wadi Ghonima sections.

An important requirement for understanding processes in the sedimentary record is to link the appropriate process with an observation, and to correlate similar observations from different regions which occurred within an equivalent time period. Therefore, the established biozones are correlated with other biozones recognized in Egypt (Table 6.2), other Tethyan regions as well as the standard ammonite zonation (Table 6.3).

Table 6. 2. Correlation of the Upper Cenomanian - Turonian ammonite zones established herein with those proposed by different authors for Egypt.

Substage	SINAI				NORTH EASTERN DESERT					
	ALY & ABDEL-GAWAD (2001)	ABDALLAH et al. (2001)	KASSAB & OBAIDALLA (2001); EL-HEDENY (2002)	ABDEL-GAWAD et al. (2004a)	LUGER & GRÖSCHKE (1989)	KASSAB (1991)	KASSAB (1996)	HEWAIDY et al. (2003)	ABDEL-GAWAD et al. (2007)	Present work
Upper Turonian			*Coilopoceras requienianum*	*Coilopoceras requienianum*		*Coilopoceras requienianum*		*Coilopoceras requienianum*	*Coilopoceras requienianum*	*Coilopoceras requienianum*
Middle Turonian			?			?		*Hoplitoides ingens*		barren
Lower Turonian	*Mammites nodosoides* *Choffaticeras segne* *Pseudaspidoceras flexuosum*	*Choffaticeras segne* *P. flexuosum* / *Vacoceras proprium*	*Choffaticeras segne* *V. proprium* /*V. obesum*	*Choffaticeras sinaiticum* - *Thomasites rollandi* *Choffaticeras segne* - *Vascoceras harttii* *Choffaticeras quaasi* - *Choffaticeras securiforme*	*Mammites* sp.- *Fagesia* cf. *supersies* *Vascoceras durandi*	*Choffaticeras segne* *Pseudaspidoceras flexuosum*	*P. flexuosum* - *V. proprium*	*Choffaticeras luciae* *Choffaticeras segne* *V. proprium* - *V. pioti*	*Choffaticeras segne*	*Wrightoceras munieri* *Choffaticeras* spp.: *Ch. luciae*; *Ch. sinaiticum*; *Ch. segne*; *Ch. quaasi*; *Ch. securiforme* - *Ch. meslei* *Vascoceras proprium*
Upper Cenomanian	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini* - *P. pseudonodosoides* - *Rubroceras alatum* *Neolobites vibrayeanus*	*Vascoceras cauvini*, *Vascoceras rumeai* *Vascoceras gamai* *Metengonoceras* cf. *acutum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Neolobites vibrayeanus*	*Vascoceras cauvini*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*

Table 6.3. Inter-regional correlation of the Upper Cenomanian - Turonian ammonite zones.

Substage	Standard Ammonite Zonation GRADSTEIN et al. (2004): Tethyan	Standard Ammonite Zonation GRADSTEIN et al. (2004): W. Interior, N. America	SPAIN BARROSO-BARCENILLA & GOY (2007): Zone	SPAIN: Subzone	MOROCCO CHARRIERE et al. (1998) & MEISTER & RHALMI (2002)	ALGERIA BUSSON et at. (1999)	TUNISIA ROBASZYNSKI et al. (1990) (1) CHANCELLOR et al. (1994) (2) ABDALLAH et al. (2000) (3)	NIGER MEISTER et al. (1992)	ISRAEL LEWY et al. (1984)	JORDAN ALY et al. (2008)	Present work North Eastern Desert Egypt: Zone	Present work: Subzone
Upper Turonian	*Subprionocyclus neptuni*	*Prionocyclus germari* through *Prionocyclus macombi* (7 zones)			*Coilopoceras* gr. *requienianum*; *Coilopoceras* aff. *newelli*		*Prionocyclus interval* (1) *Hemitissotia morreni* (2)	*Coilopoceras iflatum*	*Coilopoceras requienianum*		*Coilopoceras requienianum*	
Middle Turonian	*Romaniceras deverianum* *Romaniceras ornatissimum* *Romaniceras kallesi* *Kamerunoceras turoniense* (*Collignoniceras woollgari*)	*Prionocyclus hyatti* *Prionocyclus percarinatus* *Collignoniceras woollgari*					*Romaniceras deverianum* (1,2) *Coilopoceras* Interval (1) *Romaniceras kallesi* (1,2) *Kamerunoceras turoniense* (1)		*Romaniceras inermis*		barren	
Lower Turonian	*Mammites nodosoides* *Watinoceras coloradoense* / *Watinoceras devonense*	*Mammites nodosoides* *Vascoceras birchbyi*, *Pseudaspidoceras flexuosum*, *Watinoceras devonense*	*Mammites nodosoides* *Spathites* (*Ingridella*) *malladae* *Choffaticeras* (*Ch.*)*quaasi*	*W.munieri* *M.nodosoides* *Ch.*(*L.*)*luciae* *S.* (*I.*) *malladae*	*Choffaticeras* sp. – *Vascoceras* sp. – *Mammites nodosoides* *Vascoceras durandi* – *Pseudaspidoceras flexuosum* *Neoptychites*?	*Pseudotissotia nigeriensis* *Choffaticeras sp.* *Choffaticeras quaasi- pavillieri* *Pseudotissotia nigeriensis*	*Mammites nodosoides* (1,2,3) *Choffaticeras interval* (1) *Thomasites rollandi* (2) *Pseudaspidoceras flexuosum* (1,2,3)	*Thomasites nigeriensis* *Vascoceras proprium*	*Choffaticeras luciae trisellatum* *Choffaticeras quaasi* *Choffaticeras securiforme* *Vascoceras pioti*	*Choffaticeras segne* *Vascoceras proprium*	*Wrightoceras munieri* *Choffaticeras* spp. *Vascoceras proprium*	*Ch. luciae* *Ch. sinaiticum* *Ch. segne* *Ch. quaasi* *Ch. securiforme*-*Ch. meslei*
Upper Cenomanian	*Neocardioceras juddii* *Metoicoceras geslinianum* *Calycoceras naviculare*	*Nigericeras scotti*, *Neocardioceras juddii* through *Con. gilberti* (15 zones extended into the Middle Cenomanian)	*Spathites* (*Jeanrogericeras*) *subconciliatus* *Metoicoceras geslinianum* *Neolobites vibrayeanus* *Eucalycoceras rowei*		*Pseudaspidoceras* sp. – *Vascoceras* sp. *Vascoceras* gr. *cauvini* *P.* cf. *pseudonodosoides* *Nigericeras* ? sp. *Neolobites vibrayeanus*	*Vascoceras cauvini* & *Vascoceras gamai* *Nigericeras gadeni* *Eucalycoceras pentagonum* *Calycoceras naviculare* *Neolobites vibrayeanus*	*Vascoceras* spp. *Pseudaspidoceras pseudonodosoides* (2,3) *Euomphaloceras* cf. *septemseriatum* (1)/ *Metoicoceras geslinianum* (2) *Eucalycoceras* (1) *Calycoceras haugi* – *C. guerangeri* (2) *Neolobites vibrayeanus* (2,3)	*Vascoceras cauvini* *Nigericeras gadeni* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Kanabiceras* sp. *Calycoceras* sp. *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	

7. Lithostratigraphy

The studied Upper Cretaceous successions on the slopes of the western extensions of the northern and southern Galala plateaus in Wadi Araba are classified lithostratigraphically into three formations. They are, from older to younger: Malha, Galala, and Maghra El Hadida formations. The full descriptions of these rock units are giving below.

7.1. Malha Formation

Author: ABDALLAH & ADINDANI, 1963.

Type locality: Wadi Malha, Abu Darag area, north Eastern Desert.

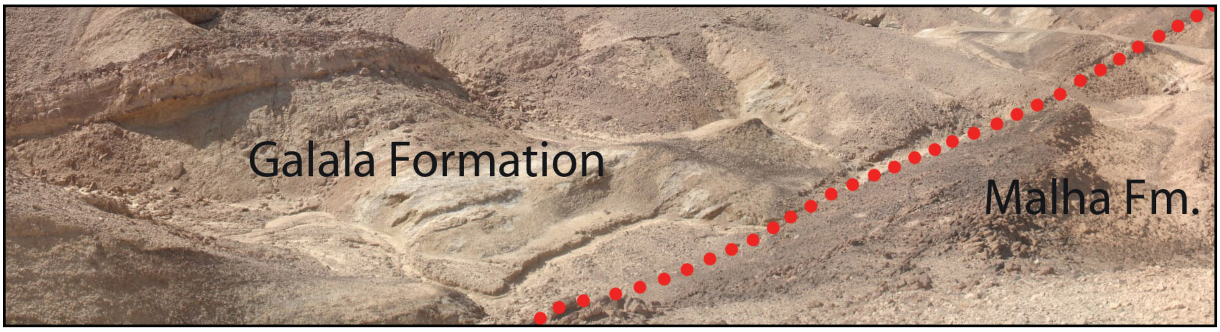
Description at the type locality: Mainly white, fine- to medium-grained sandstones with kaolinised clay, reaches up to 80 m in thickness (ABDALLAH & ADINDANI, 1963).

Description in the study area: The Malha Formation constitutes the base of the studied sections. Only the upper part of this formation is measured in order to identify the lower boundary of the Cenomanian Galala Formation (the target of this study). The measured part of the Malha Formation consists of unfossiliferous brownish, medium- to coarse-grained, cross-bedded sandstone with wood fragments and bioturbation. At Wadi Ghonima, this unit is characterized by brownish sandstone rich in well rounded quartz grains. At the top of this unit, the sandstone becomes coarser-grained and bioturbated with *Treptichnus*? isp. (Text-fig. 7.1). Bioturbation in the upper part of the Malha Formation indicates initial marine influence and a gradual interfingering of marine and non-marine deposits.

Thickness in the study area: The maximum exposed thickness of the Malha Formation in the study area is about 15 m. Only the upper part of this formation was measured (2 m at Wadi Ghonima, 4 m at East Wadi Ghonima, 5 m at Wadi Askhar, and 2 m at Saint Anthony).

Stratigraphic boundaries: In the study area, the base of the Malha Formation is not exposed because the bulk of the formation is subsurface and only the upper part is exposed. The Malha Formation underlies unconformably the Galala Formation and the contact between them (Text-fig. 7.2) is marked by the transition from varicolored sandstone to pale grey siltstone of the Galala Formation.

Text-fig. 7.1. *Treptichnus*? isp. in the upper part of the Malha Formation.



Text-fig. 7.2. The lower part of East Wadi Ghonima section, with indication of the contact between the Malha and Galala formations.

Age: According to ABDALLAH et al. (1963), the Malha Formation is assigned to the Early Cretaceous (Aptian) because it invariably underlies the marine Cenomanian rocks, and the Malha Formation includes marine interbeds with *Ostrea falco*, *O. boussignaulti*, *O. palaomon*, *O. renevierios* and *Aspidiscus* sp.

In the study area, it is difficult to determine the age of the Malha Formation, because the exposed part is unfossiliferous. However, it is considered here as Early Cretaceous age, and the topmost part may be ranging into the Cenomanian.

Remarks: ABDALLAH et al. (1963) described the Malha Formation at the south eastern cliffs of the northern Galala massif (near to its type locality) as pale brown, pinkish, coarse-grained, friable, cross-stratified, jointed sandstone, followed by poorly-cemented sandstone with plant remains, topped by white fine-grained clayey sandstone. At this locality, this unit reaches up to 50 m and overlies the red shales of the Triassic Qiseib Formation and underlies the Cenomanian Galala Formation. ABDALLAH et al. (1963) noted that the Malha Formation possesses variable thicknesses within short distances and this may be explained by a break in sedimentation or erosion after deposition. According to SAID (1990), the thickness of the Malha Formation in the north Eastern Desert varies greatly from one place to another ranging from 70 to 130 m. In Sinai, the thickness of the Malha Formation varies from 40 to 100 m in west Sinai, to 250 m in east Sinai, and to more than 1000 m in the subsurface of north Sinai (ISSAWI et al., 1999).

7.2. Galala Formation

Author: ABDALLAH & ADINDANI, 1963.

Type locality: Eastern cliffs of the Northern Galala massif, west Gulf of Suez.

Description at the type locality: 80 – 120 m of shallow marine, greenish-yellow marl-shale succession, intercalated with thin sandstone and thick fossiliferous limestone beds (HERMINA et al., 1989).

Description in the study area: The Galala Formation is considered as the product of the first marine transgression during Cretaceous times in the north Eastern Desert. This formation, in the study area, can be divided into five shallowing-upward cycles, each cycle starting with marly-silty deposits at the base and grading into highly fossiliferous lagoonal limestones at the top. The lowermost part of the Galala Formation consists of unfossiliferous, greenish sandy siltstone changing upward into siltstone intercalated with thin, cross-bedded, bioturbated, fine- to medium-grained sandstones. Some beds of the lower part of the Galala Formation are crowded with oyster fragments (Text-fig. 7.4A) which come from the Upper Cenomanian middle and upper parts of the formation. The lower part of the Galala Formation ends with well exposed yellowish marly siltstone topped by nodular highly fossiliferous lagoonal limestone, considered as the first oyster bed (Text-fig. 7.4B). The top surface of this limestone bed is marked by brownish bored hardground (Text-fig. 7.4C), representing the end of the first cycle in the Galala Formation. The second cycle consists of greyish, poorly exposed marly siltstone followed by marl and capped by marl and brownish, nodular, fossiliferous wackestone intercalations. The basal surface of some of these limestone beds is marked by bioturbation with a dense network of *Thalassinoides* burrows (Text-fig. 7.4D). The next cycle consists of shaley marl with intercalations of bioclastic float- and rudstones rich in bivalves (*Ilymatogyra africana*, *Rhynchostreon suborbiculatum*, *Ceratostreon flabellatum*), gastropods (*Nerinea* sp. and *Cimolithium tenouklense*), and echinoids (*Hemiaster cubicus*), indicating, a fully marine, lagoonal environment. The following cycle consists of shaley marl, nodular at the base and changing into pure marl with intercalation of nodular rudstone containing rudists (*Eoradiolites liratus*) and *Chondrodonta* (Text-fig. 7.4E), suggesting a shallow-marine, warm water setting. This part is topped by nodular limestone, fossiliferous in bivalves (*Costagyra olisiponensis*) at the base, and with the ammonite *Neolobites vibrayeanus* (Text-fig. 7.4F) at the top. The last cycle in the Galala Formation is not complete and composed of well exposed shaley marl which constitutes the topmost part of the Galala Formation.

Thickness in the study area: The Galala Formation is about 62 m thick at Wadi Ghonima, 95 m at East Wadi Ghonima, 85 m at Wadi Askhar, and 55 m at Saint Anthony (see Text-fig. 7.3).

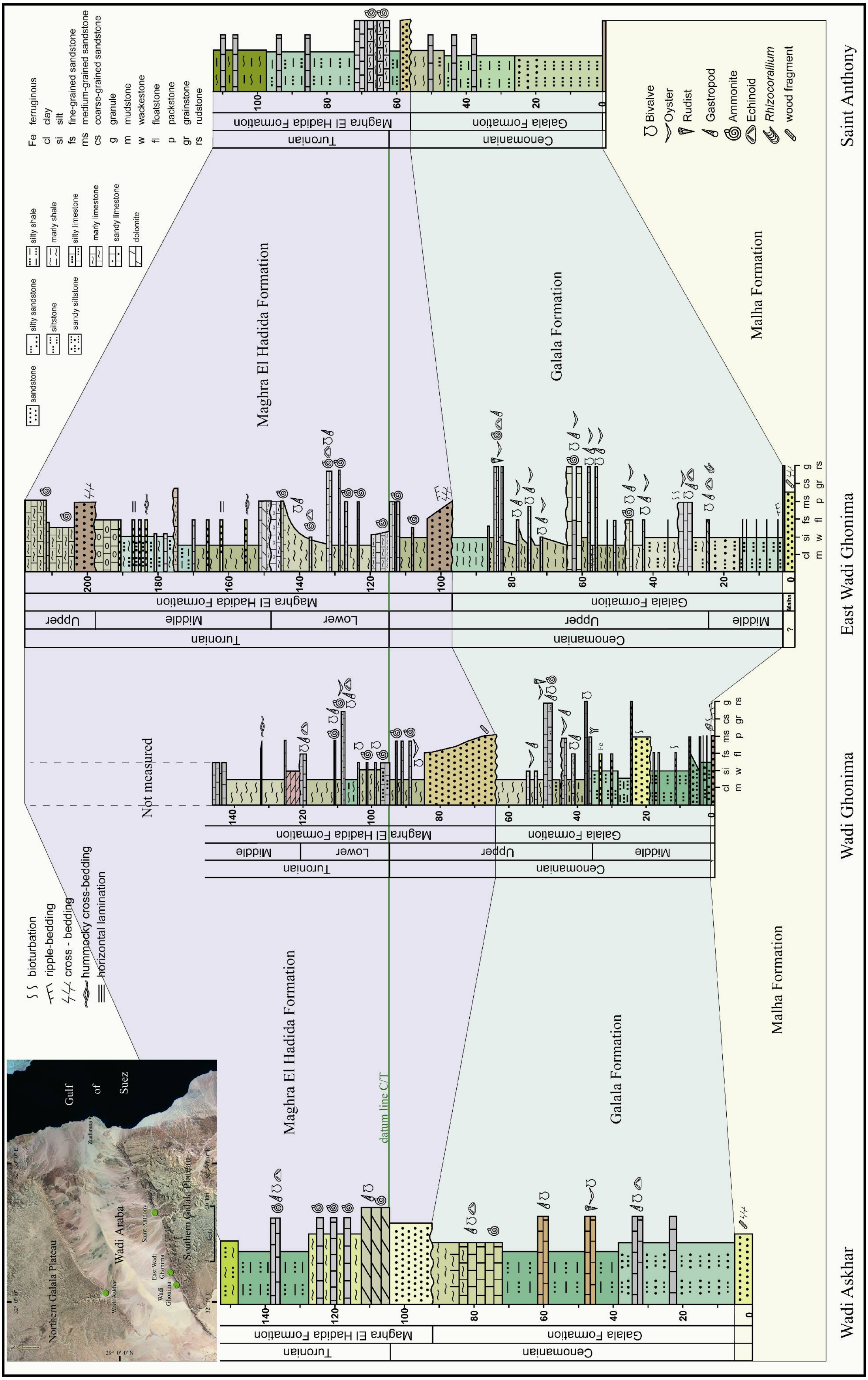
Stratigraphic boundaries: The Galala Formation overlies unconformably the Lower Cretaceous Malha Formation, but with no major break in sedimentation. The Malha – Galala boundary (Text-fig. 7.2) is easily defined at the contact between unfossiliferous sandstones and the silty-marly sediments of the lower part of the Galala Formation. The upper boundary of the Galala Formation is characterized by a major unconformity at the base of the Maghra El Hadida Formation (Text-fig. 7.5A). This surface is defined at the change from the fossiliferous marly sediments of the Galala Formation to unfossiliferous sandstones (Ghonima Member) of the Maghra El Hadida Formation.

Areal distribution: At the beginning of the Cenomanian, a southward-directed transgression from the Tethyan Sea took place all over the northern part of Egypt (SAID, 1990). This transgression is represented by the Galala Formation in most parts of the north Eastern Desert. It is well distributed in the northern and southern Galala plateaus and in the Gebel Ataqa area, represented by shallow marine, greenish-yellow marl-shale successions intercalated with thin sandstone and thick fossiliferous limestone beds. In central Wadi Qena, it attains 64 m in thickness of lagoonal claystone with occasional thin siltstone, sandstone, limestone and marl beds (HERMINA et al., 1989). The Galala Formation disappears under the younger sediments at the extreme western part of Wadi Araba, west of the study area. In addition, the Galala Formation is well exposed in some exposures in central and northern parts of Sinai (SAID, 1990).

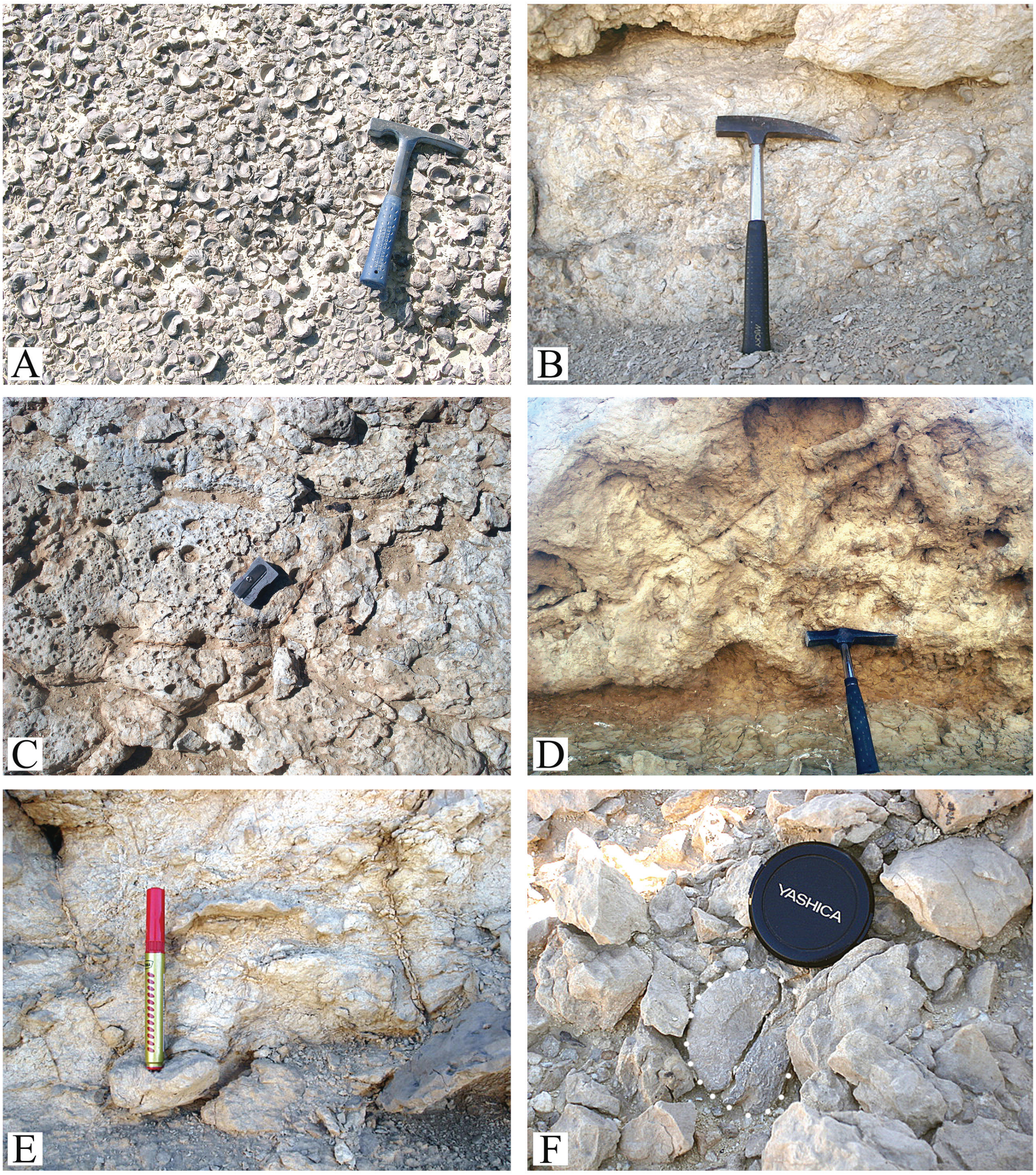
Important faunal elements:

- Bivalvia: *Barbatia aegyptiaca* (FOURTAU, 1917), *Pycnodonte vesicularis* (LAMARCK, 1806)-*vesiculosa* (J. SOWERBY, 1823), *Costagyra olisiponensis* (SHARPE, 1850), *Ceratostreon flabellatum* (GOLDFUSS, 1833), *Ilymatogyra africana* (LAMARCK, 1801), *Rhynchostreon suborbiculatum* (LAMARCK, 1801), *Amphidonte conica* J. DE C. SOWERBY (1813), *Eoradiolites liratus* (CONRAD, 1852), *Granocardium productum* (J. DE C. SOWERBY, 1832), *Protocardia hillana* (J. SOWERBY, 1813), *Arctica picteti* (COQUAND, 1862), *Parasea faba* (J. DE C. SOWERBY, 1827), *Pholadomya vignesi* LARTET (1877), and *Plectomya humei* (FOURTAU, 1917).
- Gastropoda: *Pyrazopsis* sp., *Campanile ganesha* NOETLING (1897), *Cimolithium tenouklense* (COQUAND, 1862), *Pterocera incerta* D'ORBIGNY (1842), *Harpagodes heberti* (THOMAS & PERON, 1889), *Pterodonta deffisi* THOMAS & PERON (1889), *Mrhilaia nerineaeformis* COQUAND (1916), and *Nerinea* sp.
- Cephalopoda: *Angulithes mermeti* (COQUAND, 1862), *Eutrephoceras* sp., *Neolobites vibrayeanus* (D'ORBIGNY, 1841), and *Thomelites* sp.
- Echinoidea: *Goniopygus menardi* (DESMAREST, 1825), *Tetragramma variolare* (BRONGNIART, 1822), *Heterodiadema libycum* (DESOR, 1846), *Coenholectypus larteti* (COTTEAU, 1869), and *Hemiaster cubicus* DESOR (1847).

Age: In the study area, the lower, unfossiliferous part of the Galala Formation is difficult to date. However, it is considered here as late Middle Cenomanian depending on its conformable relation with the overlying lower Upper Cenomanian beds. This lower part reaches about 35 m at Wadi Ghonima, 22 m at East Wadi Ghonima, 34 m at Saint Anthony, and 18 m at Wadi Askhar. The remaining part of this formation is considered here as Late Cenomanian in age depending of its ammonite content (*Neolobites vibrayeanus*).



Text-fig. 7.3. Lithostratigraphic correlation of the study area.



Text-fig. 7.4. Important features of the Galala Formation in the study area. A, abundant oyster shells in the lower part of the Formation; B, first Upper Cenomanian oyster bed; C, bored hardground; D, *Thalassinoides* burrows; E, *Chondrodonta* sp.; F, *Neolobites vibrayeanus*.

Remarks: The name "Galala Formation" was introduced by ABDALLAH & ADINDANI (1963) to describe the Cenomanian marl-shale succession, intercalated with sandstone and limestone beds, overlying the Malha Formation and underlying the Turonian beds of the Maghra El Hadida Formation of EL AKKAD & ABDALLAH (1971) in the Northern Galala Plateau. Rapid lateral facies changes are a remarkable feature of the Galala Formation in and around its type region (EL SHAZLY et al., 1979, MAZHAR et al., 1979, HERMINA et al., 1989, KASSAB, 1991, 1994).

At the north eastern part of Egypt, the Cenomanian strata lie above the Malha or Risan Aneiza formations with no major break in sedimentation. They are represented in North Sinai by the Halal Formation, which is composed of fossiliferous limestones, dolomites and marls with subordinate shale. In South Sinai, the Cenomanian rocks have a greater clastic component and are named the Raha Formation. The name of this unit is changed to Galala Formation in the north Eastern Desert (SAID, 1990). HATABA & AMMAR (1990) suggested the term "Nezzazat Group" to designate the Cenomanian – Santonian rock units of the Gulf of Suez region including GHORAB's (1961) Raha Formation as well as Abu Qada Formation, Wata Formation, and Matalla Formation. The term "Galala Formation" has also been applied in Sinai to describe the Cenomanian rocks of central and northern Sinai (e.g. ABDEL-GAWAD & ZALAT 1992, ZIKO et al., 1993).

KASSAB (1994) considered the Galala Formation of the north Eastern Desert as Upper Cenomanian – Lower Turonian, consisting of fossiliferous carbonate (limestone, marly limestone, and dolomitic limestone), yielding ammonites, nautiloids, oysters, gastropods, and echinoids as well as intercalations of poorly fossiliferous to unfossiliferous sandy shales and shales. KASSAB (1996) raised the Galala Formation to group rank to describe the Cenomanian – Lower Turonian shallow marine clastic-carbonate successions of West Sinai. He subdivided his Galala Group into three formations: Raha, Abu Qada, and Wata (GHORAB, 1961). GALAL et al. (2001) followed the concept of KASSAB (1996) to include the three formations in the Galala Group to describe the Cenomanian – Turonian sequence of Wadi El Tarfa, Eastern Desert. ALY & ABDEL-GAWAD (2001) considered the Abu Qada Formation in north and central Sinai as equivalent to the upper part of Galala Formation in Wadi Qena and the two Galalas plateaus in the Eastern Desert.

7.3. Maghra El Hadida Formation

Author: EL AKKAD & ABDALLAH (1971).

Type section: Wadi Maghra El Hadida, southeast corner of Gebel Ataqa (north Eastern Desert).

Lithology and thickness at type section: Shallow marine sediments of grey, hard, dolomitic limestone and dolomite with alternating beds of white limestone, varicolored marls and sandstones. Basal beds are rich in large ammonites. The thickness of the formation reaches 142 m (EL AKKAD & ABDALLAH, 1971).

