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Research Article

New Findings of the Cenomanian-Turonian Successions in the Quseir Region, Red Sea, Egypt

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ABSTRACT

The investigated sediments of the Duwi and Quseir formations in Gebel Duwi and Zug El Bahar area of the Quseir Region confirmed the presence of Cenomanian-Turonian (C/T) succession for the first time. The recorded planktonic foraminifera characterized by either juvenile or dwarfed, and complete absence of benthic foraminifera due to either its extremely short duration or its restriction to nearshore, rather than open ocean environments. The C/T boundary lies within the *Whiteinella archeocretacea* Zone, where there is a flooding of free and isolated calcispheres of spherical and ovoidal shapes characterize this boundary in Gebel Duwi section. In the Quseir Region, the C/T sediments have been extremely low thickness and condensed, creating no hiatus in sedimentation during the overall global high stands of shallow water environments. Four detected planktonic foraminiferal zones in the Quseir Region; *Rotalipora cushmani, Whiteinella archeocretacea, Helvetoglobotruncana helvetica* and *Marginotruncana schneegansi*.

Keywords: Cenomanian-Turonian; Planktonic foraminifera; Quseir region; Red Sea; Egypt

INTRODUCTION

No satisfactory classification of the Cenomanian-Turonian succession in the Duwi and Zug El-Bahar areas, Quseir Region of Red Sea (Figures1a-1c). The present work is an attempted to correlate the stratigraphy of these areas with the global stratotype section and point (GSSP) at Pueblo, Colorado. The Cenomanian-Turonian of the Duwi area was neglected although it represents a significant part of the stratigraphic sequence in the Red Sea Region. Recently some authors at the southeastern margin of the Tethys in Egypt, studied the Cenomanian-Turonian depositional conditions in continental shelf in a sporadic manner [1-6].

Thorough knowledge of various aspects of the Cenomanian-Turonian geology is very important for the global understanding of the structural evolution of the Quseir Region of the Red Sea. This is because a report on petroleum resources of the Red Sea Basin Province suggests that oil and gas reserves await discovery [7]. To evaluate oil exploration in the Red Sea Province it is important to study the sedimentary rocks in the area utilizing petrographic and paleontological data from field and laboratory observations.

One of the characteristics of the Cenomanian-Turonian boundary is the deposition of a large amount of organic matter [8,9]. Such organic-rich sediments have been regarded as a sign of oxygen deficiency at the time they were deposited. It was also suggested that such conditions were associated with high sea-levels and great transgressions [8,10].

Recently, El Gammal and Orabi [11] predicted the Coniacian-Late Campanian interval comprising the uppermost 20m thick of the Duwi Formation in Gebel Duwi section, which means that the underlying Quseir Formation and lower Duwi beds (57 m thick) must be deposited in an older time (Cenomanian-Turonian?).

The purpose of the present work is to improve the stratigraphy of the Cenomanian-Turonian succession in the Quseir regional basin of southeastern Egypt to provide long-distance correlations and to reconstruct the shelf architecture. Therefore, new lithostratigraphic and biostratigraphic data are referred to the stratigraphic scheme for the study area has been established. Otherwise, for the first time, the data of this work provide more a step for understanding the presence of the Cenomanian-Turonian secession within the Duwi succession.

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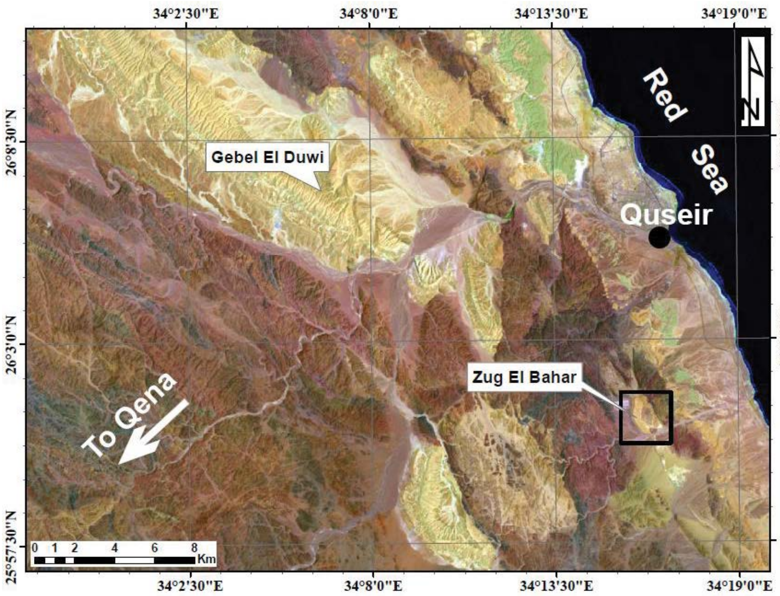

Figure 1a: General geographic locations of studied sections.

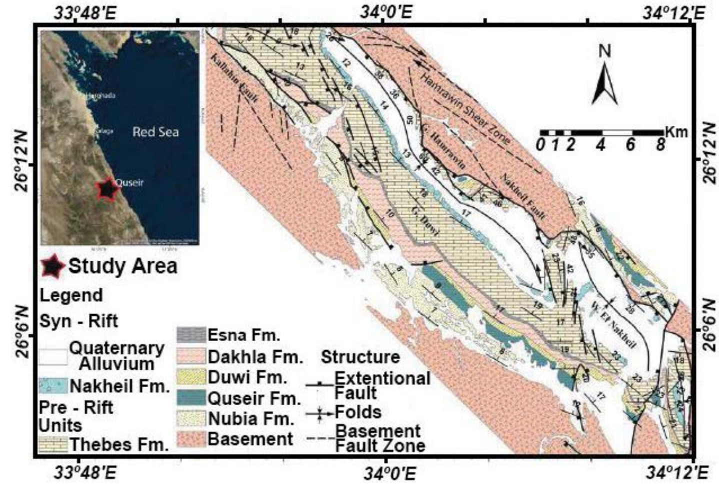

Figure 1b: Geological map of Gabal Duwi Range (modified after ElGammal and Orabi ,2019).

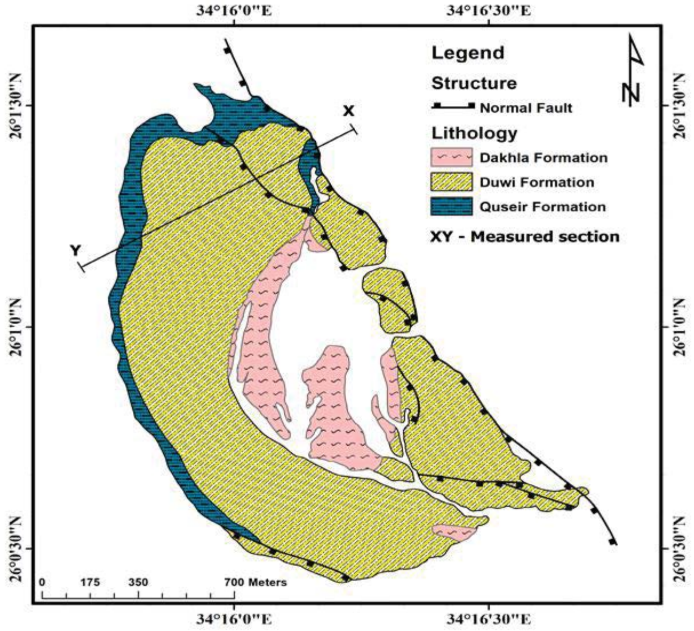

Figure 1c: Geological map of Zug El Bahar area.

