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, • *Illymatogyra africana - Heterodiadema libycum - Hemiaster* (*Mecaster*) *pseudofourneli* Assemblage Zone, • Rudists - corals - coraline 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 *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.
Table 1: Lithostratigraphic correlation of the Cenomanian – Turonian succession of Abu Darag area proposed by different authors

<table>
<thead>
<tr>
<th>Chronostratigraphic Units</th>
<th>Wadi Abu Darag</th>
<th>Bir Qiseib</th>
<th>Abu Sandouk</th>
<th>Abu Darag Lighthouse</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Galala Fm.</td>
<td>Wata Fm.</td>
<td>Wata Fm.</td>
<td>Galala Fm.</td>
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<tr>
<td>Turonian</td>
<td></td>
<td></td>
<td></td>
<td>Unm Omeiyid Fm.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Unm Omeiyid Fm.</td>
</tr>
<tr>
<td>Lower</td>
<td>Galala Fm.</td>
<td>Galala Fm.</td>
<td>Galala Fm.</td>
<td>Galala Fm.</td>
</tr>
<tr>
<td>Upper</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
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<tr>
<td>Middle</td>
<td></td>
<td></td>
<td></td>
<td>Malha Fm.</td>
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<tr>
<td>Lower Cret.</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
<td>Malha Fm.</td>
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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 Suef 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 kaolinitised clay. In the studied section, the Malha Formation represents the oldest exposed Cretaceous rocks. It overlies unconformably 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.

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<tr>
<td>Early</td>
<td>Mammites nodosoides</td>
<td>Choffaticeras segne</td>
<td>Mammites nodosoides</td>
<td>Choffaticeras segne -</td>
<td>Choffaticeras luciae</td>
<td>Choffaticeras segne -</td>
<td>Choffaticeras segne -</td>
<td>Choffaticeras segne -</td>
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<td>Choffaticeras segne -</td>
<td>Choffaticeras segne -</td>
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<tr>
<td></td>
<td>Pseud-aspidoceras flexuosum</td>
<td>Vasoceras proprium</td>
<td>Pseud-aspidoceras flexuosum</td>
<td>Vasoceras proprium</td>
<td></td>
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<tr>
<td>Cenomanian</td>
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<td>Vascoceras cauvini</td>
<td>Vascoceras cauvini –</td>
<td>Vascoceras cauvini</td>
<td>Vascoceras cauvini –</td>
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</tr>
<tr>
<td></td>
<td>Metoicoceras geslinianum</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
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<tr>
<td>Late</td>
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<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
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<tr>
<td>Middle</td>
<td></td>
<td></td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
<td>Neolobites vibrayeaus</td>
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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 fossiliferous 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 thickness of 44 m.
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 jaannae (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 (Hygrea) vesicularis (Lamarck) vesiculosa (J. Sowerby), and the echinoids Hemistia (Mecaster) heberti turonensis Fourtau and Coenholohecotyptus 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

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<td>Early</td>
<td>Mammmites nodosoides</td>
<td>Mammmites nodosoides</td>
<td>Hoplitoides</td>
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<td>Choffaticeras segne</td>
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<td></td>
<td>Thomasites rollandi</td>
<td>Vascoceratidae (Nigerucerias, Vascoceras)</td>
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<td>Choffaticeras quasi</td>
<td>Choffaticeras securiforme</td>
<td>Vascoceras pisti</td>
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<td>Watinoceras coloradoense</td>
<td>Pseudaspidoceras flexuosum</td>
<td>Neoptychites ?</td>
<td>P. flexuosum</td>
<td>Vascoceras pioti</td>
<td>Pseudaspidoceras footecanum</td>
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<td>Late</td>
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<td>Pseudaspidoceras pseudodonosoides</td>
<td>V. gamai</td>
<td>P. sp. / V. sp. V. gr. caurini</td>
<td>Metoicoceras geslinianum</td>
<td>Neolobites vibrayeanus</td>
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<td></td>
<td>Metoicoceras gellatinum</td>
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<td>Neolobites, Calycoceras</td>
<td>Niguerites ? sp</td>
<td>Costagrya olisiponensis –</td>
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<td>P. cf.</td>
<td>Neolobites fourtau</td>
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<td>Acanthoceras amphibolum</td>
<td>Acanthoceras sp.</td>
<td>Eusomphaloceras</td>
<td>Acanthoceras sp.</td>
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<td>Middle</td>
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<td>Paraconlinoceras aff. barcusi</td>
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<td>Pseudocalycoceras hungi</td>
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<td></td>
<td>Cunningtoniceras inerme</td>
<td>Acanthoceras cf. rhotomagene</td>
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<tr>
<td></td>
<td>Mantelliceras dixoni</td>
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<tr>
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<td>Mantelliceras mantellet</td>
<td>M. cf. mantellet</td>
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<td></td>
<td></td>
<td>M. cobbani</td>
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<td></td>
<td></td>
<td>M. azregensis</td>
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</table>
**Legend:**