Description in the study area: The Maghra El Hadida Formation starts with the Ghonima Member (Text-fig. 7.5B), introduced in this work to describe the brown fine- to medium-grained calcareous sandstone unit in its lower part. This member is erosionally incised into the Galala Formation, explaining its strong laterally variable thickness ranging from 3 to 21 m in the study area. It is mostly unfossiliferous except for bioturbation in its upper part. The member is assigned to the middle Upper Cenomanian, based on its stratigraphic position between the lower Upper Cenomanian *Neolobites vibrayeanus* Zone and overlying upper

Upper Cenomanian *Metoicoceras geslinianum* and *Vascoceras cauvini* zones. The transgression which started during the upper Middle Cenomanian continued in the Maghra El Hadida Formation above the Ghonima Member. The interval (Text-fig. 7.5C) which follows above the Ghonima Member is characterized by an increase of carbonate content and consists of thick, yellow, soft marl intercalated with fine-grained wackestone containing a highly fossiliferous latest Cenomanian and Early Turonian ammonite assemblage (Text-fig. 7.5D-G). This succession is also intercalated with nodular limestone beds rich in bivalves, gastropods, and echinoids. The Lower Turonian succession is terminated by a prominent palaeo-karst horizon (Text-fig. 7.5H). The Middle Turonian part of the Maghra El Hadida Formation starts with a thin, brown dolomite bed turning upward into grey limestone, with bioturbation in its upper part. The overlying part consists of thick, yellowish marl, becoming silty upward with occasional hummocky cross-bedded, medium- to coarse-grained sandstone intercalations and with marker limestone bands. This part is capped by a brown nodular wackestone bed. This succession suggests deposition of the Middle Turonian sediments in a storm-influenced shelf setting. The topmost part of Maghra El Hadida Formation consists of brownish, medium-grained sandstone topped by marly limestone with ammonites (*Coilopoceras requienianum*) of Late Turonian age.

Thickness in the study area: The measured thickness of the Maghra El Hadida Formation is about 82 m at Wadi Ghonima, 118 m at East Wadi Ghonima, 60 m at Wadi Askhar, and 59 m at Saint Anthony.

Stratigraphic boundaries: The Maghra El Hadida Formation overlies unconformably the Galala Formation and also underlies the Matulla Formation with an unconformity. The lower boundary of the Maghra El Hadida Formation (Text-fig. 7.5A) is easily defined at the contact between the fossiliferous marl of the Galala Formation and the unfossiliferous sandstone unit (Ghonima Member) of the Maghra El Hadida Formation. The upper boundary between the Maghra El Hadida Formation and the overlying Matulla Formation is defined at the change from the carbonate facies of the Maghra El Hadida Formation to the clastic facies of the Matulla Formation. This lithologic change is accompanied by the disappearance of Turonian ammonites above the boundary.

Areal distribution: The Maghra El Hadida Formation has a wide areal distribution at the slopes of the northern and southern Galala plateaus in the Wadi Araba. It disappears under younger sediments towards the west at Wadi Araba. Outside the study area, the Maghra El Hadida Formation was recorded at its type locality in Gebel Ataqa and Gebel Shabrawit (north Wadi Araba). At Wadi Qena (south Wadi Araba) the Maghra El Hadida Formation changed to the Umm Omeiyid Formation (HERMINA et al., 1989). In Sinai, the Maghra El Hadida Formation is replacement by Abu Qada, Buttum and Wata formations.

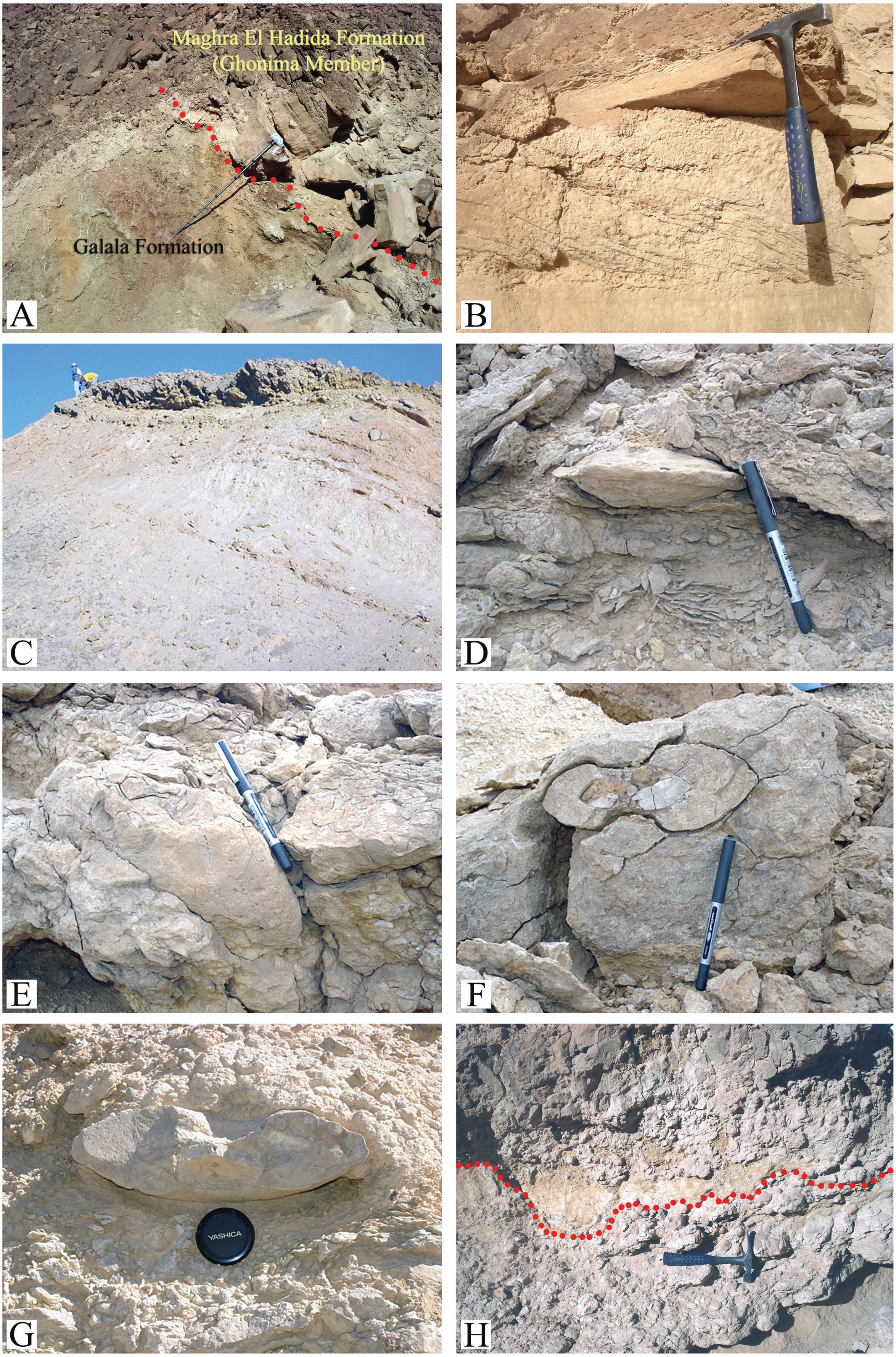
Important faunal elements:

- Bivalvia: *Mytiloides kossmati* (HEINZ, 1930), *Mytiloides labiatus* (SCHLOTHEIM, 1813), *Plicatula auressensis* COQUAND (1862), *Plicatula ferryi* COQUAND (1862), *Corbula* *parsura* STOLICZKA (1871), *Durania humei* DOUVILLÉ (1913), *Astarte tenuicostata* SEGUENZA (1882), *Crassatella materculla* MAYER-EYMAR (1896), and *Pholadomya pedernalis* ROEMER (1852).

- Gastropoda: *Tylostoma* sp. and *Ampullina* sp.
- Cephalopoda: *Euomphaloceras septemseriatum* (CRAGIN, 1893), *Kamerunoceras turoniense* (D'ORBIGNY, 1850), *Metoicoceras geslinianum* (D'ORBIGNY, 1850), *Vascoceras cauvini* CHUDEAU (1909), *Vascoceras proprium* (REYMENT, 1954), *Neoptychites cephalotus* (COURTILLER, 1860), *Thomasites rollandi* (THOMAS & PERON, 1889), *Wrightoceras munieri* (PERVINQUIÈRE, 1907), *Coilopoceras requienianum* (D'ORBIGNY, 1841), and several species of the genus *Choffaticeras*.
- Echinoidea: *Phymosoma abbatei* (GAUTHIER, 1898), *Coenholectypus turonensis* (DESOR, 1847), *Hemiaster batnensis* COQUAND (1862), *Hemiaster fourneli* DESHAYES (1847), and *Hemiaster heberti* (COQUAND, 1862)-*turonensis* FOURTAU (1921).

Age: In the study area, the Maghra El Hadida Formation is assigned to the Late Cenomanian – Turonian. The lower part of the Maghra El Hadida Formation (Ghonima Member) is of middle Late Cenomanian age, based on its stratigraphic position between the lower Upper Cenomanian *Neolobites vibrayeanus* Zone of the Galala Formation and overlying upper Upper Cenomanian *Metoicoceras geslinianum* and *Vascoceras cauvini* zones of the Maghra El Hadida Formation. The Cenomanian strata of this formation are followed by highly fossiliferous ammonite beds of Early Turonian age. The Maghra El Hadida Formation ended with fossiliferous carbonate sediments yielding *Coilopoceras requienianum* of Late Turonian age.

Remarks: SAID (1990) mentioned that the Abu Qada and Wata formations in Sinai and the Gulf of Suez area are equivalent to the Maghra El Hadida Formation in the Galalas area. ALY & ABDEL-GAWAD (2001) considered that the Wata, Buttum, and the upper part of Abu Qada formations in north and central Sinai are equivalent to the Maghra El Hadida Formation in the Ataqa and Shabrawet area, north Eastern Desert. ABDEL-GAWAD et al. (2004a) considered that the Wata Formation in northwest Sinai is equivalent to the Maghra El Hadida Formation in Gebel Ataqa and Gebel Shabrawet, north Eastern Desert. For the correlation of the studied Cenomanian – Turonian units with different works, see Table. 7.1.



Text-fig. 7.5. Important features of the Maghra El Hadida Formation in the study area. A, lower boundary of the formation; B, Ghonima Member; C, Lower Turonian part of the Formation; D-G, Lower Turonian ammonites *in situ*; H, palaeo-Karst horizon (uppermost Lower Turonian unconformity).

Table. 7.1. Lithostratigraphic classification used by different authors for the Cenomanian – Turonian rocks of north eastern Egypt.

Age \ Previous studies		Sinai: BARTOV et al. 1980	KORA & HAMAMA 1987; ABDEL-GAWAD et al. 1992	CHERIF et al. 1989; ORABI 1993	ZIKO et al. 1993	KORA & GENEDI 1995	ABDALLAH et al. 1996	ABED et al. 1996	ABDEL-GAWAD 1999	ISSAWI et al. 1999	ALY & ABDEL-GAWAD 2001	BAUER et al. 2001; 2002	North Eastern Desert: GHORAB 1961	ABU KHADRA et al. 1987	ISMAIL 1991	KASSAB 1996 (Galala Group)	GALAL et al. 2001	ELAKKAD & ABDALLAH 1971; ISSAWI et al. 1999; HEWAIDY et al. 2003	Present study
Turonian	Upper	Gerofit Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Umm Omeiyid Fm.	Maghra El Hadida Fm.	Maghra El Hadida Fm.
	Middle	Gerofit Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.	Wata Fm.; Abu Qada Fm.	Abu Qada Fm.	Buttum Fm.	Buttum Fm.	Wata Fm.; Abu Qada Fm.	Wata Fm.	Wata Fm.	Wata Fm.; Abu Qada Fm.	Wata Fm.	Wata Fm.	Maghra El Hadida Fm.	Maghra El Hadida Fm.
	Lower		Wata Fm.	Abu Qada Fm.	Wata Fm.	Abu Qada Fm.	Wata Fm.	Abu Qada Fm.	Abu Qada Fm.	Abu Qada Fm.	Abu Qada Fm.	Abu Qada Fm.	Wata Fm.	Wata Fm.	Abu Qada Fm.	Abu Qada Fm.	Abu Qada Fm.	Maghra El Hadida Fm.	Maghra El Hadida Fm.
Cenomanian	Upper	Hazera Fm.	Raha Fm.	Raha Fm.	Galala Fm.	Abu Qada Fm.; Raha Fm.	Halal Fm.	Halal Fm.	Raha Fm.	Galala Fm.	Abu Qada Fm.; Raha Fm.	Raha Fm.	Abu Qada Fm.; Raha Fm.	Galala Fm.	Raha Fm.	Abu Qada Fm.; Raha Fm.	Abu Qada Fm.	Galala Fm.	Maghra El Hadida Fm.; Galala Fm.
	Middle	Hazera Fm.	Raha Fm.	Raha Fm.	Galala Fm.	Raha Fm.	Halal Fm.	Halal Fm.	Raha Fm.	Galala Fm.		Raha Fm.	Raha Fm.	Galala Fm.	Raha Fm.	Raha Fm.	Abu Qada Fm.	Galala Fm.	Galala Fm.
	Lower	Hazera Fm.	Raha Fm.	Raha Fm.	Galala Fm.	Raha Fm.	Halal Fm.	Halal Fm.	Raha Fm.	Galala Fm.		Raha Fm.	Raha Fm.	Galala Fm.	Raha Fm.	Raha Fm.	Abu Qada Fm.; Raha Fm.	Galala Fm.	

8. Facies analysis

The facies analysis of the Cenomanian – Turonian Galala and Maghra El Hadida formations is based on microfacies investigation of 90 thin-sections with study of rock specimens by hand-lens in the field, supplemented by observations of features such as bedding, sedimentary structures and fossil content (macrofossils, trace fossils). The detailed description of the investigated thin-sections can be found in the Appendix.

The classification scheme used is that of DUNHAM (1962) with the modifications by EMBRY & KLOVAN (1972). Based of the composition and texture, the investigated thin sections have been grouped into 22 different (micro-) facies types which are briefly described in the following and illustrated in Text-figs. 8.3–8.12. Thin-section photomicrographs are shown according to their original stratigraphic orientation, i.e. up-section corresponds to the page top.

8.1. (Micro-) facies types (FT) of the Galala Formation.

FT1: Thick silty marl.

Description: Grayish-green, fine-grained, thick-bedded, soft silty marl. The silt content is higher in the lower part of the Galala Formation with occasional silt- to fine-grained sandstone interbeds. Upwards, the marls become more clayey.

Interpretation: This facies type seems to represent the deepest depositional setting of the Galala Formation and is considered as a deep lagoonal deposit.

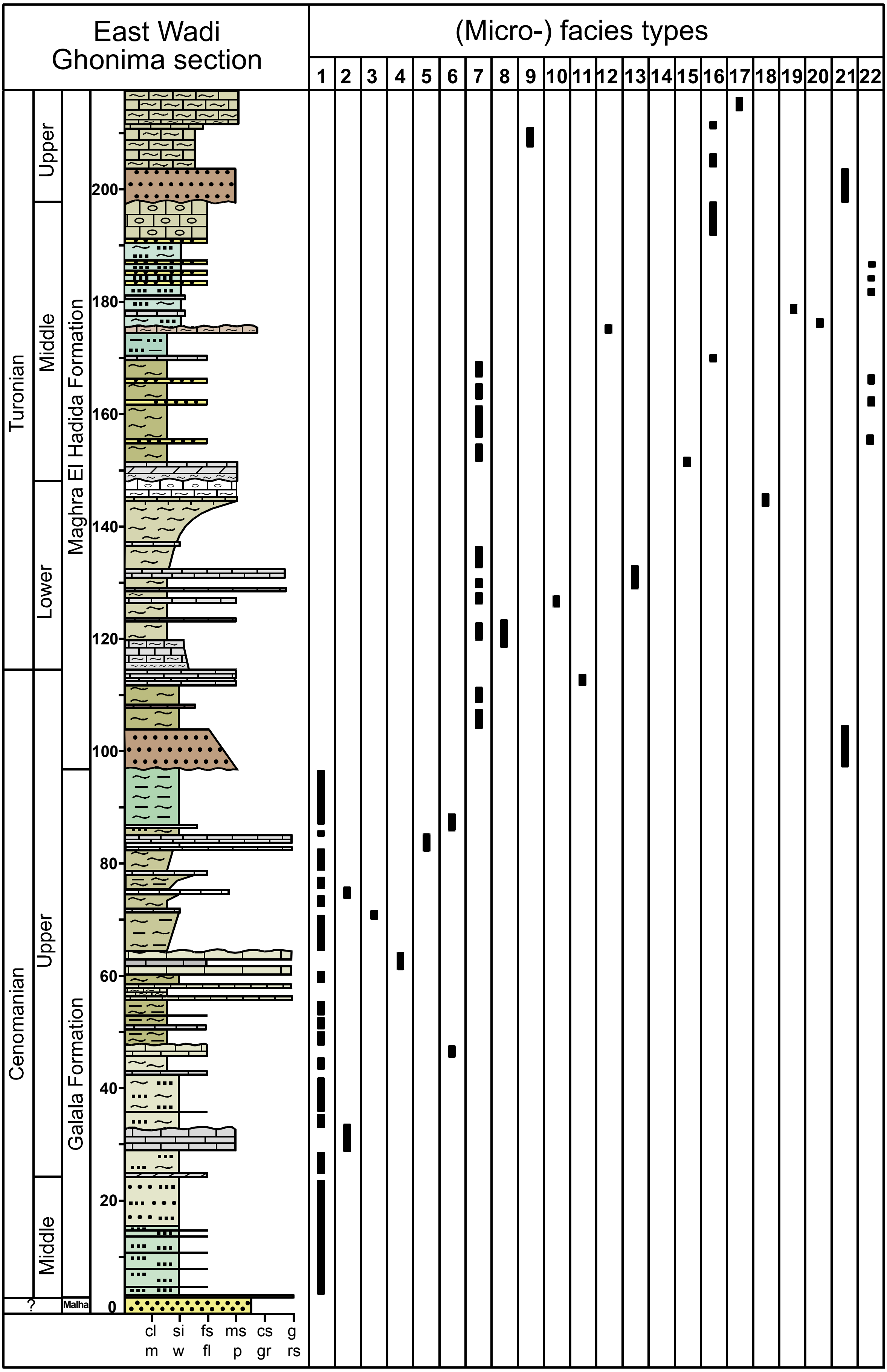
Distribution: FT1 constitutes the lower part of the Cenomanian Galala Formation and also occurs in at the middle and upper parts of the formation at East Wadi Ghonima section (Text-figs. 8.1–8.2).

FT2: Bioturbated mollusc-calcareous algae packstone (Text-fig. 8.3A-E).

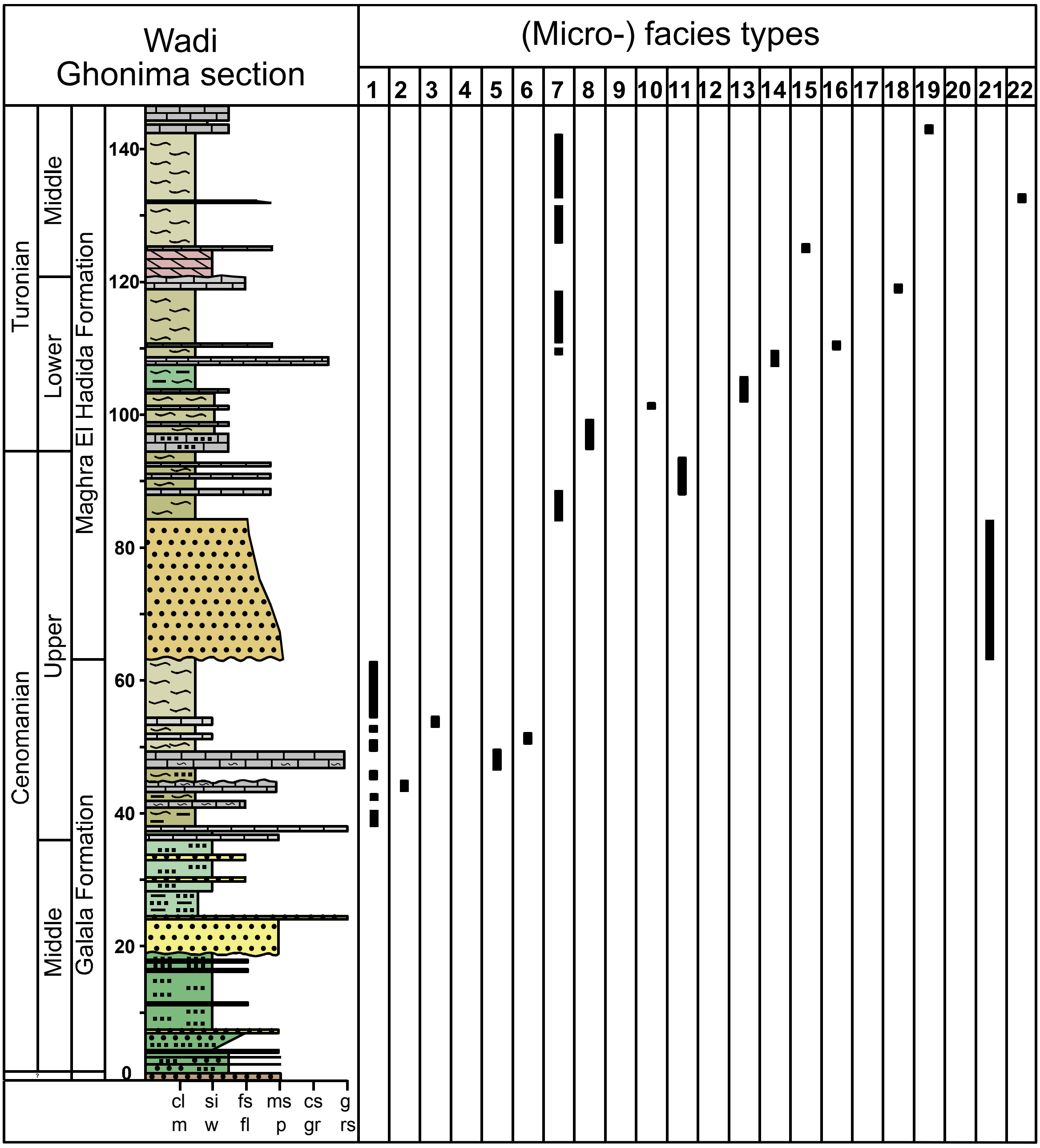
Description: Abundant udoteacean and dasycladalean algae (Text-fig. 8.4) such as *Halimeda* sp., *Neomeris mokragorensis* RADOICIC & SCHLAGINTWEIT and *Trinocladus divnae* RADOICIC are the most characteristic components of this facies type. Fine- to coarse-grained, recrystallized mollusc fragments (bivalve and gastropods) are common. Spines and corona fragments of echinoids as well as small oyster fragments with foliated shell structure are considered as accessory components. Bioturbation fabrics are well recognizable in this facies type and indicated by circular swirls (Text-fig. 8.3C) and the orientation of the components in distinctive directions (Text-fig. 8.3A) as well as a general inhomogeneous fabric. A late diagenetic selective dolomitization of burrows is often noted in this facies type.

Interpretation: The components of FT2 suggest a shallow, fully marine environment by the presence of echinoids, udoteacean and dasycladalean algae. The packstone fabrics indicate low to moderate water energy and the strong bioturbation considerable infaunal activity. An open-lagoonal setting without restriction is inferred.

Distribution: FT2 is well developed in the middle part of the Upper Cenomanian of the Galala Formation (Text-figs. 8.1–8.2).



Text-fig. 8.1. Stratigraphic distribution of the recognized (micro-) facies types at East Wadi Ghonima section. For key of symbols see Text-fig. 3.2.



Text-fig. 8.2. Stratigraphic distribution of the recognized (micro-) facies types at Wadi Ghonima section. For key of symbols see Text-fig. 3.2.

FT3: Bioturbated mollusc-dasycladalean wackestone (Text-fig. 8.3F-H).

Description: FT3 is similar to FT2, but differs in having finer grains and a more muddy matrix (i.e., wackestone). Furthermore, udoteacean algae are not so common. Abundant dasycladalean algae (*Neomeris mokragorensis* RADOICIC & SCHLAGINTWEIT and *Trinocladus divnae* RADOICIC) are the most characteristic components of this facies type. Some udoteacean algae (*Halimeda* sp.), fine-grained, recrystallized bioclasts and foraminifera (miliolids) occur. Rare bryozoa (Text-fig. 8.3 inset in F), small oyster fragments and echinoid spines are also observed.

Bioturbation fabrics are well recognizable in this facies type and indicated by the general inhomogeneous fabric. A late diagenetic selective dolomitization of burrows is often noted in this facies type, comparable to FT2.

Interpretation: The components of FT3 suggest a fully marine, shallow water environment by the presence of dasycladalean algae, echinoids and bryozoa. The wackestone fabrics indicate low water energy and the strong bioturbation considerable infaunal activity. An open-lagoonal setting without restriction is inferred.

Distribution: FT3 is well developed in the middle part of the Upper Cenomanian of the Galala Formation (Text-figs. 8.1–8.2).

FT4: Muddy oyster rudstone with superficial ooids (Text-fig. 8.5A-D).

Description: Abundant large and thick oyster shells showing foliated shell structure are the most characteristic components of this facies type. Most of these shells show intensive borings (*Entobia* isp. Type A and B). Superficial ooids with one or two laminae as well as some fine- to coarse-grained, recrystallized bivalve and gastropod fragments with udoteacean and dasycladalean algae (the same species as in FT2) are common. Few encrusting colonial serpulids as well as spines and corona fragment of echinoids are noted.

Interpretation: The components of FT4 suggest a shallow, fully marine environment by the presence of echinoids as well as dasycladalean and udoteacean algae. The muddy rudstone fabrics indicate moderate water energy and the presence of superficial ooids indicates that the local water energy was just high enough to move the smallest grains (FLÜGEL, 2004). The formation of the large bioclasts was mainly related to bioerosion. A shallow lagoonal setting without restriction is inferred.

Distribution: FT4 is well developed in the middle part of the Upper Cenomanian of the Galala Formation (Text-fig. 8.1).

FT5: Foraminiferal rudist-*Chondrodonta* float- to rudstone (Text-fig. 8.5E-H).

Description: Large and thick-shelled rudist (*Eoradiolites liratus*) and *Chondrodonta* shells are the most characteristic components of this facies type. Different types of benthic foraminifera (e.g. *Pseudolituonella reicheli* MARIE, 1954; *Textularia* sp.; *Quinqueloculina* sp.; *Pseudorhipidionina* cf. *casertana* [DE CASTRO, 1965]; *Cuneolina* ex gr. *pavonia* D'ORBIGNY, 1839; *Praealveolina cretacea* D'ARCHIAC, 1837) are common (Text-fig. 8.6). Oyster fragments, echinoderm debris, and dasycladalean algae are considered as accessory components. Rare, small recrystallized gastropods and udoteacean algae are noted. Some of the thicker shells have borings (*Entobia* isp.), which mainly occur in the originally aragonitic layers.

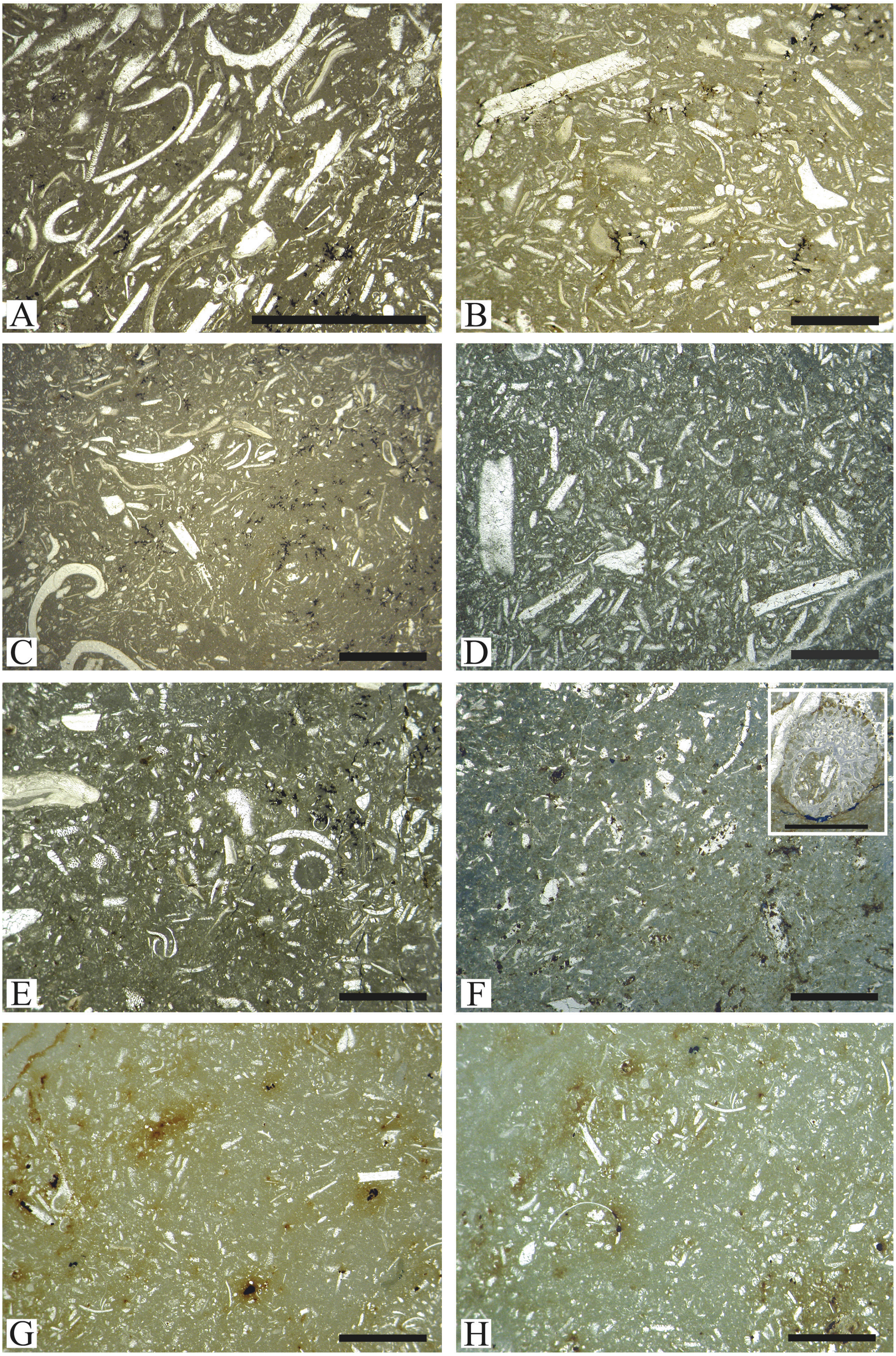
Interpretation: The components of FT5 suggest a shallow, normal marine environment. Moderate water energy is indicated by the present fabric and the large rudist fragments. The disintegration of the shells might be explained largely by bioerosion. The facies data indicate a fully marine lagoon as depositional environment.

