Paleoecology and Paleogeography of the Cenomanian-Turonian macrofossils at the north Eastern Desert and Sinai, Egypt

Mahmoud H. Darwish[1*], Nasr A. Abdel-Maksoud[2], Mohamed S. Zakhera[3] and Nageh A. Obaidalla[2]

[1] Geology Department, Faculty of Science, New Valley University, El-Kharga, 72511 Egypt
[2] Geology Department, Faculty of Science, Assiut University, Assiut, 71516, Egypt
[3] Geology Department, Faculty of Science, Aswan University, Aswan, Egypt
Doi: 10.21608/NUJBAS.2022.117895.1001

Abstract

Taphonomy, mode of life, quantitative and relative abundance, and faunal diversity of the macrofossils identified from the Cenomanian-Turonian successions at the north Eastern Desert and Sinai to deduce the paleoecological conditions and paleoenvironmental setting during the deposition. The successions are composed of shallow marine siliciclastic and carbonate facies. They are subdivided from base to top into Raha, Abu Qada, and Wata formations. Based on the paleobiogeography point of view, the geographic distribution of the identified faunal species shows a strong affinity to the Mediterranean province. A large proportion of the ammonite, bivalve, gastropod, and echinoid faunal elements link the study area with North Africa, the Middle East, and South and West Europe. Some species of Cenomanian and Turonian ages seem to be endemic to Egypt, suggesting that Egypt was an endemic center during certain the Late Cretaceous times. Countries (e.g. North Africa, West Africa, North and South America, South and West Europe, and the Middle East), refer to the Tethyan affinity of the studied fauna. The Turonian successions at the measured sections were characterized by the rare occurrence of the oysters, in contrast to the enrichment of the oysters in Cenomanian successions, this may indicate that the Cenomanian-Turonian transgression was followed by deeper conditions unfavorable for oysters.

Keywords: Paleoecology; Paleogeography; Macrofossils; Cenomanian; Turonian; Taphonomy; Diversity; Gulf of Suez; Sinai; Egypt.

Introduction

This study aims to discuss taphonomy, mode of life, quantitative abundance, faunal diversity, and relative abundance of the macrofossils. These fossils were collected and identified from the Cenomanian-Turonian successions of the four studied sections (Wadi Tarfa and Wadi El-Dakhl in the north Eastern Desert and Wadi Abu Qada and Wadi Feiran in Sinai) (**Fig. 1**), to deduce the paleoecological conditions and paleoenvironmental setting prevailing during the deposition.

The strata of this succession are composed of mixed siliciclastic and carbonate rocks, they are subdivided lithostratigraphically into Raha (at base), Abu Qada (at middle), and Wata (at top) formations. **Darwish,** [**1**] described these sections with fossils contents (**Figs. 2, 3, 4, 5 and 6**). The descriptions explained the following: The Raha Formation comprises calcareous sandstones, siltstones, marls, mudstones, and shales, which sometimes are calcareous, and others are marly. Generally, the upper part is fossiliferous and yields Late Cenomanian macro-fossils (ammonites, bivalves, and gastropods).

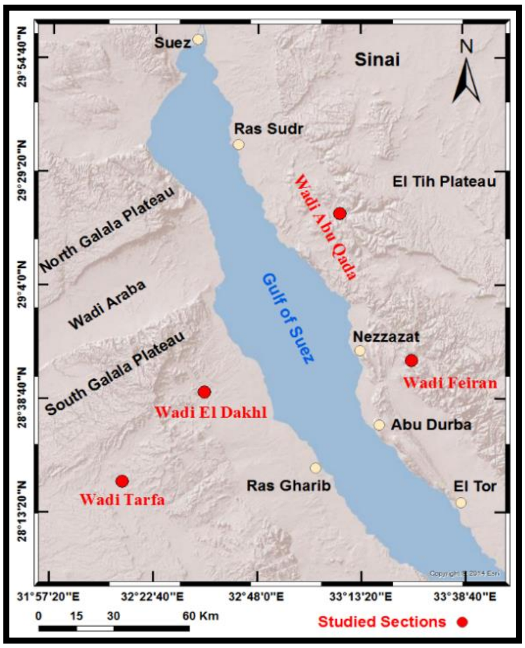
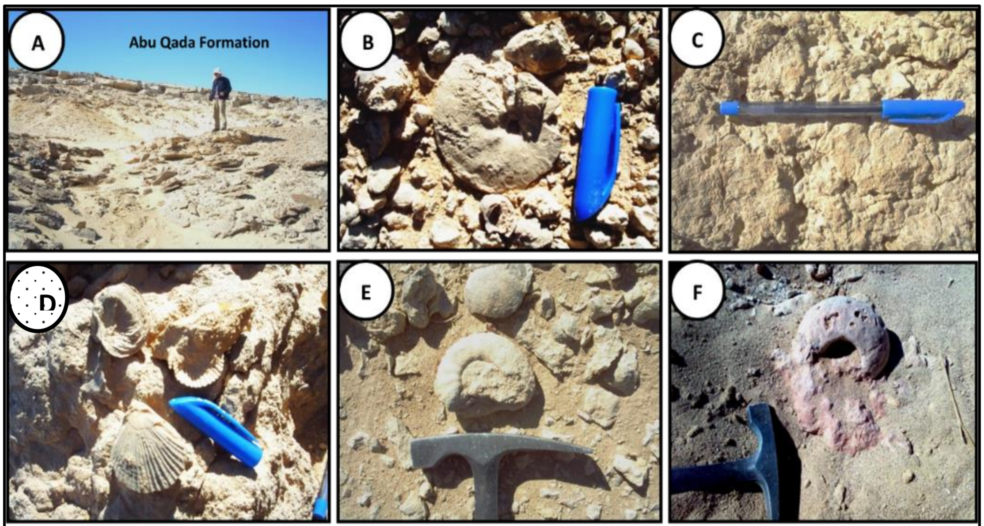


Fig. (1): Location map of the studied sections.

The lower part is poorly fossiliferous but contains bioturbated horizons rich in small oysters.

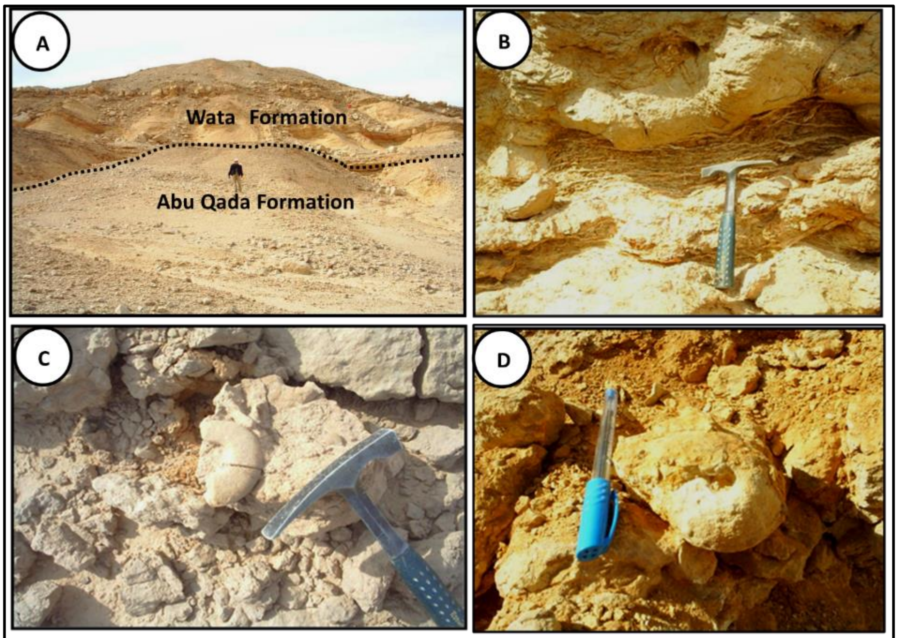
* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Accordingly, the sediments of the Raha Formation reflect the first marine transgression during the Cenomanian. Paleontologically, the Raha Formation contains numerous macro-fossils (cephalopods, bivalves, gastropods, and echinoids of the Late Cenomanian age.



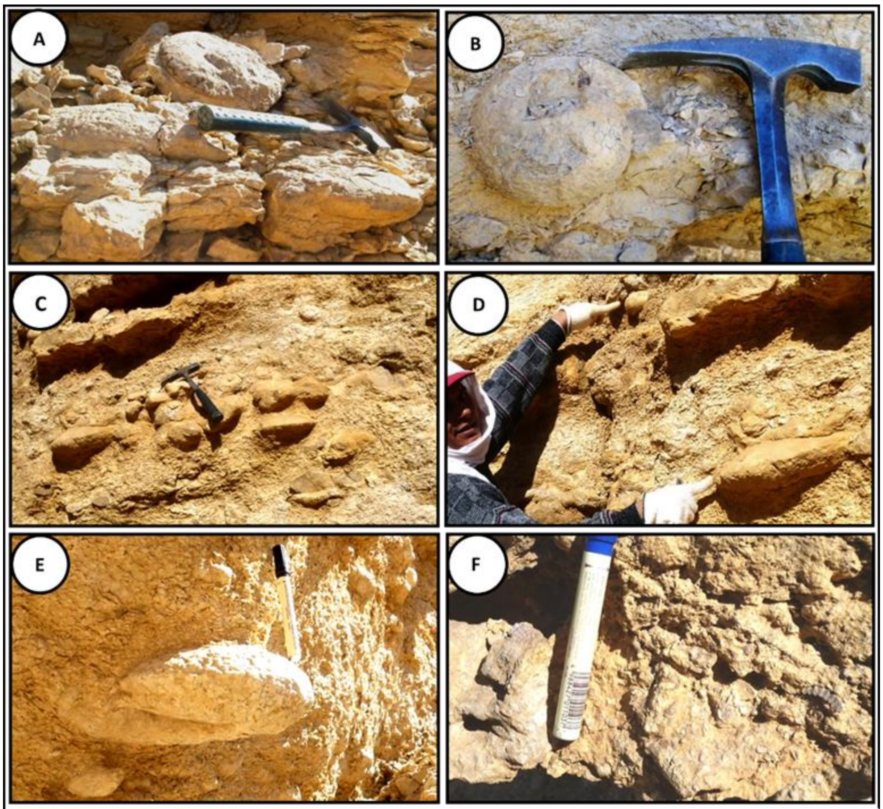
A. General view showing the lower part of Abu Qada succession**. B.** *Neolobites vibrayeanus* fossil within the Abu Qada Formation sediments. **C.** Fossiliferous limestone bed (oysters), Abu Qada Formation. **D.** *Neithea (Neithea) aequicostata* with oyster fossils in limestone bed within the Abu Qada Formation sediments. **E & F.** *Vascoceras cauvini* fossils within the Abu Qada Formation sediments.

