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MACROBIOSTRATIGRAPHY OF THE UPPER CRETACEOUS SUCCESSION FROM SOUTHERN GALALA, EASTERN DESERT, EGYPT

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ABSTRACT

The Upper Cretaceous succession exposed at Wadi El Dier, Saint Paul area, and Wadi El Dakhl was measured and studied in detail using macrofossil assemblages. The studied sequence is subdivided lithostratigraphically, into the Galala Formation (Cenomanian - Early Turonian), the Umm Omeiyid Formation (early Middle Turonian), the Wata Fotrmation (late Middle -Late Turonian), the Matulla Formation (Coniacian –?Early Campanian), and the Sudr Chalk (Campanian-Maastrichtian). Biostratigraphically, five ammonite zones have been recognized from Wadi El Deir section; *Acanthoceras amphibolum* Zone (late Middle Cenomanian), *Vascoceras cauvini* Total Range Zone (late Late Cenomanian), *Choffaticeras segne* Total Range Zone (Early Turonian), *Coilopoceras requienianum* Total Range Zone (late Middle - early Late Turonian), *Metatissotia fourneli* Total Range Zone (Middle – Late Coniacian). Six ammonites zones are recognized from Wadi El Dakhl section, the same five zones mentioned from Wadi El Deir and a sixth zone namely *Texanites texanus* Total Range Zone (Early Santonian). Based on the macrofossil assemblages other than the ammonites eleven zones are identified from Wadi El Deir section. These are from older to younger as follows: *Inoceramus* cf. *atlanticus* Total Range Zone = *Hemiaster* (*Hemiaster*) *cubicus* Total Range Zone, *Ilymatogyra africana* Total Range Zone, *Costagyra olisiponensis* Total Range Zone, *Mytiloides labiatus* Total Range Zone = *Hemiaster* (*Mecaster*) *heberti turonensis - Coenholectypus turonensis* Acme Zone, *Trochactaeon salomonis* Total Range Zone, *Pseudamaura bulbiformis - Hemiaster* (*Mecaster*) *fourneli* Assemblage Zone, *Nicaisolopha tissoti* Total Range Zone, *Nicaisolopha nicaisei* Total Range Zone, *Pycnodonte* (*Phygraea*) *vesicularis* Acme Zone, and *Terebratulina gracilis* Total Range Zone. Seven biozones are recognized from Wadi El Dakhl section from older to younger as follows: *Hemiaster* (*Hemiaster*) *cubicus* Total Range Zone, *Ilymatogyra africana* Total Range Zone, *Costagyra olisiponensis* Total Range Zone, *Pycnodonte* (*Ph.*) *vesiculosa* Interval Zone, *Hemiaster* (*Mecaster*) *heberti turonensis - Coenholectypus turonensis* Acme Zone, *Pycnodonte* (*Costeina*) *costei* Total Range Zone, and *Oscillopha dichotoma* Total Range Zone. The integration between the proposed ammonites and non-ammonite zones as well as local and inter-regional correlation with other well dated zonal schemes has been discussed. The stage boundaries of the studied strtatigraphic intervals are discussed by using macrofossil groups.

INTRODUCTION

The stratigraphic studies carried out on the Upper Cretaceous rocks exposed in the Southern Galala Plateau are numerous e.g. Farag (1957), Abdallah and Adindani (1963a, b), Awad and Abdallah (1966), Abdou (1969), Abdou et al. (1969), Abdallah and Eissa (1972), Abdel Kireem and Abdou (1969), Abu Khadrah et al. (1987), Bandel et al. (1987), Zein El Din et al. (1987), Kuss (1989), Malchus (1990), Faris (1994), Kassab and Zakhera (1999), Kuss et al. (2000), Galal et al. (2001), Abd-Elshafy et al. (2002a,b), Zakhera and Kassab (2002), Galal and Nafae (2003), Abdelhamid and Azab (2003), and El Hedeny and El-Sabbagh, (2005). A few works had been carried out using the integrated macrobiostratigraphic schemes in Egypt and on the studied area in particular as Obidallah and Kassab (2002) and Galal et al. (2001) who used the ammonites, planktonic foraminifera and bivalve zones. The present study aims to introduce an integrated macro-biostratigraphic scheme for the Cenomanian – Maastrichtian succession of the Southern Galala plateau (Fig. 1) and to discuss the various stage boundaries of the studied stratigraphic sections based on the intercalibration method between ammonites as well as some other diagnostic macroinvertebrates as bivalves, gastropods, and echinoids. The suggested biozones are correlated with the biozones of the same stratigraphic interval introduced by previous authors for different localities in Egypt and with their counterparts in the neighbouring countries and the standard zones as well. The studied sections are located at Wadi El Deir Latitude 28° 48` N and Longitude 32° 38` E and Wadi El Dakhl Latitude 28° 42` N and Longitude 32° 25` E (Fig. 1).

Material and Methods

The present study is based on bed by bed collecting of the various macrofossil assemblages of the Upper Cretaceous succession exposed at the two studied sections (Wadi El Deir and Wadi El Dakhl). 118 macrofossil species are identified from the two sections; 63 bivalves, 19 gastropods, 11 ammonites, 1 nautiloid, 23 echinoids, and 1 brachiopod. The systematic paleontological studies of the aforementioned material are in preparation by the present authors. The studied material is housed as follows; the cephalopod, echinoid, and brachiopod species are deposited at the Geology Department, Benha University, whereas the bivalves and gastropods are deposited at Geology Department, Suez Canal University.

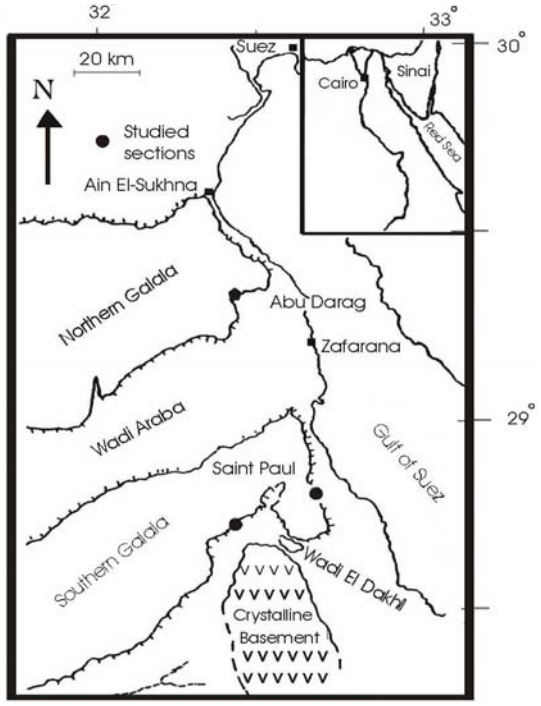

Fig. 1: Location Map of the Studied Sections

STRATIGRAPHY

Nearly a complete Upper Cretaceous sequence (Cenomanian-Maastrichtian) is exposed in both studied sections; Wadi El Dier, Saint Paul area, and Wadi El Dakhl (Fig. 1). The following is a brief description of the recognized rock units from the base to the top as follows:

The Galala Formation (Cenomanian – Early Turonian)

This formation was first proposed by Abdallah and El Adindani (1963b) in the Northern Galala Plateau. 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 sections, the Galala Formation overlies unconformably the Lower Cretaceous Malha Formation and underlies the Umm Omeiyid Formation (Figs. 2, 3; Pl. 1 A-C) of the early Middle Turonian. It measures 67 m in Wadi El Deir and 94 m in Wadi El Dakhl, composed mainly of shale, fossiliferous marl, dolomitic limestone, with minor sandstone, claystone, siltstone interbeds in the lower part of the formation. The lower part of the formation in the two studied sections is poorly fossiliferous, whereas the middle part is highly fossiliferous with Cenomanian fauna. The followings are the zonal and the most common taxa recorded from the middle part of the formation *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Ilymatogyra africana* (Lamarck), *Costagyra olisiponensis* (Sharpe), *Eoradiolites liratus* (Conrad), and *Pterocera incerta* d'Orbigny, *Pterodonta deffisi* Thomas and Peron, and *Harpagodes heberti* (Thomas and Peron); *Acanthoceras amphibolum* Morrow, *Angulithes mermeti* (Coquand); *Heterodiadema libycum* (Desor), *Coenholectypus cenomanensis* (Gueranger), and *Hemiaster* (*H.*) *cubicus* Desor. The upper part of the formation includes the uppermost Cenomanian ammonites *Vascoceras cauvini* Chudeau, *Pseudaspidoceras pseudonodosoides* (Choffat) that were recorded from both sections and *Rubroceras alatum* (Cobban, Hook and Kennedy) which was recorded only from Wadi El Deir section (Figs. 2,3) and the lower Turonian ammonites (Pl. 1, F; Pl. 3) *Choffaticeras segne* (Solger), *Thomasites rollandi* (Thomas and Peron), and *Vascoceras durandi* (Thomas and Peron), along with the bivalves *Plicatula auressensis* (Coquand), *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), *Rastellum carinatum* (Lamarck), *Mytiloides labiatus* (Schlotheim) and the echinoids *Hemiaster* (*Mecaster*) *heberti turonensis* Fourtau and *Coenholectypus turonensis* (Desor). The aforementioned faunae indicate a Cenomanian - Early Turonian age for the Galala Formation in both studied sections.

The Umm Omeiyid Formation (Early Middle Turonian)

The Umm Omeiyid Formation first appeared on a preliminary interpretative geological map worked out by Klitzsch and List (1980). They introduced this name 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 Turonian age intercalated with ammonite rich inner shelf sediments.

