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Biostratigraphy of the Upper Cretaceous Sequence of the Gebel Musabaa Salama Area, Southwest Sinai, Egypt

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ABSTRACT. The Upper Cretaceous Sequence exposed in the Southwest of Sinai at Gebel Musabaa Salama is divisible into four rock units. They are, from base to top, the Raha, Abu Qada, Wata, and Matulla Formations. Based on macrofossil occurrences, four molluscan biozones have been established which facilitate the inter-regional correlation of the sequence studied. They are: the *Ilymatogyra africana-Exogra olisiponensis* range zone of late Cenomanian age, the Early Turonian *Vascoceras proprium* interval zone and *Choffaticeras* range zone, and the Santonian *Pycnodonte proboscideum* range zone. Several minor breaks in sedimentation of the studied sequence, probably diastems, have been recognized. The Lower Turonian succession is bounded by two unconformity surfaces separating it from the overlying Santonian and underlying Cenomanian successions. It is concluded that Upper Turonian and Coniacian Sequences are missing.

Strata of Late Cretaceous age yield a rich macrofauna in many places in Egypt. Despite such macrofaunal enrichment, little attention has been given to their vertical distribution. Consequently little has been published dealing with the macrozonation of the Egyptian Upper Cretaceous in general (*e.g.* Hume 1911, Hermina 1967, Awad and Issawi 1975, Kora and Hamama 1987, Hamama and Kassab 1990, Kassab 1991, Kassab *et al.* 1995). None of these works has been done on macrozonation of the Southwest Sinai. Moreover, detailed stratigraphic publications on the Upper Cretaceous outcrops of Southwest Sinai are generally lacking. This is contrary to the substantial information published on its subsurface stratigraphy (*e.g.* Viotti and El Demerdash 1968, Ansary *et al.* 1969, Andarawis 1970, Bassiouni *et al.* 1974, El Shinnawy and Sultan 1973, 1975, Boukhary and Abd El Malik 1983).

The present study aims at providing a detailed macrozonation for the Upper Cretaceous Sequence exposed at Gebel Musabaa Salama (Fig. 1), attempting its inter-regional correlation, and discussing the discontinuity episodes that interrupted the sedimentation. The succession from which the studied material was collected can be divided lithostratigraphically into four rock formations. They are the Raha (base), Abu Qada, Wata, and Matulla Formations. Environmental setting and facies changes of these formations, the palaeogeographic affinity and sea-level curve of the study area, and comparison with global eustatic sea-level changes, as well as the systematic palaeontology of the macrofossils used in this study have been discussed in detail by Kassab and Ismael (1994). Thus, to avoid duplication, only stratigraphic details of the studied sequence are given here (Figs. 2,3).