Fig. (2): Field views show some characteristic features of, Wadi Tarfa section, north Eastern Desert.



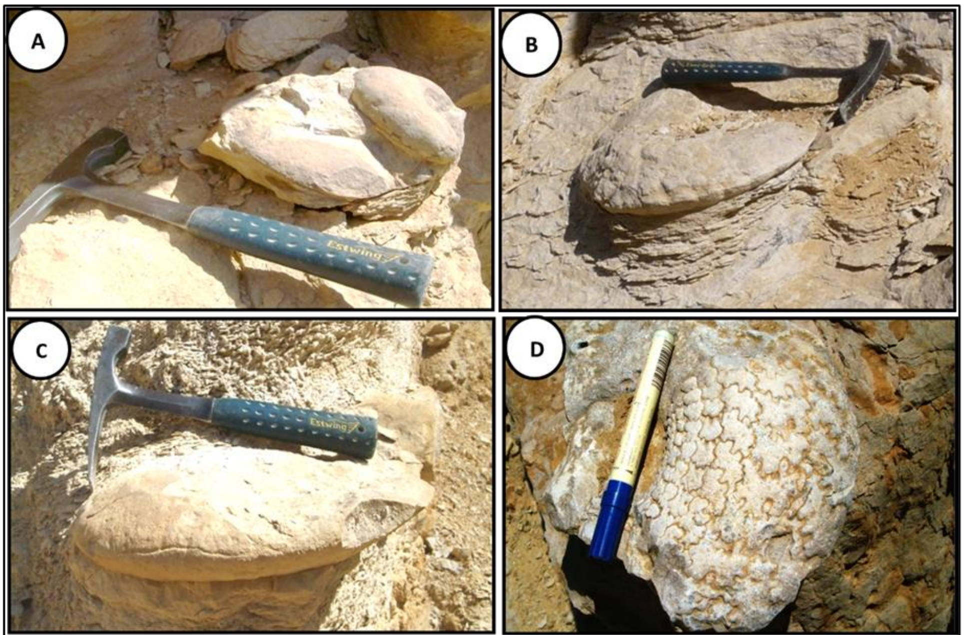
A. General view of Wadi El Dakhl section. **B.** limestone beds with Shale intercalations, Abu Qada Formation, Wadi El Dakhl section. **C.** *Spathites (Jeanrogericeras) subconciliatus* fossils**,** Abu Qada Formation, Wadi El Dakhl section.. **D.** *Thomasites rollandi globosa* fossils, Wata Formation, Wadi El Dakhl section.

Fig. (3): Field views show some characteristic features of, Wadi El Dakhl section, north Eastern Desert.



A. *Neoptychites cephalotus* fossils within the marly limestone bed, Abu Qada Formation, Wadi Abu Qada section. **B.** *Vascoceras proprium* fossils within brownish Shale, Abu Qada Formation. **C& D.** Marly limestone ammonites bed, Wata Formation. **E.** *Coilopoceras* sp., fossils within the marly limestone bed, Wata Formation. **F.** Fossiliferous marly limestone bed, Wata Formation, Wadi Abu

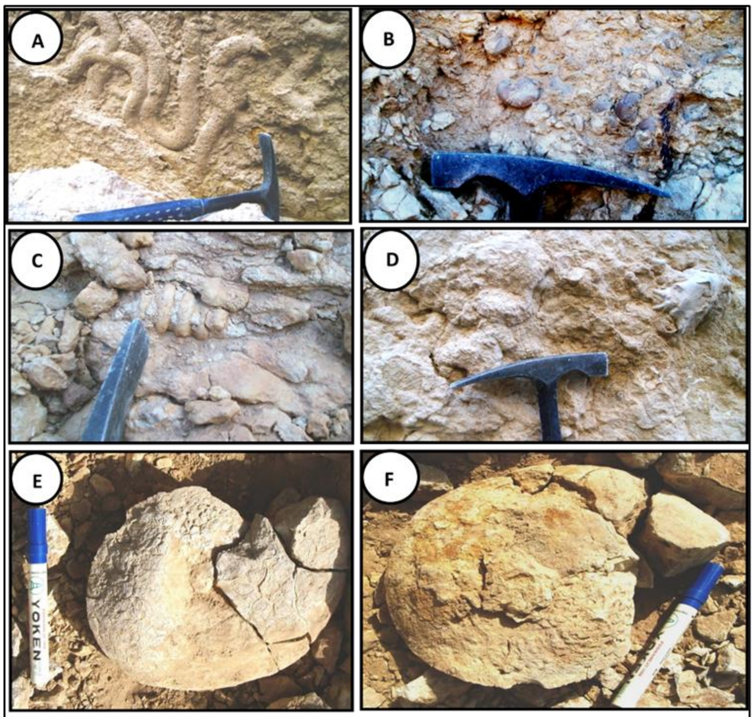
Fig. (4): Field views show some characteristic features of, Wadi Abu Qada section, Sinai.



A. *Vascoceras durandi* and *Choffaticeras segne* fossils within the sandy limestone bed, Abu Qada Formation, Wadi Abu Qada section. **B. C, and D.** Large *Choffaticeras segne* fossils within sandy limestone bed, Abu Qada Formation, Wadi Abu Qada section.

Fig. (5): Field views show some characteristic features of, Wadi Abu Qada section, Sinai.

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg



A. Bioturbated beds, Raha Formation. **B.** *Ilymatogyra (Afrogyra) africana* fossils within marl bed, Raha Formation. **C.** Gastropods fossils within limestone bed, Abu Qada Formation. **D.** *Exogyra (Costagyra) olisiponensis* and *Plicatula* fossils within limestone bed, Abu Qada Formation. **E & F.** *Coilopoceras requienianum* fossils within marly limestone bed, Wata Formation.

Fig. (6): Field views show some characteristic features, Wadi Feiran section, Sinai

The Abu Qada Formation is represented by fossiliferous mixed siliciclastic and carbonate sediments. It is composed of marl, marly limestones, dolomitic limestone, and argillaceous limestone with beds of calcareous shale, shale, silty shale, and banded sandstone. Paleontologically, the Abu Qada Formation contains numerous oyster banks and is rich in ammonites, bivalves, gastropods, and echinoids. These macro-fossils are of the Late Cenomanian-Early Turonian age. The Wata Formation composed of limestone, dolostone, dolomitic limestone, marly limestone, nodular limestones, marl with siltstone, and shale interbeds with abundant ammonites of the Turonian age. The contact between the Wata Formation and its underlying Abu Qada Formation is located at the base of a dolomitic bed, coinciding with the topmost shale bed of the Abu Qada Formation. Paleontologically, the Wata Formation contains macro-fossils such as ammonites, bivalves, gastropods, and echinoids of the Middle-Late Turonian age. According to the field observations, there is a repetition in the strata of the Abu Qada Formation at Wadi Abu Qada due to the affection of this area by a thrust fault.

Based on the vertical distribution of the macro-fauna, **Darwish et al.** [**2**] subdivided the Cenomanian–Turonian successions into five bivalve zones, and four echinoid zones coeval with eight ammonite zones. The bivalve zones are *Ceratostreon flabellatum*, *Exogyra* (*Costagyra*) *olisiponensis*, and *Pycnodonte* (*Phygraea*) *vesiculosa* for the Cenomanian age, *Arca passyana* and *Crassatella sequenzai* for the Turonian age. The echinoid zones are *Mecaster cubicus*, *Mecaster pseudofourneli*, and *Mecaster batnensis* for the Cenomanian age and *Mecaster turonensis* for the Turonian age. The ammonite zones are *Neolobites vibrayaenus*, *Metoicoceras geslinianum* and *Vascoceras cauvini* for the Cenomanian age, *Watinoceras praecursor, Vascoceras proprium, Mammites nodosoides, Choffaticeras segne* and *Coilopoceras requienianum* for the Turonian age. The index ammonite *Watinoceras devonense* is here recorded for the first time in Egypt. This species was used as a marker for the base of the Turonian Stage at Pueblo, Colorado, U.S.A. (GSSP).

2- Paleoecology

In Wadi Tarfa and Wadi El Dakhl sections (north Eastern Desert), the bivalves are the first main constituent, the cephalopods are the second main constituent while the gastropods and the echinoids are the third main constituent. The Turonian cephalopods are the main constituent at Wadi Abu Qada (Sinai). At Wadi Feiran (Sinai), the bivalves and gastropods are the first main constituent, and the cephalopods are the second main constituent, but very rare individuals represent the echinoids.

2.1-Taphonomy and Preservation

The macrofossils, collected from the measured sections, are generally of low to moderate diversity. They are composed of bivalves, cephalopods, gastropods, and echinoids, which are distributed at several horizons. They indicate the predominance of moderate energy conditions during their life span.

In the studied sections, gastropods follow bivalves and cephalopods in diversity and abundance, whereas echinoids are less abundant. Most of the collected bivalves are molds and casts referring to different diagenetic processes that lead to different preservational styles in skeletal materials. Some bivalve shells are well preserved and articulated, suggesting a short time of exposure and very rapid burial. Some oyster beds were recorded in the Abu Qada Formation, characterized by disarticulated and disoriented shells. Articulated oyster shells are rarely present. The dominance of disarticulated and disoriented shells of the epifaunal oysters suggests reworking, transportation, and fragmentation due to high energy events, longer phases of raised energy levels, storms, and oscillatory currents [**3,4**].

Many of the collected cephalopods and gastropods of the measured sections were preserved as molds and casts. Most of the cephalopods occurred as fragments and were preserved as phragmocones and/or body chambers. A few of the cephalopods are preserved as complete individuals such as *Neolobites vibrayeanus* (d'Orbigny), *Vascoceras cauvini* Chudeau, and *Choffaticeras* spp.

Most of the echinoids are well-preserved but randomly oriented. Others were found particularly crushed. At certain levels, echinoid tests are abraded and distorted. The tests were filled with the same material as the bearing sediments indicating that the echinoids were lived and buried in the same location with no post-mortem transportation.