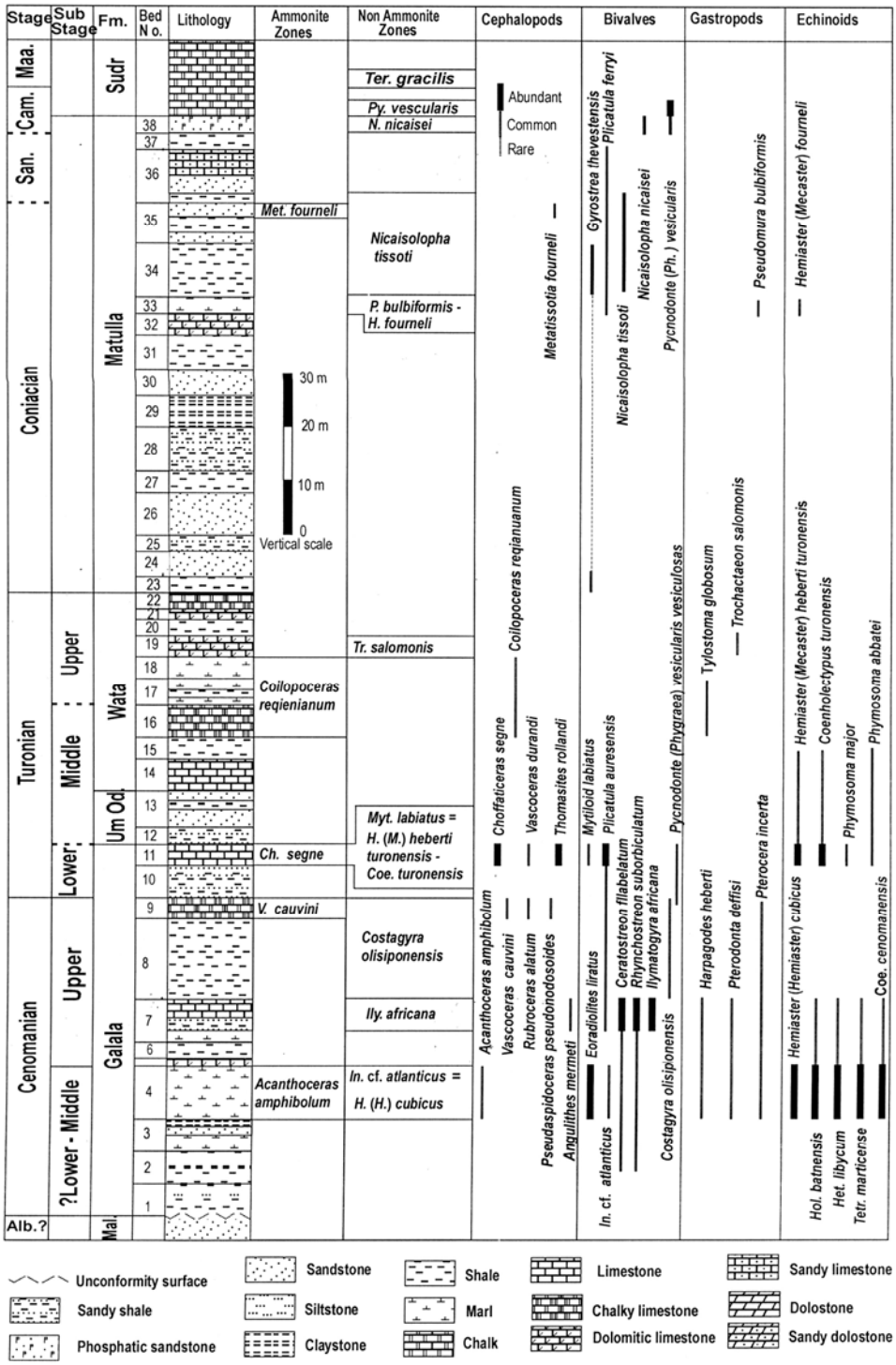

Fig.2: Stratigraphy of the Upper Cretaceous succession of Saint Paul section (Wadi El Deir), and the integration between the ammonite and non-ammonite macrobiozones.

Abdel Gawad (1999a) 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 Buttum Formation by Issawi et al. (1999).

In the studied sections, the Umm Omeiyid Formation overlies the Cenomanian - Lower Turonian Galala Formation (Pl. 1, B). In Wadi El Deir, it attains a thickness of 10 m and consists mainly of brown to yellowish brown, medium- to fine-grained cross-bedded sandstone intercalated with minor shale beds. The formation is rich in plant remains, barren of macrofauna. At Wadi El Dakhl, it measures 22 m and consists mainly of brown to yellowish brown, medium- to fine-grained cross-bedded sandstone intercalated with shale, sandy limestone, dolomitic limestone interbeds. Therefore, the Umm Omeiyid Formation is considered early Middle Turonian age in both studied sections based on its stratigraphic position between the Early Turonian ammonites *Choffaticeras segne* Zone and the late Middle - early Late Turonian *Coilopoceras requienianum* Zone.

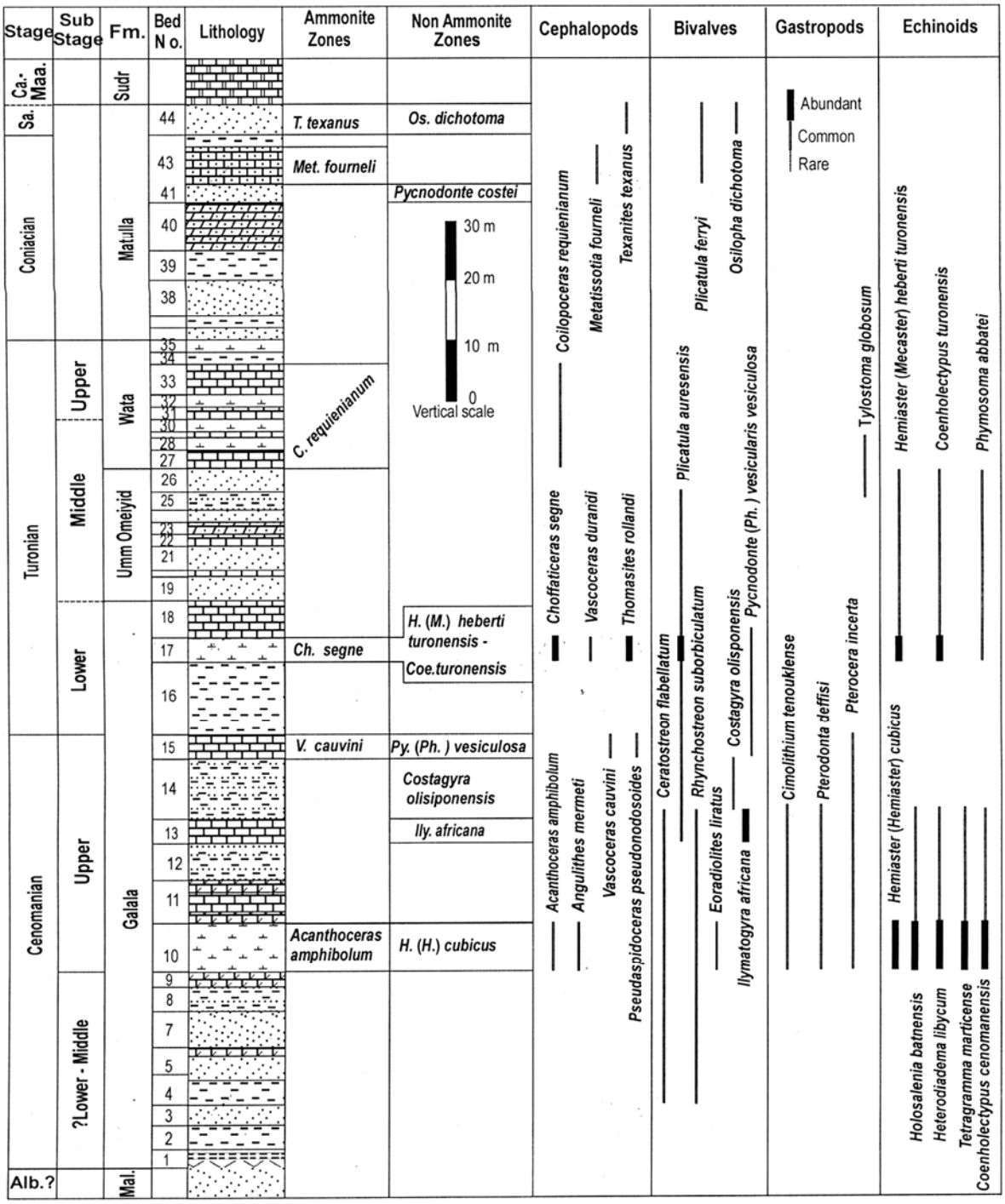

Fig. 3: Stratigraphy of the Upper Cretaceous succession of Wadi El Dakhl area, and the integration between the ammonite and non-ammonite macrobiozones.

The Wata Formation (Late Middle - Late Turonian)

The Wata Formation was first introduced by Ghorab (1961) at Wadi Wata, west-central Sinai. The Wata Formation herein, overlies the Umm Omeiyid Formation and underlies the Matulla Formation in both sections (Figs. 2, 3; Pl. 1. B, D). It is composed of chalky limestone, sandy limestone, dolomitic limestone, sandy dolostone, and marl intercalations with minor shale interbeds. It measures 36 m in thickness at Wadi El Deir and 21 m at Wadi El Dakhl. The Wata Formation is relatively less fossiliferous in comparison with the Galala Formation including *Cucullaea* (*Idonearca*) *trigona* (Seguenza), *Parasea dutrugei* (Coquand), *Pholadomya pedernalis* Roemer, *Tylostoma* (*Tylostoma*) *globosum* Sharpe, *Trochactaeon salomonis* (Fraas), *Phymosoma abbatei* (Gauthier), *Rachiosoma irregulare* Fourtau, and *Hemiaster* (*Mecaster*) *heberti turonensis* Fourtau. In both sections, the Wata Formation yields *Coilopoceras requienianum* (d'Orbigny) of late Middle - early Late Turonian age; an age assigned to the Wata Formation.