Text-fig. 8.3. Upper Cenomanian microfacies of the Galala Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-E: FT2, bioturbated mollusc-calcareous algae packstone; A, 080217-3 EWG section; B, C, 080216-6 WG section; D, 080217-16 EWG section; and E, 080217-6 EWG section.

F-H: FT3, bioturbated mollusc-dasycladalean wackestone; bryozoa inset in Fig. F; F, 080217-15 EWG section; and G, H, 080216-10 WG section.

Text-fig. 8.3



Distribution: FT5 is well developed in the upper part of the Upper Cenomanian of the Galala Formation (Text-figs. 8.1–8.2).

FT6: Fenestral foraminifera wackestone (Text-fig. 8.7A-B).

Description: Birdseyes (irregular and oval in shape, millimeter-sized, blocky calcite-filled voids) and benthic foraminifera (miliolids and *Textularia*) are the most characteristic features of this facies type. Rarely, small bioclasts are noted.

Interpretation: The wackestone fabric with birdseyes and only few benthic foraminifera (especially miliolids) suggests a low-energy, shallow restricted lagoonal (inter- to supratidal) environment with potentially weakly increased salinities.

Distribution: FT6 is developed in the middle and upper parts of the Upper Cenomanian Galala Formation (Text-figs. 8.1–8.2).

8.2. (Micro-) facies types (FT) of the Maghra El Hadida Formation.

FT7: Thick-bedded fine-grained marl.

Description: Brownish-yellow, thick-bedded, soft marl with very thin limestone bands. The lower part of this facies type yielding upper Upper Cenomanian ammonites (*Vascoceras cauvini*), while the upper fossiliferous part yielding Lower Turonian ammonites (*Vascoceras proprium* and the *Choffaticeras* interval).

Interpretation: This facies type seems to be the deepest part of the Maghra El Hadida Formation and is considered as a deep subtidal deposit.

Distribution: FT7 is well developed in the lower and middle parts of the Upper Cenomanian – Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT8: Ammonite-filament-bearing planktic foraminifera wackestone (Text-fig. 8.7C-D).

Description: Abundant planktic foraminifera are the most characteristic components of this facies type. The bulk of these forams are non-keeled, while very rare keeled ones are noted. This facies type contains common filaments and small ammonites. Rare echinoderm debris is observed.

Interpretation: The abundant planktic foraminifera with filaments and ammonites in wackestone fabric suggest an open marine, deep subtidal environment with low energy.

Distribution: FT8 is well developed in the lower part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

Text-fig. 8.4. Calcareous algae from the Upper Cenomanian of the Galala Formation.
Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-B: Fragments of Halimedaceae indet.; A, B, 080217-3 EWG section.

C-F: *Neomeris mokragorensis* RADOICIC & SCHLAGINTWEIT; C, D, F, 080217-3 EWG section; and E, 080217-6 EWG section.

G-H: *Trinocladus divnae* RADOICIC; G, 080217-16 EWG section; and H, 080217-6 EWG section.

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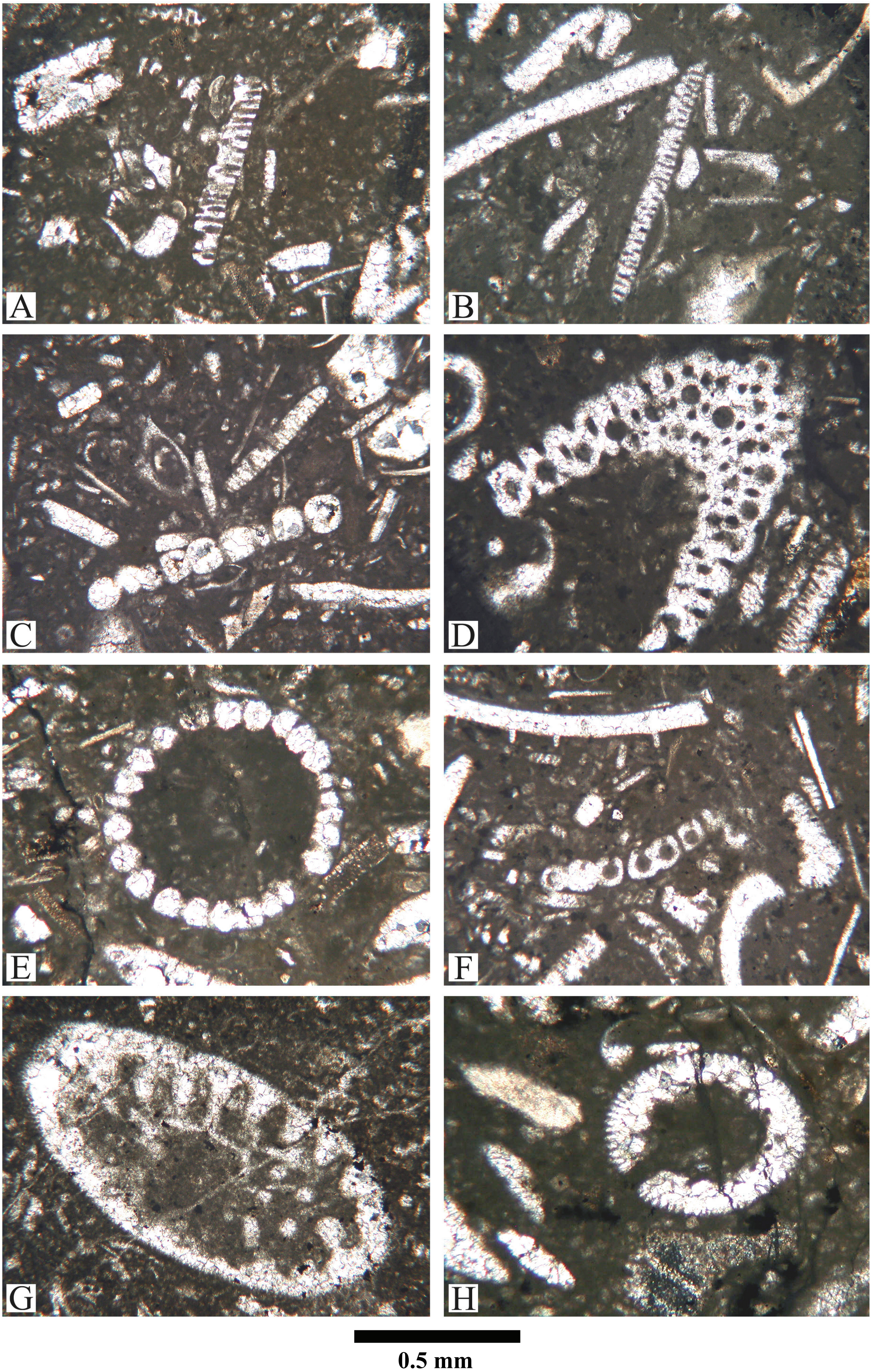
Text-fig. 8.4



FT9: Bioclastic wackestone with filaments (Text-fig. 8.7E-F).

Description: Fine- to medium-grained, recrystallized mollusc fragments (gastropods and bivalves) are the most characteristic components of this facies type. Some filaments and echinoderm debris as well as rare ostracods occur. Bioturbation (burrows filled with fecal pellets) is noted.

Interpretation: The components and texture of FT9 suggest an open marine, subtidal environment with low-energy.

Distribution: FT9 is well developed in the upper part of the Turonian Maghra El Hadida Formation (Text-fig. 8.1).

FT10: Bioclastic planktic foraminifera packstone (Text-fig. 8.7G-H).

Description: Abundant planktic, non-keeled foraminifera are the most characteristic components of this facies type. Filaments, small fragments of bivalves as well as small oyster shells are common and considered as accessory components. Echinoderm debris and rare ammonites are noted.

Interpretation: The components and texture of FT10 suggest open marine, deep subtidal deposition with low- to moderate-energy.

Distribution: FT10 is well developed in the lower part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT11: Fine-grained peloidal packstone.

This facies type can be subdivided into two subtypes: fine-grained peloidal packstone with and without crustacean coprolites.

FT11A: Fine-grained peloidal packstone (Text-fig. 8.8A-B).

Description: Abundant, densely packed, fine-grained peloids are the most characteristic component of this facies type. Rare ammonites and planktic foraminifera are noted. Bioturbation is indicated by patchy distribution of the components.

Interpretation: The presence of planktonic foraminifera and ammonites in the peloidal packstone facies indicates relatively deep subtidal conditions with low to moderate water energy, but the water depth was shallower than for FTs 7-10.

Distribution: FT11A is well developed in the lower part of the Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT11B: Fine-grained peloidal packstone, with coprolites (Text-fig. 8.8C-D).

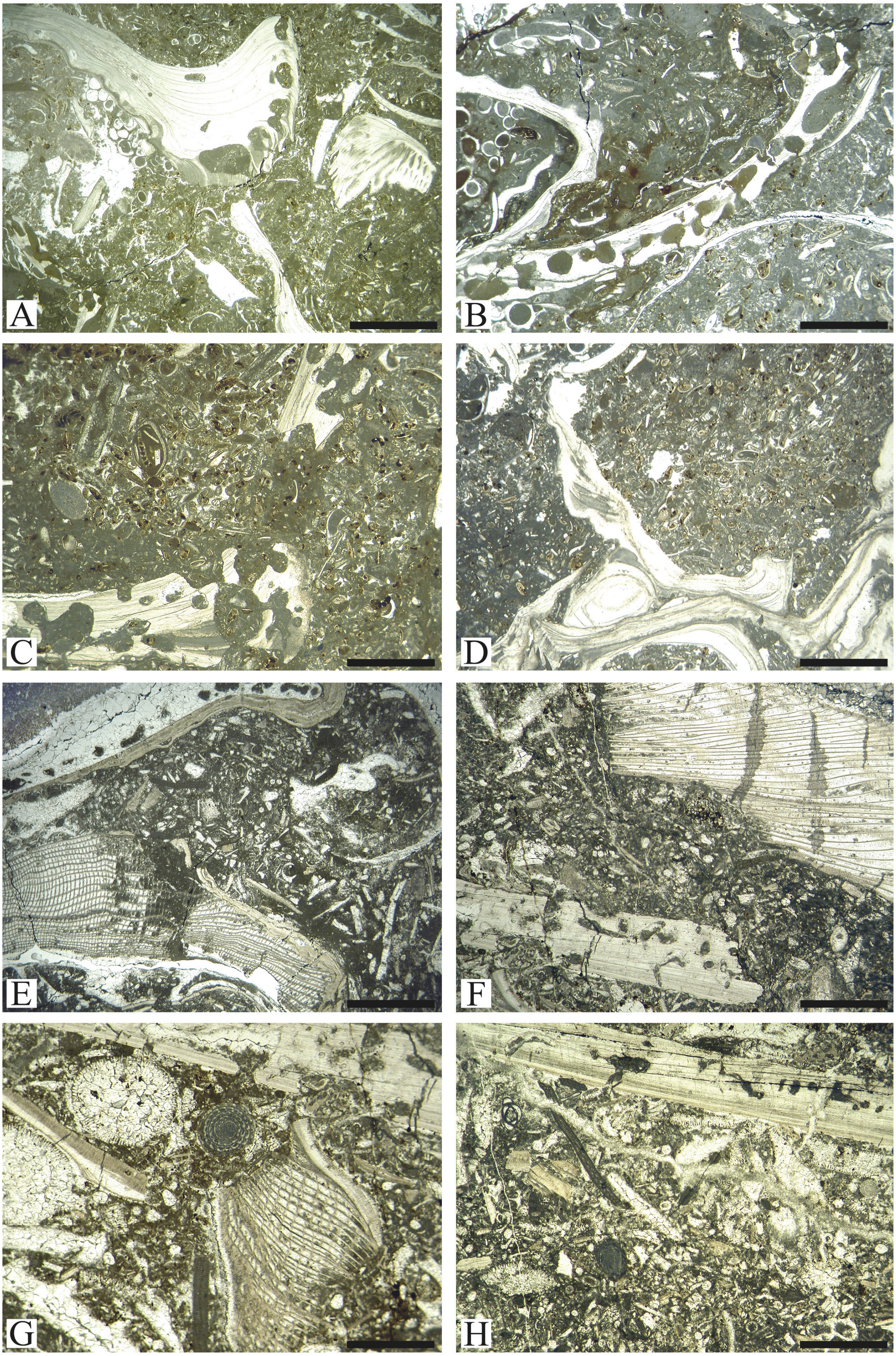
Description: This facies-sub-type is similar in fabric and components to FT11A, but differs in having abundant and diverse types of crustacean microcoprolites (such as *Palaxius caucaensis* BLAU et al., 1995), (Text-fig. 8.9).

Text-fig. 8.5. Upper Cenomanian microfacies of the Galala Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-D: FT4, muddy oyster rudstone, with superficial ooids; A, B, 080217-12 EWG section; and C, D, 080217-13 EWG section.

E-H: FT5, foraminiferal rudist-*Chondrodonta* float- to rudstone; E, 080217-18 EWG section; and F-H, 080213-2 WG section.

Text-fig. 8.5



Interpretation: Based on the interfingering with ammonite- and filament-bearing facies, a subtidal fully marine setting with low to moderate water energy is inferred.

Distribution: FT11B is well developed in the lower part of the Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT12: Bioclastic peloidal wackestone (Text-fig. 8.8E-F).

Description: Abundant fine peloidal grains are the most characteristic components of this facies type. A few recrystallized bivalves and coprolites are considered as accessory components. Bioturbation is recognizable in this facies type, indicated by a general inhomogeneous fabric. Furthermore, a late diagenetic selective dolomitization of burrows is often noted.

Interpretation: Normal marine conditions are suggested for FT12. The wackestone fabrics indicate low water energy and the bioturbation considerable infaunal activity. The components and fabric of this facies type suggest a warm subtidal environment.

Distribution: FT12 occurs in the middle part of the Maghra El Hadida Formation (Text-fig. 8.1).

FT13: Muddy bioturbated mollusc float- to rudstone (Text-fig. 8.8G-H, 8.10A-B).

Description: Abundant large mollusc fragments (bivalves, gastropods and ammonites) are the most characteristic components of this facies type. Fine- to coarse-grained, recrystallized shell fragments as well as spines and corona fragments of echinoids and small oyster fragments are common and considered as accessory components. Rare benthic foraminifera (textulariids) and crustacean microcoprolites are noted. Some shells are showing clionid sponge borings (*Entobia* isp.). Bioturbation fabrics are well recognizable in this facies type and indicated by circular swirls (Text-fig. 8.8H). Furthermore, repeated reworking of the components is observed by means of overturned geopetal fabrics. A late diagenetic selective dolomitization of burrows is noted in this facies type. This facies type is highly fossiliferous, yielding abundant Lower Turonian ammonites.

Interpretation: The components of FT13 suggest a deep subtidal setting by the presence of ammonites. This facies type represents a condensed deposit with abundant shell fragments due to bioerosion and reworking by moderate water energy. A moderately deep subtidal setting is inferred, subject to episodically increased water energy.

Distribution: FT13 is developed in the middle Lower Turonian part of the Maghra El Hadida Formation (Text-figs. 8.1–8.2).

Text-fig. 8.6. Benthic foraminifera from the Upper Cenomanian Galala Formation.
All scale bars equal 0.5 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-B: *Pseudolituonella reicheli* MARIE, 1954.

C-D: *Textularia* sp.

E-H: *Quinqueloculina* sp.

I: *Pseudorhipidionina* cf. *casertana* (DE CASTRO, 1965).

J-M: *Cuneolina* ex gr. *pavonia* D'ORBIGNY, 1839.

N-S: *Praealveolina cretacea* D'ARCHIAC, 1837.

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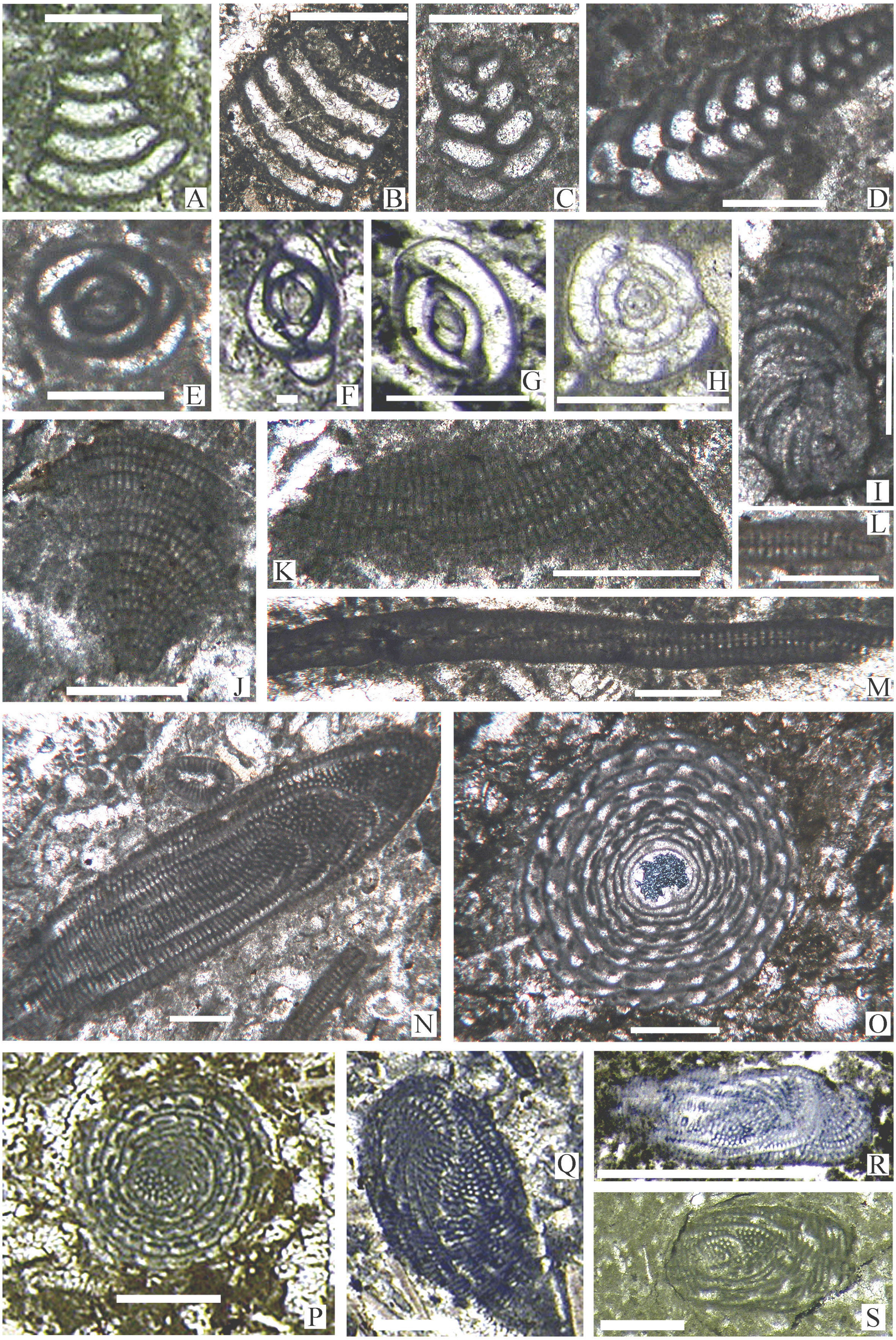
Text-fig. 8.6



FT14: Phosphorite-bearing, muddy bivalve rudstone (Text-fig. 8.10C-F).

Description: Abundant fine- to coarse-grained, recrystallized bivalve fragments with fine- to medium-grained phosphorite particles are the most characteristic components of this facies type. Some of the bivalves show prismatic shell structure whereas the bulk is completely recrystallized. Disintegrated, small and completely recrystallized gastropod shells as well as echinoderm debris are considered as accessory components. Rare benthic foraminifera (textulariids), serpulids and lithoclasts are noted.

Interpretation: This facies type is characterized as a condensed deposit, indicated by enrichment of phosphatic material. The abundant bioclasts are predominantly related to bioerosion. Moderate energy at the transition between the shallow and deep subtidal setting is inferred.

Distribution: FT14 is occurs in the middle Lower Turonian part of the Maghra El Hadida Formation (Text-fig. 8.2).

FT15: Bioclastic bivalve pack- to rudstone (Text-fig. 8.10G-H).

Description: Densely packed, bioclastic packstone or muddy rudstone characterized by accumulations of commonly one type of shells. These shell concentrations consists of small- to medium-sized, thin-shelled, recrystallized bivalves which are considered as the most characteristic components of this facies type. In some cases, the shells are concentrated in cm-sized burrows. Oyster fragments and small recrystallized gastropods are common. Fine glauconite grains as well as echinoderm debris are considered as accessory components. Rare lithoclasts are noted. Shelter porosity and vadose silt are observed in rudstone fabric (Text-fig. 8.10H).

Interpretation: The components of FT15 suggest normal marine conditions. Storm-influence (tempestites) is indicated by the shell concentrations of disarticulated, convex-up oriented bivalve shells, due to short-term high-energy conditions. A shallow subtidal setting without restriction is inferred, below fair-weather wave base. The densely packed shells in burrows may represent tubular tempestites (TEDESCO & WANLESS, 1991).

Distribution: FT15 occurs in the middle part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

Text-fig. 8.7. Microfacies of the Upper Cenomanian of the Galala Formation and the Lower Turonian of the Maghra El Hadida Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

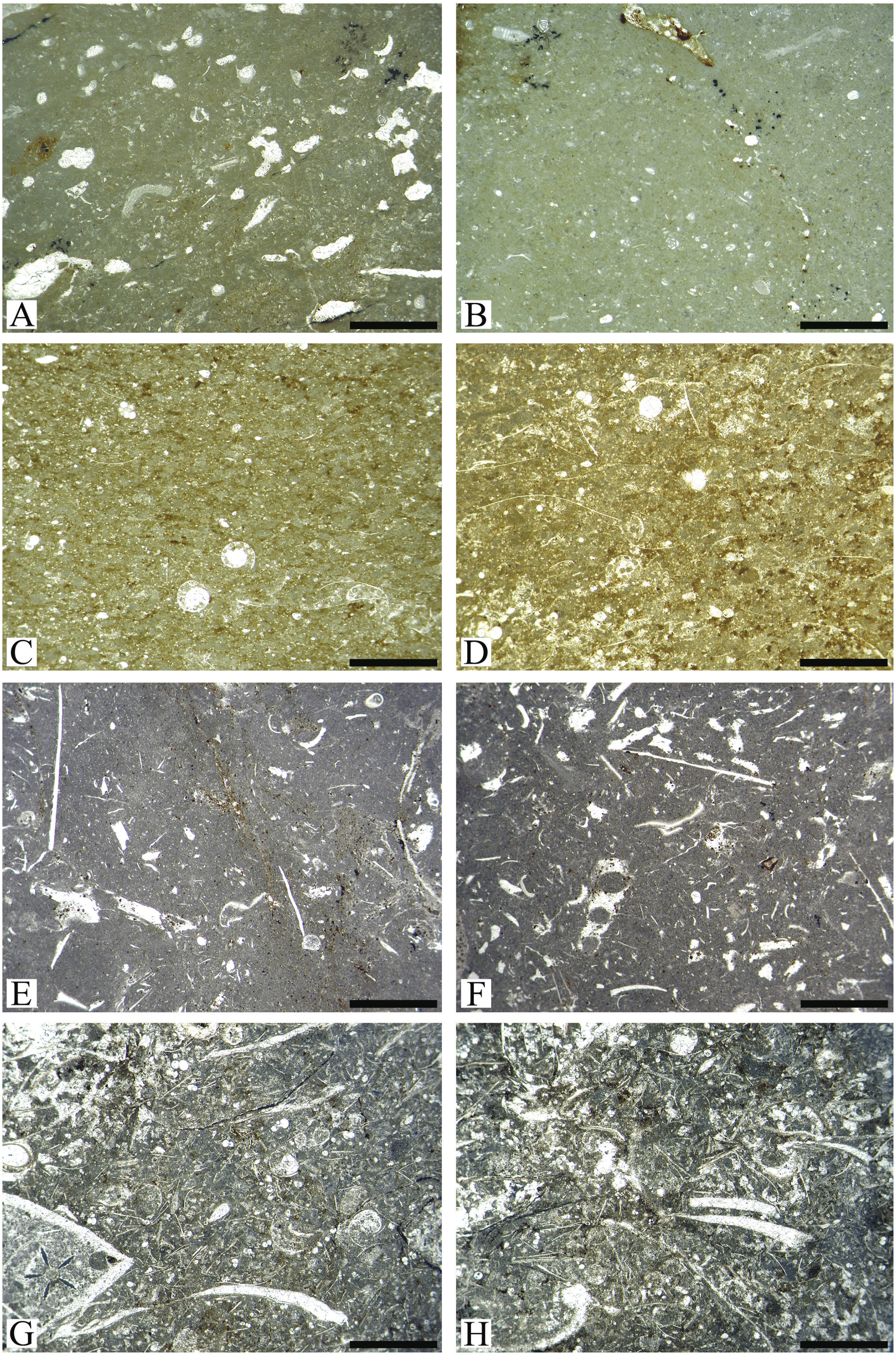
A-B: FT6, fenestral foraminifera wackestone; 080216-9 WG section.

C-D: FT8, Ammonite-filament planktic foraminifera wackestone; C, 080217-18.5 EWG section; and D, 080216-13 WG section.

E-F: FT9, Bioclastic wackestone, with filaments; 080217-41.5 EWG section.

G-H: FT10, Bioclastic planktic foraminifera packstone; 080217-19 EWG section.

Text-fig. 8.7



FT16: Bioclastic mollusc packstone (Text-fig. 8.11A-C).

Description: Abundant fine- to coarse-grained, recrystallized mollusc fragments (bivalves and gastropods) are the most characteristic components of this facies type. Small oyster fragments showing foliated shell structure as well as spines and corona fragment of echinoids are common. Some lithoclast grains and a few colonial encrusting serpulids as well as rare ostracods are noted.

Interpretation: The components of FT16 suggest a normal marine environment. The packstone fabrics indicate low to moderate water energy as the bioclasts are considered to have been formed predominantly by bioerosion. An open-shallow subtidal setting is inferred.

Distribution: FT16 is developed in the middle and upper part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT17: Peloidal bivalve packstone (Text-fig. 8.11D-E).

Description: Abundant fine- to coarse-grained, recrystallized bivalve fragments and fine peloidal grains are the most characteristic components of this facies type. Few oyster fragments showing foliated shell structure and bioturbation fabrics are observed. Rare recrystallized gastropod fragments as well as calcified cyanobacteria (*Cayeuxia*?) are noted.

Interpretation: The components of FT17 suggest a normal marine, relatively shallow environment. The packstone fabrics indicate low to moderate water energy, and the bioturbation considerable infaunal activity. A shallow subtidal setting is inferred.

Distribution: FT17 is well developed in the upper part of the Turonian Maghra El Hadida Formation (Text-fig. 8.1).

FT18: Udoteacean packstone (Text-fig. 8.11F-H, 8.12A-C).

Description: Abundant udoteacean algae (*Halimeda* cf. *elliotti* CONARD & RIOULT) are the most characteristic components of this facies type. However, their density differs from one thin-section to another. Spines and corona fragments of echinoids as well as fine-grained, recrystallized mollusc fragments (bivalve and gastropods) are common. A few small oyster fragments as well as rare ostracods, bryozoa and serpulids are noted. Bioturbation fabrics are recognizable in this facies type and indicated by a general inhomogeneous fabric. A late diagenetic selective dolomitization of burrows is often noted in this facies type.

Text-fig. 8.8. Lower Turonian microfacies of the Maghra El Hadida Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

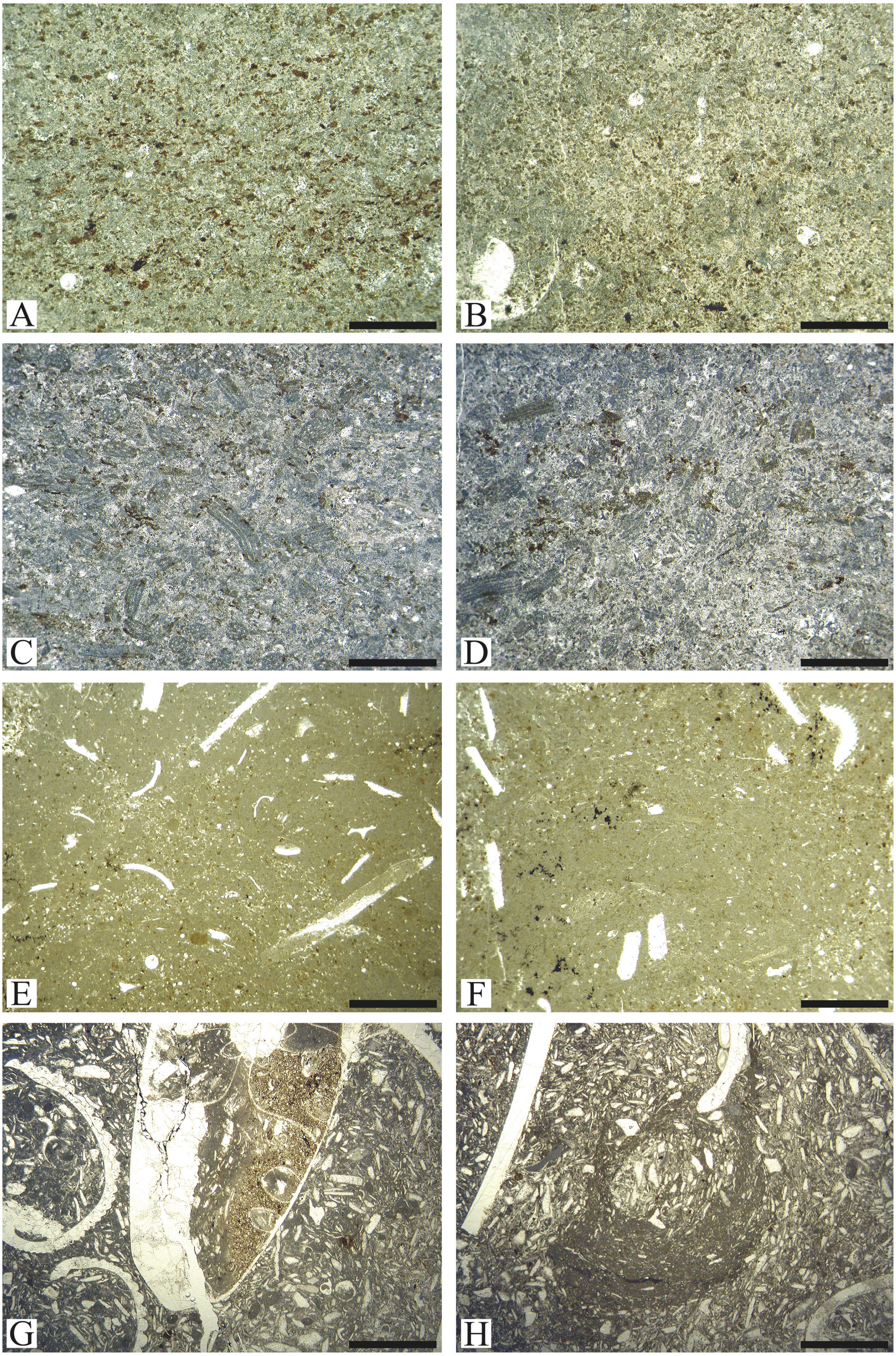
A-B: FT11 A, fine-grained peloidal packstone; A, 080215-6 WG section; and B, 080217-22 EWG section.