GEOLOGICAL SETTING

At the Quseir-Safaga District, the deposition of the Late Cretaceous rocks took place at troughs of synclinal-like folds at the southern Tethyan margin in dynamic terrestrial-shallow marine continental environments as reflected by strongly variable thicknesses, facies and lithologies [11-17].

The Cenomanian-Turonian succession in the Quseir regional basin, southeastern Egypt is composed of shallow marine siliciclastic and limestones platform but was drowned during the Cenomanian compounded with global forcing factors associated with the Cenomanian-Turonian Anoxic Event documented worldwide [18].

During the Cenomanian, a major sea-level rise flooded the continental shelf of the region as E-W trending south Quseir Region, the Western Desert through the Nile basin resulting in the north to northwestward directed Cenomanian-Turonian marine strata onto the older Paleozoic-Early Cretaceous Nubian Sandstone facies [13,19]. The Initial marine transgression from the Tethyan Ocean covered Egypt from north to south generally occurred in Cenomanian times [20].

MATERIAL AND METHODS

Due to the proximal position, two sections of the Gabal Duwi (Figure 2a) and Zug El-Bahar (Figure 2b) areas, which display condensed facies developed and reduced sediment thicknesses within the Quseir Region, Red Sea. Intensive several field visits to the outcrops of Gebel Duwi and Zug El-Bahar section, these intervals were measured and sampled more precisely very close spaced for intensive micropaleontological study. All fields, sedimentological, biostratigraphical data are documented, illustrated, and photographed, as well as the index species, are scanned and illustrated. The material has been deposited as a collection of the present authors.

LITHOSTRATIGRAPHY

The sediments of the present area consist of siliciclastic Nubian facies, overlain by the interbedded shales, sandstones, and limestones of the Quseir, Duwi, Dakhla, Tarawan, Esna and Thebes's formations respectively (Figure 2a). Both Quseir and Duwi formations of Gabal Duwi Range attracted the scientific and economic attention for their phosphates and black shale contents as Campanian-Maastrichtian sediments. These two formations are accumulated in a peri-continental depositional environment barren to very rare in foraminiferal content because of the nature of the anoxic environmental and diagenetic conditions. Some beds of both Quseir and Duwi Formations are of organic-rich and black shales with scattered thin beds of phosphatic intervals [17]. The detailed lithological units are illustrated (Figure 3a and 3b).

Quseir Formation (Quseir variegated shales) [12]

Quseir Formation consists of varicolored shales with minor sandstone bands and siliceous phosphatic bands widespread in Red Sea Region, Eastern Desert, Western Desert, Nile Valley sectors. It overlies unconformably the Nubian Sandstones of may be Paleozoic to Lower Cretaceous [12,14], and underlies conformably the Duwi Formation. Thin phosphatic bed separating Quseir Formation and the overlying Hamadat Beds (C-Beds) of the Duwi Formation in the two measured sections. The exposed parts of the Quseir Formation reached 19m and 12m thick in Zug El-Bahar and Gabal Duwi sections respectively (Figures 2,g,h).

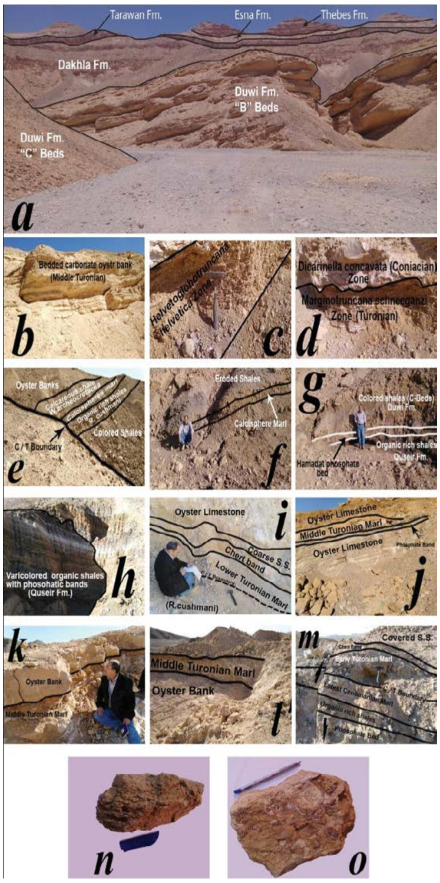

Figure 2: Field photographs: Photos (a,b,d-g) from Gabal Duwi section; photos nos. (c,h-m) from Zug El Bahar section; Photo "n": Small sample organic rich shale of Duwi section; photo "o": Sample of oyster bank, late Turonian, Duwi section.

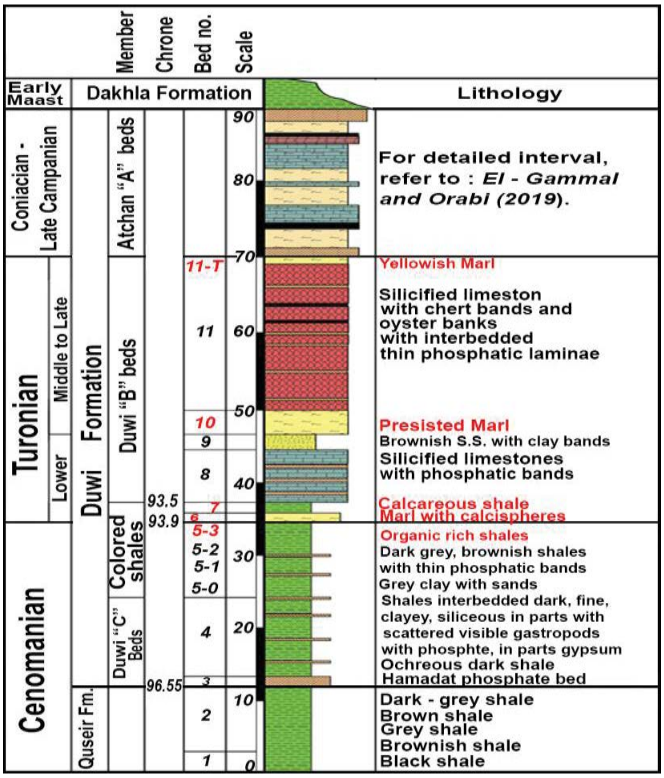

Figure 3a: Stratigraphy and lithostratigraphic subdivisions of the Cenomanian-Turonian, Gabal Duwi section.