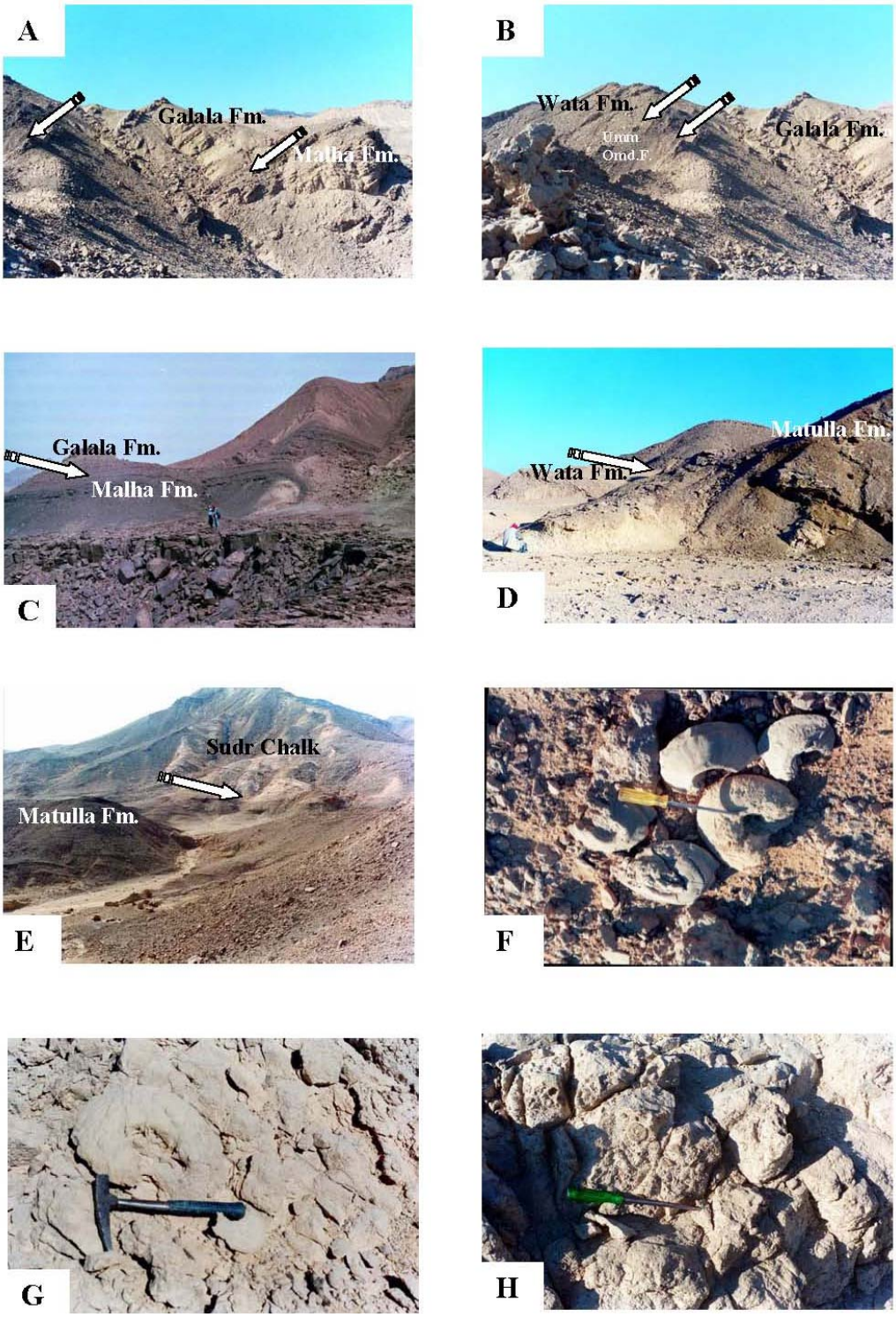

Plate 1

A. The Galala Formation overlies the Malha Formation and underlies the Umm Omeiyid Formation at Wadi El Deir section. The arrows mark the contact. B. The Umm Omeiyid Formation overlies the Galala Formation and underlies the Wata Formation at Wadi El Deir section. The arrows mark the contact. C. The Galala Formation overlies the Malha Formation at Wadi El Dakhl section. The arrow marks the contact. D. The Matulla Formation overlies the Wata Formation at Wadi El Deir section. The arrow marks the contact. E. The Sudr Chalk overlies the Matulla Formation at Wadi El Deir section. The arrow marks the contact. F. *Choffaticeras segne* (Solger) in the *Choffaticeras segne* Total Range Zone (Ammonit bed), Lower Turonian, Galala Formation, at Wadi El Deir section. G. *Coilopoceras requienianum* (d'Orbigny) in the *Coilopoceras requienianum* Total Range Zone, upper Middle - lower Upper Turonian, Wata Formation, at Wadi El Deir section. H. *Trochactaeon salomonis* Fraas, *Trochactaeon salomonis* Total Range Zone, Upper Turonian, Wata Formation, Wadi El Deir.

The Matulla Formation (Coniacian – ?Early Campanian)

This formation was established by Ghorab (1961) at Wadi Matulla, west-central Sinai. The stratigraphical classification and facies of this unit are subjected to several studies eg. Issawi et al. (1981), Cherif et al. (1989) Abu Khadrah et al. (1990), Orabi and Ramadan (1995), Abdel-Gawad (1999b), El Sheikh (1999), and Abdel-Gawad et al. (2004). In Wadi El Deir section, the Matulla Formation represents the Coniacian – ?Early Campanian succession, and measures 86 m thick. It consists mainly of clastic rocks; sandstone, shale, claystone, intercalated with sandy limestone and dolomitic limestone interbeds. It is sandy at the base, shaly at the middle part, whereas phosphatic sandstone characterizes the upper part of the formation (Fig. 2, Pl. 1. D, F). In Wadi El Dakhl, the Matulla Formation measures 39 m thick. The lower part of the formation is composed of sandstone and shale intercalations, while the upper part of the formation is composed of sandy dolostone and sandy limestone, intercalated with fossiliferous calcareous sandstone (Fig. 3). The Matulla Formation especially in Wadi El Dakhl section is highly fossiliferous containing *Plicatula ferryi* Coquand, *Pycnodonte* (*Costeina*) *costei* (Coquand), *Oscillopha dichotoma* (Bayle), *Pterotrigonia* (*Scabrotrigonia*) *scabra* (Lamarck), *Aporrhais fourneli* (Coquand), *Caricella stromboides* (Munier-Chalmas), *Hemiaster* (*Mecaster*) *fourneli* Deshayes, *Metatissotia fourneli* (Bayle), and *Texanites texanus* Roemer. The aforementioned faunae indicate a Coniacian – Early Santonian age for the Matulla Formation in Wadi El Dakhl section. In Wadi El Deir, beside most of the prementioned fauna the section yields the oysters; *Gyrostrea thevestensis* (Coquand), *Nicaisolopha tissoti* (Thomas and Peron), and *Nicaisolopha nicaisei* (Coquand). The latter species is restricted to Campanian – Maastrichtian age (Malchus 1990, Aqrabawi 1993, and Dhondt et al. 1999). Consequently, the age of the Matulla Formation in Wadi El Deir section may extend to the Early Campanian.

The Sudr Chalk (Campanian – Maastrichtian)

This rock unit was first proposed by Ghorab (1961). It represents the topmost part of the Cretaceous succession in both sections (Figs. 2, 3; Pl. 1. E). It is composed of snow-white, massive chalk with minor marl, shale and limestone interbeds. It is poorly fossiliferous with respect to macrofauna, yielding *Pycnodonte* (*Phygraea*) *vesicularis vesicularis* (Lamarck), from the lower part of the formation in both sections. Whereas in Wadi El Deir section, this lower part yields also *Terebratulina gracilis* (Schlotheim, 1813) and shell fragments of *Pecten farafrensis* Zittel. In contrast, it is very rich in microfossils (see Abdel Kireem and Abdou 1969, Faris 1994, Abd-Elshafy et al., 2002). The Sudr Chalk is regarded to be of Campanian – Maastrichtian in age based on its microfossil content identified by the aforementioned authors.

BIOSTRATIGRAPHY

The recognized ammonite zones and the other macroinvertebrate biozones of the studied sections are summarized in the following.

Ammonite Zones

The stratigraphic distribution of the identified ammonites enabled the subdivision of the studied sequence into five ammonite zones in Wadi El Deir and six zones in Wadi El Dakhl (Figs. 2, 3; Pls. 2-4). The proposed zones are to be correlated with the ammonite zones proposed by previous authors for different localities in Egypt as well as the standard ammonite zones and other ammonite zonal schemes of adjacent Tethyan regions (Tables 1, 2). The following is a brief description of the proposed ammonite zones.

***Acanthoceras amphibolum* Total Range Zone:** The zone is defined by the total range of the zonal species *Acanthoceras amphibolum* Morrow. It measures a thickness of 10 m in Wadi El Deir and 8 m at Wadi El Dakhl. The associated faunal elements are *Barbatia aegyptiaca* (Fourtau), *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Eoradiolites liratus* (Conrad), *Parasea faba faba* (J. de C. Sowerby), *Maghrebella forgemoli* (Coquand), *Tenea delettrei* (Coquand), *Holosalenia batnensis* (Peron and Gauthier), *Heterodiadema libycum* (Desor), *Tetragramma marticense* (Cotteau), *Coenholectypus cenomanensis* (Gueranger), in addition to numerous individuals of *Hemiaster* (*Hemiaster*) *cubicus* Desor. *Acanthoceras amphibolum* Zone was recorded by Robaszynski et al. (1993) from Tunisia and was regarded to be of late Middle Cenomanian age. This zone was recorded by Abdel-Gawad et al. (2006) as *Acanthoceras* sp. from Abu Darag section, Northern Galala plateau, just below the lower Upper Cenomanian *Neolobites vibrayeanus* Zone.

***Vascoceras cauvini* Total Range Zone:** The *Vascoceras cauvini* Zone represents the latest Cenomanian zone recorded in Egypt. It is defined by the total range of *Vascoceras cauvini* Chudeau in both sections where it attains a thickness of 3 m. The associated ammonites with the zonal species are *Pseudaspidoceras pseudonodosoides* (Choffat) that was recorded from both sections and *Rubroceras alatum* (Cobban, Hook and Kennedy) which was recorded only from Wadi El Deir section. The other associated faunal elements are the oysters *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), *Costagyra olisiponensis* (Sharpe), and *Rastellum carinatum* (Lamarck), and the echinoids *Hemiaster* (*Mecaster*) *batnensis* Coquand and *Hemiaster* (*H.*) *syriacus* (Conrad). The *cauvini* Zone recorded herein is equivalent to the *V. cauvini* Zone, which has been recorded by many authors in Egypt and the Middle East (Tables 1, 2). It is equivalent also to the *V. cauvini – Ps. pseudonodosoides – R. alatum* Assemblage Zone that was recorded by Abdel-Gawad et al. (2004) from Sinai. The co-occurrence of *Ps. pseudonodosoides* (Choffat), *R. alatum* with the standard *Neocardioceras juddii* Zone in New Mexico (Cobban et al. 1989), and the recording of both species from the *cauvini* Zone from Sinai (Abdel-Gawad et al. 2004) and in the present study confirmed that, this zone is equivalent to the standard *N. juddii* Zone.