C-D: FT11 B, fine-grained peloidal packstone, with coprolites; C, 080215-7 WG section; and D, 080217-23 EWG section.

E-F: FT12, Bioclastic peloidal wackestone; 080217-34 EWG section.

G-H: FT13, Muddy bioturbated mollusc float- to rudstone; 080217-25 EWG section. Note overturned geopetal fabric in G.

Text-fig. 8.8



Interpretation: The components of FT18 suggest a shallow marine, warm-water environment. The packstone fabrics indicate low to moderate water energy. Due to abundant udoteacean algae and the other skeletal grains, an open-lagoonal setting without restriction is inferred.

Distribution: FT18 is well developed in the middle part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

FT19: Homogenous mudstone (Text-fig. 8.12D).

Description: FT19 is characterized by the nearly complete absence of skeletal or non-skeletal grains, except rare shell fragments of bivalves and thin-shelled ostracods.

Interpretation: The extreme low content of components of this facies type suggests a shallow, low-energy lagoonal setting with some sort of restriction, maybe representing intertidal mudflats.

Distribution: FT19 occurs in the upper part of the Turonian Maghra El Hadida Formation (Text-fig. 8.1, 2).

FT20: Pisolithic, bio- and lithoclastic grainstone (Text-fig. 8.12E-F).

Description: Abundant pisolithic, bio- and lithoclastic grains are the most characteristic components of this facies type. Echinoderm debris as well as a few superficial ooids with one or two laminae occur. Rare benthic foraminifera are noted.

Interpretation: The components of FT20 reflect high-energy conditions. This facies type represents a transgressive lag onlapping and infilling the relief of a mid-Turonian unconformity (see Chapter 9).

Distribution: FT20 is represented in the upper part of the Turonian Maghra El Hadida Formation (Text-fig. 8.1).

FT21: Thick fine- to medium-grained sandstone (Text-fig. 8.12G).

Description: This facies type is characterized by nodular fabrics and wood fragments in varicoloured, friable, quartz-rich, fine- to medium-grained sandstones with bioturbation. The microfacies shows ferruginous quartz sandstone with moderate to good sorting but poor rounding. Occasional sandstone pebbles and trough-cross bedding may occur.

Interpretation: This facies type represents channel deposits and probably channel fills of marginal rivers and estuaries. Fluvial to marginal marine (brackish) conditions are inferred.

Distribution: FT21 is well developed in the lower and upper part of the Upper Cenomanian – Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2), associated with two major unconformities (See Chapter 9).

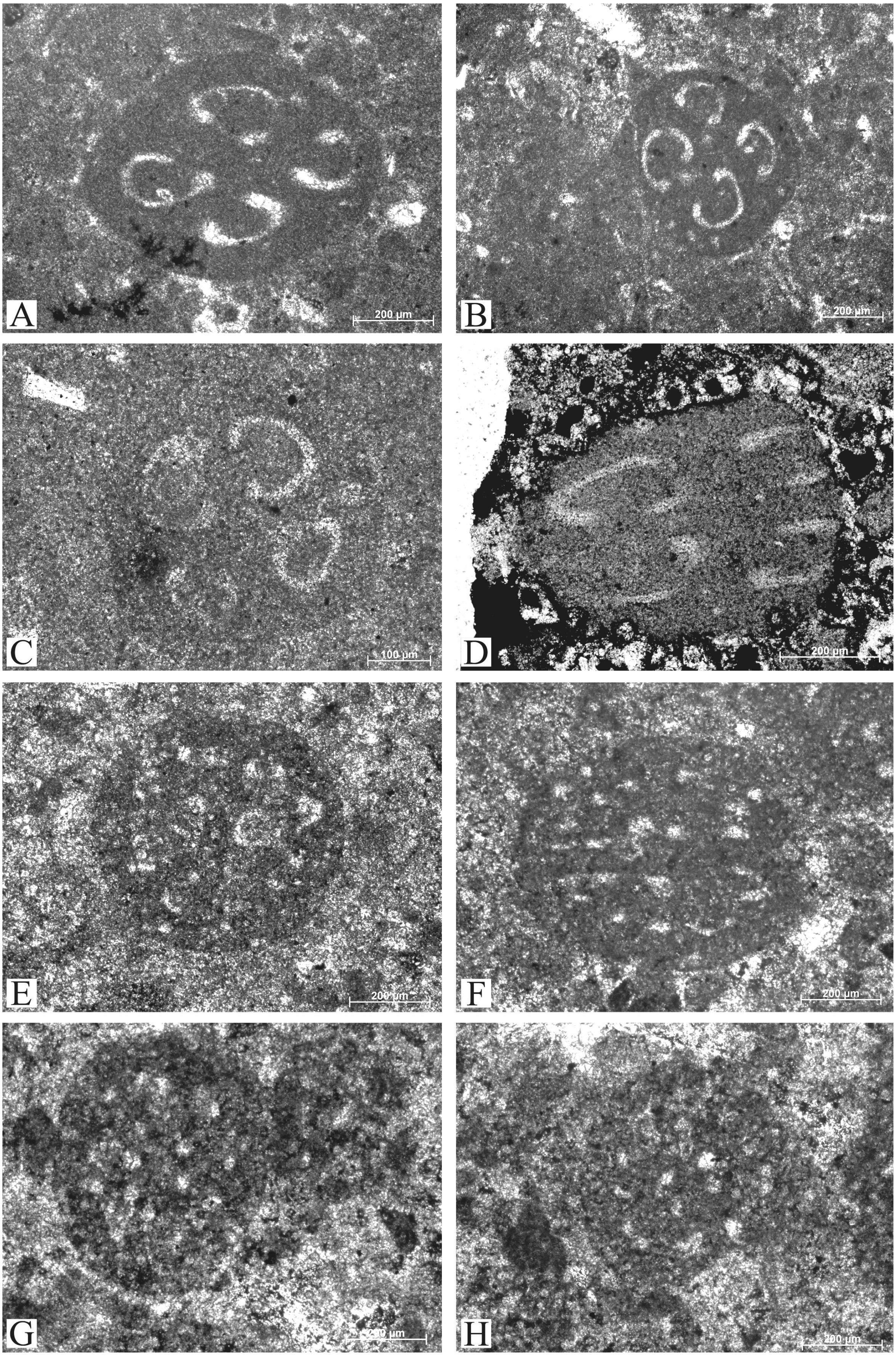
Text-fig. 8.9. Crustacean microcoprolites from the Maghra El Hadida Formation.
Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-D: *Palaxius caucaensis* BLAU et al., 1995; 080217-3 EWG section.

E-H: *Palaxius* sp.; 080217-23 EWG section.

Det. Prof. Dr. BABA SENOWBARI-DARYAN, May 2009.

Text-fig. 8.9



FT22: Sharp-based, medium- to coarse-grained sandstone (Text-fig. 8.12H).

Description: Hummocky cross-stratified, brownish, medium- to coarse-grained sandstone. This facies type is represented by thin intercalations (cm-dm) of sandstone with sharp bases and normal grading into thick marl sediments. The microfacies shows ferruginous quartz sandstone.

Interpretation: Storm action is documented by hummocky cross-stratification and grading. Therefore, a storm-dominated (tempestite) shelf environment (deep subtidal above storm wave-base) is inferred.

Distribution: FT22 is well developed in the middle part of the Turonian Maghra El Hadida Formation (Text-figs. 8.1–8.2).

8.3. Depositional environment of the Galala Formation.

During Cenomanian times, the study area was situated at the southern margin of the Tethyan Realm. A marine transgression started at the base of the Galala Formation, documented by the marine sediments of the Galala Formation deposited above the non-marine sandstone of the Malha Formation. This transgression has been recorded in many countries around the world, indicating its eustatic origin, e.g. KASSAB (1991, 1994), KASSAB & ISMAEL (1994) from Egypt; BUSSON (1972), COLLIGNON & LEFRANC (1974) from the Saharan Platform; ABDALLAH & MEISTER (1997) from central Tunisia; MEISTER et al. (1992), MEISTER & ABDALLAH (1996) from West Africa; FLOQUET (1984) from Spain; HANCOCK & KAUFFMAN (1979), HAQ et al. (1987), WILMSEN (2003) from western Europe). The facies types of the upper Middle – Upper Cenomanian Galala Formation suggest a fully marine, lagoonal environment during the deposition of this formation. The basal part of the Galala Formation is represented by thick-silty marl (FT1). This facies type was rapidly succeeded, as sea-level rose, by a thick succession of grayish green, fine-grained, thick-bedded soft silty marl sediments formed below the FWWB in a deep-lagoon environment (Text-fig. 8.13). The bulk of the middle part of the Galala Formation (FT2, FT3) was deposited in a fully marine, open-lagoon setting (Text-fig. 8.13). Warm water with low to moderate water energy at 10–15m depth is suggested as the environment for this interval depending on the high content of euphotic biota (udoteacean and dasycladalean algae) with echinoid debris as well as bivalve and gastropod fragments in wacke- to packstone fabric (FLÜGEL, 2004). FT4 and FT5 dominate in the upper part of the Galala Formation, characterized by rudists, *Chondrodonta* and benthic foraminifera in float- to muddy rudstone fabric, indicating normal salinity, moderate water energy and warm shallow water (less than 10 m depth) in a shallow-lagoon environment (Text-fig. 8.13).

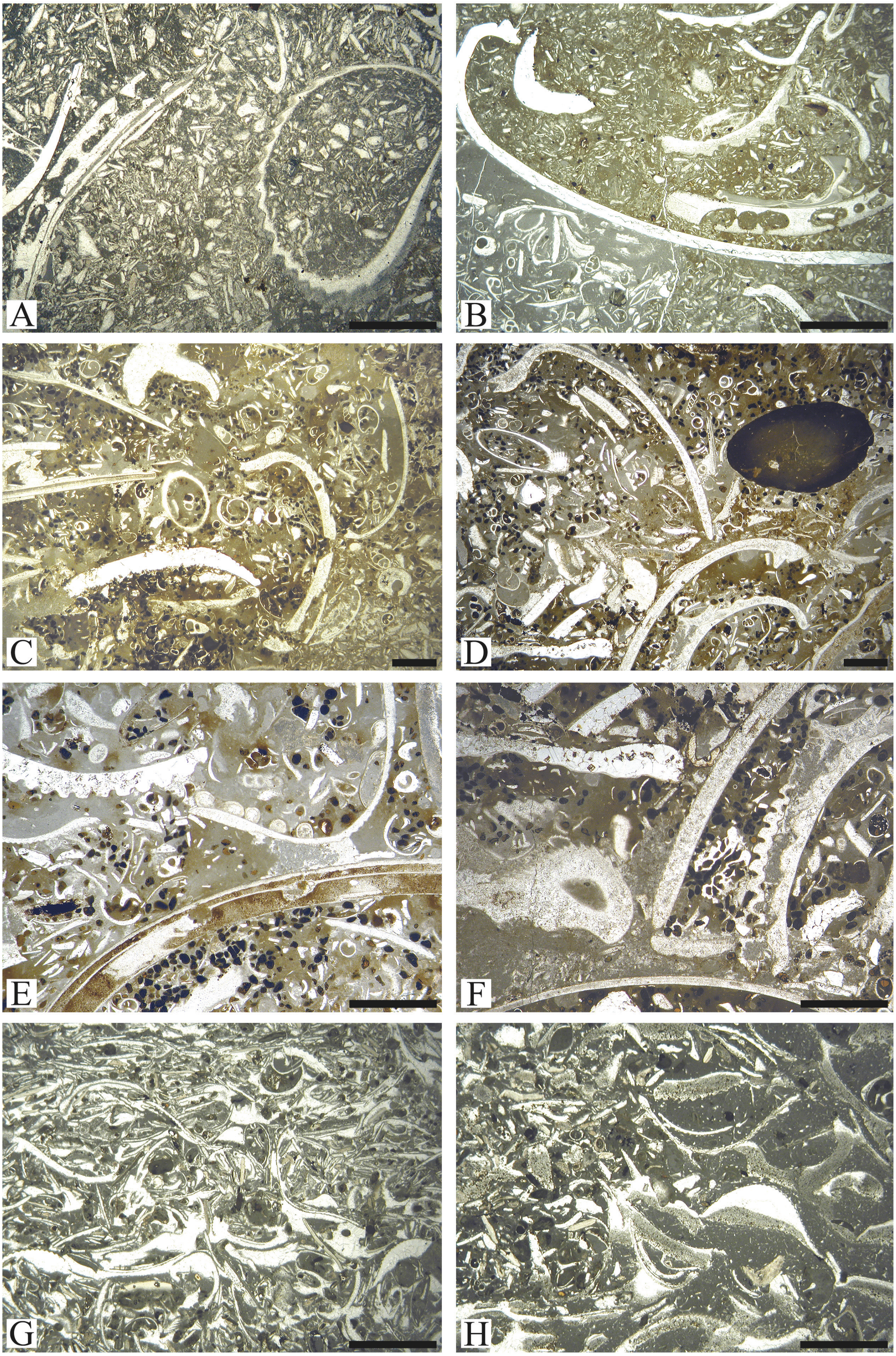
Text-fig. 8.10. Turonian microfacies of the Maghra El Hadida Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

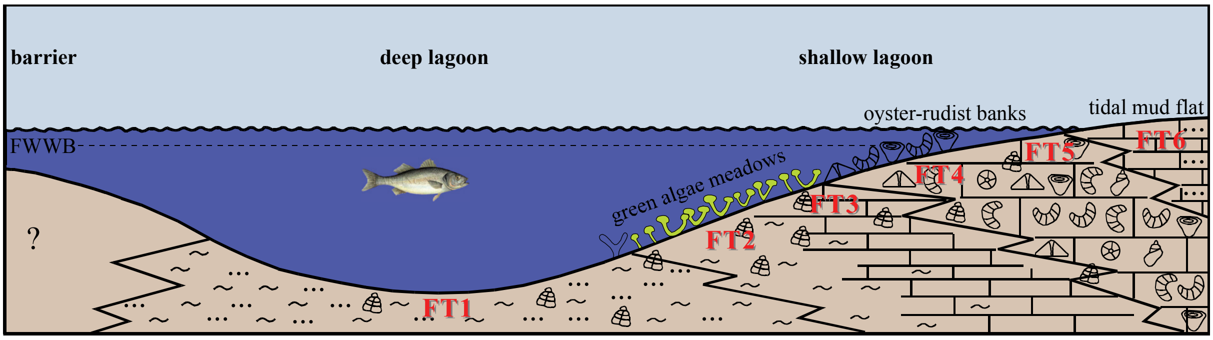
A-B: FT13, muddy bioturbated mollusc float- to rudstone; A, 080217-25 EWG section; and B, 080215-2 WG section.

C-F: FT14, phosphorite-bearing, muddy bivalve rudstone; 080216-16 WG section.

G-H: FT15, bioclastic bivalve pack- to rudstone; G, 080216-22 WG section; and H, 080217-31 EWG section.

Text-fig. 8.10





Text-fig. 8.13. Depositional environment of the Galala Formation.
For key of symbols see Text-fig. 8.14

Most parts of the middle and upper Galala Formation are rich in with suspension-feeding epifauna (oysters *Ceratostreon flabellatum*, *Ilymatogyra africana*, *Costagyra olisiponensis*), requiring a nutrient-rich and well oxygenated water column. The top part of the Galala Formation documents a restricted lagoon (inter- to supratidal) environment with high salinity and low water energy as indicated by fenestral wackestone fabrics with birdseyes and an impoverished fauna with only few benthic foraminifera (miliolids).

8.4. Depositional environment of the Maghra El Hadida Formation.

The most appropriate model for the Maghra El Hadida Formation appears to be a very low-gradient homoclinal carbonate ramp. The absence of a slope or a shelf-break is corroborated by the lack of resedimented lowstand deposits (see chapter 9). The facies types of the Maghra El Hadida Formation suggest a deposition in an open-marine ramp setting ranging from deep-subtidal to intertidal environments. The deepest part of the Maghra El Hadida Formation (FT7) is represented by thick-bedded, fine-grained marl with very thin, fossiliferous limestone bands, with latest Cenomanian and Early Turonian ammonites which is interpreted to be deposited in a deep subtidal environment (Text-fig. 8.14). The uppermost Cenomanian to lower Lower Turonian sediments of the Maghra El Hadida Formation contain abundant planktic foraminifera, filaments and ammonites in wackestone fabric, suggesting a deposition in a normal marine, deep subtidal environment with low water energy (FT8). The amount of the planktic foraminifera and filaments increased in packstone texture (FT10), indicating also a deep subtidal setting with moderate water energy. Intercalated limestone beds are characterized by fine peloidal packstone with coprolites (FT11) indicating the deposition in normal marine, slightly shallower parts of the subtidal environment (Text-fig. 8.14) with low- to moderate water energy.

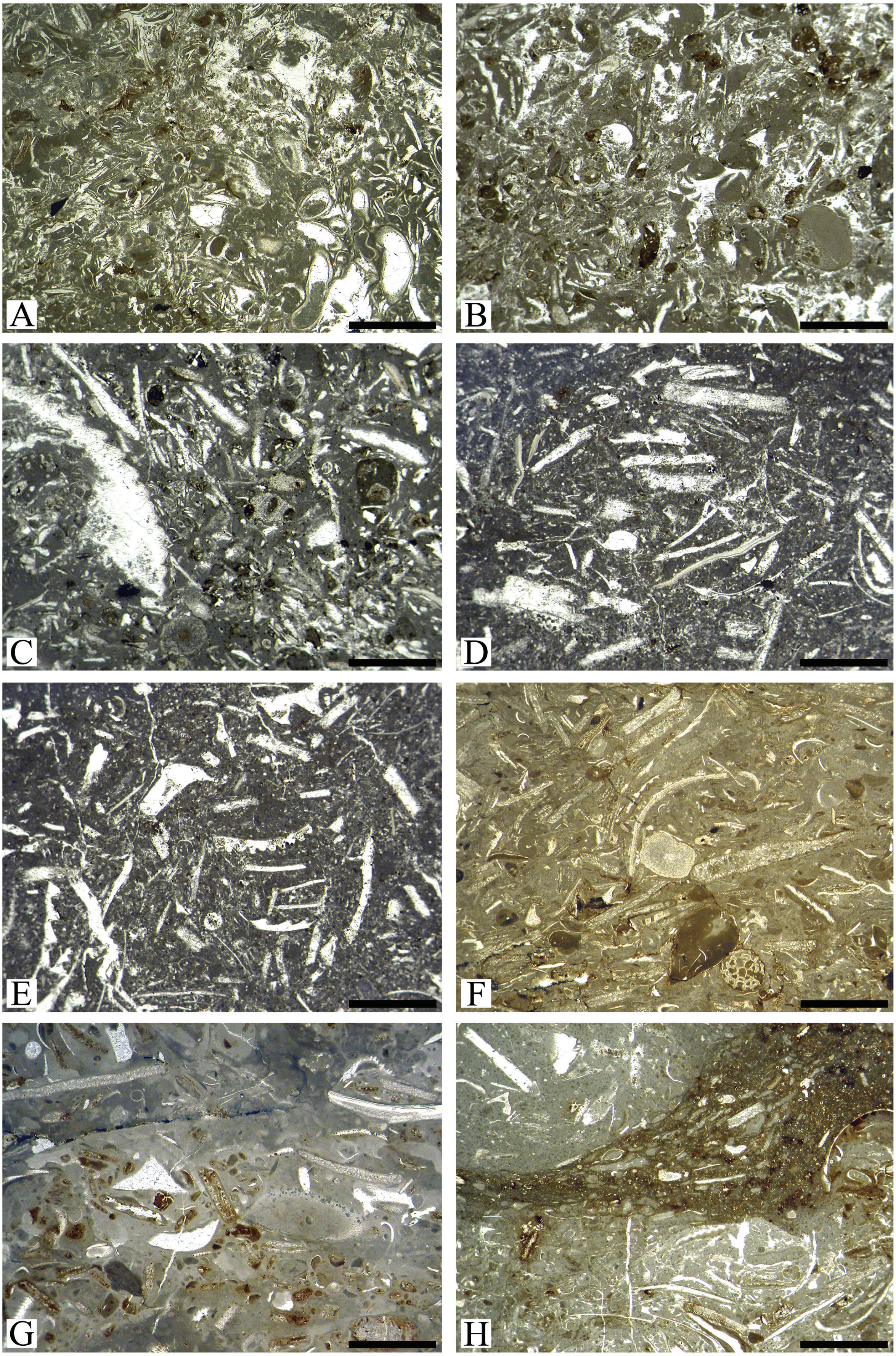
Text-fig. 8.11. Turonian microfacies of the Maghra El Hadida Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

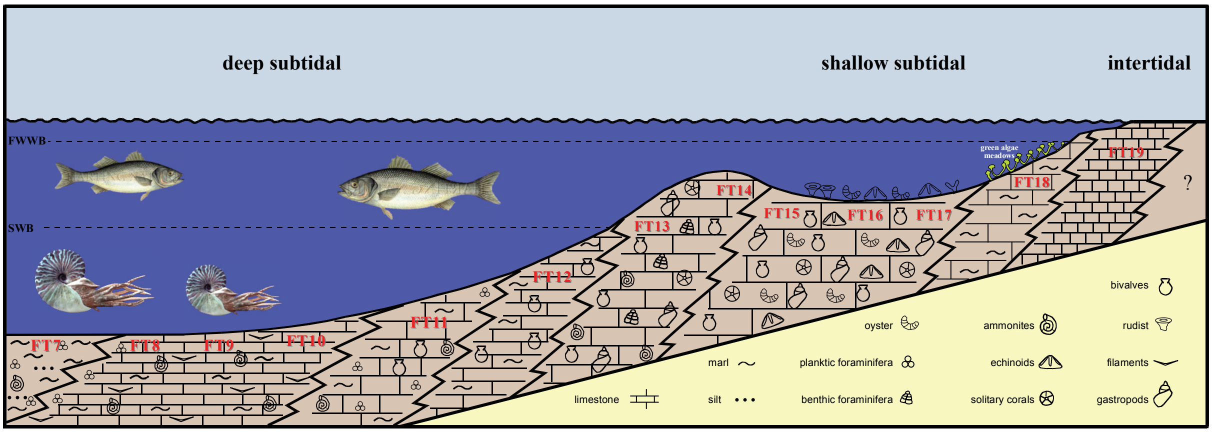
A-C: FT16, bioclastic mollusc packstone; A, 080216-17 WG section; and B, C, 080217-40 EWG section.

D-E: FT17, peloidal bivalve packstone; 080217-43 EWG section.

F-H: FT18, Udoteacean packstone; F, 080217-29 EWG section; G, 080216-19 WG section; and H, 080217-28 EWG section.

Text-fig. 8.11





Text-fig. 8.14. Depositional environment of the Maghra El Hadida Formation.

In the middle part of the Lower Turonian, FT13 with abundant large mollusc fragments (ammonites, bivalves, gastropods) as well as spines and corona fragments of echinoids in bioturbated float- to rudstones and muddy rudstones with phosphatic material (FT14) indicate condensation with reworking by moderate water energy and shell fragmentation due to bioerosion. Towards the end of the Lower Turonian, the shallowing episodes from deep to shallow subtidal settings is indicated by bioclastic mollusk packstones (FT16-17) and udoteacean packstones (FT18). The Lower Turonian is terminated by a prominent palaeo-karst horizon indicating the end of the transgressive/regressive cycles which started with the Cenomanian Galala Formation.

The Middle Turonian deposits are initially represented by strongly bioclastic packstone or muddy rudstones characterized by accumulations of commonly one type of shells (FT15), suggesting normal marine conditions under storm-influence (tubular tempestites and convex-up shells indicate short-term, high-energy conditions). Up-section, thick-bedded marl predominates (FT7). Storm influence is documented by intercalated hummocky cross-stratified sandstone beds (FT22). These strata are interpreted to have been deposited above storm wave-base in a subtidal environment (Text-fig. 8.14). Within and towards the end of the Middle Turonian, the environment shallowed again which is indicated by the deposition of FT 19 and FT20 (slightly restricted mudstones and pisolithic-bioclastic grainstones) and mollusc packstones (FT16), suggesting a shallow to marginal marine settings (Text-fig. 8.14). At the transition from the Middle to Upper Turonian, the intercalation of thick-bedded sandstones (FT21) suggest a significant regression with the deposition of estuarine sediments. In the Upper Turonian, the environment fluctuated between shallow and moderately deep subtidal settings, indicated by the deposition of packstone with mollusc fragments and a few ammonites (FT 17).

Text-fig. 8.12. Turonian microfacies of the Maghra El Hadida Formation.
All scale bars equal 2 mm. Abbreviations: EWG, East Wadi Ghonima; WG, Wadi Ghonima.

A-C: Udoteacean algae (*Halimeda* cf. *elliotti* CONARD & RIOULT); A, B, 080216-19 WG section; and C, 080217-29 EWG section.

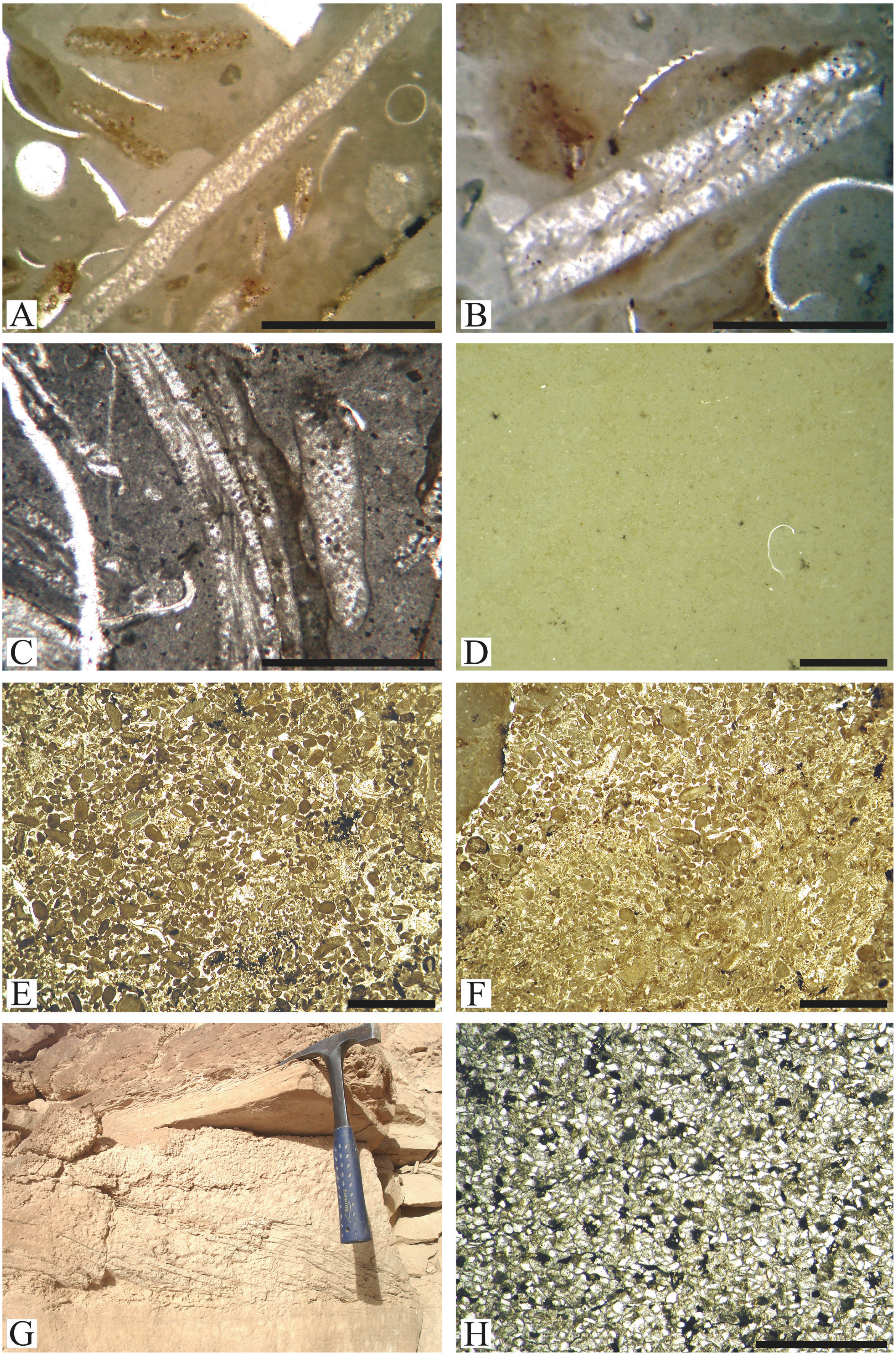
D: FT19, homogenous mudstone; 080216-24 WG section.