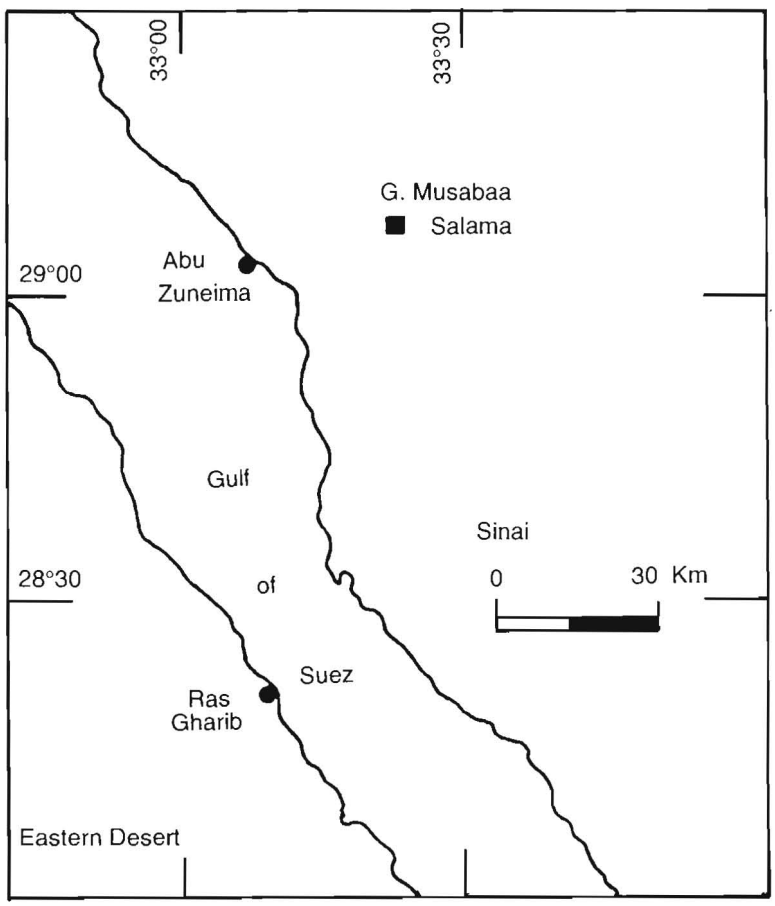

Fig. 1. Location map.

Biostratigraphy

The vertical distribution of molluscan and echinodermal species (Figs. 2,3) is used to divide the Upper Cretaceous Sequence of the study area into four macrozones which are employed as biostratigraphic units.

In ascending order the established macrozones are :

A. The *Ilymatogyra africana-Exogyra olisiponensis* Range zone:

This zone is the oldest macrozone encountered in the studied succession. It is characterized by the occurrence of large quantities of oysters, forming conspecuous oyster horizones. The lower boundary is marked by the first appearance of *Ilymatogyra Africana* (Lamarck), including forms generally known as "*Exogyra columba*" and "*Exogyra suborbiculata*" in Egypt. The upper boundary is delineated by the last appearance of *Exogyra (Costagyra) olisiponensis* (Sharpe). Other faunal elements are *Arciacia pescameli* (Schweinfurth), *Holectypus excisus* (Desor), *Micraster leskei* (Desmoulins), *Pterodonta altispira* (Whitfield), *Strombus incertus* (Orbigny), *Conotomaria* sp., *Amphidonte obliquatum* (Pulteney), *Ceratostreon flabellatum* (Goldfuss), *Gyrostrea delettrei* (Coquand), *Septifer* (Septifer) *samiri Abbass, Neithea aequicostata* (Lamarck), *Plicatula reynesi Coquand, Arctica humei* (Cox), *Glossus solimani Abbass, Venus reynesi* Coquand, *Dosinia delettrei* (Coquand), and *Thracia seguenzai* Greco.

Such macrofaunal content refers the *Ilymatogyra africana-Exogyra olisiponensis* Zone to a Late Cenomanian age.

This zone includes sediments of the Raha Formation and the lower part of Abu Qada Formation. It is an equivalent to the *Exogyra africana-Neolobites fourtaui* and *Exogyra suborbiculata-Ostrea mermeti* zones of Awad and Issawi (1975), to the *Neolobites-Ilymatogyra* zone of Kassab (1985), to the *Exogyra olisiponensis-Ilymatogyra africana* zone of Kora and Hamama (1987), and to the *Neolobites vibrayeanus* zone of Kassab (1991).

B. The *Vascoceras proprium* Interval Zone :

The occurrence of globose vascoceratid ammonites is a useful tool for recognition of this zone in the field. The lower boundary coincides with the appearance of Vascoceras proprium (Reyment). The upper boundary is delimited by the appearance of choffaticeratid ammonites. Besides the index species, *Vascoceras*

