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CENOMANIAN-TURONIAN MACROBIOSTRATIGRAPHY OF ABU DARAG AREA, NORTHERN GALALA, EASTERN DESERT, EGYPT.

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Abstract. The Cenomanian-Turonian succession of Abu Darag area is subdivided, lithostratigraphically, into the Galala Formation (Cenomanian–Early Turonian) and the Umm Omeiyid Formation (? Middle-Late Turonian).

Biostratigraphically, three ammonite zones have been recognized in the studied section; *Acanthoceras* sp. Zone (Middle Cenomanian), *Neolobites vibrayeanus* Total Range Zone (early Late Cenomanian), and *Choffaticeras segne* Total Range Zone (Early Turonian). The corresponding zones based on other macrofossils include from older to younger:

- *Ceratostreon flabellatum – Rhynchostreon suborbiculatum* Acme Zone,
- *Hemiaster* (*Hemiaster*) *cubicus* Total Range Zone,
- *Ilymatogyra africana - Heterodiadema libycum - Hemiaster* (*Mecaster*) *pseudofourneli* Assemblage Zone,
- Rudists - corals - coralline sponge Assemblage Zone, and
- *Hemiaster* (*Mecaster*) *heberti turonensis - Coenholectypus turonensis* Total Range Zone.

The integration between the proposed ammonite and non-ammonite zones as well as local and inter-regional correlation with other well dated zonal schemes has been discussed. The Cenomanian/Turonian boundary is placed at the base of the *Choffaticeras segne* Zone.

Key words: *Cenomanian,Turonian, ammonit, biozones, Eastern Desert, Egypt.*

INTRODUCTION

Numerous studies have been carried out on the stratigraphy of the exposed Upper Cretaceous rocks in the northwestern part of the Gulf of Suez, e.g. Sadek (1926), Abdallah and El Adindani (1963), Abdallah *et al.* (1963), Awad and Abdallah (1966), El-Akkad and Abdallah (1971), Abu Khadrah *et al.* (1987), Kuss (1989), Kassab (1999), and Kora *et al.* (2001 a and b). Several works had been carried out on the stratigraphy of Abu Darag area, from Wadi Abu Darag to Abu Darag Lighthouse (Fig.1) (Malchus, 1990; Abd-Elazeam and Metwally, 1998; Kassab and Zakhera, 1999; Ismail and Akarish, 2000; Orabi, 2000; El-Hedeny and Nafee, 2001; Abd-Elshafy *et al.*, 2002 a and b; and Galal and Nafee, 2003). Intensive faulting of the Gulf of Suez Rift led to the dominance of incomplete Cretaceous sections in the area. However, a rather complete surface Cretaceous succession is reported along the southern escarp of the Northern Galala in Wadi Askhar (Hewaidy *et al.*, 2003). This may explain the confusion in both lithostratigraphy and biostratigraphy among authors, who studied the Cretaceous sediments of the western side of the Gulf of Suez (Tables 1-3). For instance, the Cretaceous succession of Bir Qiesib section was studied by Malchus (1990; oysters), Orabi (2000; benthic foraminifera), Ismail and Akarish (2000; stratigraphy and facies), and El-Hedeny and Nafee (2001; ammonites). Both Orabi (2000) and El-Hedeny and Nafee (2001) are inclined to Malchus's opinion that there is no lower Turonian fauna in Bir Qiseib section. On the other hand, Ismail and Akarish (2000) described a complete Cenomanian-Turonian succession from the same locality (Bir Qiseib section).

The present study aims to construct an integrated macro-biostratigraphic scheme for the Cenomanian–Turonian succession of Abu Darag area (Fig. 1) and to determine the Cenomanian–Turonian boundary based on the ammonites.

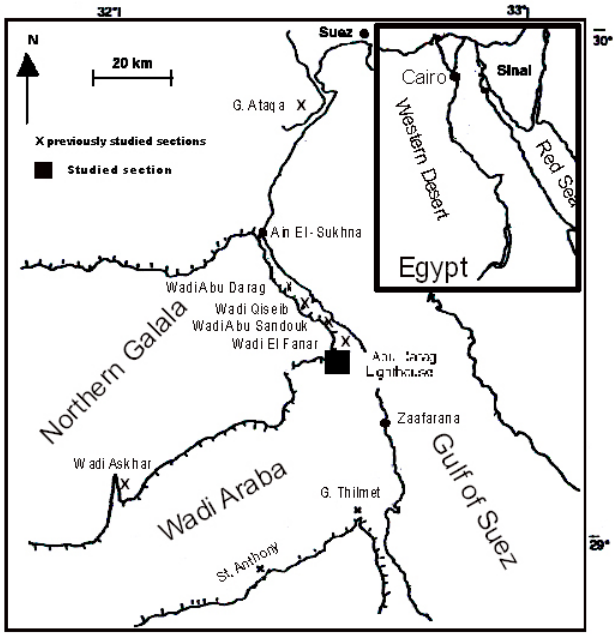

Fig. 1: Location map of the studied section (Abu Darag Lighthouse), Northern Galala.

Table1: Lithostratigraphic correlation of the Cenomanian – Turonian succession of Abu Darag area proposed by different authors

Chronostratigraphic Units		Wadi Abu Darag	Bir Qiseib		Abu Sandouk		Abu Darag Lighthouse	
		Abd-Elazeam and Metwally (1998),Abd -Elshafy *et al.* (2002a, b)	Malchus (1990), Orabi (2000), El-Hedeny and Nafee (2001)	Ismail and Akarish **(2000)**	Kora *et al.* (2001a, b)	Galal and Nafee (2003)	Kassab and Zakhera (1999)	Present Study
Turonian	Upper	Wata Fm.		Wata Fm.		Wata Fm.	Umm Omeiyid Fm.	Umm Omeiyid Fm.
	Middle							
	Lower			Abu Qada Fm.			Galala Fm.	Galala Fm.
Cenomanian		Galala Fm.	Galala Fm.	Galala Fm.	Galala Fm.	Abu Qada Fm.		
Lower Cret.		Malha Fm.	Malha Fm.	Malha Fm.	Malha Fm.	Malha Fm.	Malha Fm.	Malha Fm.

Material and Methods:

The present study is based on a bed by bed collection of macrofossils including cephalopods (8 species; 7 ammonite and one nautiloid species), bivalves (31 species), gastropods (16 species), echinoids (13 species), corals (3 species), and coralline sponge (one species) through the Cenomanian–Turonian succession exposed at Abu Darag area. The systematic description of the aforementioned material is presented in the 6th annual meeting of the Paleontological Society of Egypt (Abdel Gawad *et al.* 2006). The studied cephalopods and echinoids are deposited at the Geology Department, Benha University. The bivalves and gastropods are deposited at the Geology Department, Suez Canal University, whereas corals and coralline sponges are deposited at the Geology Department, Beni Sueif University.