E-F: FT20, pisolithic, bio- and lithoclastic grainstone; 080217-35 EWG section.

G: FT21, Fine- to medium-grained quartz sandstone; 080213-4 EWG section.

H: FT22, Fine-grained quartz sandstone, with abundant ferruginous material; 080217-38 EWG section.

Text-fig. 8.12



9. Sequence stratigraphy

Sequence stratigraphy is used to interpret the development of sedimentary environments in time and space and therefore, it is an important tool in sedimentary basin analysis (COE, 2003). The basic definitions of sequence stratigraphic terminology are described by MITCHUM in VAIL et al. (1977) and HAQ et al. (1987, 1988) with modification for carbonate systems by SCHLAGER (1992). Regional sequence stratigraphic studies (ROBASZYNSKI et al., 1990, 1993; VAN BUCHEM et al., 1996; ABDALLAH et al., 2000; SCOTT et al., 2000; BAUER et al., 2003) show the important impact of relative and eustatic sea-level changes in north Africa and the Arabian Plate. Among these, the well known Late Cenomanian to Early Turonian global sea-level rise perhaps resulted in the highest sea-level stand of the entire Phanerozoic (HAQ et al., 1987; HANCOCK, 1993). For the Cenomanian – Turonian in Egypt, this is the first sequence stratigraphic study in the Eastern Desert, while some papers on contemporaneous deeper marine successions in Sinai have already been published (e.g., LÜNING et al., 1998; BACHMANN & KUSS, 1998; BAUER et al., 2003).

9.1. Sequence stratigraphy model and terminology

The Cenomanian – Turonian Galala and Maghra El Hadida formations in the study area represent a mixed carbonate and siliciclastic ramp setting and thus can be interpreted in the sense of ramp model by COE (2003). The sequence stratigraphic key surfaces and systems tracts are recognized by the following criteria (see also ERNST et al., 1996; ROBASZYNSKI et al., 1993, 1998; WILMSEN, 2003).

Sequence boundary (SB): Sequence boundaries are well-developed erosional or non-depositional unconformities represented by prominent palaeokarst horizons or, at the base of siliciclastic units, by channelized erosion surfaces cutting into predominantly fine-grained highstand sediments. Sequence boundaries are fused with the transgressive surfaces in the Cenomanian – Turonian succession of the study area. SCHLAGER (1991) showed that although drowning unconformities have repeatedly been identified as prominent sequence boundaries, they are not necessarily associated with significant lowstand. Thus, he defined a third type of boundary (Type-3, SCHLAGER, 1999) which is represented by a flooding surface between a HST and overlying TST.

Falling stage and lowstand system tracts (FSST & LST): Due to the proximal position of the study area and the resulting lack of accommodation space during this phase of a 3rd-order depositional sequence, FSST and LST are generally missing. It may be possible the basal part of the ivf (incised valley fills) recognized at the base of the Maghra El Hadida Formation is related to infilling starting in the late phase of the lowstand.

Transgressive surface (ts): Transgressive surfaces are subordinate erosion surfaces. Commonly, they are fused with the sequence boundaries, resulting in a TST/HST stacking of depositional sequences. Transgressive surfaces commonly show intensive bioturbation and occur at the base of nodular, often fossiliferous sediments.

Transgressive system tract (TST): In the study area, the deposits of TSTs are characterized by retrogradational parasequences and a general fining-upward trend. TST deposits are characterized by hardgrounds, highly bioturbated and nodular sediments with relatively high fossil content. Within the TSTs, shallow subtidal deposits prevail, which are mostly composed of calcareous marls and coarse bioclastic limestones with a rich benthic fossil assemblage (bivalves: *Ceratostreon flabellatum*, *Ilymatogyra africana*, *Costagyra olisiponensis*, *Plicatula auressensis*, *Crassatella materculla*; gastropods: *Campanile ganesha*, *Cimolithium tenouklense*; echinoids: *Heterodiadema libycum*, *Hemiaster cubicus*). Protected subtidal or open lagoonal settings are commonly documented. TST deposits of greater water depth occur only in the Lower Turonian, yielding abundant ammonites, planktonic foraminifera and filaments.

Maximum flooding surface/zone (mfs/mfz): Condensation with phosphate enrichment and abundant ammonites often corresponds to maximum flooding conditions in the study area. However, the maximum flooding surface of some depositional sequences is difficult to detect. This maybe related to continuous vertical accretion of carbonate mud during maximum flooding conditions and therefore, the maximum flooding could not be confined to a single surface. Thus, the term maximum flooding zone (WIESE & WILMSEN, 1999; WILMSEN 2003) was used for an interval of strata inferred to represent the most distal conditions within a depositional sequence (mostly fine-grained marls).

Highstand system tract (HST): Highstand deposits consist of fine-grained, shallow-subtidal sediments and are characterized by aggradational or progradational stacking patterns of parasequences. Often they are composed of thick-bedded marl with thin packstone intercalation commonly with oysters, benthic foraminifera, calcareous algae and echinoderms.

9.2. Sequence stratigraphy of the Galala and Maghra El Hadida formations

Based on sequence stratigraphic analysis, five major unconformities are recognized which define five depositional sequences, the uppermost one of which is incomplete. They are named for where they occur (WA= Wadi Araba), and numbered upward from base to top. The analyzed successions contain 3rd-order depositional sequences, consisting of a transgressive systems tract and a highstand systems tract (Text-fig. 9.1). They are considered to originate from the repeated rise and fall of relative sea level (VAIL et al., 1991). The following five sequence boundaries (Text-fig. 9.2) are recognized:

SB WA 1: Upper Middle Cenomanian (Malha–Galala contact).
SB WA 2: Upper Cenomanian (base of *Metoicoceras geslinianum* Zone).
SB WA 3: Topmost Lower Turonian (top of *Wrightoceras munieri* Zone).
SB WA 4: Intra-Middle Turonian.
SB WA 5: Lowermost Upper Turonian (base of *Coilopoceras requienianum* Zone).

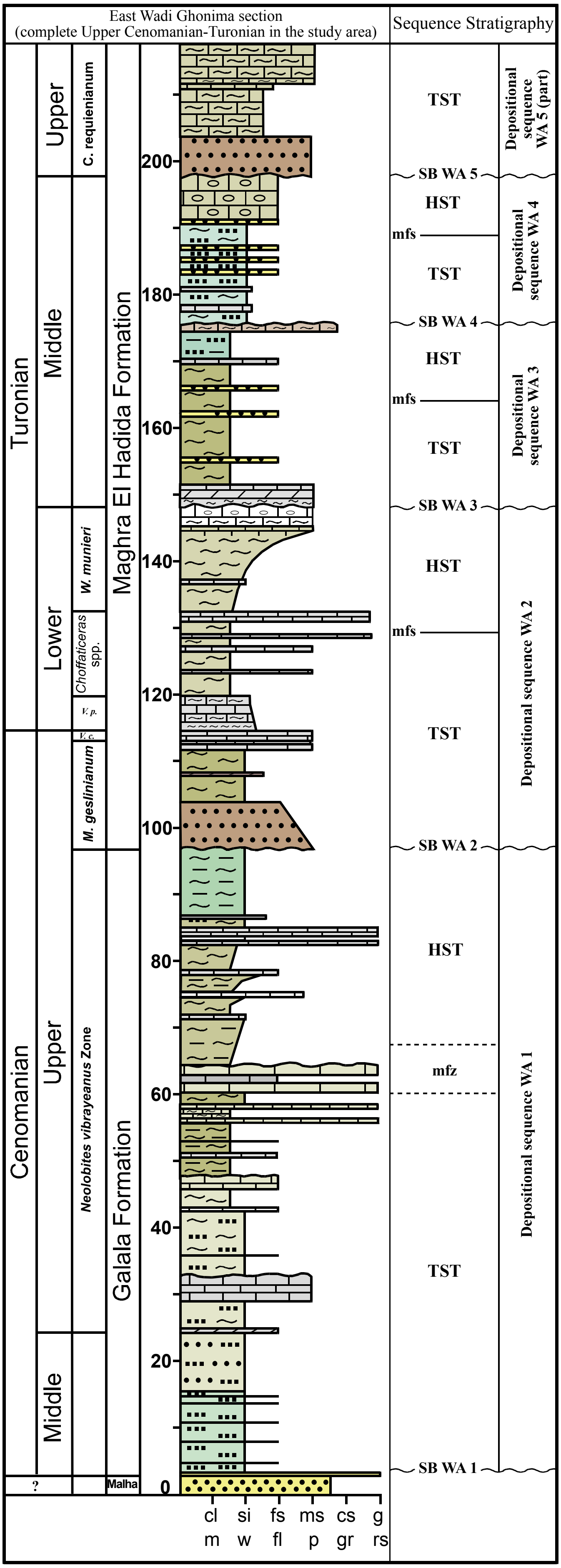
The five depositional sequences (DS) defined by the unconformities listed above are described in detail below.

DS WA 1

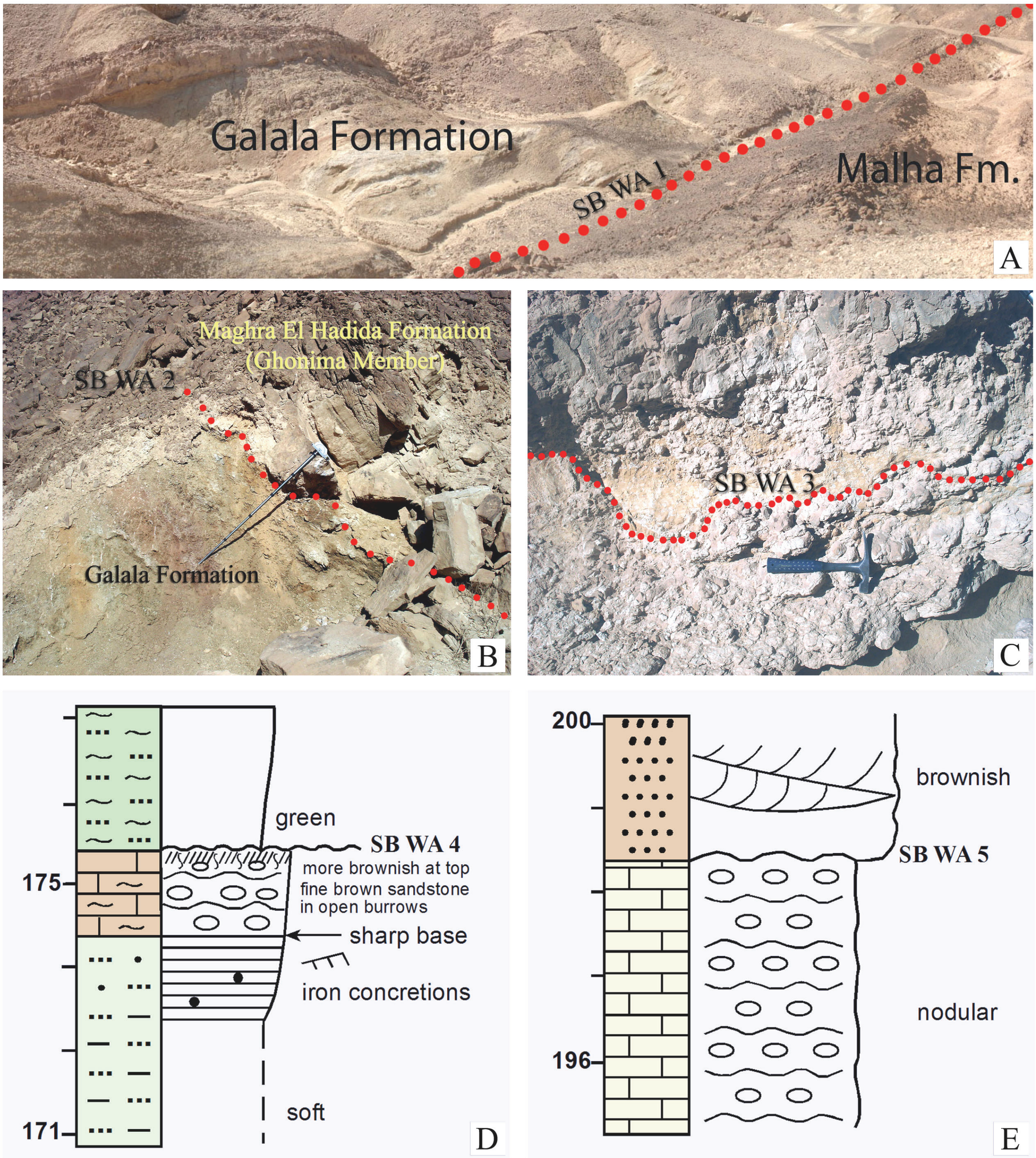
SB: The total thickness of the Galala Formation is included in the upper Middle – Upper Cenomanian sequence DS WA 1. The basal sequence boundary of the Galala Formation (Malha–Galala formational contact) is marked by an unconformity surface (SB WA 1), i.e., the change from coarse-grained non-marine sandstone of the Malha Formation to the fine-grained, marine siltstone of Galala Formation. This surface likewise represents the transgressive surface of DS WA 1.

Ts and TST: The transgression started at the top of the Malha Formation, indicated by bioturbation in this interval. Therefore, the ts fuses with the SB, resulting in a TST/HST stacking of depositional sequences as to be expected by the proximal position of the studied sections. In the most complete Cenomanian – Turonian section (East Wadi Ghonima section), the TST consists of thick silt-silty marl grading into bioturbated fossiliferous limestones, with hardground surfaces. These features are the same at all studied sections, but it has few sandstone intercalations in the western part (Wadi Ghonima section). Commonly the TST of this sequence contains frequent oysters and abundant calcareous algae wacke- to packstone, which document a lagoonal, low-energy environment during the TST.

Mfs and HST: The maximum flooding of DS WA 1 is assumed to be represented by the interval containing ammonites (*Neolobites vibrayeanus*) and nautiloids (*Angulithes mermeti*) in carbonate-rich strata. The HST is characterized by coarse bioclastic pack- to rudstones with diverse assemblage of rudists, *Chondrodonta* and benthic foraminifera intercalated into fine-grained marly sediments. However, the marls are slightly coarser than below. The thickness of the HST is reduced in the eastern and western parts (Saint Anthony and Wadi Ghonima sections).

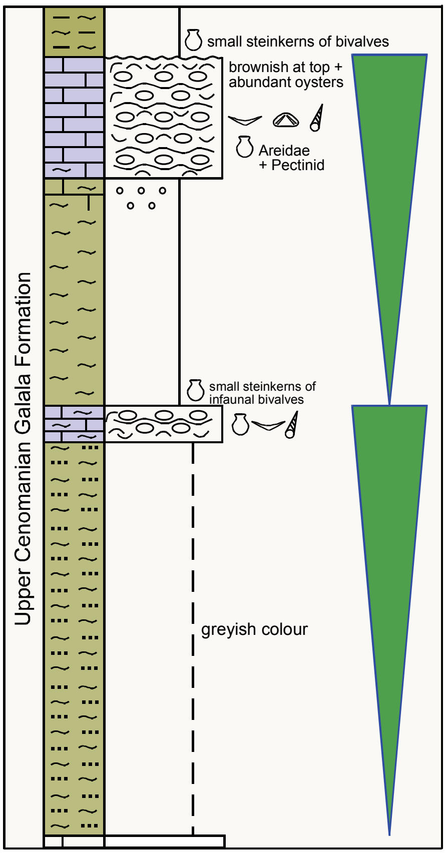


Text-fig. 9.1. Sequence stratigraphy of the most complete Cenomanian – Turonian section in the study area. For key of symbols see Text-fig. 3.2.



Text-fig. 9.2. Sequence boundaries SB WA 1 – 5 recognized in the Cenomanian – Turonian successions of the study area. For key of symbols see Text-fig. 3.2.

DS WA 1 is composed of an internal, apparently regular repetition of facies known as parasequences. In the original definition, parasequences were defined as a relatively conformable succession of genetically related beds or bedsets bound by marine flooding surfaces and their correlative surfaces (VAN WAGONER et al., 1988). Parasequences in the studied sections are shallowing-upward cycles representing a single episode of progradation. Each one started with silty or shaley marl grading into fossiliferous limestone (Text-fig. 9.3). Their boundaries (flooding surfaces) represent a rise in relative sea-level. For more details about the bundling of these sedimentary cycles, see chapter 10.



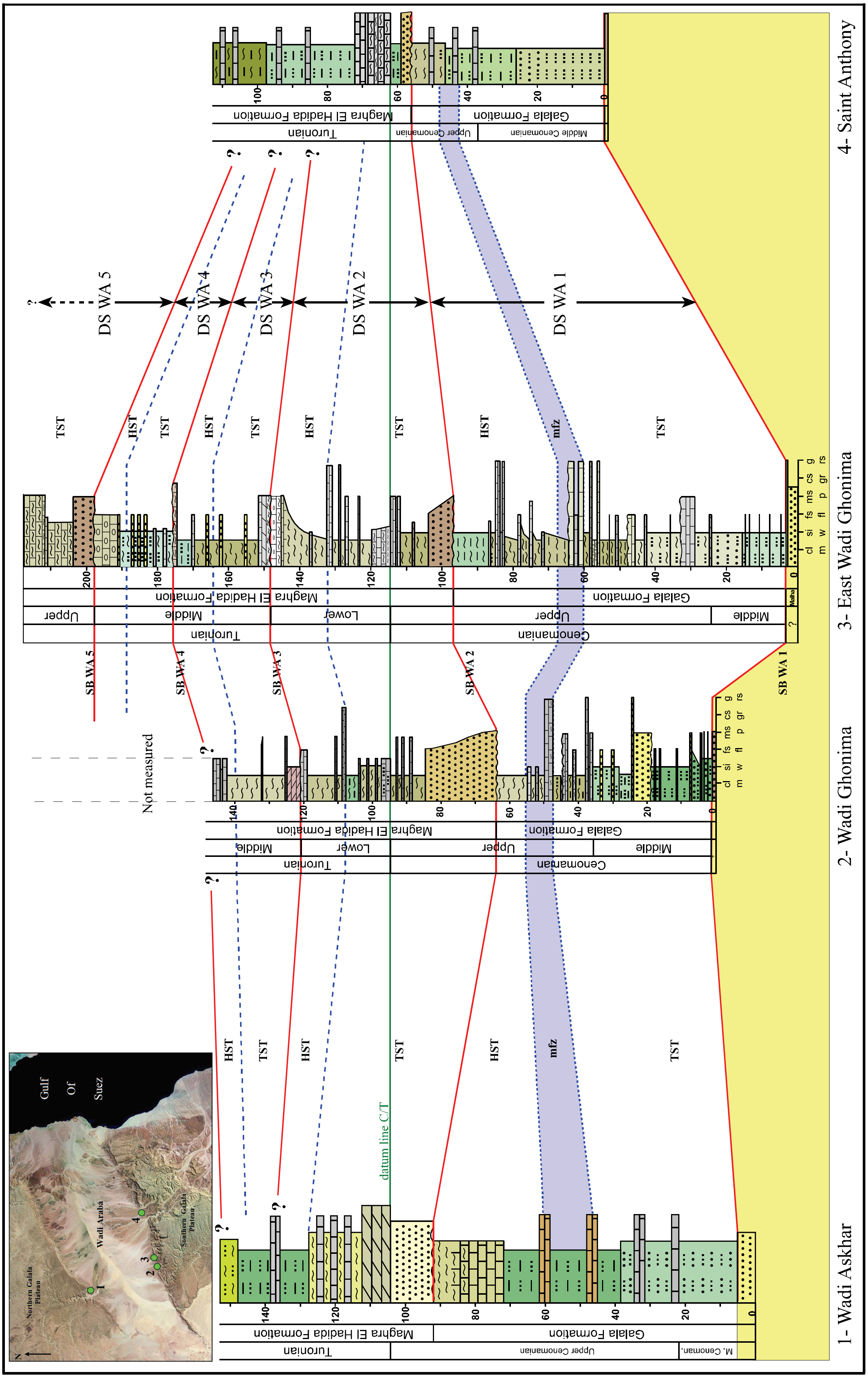
Text-fig. 9.3. Two shallowing-upward parasequences from sequence DS WA 1.

DS WA 2

SB: The Galala–Maghra El Hadida formational contact is considered as the basal SB of the Upper Cenomanian – Lower Turonian DS WA 2. The change from the fine-grained shaley marls of Galala Formation to cross-bedded, fine- to medium-grained sandstone of the Maghra El Hadida Formation (Ghonima Member) is very sharp. Furthermore, the sandstone of Ghonima Member appears to cut erosionally into the Galala Formation as indicated by its strong lateral variation in thickness from 3 m at Saint Anthony section to about 21 m at Wadi Ghonima section. Also in the Wadi Ghonima area, there are rapid lateral changes in thickness. This SB is well represented in all parts of the study area and occurs at the top of the *Neolobites vibrayeanus* Zone (=*Calycoceras guerangeri* Zone).

Ts and TST: The SB and the ts are again coinciding due to the absence of FSST and LST because the basal part of the Maghra El Hadida Formation (Ghonima Member), which is directly overlying the SB, is considered as a result of infilling of incised valleys (ivf). This usually occurs during the succeeding transgression (COE et al. 2003). However, it may be possible that the basal part of this sandstone unit is related to the onset of infilling during the late LST. The following part of the TST of this sequence is characterized by marly sediments topped by packstone beds (parasequences) yielding latest Cenomanian ammonites of the *Metoicoceras geslinianum* and *Vascoceras cauvini* zones. By the end of TST, carbonate-rich beds predominate containing abundant Lower Turonian ammonites as well as filaments and planktic foraminifera of a deep-subtidal setting. The thickness of this system tract is reduced towards the eastern part of the study area (Saint Anthony section).

Mfs and HST: Condensation phenomena with encrustations on ammonites and phosphatization characterize the mfs which is placed on the top of the lower Lower Turonian *Choffaticeras* interval. The HST consists of fossiliferous fine-grained, nodular marls and thin packstone beds containing upper Lower Turonian ammonites. It is topped by udoteacean packstone, indicating shallow conditions towards the end of the HST. Further to the north at Wadi Askhar section, this system tract is much reduced in thickness (Text-fig. 9.4).



Text-fig. 9.4. Sequence stratigraphic correlation of the studied sections in the north Eastern Desert. Datum line is the Cenomanian-Turonian boundary.

DS WA 3

SB: The Lower–Middle Turonian contact is marked by prominent palaeokarst horizon. This unconformity surface represents the lower SB of the Middle Turonian sequence DS WA 3. SB WA 3 is situated at the top of the Early Turonian *Wrightoceras munieri* Zone within the Maghra El Hadida Formation. The prominent SB indicates a hiatus spanning a significant interval of geologic time. However, it is difficult to determine this time exactly due to the absence of age-diagnostic fossils in the sediments above the unconformity.

Ts and TST: The first transgressive sediments noted above SB WA 3 are represented by a nodular, thin dolomite bed with intensive bioturbation. This suggests a fusing of the ts and the SB (see comment on TST/HST sequences above). The TST sediments of DS WA 3 continue with bioclastic packstone with bivalve rudstone filling burrows (tubular tempestites), followed by fine-grained marl intercalated with thin hummocky-cross-bedded sandstone (tempestites) indicating a storm-dominated shelf setting. ROBASZYNSKI et al. (1993) considered these features as diagnostic criteria of TST conditions in contemporaneous deposits in Tunisia. These features predominate in the central part of the study area, whereas towards the northern and eastern parts, the TST sediments become more argillaceous, less fossiliferous and thinner.

Mfs and HST: Fine-grained, argillaceous sediments with relative few small articulated bivalves mark the mfs of the DS WA 3. The HST is characterized by marl deposits grading into silty shale with thin, nodular, marly limestone beds and ends with bioclastic wackestone. However, the thickness of this system tract is obviously variable in the study area, but the increasing siliciclastic input is the most characteristic features of this HST. The thickest HST deposits were logged at East Wadi Ghonima section.

DS WA 4

SB: The upper surface of the uppermost limestone bed of DS WA 3 is marked by open burrows filled with fine brown sandstone and pisolithic bio- and lithoclastic grainstone as well as an erosional relief. It forms the basal SB of the Middle Turonian sequence DS WA 4. This SB is well expressed only at the complete section (East Wadi Ghonima section); in the other sections it could not be recognized due to the termination of the sections or lack of detailed observations.

Ts and TST: The absence of the FSST and the LST results in a fusing of the SB and the ts and suggests a gap. The transgression starts directly above the SB, indicated by the deposition of nodular, green silty marl with thin and few limestone intercalations. The TST of sequence DS WA 4 is consisting of thick-bedded silty marls, nodular at the base, with lime mudstone. Hummocky-cross-bedded sandstones at the top suggest a tempestitic shelf setting during the deposition of the TST.

Mfs and HST: The mfs of DS WA 4 is placed in the fine-grained interval above the tempestitic sandstones. The HST is characterized by silty marl at the base, followed by thick, nodular, bioclastic mollusc packstone at the top. DS WA 4 is well developed in the central part of the study area (around Wadi Ghonima), but it is very thin at the eastern part (Saint Anthony section). It was not logged in the north (Wadi Askhar section) so that nothing can be said about this sequence there.

DS WA 5

SB: The rapid change from thick-bedded carbonates to thick siliciclastic sediments in the upper part of the Maghra El Hadida Formation is taken as marker for the placing of lower SB of the Upper Turonian sequence DS WA 5. This change produces a pronounced unconformity because the two units differ with respect to water depth as well as sediment dispersal patterns (SCHLAGER, 1991). SB WA 5 is situated at the base of the Upper Turonian *Coilopoceras requienianum* Zone, which is considered as the lower Upper Turonian ammonite zone in Egypt and the Middle East (KASSAB, 1991; HEWAIDY et al. 2003; LEWY et al. 1984).

Ts and TST: The SB and the ts are coinciding due to the absence of FSST and LST because the sandstone unit which is directly overlying SB WA 5 is considered as a result of infilling of incised valleys during the transgression. However, the basal part of this sandstone unit may be related to the late LST. The following part of the TST consists of bioclastic mollusc wacke- to packstone with filaments and nodular fabric in some parts. DS WA 5 is not complete because the TST constitutes the last part of the measured sections.

9.3. Sequence stratigraphic correlation

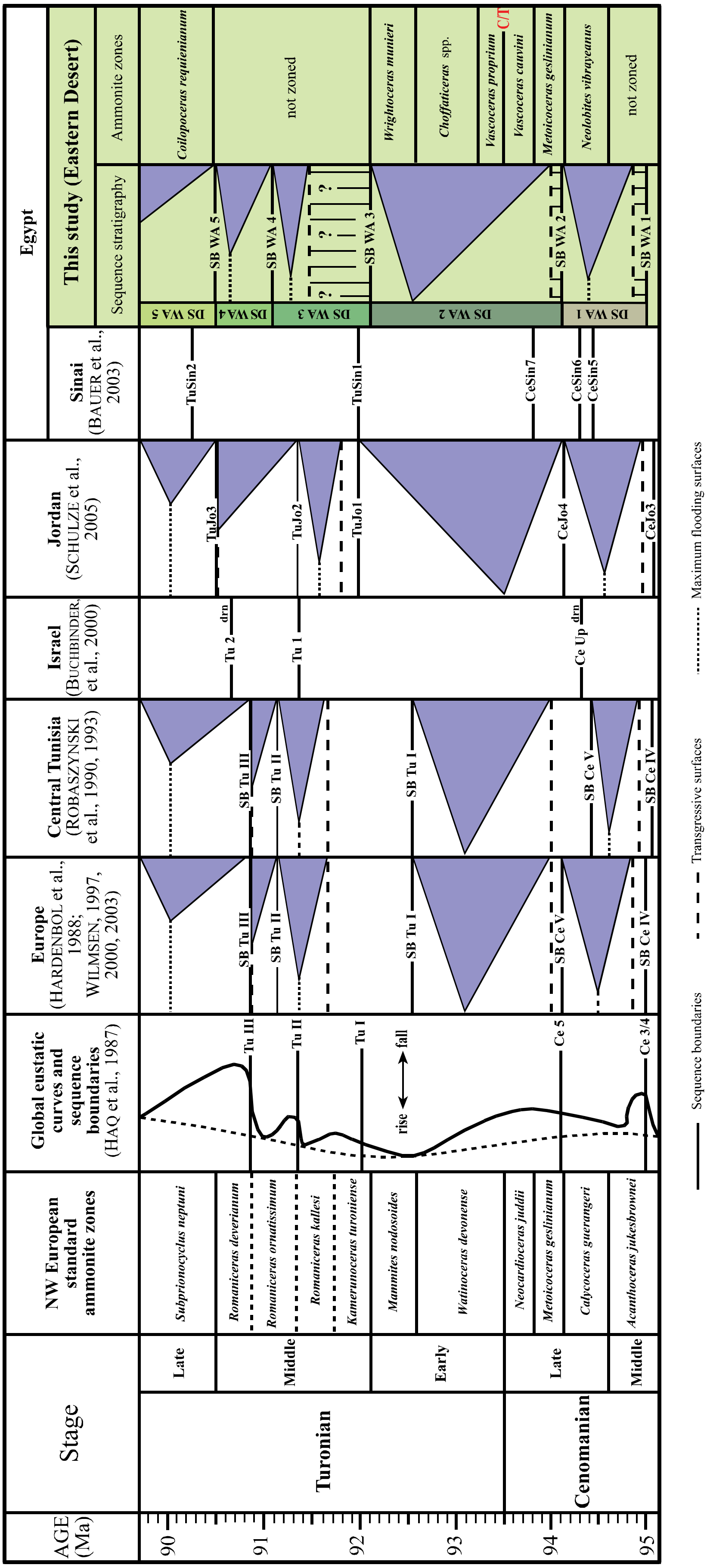
An important requirement for understanding processes in the sedimentary record is to link the appropriate process with an observation and to correlate similar observations from different regions which occurred within an equivalent time period (VAIL et al., 1991). However, a correlation of the sequence stratigraphic subdivision of the Cenomanian – Turonian successions in the study area and others from neighbouring regions can only be carried out within the constraints of reliable high-resolution biostratigraphy. The stratigraphic positions of the sequence boundaries and other surfaces have been calibrated with detailed ammonite biostratigraphy. Ammonite biostratigraphy provides the necessary resolution to attempt a correlation between the study area (Eastern Desert) and different basins in Europe, Tunisia, Israel, Jordan as well as Sinai in Egypt (Text-fig. 9.5). Most recognized sequence boundaries in the study area are matching well with those from adjacent areas. However, the small discrepancies in some correlations are most probably caused by limited biostratigraphic resolution and depend on the calibration of the biostratigraphic schemes used in the different studies.