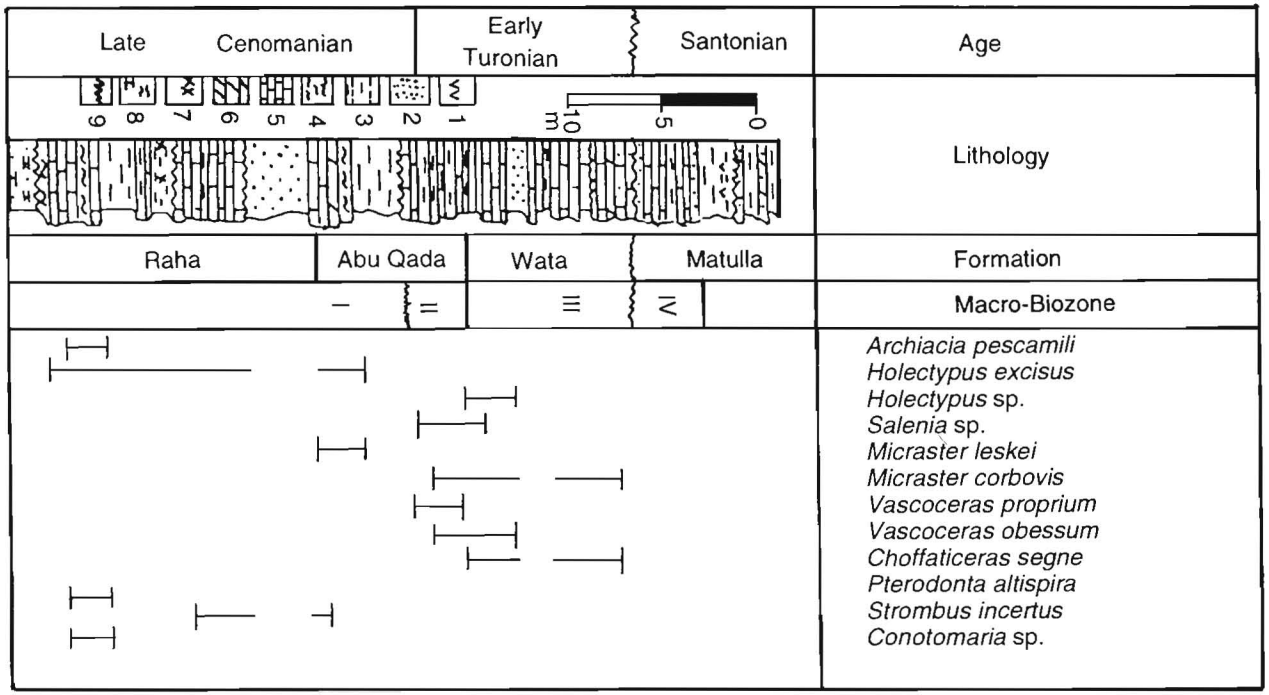

Fig. 2. Vertical distribution of the echinoides, gastropods and ammonites collected from the Upper Cretaceous succession of Gebel Musabaa Salama area, Sinai. 1, Gypsum; 2, Sandstone; 3, Shale; 4, Marl; 5, Limestone; 6, Dolomite; 7, Silty; 8, Calcareous; 9, Erosive surface; I, *Ilymatogyra africana-Exogyra olisiponesis* Zone; II, *Vascoceras proprium* Zone; III, *Choffaticeras* Zone; IV, *Pycnodonte proboscideum* Zone.