2. 2-Mode of life and paleoecological aspects of the identified macro-fauna

Mode of life and habit of the marine fauna is generally discussed for nutrition or trophic system, locomotion or position of life, and reproduction.

The trophic affinity of the identified macrofossils, as well as their relation to a substratum, was interpreted, based on the literature dealing with autecology and mode of life invertebrate macrofossils (e.g. [**5-22**]). Bathymetrical terms were used by [**8; 14; 25; 26**].

Paleoecological aspects and bathymetry of the identified macro-fauna are given in **Tables 1-3.**

A brief discussion paleoecological aspect of the identified macro-fauna in the studied sections is given in the following paragraphs.

The Bivalves

The bivalves are adapted to a wide range of habitats; epifaunal, including forms fixed by byssus or cementation and others that are freely moving; and infaunal including a variety of borrowers. Pectinid bivalves were recorded from warm shallow marine water and were common in littoral to infra-sublittoral environments [**8; 10;12;14 ;18**]. Oysters live in water depths ranging from 0 to 50 m [**5;7;8;10-12;27**] inhabiting shallow waters of about 22 fathoms [**28**] and living in the shallow water below the low tide level [**6; 29;30**] and represent shallow-marine environment [**23**]. The *Exogyra* population lives in warm shallow water [**31; 32**] and is very common in the offshore neritic environment [**14**]. *Plicatula* inhabited beaches from intertidal to just offshore [**28**] and normal marine inner to the middle neritic environment [**7**]. Venerids live over sandy and marly substrate in shallow warm water [**33**]. Ostreidae inhabited coastal waters, shelves, lagoons, and actuaries [**34**]. *Pholadomya* and *Trigonia* taxa inhabited warm water [**6**]. *Neithea*, *Trigonia*, and *Arca* genera inhabited warm water in shallow inner to the outer neritic environment, 25- 125 m depth [**6;8**]. *Neithea* is mainly found in carbonate rocks representing circa-littoral environments [**23**]. *Trigonia* and *Granocardium* taxa *were* recorded from the middle neritic environment [**8**]. The trigonids are abundant in the nearshore environment, in water depths 10-15m [**35**], and inhabited shallow water of inner neritic [**17**].

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Table (1): Paleoecological aspects and bathymetry of the bivalves identified from the studied sections. Ep= Epi-fauna; In= In-fauna; Is= Shallow infauna; Id= Deep infauna; S= suspension-feeders; C= Cemented; Si= Siphonates; N= Non-siphonated.

Taxa	Mode of life	Bathymetry		
		Littoral	Sublittoral	
			Infra-	Circa-
		0 – 10	100	200
Pycnodonte	Ep, S, C			
Exogyra	Ep, S, C			
Ceratostreon	Ep, S, C			
Ilymatogyra	Ep, S, C			
Rhynchostreon	Ep, S, C			
Gyrostrea	Ep, S, C			
Curvostrea	Ep, S, C			
Plicatula	Ep, S			
Neithea	Ep, S			
Arca	Ep, S			
Cucullaea	In, S			
Septifer	Ep, S			
Pholadomya	In, S			
Liopistha	Id, S			
Arctica	In, S			
Maghrebella	In, S			
Crassatella	In, S			
Astarte	In, S			
Granocardium	Is, S, N			
Protocardia	Is, S, N			
Glossus	In, S			
Dosinia	In, S			
Flaventia	In, S, Si			

The Cephalopods

Cephalopods, which are recorded from the studied sections mainly ammonites. Cephalopods are limited to marine environments and live in all water depths ranging from shallow to great depths [36]. The ammonites ranged from nektobenthonic to planktonic, living in both shallow and deep marine water, predominated in normal marine life at a water depth of up to 300 meters [6;7;11;13]. *Nautilus* lives in warm, relatively shallow water, but has been dredged from about 500m [6] living in open marine outer neritic to the bathyal environment [37]. Ammonites were recorded from the neritic zone [38]. Acanthoceratid ammonites were recorded from nearshore shallow waters to deep marine [39]. Vascocertid and Acanthoceratid ammonites inhabited an environment ranging from littoral to shallow circa-sublittoral settings [5;11;18;40]. *Vascoceras* lived at a depth of 20m to 45m [41]. *Neolobites* occur in shallow marine neritic settings [42].

The Echinoids

Echinoids occur from the littoral to the deep sea [6;7;43]. The neritic zone is commonly associated with reefs [44]. Echinoids live in inner to middle neritic environments [7]. Infaunal echinoids inhabited inner neritic environments 25-50m [8]. Irregular echinoids are abundant between 20–70 meters in-depth, regular echinoids are common between 0-20 meters depth, and both are present at depths up to 100 meters [5]. All echinoids are restricted to waters of near-normal salinity, although a few species of all groups, except the crinoids, are found in moderately brackish water [45]. Most echinoids are deposit-feeders or herbivores, although many will eat small animals that cling to the rocks or sediment surfaces on which they browse [46]. Infaunal echinoids are common in depths between 0-20 m in littoral - shallow sublittoral environments [5;9;10;16;18].

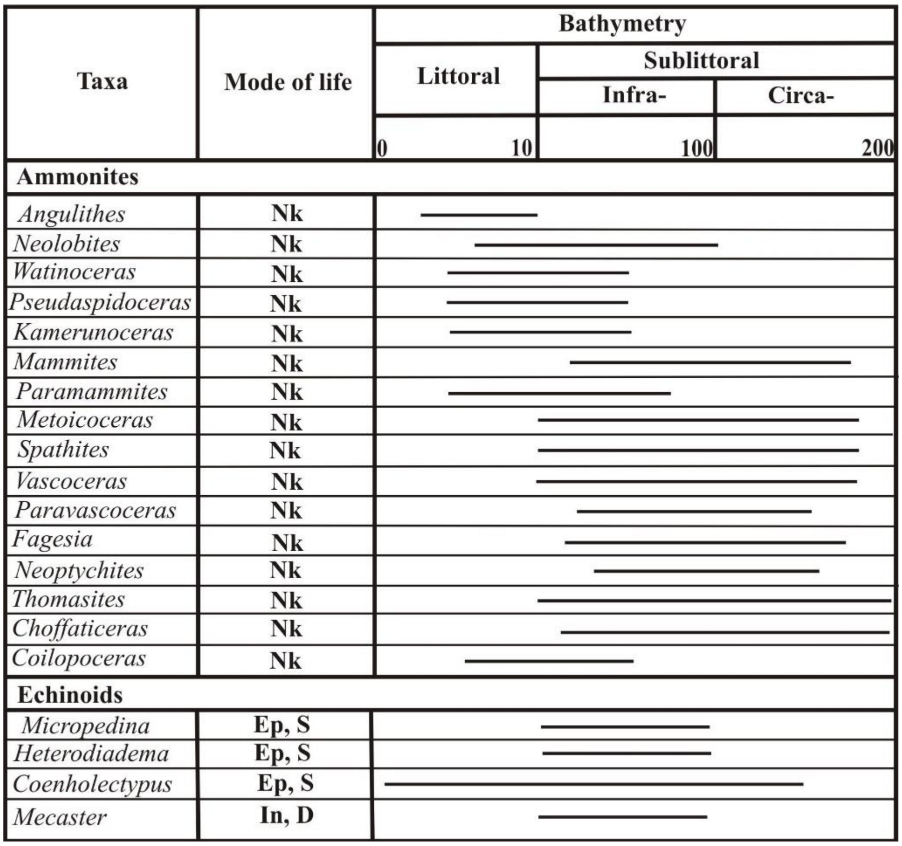
The Gastropods

Most gastropods are aquatic, found in both fresh and marine water, and some are terrestrial.

Gastropods are especially abundant in tidal flats [47;48]. Most living taxa of the order Neogastropoda are active carnivores and predators [49]. Living species of Fasciolaridae and Volutidae are predators in the Black Down [49;50]. The epifaunal volutids inhabit shallow tropical seas. Infaunal suspension-feeders gastropods inhabited normal marine inner to middle neritic conditions [34]. Turritellid gastropods inhabit shallow water about 22m depth [6] inhabiting depths of approximately 15–50m [50;51]. They occur on the Pacific coast at a depth range from 36 to 72 m [28]. Arau, [34] believed that turritellod gastropods inhabit tropical waters on shallow muddy bottoms from 15 to 100 m depth, characteristic of sheltered areas. They dominate an intertidal sublittoral habitat [52] and burrow in soft substratum just below low tide [51;53].

Abdelhady, [23] believed that turritellod gastropods represent a good indicator of cold marine water. *Nerinea* inhabited warm water in normal marine inner to middle neritic conditions at about 40-70m depth [5;6;7]. Nerineid gastropods are wholly restricted to tropical regions [54]. *Turritella, Tylostoma,* and *Nerinea* inhabited warm water under normal marine inner to middle neritic conditions [6;7;52]. *Tylostoma* has its optimum mainly in the narrow transitional zone between the temperate and Tethyan realms [54] which are of high-temperature gradients [23]. *Aporrhais* and *Ampullina* are found in the warm offshore, sandy bottom at depths of 40-85 m [50]. Most of the studied gastropods indicate a typical Tethyan character like *Nerinea olisiponensis* (Sharpe) and *Nerinea gemmifera* Coquand.

Table (2): Paleoecological aspects and bathymetry of the cephalopods and echinoids identified from the studied sections. NK= Nektonic; Ep= epifauna; In= infauna; S= suspension feeders; D= deposit feeders.



Taxa	Mode of life	Bathymetry: Littoral (0–10)	Sublittoral: Infra- (10–100)	Sublittoral: Circa- (100–200)
Ammonites				
Angulithes	Nk			
Neolobites	Nk			
Watinoceras	Nk			
Pseudaspidoceras	Nk			
Kamerunoceras	Nk			
Mammites	Nk			
Paramammites	Nk			
Metoicoceras	Nk			
Spathites	Nk			
Vascoceras	Nk			
Paravascoceras	Nk			
Fagesia	Nk			
Neoptychites	Nk			
Thomasites	Nk			
Choffaticeras	Nk			
Coilopoceras	Nk			
Echinoids				
Micropedina	Ep, S			
Heterodiadema	Ep, S			
Coenholectypus	Ep, S			
Mecaster	In, D			

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Table (3): Paleoecological aspects and bathymetry of the gastropods identified from the studied sections. Ep= Epi-fauna; In= In-fauna; S= suspension-feeders; D= Deposite-feeders; C= Carnivores; P= Predators; H= Herbivores; O= omnivores.