LITHOSTRATIGRAPHY

Both the Lower Cretaceous clastics and the marine Upper Cretaceous rocks of the Cenomanian-Turonian are exposed in the studied section, opposite to Abu Darag Lighthouse (Fig. 1). Field investigation of the studied succession led to recognition of three rock units, the following is a brief description for these units, from older to younger:

The Malha Formation (Lower Cretaceous)

The Malha Formation was established by Abdallah *et al.* (1963) at Wadi Malha, Abu Darag area, Eastern Desert and revised by Darwish (1992). It is proposed to describe the Lower Cretaceous succession, which consists mainly of white, medium to fine-grained sandstones with kaolinised clay. In the studied section, the Malha Formation represents the oldest exposed Cretaceous rocks. It overlies uncoformably the Qiseib Formation of the Early Triassic age and is unconformably overlain by the Galala Formation (Fig. 2 and Pl. 1A). The Malha Formation did not measure herein as it is beyond the scope of the present study.

The Galala Formation (Cenomanian–Lower Turonian)

The Galala Formation was first introduced by Abdallah and El Adindani (1963) to describe a Cenomanian green marl succession intercalated with

Table 2: Correlation of the Cenomanian-Turonian ammonite biozones with those proposed by previous authors for various localities of Egypt.

Age		Central and Northern Sinai (Aly and Abdel Gawad, 2001)	West Central Sinai (El-Hedeny, 2002)	Sinai (Abdel-Gawad *et al.*, 2004)	Gulf of Suez (Kassab, 1999)	Gulf of Suez (Kora *et al.*, 2001b)	North Eastern Desert (Hewaidy *et al.*, 2003)	Present Study Abu Darag Lighthouse
	Early	Mammites nodosoides Choffaticeras segne *Pseud-aspidoceras flexuosum*	*Choffaticeras segne* **Vascoceras** *Proprium*	*Choffaticeras sinaiticum – Thomasites rollandi* Total Range Zone *Choffaticeras segne – Vascoceras harttii* Total Range Zone *Choffaticeras securiforme – Choffaticeras quaasi* Total Range Zone	*Choffaticeras segne* - *Pseud-aspidoceras flexuosum*	*Mammites nodosoides*- *Choffaticeras segne*	*Choffaticeras luciae* *Choffaticeras segne Vascoceras pioti* - *Vascoceras proprium*	*Choffaticeras segne* Total Range Zone
Cenomanian	**Late**	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*Vascoceras cauvini – Pseud-aspidoceras pseudo-nodosoides – Rubroceras alatum* Assemblage Zone *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Neolobites vibrayeanus*	*Neolobites vibrayeanus*	*Neolobites vibrayeanus*
	Middle							*Acanthoceras* sp.

thin limestone beds in the Northern Galala area. It was subdivided by Awad and Abdallah (1966) into two informal members; a lower marly and shaly member and an upper limestone member.

In the studied section, the Galala Formation overlies unconformably the Lower Cretaceous Malha Formation and underlies unconformably the Middle–Upper Turonian (?) Umm Omeiyid Formation (Fig. 2 and Pl. 1B). It measures 122 m and is composed mainly of fossilferous marl, dolomitic limestone, with a few shale-siltstone interbeds. It can be subdivided into two informal members as suggested by Awad and Abdallah (1966). The lower member (marly shaly member) measures 78 m thickness and consists mainly of marl with a few limestone, shale, siltstone, claystone, and sandstone interbeds. The upper member (carbonate member) is a succession of limestones; dolomitic limestone, chaky limestone, sandy limestone, dolostone with marl interbeds. It attains a thikness of 44 m.

Table 3: Interregional correlation of the Cenomanian-Turonian ammonite zones of Abu Darag area.

Age		Standard Ammonite Zones of S. Europe (Hardenbol *et al.*, 1998)	Tunisia (Robaszynski *et al.* 1993) and Chancellor *et al.*, 1994)	Algeria (Amard *et al.*, 1981)	Morocco (Charriere *et al.* 1998)	Israel (Lewy 1989)	Present Study Abu Darag Lighthouse
	Early	*Mammites nodosoides*	*Mammites nodosoides*	*Hoplitoides*	*Ch.* sp. / *V.* sp. *M. nodosoides*	*Choffaticeras luciae trisellatum*	*Choffaticeras segne*
			Thomasites rollandi	Vascoceratidae (*Nigeraceras, Vascoceras*)	*Vascoceras durandi*	*Choffaticeras quassi* *Choffaticeras securiforme* *Vascoceras pioti*	
		Watinoceras coloradoense	*Pseudaspidoceras flexuosum*	*wrightoceras, Bauchioceras*	*P. flexuosum* *Neoptychites* ?	*Pseudaspidoceras footeanum*	
Cenomanian	Late	*Neocardioceras juddii*	*Pseudaspidoceras* *Pseudonodosoides* *Euomphaloceras* cf. *septemseriatum*	*V. gamai*	*P.* sp. / *V.* sp. *V.* gr. *cauvini* *P.* cf. *Pseudonodosoides*		
		Metoicoceras geslinianum		*Neolobites, Calycoceras*	*Nigeraceras* ? sp	*Metoicoceras geslinianum – Costagyra olisiponensis –*	
		Calycoceras naviculare / Eucalycoceras pentagonum	*Eucalycoceras pentagonum*	*Neolobites vibrayeanus*	*.Neolobites vibrayeanus*	*Neolobites vibrayeanus*	*Neolobites vibrayeanus*
	Middle	*Acanthoceras jukesbrownei*	*Acanthoceras amphibolum* *Paraconlinoceras* aff. *barcusi*			*Euomphaloceras*	*Acanthoceras* sp.
		Acanthoceras rhotomagense *Cunningtoniceras inerme*	*Acanthoceras* cf. *rhotomagense* *Cunningtoniceras inerme*			*Pseudocalycoceras haugi* *Neolobites fourtaui*	
	Early	*Mantelliceras dixoni*	*Mantelliceras dixoni*			*Mantelliceras*	
		Mantelliceras mantellei	*M.* cf. *mantellei* *M.cobbani* *M. azregensis*				

The Galala Formation is a highly fossiliferous unit (Pl. 1, C-G; Pls. 2-4). The most abundant macrofossils recorded from the lower marly shaly member include the bivalves: *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Ilymatogyra africana* (Lamarck), *Gyrostrea delettrei* (Coquand), *Chondrodonta joannae* (Choffat), *Eoradiolites liratus* (Conrad), and *Praeradiolites biskraensis* (Coquand); the gastropods: *Nerinea olisiponensis* Sharpe, *Pterocera incerta* d'Orbigny, *Pterodonta deffisi* Thomas and Peron, and *Harpagodes heberti* (Thomas and Peron); the cephalopods: *Neolobites vibrayeanus* (d'Orbigny), *Acanthoceras* sp., *Angulithes mermeti* (Coquand); and the echinoids: *Heterodiadema libycum* (Desor), *Hemiaster* (*H.*) *cubicus* Desor, and *Hemiaster* (*Mecaster*) *pseudofourneli* Peron and Gauthier.