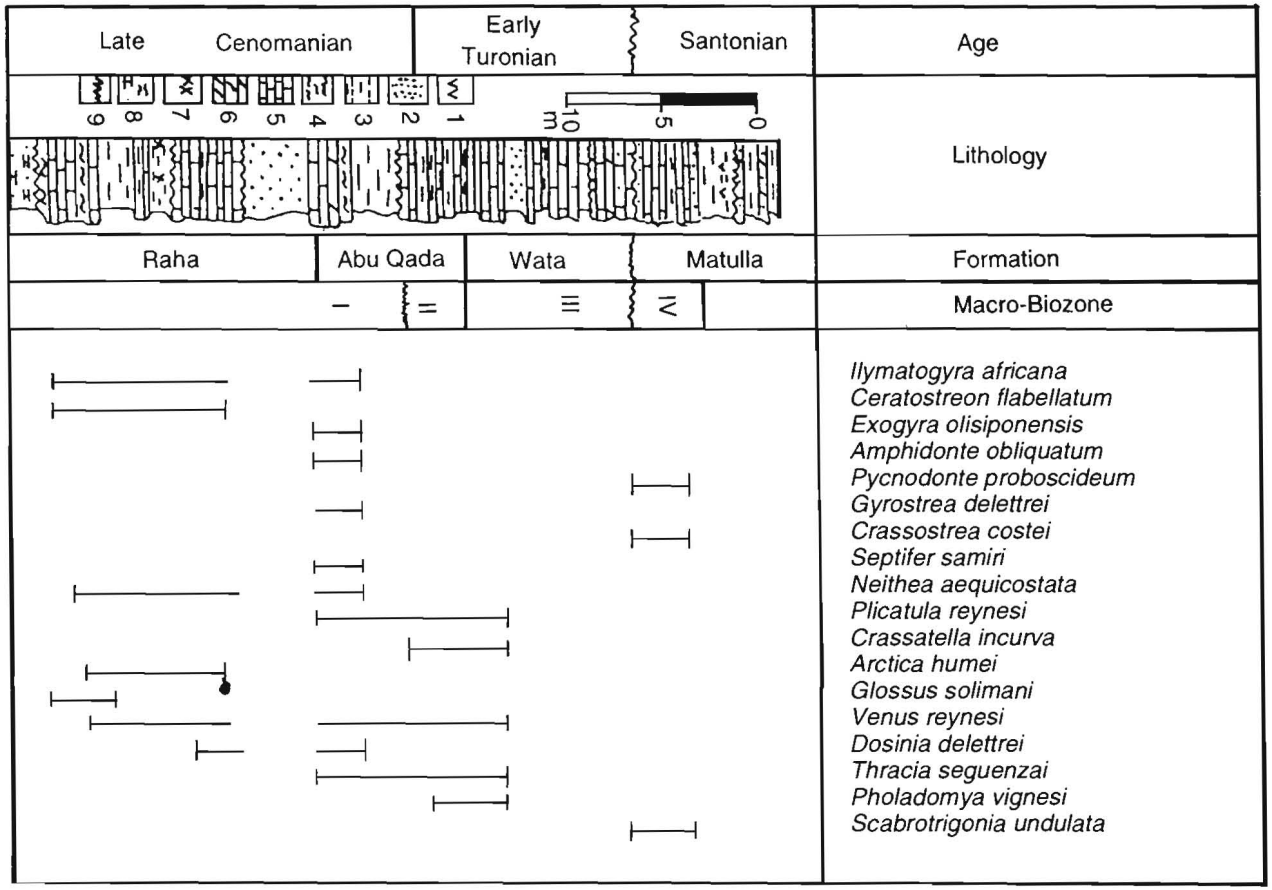

Fig. 3. Vertical distribution of the bivalves collected from the Upper Cretaceous succession of the study area. The lithologic symbols and macrozones are explained in Figure 2.

obessum (Taubenhaus), *Salenia* sp., *Micraster corbovis* (Forbes), *Plicatula reynesi* Coquand, *Crassatella incurva* Kassab and Ismael (1994), *Venus reynesi* Coquand, *Thracia seguenzi* Greco, and *Pholadomya vignesi* Lartet also occur within this zone. These macrofaunas indicate an Early Turonian age for the *Vascoceras proprium* Zone.

This zone coincides with the upper part of the Abu Qada Formation which directly overlies the lower part of the Abu Qada Formation of Cenomanian age with an erosive surface. It correlates, in parts, with the *Vascoceras douvillei* Zone of Kassab (1985), and the *Pseudaspidoceras flexuosum* zone of Kassab (1991).

C. The *Choffaticeras* Range Zone :

This ammonite zone can be recognized by the occurrence of the lanceolate compressed ammonites of the *Choffaticeras* group. The lower and upper boundaries of this zone are delineated by total range of the *Choffaticeras segne* (Solger), including *Choffaticeras pavillieri* Pervinquiere, *Choffaticeras securiforme* (Eck), *Choffaticeras schweinfurthi* (Eck) and *Choffaticeras luciae* Pervinquiere as synonames.