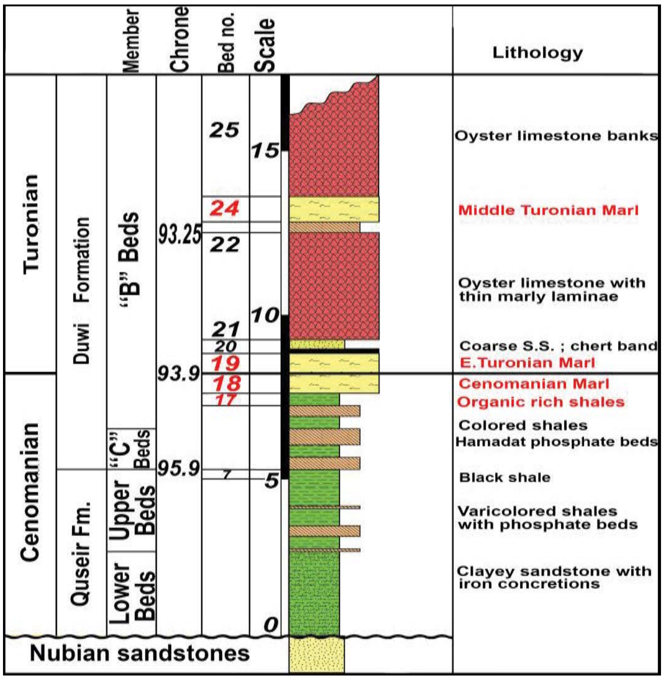

Figure 3b: Stratigraphy and lithostratigraphic subdivisions of the Cenomanian-Turonian, Zug El Bahar section.

Ward and Mc Donald [21] argued that the Quseir Formation was deposited in a low energy shallow marine and the estuarine environment with brackish lagoon transitional to shallow bays and mudflats.

Duwi Formation [12]

At its type locality of the Quseir Region, the Duwi Formation is underlain by the Quseir Formation and overlain by the Maastrichtian part of the Dakhla Formation.

In General, several authors considered the Duwi Formation comprises the best and pronounced mineable phosphates at the Red Sea Region [15]. Said (1990) classified the mineable phosphate beds as the following [19]:

Lower phosphate unit (Hamadat or C-beds): Hamadat Beds or C-Beds attain 13.5m thick at the Gabal Duwi section and 3m thick at Zug El-Bahar section and consists of interbedded dark, thinly laminated siliceous-grained organic-rich claystone and shales with scattered mega-visible phosphate peloids. The Hamadat unit is overlain by 11.5m thick of dark clay and brown (Figures 2g) organic shales interbedded with few thin phosphatic laminae. The main phosphate bed attains a thickness of 2m with rounded silicified phosphate nodules.

Middle phosphate unit (or Duwi phosphate or B-beds): It attains a thickness of 32m and 19m in the Duwi and Zug El-Bahar sections respectively and named the Duwi phosphate beds or B-Beds. The lower 8 m thick of the Duwi section is made of non-fossiliferous silicified limestone with phosphate bands and sandy phosphate. The remain 24m thick is made of the oyster bank was recorded at the uppermost of this interval. This interval consists of cross-bedded bioclastic limestone (Figure 2a,b) covered phosphatic limestone, silicified limestone, marly, some chert bands, ochreous shale and thin laminae of marl topping this unit.

Upper phosphate unit: (Atchan or A-beds): It attains a thickness of 20m (not recorded in Zug El-Bahar section) and consists of marly limestone, marls, and successive marl-shales beds. A thin dolomitic oyster bank near the uppermost of A-Beds followed by a conglomeratic phosphate bed (0.50m thick) marked the upper surface of the Duwi Formation, and capped A-Beds or the Atchan Beds. This conglomeratic phosphatic lag capped the Atchan Beds or A-Beds in Gabal Duwi section only. The overlying direct shale bed (Late Campanian) belongs to the Dakhla Formation. The main mineable phosphate bed (1m thick) is poor in phosphate content as a mixed, friable light grey bed.

PLANKTONIC FORAMINIFERAL BIOZONES

Due to shallow water sequences of both Quseir and Duwi formations in Gebel Duwi and Zug El-Bahar sections, the biostratigraphy study was very difficult and need more precisely accurate sampling. Despite the rarity, dwarfed, very low species diversity of the planktonic foraminifera and complete absence of benthic foraminifera, accurate age detecting can be obtained for the Cenomanian-Turonian transition through finding flooding free calcispheres (microfossil of the ca-dinoflagellates group) and planktonic foraminifera (Figure 4 and 5).

Mort et al. [22] used *Anaticinella (Thalmanninella) multioculata* as index fossils instead of *Rotalipora cushmani* and used *Planoheterohelix moremani* as index instead of *Whiteinella archaeocretacea* indicating the Late Cenomanian in Tarfaya section, Morocco. Throughout the global ocean rising, Heterohelicids dominated assemblages of the C/T boundary mark the change to oceanic anoxia [23-26]. The "Heterohelix" shift is represented here by *Planoheterohelix moremani* of the Duwi Formation (C/T boundary event).

There are three worldwide biozones of Robaszynski et al. [27] have provided age control covered the Late Cenomanian-Early Turonian interval. These biozones are *Rotalipora cushmani* (Late Cenomanian), *Whiteinella archaeocretacea* (Latest Cenomanian-Earliest Turonian) and *Helvetoglobotruncana helvetica* (Early Turonian). However, the Cenomanian-Turonian interval of the Duwi Formation of the Gabal Duwi and Zug El-Bahar sections (Figure 6,7) is characterized by *Rotalipora cushmani* and *Whiteinella archaeocretacea*,in spite of its restriction to nearshore, rather than open ocean environments [5].

Proposed biozones can be achieved, from older to younger as follow:

Rotalipora cushmani biozone

Author: Sigal (1955)

Definition: The zone is defined by the total range of the nominate taxon, *Rotalipora cushmani* [28].