The upper carbonate member is very rich with the Lower Turonian ammonites (Pl. 1G and Pls. 2-3) *Choffaticeras segne* (Solger), *Thomasites rollandi* (Thomas and Peron), and *Vascoceras durandi* (Thomas and Peron), together with the bivalves *Plicatula auressensis* (Coquand), *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), and the echinoids *Hemiaster* (*Mecaster*) *heberti turonensis* Fourtau and *Coenholectypus turonensis* (Desor). From the aforementioned fauna, the Galala Formation in the studied section is assigned to a Cenomanian - Early Turonian age.

The Umm Omeiyid Formation (?Middle-Upper Turonian)

The term "Umm Omeiyid" Formation appeared for the first time on the preliminary interpretative geological map (Klitzsch and List, 1980). They proposed it to describe a brown to yellowish brown, cross-bedded Mesozoic sandstone unit exposed at Wadi Umm Omeiyid, central Wadi Qena, Eastern Desert. Klitzsch *et al.* (1986) and Hermina *et al.* (1989) redefined the Umm Omeiyid Formation at its type area as brown to yellowish brown, cross-bedded, continental sandstone of

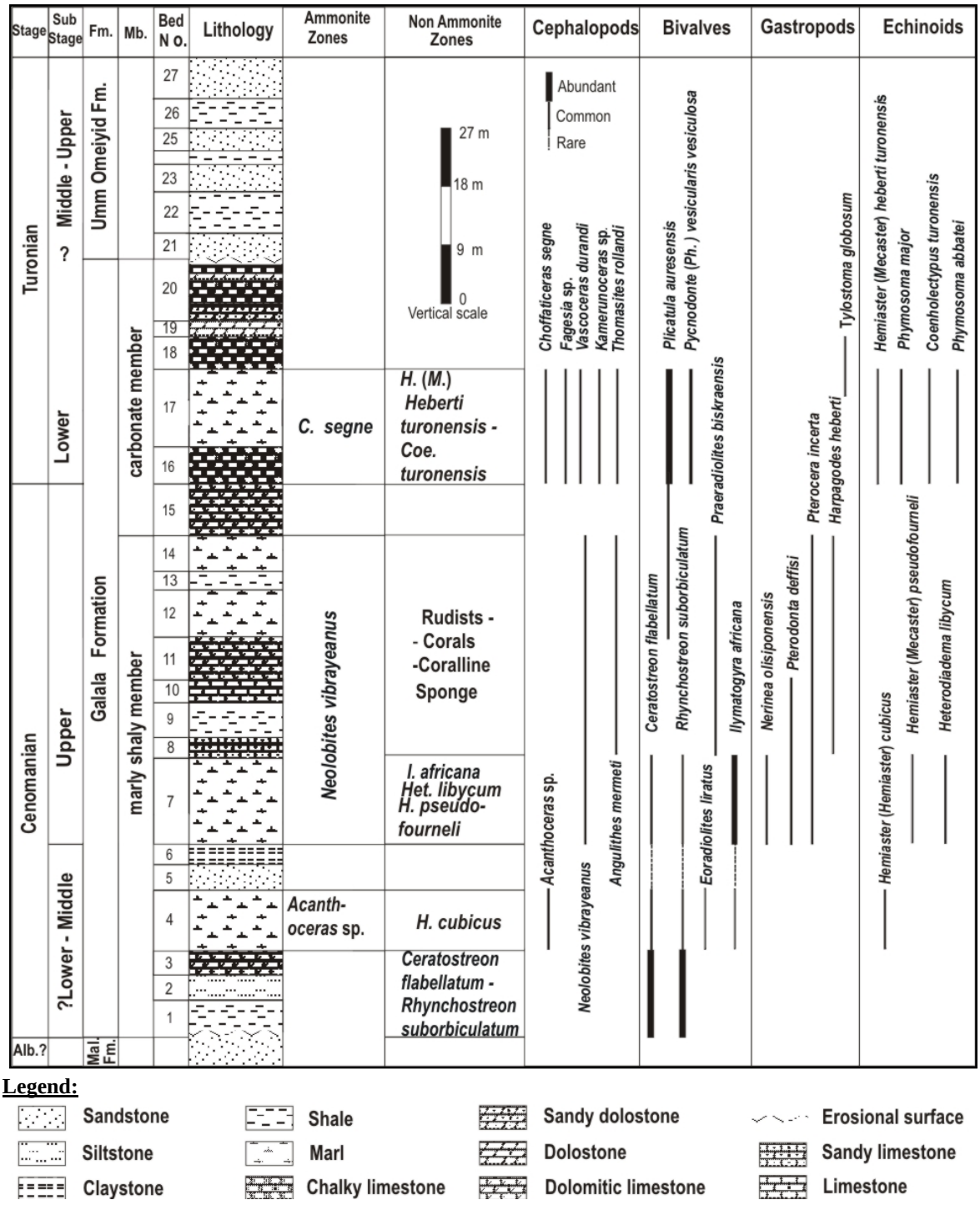

Fig. 2: Stratigraphy of the Cenomanian-Turonian succession of Abu Darag area (Lighthouse); and the integration between the ammonite and non-ammonite macrobiozones.