Other macrofossils occurring within this zone are *Holectypus* sp., *Salenia* sp., *Micraster corbovis* (Forbes), *Vascoceras obessum* (Taubenhaus), *Plicatula reynesi* Coquand, *Crassatella incurva* Kassab and Ismael (1994), *Venuis reynesi* Coquand, *Thracia seguenzai* Greco, and *Pholadomya vignesi* Lartet. They confirm an Early Turonian age of the *Choffaticeras* Range Zone.

This zone is encountered in the Wata Formation. It is probably an equivalent to the *Choffaticeras segne* zone of Kora and Hamama (1987) and Kassab (1991).

D. The *Pycnodonte proboscideum* Range Zone :

This oyster zone represents the youngest macrozone identified in this study. Its lower and upper boundaries are marked by the total range of the oyster *Pycondonte (Phygraea) proboscideum* (Archiac). Besides the index species, *Scabrotrigonia undulosa* Kassab and Ismael (1994) and *Crassostrea costei* (Coquand) were collected from the interval of this zone referring to a Santonian age.

The *Pycondonte.* (Ph.) *proboscideum* (Archiac) is a widely distributed index Santonian species (Coquand 1869, Rengarten 1964, Dhondt 1985). This zone has been recorded from the lower part of the Matulla Formation.

Inter-regional Correlation

The recording of macrofaunal elements of world-wide occurrence as well as achievement of standard macrozonation for well-dated sections in other regions of the world facilitate the inter-regional correlation of the study area.

As shown in Figure 4, the *Ily. africana-Exo. olisiponensis* range zone is correlatable with the *Neolobites vibrayeanus-Lotzeites* lotzei zone of Wiedmann and Kauffmann (1978), the *Neolobites vibrayeanus* and *Calycoceras* zones of Lewy *et al.* (1984), the *Calycoceras naviculare* zone of Berthou (1984), the *Nigericeras gadeni* zone of Popoff *et al.* (1986), and the *Calycoceras canitaurinum* zone of Kennedy *et al.* (1987).

The *Vascoceras proprium* (Reyment) is an important ammonite species used to define the basal Turonian *Pseudaspidoceras flexuosum* zone of Powell (1965) as discussed by Kennedy *et al.* (1987). In this sense, *Vascoceras proprium zone* of this study correlates well with the *Pseudaspidoceras flexuosum* zone of different authors (Fig. 4). It is partly equivalent to *Vascoceras douvillei* zone (Choffat 1898), *Vascoceras pioti* zone (Freund and Raab 1969, Lewy *et al.* 1987), and to *Paravascoceras costatum* zone (Reyment 1955, Popoff *et al.* 1986).

The *Coffaticeras* range zone probably corresponds to the Iberian V zone (Wiedmann 1960), *Choffaticeras* zones (Freund and Raab 1969, Lewy *et al.* 1984), T4-T6 zones (Lewy and Raab 1978), *Pseudotissotia-Neoptychites* zones (Wiedmann and Kauffmann 1978), *Pseudotissotia* zones (Popoff *et al.* 1986), and *Mammites nodosoides* zone (Berthou 1984, Kennedy *et al.* 1987).

The Lack of Santonian macrozonation from well-dated sections of other regions as well as the low diversity of faunal content of the present *Pycnodonte proboscideum* zone handicaps the inter-regional correlation of the Santonian of the study area.

Chronostratigraphy

A broad survey of the biostratigraphic character of the macrofauna collected from the Upper Cretaceous Sequence of the study area shows that several species are useful to ascertain accurate chronostratigraphic units for the concerned sequence. Thus rock units recognized in the study area have been attributed mainly to the Cenomanian, Turonian, and Santonian stages.