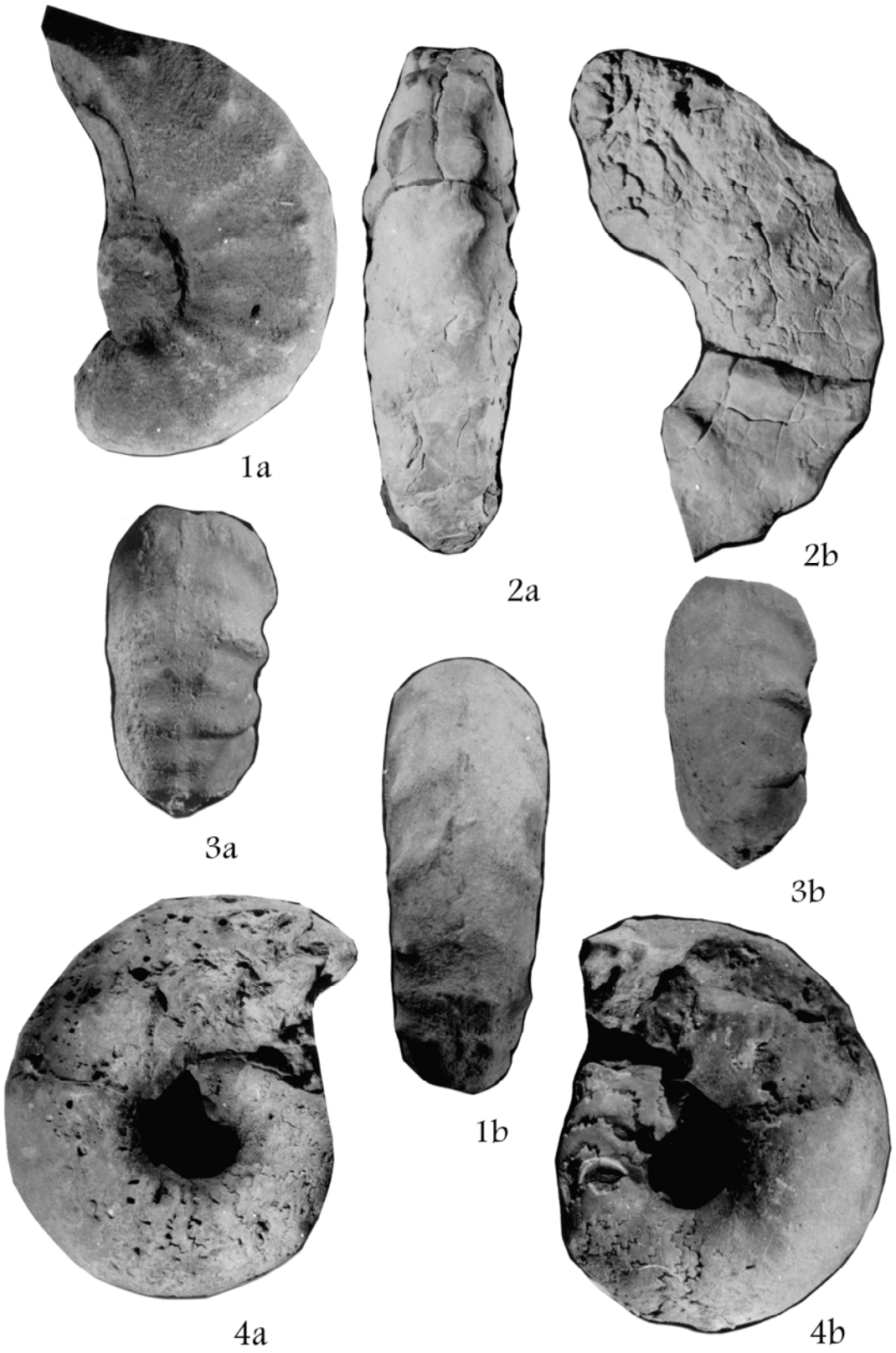

Plate 2

1a-b. *Pseudaspidoceras pseudonodosoides* (Choffat, 1899). Incomplete specimen; a: side view, b: venteral view, Upper Cenomanian, Galala Formation, Wadi El Deir, X 1. 2a-b. *Acanthoceras amphibolum* Morrow, 1936. Incomplete specimen; a: venteral view, b: side view, Middle Cenomanian, Galala Formation, Wadi El Deir, X 1. 3a-b. *Rubroceras alatum* Cobban, Hook and Kennedy, 1989. Incomplete specimen; a: venteral view, b: vento-lateral view, Upper Cenomanian, Galala Formation, Wadi El Deir, X 1. 4a-b. *Vascoceras cauvini* Chudeau, 1909. Side views, Upper Cenomanian, Galala Formation, Wadi El Deir, X 1.

***Choffaticeras segne* Total Range Zone:** The *Choffaticeras segne* Zone is very well traceable in the Southern Galala Plateau (Ammonite Bed of Abdallah and El Adindani, 1963a). It measures 3 m thickness in both sections, where it is epresented by a dolomitic limestone bed in Wadi El Deir (Fig. 2, Pl. 1. F) and a marly bed at Wadi El Dakhl (Fig. 3). It is defined by the total range of the zonal species *Choffaticeras segne* (Solger). Among the associated ammonites are *Thomasites rollandi* (Thomas and Peron), *Vascoceras durandi* (Thomas and Peron). Other associated faunal elements are *Cucullaea* (*Idonearca*) *diceras* (Seguenza), *Phelopteria gravida* (Coquand), *Mytiloides labiatus* (Schlotheim), *Plicatula auressensis* (Coquand), *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. Sowerby), *Parasea dutrugei* (Coquand), and *Pholadomya pedernalis* Roemer, as well as the abundance of the echinoids *Hemiaster* (*Mecaster*) *heberti* (Coquand) *turonensis* Fourtau and *Coenholectypus turonensis* (Desor). The *Ch. segne* Zone has been recorded by many authors from the Lower Turonian sections in different localities of Egypt (see Table 1). It is equivalent to the three *Choffaticeras* zones of Abdel–Gawad et al. (2004) from the Lower Turonian of Sinai. Based on the co-occurrence of both *Vascoceras durandi* and *Thomasites rollandi* with *Choffaticeras segne,* the zone is equivalent to the *Thomasites rollandi* Zone of Chancellor et al. (1994) from the Lower Turonian of Tunisia and the *Vascoceras durandi* Zone of Charriere et al. (1998) which was recorded at the same stratigraphic level from Morocco.

***Coilopoceras requienianum* Total Range Zone:** This zone is defined by the total range of *Coilopoceras requienianum* (d'Orbigny). It measures 15 m thick at Wadi El Deir (Fig. 2, Pl.1. G) and 18 m at Wadi El Dakhl. The *Coilopoceras requienianum* Zone is regarded by many authors to be Late Turonian in age (Lewy 1975, 1989; Lewy and Raab 1976; Lewy et al. 1984; Luger and Gröschke 1989; Kassab 1991, 1999, Kassab and Obaidalla 2001, Galal et al. 2001, and El-Hedeny 2002). It was correlated by most of the aforementioned authors with the European *Romaniceras devrianum* Zone on the basis of the common occurrence of *C. requienianum* (d'Orbigny). Lewy (1989) recorded this species from a level above the *R. devrianum* Zone. Therefore, the *C. requienianum* Zone is considered to be late Middle – early Late Turonian in age, based on the fact that, the *R. devrianum* Zone is of late Middle Turonian age (Hardenbol et al. 1998). Abdel-Gawad et al. (2004) recognized two biozones *Cucullaea* (*Idonearca*) *trigona – Rachiosoma geysi* Zone and *Nerinea requieniana* – coralline Sponge Zone overlying the *Co. requienianum* Zone and mentioned that *Co. requienianum* is not latest Turonian taxon. The recording of the Turonian *Trochactaeon salomonis* Zone overlies the *requienianum* Zone confirmed that the *Co. requienianum* Zone is not uppermost Turonian and it is of late Middle- early Late Turonian age.

***Metatissotia fourneli* Total Range Zone:** The zone is defined by the total range of *Metatissotia fourneli* (Bayle). It measures 3 m in Wadi El Deir and 6 m in Wadi El Dakhl. This zone represents the most fossiliferous interval within the Matulla Formation. The associated macrofossils are *Cucullaea* (*Idonearca*) *maresi* (Coquand), *Plagiostoma subsimplex* (Thomas and Peron), *Plicatula ferryi* Coquand, *Pterotrigonia* (*Scabrotrigonia*) *scabra* (Lamarck), *Aporrhais fourneli* (Coquand), *Caricella stromboides* (Munier-Chalmas), *Leptosalenia aegyptiaca* (Fourtau), *Hemiaster* (*Mecaster*) *fourneli* Deshayes. The zone has been recorded from the Eastern Desert of Egypt (Kassab 1991) and from Sinai (Abdel-Gawad 1999b, El Hedeny 2002, Obaidalla and Kassab 2002, and Kora et al. 2002). The zone is assigned to the Middle – Late Coniacian age.

***Texanites texanus* Total Range Zone:** This zone represents the youngest ammonite zone recorded in the present study. It is defined by the total range of *Texanites texanus* Roemer. It is recorded herein only from Wadi El Dakhl section and attains a thickness of 5 m. The associated macrofossils are the bivalves *Spondylus fimbriatus* Goldfuss, *Plicatula ferryi* Coquand, and *Oscillopha dichotoma* (Bayle), and the echinoid *Leptosalenia aegyptiaca* (Fourtau). *Texanites texanus* Zone was recorded from the Lower Santonian of southwestern Sinai (Obaidalla and Kassab, 2002). It can be correlated with the *Texanites* (*T.*) sp. of Abdel-Gawad (1999b) from Wadi Matulla. The zone can be correlated with the Lower Santonian *Texanites texanus* Zone of North America and southern Europe.

ZONATION BASED ON OTHER MACROFOSSILS

Based on the stratigraphic distribution of some diagnostic macrofossils other than ammonites the studied Upper Cretaceous sequence in Wadi El Deir could be subdivided into eleven zones (Fig. 2, Pl.4-6) and that of Wadi El Dakhl subdivided into seven zones (Fig. 3). The proposed zones were correlated with other zones proposed by some authors in different sections of Egypt (Tables 3, 4). The integration between the proposed zones and the ammonite zones are shown in Figs. 2-4.

***Inoceramus* cf. *atlanticus* Total Range Zone:** This zone is recognized for the first time from Egypt. It is reported from Wadi El Deir section, Saint Paul area (Fig. 2, Pl. 5, Fig. 5). It is defined by the total range of the zonal species *Inoceramus* cf. *atlanticus* (Heinz). The zone is considered of late Middle Cenomanian age being associated with and equivalent to the ammonite *Acanthoceras amphibolum* Zone and the echinoid *Hemiaster* (*H.*) *cubicus* Zone.