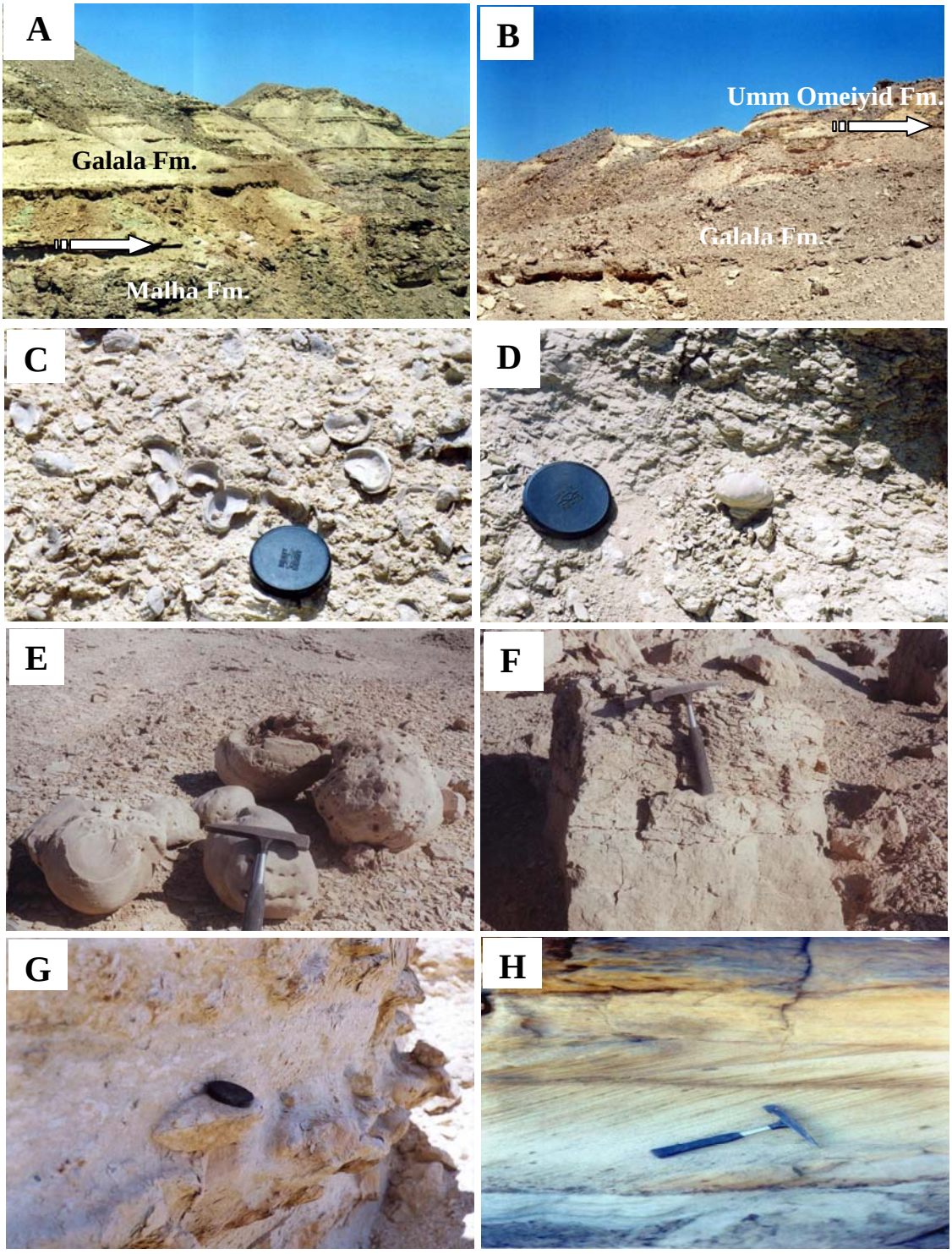

Plate 1

Fig. A: The Galala Formation overlies the Malha Formation at Abu Darag Lighthouse. The arrow marks the contact. **Fig. B:** The Umm Omeiyid Formation overlies the Galala Formation. The arrow marks the contact. **Fig. C:** *Ceratostreon flabellatum* (Goldfuss) in the *Ceratostreon flabellatum –Rhynchostreon suborbiculatum* Zone, Galala Formation, Abu Darag. **Fig. D:** *Hemiaster* (*Hemiaster*) *cubicus* Desor, *H.* (*H.*) *cubicus* Total Range Zone, lower member, Galala Formation. **Fig. E:** Coralline Sponge in the Rudists - Corals – Coralline Sponge Assemblage Zone, lower member, Galala Formation. **Fig. F:** *Chondrodonta joannae* (Choffat), (*Chondrodonta* bed) in the Rudists - Corals – Coralline Sponge Assemblage Zone, lower member, Galala Formation. **Fig. G:** *Choffaticeras segne* (Solger) in the *Choffaticeras segne* Total Range Zone (Ammonite bed), Lower Turonian, upper member, Galala Formation. **Fig. H:** Cross-bedded sandstone of the Umm Omeiyid Formation.

Turonian age intercalated with ammonite rich inner shelf sediments. Kassab (1991) and Kassab and Zakhera (1999) sugested a Late Turonian- Middle Coniacian age for the Umm Omeiyid Formation where it ovelies the Cenomanian Lower Turonian Galala Formation and underlies the Santonian Hawashiya Formation. However, Luger and Gröschke (1989) and Philobbos (1999) restricted the Umm Omeiyid Formation to the Turonian and extended the Hawashiya Formation down to the Conacian. Abdel Gawad (1999) correlated this formation with the upper clastic part of the Abu Qada Formation developed in west-central Sinai as a regressive phase "Red Beds". This unit is termed as Buttum Formation by Issawi *et al.* (1999). In Northern Galala (Table 1), Kassab and Zakhera (1999) reported this unit at Abu Darag area.

In the studied section, the Umm Omeiyid Formation overlies unconformably the Cenomanian - Lower Turonian Galala Formation (Pl. 1B) and attains a thickness of 35 m. It consists mainly of brown to yellowish brown, medium- to fine-grained cross-bedded sandstone (Fig. 2 and Pl. 1H) with some plant remains. The sandstones are intercalated with minor shale interbeds. The Formation is barren of macrofauna and is considered of ?Middle-Late Turonian age based on its stratigraphic poistion.

BIOSTRATIGRAPHY

Ammonite zones

The stratigraphic distribution of the identified ammonites enabled the subdivision of the Cenomanian - Lower Turonian sequence (Pls. 2-3) of the studied section into three ammonite zones (Fig. 2). The proposed zones are correlated with the ammonite zones proposed by other workers for different localities in Egypt. They are also correlated with the standard ammonite zones and other ammonite zonal schemes used in the adjacent Tethyan regions (Tables 2 and 3). The following is a brief description of the proposed ammonite zones from older to younger:

Acanthoceras sp. Total Range Zone

The zone is defined by the total range of the zonal species. It measures a thickness of 10 m in the lower part of the marly shaly member of the Galala Formation. The associated faunal elements are *Hemiaster* (*Hemiaster*) *cubicus* Desor, *Ilymatogyra africana* (Lamarck), *Eoradiolites liratus* (Conrad), *Barbatia aegyptiaca* (Fourtau), *Parasea faba faba* (J. de C. Sowerby), *Maghrebella forgemoli* (Coquand), *Arctica* spp., *Tenea delettrei* (Coquand). The co-occurrence of *Ilymatogyra africana* (Lamarck) of Middle–Late Cenomanian age (Malchus, 1990; Aqrabawi, 1993; and Seeling and Bengtson 1999) suggests a Middle Cenomanian age for this zone as it underlies the lower Upper Cenomanian *Neolobites vibrayeanus* Zone.

Neolobites vibrayeanus Total Range Zone

This zone is defined by the total range of the zonal species *Neolobites vibrayeanus* (d'Orbigny). It attains a thickness of 46 m including the upper part of the marly shaly member of the Galala Formation. The associated macrofauna are *Ilymatogyra africana* (Lamarck), *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Chondrodonta joannae* (Choffat), *Praeradiolites biskraensis* (Coquand), *Nayadina* (*Nayadina*) *gaudryi* Thomas and Peron, *Glossus aquilinus* (Coquand), *Parasea faba faba* (J. de C. Sowerby), *Arctica picteti* (Coquand); *Nerinea olisiponensis* Sharpe, *Pterocera incerta* d'Orbigny, *Pterodonta deffisi* Thomas and Peron, and *Harpagodes heberti* (Thomas and Peron), *Heterodiadema libycum* (Desor), *Coenholectypus pulvinatus* (Desor), and the nautiloid *Angulithes mermeti* (Coquand). The *Neolobites vibrayeanus* (d'Orbigny) is widely known from the lower Upper Cenomanian (Western Europe, North Africa, the Middle East, and South America), just below the *Metoicoceras geslinianum* Zone (Kennedy and Juignet 1981) and is in part equivalent to the standard *Calycoceras guerangeri* Zone.