- **Sandstone**
- **Shale**
- **Sandy dolostone**
- **Erosional surface**
- **Siltstone**
- **Marl**
- **Dolostone**
- **Sandy limestone**
- **Claystone**
- **Chalky limestone**
- **Dolomitic limestone**
- **Limestone**

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**Fig. 2:** Stratigraphy of the Cenomanian-Turonian succession of Abu Darag area (Lighthouse), and the integration between the ammonite and non-ammonite macrobiozones.
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 – Rhynchochirodus 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: Chondrocladus joannae (Cheffal), (Chondrocladus 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) suggested a Late Turonian- Middle Coniacian age for the Umm Omeiyid Formation where it overlies the Cenomanian Lower Turonian Galala Formation and underlies the Santonian Hawashiya Formation. However, Luger and Gröschke (1989) and Phillobos (1999) restricted the Umm Omeiyid Formation to the Turonian and extended the Hawashiya Formation down to the Coniacian. Abdel Gawad (1999) correlated this formation with the upper clastic part of the Abu Qada Turonian and extended the Hawashiya Formation down to the Coniacian. Abdel Gawad (1999) correlated this formation with the upper clastic part of the Abu Qada Formation developed in west-central Sinai as a formation with the upper clastic part of the Abu Qada Turonian and extended the Hawashiya Formation down to the Coniacian.

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 position.

**BIOSTRATIGRAPHY**

**Ammonite zones**

The stratigraphic distribution of the identified ammonites enabled the subdivision of 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 position.

**Acanthoceras** *sp. Total Range Zone*

The zone is defined by the total range of the zonal species *Acanthoceras* (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) *vesiculosus* (J. Sowerby), *Cucullaea* (*Idonearca*) *diceras* (Seguenza), *Parasea durutrei* (Coquand), *Phelopteria gravida* (Coquand), *Phymosoma major* Coquand, and Orthopis ovata (Coquand), *Hemister* (*Mecaster*) *heberti* (Coquand) *turonensis* Fourtau and *Coenholectypus turonensis* (Desor). This zone is equivalent to the *Hemister* *turonensis* Zone, recorded by many authors from the Lower Turonian of different localities in 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 Charrerie et al. (1998) Which recorded at the same stratigraphic level from Morocco. Consequently, the zone is of Early Turonian age.

**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), *Rhynchocestreus suborbiculatum* (Lamarck), *Chondrodonta joannae* (Choffat), *Praeradiolites biskransis* (Coquand), *Nayadina* (Nayadina) gaudryi Thomas and Peron, *Glossus aequilinus* (Coquand), *Parasea faba faba* (J. de C. Sowerby), *Arctica picteti* (Coquand); *Nerinea olsiponensis* Sharpe, *Pterocera incerta* d’Orbigny, *Pterodonta deffisi* Thomas and Peron, and *Harpagodes heberti* (Thomas and Peron), *Heterodiadema libycam* (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 *Metococeras gesslinianum* 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) *vesiculosus* (J. Sowerby), *Cucullaea* (*Idonearca*) *diceras* (Seguenza), *Parasea durutrei* (Coquand), *Phelopteria gravida* (Coquand), *Phymosoma major* Coquand, and Orthopis ovata (Coquand), *Hemister* (*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 in 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 Charrerie 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
Plate 3