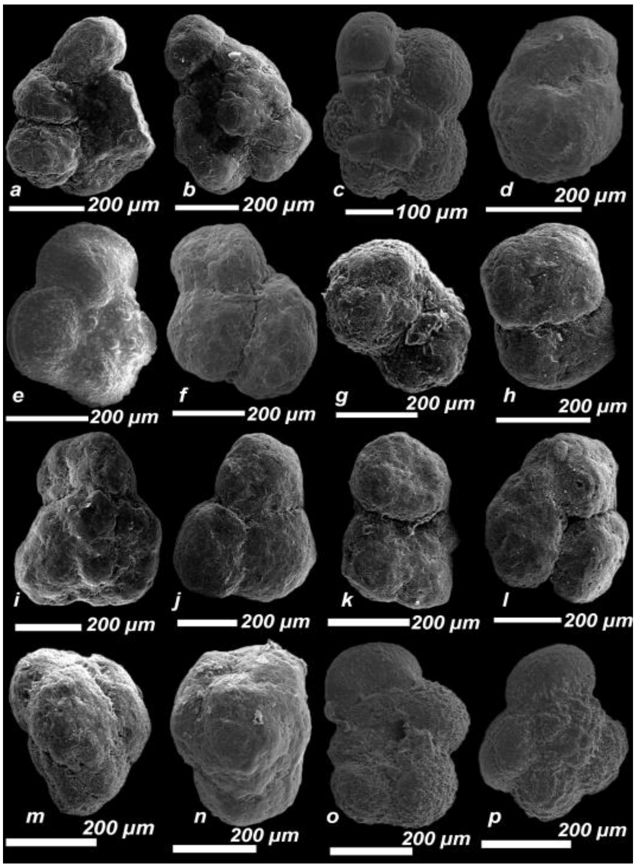

Figure 4: SEM Images for important planktic foraminiferal species (a,b) *Anaticinella multioculata* (Morrow,1934), (c) *Archeoglobigerina cretacea* (Orbigny,1840), (d) *Dicarinella hagni* (Scheibnerova,1962), (e) *Dicarinella primitiva* (Dalbiez, 1955), (f) *Dicarinella takayanagii* Hasegawa 1999, (g,i,k) *Favusella confusa* Longoria and Gamper 1977, (h) *Favusella stiftia* Rosler,Lutze and Pflaumann 1979, (h) *Favusilla wenoensis* Michael 1973, (l) *Favusella washitensis* (Carsey,1926), (m) *Guembelitrea cenomana* (Keller,1935), (n) *Guembelitrea harrisi* Tappan 1940, (o & p) *Helvetoglobotruncana helvetica* (Bolli, 1945).

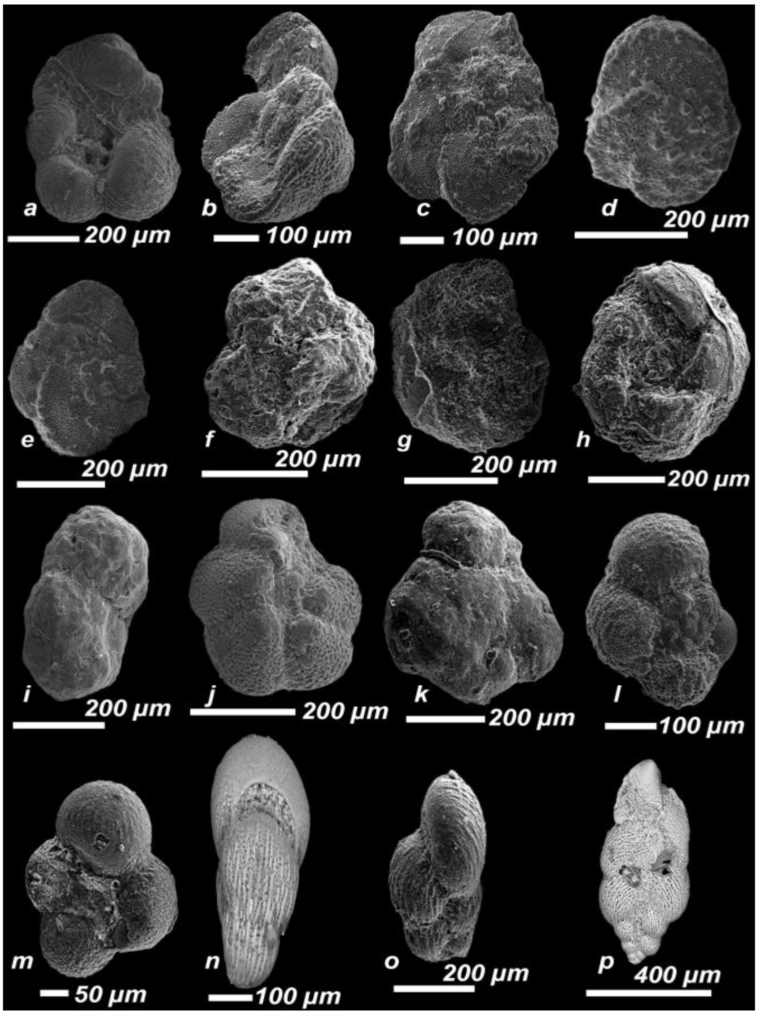

Figure 5: SEM Images for important planktic foraminiferal species. (a)*Loeblichella hessi* (Pessagno,1962), (b)*Marginotruncana schneeganzi* (Sigal,1952) (c,d,e)*Marginotruncana paraconcavata* (Porthault,in Donze et al.,1970), (f) *Parathalmanninella appeninnica* (Renz,1936), (g)*Parathalmanninella ticinensis* (Gandolfi,1942), (h)*Praeglobotruncana algeriana* (Caron,1966), (i)*Praeglobotruncana compressa* Hasegawa 1999, (j)*Rotalipora cushmani* (Morrow,1934), (k) *Rotalipora montslavensis* (Mornod,1950), (l)*Whiteinella archaeocretacea* Pessagno 1967, (m)*Whiteinella baltica* Douglas and Rankin 1969, (n,o)*Planoheterohelix paraglobulosa* (Georgescu and Huber,2009), (p)*Planoheterohelix moremani* (Cushman, 1938).

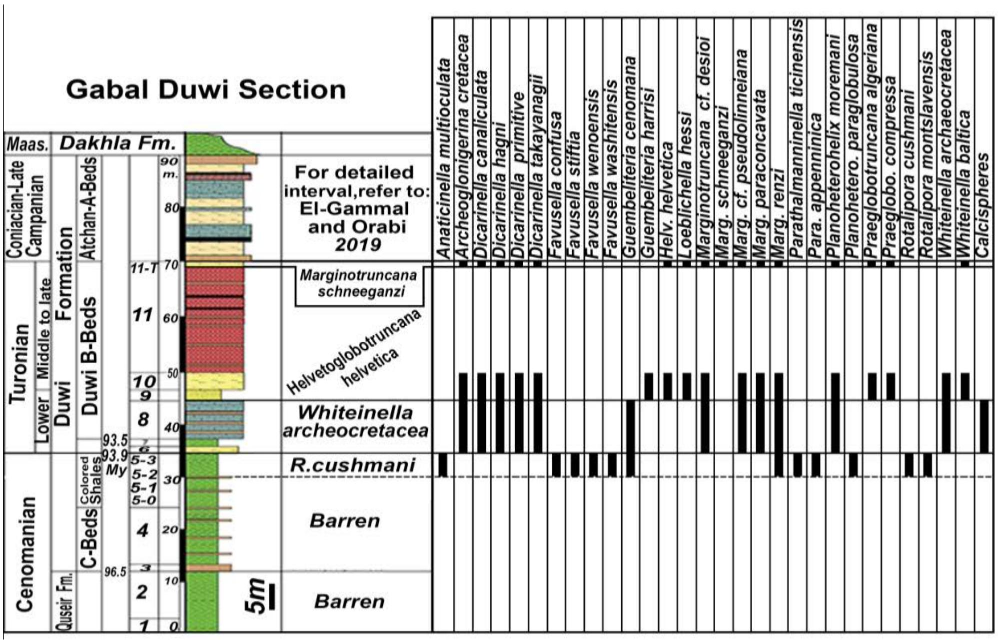

Figure 6: Planktic foraminiferal occurrences and proposed biozones across the Cenomanian- Turonian boundary of the Gabal Duwi section.