Choffaticeras segne Total Range Zone

The zone attains a thickness of about 18 m in the carbonate member of the Galala Formation. It is defined by the total range of the zonal species *Choffaticeras segne* (Solger). It yields also the ammonites *Thomasites rollandi* (Thomas and Peron), *Vascoceras durandi* (Thomas and Peron), *Fagesia* sp., and *Kamerunoceras* sp. Other associated faunal elements are *Plicatula auressensis* (Coquand), *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), *Cucullaea* (*Idonearca*) *diceras* (Seguenza), *Parasea dutrugei* (Coquand), *Phelopteria gravida* (Coquand), *Phymosoma major* Coquand, and *Orthopsis ovata* (Coquand), *Hemiaster* (*Mecaster*) *heberti* (Coquand) *turonensis* Fourtau and *Coenholectypus turonensis* (Desor). This zone is equivalent to the *Choffaticeras segne* Zone, recorded by many authors from the Lower Turonian of different localities of Egypt, e.g. Kassab (1991 and 1994) and Aly and Abdel–Gawad (2001). It is equivalent also to the three *Choffaticeras* zones of Abdel–Gawad *et al.* (2004) from the Lower Turonian of Sinai. The occurrence of *Thomasites rollandi* (Thomas and Peron) and *Vascoceras durandi* (Thomas and Peron) in the *Choffaticeras segne* Zone, indicates that, the *segne* Zone is equivalent to the *Thomasites rollandi* Zone of Chancellor *et al.* (1994) from the Lower Turonian of Tunisia and *Vascoceras durandi* Zone of Charriere *et al.* (1998) Which recorded at the same stratigraphic level from Morocco. Consequently, the zone is of Early Turonian age.

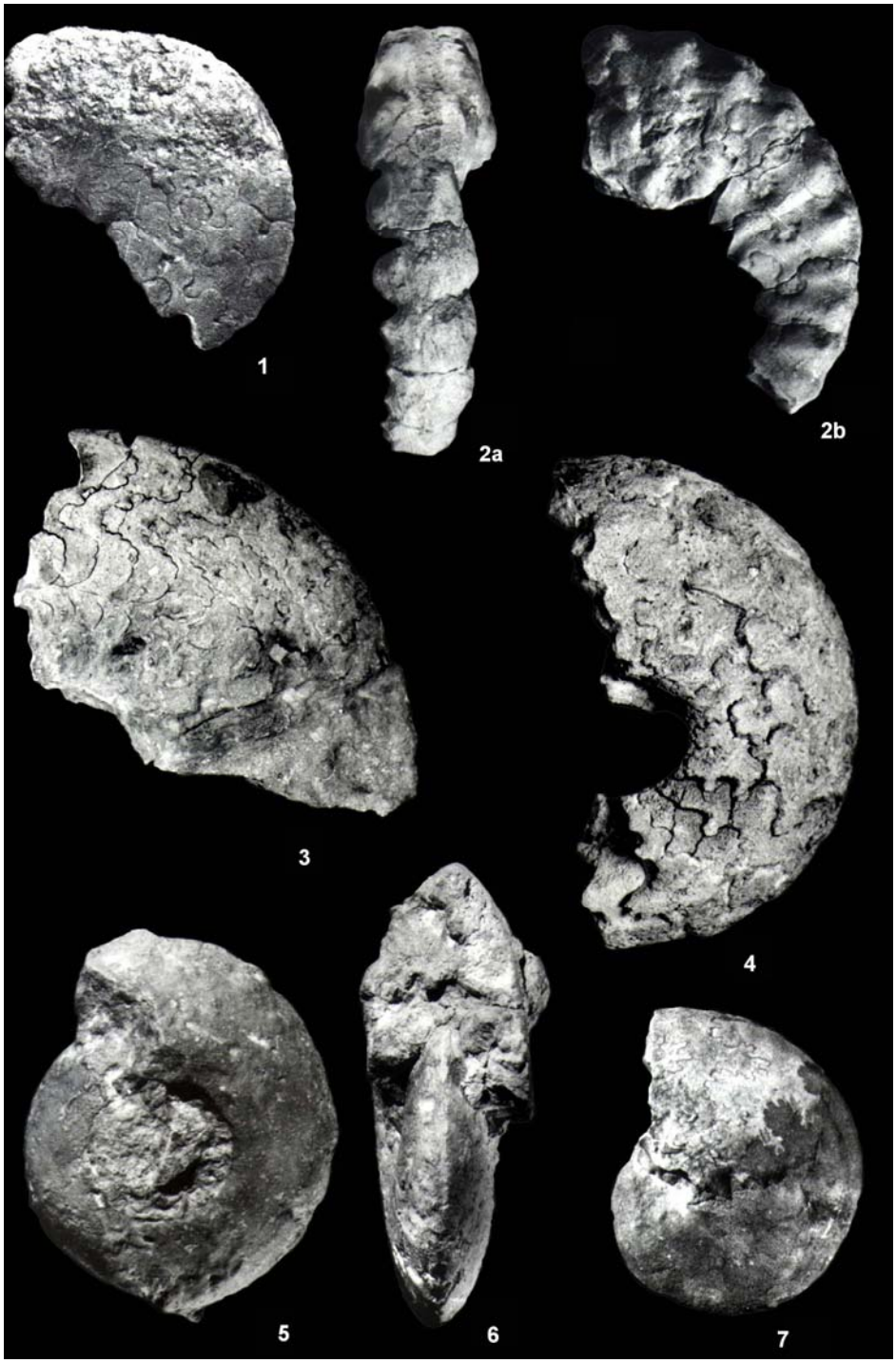

Plate 2

1. *Neolobites vibrayeanus* (d'Orbigny), side view, X1 **2.** *Acanthoceras* sp.; a: venter view, b: side view, X1 **3, 4, 6.** *Choffaticeras segne* (Solger); 3, 4: side views, 6: apertural view, X1 **5.** *Vascoceras durandi* (Thomas and Peron), side view, X1 **7.** *Thomasites rollandi* (Thomas and Peron), side view, X1.