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* – *Rhynchoestreon 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 gabrielis* Peron and Gauthier. This zone is equivalent to the *Rhynchoestreon suborbiculatum* Zone of Ziko et al. (1993) and the *Gyrostra deletrei–Rhynchoestreon suborbiculatum–Hemiaster* (H.) *gabrielis* Zone of Abdel–Gawad et al. (2004). It is equivalent also to the *Rhynchoestreon 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 *Rhynchoestreon mermeti – Neolobites fourtaui* Zone recorded by El-Sheikh et al. (1998) from Gebel El-Minsherah. It is also coeval to the upper part of the *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 *Rhynchoestreon suborbiculatum* (Lamarck) are of wide stratigraphic range. Whereas C. *flabellatum* is of Albain – Senonian age (Freneix 1972, Freneix and Vianud 1986), Aaptan? – Cenomanian age (Malchus 1990, Aq rabawi 1993, and Seeling and Bengston 1999). R. *suborbiculatum* is of Cenomanian – Santonian (Dhondt 1985) and Cenomanian – Turonian (Seeling and Bengston 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 deletrei* (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) pseudoourneli 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) *pseudoourneli* Peron and Gauthier (Pl. 3, 11-12). The most associated fauna are *Protocardiella villana* (J. Sowerby), *Parasea faba faba* (J. de C. Sowerby), *Arctica picteti* (Coquand); *Nerinea olisiponensis* Sharpe, *Pterodonta defissi* 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 pseudoourneli* 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 *Costagya olisiponensis–Ilymatogyra africana* horizon of El-Sheikh et al. (1998). It is also coeval to the upper part of the *Ilymatogyra* (A.) *africana–Neolobites vibryeaus* 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 vibryeaus* 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.

<table>
<thead>
<tr>
<th>Age</th>
<th>East Central Sinai (Ziko et al., 1993)</th>
<th>West Central Sinai (Zakhera and Kasub, 2002)</th>
<th>Sinai (Abdel-Gawad et al., 2004)</th>
<th>Sinai (Kora et al., 1993) and Gulf of Suez (Kora et al., 2001b)</th>
<th>N. Eastern Desert (Kassab and Zakhera, 1999)</th>
<th>Present work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turonian</td>
<td>Arca passyana</td>
<td>Inoceramus opalensis elongata</td>
<td>Hemiaster (Mecaster) heberti turonensis – Coenheolctypus turonensis Acme Zone</td>
<td>Inoceramus labiatus – Arca passyana Crassatella incurva</td>
<td>Hemiaster (Mecaster) heberti turonensis – Coenheolctypus turonensis Total Range Zone</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>Exogyra olisaponensis – Pycnodonte vesiculosus</td>
<td>Pycnodonte (Phygraea) vesiculosus Inoceramus ex gr. pictus Interval Zone</td>
<td>Costagryra olisaponensis Total Range Zone</td>
<td>Ilymatogyra africana Acme Zone</td>
<td>Ilymatogyra africana – Ceratostreon flabellatum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ceratostreon flabellatum – Ilymatogyra africana</td>
<td>Ilymatogyra africana – Granocardium bimarginatum</td>
<td>Nerinea gemmifera – Praeradiolites biskraensis Acme Zone</td>
<td>Ilymatogyra africana</td>
<td>Ilymatogyra africana – Heterodiadema</td>
<td></td>
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<tr>
<td></td>
<td>Nerinea gemmifera</td>
<td>Ceratostreon flabellatum - Neitha dutruegi</td>
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<td></td>
<td>Strombus incertus</td>
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<tr>
<td>Cenomanian</td>
<td>Rhynchostreon suborbiculatum</td>
<td>Gyrastrea delettrei – Rhynchostreon suborbiculatum – Hemiaster (H.) gabrielis Acme Zone</td>
<td>Eoradiolites lirana Total Range Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>rudists</td>
<td></td>
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</tbody>
</table>

**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), *Ichthyosarcolitites* sp., *Thecosmilia tommasi* Prever, *Fungiastraea* 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 dutruegi* (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 vibrayeaus* Zone suggests an early Late Cenomanian age for this zone.
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. *Illymatogyra 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 auresensis (Coquand), Pycnodonte (Phygraea) vesicularis (Lamarck) vesiculoja (J. Sowerby), Cucullaea (Idonearca) diceras (Seguenza), Parasea utrariae (Coquand), Phelopteria gravida (Coquand), Phymosoma major Faurtou, 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 turonensis horizon at Gebel El-Hamra and the lower part of the Phymosoma abbatiae–Hemiaster heberti turonensis horizon from Gebel El-Minsherah (El-Sheikh et al., 1998). The zone coincides with the Lower Turonian Choffaticerases 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 cauvinii 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 Pseudaspisjoceras flexuosum-Vascoceras proprium Zone).

As there is no strong evidence or criteria to suggest the presence of unconformity between the N. vibrayeanus and the Choffaticerases segne zones, the present authors are inclined to argue the absence of these two zones to the very shallowing conditions 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 Choffaticerases segne Total Range Zone. It coincides with the base of the Hemiaster (Mecaster) heberti turoensis-Coenholectypus turoensis Total Range Zone.

REFERENCES