Age: Late early Cenomanian-early Late Cenomanian.

Planktonic assemblage: *Rotalipora cushmani*, *Rotalipora montslavensis*, *Parathalmanninella appenninica*, *Parathalmanninella ticinensis*, *Anaticinella (Thalmanninella) multioculata*, *Favusella washitensis*, *F. confusa*, *F. wenoensis*, *Marginotruncana renzi*, *Guembelitrea cenomana* and *Planoheterohelix moremani*. This assemblage indicative of the upper most *Rotalipora cushmani* zone [23,26].

Remarks: The occurrence of the nominate zonal species was noted by many authors starting with Sigal [28]. A gradual transition from *Hedbergella* to *Rotalipora cushmani* was defined by Georgescu et al. [29,30], where *Rotalipora montslavensis* of Mornod et al. [31] was considered morphologically close to *Rotalipora cushmani*. Therefore, *R. montslavensis* was considered a junior synonym of *R. cushmani* [30,32]. *Rotalipora cushmani* is originally present in our present material. *Rotalipora montslavensis* is present besides other Rotaliporids as *Anaticinella multioculata* to characterize the uppermost Cenomanian at Quseir Region.

Occurrence: They are recorded from bed No. 18 (Figure 3b) within the lower colored shales interval underlain the B-Beds of the Duwi Formation in Zug El-Bahar section and bed No. 5-3 (Figure 3a) of dark grey to brownish shale with thickness about 40cm of the lower lithologic level of Gebel Duwi section (Figures 2,e, and i).

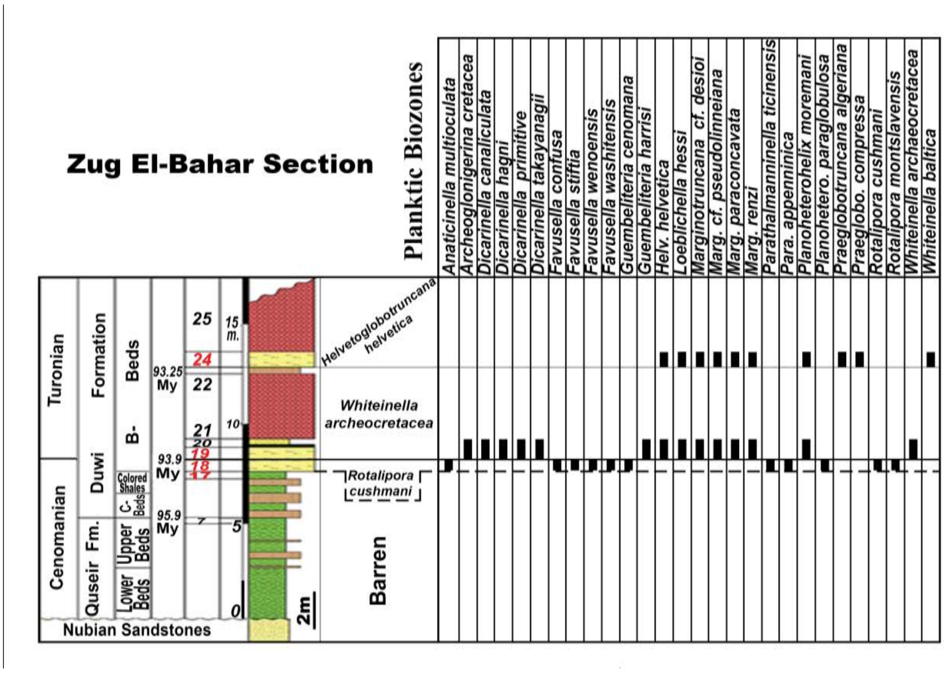

Figure 7: Planktic foraminiferal occurrences and proposed biozones across the Cenomanian- Turonian boundary of the Zug El Bahar section.

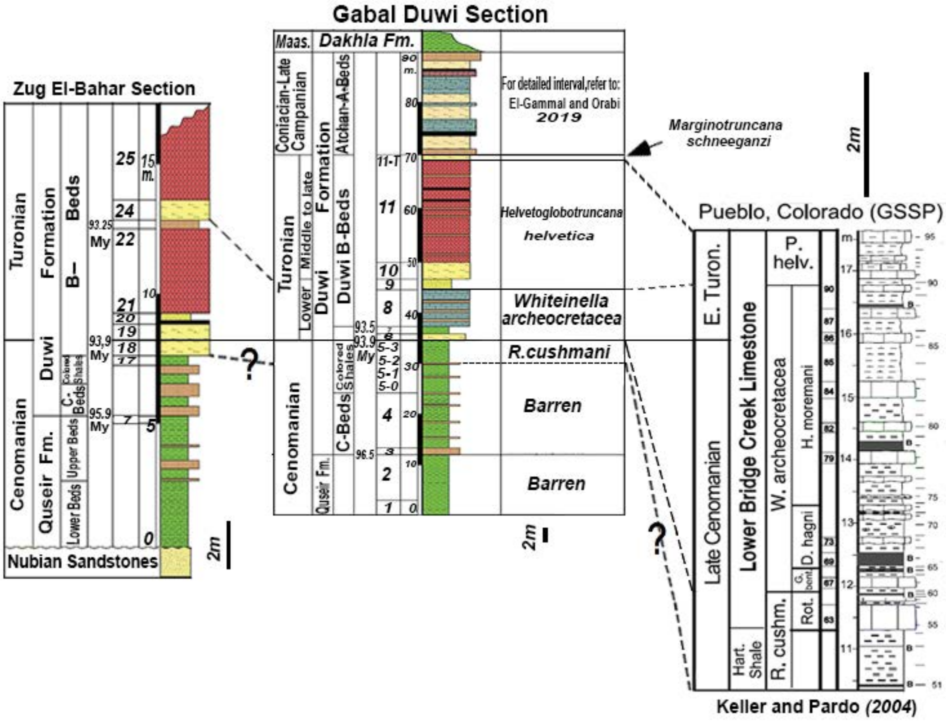

Figure 8: Correlation scheme for the Cenomanian-Turonian transition based on the planktic foraminiferal zonations between the studied sections and Pueblo,Colorado section (GSSP).