Taxa	Mode of life	Bathymetry		
		Littoral	Sublittoral	
			Infra-	Circa-
		0 – 10	100	200
Tylostoma	Ep, Cp			
Ampullina	Ep, Cp			
Strombus	Ep, P			
Aporrhais	Ep, D			
Harpagodes	Ep, D			
Helicaulax	Ep, D			
Pterodonta	Ep, P			
Columbellina	Ep, H, o			
Cimolithium	Ep, HP			
Nerinea	Ep, H			
Marhilaia	Ep, H			
Turriscala	In, Cp			
Torinia	Ep			
Turritella	In, S			
Mesalia	In, S			
Volutomorpha	In, P			
Fasciolaria	Ep, Cp			

2. 3. Faunal diversity

The species diversity curves of the collected macro-fauna (**Figs. 7-10**) show that the mollusks represent the major supplier to the Cenomanian- Turonian sediments. The species diversity is very highly fluctuated reflecting the sea-level oscillations and changes in the environmental conditions. The diversity rates of the identified macro-fauna increased with increasing carbonate sediments. Bivalves had a high diversity of the collected fauna.

From the quantitative abundance of the identified macro-fauna in the study area **(Tables, 4-6),** it is clear that the bivalves families Gryphaeidae, Veneridae, Plicatulidae, Ostreidae, Arcticidae, Carditidae, Astartidae, Arcidae and Cucullaeidae show the greatest abundance, while families Pteriidae, Limidae, Mytilidae, Poromyidae, Laternulidae, Tellinidae and Anatinidae show the lowest abundance. The Cephalopods families Pseudotissotiidae, Vascoceratidae, Acanthoceratidae, and Engonoceratidae have the greatest abundance, while families Coilopoceratidae and Nautilidae have the lowest abundance. The gastropods families Naticidae, Procerithiidae, Nerineidae, Aporrhaidae, Columbellinidae, and Strombidae show the greatest abundance, while families Scalidae, Architectonicidae, Turritellidae, Volutidae, and Fasciolaridae show the lowest abundance. The echinoid families Hemiasteridae and Holectypidae show the greatest abundance, while the families Pedinidae and Hemicidaridae show the lowest abundance.

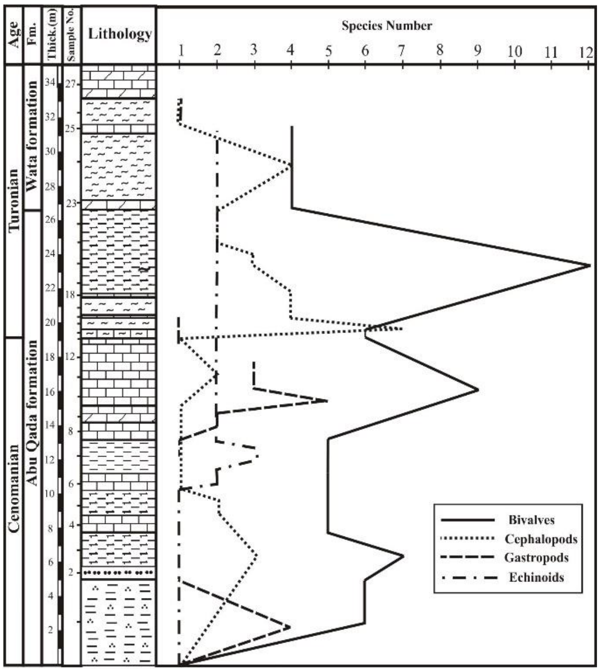


Fig. (7): Species diversity curves of the macro-fossils, Wadi Tarfa section.

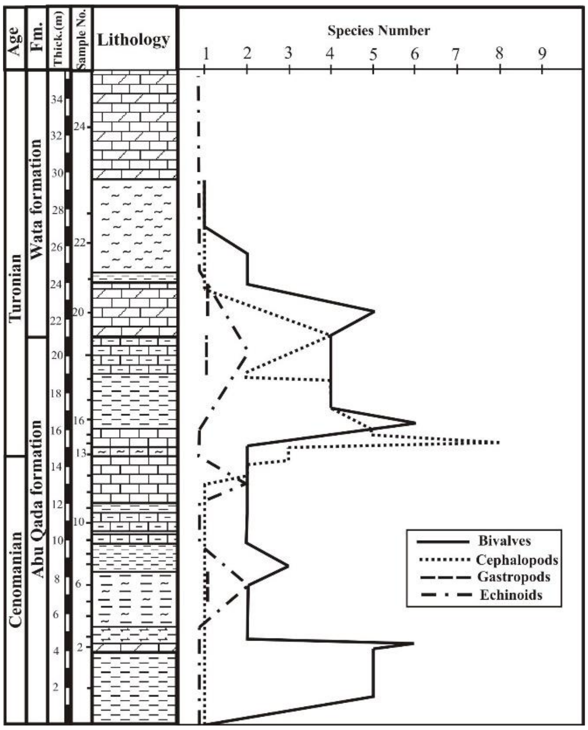


Fig. (8): Species diversity curves of the macro-fossils, Wadi El Dakhl section.

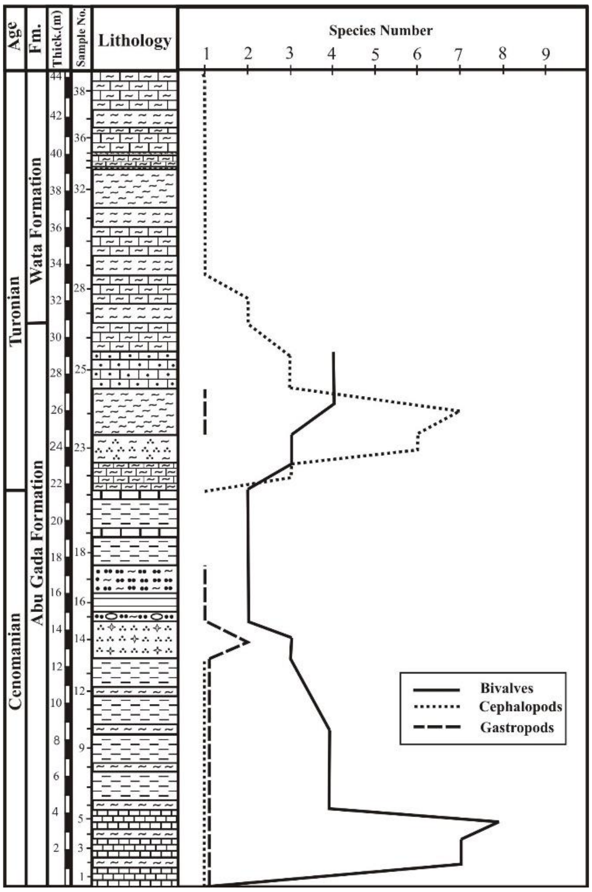


Fig. (9): Species diversity curves of the macro-fossils, Wadi Abu Qada section.

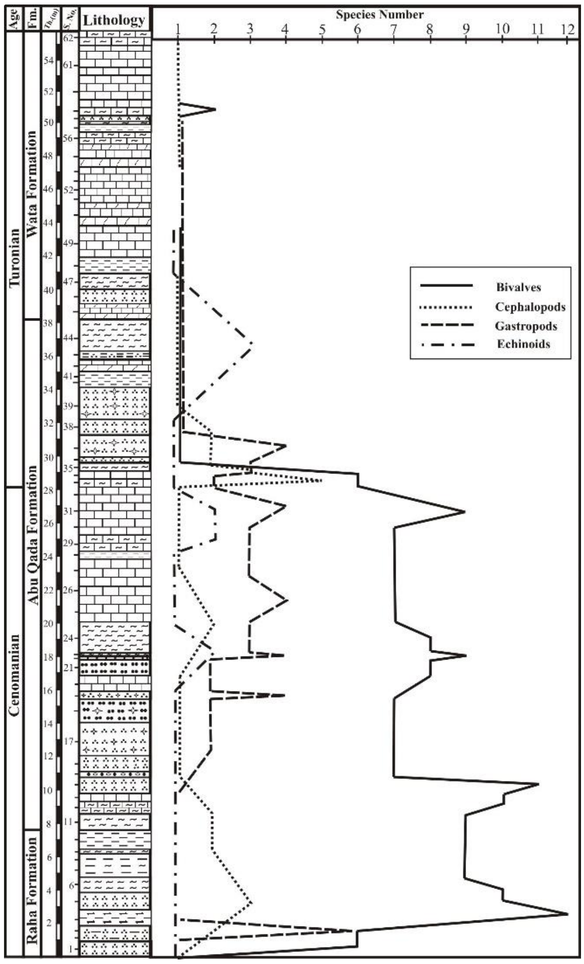


Fig. (10): Species diversity curves of the macro-fossils, Wadi Feiran section.

The relative abundance curves of the collected macro-fauna (**Figs. 11-14**) clear that the bivalves are the highest abundant Fossil Group at different levels in the studied sections, followed by cephalopods, gastropods, and echinoids.

3- The Paleoenvironmental conditions

Depending upon the mode of life, quantitative abundance, diversity, relative abundance, and the paleoecological significance of the identified macro-fauna as well as the lithology of the studied successions, paleoenvironmental conditions prevailing during deposition of the Cenomanian-Turonian successions are given as follows:

3.1. Raha Formation

The measured part of the Raha Formation is composed of sandstones, siltstones, marls, mudstones, and shales, which sometimes are calcareous.

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Table (4): Quantitative abundance of the bivalves in the studied sections.

Family	No. of genera	No. of species	No. of specimens
Gryphaeidae	5	7	696
Ostreidae	2	2	75
Plicatulidae	1	5	186
Pectinidae	1	1	6
Pteriidae	1	1	1
Limidae	1	1	2
Arcidae	1	3	42
Cucullaeidae	1	2	12
Mytilidae	1	1	3
Pholadomyidae	1	2	6
Poromyidae	1	1	2
Laternulidae	1	1	1
Arcticidae	2	5	14
Carditidae	2	2	5
Crassatellidae	1	1	20
Astartidae	1	1	152
Tellinidae	1	1	3
Cardiidae	2	2	4
Mactridae	1	1	10
Glossidae	1	2	6
Veneridae	2	5	570
Anatinidae	1	1	3
Total = 22 Families	31	48	1819

Table (5): Quantitative abundance of the cephalopods and echinoids in the studied sections.