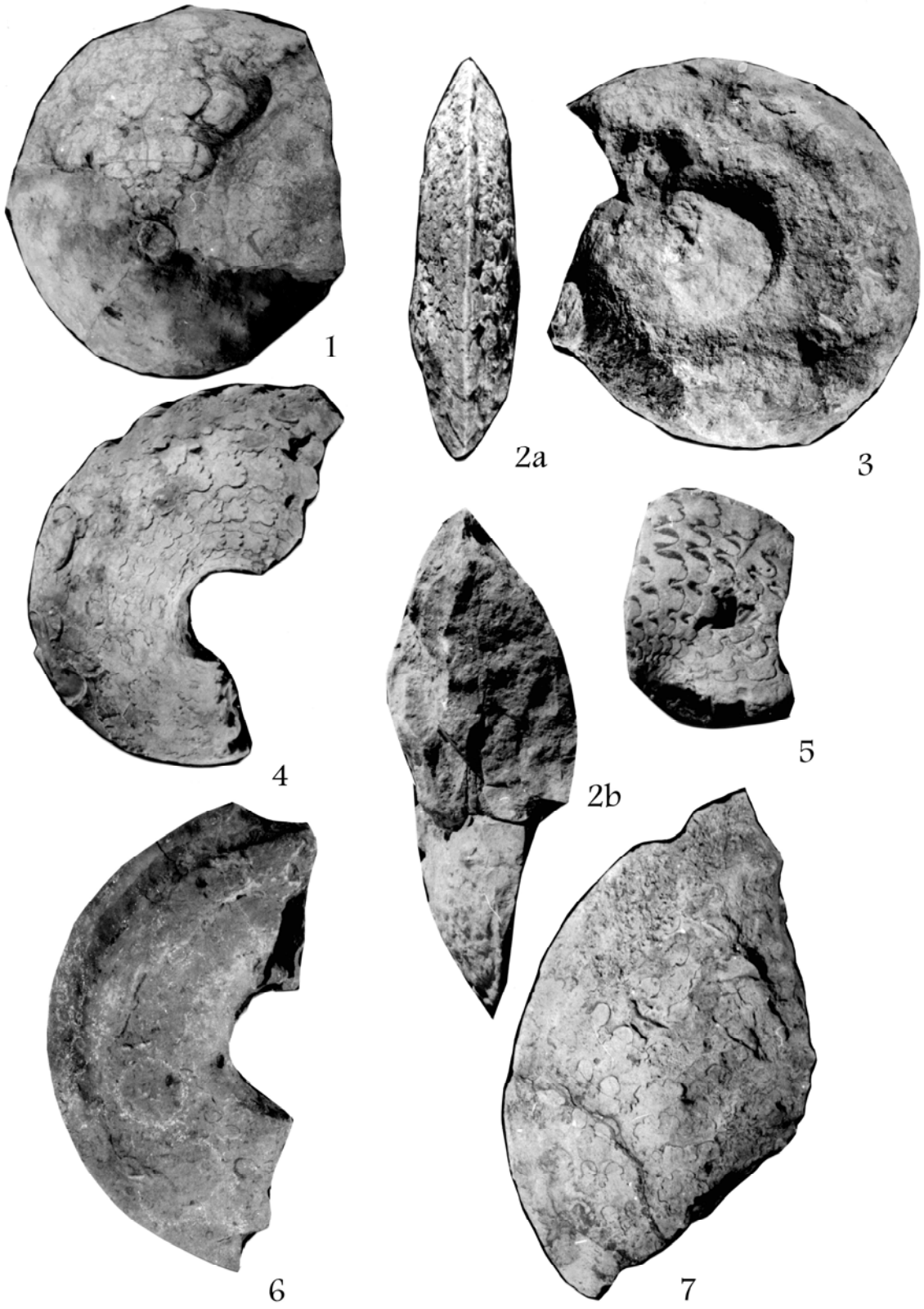

Plate 3

1. *Thomasites rollandi* (Thomas and Peron, 1889). Side view, Lower Turonian, Galala Formation, Wadi El Deir, X 1. 2a-b, 5, 7. *Coilopoceras requienianum* (d'Orbigny, 1841). 2a: venter view, b: apertural view, 5, 7: incomplete specimens, side views, upper Middle – lower Upper Turonian, Wata Formation, Wadi El Deir, 2: X 0.25, 5: X 0. 75, 7: X 1.5. 3. *Vascoceras durandi* (Thomas and Peron, 1890). Side view, Lower Turonian, Galala Formation, Wadi El Deir,X 1. 4 , 6. *Choffaticeras* (*Choffaticeras*) *segne* (Solger, 1903). Incomplete specimens side views, Lower Turonian, Galala Formation, Wadi El Deir, X 0.5.

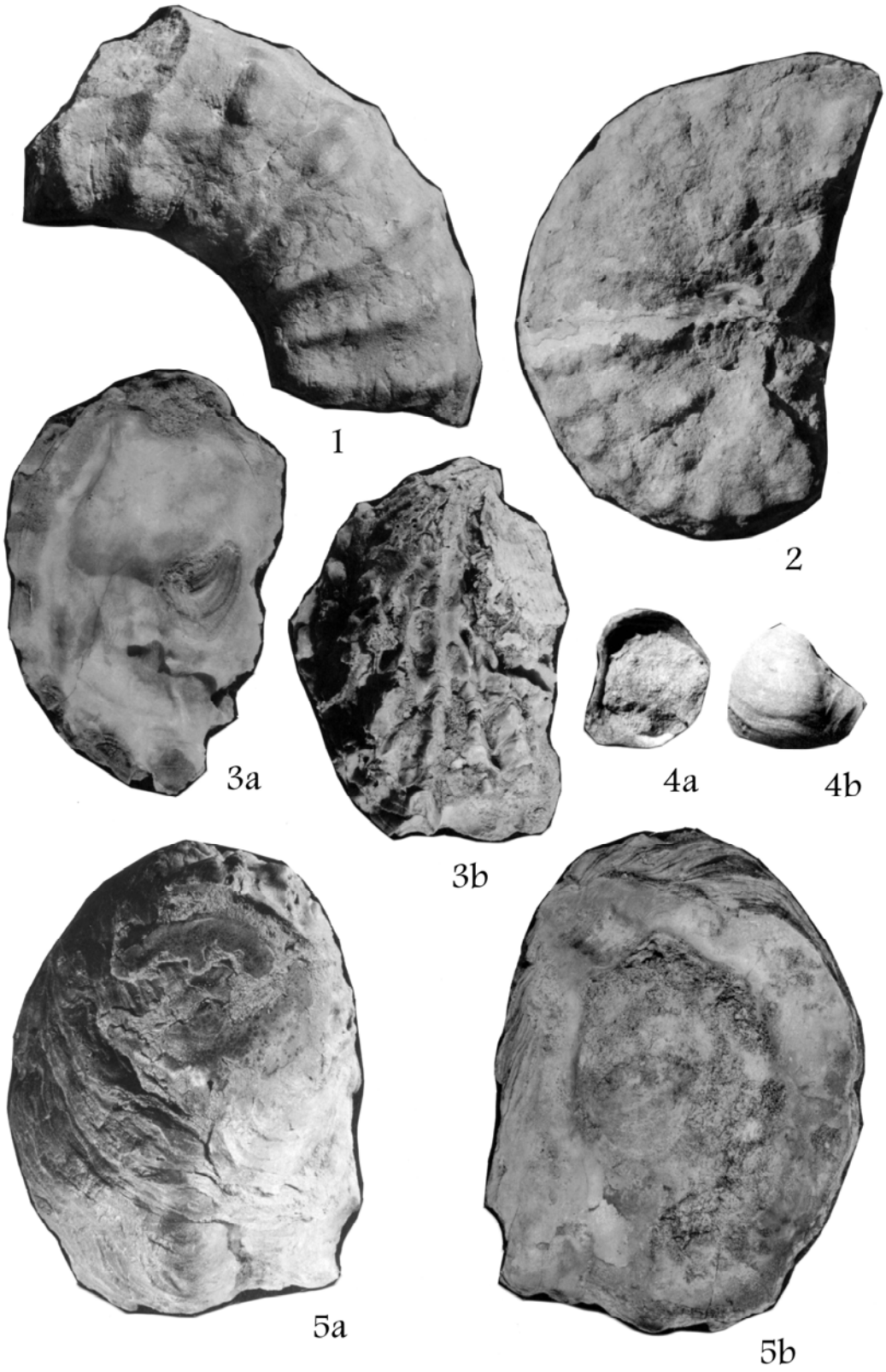

Plate 4

1. *Texanites texanus* (Roemer), side view, Lower Santonian, Matulla Formation, Wadi El Dakhl, X 0.25. 2. *Metatissotia fourneli* (Bayle) side view, Upper Coniacian, Matulla Formation, Wadi El Dakhl, side view, X 0.25. 3. *Oscillopha dichotoma* (Bayle), right valve, a: interior view, b: exterior view, Lower Santonian, Matulla Formation, Wadi El Dakhl, X 1. 4. *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck) *vesiculosa* (J. Sowerby), left valve, a: interior view, b: exterior view, Upper Cenomanian, Galala Formation, Wadi El Dakhl, X 1. 5. *Pycnodonte* (*Costeina*) *costei* (Coquand), left valve, a: exterior view, b: interior view, Coniacian, Matulla Formation, Wadi El Dakhl, X 1.

Table 1. Correlation of the Cenomanian-Turonian ammonite biozones with those proposed by previous authors for various localities of Egypt.

Age		Sinai			North Eastern Desert					Present Study
		Aly & Abdel-Gawad (2001)	El-Hedeny (2002)	Abdel-Gawad et al. (2004)	Kassab (1999)	Kora et al. (2001)	Galal et al. (2001)	Hewaidy et al. (2003)	Abdel-Gawad et al. (2006)	Wadi El Deir & Wadi El Dakhl
Turonian	Late	*Coilopoceras requienianum*	*Co. requi-enianum*	*Co. requi-enianum*	*Co. requi-enianum*	*Co. requi-enianum*	*Co. requi-enianum*	*Co. requi-enianum*		*Co. requi-enianum*
	Middlle							*Hoplitoides ingens*		
	Early	Mammites nodosoides Choffaticeras segne *Pseud-aspidoceras flexuosum*	*Ch. segne* Vascoceras *Proprium*	*Choffaticeras sinaiticum – Thomasites rollandi* *Ch. segne – V. harttii* *Choffaticeras securiforme – Choffaticeras quaasi*	*Ch. segne -* *Pseud-aspidoceras flexuosum*	*Mammites nodosoides - Ch. segne*	*Ch. segne* *V. proprium*	*Ch. luciae* *Ch. segne* *V. pioti - V. proprium*	*Ch. segne*	*Choffaticeras segne*
Cenomanian	Late	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Neolobites vibrayeanus*	*V. cauvini – Pseud-aspidoceras pseudo-nodosoides – Rubroceras alatum* *Neolobites vibrayeanus*	*Vascoceras cauvini* *Metoicoceras geslinianum* *Neolobites vibrayeanus*	*Neolobites vibrayeanus*		*Neolobites vibrayeanus*	*Neolobites Vibrayeanus*	*Vascoceras cauvini*
	M.								*Acanthoceras* sp	*Acanthoceras amphibolum*

***Hemiaster* (*Hemiaster*) *cubicus* Total Range Zone:** The zone is defined by the total range of the *Hemiaster* (*H.*) *cubicus* Desor (Pl. 6, Fig.8). It attains a thickness of 10 m in Wadi El Deir and 8 m in Wadi El Dakhl. It is represented by a marly bed being flooded with the zonal species. It coincides with the ammonite *Acanthoceras amphibolum* Zone. This zone is equivalent to the *Hemiaster* (*H.*) *cubicus* Zone of Abdel–Gawad et al. (2006) from Abu Darag area, Northern Galala. It is coeval with the upper part of the *Hemiaster cubicus* Zone of Kora et al. (2001) from the Lower-Middle Cenomanian of the eastern side of the Gulf of Suez. The zone is of late Middle Cenomanian age as it is associated with the ammonite *Acanthoceras amphibolum* Zone.

***Ilymatogyra africana* Total Range Zone:** The zone is defined by the total range of the zonal species *Ilymatogyra africana* (Lamarck) in both sections. It measures 4 m thick in Wadi El Dakhl and 6 m in Wadi El Deir. The most associated fauna are *Protocardia hillana* (J. Sowerby), *Parasea faba faba* (J. de C. Sowerby), *Arctica picteti* (Coquand), *Pterodonta deffisi* Thomas and Peron, in addition to the abundance of oysters *Ceratostreon flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck). 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* Zone of Ziko et al. (1993), the *Ceratostreon flabellatum – Ilymatogyra africana* Zone of Abdel-Gawad (1999a), the *Ilymatogyra africana – Ceratostreon flabellatum* Zone of Kassab and Zakhera (1999), the *Ilymatogyra africana – Granocardium bimarginatum* Zone of Zakhera and Kassab (2002), the *Ambigostrea pseudovillei - Ilymatogyra africana* Zone of Abdel-Gawad et al. (2004) and the *Ilymatogyra africana - Heterodiadema libycum - Hemiaster* (*Mecaster*) *pseudofourneli* Zone of Abdel-Gawad et al. (2006). It can be correlated with the *Ostrea africana*, *Ostrea flabellata*, *Dosinia, Venus* and *Neolobites* horizon of Awad and Fawzi (1956). It is also coeval with the upper part of the *Ilymatogyra* (*A.*) *africana* –

Neolobites vibrayeanus Zone of Kora et al. (2001), which is Middle-early Late Cenomanian age from the sediments of the Gulf of Suez. The zone overlies herein, the late Middle Cenomanian *Acanthoceras amphibolum* Zone and associated with the lower Upper Cenomanian *Neolobites vibrayeanus* Zone by most of the aforementioned authors. Therefore, the zone is considered of early Late Cenomanian age.