Comparison with sequences from Sinai (*Egypt*)

BAUER et al. (2003) described five sequence boundaries in the Upper Cenomanian – Turonian successions of Sinai (Text-fig. 9.5). However, there are some differences between the proposed sequences in the Eastern Desert and Sinai. This appears to be related mostly to the poor biostratigraphic zonation of the Cenomanian – Turonian successions in the sections studied by BAUER et al. (2003). Their Upper Cenomanian sequence boundary Ce Sin 5 was placed at the base of alternating beds of siltstone and claystone, which overlie coarse-grained sandstones. This SB may be equivalent to SB WA 1 in the present study, which was placed based on similar lithological features with similarity in system tracts stacking. However, SB WA 1 is assigned to the upper Middle Cenomanian and the first early Late Cenomanian ammonites (*Neolobites vibrayeanus*) enter still higher up at the end of TST whereas Ce Sin 5 was placed within the *Neolobites vibrayeanus* Zone. SB Ce Sin 6 of BAUER et al. (2003) is not noted in the study area. Most of the facies of their sequence above the proposed SB is equivalent to the HST deposits of DS WA 1 in the study area. Furthermore, they indicate that it is difficult to distinguish between TST and HST deposits of their proposed sequences in central and southern Sinai. SB Ce Sin 7 was placed by BAUER et al. (2003) at the base of deposits containing common Lower Turonian ammonites. They introduced two possible age assignments for this SB, latest Cenomanian or Early Turonian. The correlation of their sections with the successions in the study area (considering the high resolution ammonite biostratigraphy in the present work) suggests a hiatus in the Cenomanian – Turonian boundary interval of the sections studied by BAUER et al. (2003). This hiatus includes the late Late Cenomanian (above the *Neolobites vibrayeanus* Zone) and continued into the Early Turonian, until the *Choffaticeras* interval. Therefore, SB Ce Sin 7 in Sinai is equivalent to the Upper Cenomanian SB WA 2 in the study area, which is much lower, at the base of *Metoicoceras geslinianum* Zone. The Middle Turonian SB Tu Sin 1 was placed by BAUER et al. (2003) at an emersion surface with thin palaeosols or meteoric diagenesis, indicating subaerial exposure. This SB may correlate with the prominent palaeokarst horizon (SB WA 3) in the study area. However, SB WA 3 is placed slightly lower, at the base of the Middle Turonian (at the top of the latest Early Turonian ammonite *Wrightoceras munieri* Zone), but the two surfaces seem to be correlatives. The Upper Turonian sequence boundary Tu Sin 2 of BAUER et al. (2003) in Sinai seems to match with SB WA 5 in the study area. However, the SB in the study area is slightly lower at the base of the Upper Turonian *Coilopoceras requienianum* Zone whereas SB Tu Sin 2 was placed in the lower part of the Upper Turonian.

Comparison with sequences in Jordan and Israel

The stratigraphical position of the depositional sequences and their bounding unconformities of Jordan (SCHULZE et al., 2003, 2005) and Israel (BUCHBINDER et al., 2000) matches well with the proposed sequences of the present study. However, there are a few differences which are possibly related to the variability in the biostratigraphic schemes and resolution between the study area and those regions. The stratigraphical position of the sequence boundaries (Ce Jo 3 – Tu Jo 3) proposed by SCHULZE et al. (2003, 2005) for the upper Middle Cenomanian – Turonian sequences of Jordan matches well with all sequence boundaries in the study area (Text-fig. 9.5). Furthermore, most of their sequences are 3rd-order TST/HST sequences as in the study area. However, there are a few differences compared with the present study. The mfs of their Upper Cenomanian – Lower Turonian depositional sequence was placed at the Cenomanian – Turonian boundary, but in the study area it placed at the top of the Lower Turonian *Choffaticeras* interval. In addition, they proposed a LST above the SB Tu Jo 2 for the supratidal deposits which are missing in the study area. On the other hand, the main differences appear in the sequence stratigraphic subdivision from Israel proposed by BUCHBINDER et al. (2000). These differences are related to missing of the upper Middle Cenomanian SB WA 1 and the topmost Lower Turonian SB WA 3 in Israel. In addition, the sequence boundaries of the Cenomanian – Turonian of Israel are placed somewhat lower than the equivalent surfaces in the Wadi Araba area (Text-fig. 9.5).



Text-fig. 9.5. Correlation of the sequence boundaries in the study area with those of the regional studies and the Exxon chart (HAQ et al. 1987). Some sequence boundaries in Israel are related to platform drowning (indicated by 'drn').

Comparison with sequences from Tunisia and Boreal Europe

There is a good correlation between the sequences of Europe and Tunisia (ROBASZYNSKI et al., 1990, 1993; HARDENBOL et al., 1988; HARDENBOL & ROBASZYNSKI, 1988; WILMSEN, 2003) and the sequences recognized in the study area. All authors distinguished five 3rd-order sequences boundaries in the late Middle Cenomanian – early Upper Turonian of central Tunisia and Boreal Europe (Text-fig. 9.5). Sequence boundaries SB WA 1 and SB WA 2 of the present study correlate well with SB Ce 4 and SB Ce 5, respectively, in Europe, while they are placed slightly lower in Tunisia. The Lower Turonian SB Tu 1 in Europe and Tunisia are placed in the lower part of *Mammites nodosoides* Zone, while the equivalent surface, SB WA 3 in the Wadi Araba area, is located at the top of the *Wrightoceras munieri* Zone which equivalent to the upper part of the *Mammites nodosoides* Zone. The Middle Turonian unconformities (SB Tu 2+3) in Europe and Tunisia correlate well with SB WA 4+5 of the study area. However, the slight up-shift of these unconformities in the study area is probably related to the poor biostratigraphic resolution of the Middle Turonian and may, thus, be an artifact.

Comparison with the Exxon chart

The first global Mesozoic sequence stratigraphic schemes (“Exxon chart”) were published by HAQ et al. (1987, 1988). The correlation of the regional Wadi Araba chart to this supposed global chart is fairly good. There are five sequence boundaries in the Exxon chart, the stratigraphical position of which matches well with unconformities WA 1 – 5. The only exception is sequence boundary WA 5 and SB Tu III, the latter being placed in the upper Middle Turonian, at the base of *Romaniceras deverianum* Zone. However, this is probably related to bio- and chronostratigraphic problems in defining the Middle – Upper Turonian boundary (see WIESE, 1997, for discussion).

10. Cyclostratigraphy

This part deals with the description and interpretation of the sedimentary cycles and their use in constructing and improving a high-resolution stratigraphic framework. This approach allows to quantify the rates of geological and palaeontological processes based on orbital forcing in the MILANKOVITCH frequency band.

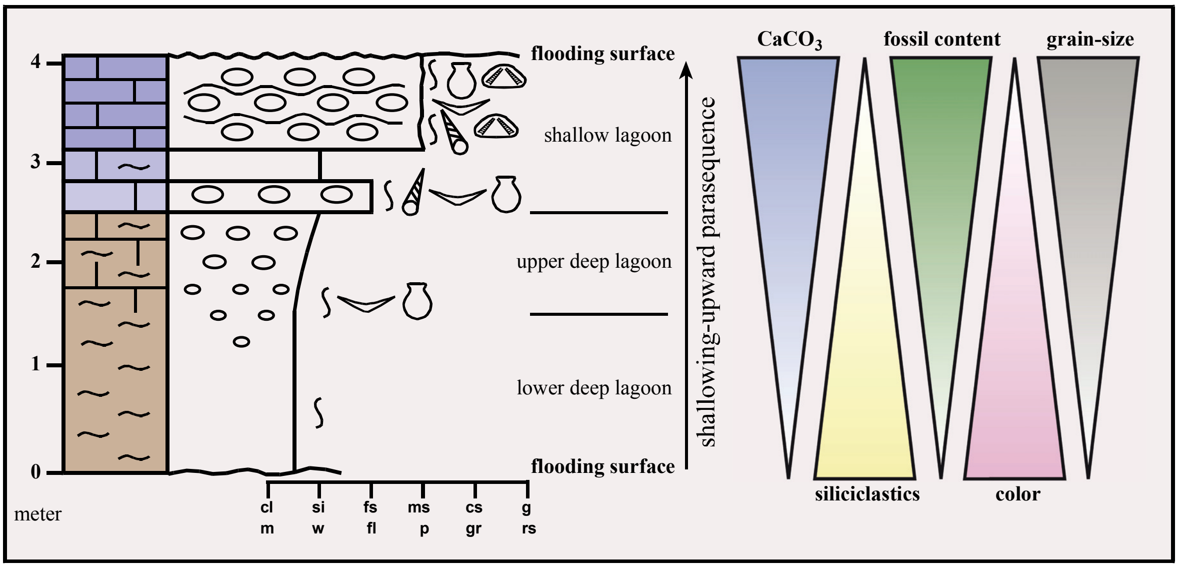
In the middle of the 20th century, MILANKOVITCH (1941) realized that the change in time of the solar radiation received at the upper limit of the atmosphere depends on the latitude, orbital elements of the Earth and solar luminosity. He suggested that the secular variations known to affect some of the Earth's orbital elements (eccentricity, obliquity, and precession) could possibly cause periodic variations in the amount of solar radiation, thus influencing the climatic system. The coupling between secular variations (MILANKOVITCH cycles) and climate changes leaves strong signatures in the geologic record (DE BOER & WONDERS, 1984). The oscillations in MILANKOVITCH frequency band are the eccentricity cycle of the Earth's orbit (mean periods of 400 kyr for the long and 100 kyr for the short cycle), modulation of the tilt of the Earth axis, obliquity (about 41 kyr cycle), and the precession cycle which modifies the equinoxes so that during one cycle the time of perihelion shifts through the seasons (approximate period of 21 kyr). MILANKOVITCH processes are the most widely accepted driving mechanism for high-frequency sea-level changes and are therefore an obvious mechanism to propose for generation of high-frequency flooding surfaces and sequence boundaries in the sedimentary record and specifically the Quaternary sedimentary cycles (COE, 2003). For the Cretaceous, the Cenomanian shelf sequences across northwest Europe are inferred to reflect the cyclicity of the MILANKOVITCH band very convincingly and were used to construct an orbitally tuned time scale for the Cenomanian age (e.g. GALE, 1990, 1995; GALE et al., 1999; WILMSEN, 2003).

This is the first attempt to describe and interpret the sedimentary cycles which are recorded in the Cenomanian – Turonian sediments of Egypt in the frame of Earth' orbital (MILANKOVITCH) periodicities in order to build a high-resolution time-scale for the studied successions.

10.1. Description of cyclicity of the Galala Formation

***Basic cycles* (*parasequences*)**

Parasequences are defined as a relatively conformable succession of genetically related beds or bedsets bound by marine flooding surfaces and their correlative surfaces (VAN WAGONER et al., 1988). Parasequences are considered as the basic building blocks of most sequences and systems tracts. Each parasequence results from a small-amplitude, short-term oscillation in the balance between sediment supply and accommodation space (COE, 2003). In the study area, the Galala Formation (which represents by the first depositional sequence DS WA 1) is composed of an internal, apparently regular repetition of facies which represent parasequences. Keeping in mind WALTHER's Law of Facies, the facies succession represents conformable deposits that accumulated through time in progressively shallower-water depths, and, thus, the vertical succession through the parasequence is shallowing-upward and usually coarsening-upward. This clear trend suggests that the parasequences of the Galala Formation represent a single episode of progradation. Each one contains a variety of different facies, starting with fine-grained, silty or shaley marl representing deep lagoonal conditions, grading into coarse-grained fossiliferous limestone of shallow lagoonal settings (Text-fig. 10.1). Their boundaries (flooding surfaces) represent a rapid rise in relative sea-level, indicated by the sudden upward change from shallow- to deeper-water facies marked by sharp surfaces. The thicknesses of parasequences of the Galala Formation are variable, ranging from 2m to 8m. There are at least 18 lagoonal shallowing-upward parasequences in the Middle – Upper Cenomanian Galala Formation, but it may be more (due to the poor exposures in some intervals of the sections it is difficult to recognize these small-scale cycles).

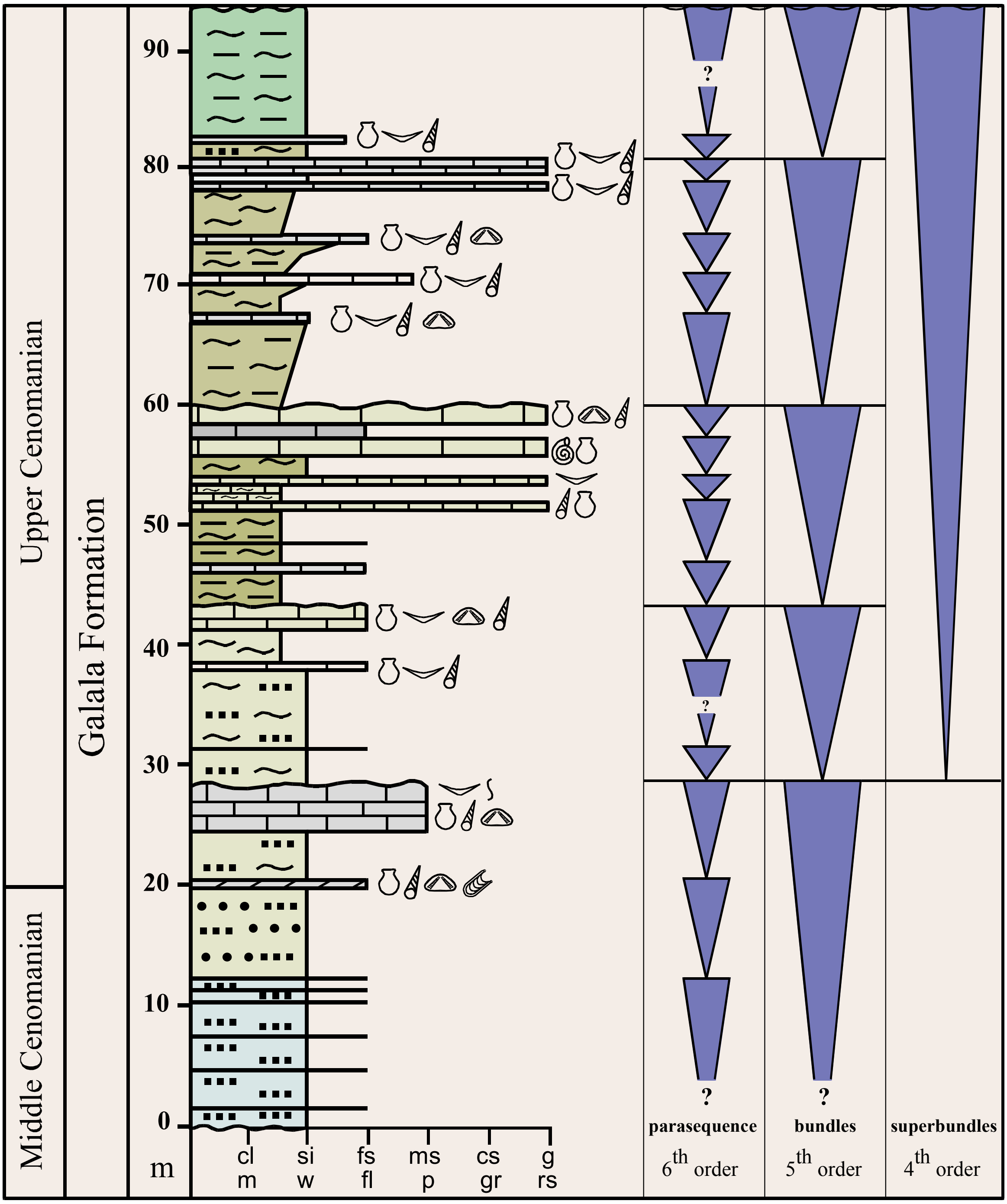


Text-fig. 10.1. Features and trends of one of the parasequences characterizing in the Galala Formation.

Parasequence sets (bundles and superbundles)

The basic cycles appear assembled in bundles, and the bundles in superbundles: the evidence of this grouping emerges from the internal organization of the lithofacies and also from the morphology of the slopes where the periodic changes in lithology imposed by the environmental oscillations result in characteristic steps. The parasequences of the Galala Formation commonly occur in sets that exhibit a distinctive stacking pattern of progradation. Five parasequence sets (bundles, Text-fig. 10.2) can be recognized in the Middle – Upper Cenomanian Galala Formation, each being internally composed of up to five parasequences. Commonly the lower basic cycles of each bundle are thicker or thickening-upward into thick middle parasequences, while the upper ones are thinner. The first and last bundles only have two or three parasequences. However, the lower part of the first bundle seems to be non-rhythmic and the uppermost bundle is truncated along sequence boundary SB WA 2. The second bundle also shows only three parasequence, but this may be related to the poor exposure of this parasequence set. The parasequence sets of the Galala Formation also show principal shallowing-upwards trends: the fine-grained marl sediments are thicker than the fossiliferous limestone in the lower basic cycles while the coarse-grained, fossiliferous limestone beds are thicker than the marl sediments towards the top of each set. The boundaries of these bundles are marked by discontinuity surfaces (mostly hardgrounds). The thickness of the bundles ranges from 12 to 30 m. The upper four bundles can be group in one superbundle (Text-fig. 10.2). The identification of this superbundle followed criteria analogous to those used to single out the bundles. At its base, a very prominent bored hardground surface indicates a cycle-bounding surface of higher magnitude than those of normal bundles. The upper boundary of the superbundle is coincident with SB WA 2.

The hierarchy of superbundles, bundles and parasequences building 3rd-order depositional sequences suggest that superbundles are 4th-order cycles, bundles are 5th-order cycles and parasequences are 6th-order cycles. Their stacking pattern of 1:4:20 (5 parasequences per bundle) strongly suggest an orbital forcing by MILANKOVITCH periodicities (see below).



Text-fig. 10.2. Hierarchical bundling pattern of sedimentary cycles in the Galala Formation.

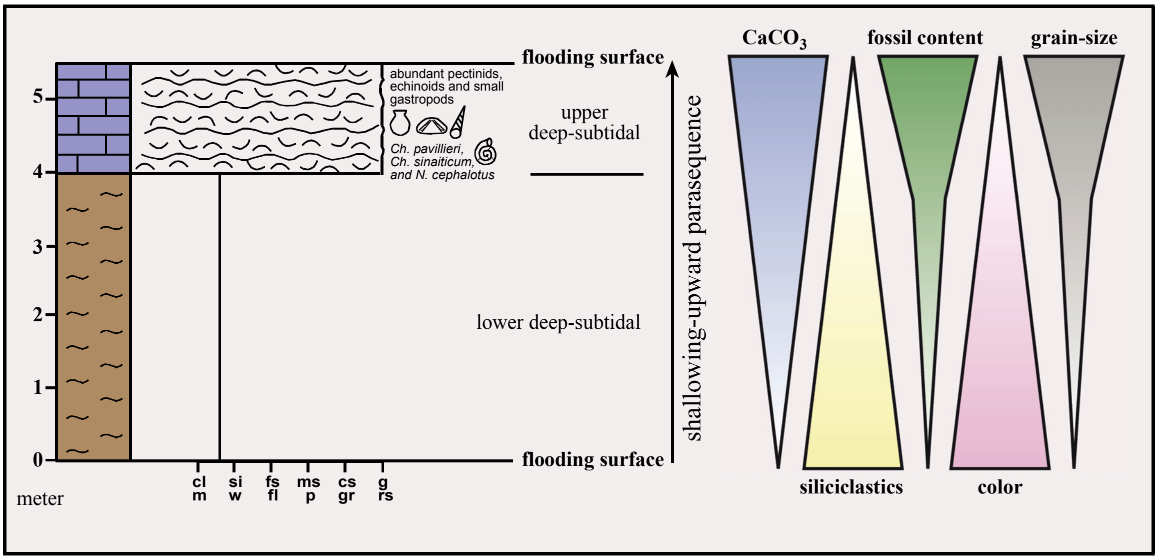
10.2. Description of cyclicity of the Maghra El Hadida Formation

Basic cycles (parasequences)

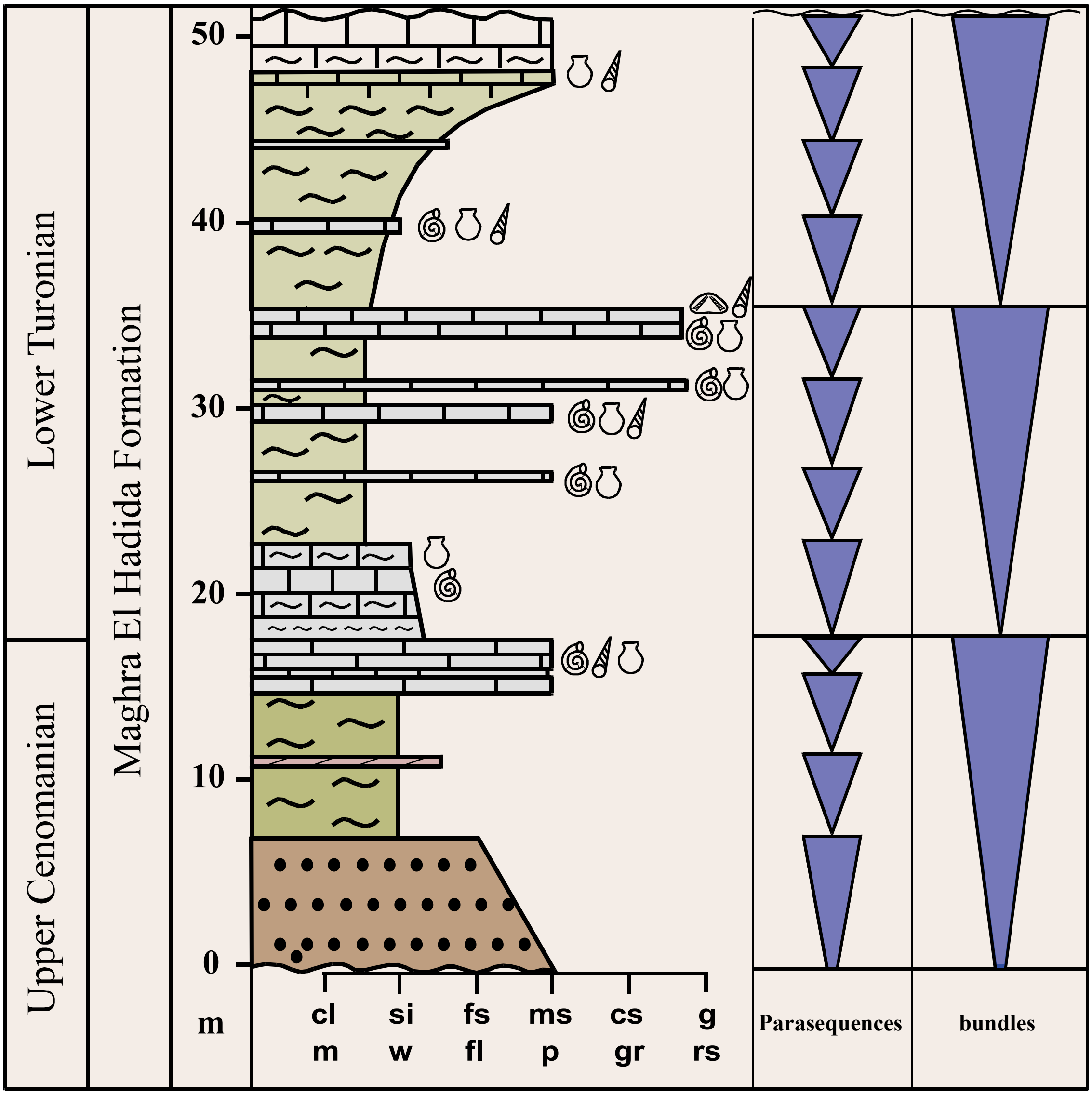
The facies distribution throughout the Maghra El Hadida Formation shows a distinctive stacking pattern which allows detecting the basic cycles of this formation. The first parasequence of the Maghra El Hadida Formation consists of cross-bedded, fine- to medium-grained sandstone. The rest of the parasequences of the Maghra El Hadida Formation are composed of calcareous sediments and are also shallowing-upward successions, but were deposited in deeper settings than the parasequences of the Galala Formation. Each parasequence contains a variety of different facies, starting with fine-grained marl or silty marl of a deep-subtidal setting grading into coarse-grained, fossiliferous limestone reflecting shallower subtidal conditions (Text-fig. 10.3). The facies of these limestone beds ranges from ammonite-foraminifera-bearing wackestone to muddy, bioturbated mollusc rudstone. The parasequences are bounded by sharp surfaces (flooding surfaces) representing a rise in relative sea-level. The thicknesses of the basic cycles of the Maghra El Hadida Formation are variable, ranging from 2 to 6m. There are 12 shallowing-upward parasequences in the Upper Cenomanian – Lower Turonian interval of the Maghra El Hadida Formation.

Parasequence sets (bundles)

Depending on the internal organization of the lithofacies (distinctive stacking pattern) of the Upper Cenomanian–Lower Turonian Maghra El Hadida Formation (DS WA 2), the 12 parasequences of this interval can be grouped into three parasequence sets (Text-fig. 10.4). Each parasequence set (bundle) is internally composed of four parasequences. In all bundles, the lower basic cycles are thicker, while the upper ones are thinner. As in the Galala Formation, the bundles of the Maghra El Hadida Formation also show an overall shallowing-upwards trend: the fine-grained marl sediments are thicker and less fossiliferous in the lower basic cycles whereas the coarse-grained, fossiliferous limestone beds seem to be thicker than the marly sediments towards the top of each bundle. The boundaries of these parasequence sets are marked by sharp flooding surfaces indicating a considerable rise in the relative sea-level. The thickness of the bundles of the Maghra El Hadida Formation is nearly constant throughout, ranging from 16 to 18 m.



Text-fig. 10.3. Typical parasequence of the Maghra El Hadida Formation. Trends and environmental interpretation are indicated.



Text-fig. 10.4. Hierarchical bundling pattern of sedimentary cycles in the Upper Cenomanian-Lower Turonian of the Maghra El Hadida Formation.

10.3. Cyclostratigraphic interpretation

Galala Formation

The hierarchical cycle organisation (basic cycles and bundles) recognized in the Galala Formation is used to hypothesize that this cyclicity was controlled by high-frequency climatic and eustatic changes triggered by variations in orbital parameters (MILANKOVITCH-type cycles). Bundles of five precession cycles are inferred to indicate the *c.* 100 kyr short eccentricity cycle of the MILANKOVITCH frequency band (GALE, 1990; MITCHELL & CARR, 1998; WILMSEN, 2003). In the study area, based on 5:1 stacking pattern of the basic cycles and bundles in the Galala Formation, the basic cycles (parasequences) are considered to represent the precession cycle of the equinoxes (*c.* 20 kyr), the bundles the short eccentricity cycle (*c.* 100 kyr), and the superbundles the long eccentricity cycle of the Earth's orbit (*c.* 400 kyr). The number of cycles actually recorded in the sequences in not ideal in every case (i.e., 5 parasequences per bundle and 4 bundles per superbundle) because several local conditions may produce omission or coalescence at basic cycle or group of cycles level (FISCHER, 1991; D'ARGENIO et al., 1997; BUONOCUNTO et al., 1999). However, in terms of the rock record a substantial amount of time may not be represented, in terms of elapsed time we assume that a single cycle represents *c*. 20 kyr here (regardless of the amount of time not represented by sediments), a bundle represents *c*. 100 kyr (even if one or two parasequences are missing or were not recognized) and, accordingly, a superbundle may be considered to be a result of a sedimentary process developing during *c*. 400 kyr. Support for this interpretation comes from the absolute age of the Galala Formation which can be inferred from the correlation of the biostratigraphy to the time scale of GRADSTEIN et al. (2004). The Galala Formation equals to ~ 500 kyr and is composed of five bundles, strongly suggesting that each one equals ~ 100 kyr. Every bundle has five basic cycles, each one thus representing ~ 20 kyr.

The above presented data allow to interpret the cycles of the Galala Formation as orbitally driven MILANKOVITCH cycles. Whether these cycles formed by climatic change and/or eustatic variations associated with them can be inferred from trends within bundles and superbundles: The stacking pattern of basic cycles suggests accommodation control because commonly the lower ones are thicker and represent deeper environments, while the upper ones are thinner and shallower. Therefore, high-frequency sea-level changes must have been associated with short eccentricity cycles.

Also the accumulation rate of the Galala Formation can be estimated using cyclostratigraphy: accepting the duration of *c*. 100 kyr for each bundle, it follows that the 5 bundles comprising the Galala Formation (95 m thick) record a minimum time interval equal to *c*. 500 kyr. Taking into account the ratio of thickness and the time interval (~ 100 kyr), it is possible to calculate the accumulation rate of each bundle and, consequently, the average accumulation rate of the Galala Formation (Table 10.1).