Sub Stage	Egypt SW Sinai The present Study	Egypt E Desert Kassab 1991	Israel Lewy *et al.* 1984	Portugal Berthou 1984	Spain Wiedmann and Kauffmann 1978	Nigeria Popoff *et al.* 1986	New Mexico Kennedy *et al.* 1987
Lower Turonlan	*Cholfaticeras* *V proprium*	*C segne* *Ps flexuosum*	*C Lucae* *C quassi* *C Securiforme* *V Pioti*	*Ma nodosoides* *W Coloradoense*	*Collingonoceras* *Neoptychites* *Pst armatum* *Pst sulcatus* *I malladae* *P saenzi*	*C barjonai/Fg spheroidalis* *Pst wallsi* *Pst nigeriensis* *Pv costatum*	*Ma nodosoides* *V birchbyi* *Ps flexuosum*
Upper Cenomanian	*Il africana/ Ex olisiponensis*	*V cauvini* *Me geslinianum* *N vibrayeanus*	*V cauvini* *kanabiceras* *Calycoceras* *N vibrayeanus*	*Ne juddii* *Un-named Zone* *Me geslinianum* *Ca naviculare*	*F subconciliatus* *V gamai* *Me geslinianum* *Me muelleri* *L lotzei* *+* *N vibrayeanus*	*V bulbosum* *V tavense* *Ng gadeni*	*Ne juddii* *V cauvini* *S gracile* *Ma mosbyense* *Ca canitaurinum*

Fig. 4. Inter-regional correlation of the Upper Cenomanian-Lower Turonian macrozones of the present study. The cenomanian/Turonian boundary is defined mainly after Kennedy *et al.* (1987) and Kassab (1991). *Ex, Exogyra; Il, Ilymatogyra; V, Vascoceras; C, Choffaticeras; Ps, Pseudaspidoceras; Me, Metoicoceras; N, Neolobites; Ca, Calycoceras; Ne, Neocardioceras; W, Watinoceras; Ma, Mammites; Pst, Pseudotissotia; Spa, Spathites; L, Lotzeites; F, Fallotites; P, Paramammites; I, Ingridella; Fg, Fagesia; Pv, Paravascoceras; Ng, Nigericeras; S, Sciponoceras.*

A. The Cenomanian :

Faunal elements of Late Cenomanian age were collected from several horizones within the Raha Formation and the lower part of the Abu Qada Formation. These two units comprise the *Ilymatogyra africana-Exogyra olisiponensis* Zone.

B. The Cenomanian/Turonian boundary :

The Upper Cenomanian/Lower Turonian boundary is unconformably located within the upper part of the Abu Qada Formation coinciding with an erosive surface. It follows the contact between the Upper Cenomanian *Ily. africana-Exo. olisiponensis* Zone and the basal Turonian *Vascoceras proprium* Zone demonstrating the absence of two Upper Cenomanian zones (Fig. 4).

C. The Turonian :

The Upper part of the Abu Qada Formation yields the fauna of *Vascoceras proprium* Zone, whereas elements of *Choffaticeras* Zone were collected from the Wata Formation. Thus an early Turonian age is here assigned to the upper Abu Qada and the Wata Formations.

D. The Santonian :

The Matulla Formation comprises the Santonian *Pycnodonte proboscideum* Zone and directly overlies the Wata Formation with its Lower *Turonian Choffaticeras* Zone.

No Upper Turonian and Coniacian successions are met with in the study area.

Discontinuity Episodes

It is likely that sedimentation of the Upper Cretaceous System in the study area was not continuous, and was interrupted by several erosional and non-depositional episodes.

The Upper Cenomanian succession of the study area is represented by the Raha Formation and a part of the Abu Qada Formation. The Raha Formation is composed of marine siliciclastic and carbonate sediments terminated by a continental sandstone unit. Such occurrance of marine and non-marine succession, as well as presence of erosive surfaces at different horizons (Figs. 2,3) indicate that several discontinuity episodes prevailed the study area during the time span of the *Ily. africana-Exo.*

olisiponensis Zone. Such discontinuities are probably diastems caused by uplifting of the study area for short times, and subjected to erosional periods and/or relative sea-level changes.