Family	No. of genera	No. of species	No. of specimens
Cephalopods			
Nautilidae	1	1	5
Engonoceratidae	1	2	32
Acanthoceratidae	8	11	86
Vascoceratidae	3	10	156
Pseudotissotiidae	2	7	128
Coilopoceratidae	1	1	10
Total= 6 Families	16	32	417
Echinoids			
Pedinidae	1	1	8
Hemicidaridae	1	1	5
Holectypidae	1	2	11
Hemiasteridae	1	4	551
Total = 4 Families	4	8	575

Generally, the upper part is fossiliferous and yields Late Cenomanian macrofossils (cephalopods, bivalves, and gastropods). The lower part is poorly fossiliferous but contains bioturbated horizons that are rich in small oysters and trigonid bivalves. Generally, the sediments of the Raha Formation reflect the first marine transgression during the Late Cretaceous at south Sinai. The measured part of the Raha Formation includes bivalve's genera such as *Ilymatogyra, Ceratostreon, Exogyra, Maghrebella, Curvostrea, Mreretrix, Dosinia, Cucullaea, Plicatula, Venericardia* and *Arctica*, the cephalopods genera *Angulithes* and *Neolobites*, the echinoids genera *Mecaster* and the gastropods genera *Pterodonta, Aporrhais, Torinia, Helicaulax,* and *Nerinea.* These criteria indicate that the Raha Formation is deposited under shallow marine conditions ranging from the littoral less 10m for the lower part sediments to the infra-littoral (10-100) for the upper part. The sea was highly oscillating and interrupted by several transgressive and regressive phases.

Table (6): Quantitative abundance of the gastropods in the studied sections.

Family	No. of genera	No. of species	No. of specimens
Naticidae	**2**	**5**	**32**
Strombidae	**1**	**2**	**9**
Aporrhaidae	**3**	**5**	**14**
Columbellinidae	**2**	**3**	**9**
Procerithiidae	**1**	**2**	**33**
Nerineidae	**2**	**7**	**22**
Scalidae	**1**	**1**	**1**
Architectonicidae	**1**	**1**	**1**
Turritellidae	**2**	**2**	**2**
Volutidae	**1**	**1**	**1**
Fasciolaridae	**1**	**1**	**2**
Total = 11 Families	**17**	**30**	**128**

3. 2. Abu Qada Formation

In the studied sections, the Abu Qada Formation is generally represented by fossiliferous mixed siliciclastic and carbonate sediments. It is composed of marl, marly limestones, dolomitic limestone, and argillaceous limestone with beds of calcareous shale, marly shale, shale, silty shale, and bands of sandstone. Paleontologically, the Abu Qada Formation is characterized by containing numerous oyster banks and is rich in bivalves, cephalopods, gastropods, and echinoids.

The sediments of the Abu Qada Formation comprise the bivalves genera *Ilymatogyra, Ceratostreon, Exogyra, Rhynchostreon, Gyrostrea, Glossus, Astarte, Neithea, Pycnodonte, Rastllum, Maghrebella, Curvostrea, Mreretrix, Dosinia, Cucullaea, Plicatula, Venericardia, Liopistha, Granocardium, Arca, Linearia, Septifer, Schedotrapezium, Crassatella, Pteria, Priscomactra, Anatina, Pholadomya* and *Arctica*, the cephalopods genera *Angulithes, Neolobites, Metoicoceras, Vascoceras, Paravascoceras, Spathites, Pseudaspidoceras, Watinoceras, Fagesia, Kamerunoceras, Thomasites, Paramammites, Mammites, Neoptychites* and *Choffaticeras*, the echinoid genera *Mecaster, Coenholectypus, Heterodiadema* and *Micropedina*, and the gastropods genera *Pterodonta*, *Tylostoma, Cimolithium, Turritella, Aporrhais, Strombus, Columbelina, Marhilaia, Harpagodes, Turriscala, Fasciolaria, Ampullina, Mesalia*, and *Nerinea.*

Abdelhady, [**23**] stated that the Abu Qada Formation was deposited under an upper infralittoral to upper Circalittoral environment with high temperature, low oxygen percentage, and quiet water conditions.

From the lithology of this formation and the fossils continent, the Abu Qada Formation of the studied sections was deposited in a littoral to shallow circa-sublittoral environment (10-150m) during a transgressive phase.

3. 3. Wata Formation

In the studied sections, the Wata Formation is generally composed of limestone, dolostone, dolomitic limestone, marly limestone, and marl with siltstone and shale interbeds. The Wata Formation comprises the bivalve's genera *Arca, Mreretrix, Plicatula, Crassatella, Priscomactra,* and *Pholadomya*, the cephalopods genera *Thomasites, Coilopoceras,* and *Choffaticeras*, the echinoids genera *Mecaster* and *Coenholectypus*, and the gastropods genera *Tylostoma*, *Cimolithium*, and *volutomorpha.*

The lithology and fossil content indicate that the sediments of the Wata Formation were probably deposited in the infra-littoral environment (10-100m).

4. Paleobiogeography

Based on the geographic distribution of the identified bivalve species **(Table 7),** there is a strong affinity to the Mediterranean Province of the Tethyan Realm. A large proportion of the faunal elements link the study area with other regions in South and West Europe (66%), North Africa (55%), and the Middle East (55%).

The geographic distribution of the identified cephalopod species (**Table, 8**), also shows a strong affinity to the Tethyan province, linking the study area with other regions in North Africa (78%), the Middle East (66%), South and West Europe (59%),

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

North and South America (56%) and West Africa (31%).

The geographic distribution of the identified gastropod species (**Table, 9**), also shows a strong affinity to the Tethyan province, linking the study area with other regions in North Africa (50%), the Middle East (30%), and South and West Europe (27%).

The geographic distribution of the identified echinoid species (**Table, 10**) shows a strong affinity to the Tethyan province. It links the study area with other regions in North Africa (75%), the Middle East (62.5%), and other regions (37%).

In many countries in the Tethyan region, the latest Cenomanian-earliest Turonian transgression indicates eustatic origin [**11;12;18;55-59**]. The connection between the Tethyan regions and West Africa via the Trans-Saharan others has also been reported by Epicontinental Sea authors such as [**60;61**]. It seems that this connection occurred during the Late Cenomanian level and the Earliest Turonian [**56**]. The *Neolobites vibrayeanus* (d'Orbigny) is a typical Tethyan ammonite of wide distribution recorded from the Middle East, North Africa, and South Europe and not recorded from the South Atlantic and northeast Niger [**62**]. This means that the Tethyan Sea did not extend to West Africa, America, and India during the Middle-Late Cenomanian age.

The Late Cenomanian-Early Turonian other ammonites as *Metoicoceras geslinianium* (d'Orbiginy), *Pseudaspidoceras flexuosum* Powell and *Mammites nodosoides* (Schlüter) and Oysters especially *Ilymatogyra* (*Afrogyra*) *africana* (Lamarck), *Gyrostrea delettrei* (Coquand) and *Exogyra* (*Costagyra*) *olisiponensis* (Sharpe) are very helpful in the paleogeographic implications. Their occurrence reflects the high similarity between the fauna from the studied sections (Egypt) with the Cenomanian-Turonian fauna of other countries in the Tethyan Realm such as Portugal, Spain, France, Morocco, Algeria, Tunisia, Libya, Palestine, Turkestan, in addition to West Africa, North and South America.

Other somewhat successful groups in studying paleobiogeography are gastropods and echinoids. *Tylostoma cossoni* Thomas and Péron, *Strombus incertus* (d'Orbigny), and *Hemiaster pseudofourneli* Péron and Gauthier are characteristic forms recorded from the Cenomanian-Turonian sediments in many countries of South-West Europe and West Africa to the Middle East. The general distribution of these fossil groups advocates the direct connection between all these regions and links the Egyptian region with other Tethyan localities.

Endemism of some Egyptian taxa such as *Glossus solimani* (Abbass), *Nerinea sinaiensis* (Fawzi), and *Mecaster turonensis* (Fourtau), is probably due to restriction in environments caused by tectonic events or climatic changes [**18**].

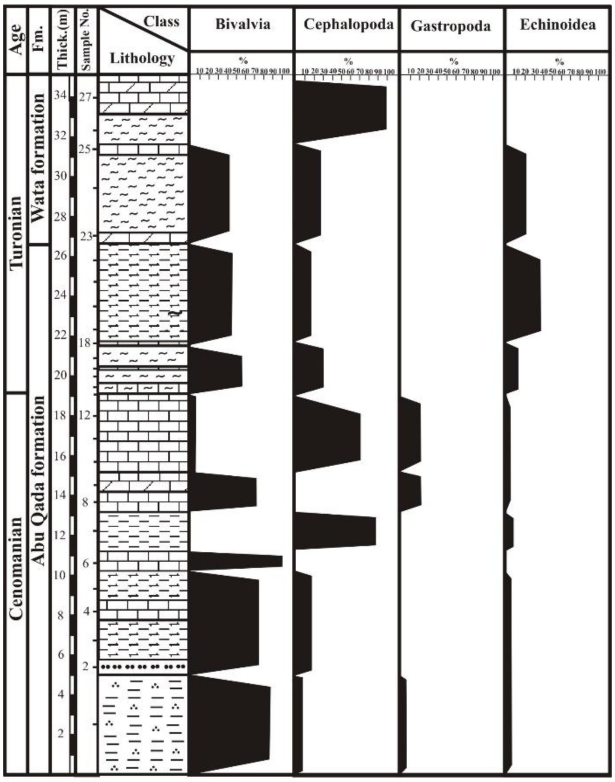


Fig. (11): Relative abundance of the macro-fauna classes, Wadi Tarfa section.

5. Conclusions

To achieve the main goals of the present study, four columnar sections, namely: Wadi Tarfa, Wadi El Dakhl (north Eastern Desert), Wadi Abu Qada, and Wadi Feiran (Sinai) were measured and described, as well as their macrofossils were collected. The present study is mainly concerned with the bivalves, cephalopods, gastropods, and echinoids for paleoecological studies.

Taphonomy, mode of life, quantitative abundance, faunal diversity, species diversity curves, and the relative abundance of the identified fauna from the measured sections are inferred, discussed, and used to deduce the paleoecological conditions.