Table 10.1. Accumulation rate of bundles of the Galala Formation in cm per kyr, assuming that each bundle took *c*. 100 kyr to form (short eccentricity of the MILANKOVITCH frequencies).

Bundles	Thickness (m)	Accumulation rate (cm/kyr)	Average accumulation rate of the Galala Fm (cm/kyr)
5	12	12	**19**
4	22	22	
3	16	16	
2	15	15	
1	30	30	

The accumulation rates of the Galala Formation bundles are variable and range from 12 to 30 cm/kyr with mean sedimentation rate of 19 cm/kyr. This variation may be related to the differentiation in the grain size of each bundle, which resulting in differences in the thickness of the bundles. In addition, the thickness of the last bundle is not complete due to the incision at SB WA 2.

Trying to calculate the rate of sea-level change is very difficult and cannot be detected from the present data alone. However, only in the case of sequence boundary WA 2 (equivalent to the quasi-global SB Ce V), the change of sea-level can be estimated. This can be done based on the thickness of incision at the sequence boundary (incised valley fill of the Ghonima Member) which reaches 20 m and a minimum estimation of the change of water depth (deep lagoon = ca. 15 m deep). This adds up to at least 35 m of sea-level fall. Unfortunately, it is not possible to estimate how fast this fall happened from the study area. However, based on the correlation with the more complete north western European Cenomanian – Turonian sections (such as Wunstorf in northern Germany), it can be inferred that the sea-level fall and lowstand is equal to 100 kyr (WILMSEN, unpublished data). This means that the rate of (eustatic) sea-level change is at least 35 cm/kyr and this can be considered as quite large and fast. MILLER et al. (2003, 2005) showed that Late Cretaceous sea-level changes were large (>25 m) and rapid (<1 m.y.) and they interpreted those as glacioeustatically controlled. Thus, the sea-level fall associated with SB WA 2 may also indicate glacio-eustasy during the Late Cenomanian.

Maghra El Hadida Formation

Three fourth-order cycles are well developed in the Upper Cenomanian – Lower Turonian part of the Maghra El Hadida Formation, constituting the building blocks of the 3rd-order sequence DS WA 2 (Text-fig. 10.4). 4th-order cycles are often interpreted to reflect the long eccentricity (c. 400 kyr) of the MILANKOVITCH band (WILMSEN, 2003). Based on 4:1 stacking pattern of the basic cycles and bundles in the Maghra El Hadida Formation, the basic cycles are considered to represent the short eccentricity cycle (*c*. 100 kyr, 5th-order cycles), and the bundles the long eccentricity cycle of the Earth's orbit (*c*. 400 kyr). This interpretation is supported by the absolute age of the Upper Cenomanian – Lower Turonian Maghra El Hadida Formation which can be inferred from the correlation of the biostratigraphy to the time scale of SAGEMAN et al. (2006): the interval from the base of *Metoicoceras geslinianum* Zone to top of the Early Turonian corresponds to ~ 1.2 myr. This part of the Maghra El Hadida Formation is composed of three bundles. Thus, each one equals to ~ 400 kyr. Every bundle has four basic cycles, each one equalling to ~ 100 kyr.

The stacking pattern of the basic cycles suggests accommodation control: the lower ones are thicker, while the upper ones are thinner despite the same time content. It is also emphasised that there usually exists a direct relationship between cycle thickness and sedimentary facies, where the thicker ones show a prevalence of more open marine lithofacies, while the thinner cycles normally being characterised by a prevalence of more restricted lithofacies (D'ARGENIO et al., 1997). The accumulation rate for the Maghra El Hadida Formation can be estimated by accepting the duration of *c*. 400 kyr for each bundle: it follows that the three bundles comprising the Upper Cenomanian–Lower Turonian of the Maghra El Hadida Formation (51 m thick) record a minimum time interval equal to *c*. 1200 kyr. Taking into account the ratio of bundle thickness and time represented by each of them, it is possible to calculate their accumulation rates and, consequently, the average accumulation rate of the Maghra El Hadida Formation (Table 10.2).

Table 10.2. Accumulation rate of 4th-order cycles bundles of the Upper Cenomanian – Lower Turonian of the Maghra El Hadida Formation in cm per kyr, assuming that each bundle took *c*. 400 kyr to form.

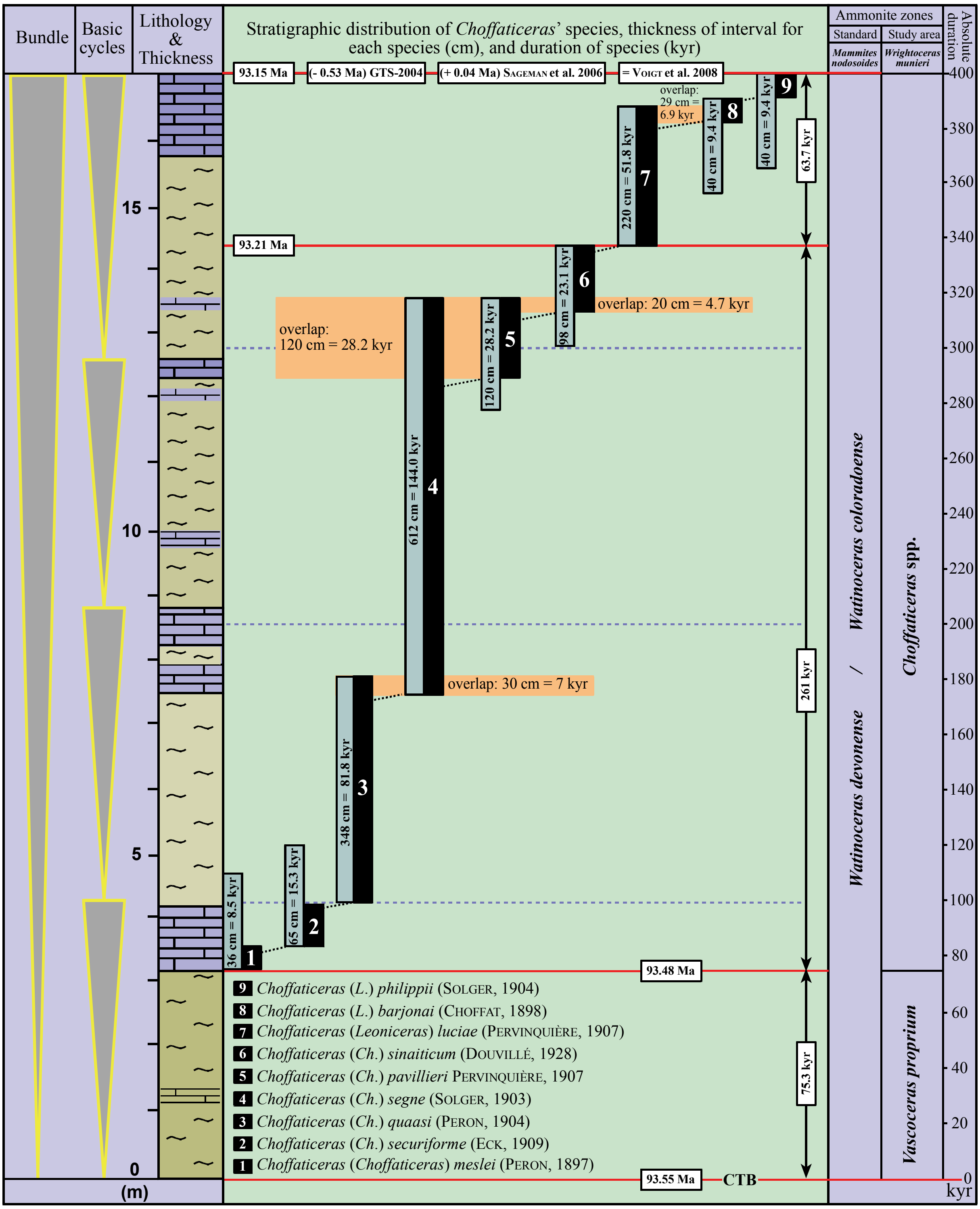
Bundles	Thickness (m)	Accumulation rate (cm/kyr)	Average accumulation rate of the Maghra El Hadida Fm (cm/kyr)
3	16	4.0	**4.25**
2	17	4.25	
1	18	4.5	

The above presented calculations show that the mean accumulation rate of the lower Maghra El Hadida Formation is more than four times lower than that of the Galala Formation (~ 19 vs ~ 4.25 cm/kyr). This can be explained by the much more distal setting of the former formation and the corresponding change in predominating sedimentation processes (accretion of fine pelagic carbonate particles). Such shifts are usually accompanied by considerable reduction of accumulation rates due to the reduced capacity of the pelagic carbonate factory (compared to the benthic ones) and diminishing terrigenous input (WILMSEN 2003, 2007). Furthermore, the low accumulation rates explain why no 6th-order cycles (as in the Galala Formation) were recognized: their recording is increasingly difficult at reduced accumulation rates (their thickness would be ~ 85 cm in the Maghra El Hadida Formation).

In addition to the estimation of sedimentation rates for the studied successions, the evolutionary pattern and speciation processes of selected faunal groups can be also estimated based on the cyclostratigraphic analysis proposed for the Cenomanian – Turonian. An excellent example for this approach is the Early Turonian genus *Choffaticeras* (HYATT, 1903). This genus is abundant and well preserved in the Lower Turonian of the study area and documents different evolutionary stages in the second bundle of the Maghra El Hadida Formation by means of morphological changes. Tacking into account the thickness of sediments of each species and the rate of sedimentation during this interval (4.25 cm/kyr), it is possible to fine-tune the duration of the morphological changes in this genus (Text-fig. 10.5).

The genus *Choffaticeras* is subdivided into two subgenera the oldest is *Ch*. (*Choffaticeras*) and the youngest is *Ch*. (*Leoniceras*). The first appearance of this genus is represented by *Choffaticeras* (*Ch*.) *meslei* (PERON) which is considered as the oldest species of this genus. It shows the diagnostic features of the genus and a ventral region resembling *Pseudotissotia* (PERON, 1897), from which *Choffaticeras* seems to derive (BARROSO-BARCENILLA & GOY, 2007). It first appeared 93.48 Ma ago (~ 75.3 kyr after the start of the Turonian; Text-fig. 10.5). This species is recorded from the upper part of the first basic cycle of the second bundle of the Maghra El Hadida Formation. The recorded duration of this species is ~ 8.5 kyr. Its last appearance is associated with the first appearance of *Choffaticeras* (*Ch*.) *securiforme* (ECK), persisting ~ 15.3 kyr. A new series of the subgenus *Choffaticeras* arose directly after the last appearance of *Choffaticeras* (*Ch*.) *securiforme* (ECK). It is started with *Choffaticeras* (*Ch*.) *quaasi* (PERON) which marks the end of the first basic cycle (~ 100 kyr after the base of the Turonian; Text-fig. 10.5). *Choffaticeras* (*Ch*.) *quaasi* (PERON) is persisting for ~ 81.8 kyr. In the last 7 kyr of its lifespan, some forms of *Choffaticeras* (*Ch*.) *segne* (SOLGER) were developed. *Choffaticeras* (*Ch*.) *segne* (SOLGER) is considered as the species in the *Choffaticeras* interval with the longest lifespan (~ 144 kyr). It extended from the upper part of the second to the lower part of the basic fourth cycle. In the last 28.2 kyr of *Choffaticeras* (*Ch*.) *segne* (SOLGER), *Choffaticeras* (*Ch*.) *pavillieri* (PERVINQUIÈRE) arose. *Choffaticeras* (*Ch*.) *sinaiticum* (DOUVILLÉ), which co-occurred with the last two species only for ~ 4.7 kyr, is persisting for another 18.4 kyr. The last appearance of *Choffaticeras* (*Ch*.) *sinaiticum* (DOUVILLÉ) was noted ~ 336.3 kyr after the start of the Turonian. It marks the extinction of the subgenus *Choffaticeras* (~ 93.21 Ma ago). This means that the lifespan of the subgenus *Choffaticeras* is about 261 kyr. The subgenus *Leoniceras* started to develop at the middle of the last basic cycle of the second bundle of the Maghra El Hadida Formation. *Choffaticeras* (*Leoniceras*) *luciae* (PERVINQUIÈRE) is the oldest species of this subgenus. It is persisting ~ 51.8 kyr. In the last 6.9 kyr of its lifespan, *Choffaticeras* (*L*.) *barjonai* (CHOFFAT) appears. Only ~ 2.5 kyr later, *Choffaticeras* (*L*.) *philippii* (SOLGER) started to arise. This species persisted ~ 9.4 kyr and is the last representative of the genus *Choffaticeras*. Therefore, the total duration the subgenus *Leoniceras* is ~ 63.7 kyr. Consequently, the morphological changes in genus *Choffaticeras* took place in ~ 325 kyr.

The last appearance datum of the genus *Choffaticeras* was ca. 93.15 Ma ago, being very close to the first appearance datum of *Mammites nodosoides* (Text-fig. 10.5) according to the correlation with orbital time scales of SAGEMAN et al. (2006) and VOIGT et al. (2008).



Text-fig. 10.5. Rate of evolutionary change for different species in the genus *Choffaticeras* during the Early Turonian based on the cyclostratigraphic analysis of the Maghra El Hadida Formation. This bundle is the second bundle in the Maghra El Hadida Foramtion and represents ~ 400 kyr, each basic cycle ~ 100 kyr. (see text for further explenation).

11. Conclusions

The integrated stratigraphical, palaeontological and sedimentological approach of this study resulted in a very detailed picture of the Cenomanian – Turonian Galala and Maghra El Hadida formations of the north Eastern Desert of Egypt. The main results (Text-fig. 11.1) are the following:

Four sections (Wadi Ghonima, East Wadi Ghonima, Wadi Askhar and Saint Anthony) of the Galala and Maghra El Hadida formations on the slopes of the northern and southern Galala plateaus in Wadi Araba (Eastern Desert) were measured and sampled in great detail.

The Galala Formation is ranging in thickness from 55 m at Saint Anthony to 95 m at East Wadi Ghonima. This formation overlies unconformably the Malha Formation which forms the base of the studied sections. The upper boundary of the Galala Formation is characterized by a major unconformity which separates it from the overlying the Maghra El Hadida Formation. The Galala Formation can be subdivided into five shallowing-upward cycles, each cycle starting with deep-lagoonal, marly-silty deposits at base and grading into highly fossiliferous shallow-lagoonal limestones at top. The basal part of the Galala Formation consists of unfossiliferous, greenish sandy siltstones intercalated with thin cross-bedded, bioturbated, fine- to medium-grained sandstones. Even if biostratigraphic markers are lacking in that lower part, its age can be assigned to the late Middle Cenomanian because the conformably overlying strata contain the ammonite *Neolobites vibrayeanus* (D'ORBIGNY), the index marker of the lower Upper Cenomanian which ranges into the top of the formation.

The measured thickness of the overlying Maghra El Hadida Formation ranges from 59 m at Saint Anthony to 118 m at East Wadi Ghonima. This formation starts with the Ghonima Member, introduced in this work to distinguish a basal brown, fine- to medium-grained, calcareous sandstone unit. This member is erosionally incised into the Galala Formation, explaining its laterally variable thickness ranging from 3 m at Saint Anthony to 21 m at Wadi Ghonima section. It is mostly unfossiliferous except for irregular bioturbation in its upper part. The Ghonima Member is assigned to the middle Upper Cenomanian, based on its stratigraphic position between the lower Upper Cenomanian *Neolobites vibrayeanus* Zone and overlying upper Upper Cenomanian *Metoicoceras geslinianum* and *Vascoceras cauvini* zones. This means that the lower part of the Maghra El Hadida Formation, about 20 – 30 m thick, accumulated during the latest Cenomanian and that the base of the formation, thus, does not coincide with the base of the Turonian as commonly reported. The overlying succession of the Maghra El Hadida Formation is characterized by an increase of carbonate content, represented by yellow soft marls intercalated with fine-grained wacke- to packstones containing a highly fossiliferous ammonite assemblage of the upper Upper Cenomanian and the Lower Turonian. The Lower Turonian ammonite zones are defined by *Vascoceras proprium* (REYMENT), *Choffaticeras* spp., and *Wrightoceras munieri* (PERVINQUIÈRE). The Lower Turonian succession is terminated by a prominent palaeo-karst horizon. The Middle Turonian part of the Maghra El Hadida Formation consists of poorly fossiliferous, thick, yellowish marls with upward-increasing silt content, showing occasional intercalations of medium- to coarse-grained sandstones with hummocky cross-stratification. The topmost part of the Maghra El Hadida Formation consists of brownish, medium-grained sandstones topped by fossiliferous marly limestones yielding the Upper Turonian zonal index ammonite *Coilopoceras requienianum* (D'ORBIGNY).

The Cenomanian – Turonian successions in the study area contains seven ammonite biozones, which provide the age constrains for the upper Middle – lower Upper Cenomanian Galala Formation and the upper Upper Cenomanian – Turonian Maghra El Hadida Formation. The following zones have been recognized (in ascending order): *Neolobites vibrayeanus*, *Metoicoceras geslinianum*, *Vascoceras cauvini* (Upper Cenomanian); *Vascoceras proprium*, *Choffaticeras* spp., *Wrightoceras munieri* (Lower Turonian); *Coilopoceras requienianum* (Upper Turonian). All zones are total range zones defined by the first and last appearances of the zonal index. A correlation of the established biozones to the standard ammonite zonation and other biozones recognized in Egypt for Late Cenomanian – Turonian times has been proposed in order to calibrate the observations from the study area to different regions.

Based on sequence stratigraphic analysis, four complete 3rd-order depositional sequences and the lower part of a fifth one, bounded by five major unconformities, can be recognized: DS WA 1 (upper Middle – Upper Cenomanian) includes the total Galala Formation, while the Maghra El Hadida Formation comprises all the overlying depositional sequences: DS WA 2 (upper Upper Cenomanian – Lower Turonian) reaches from the base of the *Metoicoceras geslinianum* Zone to the top of *Wrightoceras munieri* Zone, DS WA 3 and DS WA 4 comprise the Middle Turonian, while only the lower part of Upper Turonian DS WA 5 is exposed. The sequence boundaries in the study area are well-developed erosional or non-depositional unconformities, represented by prominent palaeokarst horizons or, at the base of siliciclastic units, incision into predominantly fine-grained highstand sediments. Due to the proximal position of the study area and the resulting lack of accommodation space during this phase of a 3rd-order depositional sequence, FSST and LST are generally missing. It may be possible the basal part of the ivf (incised valley fills) recognized at the base of the Maghra El Hadida Formation is related to infilling starting in the late phase of the lowstand. Transgressive surfaces are subordinate erosion surfaces and, commonly, they are fused with the sequence boundaries, resulting in a TST/HST stacking of depositional sequences. Transgressive surfaces commonly show intensive bioturbation and occur at the base of nodular, often fossiliferous sediments. In the study area, the deposits of TSTs are characterized by retrogradational parasequences, a general fining-upward trend, hardgrounds, and highly bioturbated fabrics with relatively high fossil content. Within the TSTs, shallow subtidal deposits prevail, which are mostly composed of calcareous marls and coarse bioclastic limestones with a rich benthic fossil assemblage. Condensation with phosphate enrichment and abundant ammonites often corresponds to maximum flooding conditions. Highstand deposits consist of fine-grained, shallow-subtidal sediments and are characterized by aggradational or progradational stacking patterns of parasequences. Often they are composed of thick-bedded marl with thin packstone intercalation with oysters, benthic foraminifera, calcareous algae and echinoderms. The correlation of the recognized depositional sequences with others from adjacent basins and beyond shows that the stratigraphic positions of the recognized sequence boundaries match well with contemporaneous sequence boundaries known from European basins and elsewhere.

The hierarchical cycle organisation (basic cycles and bundles) which was recognized in the Cenomanian – Turonian of the study area is used to hypothesize that this cyclicity was controlled by high-frequency climatic and eustatic changes triggered by variations in orbital parameters (MILANKOVITCH-type cycles). Based on 5:1 stacking pattern of the basic cycles and bundles in the Galala Formation, the basic cycles are considered to represent the precession cycle of the equinoxes (*c*. 20 kyr), the bundles the short eccentricity cycle (*c*. 100 kyr), and the superbundles (stacks of four bundles) the long eccentricity cycle of the Earth's orbit (*c*. 400 kyr). Support for this interpretation comes from the absolute age of the Galala Formation which can be inferred from the correlation of the biostratigraphy to the time scale of GRADSTEIN et al. (2004): the Galala Formation is considered to be equal to ~ 500 kyr and is composed of five 5^{th}-order bundles, each one equalling to ~ 100 kyr. Every bundle has five 6^{th}-order basic cycles, each one being equal to ~ 20 kyr. The accumulation rate for the up to 95 m thick Galala Formation can thus be estimated, reaching up to 19 cm/kyr. The stacking pattern of basic cycles of the Galala Formation suggests accommodation control because commonly the lower ones are thicker and represent deeper environments, while the upper ones are thinner and shallower. Therefore, high-frequency sea-level changes must have been associated with short eccentricity cycles. The rate of (eustatic) sea-level fall at SB WA 2 (equivalent to SB Ce V) has been estimated from amount of incision and water depth change evident in the study area and the inferred length of sea-level fall and lowstand (WILMSEN, unpublished data). The resulting rate of fall of 35 cm/kyr is large and fast, and interpreted to have been caused by glacioeustasy.

In the Maghra El Hadida Formation, based on 4:1 stacking pattern, the basic cycles are considered to represent the short eccentricity cycle (*c*. 100 kyr), and the bundles the long eccentricity cycle of the Earth's orbit (*c*. 400 kyr). The upper Upper Cenomanian – Lower Turonian of the Maghra El Hadida Formation is considered to be equal to ~ 1200 kyr, being composed of three 4^{th}-order bundles, each one approximating to ~ 400 kyr. Every bundle has four 5^{th}-order basic cycles (~ 100 kyr). This means that, in the study area, the Upper Cenomanian part of the Maghra El Hadida Formation comprises the first bundle (= 400 kyr), while the Lower Turonian consists of the two upper bundles (800 kyr). This is in much better agreement with the recently proposed 785 kyr duration of the Lower Turonian (SAGEMAN et al., 2006; VOIGT et al., 2008) than with 1300 kyr duration according to the standard time scale of GRADSTEIN et al. (2004). According to this result, the 51 m thick Upper Cenomanian – Lower Turonian Maghra El Hadida Formation records a time interval equal to *c*. 1200 kyr and was deposited with a mean accumulation rate of ~ 4.25 cm/kyr. This accumulation rate is more than four times lower than that of the Galala Formation (~ 19 vs. ~ 4.25 cm/kyr), related to the much more distal setting of the Maghra El Hadida Formation and the corresponding change in predominating sedimentation processes (accretion of fine pelagic carbonate particles). Such shifts are usually accompanied by considerable reduction of accumulation rates due to the reduced capacity of the pelagic carbonate factory (compared to the benthic ones) and diminishing terrigenous input.

In addition, based on the cyclostratigraphic analysis, the range of the Early Turonian genus *Choffaticeras* (HYATT, 1903) accounts to ~ 325 kyr. The genus first appeared 93.48 Ma ago (~ 75.3 kyr after the start of the Turonian). The evolutionary lineage started with the subgenus *Ch*. (*Choffaticeras*) which persisted for ~ 261 kyr and ended with the subgenus *Ch*. (*Leoniceras*), persisting ~ 63.7 kyr. The last appearance datum of the genus *Choffaticeras* was ca. 93.15 Ma ago, being very close to the first appearance datum of *Mammites nodosoides* according to the correlation with orbital time scales of SAGEMAN et al. (2006) and VOIGT et al. (2008).

The macrobenthos of the Galala and Maghra El Hadida formations in the study area has been identified, classified, and illustrated in seven figures. In total, 62 macrobenthic taxa are recorded (bivalves: 32 species belonging to 29 genera; gastropods: 15 species belonging to 14 genera; echinoids: 15 species belonging to 9 genera).

The Cenomanian – Turonian successions in the study area are also characterized by rich and abundant cephalopod faunas which were identified, classified, and illustrated in 17 figures, with complete discussion of their taxonomy, stratigraphy and palaeobiogeographic distribution. The identified cephalopods comprise 2 taxa of nautiloids belonging to 2 genera, and 27 species of ammonites belonging to 14 genera. 4 genera and 7 species of ammonites are recorded from Egypt for the first time [*Thomelites* sp.; *Euomphaloceras septemseriatum* (CRAGIN, 1893); *Fagesia* cf. *peroni* PERVINQUIÈRE, 1907; *Wrightoceras munieri* (PERVINQUIÈRE, 1907); *Choffaticeras* (*Choffaticeras*) *meslei* (PERON, 1897); *Choffaticeras* (*Leoniceras*) *barjonai* (CHOFFAT, 1898); *Choffaticeras* (*Leoniceras*) *philippii* (SOLGER, 1904); *Coilopoceras africanum* PERVINQUIÈRE, 1910; *Eubostrychoceras* sp.). The Lower Turonian *Choffaticeras* interval is the most fossiliferous unit in the study area. Polished sections of the early growth stages are used to differentiate between the tricarinate subgenus *Choffaticeras* and the monocarinate subgenus *Leoniceras*.

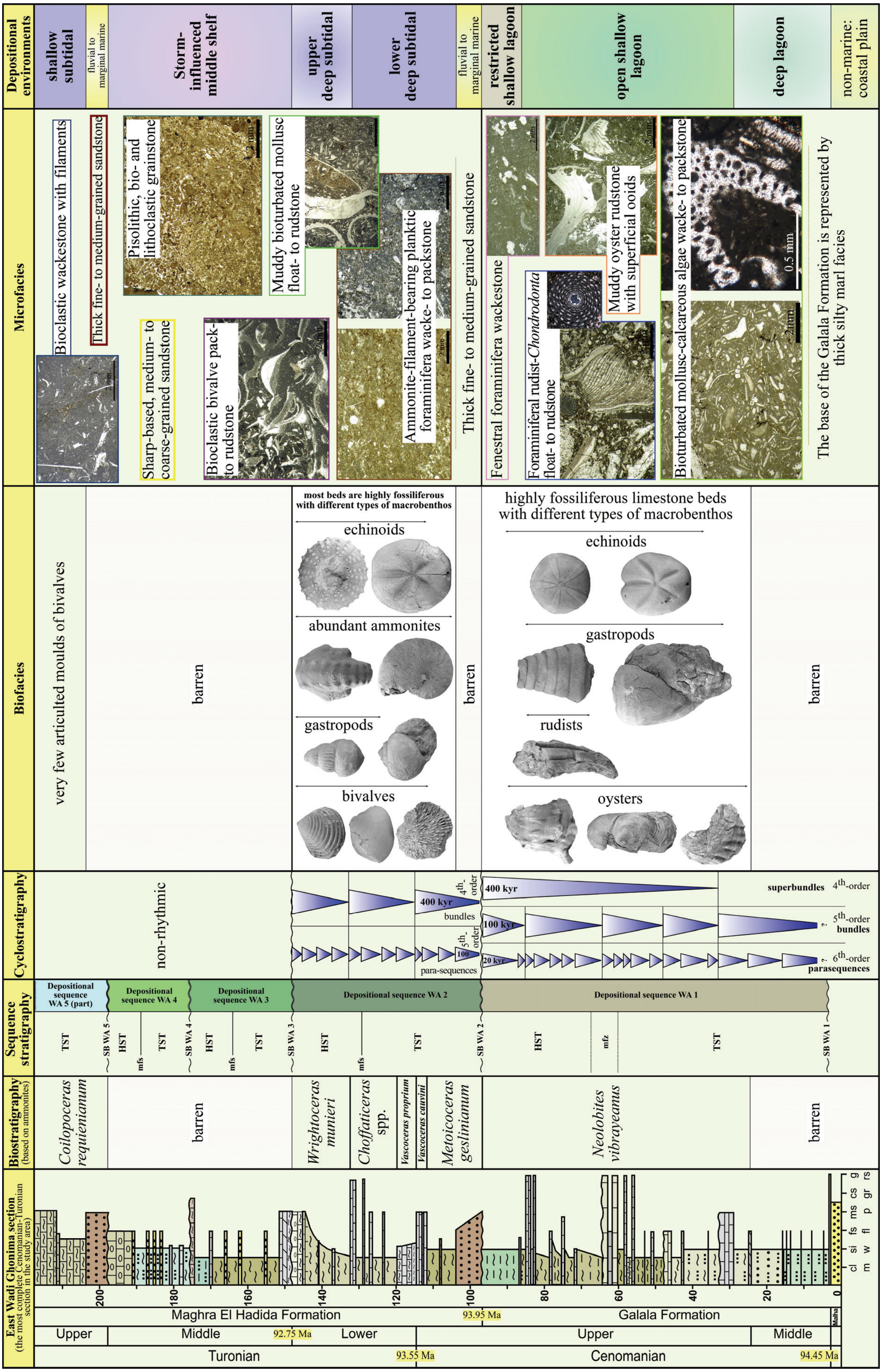
Micropalaeontologically, two species of dasycladalean algae (*Neomeris mokragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC), two taxa of udoteacean algae (*Halimeda* cf. *elliotti* CONARD & RIOULT, *Halimeda* sp.), five taxa of benthic foraminifera (*Pseudolituonella reicheli* MARIE, 1954; *Textularia* sp.; *quinqueloculina* sp.; *Pseudorhipidionina* cf. *casertana* (DE CASTRO, 1965); *Cuneolina* gr. *pavonia* D'ORBIGNY, 1839; *Praealveolina cretacea* D'ARCHIAC, 1837), and two taxa of crustacean microcoprolites (*Palaxius caucaensis* BLAU et al., 1995; *Palaxius* sp.) have been identified from the thin-sections. The data have been used in micro-bio-facies analysis.