Table 2. Interregional correlation of the Cenomanian- Turonian ammonite zones of Wadi El Deir and Wadi El Dakhl sections.

Age		Standard Ammonite Zones of S. Europe *in* (Hardenbol et al. 1998)	Tunisia (Robaszynski et al. 1993) & Chancellor et al. 1994)	Morocco (Charriere et al. 1998)	Israel (Lewy 1989)	Present Study Wadi El Deir & Wadi El Dakhl
Turonian	Late	Subprionocyclus neptuni	Hemitissotia morreni		*Coilopoceras requienianum*	*Coilopoceras requienianum*
	Middle	*Romaniceras deverianum* *Romaniceras ornatissimum* *Romaniceras kallesi* *Kamerunoceras turoniense*	*R. deverianum* *R. kallesi*		*R. deverianum* *Collignoniceras woollgari* *Coilopoceras* sp. *R. ornatissimum* *Neoptychites cephalotus* *Lecointriceras fleuriausianum*	
	Early	*Mammites nodosoides*	*Mammites nodosoides*	*Ch.* sp. / *V.* sp. *M. nodosoides*	*Choffaticeras luciae trisellatum*	*Choffaticeras segne*
			Thomasites rollandi	*Vascoceras durandi*	*Choffaticeras quaasi* *Choffaticeras securiforme* *Vascoceras pioti*	
		Watinoceras coloradoense	*Pseudaspidoceras flexuosum*	*P. flexuosum* *Neoptychites ?*	*Pseudaspidoceras footeanum*	
Cenomanian	Late	*Neocardioceras juddii*	*Pseudaspidoceras pseudonodosoides* *Euomphaloceras* cf. *septemseriatum*	*P.* sp. / *V.* sp. *V.* gr. *cauvini* *P.* cf. *pseudonodosoides*		*Vascoceras cauvini*
		Metoicoceras geslinianum		*Nigeraceras* ? sp *Neolobites vibrayeanus*	*Metoicoceras geslinianum –* *Costagyra olisiponensis –*	
		Calycoceras naviculare / *Eucalycoceras pentagonum*	*Eucalycoceras pentagonum*		*Neolobites vibrayeanus*	
	Middle	*Acanthoceras jukesbrownei* *Acanthoceras rhotomagense* *Cunningtoniceras inerme*	*Acanthoceras amphibolum* *Paraconlinoceras* aff. *barcusi* *Acanthoceras* cf. *rhotomagense* *Cunningtoniceras inerme*		*Euomphaloceras* *Pseudocalycoceras haugi* *Neolobites fourtaui*	*Acanthoceras amphibolum*
	Early	*Mantelliceras dixoni*	*Mantelliceras dixoni*		*Mantelliceras*	
		Mantelliceras mantellei	*M.* cf. *mantellei* *M.cobbani* *M. azregensis*			

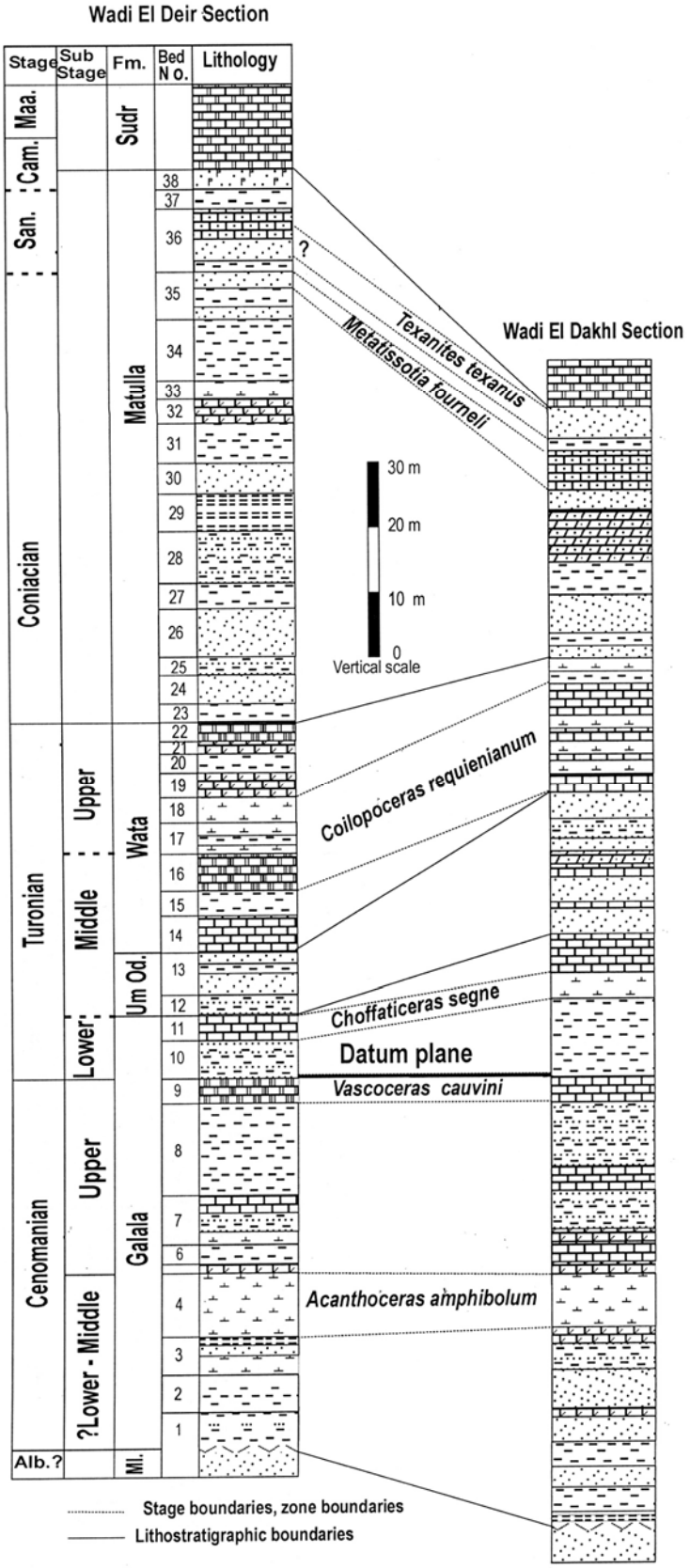

Fig.4. Correlation of the Upper Cretaceous succession of Wadi El Deir section Saint Paul area and Wadi El Dakhl section.

Table 3. Correlation of the proposed non ammonite Cenomanian – Turonian macrobiozones with those proposed by previous authors in Egypt.

Age		Sinai			North Eastern Desert			Present work
		Ziko et al. (1993)	Zakhera & Kassab (2002) C. Sinai	Abdel-Gawad et al. 2004	Kora et al. (2001)	Kassab & Zakhera (1999)	Abdel-Gawad et al. 2006	Wadi El Deir & Wadi El Dakhl
Turonian	Late	*Durania*	*Pycnodonte kansasense – Flaventia garudana*	*Nerinea requieniana* *Cucullaea* (*Idonearca*) *trigona – Rachiosoma geysi* *Trochactaeon salomonis*		*Pholadomya sazbergensis – Flaventia garudana*		*Trochactaeon salomonis*
	Middle			*Durania* spp. – *Praeradiolites* spp. *Phymosoma abbatei – Tylostoma* (*T.*) spp.				
	Early	Large Ammonites	*Arca passyana* *Inoceramus opalensis elongata*	*Hemiaster* (*Mecaster*) *heberti turonensis – Coenheolctypus turonensis* Acme Zone		*Inoceramus labiatus - Arca passyana* *Crassatella incurva*	*Hemiaster* (*Mecaster*) *heberti turonensis – Coe. turonensis*	*Mytiloides labiatus = H.* (*M.*) *heberti turonensis – Coe. turonensis*
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*	*Py.* (*Ph.*) *vesiculosa Inoceramus* ex gr. *pictus* Interval Zone *Costagyra olisiponensis* Total Range Zone *Ambigostrea pseudovillei 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* *Ilymatogyra* africana-Heterodiadema *libycum – Hemiaster* (*Mecaster*) *pseudofourneli*	*Pycnodonte* (*Phygraea*) *vesiculosa* *Costagyra olisiponensis* *Ilymatogyra africana*
	Middle				*Hemiaster cubicus*		Hemiaster (H.) *cubicus*	*In* cf. *atlanticus* =Hemiaster (H.) *cubicus*
	Early	*Rhynchostreon suborbiculatum* rudists		*Gyrostrea delettrei – Rhynchostreon suborbiculatum – Hemiaster* (*H.*) *gabrielis* *Eoradiolites liratus*			*Ceratostreon flabellatum – Rhynchostreon suborbiculatum*	

Table 4. Correlation of the proposed non ammonite Conacian – Maastrichtian macrobiozones with those proposed by previous authors in Egypt.

Age	Egypt G. Z.	Sinai				N. E. Desert	Present work
	Awad & Issawi (1975)	Kora & Hamama (1987b)	Abdel Gawad (1990, 1999b)	Kora et al. (2002)	Abdel-Gawad et al. 2004	Kassab & Zakhera (1999)	Wadi El Deir, W. Dakhl
Maastrichtian	*Trigonarca gauldrina Libycoceras bersensis Exogyra overwegi – Libycoceras ismaeli or Py. vesicularis Isocardia chargensis* *Inoceramus regularis – Roudairae drui* *Lopha villei* *Neara* sp. – *Arca* (*Tr.*) *multidentata*		*Lyropecten* (*A.*) *acutiplicatus* *Terebratulina gracilis*	*Terebratulina gracilis*	*Pycnodonte* (*Phygraea*) *vesicularis vesicularis*	*In. faragi – Amphidonte pyrenaicum Agerostrea ungulata – Chlamys acuteplicatus Grammatodon japiticum Venericardia vredenburgi - Inoceramus regularis Entolium membrnaceu Nicaisolopha pomeli*	*Terebratulina gracilis*
Campanian	*Ostrea cornuarietis*	*Pycnodonta* (*Phygraea*) *vesicularis*	*Solenoceras humei – Nostoceras* spp. *Pycnodonte vesicularis*	*Pycnodonte* (*Phygraea*) *vesicularis*	*Ambigostrea bretoni – Nicaisolopha nicaisei*	*Plicatula pausicostata – Curvostrea heinzi*	*Pycnodonte* (*Phygraea*) *vesicularis* *Nicaisolopha nicaisei*
Santonian	*Lopha dichotoma – Plicatula ferryi*	*Lopha* (*Actinostreon*) *dichotoma – Plicatula ferryi*	*Texanites* sp.	*Oscilopha dichotoma – Pycnodonte* (*Phygraea*) *proboscideum*	*Nicaisolopha tissoti* *Cladoceramus undulatoplicatus*	*Plicatula ferryi – Crassostrea roachensis*	*Oscillopha dichotoma* *Nicaisolopha tissoti*
Coniacian	*Natica bulbiformis*	*Heterotissotia neoceratites – Plesiotissotia michaltei* *Tissotia tissoti*	*Metatissotia fourneli*	*Metatissotia fourneli* Poorly fossiliferous	*Pycnodonte* (*Costeina*) *costei* *Oscillopha dichotoma - Plicatula ferryi* *Hemiaster* (*Mecaster*) *fourneli – Petalobrissus waltheri*		*Pycnodonte* (*Costeina*) *costei* *Pseudamaura bulbiformis - Hemiaster* (*Mecaster*) *fourneli*

***Costagyra olisiponensis* Total Range Zone:** The zone ranges in thickness from 10 m in Wadi El Dakhl to 18 m in Wadi El Deir. It is defined by the total range of *Costagyra olisiponensis* (Sharpe). The zone is equivalent to the *Exogyra (C.) olisiponensis* Zone of Kora et al. (2001) and the *Costagyra olisiponensis* of Abdel-Gawad et al. (2004). It is equivalent to the lower part of the *Exogyra olisiponensis – Pycnodonte vesiculosa* zone of Ziko et al. (1993), and the *Pycnodonte vesiculosum – Exogyra olisiponensis* of Abdel-Gawad (1999a). It is equivalent to the upper part of *Exogyra (C.) olisiponensis – Ilymatogyra africana* Zone of Kora and Hamama (1987a), and the *Costagyra olisiponensis – Ilymatogyra africana* horizon of El-Sheikh et al. (1998). It can also be correlated with the second *Ostrea* and lamellibranch horizon of Awad and Fawzi (1956).

***Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* Interval Zone:** In Wadi El Dakhl section, the zone is defined by the interval from the LO of *Costagyra olisiponensis* (Sharpe) to LO of *Vascoceras cauvini* Chudeau. The zone measures 3m thick and is associated with the latest Cenomanian ammonite *Vascoceras cauvini* zone. In Wadi El Deir section, the *Costagyra olisiponensis* Zone continues till LO of *Vascoceras cauvini* Chudeau while *Pycnodonte* (*Phygraea*) *vesicularis vesiculosa* (J. Sowerby) first appeared in the upper part of the zone. In both sections *Py*. (*Ph.*) *vesicularis vesiculosa* is extended upwards to the Lower Turonian *Choffaticeras segne* Zone. The zone is equivalent to the *Pycnodonte* (*Phygraea*) *vesiculosa – Rastellum carinatum – Inoceramus* ex gr. *pictus* Assemblage Zone of Abdel-Gawad et al. (2004). It is equivalent to the upper part of *Pycnodonte vesiculosum – Exogyra olisiponensis* Zone of Abdel–Gawad (1999a), and *Exogyra olisiponensis – Pycnodonte vesiculosa* Zone of Ziko et al. (1993) from Sinai. The zone is regarded late Late Cenomanian associated with the latest Cenomanian ammonite *Vascoceras cauvini* Zone.

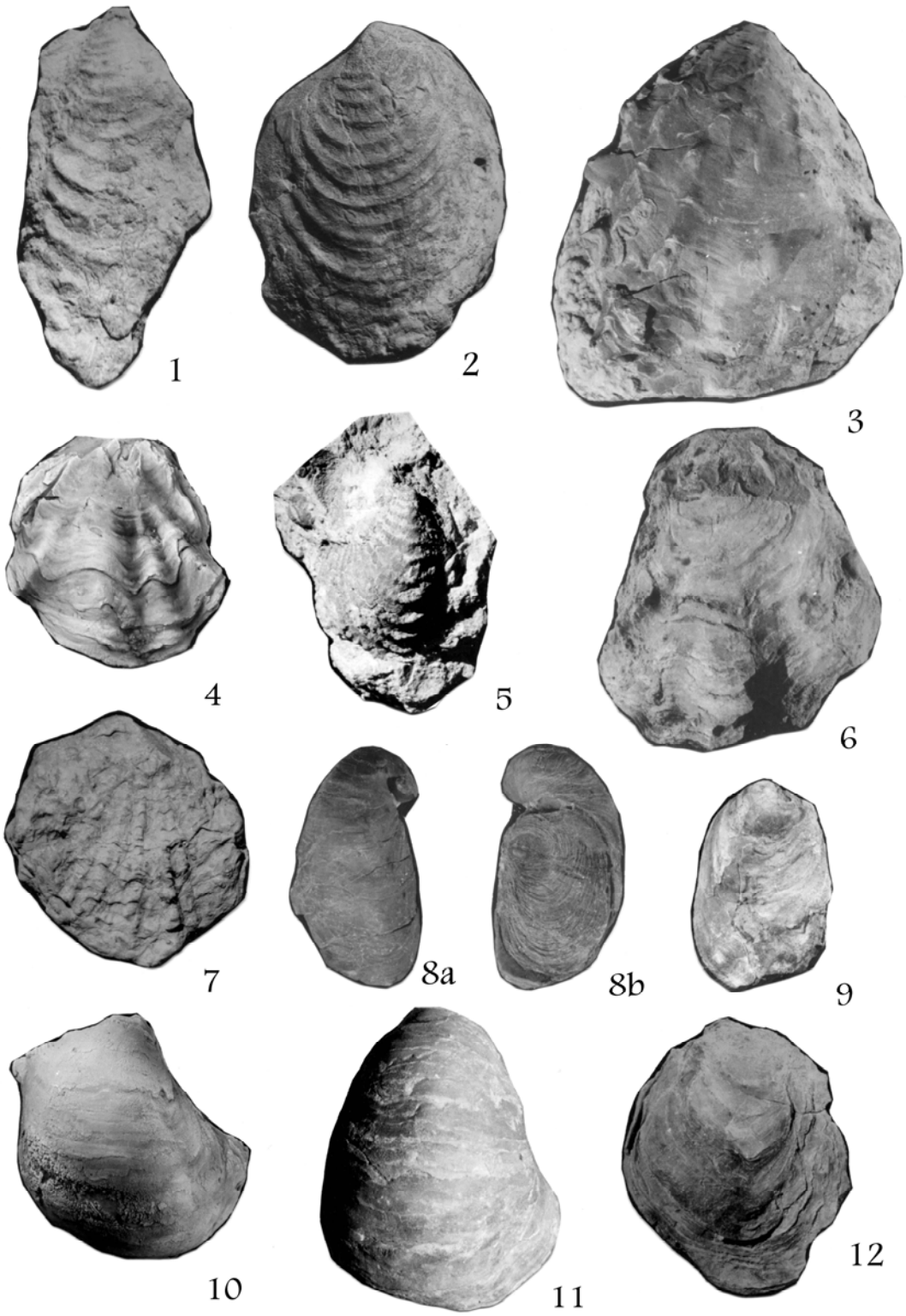

Plate 5

1, 2. *Mytiloides labiatus* (Schlotheim, 1813), side views, Lower Turonian, Galala Formation, Wadi El Deir, X 1. 3. *Costagyra olisiponensis* (Sharpe, 1850), side view, Upper Cenomanian, Galala Formation, Wadi El Deir, X 1. 4. *Nicaisolopha tissoti* (Thomas & Peron, 1891), side view, Upper Coniacian, Matulla Formation, Wadi El Deir, X 1.5. 5. *Inoceramus* cf. *atlanticus* (Heinz, 1936), Incomplete specimen, side view, upper Middle Cenomanian, Galala Formation, Wadi El Deir, X 1. 6. *Nicaisolopha nicaisei* (Coquand, 1862), side view, Lower Campanian, Matulla Formation, Wadi El Deir, X 1.5. 7. *Plicatula ferryi* Coquand, 1862, side view, Middle Coniacian, Matulla Formation, Wadi El Deir, X 1. 8a, b. *Ilymatogyra africana* (Lamarck), side views, Upper Cenomanian, Galala Formation, Wadi El Deir, X 1. 9, 12. *Gyrostrea thevestensis* (Coquand, 1862), side views, Middle Coniacian, Matulla Formation, Wadi El Deir, X 1. 10, 11. *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck, 1806), side views, Campanian, Matulla Formation, Wadi El Deir, X 1.