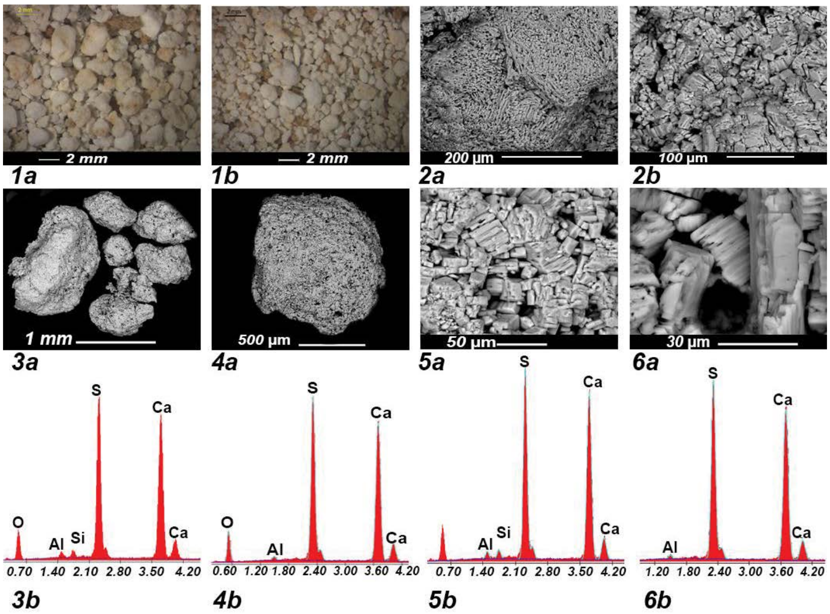

Figure 9: Early Turonian Calcispheres,from sample no. 6 (Gabal Duwi section). Photos nos (1a & 1b): Light Steroscopic microscope of flooded loosely bloom and acme, oval and sphere shapes of calcisphere samples. Photos nos (2a & 2b): SEM images show the diagenetic calcite crystals of the outer wall on calcisphere cyst. Photos nos (3a-6a): SEM images of single calcified cyst with pores. Photos nos (3b-6b): Different results of SEM with EDX (Energy Dispersive X-Ray) showing the elemental composition of different calcisphere cysts as the majority of Ca (Calcite) and S (Sulpher) contents.

Discussion: The lower lithologic level of Gebel Duwi section comprises planktonic association resembles that of bed No. 18, of Zug El-Bahar section, but the present specimens of the Gebel Duwi section are impregnated by black color causing unclean specimens and arenaceous sand fragments and ochreous sand grains with other rock fragments are present.

Whiteinella archaeocretacea **biozone**

Author: Bolli (1966)

Definition: from the last appearance of *Rotalipora cushmani* to the first appearance of *Helvetoglobotruncana helvetica* [33-35].

Age: Latest Cenomanian to Earliest Turonian.

Planktonic assemblage: *Whiteinella archaeocretacea*, *Helvetoglobotruncana helvetica*, *Planohetrohelix moremani*, *Dicarinella hagni*, *Dicarinella takayanagii*, *Marginotruncana paraconcavata* and free acme friable flooded Calcispheres.

Remarks: This biozone is included the C/T boundary in many works on the Cretaceous planktonic foraminiferal biostratigraphy. It encompasses the critical interval of oxic and anoxic events to the Cenomanian-Turonian boundary [36]. The presence of *Dicarinella hagni*, *Marginotruncana cf desioi* and *M. cf pseudolinneiana* in Gabal Duwi section, otherwise the presence of *Helvetoglobotruncana helvetica, Dicarinella hagni* and *Planoheterohelix moremani* in Zug El-Bahar section, indicates that the both sections sharing the *Dicarinella hagni* subzone and "*Heterohelix*"=*Planoheterohelix moremani* subzone of Keller et al. [36] at Pueblo, Colorado GSSP section and point as earliest Turonian interval (Figure 8).

Occurrence: Bed No. 19 of the B-Beds of Zug El-Bahar Section and beds No.6,7 & 8 of Gabal Duwi section.

Discussion: The occurrence of *Whiteinella archaeocretacea Helvetoglobotruncana helvetica, Planoheterohelix moremani* and *Guembelitrea cenomana* and completely extinctions of the Rotaliporids are clearly marking the Cenomanian-Turonian boundary (C/T). In the C/T boundary all Rotaliporids are disappeared as reported in many studies [22] and in Pueblo GSSP section [5,25,26].

The lithology of the Gabal Duwi section is represented by marl (Bed No. 6) with highly flooded friable "calcispheres" (Pithonellids) of spherical and ovoidal shapes and diagenetically calcified by more repetitive layers of calcite (Figure 9). The presence of heterohelicids in the Zug El-Bahar section could not be confirmed in the samples of the Gabal Duwi section, which instead of yielding an increased flooding of calcispheres. A similar observation was reported by Pearce et al. [37].

Helvetoglobotruncana helvetica **biozone**

Author: Originally, Sigal [28]

Definition: The total range of *Helvetoglobotruncana helvetica* defines this zone, which is generally regarded as marking the middle Turonian. Otherwise, Georgescu defined this zone from the first apparent of *Helvetoglobotruncana helvetica* to the first appearance of *Marginotruncana schneegansi* [38].

Age: Middle Turonian.

Planktonic assemblage: By the occurrence of *Hv. helvetica* and presence of *Praeglobotruncana algeriana*, *Praeglobotruncana compressa*, *Dicarinella canaliculata*, and *Planoheterhelix moremani*, *Guembelitrea harrisi* and *Loeblichella* (Praeglobotruncana) *hessi* (from bed No. 24 of the Zug El-Bahar section) and with *Whiteinella baltica* (bed No.10 of the Gebel Duwi section) are marking the Middle Turonian until appearance of *Marginotruncana schneegansi*.

Remarks: Gradstein et al. [39] pointed out the importance of *Hv.* helvetica as index taxon that has been characterized by a short stratigraphic range within the Early-Middle Turonian but very rare at the C/T level and more dwarfed [40,41].

Occurrence: The marl interval of bed No. 24 of B-Beds of the Duwi Formation of Zug El-Bahar section and Bed No.10 of B-Beds of Gabal Duwi section.

Discussion: The planktonic foraminifera assigned to the Early-Middle Turonian age (*Whiteinella baltica, Helvetoglobotruncana helvetica*, *Dicarinella hagni, Dicarinella primitiva*) as suggested by Jarvis et al. [42] are represented. The appearance of *Whiteinella spp.* marks the end of the anoxic event and returns to a more normal oxic water column of Early Turonian. Similar assemblage is found in B-Beds of the Duwi Formation in the Gabal Duwi section indicating the Middle Turonian age [5].

Marginotruncana schneegansi **biozone**

Author: Robaszynski and Caron [35].

Definition: Interval from heights occurrence of *Helvetoglobotruncana helvetica* to the first appearance of *Concavotruncana (Dicarinella) concavata*.

Age: Middle Turonian to the base of the Coniacian.

Planktonic assemblage: *Marginotruncana paraconcavata*, *Dicarinella canaliculata*, *Planoheterohelix moremani*, and *Marginotruncana schneegansi* with very rare *Hv. helvetica* have characterized this biozone. The upper limits of Late Turonian/Coniacian boundary contain *Marginotruncana schneegansi* with very rare or absent of *Hv. helvetica*. This interval is represented clearly by *Marginotruncana schneegansi* as the biozone of the Late Turonian until the first occurrence of *Concavotruncana concavata* which is considered as more precisely taxon of the Early Coniacian even locally [11]. Therefore, we interpret the major changes between the Late Turonian and Coniacian planktonic foraminiferal assemblages as a real emergence of *Marginotruncana schneegansi* environmental changes which led to increasing the content of *Marginotruncana spp.* and complete extinction of *Helvetoglobotruncana helvetica* within the Early Coniacian *Concavotruncana concavata* Zone.