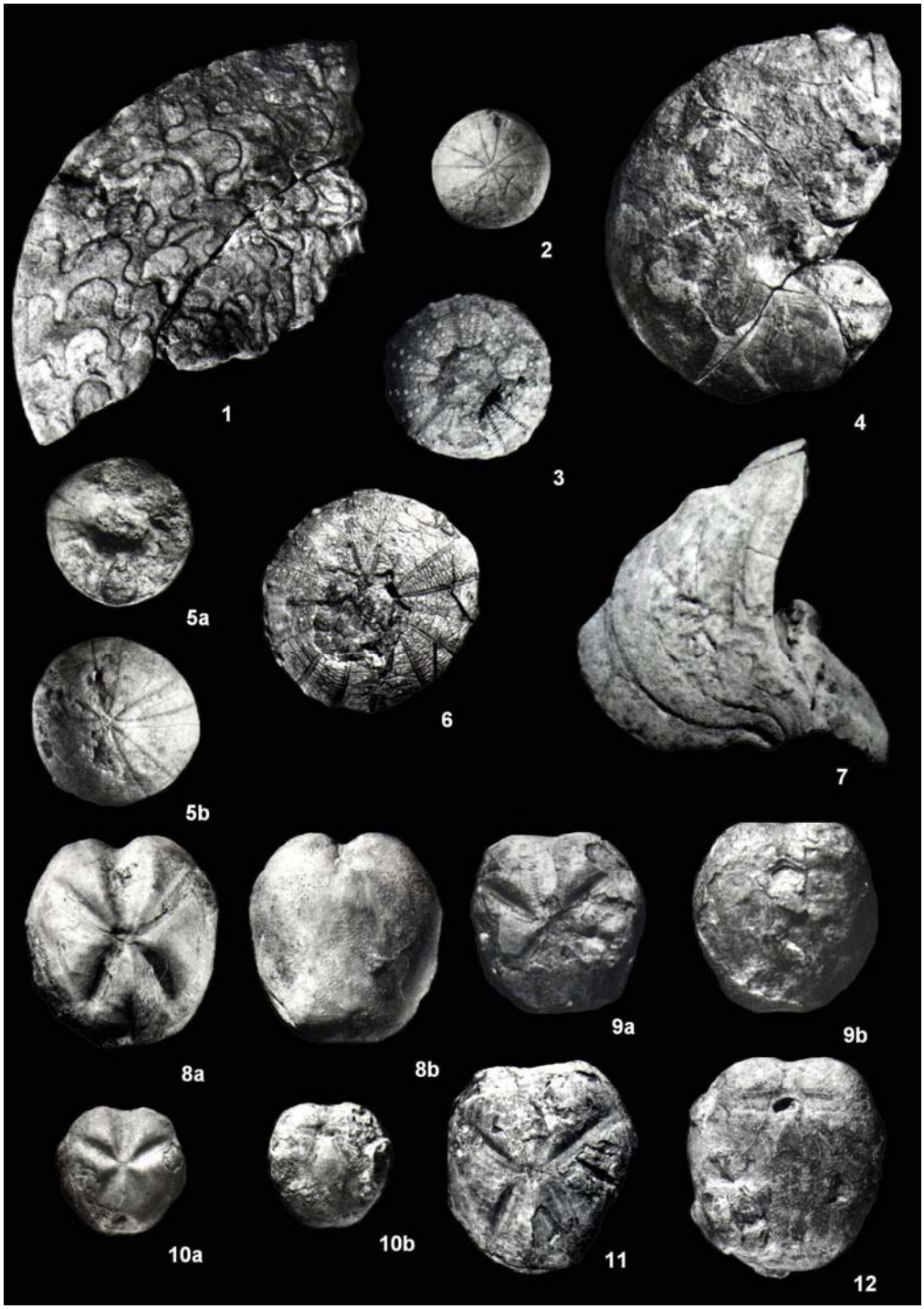

Plate 3

1. *Neolobites vibrayeanus* (d'Orbigny), side view, X1 **4, 7.** *Angulithes mermeti* (Coquand), side views, 4: X1, 7: X1.5 **2, 5.** *Coenholectypus turonensis* (Desor), 2, 5b: aboral views, 5a: oral view, 2, 5a: X1, 5b: X1.2. **3, 6.** *Heterodiadema libycum* (Desor), 3: oral view, 6: aboral view, X1.5 **8.** *Hemiaster* (*H.*) *cubicus* Desor, a: aboral view, b: oral view, X1 **9, 10.** *Hemiaster* (*Mecaster*) *heberti* (Coquand) *turonensis* Fourtau, a: aboral view, b: oral view; 9: X2, 10: X1 **11, 12.** *Hemiaster* (*M.*) *pseudofourneli* Peron and Gauthier, 11: aboral view, 12: oral view, X1.5.

Zonation based on other macrofossils:

The studied succession of the Galala Formation could be subdivided into five biozones based on the stratigraphic distribution of some diagnostic macrofossils other than ammonites. The proposed zones were correlated with other zones proposed by some authors in different localities of Egypt (Table 4). The integration between the proposed zones and the ammonite zones are shown (Fig. 2).

***Ceratostreon flabellatum – Rhynchostreon suborbiculatum* Acme Zone**

This zone is characterised by the presence of numerous individuals of the two zonal species (Pl. 1C and Pl. 4, 1-6). It attains a thickness of 14 m in the basal part of the Galala Formation. Associated fauna include *Nucula* (*N.*) *margaritifera* Douvillé, *Arctica picteti* (Coquand), *Parasea faba faba* (J. de C. Sowerby), *Plectomya? humei* Fourtau, and *Hemiaster* (*Hemiaster*) *gabrielis* Peron and Gauthier. This zone is equivalent to the *Rhynchostreon suborbiculatum* Zone of Ziko *et al.* (1993) and the *Gyrostrea delettrei–Rhynchostreon suborbiculatum–Hemiaster* (*H.*) *gabrielis* Zone of Abdel–Gawad *et al.* (2004). It is equivalent also to the *Rhynchostreon mermeti – Hemiaster gabrielis* horizon of El-Sheikh *et al.* (1998) at Gebel El-Hamra. It can be correlated with the upper part of the rudists – *Hemiaster gabrielis* horizon and the lower part of the *Rhynchostreon mermeti – Neolobites fourtaui* Zone recorded by El-Sheikh *et al.* (1998) from Gebel El-Minsherah. It is also coeval to the upper part of *Hemiaster cubicus* Zone of Kora *et al.* (1993) described from the Lower Cenomanian sediments of Sinai and the lower part of the *Hemiaster cubicus* Zone of Kora *et al.* (2001b) from the Lower-Middle Cenomanian deposits of the Gulf of Suez.

The two zonal species *Ceratostreon flabellatum* (Goldfuss) and *Rhynchostreon suborbiculatum* (Lamarck) are of wide stratigraphic range. Whereas *C. flabellatum* is of Albian – Senonian age (Freneix 1972, Freneix and Viaud 1986), Aptian? – Cenomanian age (Malchus 1990, Aqrabawi 1993, and Seeling and Bengtson 1999). *R. suborbiculatum* is of Cenomanian – Santonian (Dhondt 1985) and Cenomanian - Turonian (Seeling and Bengtson 1999). Due to the absence of ammonites and the wide range of the two zonal species as well as the associated fauna of this zone and based on the fact that, the second zonal species has not been recorded elsewhere from levels below the Cenomanian. Therefore, this zone is assigned to an ?Early–Middle Cenomanian age as it underlies the middle Cenomanian *Acanthoceras* sp. Zone.

***Hemiaster* (*Hemiaster*) *cubicus* Total Range Zone**

The zone is defined by the total range of the *Hemiaster* (*H.*) *cubicus* Desor. It attains a thickness of 10 m within the lower part of the Galala Formation, being flooded with the zonal species (Pl. 1D; and Pl. 3 and 8). It coincides with the ammonite *Acanthoceras* sp. Zone. The associated faunal elements are *Eoradiolites liratus* (Conrad), *Barbatia aegyptiaca* (Fourtau), *Parasea faba faba* (J. de C. Sowerby), *Maghrebella forgemoli* (Coquand), *Arctica* spp., *Tenea delettrei* (Coquand), in addition to *Ilymatogyra africana* (Lamarck) (Pl. 4, 7-10). This zone is coeval to the upper part of the *Hemiaster cubicus* Zone of Kora *et al.* (2001b) from the Lower-Middle Cenomanian deposits of the Gulf of Suez. The zone is of late Middle Cenomanian age based on correlation with the ammonite *Acanthoceras* sp. Zone.