The microfacies investigation of 90 thin-sections supplemented by the study of rock specimens by hand-lens in the field and observations of features such as bedding, sedimentary structures and fossil content (macrofossils, trace fossils) resulted in the recognition of 22 facies types for the Cenomanian – Turonian strata of the study area. These facies types are used to interpret the depositional environment of the Galala and Maghra El Hadida formations:

During Cenomanian times, the study area was situated at the southern margin of the Tethyan Realm. A marine transgression started at the base of the Galala Formation, documented by the marine sediments of the Galala Formation following above the non-marine sandstones of the Malha Formation. The facies types of the upper Middle – Upper Cenomanian Galala Formation are characterized by fine-grained, thick-silty marl grading into highly fossiliferous wacke- to packstone yielding calcareous algae (dasycladaleans and udoteaceans), suggesting a fully marine, warm water, open lagoonal environment with low to moderate water energy. The upper part of the Galala Formation is dominated by rudists, *Chondrodonta* and benthic foraminifera in limestones with float- to muddy rudstone fabric indicating normal salinity and moderate water energy in a shallow lagoonal environment. The topmost part of the Galala Formation documents a restricted lagoon (inter- to supratidal) environment with high salinity and low water energy as indicated by wackestone fabrics with birdseyes and an impoverished fauna with only few benthic foraminifera (miliolids).

The facies types of the Maghra El Hadida Formation suggest a deposition in an open-marine ramp setting ranging from deep-subtidal to intertidal environments. The deep subtidal deposits predominate in the upper Upper Cenomanian to Lower Turonian part of the formation. This interval is characterized by abundant planktic foraminifera, filaments and ammonites in wacke- to packstone fabric, suggesting a deposition in normal marine, deep subtidal environments with low- to moderate water energy. Shallowing episodes from deep to shallow subtidal settings are commonly marked by abundant large mollusc fragments (bivalves, gastropods) with some ammonites as well as spines and corona fragments of echinoids in bioturbated float- to rudstones. These sediments are followed by abundant mollusc fragments (bivalves, gastropods) and echinoids debris in packstones indicating low to moderate water energy in open, shallow subtidal settings which dominated by the end of the Lower Turonian of the Maghra El Hadida Formation. The Lower Turonian sediments are terminated by a prominent palaeo-karst horizon, indicating the end of the T/R cycle which started with the Cenomanian Galala Formation. The shallow subtidal sediments are characterized by densely packed bioclastic packstone or muddy rudstones showing accumulations of commonly one type of shells, suggesting normal marine conditions under storm-influence (tempestites indicating short-term high-energy conditions). This storm action is documented by hummocky cross-stratified sandstone intercalations which are common in the Middle Turonian part of the formation. The environment fluctuated between shallow and moderately deep subtidal environments during the remainder of the Turonian, indicated by the deposition of packstone with abundant mollusc fragments and a few ammonites.

Text-fig. 11.1. Summary of the main results of the present study


Depositional environments
shallow subtidal
fluvial to marginal marine
Storm-influenced middle shelf
upper deep subtidal
lower deep subtidal
fluvial to marginal marine
restricted shallow lagoon
open shallow lagoon
deep lagoon
non-marine: coastal plain
Microfacies
Bioclastic wackestone with filaments
Thick fine- to medium-grained sandstone
Pisolithic, bio- and lithoclastic grainstone
Sharp-based, medium- to coarse-grained sandstone
Bioclastic bivalve pack- to rudstone
Muddy bioturbated mollusc float- to rudstone
Ammonite-filament-bearing planktic foraminifera wacke- to packstone
Thick fine- to medium-grained sandstone
Fenestral foraminifera wackestone
Foraminiferal rudist-Chondrodonta float- to rudstone
Muddy oyster rudstone with superficial ooids
Bioturbated mollusc-calcareous algae wacke- to packstone
The base of the Galala Formation is represented by thick silty marl facies
Biofacies
very few articulted moulds of bivalves
barren
most beds are highly fossiliferous with different types of macrobenthos
echinoids
abundant ammonites
gastropods
bivalves
barren
highly fossiliferous limestone beds with different types of macrobenthos
echinoids
gastropods
rudists
oysters
barren
Cyclostratigraphy
non-rhythmic
400 kyr
4th-order
bundles
5th-order
100
para-sequences
superbundles 4th-order
5th-order bundles
6th-order parasequences
100 kyr
20 kyr
Sequence stratigraphy
Depositional sequence WA 5 (part)
Depositional sequence WA 4
Depositional sequence WA 3
Depositional sequence WA 2
Depositional sequence WA 1
TST
SB WA 5
HST
mfs
SB WA 4
SB WA 3
SB WA 2
mfz
SB WA 1
Biostratigraphy (based on ammonites)
Coilopoceras requienianum
barren
Wrightoceras munieri
Choffaticeras spp.
Vascoceras proprium
Vascoceras cauvini
Metoicoceras geslinianum
Neolobites vibrayeanus
barren
East Wadi Ghonima section (the most complete Cenomanian-Turonian section in the study area)
200
180
160
140
120
100
80
60
40
20
0
cl si fs ms cs g
m w fl p gr rs
Maghra El Hadida Formation
Galala Formation
Malha
93.95 Ma
Upper
Middle
Lower
Upper
Middle
92.75 Ma
Turonian
Cenomanian
93.55 Ma
94.45 Ma

ACKNOWLEDGEMENTS

I wish to express my deep appreciation and thanks to PD. Dr. MARKUS WILMSEN (Senckenberg Naturhistorische Sammlungen Dresden, Germany) for his supervision of my work, helpful discussions, and overall guidance. I am very grateful for his hospitality and help during my stay in Germany.

I am grateful to Prof. Dr. FRANZ T. FÜRSICH, Dr. MICHAEL HEINZE (GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg), and Dr. BIRGIT NIEBUHR (SARAH) for their help and hospitality in the institute.

My special thanks for assistance and pleasant cooperation go to Prof. Dr. ABDEL GALIL HEWAIDY (AL-AZHAR University, Egypt). My deep thanks to Prof. Dr. MOHAMED F. ALY (Cairo University, Egypt) for his support of my work and discussions on ammonite taxonomy.

I would like to thank Prof. Dr. JOCHEN KUSS (Bremen University, Germany) for aid in identification of benthic foraminifera, Prof. Dr. IOAN BUCCUR (Babes-Bolyai University, Romania) for identification of calcareous algae, Dr. F. BARROSO-BARCENILLA (Universidad Complutense de Madrid, Spain) for discussion on ammonite taxonomy, and Prof. Dr. SENOWBARI-DARYAN (GeoZentrum Nordbayern, Erlangen) for identification of microcoprolites.

Furthermore, thanks to Mrs. HILDEGARD SCHÖNIG (Würzburg) for the photographic work and to Mr. WASSERMANN (Würzburg) for the preparation of thin-sections.

I express deepest gratitude to my wife FATMA and my son MAHMOUD for their love, support, encouragement and understanding throughout this toil. My deep appreciation and thanks for my parents, for their love and support in all times.

Lastly, financial support by the Egyptian Missions Sector for the first two year is gratefully acknowledged.

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Appendix

Description of thin-section

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-2 Upper Cenomanian Galala Formation.	Sandy dolostone.	Very fine dolomite grains, with a few quartz sand grains.	Equigranular fabric.	Dendritic iron-manganese mineralizations.
080217-3 Upper Cenomanian Galala Formation.	Bioturbated mollusc-calcareous algae packstone.	Abundant different udoteacean and dasycladalean algae (*Halimeda* sp., *Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); fine- to coarse-grained recrystallized mollusc fragments (oysters, other bivalves, and gastropods) are common; some echinoderm debris; few ostracod shells.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbation is indicated by circular swirls and inhomogeneous fabric.
080217-4 Upper Cenomanian Galala Formation.	Bioturbated mollusc-calcareous algae packstone.	Abundant udoteacean and dasycladalean algae (*Halimeda* sp., *Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); fine- to coarse-grained recrystallized mollusc fragments (bivalves, some oysters, and few gastropods); rare echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbation is indicated by inhomogeneous fabric.
080217-6 Upper Cenomanian Galala Formation.	Bioturbated mollusc-calcareous algae packstone.	Abundant udoteacean and dasycladalean algae (*Halimeda* sp., *Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); some fine- to coarse-grained recrystallized mollusc fragments (bivalves, and few gastropods); some echinoderm debris as well as rare benthic foraminifera and serpulids.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbation is indicated by inhomogeneous fabric.
080217-8 Upper Cenomanian Galala Formation.	Fenestral foraminiferal wackestone.	Birdseyes (irregular and oval shape, millimeter-sized of blocky calcite-filled voids in a wackestone), few foraminifera (miliolids and *Textularia*) and small ostracods; rare bioclasts as well as echinoid spine.	Sparitic fill of birdseyes (blocky calcite).	
080217-12 Upper Cenomanian Galala Formation.	Muddy oyster rudstone with superficial ooids.	Abundant large and thick oyster fragments, with some recrystallized mollusc fragments (bivalves and gastropods); some oyster shells show foliated shell structure, some of them are intensively bored (*Entobia* isp.); udoteacean and dasycladalean algae occur as well as encrusting, colonial serpulids; subordinate are echinoderm debris, ostracod shells, corals, and foraminifera (*Textularia*). Simple ooids with one or two laminae are common, with a few aggregates grains.	Early diagenetic aragonite recrystallization.	*Entobia* isp. Type A.

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-13 Upper Cenomanian Galala Formation.	Muddy oyster rudstone with superficial ooids.	Large and thick oyster shell, with some recrystallized bivalves some of them are intensively bored (*Entobia* isp.); some small recrystallized gastropods; some udoteacean and dasycladalean algae; rare echinoderm debris; and rare benthic foraminifera. Rich simple ooids with one or two laminae, with few aggregates grains.	Early diagenetic aragonite recrystallization.	*Entobia* isp. Type A and B.
080217-14 Upper Cenomanian Galala Formation.	Echinoderm-bivalve rudstone.	Fine- to coarse-grained, thick recrystallized bivalves predominate, some of them show foliated shell structure, few of these shells are bored (*Entobia* isp.); some echinoderm debris occur as well as rare echinoid spines; dasycladalean algae, and small foraminifera (*Textularia*).	Early diagenetic aragonite recrystallization.	Many broken shells are related to bioerosion.
080217-15 Upper Cenomanian Galala Formation.	Bioturbated mollusc-dasycladalean wackestone.	Abundant fine-grained recrystallized bioclasts of dasycladalean algae, and a few small bivalve shells, some of them strongly bored; subordinate echinoderm debris, bryozoa, and rare foraminifera (*Textularia* & miliolids).	Early diagenetic aragonite recrystallization, patchy selective late diagenetic dolomitization (iron-rich, zoned with coarse-grained rhomboids).	Matrix sometimes with peloidal fabric. Bioturbation common.
080217-16 Upper Cenomanian Galala Formation.	Bioturbated mollusc calcareous algae packstone.	Abundant fragments of different types of udoteacean and dasycladalean algae (*Halimeda* sp., *Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); abundant fine- to medium-sized, recrystallized bivalve fragments with a few small gastropods; rare benthic foraminifera; and one small planktonic foraminifera (*Rotalipora* sp.).	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbation is indicated by and inhomogeneous fabric.
080217-18 Upper Cenomanian Galala Formation.	Foraminifera-rudist rudstone.	Large and thick rudist shells (*Eoradiolites liratus*), with borings (*Entobia* isp.); recrystallized fine- to coarse-grained of mollusc fragments (bivalves and gastropods); some foraminifera (miliolids, *Praealveolina cretacea*, and *Choffatella* sp.); few dasycladalean algae; rare echinoderm debris.	Early diagenetic aragonite recrystallization.	Entobia only in aragonitic shell layer of rudists; sparitic cement and muddy matrix.
080217-21 Upper Cenomanian Maghra El Hadida Fm.	Sandy, fine-grained dolostone.	Fine-grained dolomite, with some very fine quartz sand grains.		

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-22 Upper Cenomanian Maghra El Hadida Formation	Fine-grained peloidal packstone.	Abundant fine-grained peloids; few planktonic foraminifera, with rare ammonites.	Aggrading recrystallization transferred the micritic matrix into neomorphic microspar with peloidal fabric; patchy late diagenetic dolomitization (brownish, iron-rich) ocuurs.	
080217-23 Upper Cenomanian Maghra El Hadida Formation	Peloid coprolites packstone.	Abundant coprolites (*Palaxius caucaensis* BLAU et al., 1995), few echinoderm debris, and rare recrystallized ammonites.	Early diagenetic aragonite recrystallization.	
080217-24 Turonian Maghra El Hadida Formation	Filament-foraminiferal wackestone.	Some planktonic foraminifera, few recrystallized bivalve fragments, rare echinoderm debris, and rare recrystallized ammonites.	Early diagenetic aragonite recrystallization, patchy late diagenetic dolomitization.	
080217-18.5 Turonian Galala Formation.	Ammonite-foraminifera bearing wackestone.	Abundant small planktonic foraminifera; some recrystallized ammonites (*Choffaticeras* sp.); and rare filament.	Early diagenetic aragonite recrystallization.	
080217-19 Turonian Maghra El Hadida Formation	Bioclastic planktonic foraminifera-filament packstone.	Abundant filaments; planktonic foraminifer; fine- to coarse-grained recrystallized bivalve fragments are common; some echinoderm debris, few small recrystallized ammonites, and rare sponge spicules are occur.	Early diagenetic aragonite recrystallization.	
080217-20 Turonian Maghra El Hadida Formation	Bioclastic planktonic foraminifera-filament packstone.	Abundant planktonic foraminifera, with few *Textularia*; filaments are common; some echinoderm debris, few sponge spicules, and rare ammonites as well as few recrystallized bivalve fragments.	Early diagenetic aragonite recrystallization.	
080217-25 Turonian Maghra El Hadida Formation	Muddy bioturbated mollusc rudstone.	Abundant fine- to coarse-grained recrystallized mollusc fragment (bivalves and gastropods), some of them are bored (*Entobia* isp.), the bivalve fragments are aragonitic and calcitic; some encrusting serpulids; few echinoderm debris; large recrystallized ammonite (*Choffaticeras* sp.) and rare peloidal grains are occur.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbation is indicated by circular swirls and inhomogeneous fabric. Reworking and bioerosion are noted.

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-26 Turonian Maghra El Hadida Formation	Fine bioclasts mollusc packstone.	Abundant fine-grained recrystallized mollusc fragment (bivalves and gastropods), with some coarse-grained mollusc fragments with intensive bores (*Entobia* isp.); some echinoderm debris; few echinoid spins; few foraminifera (*Textularia*); rare sponge spicules, peloid grains, as well as serpulids.	Late diagenetic selective dolomitization of burrows.	Bioturbated fabric.
080217-28 Turonian Maghra El Hadida Formation	Mollusc-udoteacean packstone.	Abundant udoteacean algae (*Halimeda* cf. *elliotti* CONARD & RIOULT); fine-grained mollusc fragments (bivalves and gastropods) are common, few of them have encrusting bores; some echinoderm debris; rare ostracods and irregular echinoid spin.	Late diagenetic selective dolomitization of burrows.	Bioturbated fabric; the micritic fabric formed by peloid disintegration (relicts of sparitic rims around some of the peloids are noted).
080217-29 Turonian Maghra El Hadida Formation	Udoteacean packstone.	Abundant udoteacean algae (*Halimeda* cf. *elliotti* CONARD & RIOULT); echinoderm debris are common; some small recrystallized gastropods; few thin-shelled of bivalves with prismatic structure; some ostracods; rare bryozoa and serpulids.	Early diagenetic aragonite recrystallization.	Bioturbated fabric.
080217-30 Turonian Maghra El Hadida Formation	Dolostone.	Recrystallized fine-grained dolomite, rare small bioclasts grains.	Dolomitization (fine-grained rhomboids).	
080217-31 Turonian Maghra El Hadida Formation	Bioclastic packstone with bivalve rudstone filling a burrow (tubular tempestite).	Abundant fine- to medium-grained recrystallized bivalves, some of them filled with vadose silt; some small recrystallized gastropods; fine- to-medium-grained echinoderm debris are common; some calcite mollusc fragment are occur.	Early diagenetic aragonite recrystallization.	vadose silt is clearly observed.
080217-32 Turonian Maghra El Hadida Formation	Dolostone.	Very fine-grained dolomite, with few sand particles and rare small bioclasts.	Dolomitization (fine-grained rhomboids).	
080217-33 Turonian Maghra El Hadida Formation	Bioclastic packstone with lithoclasts.	Fine- to medium-grained oyster shells, most of them showing foliated shell structure, with some recrystallized bivalve fragments; some litho- and intraclasts, with some fine sand grains; few small recrystallized gastropods; some glauconitic gains; and rare planktonic foraminifera.	Early diagenetic aragonite recrystallization.	

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-34 Turonian Maghra El Hadida Formation	Bioclastic peloidal wackestone.	Abundant very fine peloidal grains, few recrystallized mollusc fragments, and few coprolites.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	vadose silt is observed.
080217-35 Turonian Maghra El Hadida Formation	Pisolithic, bio- and lithoclastic grainstone.	Abundant fine-grained pisolithic, bio- and lithoclasts, with few simple ooids grains.	Early diagenetic recrystallization.	The components infilling erosional relief of SBWA3 (transgressive lag).
080217-36 Turonian Maghra El Hadida Formation	Lime mudstone.	Very fine-grained mud.		
080217-39 Turonian Maghra El Hadida Fm.	Dolostone.	Very fine dolomite grains, with rare bioclasts.	Dolomitization (fine-grained rhomboids).	
080217-40 Turonian Maghra El Hadida Formation	Bioclastic mollusc packstone.	Abundant recrystallized mollusc fragments of bivalves and gastropods, with few oyster shells showing foliated shell structure; some lithoclasts grains; few echinoderm debris; and rare ostracods.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbated fabric.
080217-41 Turonian Maghra El Hadida Formation	Bioclastic mollusc packstone.	Nearly the same of 080217-40, but differs in having coarser bivalve fragments and with little dolomitization.	Early diagenetic aragonite recrystallization, late diagenetic selective dolomitization of burrows.	Bioturbated fabric.
080217-41.5 Turonian Maghra El Hadida Formation	Bioclastic wackestone, with filaments.	Some fine- to medium-grained recrystallized gastropods and bivalves, with few filaments; few echinoderm debris; rare ostracods; and some bores filled with fecal pellets.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated fabric.
080217-42 Turonian Maghra El Hadida Formation	Fine-grained bioturbated bioclastic wacke- to packstone.	Fine-grained recrystallized mollusc fragments (most of them are bivalves and rare gastropods), with few oyster shells showing foliated structure; echinoderm debris are common; few echinoid spins; rare planktonic foraminifera; and rare ostracods.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated fabric.

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080217-43 Turonian Maghra El Hadida Formation	Peloidal bivalve packstone.	Abundant fine peloidal grains; recrystallized bivalve fragments are common; few oyster shells showing foliated structure; rare gastropods; rare calcified cyanobacteria.	Early diagenetic aragonite recrystallization.	Bioturbated fabric.
080216-6, 080216-6.5 Upper Cenomanian Galala Formation.	Bioturbated mollusc-calcareous algae packstone.	Abundant udoteacean and dasycladalean algae (*Halimeda* sp., *Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); fine- to coarse-grained recrystallized mollusc fragments (bivalves and gastropods) are common; few thin oyster shells showing foliated structure; and echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbation is indicated by inhomogeneous fabric.
080216-7 Upper Cenomanian Galala Formation.	Bioturbated mollusc-calcareous algae packstone.	This thin-section is similar to 028016-6, but differs in having finer components.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbation is indicated by inhomogeneous fabric.
080216-8 Upper Cenomanian Galala Formation.	Foraminifera-*Chondrodonta* floatstone.	Large and thick *Chondrodonta* shells; fine- to coarse-grained recrystallized bivalve are common; few oyster shell showing foliated structure; rare recrystallized gastropods; few small rudist fragments; some shells of bivalve have bores (*Entobia* isp.); some foraminifera (*Praealvolin cretacea* and miliolids); few echinoderm debris; and rare sponge.	Early diagenetic aragonite recrystallization.	Bioturbation is indicated by inhomogeneous fabric.
080216-8 Upper Cenomanian Galala Formation.	Foraminifera-*Chondrodonta* floatstone.	Large and thick *Chondrodonta* shells; fine- to coarse-grained recrystallized bivalves; few oyster shell showing foliated structure; rare gastropods; few large rudist; common with foraminifera (*Textularia* sp.; *Pseudorhipidionina* cf. *casertana*; *Pseudolituonella reicheli*; *Cuneolina* gr. *Pavonia*); few echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbation is indicated by inhomogeneous fabric.
080216-8.5 Upper Cenomanian Galala Formation.	Foraminifera rudist-*Chondrodonta* rudstone.	Abundant large and thick rudist shell (*Eoradiolites liratus*), with intensive bores (*Entobia* isp.); large *Chondrodonta* fragments; benthic foraminifera (*Pseudolituonella reicheli*; *Textularia* sp.; *quinqueloculina* sp.; *Praealveolina cretacea*) are common; few bioclasts mollusc fragments (bivalve and gastropod); rare echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbation is indicated by inhomogeneous fabric.

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080216-9 Upper Cenomanian Galala Formation.	Fenestral foraminifera wackestone.	Some recrystallized shell fragments; few foraminifera (miliolids, *Textularia* sp.); birdseyes are occur.	Early diagenetic aragonite recrystallization, sparitic fill of birdseyes (blocky calcite).	Fenestral fabric.
080216-10 Upper Cenomanian Galala Formation.	Bioturbated mollusc-dasycladalean wackestone.	Abundant dasycladalean algae (*Neomeris makragorensis* RADOICIC & SCHLAGINTWEIT, *Trinocladus divnae* RADOICIC); some fine- to medium-grained recrystallized mollusc fragments (bivalves and rare gastropods) are common; few echinoderm debris; rare foraminifera (*Textularia* sp.).	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated fabric.
080216-11 Turonian Maghra El Hadida Fm.	Foraminiferal wackestone.	Some planktonic foraminifera, some coprolites; rare filaments and recrystallized small bioclasts.	Early diagenetic aragonite recrystallization.	
080216-12 Turonian Maghra El Hadida Formation	Foraminiferal -filament wackestone.	Some filaments, few planktonic foraminifera and rare recrystallized small bioclasts.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization.	
080216-13 Turonian Maghra El Hadida Formation	Filament - planktonic foraminifera wacke- to packstone.	Abundant planktonic foraminifera; some filaments; some small recrystallized ammonites; few recrystallized bivalves, and rare echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization.	
080216-14 Turonian Maghra El Hadida Formation	Filament-foraminifera bearing wackestone.	Abundant small planktonic foraminifera; filaments are common; few thin recrystallized bivalve fragments; and some ammonites.	Early diagenetic aragonite recrystallization.	Brownish color due to oxidation.
080214-14.5 Turonian Maghra El Hadida Formation	Planktonic foraminifera-filament-bivalve packstone.	Abundant fine- to coarse-grained recrystallized bivalves; planktonic foraminifera and filaments are common; some echinoderm debris; some ammonites; rare small gastropods.	Early diagenetic aragonite recrystallization.	
080216-15 Turonian Maghra El Hadida Formation	Muddy bivalve rudstone.	Abundant fine- to coarse-grained recrystallized bivalve fragments with rare gastropods; some coprolite; few filaments; rare echinoderm debris; rare foraminifera (*Textularia* sp.); and rare lithoclasts.	Early diagenetic aragonite recrystallization.	

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080216-15.5 Turonian Maghra El Hadida Formation	Muddy bivalve rudstone.	Similar to sample 080216-15, but differs in have bivalve shells with bores (Entobia isp.) and without foraminifera content.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization.	Bioturbated fabric.
080216-16 Turonian Maghra El Hadida Formation	Phosphorite-bearing, muddy bivalve rudstone.	Abundant fine- to coarse-grained recrystallized bivalve fragments and small gastropods, some bivalve shells showing prismatic structure; fine- to medium-sized phosphorite grains are common; rare echinoderm debris, foraminifera (*Textularia* sp.), few serpulids, and rare lithoclasts are occur.	Early diagenetic aragonite recrystallization.	Correspond to condense interval.
080216-17 Turonian Maghra El Hadida Formation	Bioclastic mollusc packstone.	Abundant recrystallized mollusc fragments of bivalves and gastropods, with few oyster shells showing foliated structure; some lithoclasts grains; few echinoderm debris; rare echinoid spins; and rare foraminifera.	Early diagenetic aragonite recrystallization.	Bioturbated fabric.
080216-19 Turonian Maghra El Hadida Formation	Udoteacean bivalve packstone.	Abundant recrystallized bivalve fragments; udoteacean algae (*Halimeda* cf. *elliotti* Conard & Rioult) are common; some small gastropods and few echinoderm debris.	Early diagenetic aragonite recrystallization.	Bioturbation is indicated by inhomogeneous fabric.
080216-21 Turonian Maghra El Hadida Formation	Dolostone.	Fine recrystallized dolomite grains taken rhomb shape and showing zonations around the crystals.	Strong dolomitization.	
080216-22 Turonian Maghra El Hadida Formation	Bivalve pack- to rudstone.	Dense fine- to coarse-grained recrystallized bivalve shells with small gastropods and few oyster fragments showing foliated structure; some glauconitic grains; few echinoderm debris; few lithoclasts; and rare echinoid spins.	Late diagenetic selective dolomitization.	Tempestite setting.
080216-24 Turonian Maghra El Hadida Formation	Lime mudstone.	Very fine-grained mud with rare ostracod shells.	Early diagenetic aragonite recrystallization.	
080215-1 Turonian Maghra El Hadida Formation	Fenestral foraminifera wackestone.	Some small foraminifera (miliolids and *Textularia* sp.); birdseyes are occur with a few small recrystallized bioclasts.	Early diagenetic aragonite recrystallization, sparitic fill of birdseyes (blocky calcite).	Fenestral fabric.

Thin-section No.	Dunham classification	Components	Diagenesis	Remarks
080215-2 Turonian Maghra El Hadida Formation	Bivalve float- to rudstone.	Abundant fine- to coarse-grained recrystallized bivalve fragments with small gastropods, some of the bivalve shells are bored (*Entobia* isp.); some echinoderm debris; few echinoid spins; rare foraminifera (*Textularia* sp.), serpulids worms and lithoclasts.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated fabric.
080215-6; 080215-6.5 Turonian Maghra El Hadida Formation	Fine-grained peloidal packstone.	Abundant fine-grained peloids with few recrystallized bioclasts and rare small ammonites.	Early diagenetic aragonite recrystallization.	Bioturbated.
080215-7; 080215-8 Turonian Maghra El Hadida Formation	Peloidal coprolite wackestone.	Abundant fine-grained peloids; coprolite are common; rare small recrystallized bioclasts.	Early diagenetic aragonite recrystallization.	Bioturbated.
080213-2 Turonian Maghra El Hadida Formation (two samples)	Foraminifera-bivalve bearing pack- to rudstone.	Abundant fine- to coarse- rudist fragments (*Eoradiolites liratus*) and *chontrodonta* with few oyster shells showing prismatic structure, some of these bivalves are bores (*Entobia* isp.); benthic foraminifera (most types recoded from the studied thin section); some dasycladalean algae; and few echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated.
080213-3 Turonian Maghra El Hadida Formation	Bioclastic-foraminifera bearing pack- to rudstone.	Abundant benthic foraminifera (most types recoded from the studied thin section); fine- to coarse- bivalve fragments, some them are *Eoradiolites liratus* with some oyster shells showing prismatic structure, some of these bivalve fragments are bored (*Entobia* isp.); rare small recrystallized gastropods; few dasycladalean algae; and few echinoderm debris.	Early diagenetic aragonite recrystallization, late diagenetic selective partial dolomitization related to bioturbation.	Bioturbated.

Lebenslauf

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AUSBILDUNG

- 1983–1989: Grundschule
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- 1996–2000: Bachelorstudium in Geologie (Abteilung Geologie, Fakultät für Wissenschaften, Al-Azhar Universität, Ägypten)
- 05/2000: Bachelor in Geologie (*BSc in Geology*), Abteilung Geologie, Fakultät für Wissenschaften, Al-Azhar Universität, Ägypten
- 01/2001–02/2002: Militärdienst in Ägypten
- 2002–2004: Masterstudium in Geologie (Stratigraphie), Abteilung Geologie, Fakultät für Wissenschaften, Al-Azhar Universität, Ägypten
- 13.06.2004: Master in Geologie (Stratigraphie), Abteilung Geologie, Fakultät für Wissenschaften, Al-Azhar Universität, Ägypten
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EINSCHLÄGIGE ERFAHRUNG

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- Geländeexkursionen im Hauptstudium Geologie/Paläontologie:
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- Sprachen:
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- 2002–2004: Wissenschaftlicher Mitarbeiter in der Abteilung Geologie, Fakultät für Wissenschaften, Azhar-Universität, Abteilung Assuit
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Publikationen von Emad Hamdy Mahmoud Nagm aus Menofiya, Ägypten

AUFSÄTZE

- SENOWBARI-DARYAN, B., **NAGM**, E., BLAU, J. & WILMSEN, M. (eingereicht): Crustacean microcoprolites from the Upper Cretaceous of the Eastern Desert, Egypt. – Facies; Erlangen.

ABSTRACTS

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- WILMSEN, M. & **NAGM**, E. (2008): Stratigraphy and facies development of the Galala and Maghra El Hadida formations (Cenomanian–Turonian, Eastern Desert, Egypt). – Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften (SDGG), **58**: 297; Hannover.
- **NAGM**, E., WILMSEN, M., ALY, M. & HEWAIDY, A. (2009): Cenomanian–Turonian (Cretaceous) ammonoids from the western Wadi Araba area, Eastern Desert, Egypt. – Poster, 8th International symposium on the Cretaceous, September 2009, University of Plymouth, United Kingdom.
- WILMSEN, M. & **NAGM**, E. (2009): Biofacies, stratigraphy and facies development of the Galala and Maghra El Hadida formations (Cenomanian–Turonian, Eastern Desert, Egypt). – Poster, 8th International symposium on the Cretaceous, September 2009, University of Plymouth, United Kingdom.