Remarks: In Southeast France, Conrad-Noireau [43] defined an assemblage of *Marginotruncana paraconcavata*, *M. sinuosa*, *Hedbergella flandrini* as representing the Turonian-Coniacian boundary and used *M. undulata*, *M. tarfayaensis*, *Dicarinella primitiva*, for marking the beginning of the Coniacian. Robaszynski and Caron defined the appearance of *D. primitiva* belongs to the *D. concavata* Zone of Late Turonian age. This zone is recorded only in the Gabal Duwi section.

Occurrence: Bed No. 11-T of upper Duwi Formation at the Gabal Duwi section.

Discussion: Georgescu mentioned that *Helvetoglobotruncana helvetica* was noted through the Coniacian [38]. Meanwhile, in the Coniacian of the Gebel Duwi section El Gammal and Orabi [11] recorded *Concavotruncana concavata* and *Marginotruncana schneegansi*, where *Hv. helvetica* disappeared within the upper limits of *Concavotruncana concavata*. The extinction of *Hv. helvetica* has been accepted within the Coniacian *Concavotruncana concavata* Zone of the Duwi section.

The extinction of very rare *Hv. helvetica* is recorded within the marl layer of *Concavotruncana concavata* Zone with *Marginotrunana schneegansi*, *M. coronata*, *M. pseudolinneiana*. The placement of the base of *Hv. helvetica* Zone may be highly unreliable depending on the paleoenvironmental setting and time spent searching for its lowest or upper occurrence [44]. *Marginotruncana pseudolinneiana* (latest Middle Turonian), *M. schneegansi*, *M. coronata* and *M. sinuosa* followed by *Concavotruncana concavata* Zone (Coniacian), this view is in concordant with El Gammal and Orabi [11]. Therefore, this work accepted the first appearance of *Marginotruncana schneegansi* as the index of the Late Turonian interval.

SIGNIFICANT OF CALCISPHERES AT THE C/T BOUNDARY

For the first time in Egypt, in the C/T boundary of the Duwi section, it documents the occurrence of more than 80% fully flooded friable calcispheres within a thin bed of mud to grain supported fabric recorded after the complete extinction of all Cenomanian fauna marking the Earliest Turonian age. The present calcispheres are nearly sorted calcic-grains, showing a high degree of diagenetically calcification has been masked the original cyst (Figure 9).

Robaszynski et al. described calcispheres from a lower 5 m of the C/T boundary in Tunisia [45]. Hart [46] found an abundant flood of calcispheres was recorded in the Cenomanian-Turonian boundary in many localities as former Yogoslavia [47], in Germany [48], in Portugal [49] and the Sopeira basin of Spain. Kennedy and Simmons recorded calcispheres as *Pithonella ovalis* and *Pithonella spherical* in Europe [50], North Africa, Middle East, detected in Oman [51-53]. Even in southern Tibet, Wendler et al. in Tanzania it is reported that the calcispheres at the same present stratigraphic level [54].

The proposed C/T boundary of the Quseir Region in Gebel Duwi section has about 1 m thick marl bed representing by very condensed small lamellar bedding characterized by flooded isolated free calcispheres (10-180 μm) as suggested by Dali [55]. The calcispheres-rich bed (the uppermost bed no.6 before B-beds of the Duwi Formation), (Figure 9) followed by a large regressive episode represented by hard bioclastic and siliceous phosphatic limestone beds (Figure 2k) and assigned to Early-Late Turonian age.

The presence of flooded calcispheres reflects the existence of temperate or tropical climatic conditions in the mid-latitudes as north Africa during the Cretaceous prior to Coniacian age and it is a significant ecological drowning component for the C/T boundary event, either by diachroneity of the ecological perturbation or local origin for the ecological component or may dissolution process of all planktonic and/or benthic fauna from the Cenomanian to probable Latest Cenomanian [56]. The presence of the calcispheres alone without any foraminiferal fauna in marine dissolute persist marl bed, as shown in the present work in the Duwi section (Figures 1-3 and 9) may reflect more resistant to the dissolution than foraminifers. The presence of pyrite mineral (FeS_2) associated with the calcispheres (Figures 3b,4b,5b and 6b) indicate reducing conditions and presence of Sulphur within the sediment prior the lithification and digenesis.

Many authors recorded calcispheres in the *Whiteinella archaeocretacea* Zone it is recorded blooms of the calcispheres in the Late Cenomanian-Early Turonian boundary and known as bioevent associated with OAE2 interval [57-61]. More recently Wiese et al. recorded dominated *Pithonella spp.* at the Latest Cenomanian at Sussex Chalk (England), where the extinction of Pithonellids indicating the shallowing sea in the Turonian platform [62].

In Egypt, Shahin and El-Baz [63] recorded in thin sections calcispheres within the *Whiteinella archaeocretacea* Zone, below the Cenomanian-Turonian boundary of Gebel Musabaa Salama, West-Central Sinai. Likewise, Abdel-Fattah et. al [64] recorded calcispheres in the Galala Formation, North Eastern Desert, Nagm [65]; in Sinai, Farouk and finally El-Baz and Khalil recorded flourishing calcispheres (in thin-sections) at the C/T boundary of Sinai sections [66,67].

The association of both small specimens of *Hv. helvetica* with the occurrence of flooded calcispheres is quite characteristic of the C/T boundary event at the Gabal Duwi section.

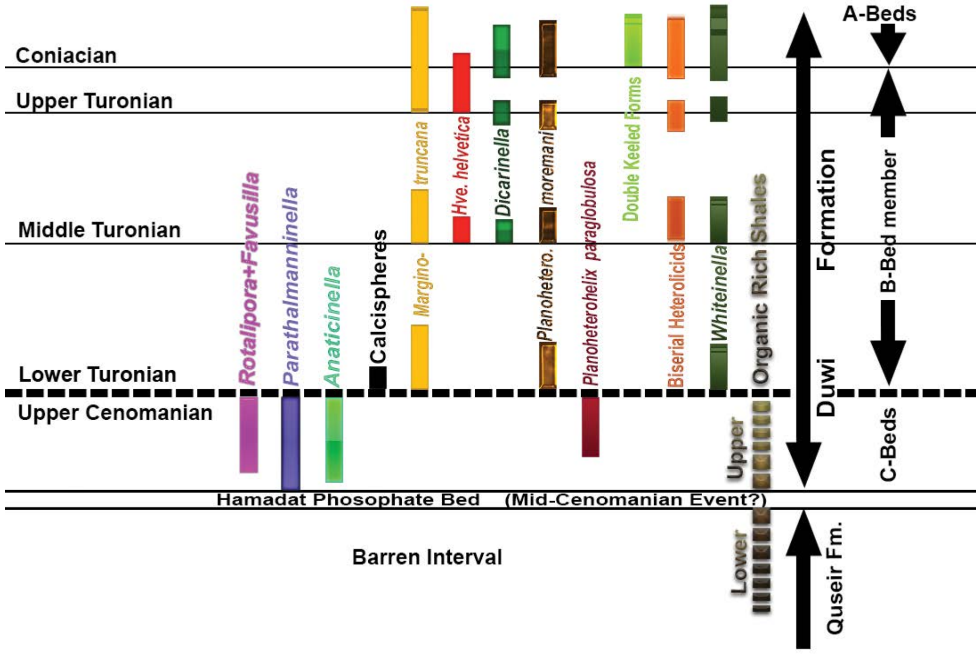

Figure 10: Mode of occurrence and extinctions of the distinguished planktic foraminiferal groups and species of the Cenomanian- Turonian transition interval of Quseir region, Red sea, Egypt.