***Ilymatogyra africana* - *Heterodiadema libycum* – *Hemiaster* (*Mecaster*) *pseudofourneli* Assemblage Zone**

This zone represents the most fossiliferous interval recorded in the present study. It measures 15 m thick in the marly shaly member of the Galala Formation. It is defined by an assemblage consists of *Ilymatogyra africana* (Lamarck), *Heterodiadema libycum* (Desor) (Pl. 3, 3, 6), and *Hemiaster* (*Mecaster*) *pseudofourneli* Peron and Gauthier (Pl. 3, 11-12). The most associated fauna are *Protocardia hillana* (J. Sowerby), *Parasea faba faba* (J. de C. Sowerby), *Arctica picteti* (Coquand); *Nerinea olisiponensis* Sharpe, *Pterodonta deffisi* Thomas and Peron, and *Coenholectypus pulvinatus* (Desor), *Goniopygus major* Agassiz. This zone is equivalent to the *Exogyra africana–Neolobites fourtaui* Zone and the lower part of the *Exogyra olisiponensis* - *Hemiaster pseudofourneli* of Awad and Isswai (1975), the *Ceratostreon flabellatum–Ilymatogyra africana* Acme Zone of Ziko *et al.* (1993), and the *Ceratostreon flabellatum – Ilymatogyra africana* Zone of Abdel-Gawad (1999), the *Ilymatogyra africana–Ceratostreon flabellatum* Zone of Kassab and Zakhera (1999), the *Ilymatogyra africana–Granocardium bimarginatum* Zone of Zakhera and Kassab (2002), and the *Ambigostrea pseudovillei-Ilymatogyra africana* Zone of Abdel-Gawad *et al.* (2004). It is equivalent to the *Ostrea africana*, *Ostrea flabellata*, *Dosinia*, *Venus* and *Neolobites* horizon of Awad and Fawzi (1956). It is coeval to the lower part of the *Exogyra* (*C.*) *olisiponensis–Ilymatogyra africana* Zone of Kora and Hamama (1987); and the *Costagyra olisiponensis–Ilymatogyra africana* horizon of El-Sheikh *et al.* (1998). It is also coeval to the upper part of the *Ilymatogyra* (*A.*) *africana–Neolobites vibrayeanus* Zone of Kora *et al.* (2001b), assigned to the Middle-early Late Cenomanian age from the deposits of the Gulf of Suez. This zone coincides with the lower part of the lower Upper Cenomanian *Neolobites vibrayeanus* Zone. Therefore, the zone is considered to be of early Late Cenomanian age.

Table 4: Correlation of the proposed non ammonite macrobiozones with the Cenomanian–Turonian in Egypt proposed by previous authors.

Age		East Central Sinai (Ziko *et al.*, 1993)	West Central Sinai (Zakhera and Kassab, 2002)	Sinai (Abdel-Gawad *et al.*, 2004)	Sinai (Kora *et al.*, 1993) and Gulf of Suez (Kora *et al.*, 2001b)	N. Eastern Desert (Kassab and Zakhera, 1999)	Present work *Abu Darag Lighthouse*
Turonian	Early		*Arca passyana* *Inoceramus opalensis elongata*	*Hemiaster* (*Mecaster*) *heberti turonensis* – *Coenheolctypus turonensis* Acme Zone		*Inoceramus labiatus* - *Arca passyana* *Crassatella incurva*	*Hemiaster* (*Mecaster*) *heberti turonensis* – *Coenheolctypus turonensis* Total Range Zone
Cenomanian	Late	*Exogyra olisiponensis* - *Pycnodonte vesiculosa* *Ceratostreon flabellatum* – *Ilymatogyra africana* *Nerinea gemmifera* *Strombus incertus*	*Pycnodonte vesiculosum* – *Exogyra olisiponensis* *Ilymatogyra africana* – *Granocardium bimarginatum* *Ceratostreon flabellatum* - *Neithea dutrugei*	*Pycnodonte* (*Phygraea*) *vesiculosa Inoceramus* ex gr. *pictus* Interval Zone *Costagyra olisiponensis* Total Range Zone *Ilymatogyra africana* Acme Zone *Nerinea gemmifera* – *Praeradiolites biskraensis* Acme Zone	*Exogyra* (*Costagyra*) *olisiponensis* *Ilymatogyra africana*	*Acesta obliquistriata* *Ilymatogyra africana* – *Ceratostreon flabellatum*	Rudists - Corals – Coralline Sponge Assemblage Zone *Ilymatogyra africana* - Heterodiadema *libycum* – *Hemiaster* (*Mecaster*) *pseudofourneli* Assemblage Zone
	Middle				*Hemiaster cubicus*		*Hemiaster (H.) cubicus*
	?Early	*Rhynchostreon suborbiculatum* rudists		*Gyrostrea delettrei* – *Rhynchostreon suborbiculatum* – *Hemiaster* (*H.*) *gabrielis* Acme Zone *Eoradiolites liratus* Total Range Zone			*Ceratostreon flabellatum* – *Rhynchostreon suborbiculatum*

Rudists – corals – coralline sponge Assemblage Zone

The zone is characterised by an assemblage of the rudists, corals, and coralline sponges, the faunal elements of this assemblage are *Praeradiolites biskraensis* (Coquand), *Ichthyosarcolites* sp., *Thecosmilia tommasii* Prever, *Fungiastrea* sp., *Ellipsosmilia* sp., *Phylloconia pediculata* (Deshayes), *Rennensismilia* sp., *Astraeofungia* sp., *Neophyllia angusta* (Reuss), and large globular (10-40 cm in diameter) and dendroid forms of the coralline sponge *Actinostromarianina* sp. (Pl. 1, Fig. E). It attains a thickness of 31 m in the upper part of the marly shaly member of the Galala Formation. The most associated fauna are *Chondrodonta joannae* (Choffat) that concentrated parallel to the bedding plane in a bed of about 1m thickness (Pl. 1, Fig. F), together with *Nayadina* (*N.*) *gaudryi* Thomas and Peron, *Pterocera incerta* d'Orbigny, *Harpagodes heberti* (Thomas and Peron), *Cimolithium teouklense* (Coquand), *Aporrhais dutrugei* (Coquand), and the nautiloid *Angulithes mermeti* (Coquand). This zone is equivalent to the gastropod horizon of Awad and Fawzi (1956) from Gebel El-Minsherah and to the *Strombus incertus* Zone and the *Nerinea gemmifera* Acme Zone of Ziko *et al.* (1993). It is also equivalent to the *Nerinea gemmifera* - *Praeradiolites biskraensis* Zone of Abdel-Gawad *et al.* (2004) from Sinai. This assemblage zone is reported in some sections in central and eastern Sinai that terminates the Cenomanian succession (Abdel Gawad 2001). The coincidence of this zone with the upper part of the lower Upper Cenomanian *Neolobites vibrayeanus* Zone suggests an early Late Cenomanian age for this zone.