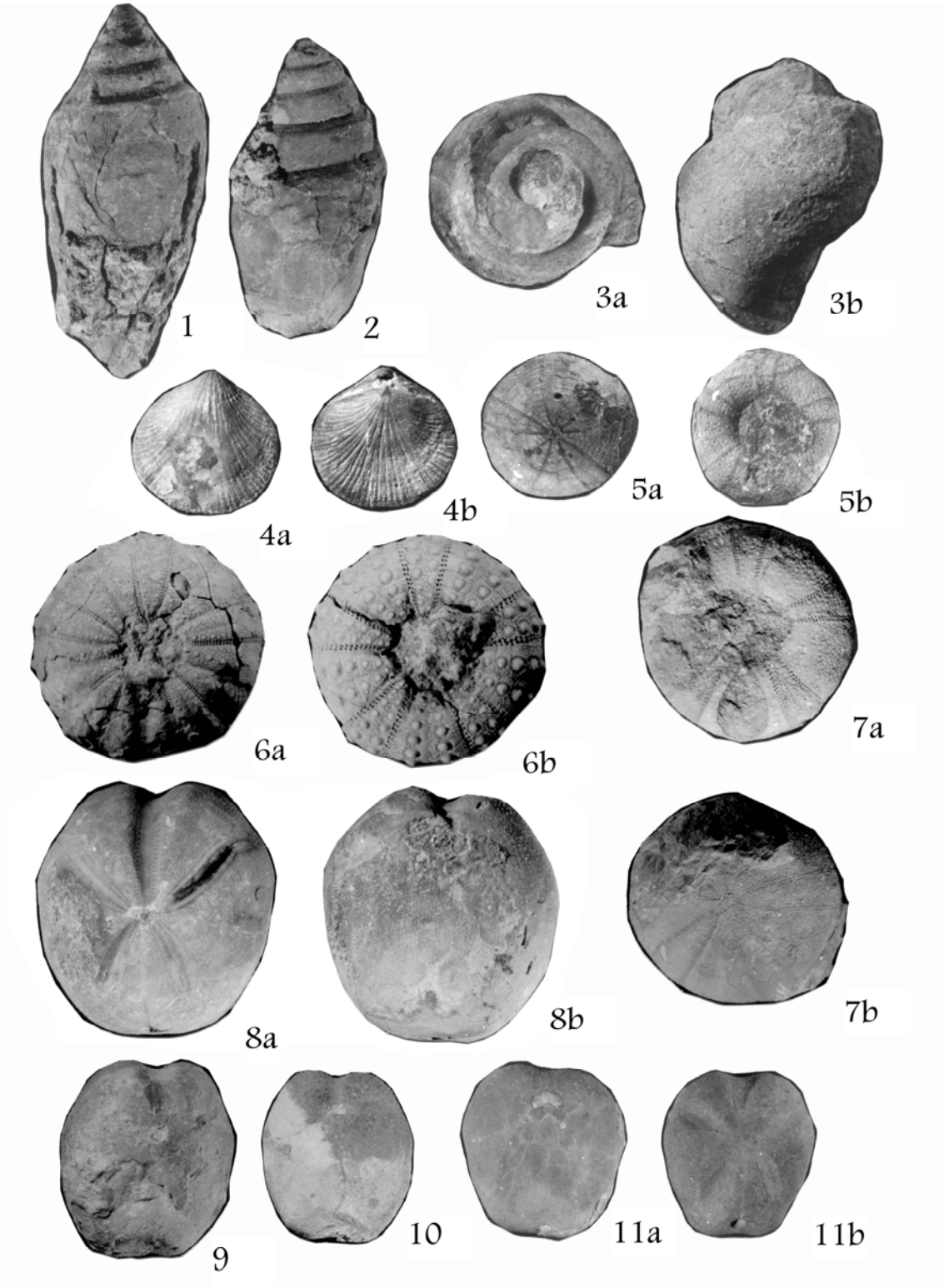

Plate 6

1, 2. *Trochactaeon salomonis* (Fraas, 1867), side views, Upper Turonian, Wata Formation, Wadi El Deir, X 1. 3a, b. *Pseudamaura bulbiformis* (J. de C. Sowerby, 1831), a: apical view, b: side view, Coniacian, Matulla Formation, Wadi El Deir, X 1. 4a, b. *Terebratulina gracilis* (Schlotheim, 1813). side views, Lower Maastrichtian, Sudr Chalk, Wadi El Deir, X 2.5. 5a,b. *Coenholectypus cenomanensis* (Gueranger, 1859), a: aboral view, b: oral view, upper Middle Cenomanian, Galala Formation, Wadi El Deir, X 2. 6a,b. *Heterodiadema libycum* (Desor, 1846), a: aboral view, b: oral view, upper Middle Cenomanian, Galala Formation, Wadi El Deir, X 4. 7a,b. *Coenholectypus turonensis* (Desor, 1847), a: oral view, b: aboral view, Lower Turonian, Galala Formation, Wadi El Deir, X 1.5. 8a,b. *Hemiaster* (*Hemiaster*) *cubicus* Desor, 1847, a: aboral view, b: oral view, upper Middle Cenomanian, Galala Formation, Wadi El Deir, X 1.5. 9,10. *Hemiaster* (*Mecaster*) *fourneli* Deshayes, 1847, 9: aboral view, 10: oral view, Coniacian, Matulla Formation, Wadi El Deir, X 1.5. 11a,b. *H.* (*M.*) *heberti* (Coquand, 1862) *turonensis* Fourtau, 1921 , a: oral view, b: aboral view, Lower Turonian, Galala Formation, Wadi El Deir, X 1.5.

***Mytiloides labiatus* Total Range Zone:** The zone is defined by the total range of the index species *Mytiloides labiatus* (Schlotheim). This zone coincides with the ammonite *Choffaticeras segne* Zone and the echinoid *Hemiaster* (*Mecaster*) *heberti turonensis – Coenholectypus turonensis* Acme Zone. The zone is equivalent to the *Inoceramus labiatus – Arca passyana* Zone of Kassab and Zakhera (1999) from north Eastern Desert. The zone is of Early Turonian age.

***Hemiaster* (*Mecaster*) *heberti turonensis – Coenholectypus turonensis* Acme Zone:** This zone measures 3 m thick and is characterised by the great abundance of the two zonal species *Hemiaster* (*Mecaster*) *heberti* (Coquand) *turonensis* Fourtau and *Coenholectypus turonensis* (Desor). The zone is reported as an Acme Zone by Abdel-Gawad et al. (2004) from Sinai and as a Total Range Zone by Abdel-Gawad et al. (2006) from Abu Darag area. It is equivalent to the *Hemiaster heberti turonensis* horizon at Gebel El-Hamra section and the lower part of the *Phymosoma abbatei – Hemiaster heberti turonensis* horizon from Gebel El-Minsherah section as reported by El-Sheikh et al. (1998). This zone is well traceable in the field, being present with the Lower Turonian *Choffaticeras segne* Zone. Consequently, it is an indicative of Early Turonian age.

***Trochactaeon salomonis* Total Range Zone**: The zone is defined by the total range of the index species *Trochactaeon salomonis* Fraas. It attains a thickness of about 3 m in Wadi El Deir section (Fig. 2, Pl. 1. H). It is equivalent to the *Acteonella salomonis* Zone of Awad & Issawi (1975) and *Trochactaeon salomonis* Zone of Abdel-Gawad et al. (2004) from Sinai. The zone is regarded herein Late Turonian in age, whereas it overlies the late Middle - early Late Turonian *Coilopoceras requienianum* Zone.

***Pseudamaura bulbiformis – Hemiaster fourneli* Assemblage Zone:** The zone is bout 3 m thick at Wadi El Deir section, being very rich with the two index species. It is equivalent to the *Natica bulbiformis* of Awad and Issawi (1975) and *Hemiaster fourneli – Petalobrissus waltheri* horizon of El–Sheikh et al. (1998), and *Echinobrissus waltheri* Zone of Ziko et al. (1993), and *Hemiaster* (*Mecaster*) *fourneli – Petalobrissus waltheri* Zone of Abdel-Gawad et al. (2004). The zone is considered of ?Early – Middle Coniacian age as it underlies the Middle – Upper Coniacian *Metatissotia fourneli* Zone.

***Pycnodonte* (*Costeina*) *costei* Total Range Zone:** The zone is defined by the total range of *Pycnodonte* (*Costeina*) *costei* (Coquand) and measures 3 m thick at Wadi El Dakhl section. It is equivalent to the *Pycnodonte* (*Costeina*) *costei* Zone of Abdel-Gawad et al. (2004) from Sinai. It is also coeval with the upper part of the *Oscillopha dichotoma - Pycnodonte* (*Costeina*) *costei* horizon of El–Sheikh et al. (1998) from Gebel El Minsherah section. The zone is considered Middle Coniacian in age as it underelies the *Metatissotia fourneli* Zone of the Middle – Late Coniacian age.

***Nicaisolopha tissoti* Total Range Zone:** This zone is defined by the total range of its index species *Nicaisolopha tissoti* (Thomas and Peron). The zone attains a thickness of 19 m thick in Wadi El Deir section. This index species has a wide stratigraphic range which extends from Coniacian to Campanian (Malchus, 1990). In Wadi El Deir section, the zone is considered Middle – Late Coniacian in age as it extends from below to above the *Metatissotia fourneli* Zone.

***Oscillopha dichotoma* Total Range Zone**: This zone is defined by the total range of *Oscillopha dichotoma* (Bayle). It measures 5 m thick in Wadi El Dakhl section associated with the Lower Santonian *Texanites texanus* Zone. It is equivalent to the *Lopha dichotoma – Plicatula ferryi* Zone of Awad and Issawi (1975), the *Lopha* (*Actinostreon*) *dichotoma – Plicatula ferryi* Zone of Kora and Hamama (1987b). It can be correlated with the *Oscillopha dichotoma – Pycnodonte (Phygraea) proboscideum* Zone of Kora et al. (2002).

***Nicaisolopha nicaisei* Total Range Zone:** The zone is defined by the total range of the index species, *Nicaisolopha nicaisei* (Coquand). It measures 3 m thick at Wadi El Deir section. The species is associated with *Ambigostrea bretoni* (Thomas and Peron) and *Pycnodonte* (*Phygraea*) *vesicularis* (Lamarck). *N. nicaisei* (Coquand) ranges from the Campanian to the Maastrichtian (Malchus 1990, Aqrabawi 1993 and Dhondt et al. 1999). Consequently, this zone is considered of an Early Campanian in age.

***Pycnodonte (Phygraea) vesicularis* Acme Zone:** The *Pycnodonte* (*Phygraea*) *vesicularis* Zone is defined by the abundance of the index species. The zone is considered by some authors Campanian in age (Issawi et al. 1981, Kora and Hamama 1987b, Kora et al. 2002), but it has also been considered Maastrichtian age and equivalent to the *Exogyra overwegi* Zone, which prevails in the central and south of the Western Desert of Egypt (Awad and Issawi 1975). In Wadi El Deir section, this zone is recorded from the upper part of the Matulla Formation and from the lower part of the Sudr Chalk. Accordingly, the zone is considered herein of Campanian age.

***Terebratulina gracilis* Total Range Zone:** The zone is defined by the total range of *Terebratulina gracilis* (Schlotheim). It measures 3 m thick in Wadi El Deir section. This brachiopod zone is regarded an Early Maastrichtian age by El-Naggar (1966), Abdel-Gawad (1990), and Kora et al. (2002).

REMARKS ON THE STAGE BOUNDARIES

Based on the presence of some wide-spread ammonite and inoceramide species, the various stage boundaries of the studied stratigraphical intervals are discussed in the following:

Cenomanian/Turonian Boundary

In both studied sections, the Cenomanian/Turonian boundary is located within the upper part of the Galala Formation, at the LO of *Vascoceras cauvini* Chudeau (top of the*V. cauvini* Zone; bed no. 9 in Wadi El Deir and bed no. 15 in Wadi El Dakhl). The boundary is determined based on the co-occurrence of *Pseudaspidoceras pseudonodosoides* with the *V. cauvini* Zone in the present study and their co-occurrence with the standard, latest Cenomanian *Neocardioceras juddii* Zone in New Mexico (Cobban et al. 1989).

Turonian /Coniacian Boundary

The Turonian/Coniacian boundary is located at the top of the Wata Formation (bed no. 22, Wadi El Deir section; bed no. 35, Wadi El Dakhl). In Wadi El Deir section, bed 24 overlies the *Trochactaeon salomonis* and the latter is underlain by the late Middle – early Late Turonian *Coilopoceras requienianum* Total Range Zone.

Coniacian /Santonian Boundary

According to Lamolda and Hancock (in Rawson et al. 1996) six criteria are proposed for the Coniacian/Santonian boundary; FO of *Texanites* (*Texanites*), FO of *Sigalia carpathica*, FO of *Dicarinella asymetrica*, FO of *Platyceramus siccensis*, FO of *Cladoceramus undulatoplicatus*, and FO of *Sphenoceramus pachti*. They selected the lowest occurrence of *Cladoceramus undulatoplicatus* as a primary marker for the Coniacian/Santonian boundary and *Sigalia carpathica* as a secondary marker. In Egypt, the Coniacian/Santonian boundary is determined by some authors based on recording some of the prementioned criteria; Abdel-Gawad (1999b) recorded *Platyceramus siccensis* (Pervinquière) and *Texanites* (*T.*) sp., Obaidalla and Kassab, (2002) recorded both *Texanites texanus* Roemer and *Sigalia carpathica* Salaj, and El Qot (2006) decribed *Cladoceramus undulatoplicatus* (Roemer) from Gebel Ekma Consequently, the Coniacian /Santonian boundary is located at the top of the Matulla Formation in Wadi El Dakhl section (bed no. 44), at the FO of the Early Santonian *Texanites texanus* Zone.

Campanian /Maastrichtian Boundary

The Campanian /Maastrichtian boundary is located within the lower part of the Sudr Chalk at Wadi El Deir at the FO of the Early Maastrichtian *Terebratulina gracilis* (Schlotheim) (El Naggar, 1966, Abdel Gawad, 1990, and Kora et al. 2002).

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