The paleoecological significance of the macro-fauna was interpreted and discussed pointing to deposition of the measured section in the marine environment ranging from littoral to circa-sublittoral.

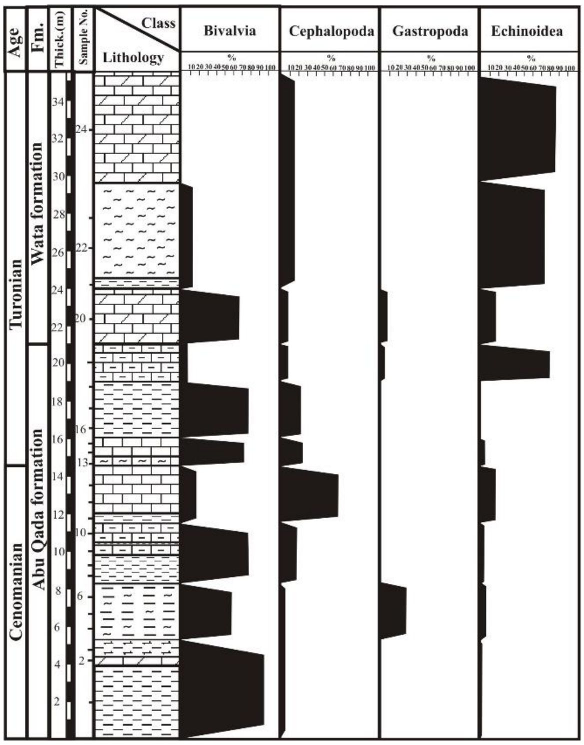


Fig. (12): Relative abundance of the macro-fauna classes, Wadi El Dakhl section.

The Raha Formation was probably deposited in a shallow marine environment ranging from the littoral (less 10m) for the lower part to the infra-sublittoral 10-100m) for the upper part. During a transgressive phase, the Abu Qada Formation was probably deposited in a littoral to the shallow circa-sublittoral environment (10-150m). The Wata Formation was probably deposited in the infra-littoral environment (10-100m).

Based on the paleobiogeography of y point of view, the geographic distribution of the identified faunal species shows a strong affinity to the Mediterranean Province. A large proportion of the ammonite, bivalve and echinoid faunal elements link the study area with North Africa, the Middle East, and South and West Europe.

Some species of Cenomanian and Turonian ages seem to be endemic to Egypt, suggesting that Egypt was an endemic center during certain Late Cretaceous times. Countries (e.g. North Africa, West Africa, North and South America, South and West Europe, and the Middle East), refer to the Tethyan affinity of the studied fauna. Turonian successions at the measured sections were characterized by the rare occurrence of the oysters, in contrast to the enrichment of the oysters in Cenomanian successions, this may indicate that the Cenomanian-Turonian transgression was probably followed by deeper conditions unfavorable for oysters.

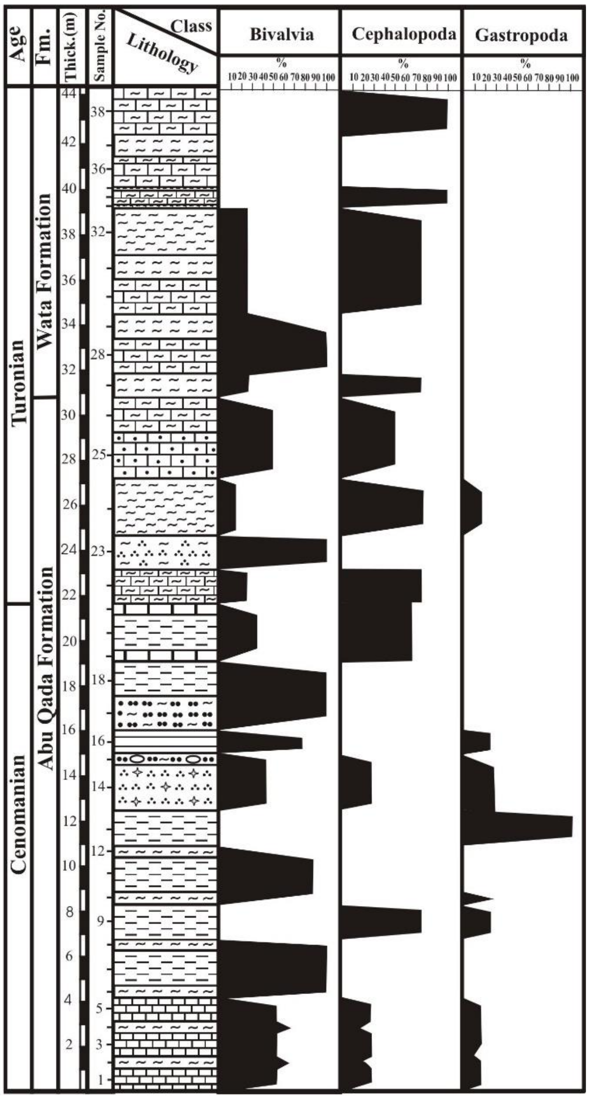


Fig. (13): Relative abundance of the macro-fauna classes, Wadi Abu Qada section.

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Table (7): Geographic distribution of the identified Cenomanian - Turonian bivalve species; (1, Wadi Tarfa - 2, Wadi El Dakhl - 3, Wadi Abu Qada and 4, Wadi Feiran) - (a, Egypt - b, North and South America - c, West Africa - d, South and West Europe - e, North Africa and f, Middle East), (+) recorded, (-) not recorded, (E) endemic to Egypt.

Taxa	Locality										Taxa	Locality									
	1	2	3	4	a	b	c	d	e	f		1	2	3	4	a	b	c	d	e	f
Pycnodonte vesiculosa	+	+	-	-	-	-	-	+	-	+	*Plectomya humei*	-	-	-	+	+	-	-	-	+	-
Exogyra olisiponensis	+	+	+	+	+	+	+	+	+	+	*Sch. trapezoidale*	+	-	-	-	+	-	-	+	-	+
Ceratostreon flabellatum	+	+	+	+	+	+	+	+	+	+	*Arctica orientalis*	+	-	-	-	+	-	-	-	-	+
Ilymatogyra africana	+	+	+	+	+	+	+	+	+	+	*Arctica picteti*	-	-	-	+	+	-	-	-	+	-
Exogyra pseudoafricana	-	-	-	+	+	-	-	+	-	-	*Arctica cordata*	+	-	-	+	+	-	-	+	-	-
Rhynchostreon mermeti	+	+	-	+	+	-	-	+	+	-	*Arctica humei*	+	-	-	-	+	-	-	-	-	E
Rastellum carinatum	+	-	-	-	+	-	-	+	+	+	*Maghrebella forgemoli*	-	-	-	+	E	-	-	-	+	-
Gyrostrea delettrei	+	+	+	+	+	+	-	+	+	+	*Venericardia deserti*	-	-	-	+	E	-	-	-	-	-
Curvostrea rouvillei	-	-	-	+	+	-	-	+	+	+	*Crassatella seguenzai*	+	+	+	+	+	-	-	+	+	-
Plicatula reynesi	+	+	-	-	+	-	-	-	+	+	*Astarte tenuicostata*	+	+	-	-	+	-	-	+	+	-
Plicatula fourneli	+	+	-	+	+	-	-	+	+	+	*Linearia subtenuistriata*	+	+	-	-	+	-	-	+	-	+
Plicatula batnensis	+	+	-	+	+	-	-	-	+	+	*Granocardium hassani*	+	-	-	+	E	-	-	-	-	-
Plicatula auressensis	+	+	-	+	+	-	-	+	+	+	*Protocardia hillana*	-	-	-	+	+	-	-	+	+	+
Plicatula instabilis	+	+	-	-	+	-	+	-	+	-	*Priscomactra angulata*	-	+	-	-	+	-	-	+	-	-
Neithea aequicostata	+	+	-	-	+	-	-	+	+	+	*Glossus solimani*	+	-	-	-	E	-	-	-	-	E
Pteria hadhirensis	+	+	-	-	+	-	-	-	-	-	*Glossus aquilina*	+	-	-	-	+	-	-	-	+	-
Acesta (Acesta) hoernesi	-	-	-	+	+	-	-	+	-	-	*Dosinia delettrei*	+	+	-	-	+	-	-	+	+	+
Arca gigantea	+	-	-	+	+	-	-	-	-	-	*Dosinia forgemoli*	-	-	-	+	+	-	-	+	-	-
Arca passyana	+	+	+	+	+	-	-	+	-	+	*Meretrix plana*	+	+	-	+	+	-	-	+	-	+
Cucullaea diceras	+	+	-	+	+	-	-	+	+	+	*Meretrix brongniartina*	-	+	-	-	+	+	-	+	+	-
Cucullaea thevestensis	+	-	-	-	+	-	-	-	+	-	*Meretrix faba*	+	-	-	+	+	-	-	+	-	-
Septifer samiri	+	-	-	-	E	-	-	-	-	E	*Anatina jettei*	-	-	-	+	+	-	-	+	-	-
Pholadomya pedernalis	-	+	-	+	+	-	-	+	+	+	**Total = 47**	**33**	**24**	**6**	**27**	**47**	**5**	**5**	**31**	**26**	**26**
Pholadomya vignesi	-	+	-	-	+	-	+	+	+	+	**%**	**70**	**51**	**13**	**57**	**100**	**11**	**11**	**66**	**55**	**55**
Liopistha aequivalves	+	-	-	-	+	-	-	+	-	+											

Table (8): Geographic distribution of the identified Cenomanian - Turonian cephalopod species; (1, Wadi Tarfa - 2, Wadi El Dakhl - 3, Wadi Abu Qada and 4, Wadi Feiran) - (a, Egypt - b, North and South America - c, West Africa - d, South and West Europe - e, North Africa and f, Middle East), (+) recorded, (-) not recorded, (E) endemic to Egypt.