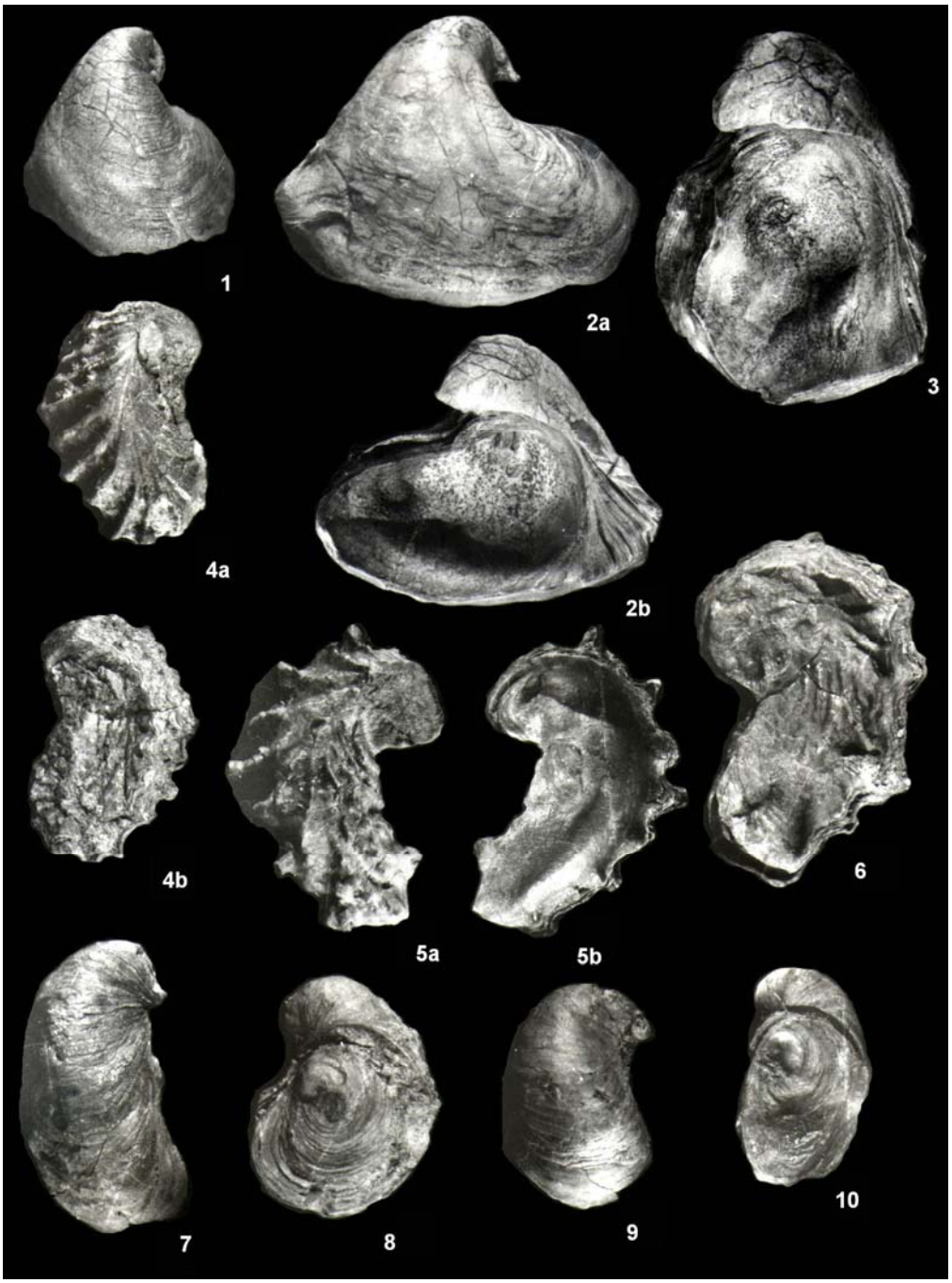

Plate 4

1-3. *Rhynchostreon suborbiculatum* (Lamarck) left valves, 1, 2a: exterior view, 2b, 3: interior view, 1: X3, 2: X1, 3: X2 **4-6.** *Ceratostreon flabellatum* (Goldfuss), 4 articulated specimen, a: exterior view of left valve, b: exterior view of right valve, X4, 5: left valve; a; exterior, b: interior, X2, 6: right valve of a connected specimen, exterior view, X1 **7- 10.** *Ilymatogyra africana* (Lamarck), 7, 9: left valves, exterior view, 7: X3, 9: X4 8, 10: right valves of articulated specimens, exterior view, 8: X1, 10: X2.

***Hemiaster* (*Mecaster*) *heberti turonensis–Coenholectypus turonensis* Total Range Zone**

This zone measures 18 m thickness in the carbonate member of the Galala Formation, and is defined by the total range of the two zonal species. It yields, besides marker species, *Plicatula auressensis* (Coquand), *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), *Cucullaea* (*Idonearca*) *diceras* (Seguenza), *Parasea dutrugei* (Coquand), *Phelopteria gravida* (Coquand), *Phymosoma major* Faurtau, and *Orthopsis ovata* (Coquand). This zone is equivalent to the *Hemiaster* (*Mecaster*) *heberti turonensis–Coenholectypus turonensis* Acme Zone (Abdel-Gawad *et al.*, 2004) from Sinai. It is also equivalent to the *Hemiaster heberti turonensi*s horizon at Gebel El-Hamra and the lower part of the *Phymosoma abbatei–Hemiaster heberti turonensis* horizon from Gebel El-Minsherah (El-Sheikh *et al.*, 1998). The zone coincides with the Lower Turonian *Choffaticeras segne* Zone. Consequently, it is of Early Turonian age.

The Cenomanian/Turonian boundary

The absence of the latest Cenomanian ammonite zones (*Metoicoceras geslinianum* Zone and *Vascoceras cauvini* Zone) in the present study can be explained in the light of the opinion of Bauer *et al.* (2001) and Kassab and Obeidallah (2001) based on their studies in Sinai. These authors proposed a hiatus within the Cenomanian/Turonian transition (top of the Upper Cenomanian *Neolobites vibrayeanus* Zone and the top of the basal Turonian *Pseudaspidoceras flexuosum-Vascoceras proprium* Zone).

As there is no strong evidence or criteria to suggest the presence of unconformity between the *N. vibrayeanus* and the *Choffaticeras segne* zones, the present authors are inclined to argue the absence of these two zones to the very shallowing condtions that prevailed in the latest Cenomanian. These two zones may be represented by bed no. 15 (dolomitic limestone bed of 10 m thickness) which terminates the *N. vibrayeanus* Zone. This is followed by the Turonian transgression yielded many Lower Turonian ammonites. Consequently, the Cenomanian/Turonian boundary in the Abu Darag area is located within the upper member (carbonate member) of the Galala Formation, base of bed no. 16, at the base of the *Choffaticeras segne* Total Range Zone. It coincides with the base of the *Hemiaster* (*Mecaster*) *heberti turonensis-Coenholectypus turonensis* Total Range Zone.

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