PALEOECOLOGY

The absence of benthic foraminifera in the two studied sections, we discuss here the paleoecology depending on the planktonic foraminifera only as follow:

Rotalipora cushmani zone

The extinction of *Rotalipora*, *Anaticinella*, *Favusella* and *Parathalmanninella foraminiferal* genera marks the onset of a major biological event or turnover due to the global maximum flooding of Late Cenomanian age [26,68-71]. The Rotaliporids are generally considered oligotrophic habitats [72], they lived in marine continental shelf during the flooding event.

The Presence of *Favusella* diverse group of Rotaliporids as *F. washitensis*, *F. wenoensis*, and *F. confusa* within the Latest Cenomanian indicate shallow continental environments at Quseir Region.

The Late Cretaceous *Guembelitrea cenomana* is rare in the Latest Cenomanian, which indicates eutrophic surface waters of shallow marginal marine environments (as a platform) with variable salinities at times of severe ecological stress [26], also the absence or even rare of heterohelicids due to the lowest sea level and highest terrigenous influx. In Early Turonian, the presence of Whiteinella, and heterohelicids as *Planoheterohelix paraglobulosa* indicates low salinity-tolerant (Figure 10).

Whiteinella archaeocretacea zone

The Cenomanian-Turonian boundary event in the two studied sections of the Quseir Region is characterized by extremely small thickness, creating no hiatus in the sedimentation as shallow-water environments as suggested in Portugal by Hart et al. [49].

Quseir Region dominated by shallow marine C/T facies lacks organic-rich deposits, where carbonates and dolomites are the dominant deposits. Black shale facies are at least controlled by the relief with more elevated areas being impinged later by oxygen minimum zone (OMZ) than lower-lying areas [73].

As indicated by Hart and Bailey [74] the distribution of an individual species and its appearance in time are a function of the water depth. They suggested that the Rotalipora lineage was to live in the adult growth stage at a specific depth in the water column. As the top of the oxygen minimum zone rose in the water column it impinged on the largest and deepest-dwelling planktonic foraminifera first, causing the extinction of *Rotalipora spp.* The intermediate water fauna, double keeled planktonic, dicarinellids and praeglobotruncanids became extinct next. This meant that only the shallow-water fauna, hedbergellids and whiteinellids, were not affected by oxygen-depleted waters and so survived [42].

Huber and Petrizzo [44] concluded that Helvetoglobotruncanads lived at relatively shallow depths in the mixed layer and present in a homogeneous zone dominated by *Dicarinella hagni*, *Whiteinella aprica*, and *Wh. baltica* of Tanzania, the same case in Quseir Region.

Helvetoglobotruncana helvetica zone

The Duwi and Zug El-Bahar sections show the stress of the biotic effect of OAE2, where the presence of flooded calcispheres and rare planktonic genera recorded in Early Turonian due to low oxygen tolerant with very close initiation of Heterohelicids or biserial heterohelicids. This observation in the Duwi and Zug El-Bahar sections is resembled that in the Tethyan sections [26,32,36,75].

The complete absence of benthic foraminifera may due to sensitivity to dramatic changes in temperature, CO_2, salinity, oxygen and nutrients [25,26,76-81].

The environmental stress on biotic effects of OAE2 observed in the planktonic foraminiferal dwarfism (Figure 4 and 5) may due to the increase of terrigenous input and shallowing facies developed through the organic-rich black fissile shales conditions of the Cenomanian (Figure 2n). Keller and Abramovich [82] indicate the size reduction is associated with greenhouse warming, mesotrophic or restricted basins of shallow marine marginal settings (as Quseir case) and volcanically active regions [60].

Marginotrucana schneegansi zone

The last appearances of very rare *Helvetoglobotruncana helvetica* in the middle Turonian of the Duwi section, is marked by an abrupt drop or absence of this species [6,44]. This level appears to be synchronous across the Tethys Ocean [54] and may indicate the most pronounced Turonian regression in the global state correspond to Late Turonian reefal facies of the Duwi bioclastic oyster limestones (Figure 2b,o).

SUMMARY AND CONCLUSION

For the first time, the proposed C/T boundary at the Quseir Region, (Duwi Formation) in Gabal Duwi section only characterized by a flooded of isolated free calcispheres, which recorded after the complete extinction of all Cenomanian fauna marking the Earliest Turonian age. The presence of the calcispheres alone without any foraminiferal fauna may reflect more resistant to the dissolution than foraminifers.

The Cenomanian-Turonian boundary event in the two studied sections Zug El-Bahar and Duwi of the Quseir Region are characterized by extremely short interval, creating no hiatus in the sedimentation as shallow water environments. Quseir Region dominated by shallow marine C/T facies lack organic-rich deposits, where carbonates and dolomites are the dominant deposited. *Guembelitrea cenomana* is rare in the Latest Cenomanian, which indicates eutrophic surface waters of shallow marginal marine environments with variable salinities at times of severe ecological stress.

The absent of benthic foraminifera in the two studied sections due to sensitivity to dramatic changes in temperature, CO_2, salinity, oxygen and nutrients, so the interpretation of paleoecology depending of planktonic foraminifera. The extinction of *Rotalipora, Anaticinella, Favusella* and *Parathalmanninella* marks oligotrophic habitats of Late Cenomanian age.

The absence or even rare of heterohelicids due to the lowest sea level and highest terrigenous influx in Latest Cenomanian, meanwhile in Early Turonian the presence of Whiteinellids, and heterohelicids indicates low salinity tolerant. The presence of heterohelicids in the Zug El-Bahar section could not be confirmed in the samples of Gebel Duwi section, which instead yielding an increase flooding of calcispheres.

The environmental stress on biotic effects of OAE2 observed in the planktonic foraminiferal dwarfism due to the increase of terrigenous input and shallowing facies developed through the organic-rich black fissile shales conditions of the Cenomanian, which associated with greenhouse warming, mesotrophic or restricted basins of shallow marine marginal settings and volcanically active regions.

The appearance of *Whiteinella baltica* marks the end of the anoxic event and return to more normal oxic water column of Early Turonian. Similar assemblage is found in B-Beds of the Duwi Formation of Quseir Region sections with *Praeglobotruncana algeriana* and *Loeblichella hessi* indicating Middle Turonian age.

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