Another unconformity is recognized within the Lower Turonian succession of the Wata Formation during the time interval of the *Choffaticeras* Zone. Such an event is documented by interruption of marine sediments of the Wata Formation by a non-marine sandstone unit at its middle part (Figs. 2, 3, 5).

Two relatively major unconformities entrap the Lower Turoinian succession. One is recognized by the occurrence of the Lower Turonian *Vascoceras proprium* Zone directly overlying the Upper Cenomanian *Ily. africana-Exo. olisiponensis* Zone. Such occurrence indicates the absence of two Upper Cenomanian zones. The missing zones are the *Vascoceras cauvini* and *Metoicoceras geslinianum* Zones, previously recorded from other Egyptian regions and neighbouring countries (Fig. 4). It is also confirmed by the occurrence of an erosive surface coinciding with the Upper Cenomanian/Lower Turonian boundary in the study area.

The other hiatus is interpreted to occur between the Lower Turonian Wata Formation and the Santonian Matulla Formation. This means that Upper Turonian and Coniacian successions are completely absent (Fig. 5). This hiatus is confirmed by occurrence of an erosive surface at the marine basal part (rich with *Pycnodonte)* of the Matula Formation directly overlying the topmost part of the marine sediments of the Wata Formation. This is also indicated by direct superposition of the Santonian *Pycnodonte proboscideum* and the Lower *Turonian Choffaticeras* Zones.

Discussion and Conclusion

Based upon the field relations, as well as the lithologic and biologic aspects, the Upper Cretaceous Sequence of the study area is lithostratigraphically classified into four rock units namely the Raha (at base), Abu Qada, Wata, and Matulla Formations. With the aid of the vertical distribution of the molluscan and echinodermal faunas, macrozonation of the studied sequence has been achieved, and four molluscan biozones are established. In ascending order, they are the Upper Cenomanian *Ilymatogyra africana-Exo. olisiponensis* Range Zone, the Lower Turonian *Vascoceras proprium* interval Zone and the *Choffaticeras* Range Zone, and the Santonian *Pycnodonte proboscideum* Range Zone.

Inter-regional correlation of these zones, with those previously established for well-dated sections from other regions, is here attempted (Fig. 4). The proposed