Taxa	**Locality**									
	The present study				**a**	**b**	**c**	**d**	**e**	**f**
	1	**2**	**3**	**4**						
Angulithes mermeti	+	-	-	+	+	+	-	+	+	-
Neolobites vibrayeanus	+	+	+	+	+	+	+	+	+	+
Neolobites fourtaui	+	-	-	+	+	-	-	+	+	+
Watinoceras devonense	-	+	-	-	-	+	-	+	-	-
Watinoceras praecursor	+	+	-	+	+	+	-	+	-	-
Pseudaspidoceras flexuosum	+	+	-	-	+	+	+	+	+	+
Pseudaspidoceras paganum	+	-	-	-	-	-	+	-	+	-
Kamerunoceras calvertense	-	+	-	-	+	+	-	-	-	-
Pseud. pseudonodosoides	-	-	-	+	+	+	-	+	+	-
Mammites nodosoides	+	+	+	+	+	+	+	+	+	+
Paramammites Polymorphus	+	-	-	-	+	-	-	-	+	+
Metoicoceras geslinianum	+	+	+	+	+	+	+	+	+	+
Spathites subconciliatus	-	+	-	-	+	+	-	+	-	-
Vascoceras gamai	+	+	-	-	+	+	+	+	+	-
Vascoceras cauvini	+	+	+	+	+	+	-	-	+	+
Vascoceras obessum	+	+	-	-	+	-	-	+	+	+
Vascoceras proporium	+	+	+	+	+	+	+	-	+	+
Vascoceras durandi	+	+	+	-	+	+	-	+	+	-
Vascoceras rumeaui	-	+	-	-	+	-	-	-	+	+
Vascoceras pioti	-	-	+	-	+	-	-	-	-	+
Paravascoceras compressum	-	-	-	+	-	+	+	-	-	-
Fagesia superstes	-	+	-	-	+	+	-	-	+	+
Fagesia peroni	-	-	+	-	+	-	-	+	+	-
Neoptychites cephalotus	+	-	+	+	+	+	+	+	+	+
Thomasites rollandi	-	+	+	-	+	-	-	+	+	+
Thomasites rollandi globosa	-	+	-	-	-	-	-	+	+	+
Choffaticeras (Ch.) quaasi	+	+	-	-	+	-	-	+	+	+
Choffaticeras (Ch.) securiforme	+	+	-	-	+	-	-	-	+	+
Choffaticeras luciae	+	-	-	-	+	-	-	-	+	+
Choffaticeras segne	+	+	+	+	+	-	-	-	+	+
Choffaticeras pavillieri	+	-	-	-	+	-	+	-	+	+
Coilopoceras requienianum	-	-	+	+	+	+	-	+	-	+
Total = 32	**20**	**20**	**12**	**13**	**28**	**18**	**10**	**19**	**25**	**21**
%	**63**	**63**	**37**	**41**	**87.5**	**56**	**31**	**59**	**78**	**66**

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

Table (9): Geographic distribution of the identified Cenomanian - Turonian gastropod species; (1, Wadi Tarfa - 2, Wadi El Dakhl - 3, Wadi Abu Qada and 4, Wadi Feiran) - (a, Egypt - b, North and South America - c, West Africa - d, South and West Europe - e, North Africa and f, Middle East), (+) recorded, (-) not recorded, (E) endemic to Egypt.

Taxa	Locality									
	The present study				a	b	c	d	e	f
	1	2	3	4						
Tylostoma athleticum	+	-	-	+	+	-	-	-	-	-
Tylostoma cossoni	-	-	+	+	+	-	-	+	+	-
Tylostoma globosum	+	-	-	+	+	-	-	+	+	-
Tylostoma (T.) pallaryi	+	-	-	-	+	-	-	-	+	-
Ampullina (A.) cretacea	-	-	-	+	+	-	-	+	+	-
Strombus incertus	+	-	+	-	+	-	+	+	+	+
Strombus tihensis	+	-	-	-	+	-	-	-	-	-
Aporrhais dutrugei	+	-	-	+	+	-	-	-	+	-
Aporrhais fourneli	-	-	-	+	-	-	-	-	+	-
Aporrhais blanckenhorni	+	-	-	-	+	-	-	-	-	-
Harpagodes heberti	+	-	-	-	+	-	-	-	+	+
Helicaulax subgibbosus	-	-	-	+	+	-	-	-	+	-
Pterodonta deffisi	-	+	-	+	+	-	-	-	+	+
Pterodonta gigantica	+	-	+	+	**E**	-	-	-	-	-
Columbellina fusiformis	+	-	-	-	**E**	-	-	-	-	-
Cimolithium tenouklense	-	-	-	+	+	-	-	+	+	-
Cimolithium inauguratum	-	+	-	+	+	-	-	-	-	+
Nerinea requieniana	-	-	+	+	+	-	-	+	-	+
Nerinea gemmifera	-	-	-	+	+				+	+
Nerinea sinaiensis	-	-	+	+	**E**	-	-	-	-	-
Nerinea olisiponensis	-	-	-	+	+	-	-	+	-	+
Nerinea cretacea	-	-	-	+	+	-	-	-	-	-
Mrhilaia nerineaeformis	-	-	-	+	+	-	-	-	-	-
Mrhilaia haugi	-	-	-	+	+	-	-	-	+	-
Turriscala shutanurensis	+	-	-	-	+	-	-	-	-	+
Torinia amini	-	-	-	+	+	-	-	-	-	-
Turritella multistriata	+	-	-	-	+	-	-	+	-	+
Mesalia Sp.	-	-	-	+	+	-	-	-	+	-
Volutomorpha baylei	+	-	-	-	+	-	-	-	+	-
Fasciolaria safrensis	-	+	-	+	**E**	-	-	-	-	-
Total = 30	**13**	**3**	**5**	**21**	**30**	**-**	**1**	**8**	**15**	**9**
%	**43**	**10**	**17**	**70**	**100**	**-**	**3**	**27**	**50**	**30**

Table (10): Geographic distribution of the identified Cenomanian - Turonian echinoid species; (1, Wadi Tarfa - 2, Wadi El Dakhl and 3, Wadi Feiran - (a, Egypt - b, North and South America - c, West Africa - d, South and West Europe - e, North Africa and f, Middle East), (+) recorded, (-) not recorded, (E) endemic to Egypt.

Taxa	Locality								
	The present study			a	b	c	d	e	f
	1	2	3						
Micropedina olisiponensis	+	+	+	+	+	+	+	+	+
Heterodiadema libycum	+	-	+	+	-	+	-	+	+
Coenholectypus pulvinatus	+	+	-	+	-	-	-	-	-
Coenholectypus turonensis	+	+	+	+	-	-	+	+	-
Mecaster turonensis	+	+	+	E	-	-	-	-	-
Mecaster batnensis	+	+	+	+	+	-	+	+	+
Mecaster cubicus	+	-	+	+	-	-	-	+	+
Mecaster pseudofourneli	+	+	+	+	+	+	-	+	+
Total = 8	**8**	**6**	**7**	**8**	**3**	**3**	**3**	**6**	**5**
%	**100**	**75**	**87.5**	**100**	**37.5**	**37.5**	**37.5**	**75**	**62.5**

References

[1] Darwish, M. H., Stratigraphic and Paleontologic Studies on the Cenomanian - Turonian Successions at north Eastern Desert and Sinai, Egypt. Unpubl. Ph. D. Thesis, (2013), Faculty of Science, Assiut University, Assiut-Egypt.

[2] Darwish, M. H., Zakhera, M. S., Abdel-Maksoud, N. A., and Obaidalla, N. A., Macro-Biostratigraphy Integration of The Cenomanian – Turonian - Transition at north Eastern Desert and southeastern Sinai, Egypt. The Eighth International Conference on the Geology of Africa, (2015)**,** p-p VII- (99 -131) Assiut- Egypt.

[3] Frusich, F. T. and Oschmann, W., Shell beds as tool in basin analysis: the Jurassic of Kachchh, western Indea. – Journal of the Geological Society, London, (1993), 150: 169-185. DOI: 10.1144/gsjgs.150.1.0169

[4] Frusich, F. T. and Pandey, D. K., Gensis and environmental significance of Upper Cretaceous shell concentration from the Cauvery Basin, southern Indea. – Paleogeography, Palaeoclimatology, Palaeoecology, (1999), 145: 119-139.

[5] Zeigler, B., Ammoniten-Ökologie am Beispiel des Oberjura. - Geol. Rundsch, (1967), 56: 439-464.

[6] Black, R. M., The elements of Palaeontology. Cambridge University Press, London, (1970), 1-340.

[7] Mancini, E. A., Depositional environment of the Grayson Formation (Upper Cretaceous) of Texas. Gulf Coast Association Geological Society Transactions, (1977), 27: 334-351.

[8] Bottjer, D. J., Structure of Upper Cretaceous Chalk Benthic Communities, Southwestern Arkansas. - Palaeogeography, Palaeoclimatology, Palaeoecology, (1981), 34: 225-256, Amsterdam. https://doi.org/10.1016/0031-0182(81)90066-3

[9] Kassab, A. S., Stratigraphical and Paleontological studies on the Upper Cretaceous rocks of northern Wadi Qena, Eastern Desert, Egypt. - Unpubl. M. Sc. Thesis, (1982), Faculty of Science, Assiut University, Assiut.

[10] Kassab, A. S., Paleontological and Stratigraphical studies of Cretaceous sections m Wadi Qena and Wadi Tarfa, Eastern Desert, Egypt. - Unpubl. Ph. D. Thesis, (1985), Faculty of Science, Assiut University, Assiut.

[11] Kassab, A. S., Biostratinomy of the Upper Cenomanian oyster storm shell beds from the Northeastern Desert of Egypt. - Bollettino Della Societa Paleontologica Italiana, (1995), 34(2): 139-145.

[12] Kassab, A. S., Late Cretaceous macrofossils of Egypt: biostratigraphy, palaeoecology, and palaeobiogeography. - Intern. Seminar: Recent advances in the study of Cretaceous sections, Abstract

* Corresponding authors: *mahmoud.hamed68@sci.nvu.edu.eg*

Volume, (1998), edited by A. Govndan, ONGC Ltd., Chennai. India: 1-60.

[13] Kassab, A. S., Cenomanian-Turonian boundary in the Gulf of Suez region, Egypt: towards an interregional correlation, based on ammonites. - Geological Society of Egypt, (1999), Special Publication, 2 (for 1996), 61–98.

[14] Jablonski, d. and Bottjer, D. T., Soft-bottom epifaunal suspension-feeders assemblages in the late cretaceous; Implications for the evoluation of the benthic paleocommunities. In Tevesz, M. I. S. & call P. L. Mc. (eds): Bioticinteractions in Resent and fossil benthic communities. - Plenum Publishing Corporation, (1983), 747-812.

[15] Murray, J., (ed.) Atlas of invertebrate macrofossils. - Longman Group Limited, UK, (1985), 1- 244. DOI: 10.1017/S001675680003555X

[16] Abdel-Gawad, G. I., Biostratigraphy and facies of the Turonian in west central Sinai, Egypt. - Annals of the Geological Survey of Egypt, (1999), 22: 99-114, Cairo.

[17] Philip, G., Aboul Ela, N. M., Abdel-Gawad, G. I. and Aly, M. F., Facies and Paleoecology of the Albian rocks of Gebel Manzour, Maghara area, North Sinai, Egypt. – Egyptian Journal of Geology, (1990), 1-2: 173-197, Cairo.

[18] Kassab, A. S. and Ismael, M., Upper Cretaceous invertebrate fossils from the area northeast of Abu Zuneima, Sinai, Egypt. - Neues Jahrbuch Für Geologie Paläontologie Abhandlungen, (1994), 191 (2): 221-249, Stuttgart.

[19] Kassab, A. S. and Zakhera, M. S., Bivalve biostratigraphy of the Upper Cretaceous sequence, North Eastern Desert, Egypt. – 1th International Conference on the Geology of Africa, (1999), 1: 15-25 Assiut, Egypt.

[20] Abdelhamid, M. A., Turonian-Santonian echinoids from Wadi Sudr and Wadi Matulla, West central Sinai, Egypt. - Middle East Research Center, Earth Science Series, (1997), 11: 136-158, Cairo.

[21] Zakhera, M. S. and Kassab, A. S., Bivalve biostratigraphy of the Upper Cretaceous sequence, North Eastern Desert, Egypt. - 1st International Conference on the Geology of Africa, (1999), 1: 15-25, Assiut, Egypt.

[22] Abdelhady, A. A., Stratigraphical and Paleontological Studies on the Upper Cretaceous Strata, North Wadi Qena Area, Eastern Desert, Egypt. - Unpubl. M. Sc. Thesis, (2007), Faculty of Science, Minia University, Minia.

[23] Abdelhady, A. A., Cenomanian / Turonian mass extinction of macroinvertebrates in the context of Paleoecology; A case study from North Wadi Qena, Eastern Desert, Egypt. – Mass Extinction, Springer-Verlag Berlin Heideberg, (2008), 103-127 pp.

[24] Hedgpeth, J.W., Classification of marine environments, in: Ladd, H. S., (ed.): Treatise of marine ecology and paleoecology. - Geological Society of America, (1957), 2(67): 93-100.

[25] Ager, D. V., Principle of Paleoecology, Mc Graw-Hill, (1963), New York.

[26] Bottjer, D. J. and Jablonski, D., Paleoenvironmental patterns in the evolution of post-Paleozoic benthic marine invertebrates. – Palaios, (1988), 3: 540-560.https://doi.org/10.2307/3514444

[27] El-Ayyat, A. M. and Kassab, A. S., Biostratinomy and facies analysis of the upper Cretaceous oyster storm shell beds of the Duwi formation, Qusseir District, Red Sea Region, Egypt. – Journal of African Earth Sciences, (2004), 39: 421-428. DOI: 10.1016/j.jafrearsci.2004.07.024

[28] Smith, A. B., Paleoecology of Molluscan fauna from the Trent Formation. – Journal of paleontology, (1959), 33(5): 855-871.

[29] Nicol, D., Some characteristics of cold-water marine pelecypods. - Journal of Paleontology, (1967), 41(6): 13340-13340.

[30] Dance, S. P., the Encyclopidia of shells. - Blandford Press, (1974), 1-288.

[31] Mullerried, F. K., El Genera ptychomya en Mexico (Moll. Plecyp.) – Ciencia, (1947), 8(10-12): 269-280, Mexico.

[32] Laad, H. S., Treatise on marine ecology and palaeoecology. – Geological Society of America Bulletin, (1957), 2: 1-67.

[33] Cherif, O. H., Bassioni, M. A. and Ghonima, S. A., Stratigraphy, paleoecology, and climates of Neogene and Quaternary of the Mersa Matrouh area,

Northern Western Desert, Egypt. – Annals of the Geological Survey, Egypt, (1975), 5: 137-147.

[34] Arau, I., Paleoecology of the Eocene Ameki Formation of Southeastern Nigeria. – Journal of African Earth science, (1988), 7(718): 925-832. DOI: 10.1016/0899-5362(88)90007-3

[35] Stanley, S. M., Coadaptation in the trigoniidae, a remarkable family of burrowing bivalves. – Paleontology, (1977), 20: 869-899.

[36] Summers, W. C., Physiological and Trophic Ecology of Cephalopods. In Russel-Hunter, W. D. (edited) The Mollusca, Ecology. – Academic press, (1983), 6: 261-279.

[37] Immel, H., Klinger, H. C. and Wiedmann, J., Die Cephalopoden des Unteren Santon der Gosau von Brandenberg/ tirol, Osterreich. – Zitteliana, (1982), 8: 3-32, Munchen.

[38] Kennedy, W. J., Cretaceous. In Mckerpow, W. S. (ed.): the ecology of fossils. – Mit Press, (1978), 280-322, Cambridge press.

[39] Tanabi, K., Palaeoecological analysis of the ammonoid assemblages in the Turonian Scaphites facies of Hokkaido, Japan. – Paleontology, (1979), 22: 609-630.

[40] Wiedmann, J. and Kauffmann, E. G., Mid-Cretaceous biostratigraphy of Northern Spain. - Annales du Museum d'Històire naturelle deNice, (1978), 4(3): 1-34, Nice.

[41] Westermann, G. E. G., Ammonoid life and habitat. In Ammonoid paleobiology, - Topics in Geobiology edited by N. H. Landman, K. Tannabe and R. A. Davis, (1996), 13/16: 607-707.

[42] Wiese, F. and Schulze, F., The Upper Cenomanian (Cretaceous) ammonite *Neolobites vibrayeanus* (d'Orbigny, 1841) in the Middle East: Taxonomic and palaeoecologic remarks. - Cretaceous Research, (2005), 26: 930-946, London. DOI:10.1016/j.cretres.2005.06.005

[43] Milliman, J. D., Marine Carbonates Part 1. – Springer Verlag, Berlin-Heidelberg-New York, (1974), 1- 375.

[44] Jones, D. J., Introduction to microfossils. – Haber and Brothers, (1956), 406p.; New York.

[45] Binyon, J., Salinity tolerance and ion regulation. – In Boolootain, R. A. (edited). - Physiology of Echinoderma. Interscience, New York, (1966), 359-377.

[46] Barns, R. D., Invertebrate Zoology. – (3 rd edited), Sanunders, philadelhia, (1974), 1- 870.

[47] Wilson, J. L., Carbonate facies in Geologic history. – Springer Verlag, (1975), 1- 471, Berlin-Heidelberg-New York.

[48] Makurath, J. H., Marine faunal assemblages in the Silurian-Devonian Keyser Limestone of the Central Appalachians. – Lethaia, (1977), 10: 235-256, Oslo.

[49] Taylor, J. D., Morris, N. J. and Taylor, C. N., Food specialization and the evolution of predatory prosobranch gastropods. – Palaeontology, (1980), 23: 375-409.

[50] Taylor, J. D., Cleevely, R. G. and Morris, N. J., Predatory gastropods and their activites in the Blackdown Greens and (Albian) of England. – Paleontology, (1983), 26(3): 521-533.

[51] Thorson, G., Bottom communities (sublittoral or shallow shelf). – Mem. Geological Society of America, (1957), 67: 461-534, Baltimore, Maryland.

[52] Basahal, A. N., Bahafzallah, A., Jux, U. and Omara, S., Age and structural setting of a proto-Red Sea embayment. – Neues Jahrbuch für Geologie Paläeontologie, Monatshefte, (1982), H (8): 456-468.

[53] Saul, L. R., *Turritella* zonation across the Cretaceous- Tertiary boundary. – California. University of California Publications in Geological Sciences, (1983), 125: 1-149

[54] Sohl, N. F., North American Cretaceous biotic province delineated by gastropods. – Proceeding, North American Palaeontological Convention, Chicago, (1971):, 2: 1610-1638.

[55] Collignon, M. and Lefranc, J. P., Mise en évidence de la communication saharienne entre Téthys et Atlantique sud d'aprés les fossiles Cénomaniens et Turoniens du Tademait (Sahara algérien). – Comptes Rendus de l' Académie des Sciences de Paris, (1974), 278: 2257-2261.

[56] Abdallah, H. and Meister, C., The Cenomanian-Turonian boundary in the Gafsa-Chott area (southern

* Corresponding authors: mahmoud.hamed68@sci.nvu.edu.eg

part of central Tunisia): biostratigraphy, palaeoenvironments. - Cretaceous Research, (1997), 18: 197-236, London.

[57] Kora, M., Shahin, A. and Semiet A., Biostratigraphy and Paleoecology of some Cenomanian successions in the west central Sinai, Egypt. – Neues Jahrbuch Für Geologie und Paläontologie Monatshefte, (1994), 10: 597-617.

DOI:10.1127/njgpm/1994/1994/597

[58] Gräfe, K. U., Sequence stratigraphy in the Cretaceous and Paleogene (Aptian to Eocene) of the Basco-Cantabrian basin (N. Spain). – Tübinger Geowissenschafliche Arbeiten, (1994), A18: 1- 418.

[59] Haq, B. U., Hardenbol, J. and Vail, P., Chronology of fluctuating sea levels since the Triassic. – Sciences, (1987), 235: 1156-1167. DOI: 10.1126/science.235.4793.1156

[60] Shahin, A., Kora, M. and Semiet, A., Cenomanian ostracods from west-central Sinai, Egypt. - Mansoura Science Bulletin, (1994), 21(1): 33- 102, Mansoura.

[61] Meister, C. and Abdallah, H., Les ammonites du Cénomanien supérieur et du Turonien inférieur de la région de Gafsa-Chotts, Tunisie du centre-sud. – Geobios, (1996), 29(5): 3-49, Lyon. DOI:10.1016/S0016-6995(96)80009-X

[62] Mathey, B., Alzouma, K., Lang, J., Meister, C., Néraudeau, D. and Pascal, A., Unusual faunal associations during Upper Cenomanian-Lower Turonian floodings on the Niger ramp (central West Africa). – Palaeogeography, Palaeoclimatolology, Palaeoecology, (1995), 119: 63-75. https://doi.org/10.1016/0031-0182(95)00060-7