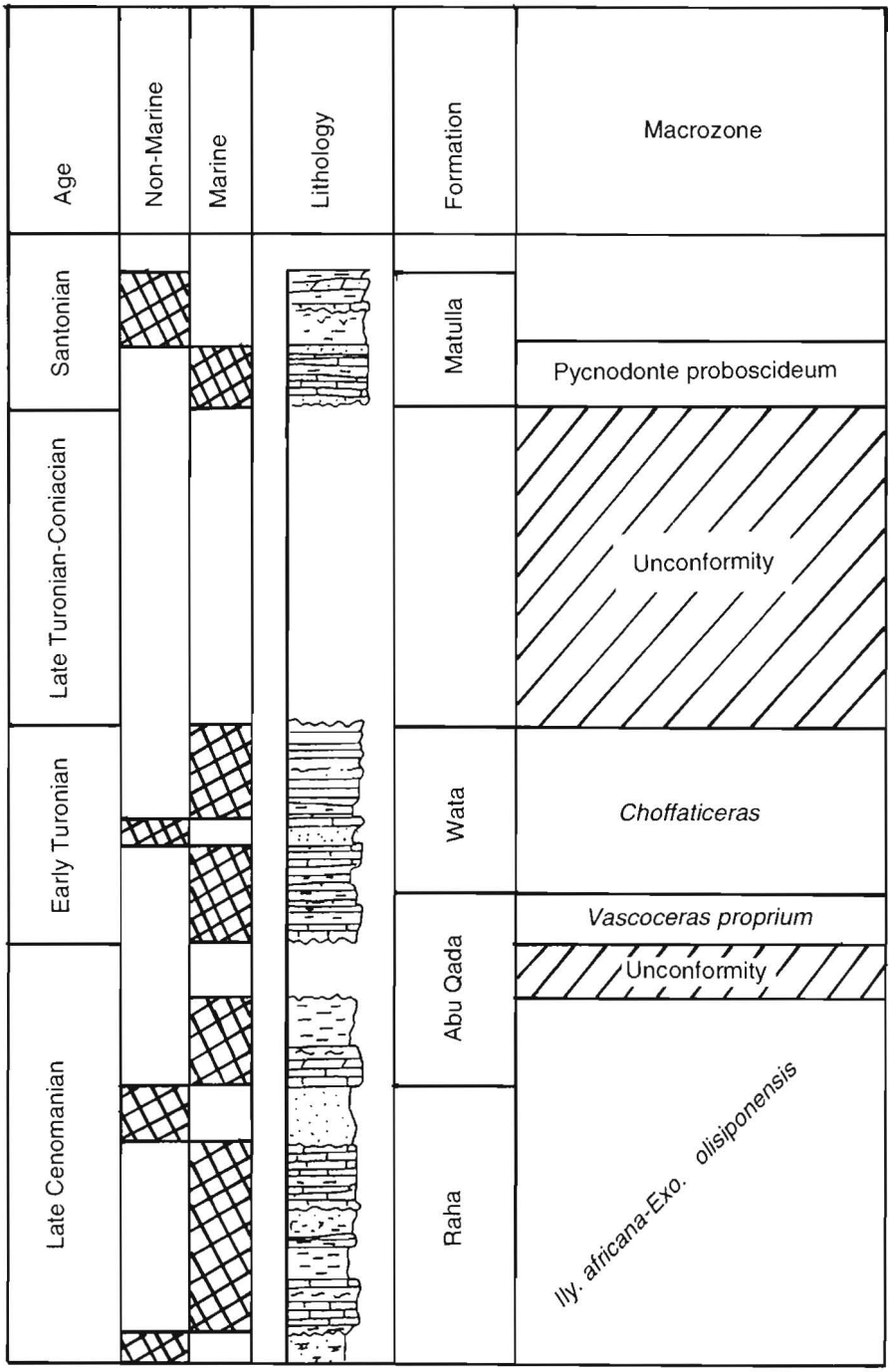

Fig. 5. The hiatuses and diastems depicted within the Upper Cretaceous Sequence of the study area.

macrozonation of the study area links it with regions from New Mexico, Nigeria, North Africa, Est Asia, Spain, and Portugal confirming its affinity to the Mediterranian Province of the Tethyan Realm.

It has been concluded that sedimentation of the Upper Cretaceous System in the study area was not continuous and was interrupted by several erosional episodes. This conclusion has been detected by the recognition of several minor breaks, probably diastem, within the Upper Cenomanian succession where they are represented by irregular surfaces within the Raha and Abu Qada Formations and also between them (Fig. 5).

A major stratigraphic gap is also traced along the Cenomanian/Turonian contact within the Abu Qada Formation. This means that the study area was probably uplifted and exposed by the end of Late Cenomanian time until the beginning of the Turonian when a marine transgression took place. Such a phase of erosion and non-deposition explains the absence of the Upper Cenomanian *Metoicoceras geslineanum* and *Vascoceras cauvini* Zones in the study area.

Once more, the study area was uplifted by the end of Early Turonian time. Consequently non-depositional episodes were prevailing until the transgression by the Santonian sea took place. Thus a major hiatus comprising the Upper Turonian and the Coniacian is well documented by the unconformable superposition of marine sediments of the Matulla Formation with Santonian fossils on marine sediments of the Wata Formation with Lower Turonian fossils.

It is believed that a combined effect of synsedimentary tectonism and sea-level fluctuations, probably an echo of the Laramide event, is responsible for such discontinuity episodes.

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بيوستراتجرافية الكريتاوي العلوي بمنطقة جبل مسبع سلامه- جنوب غرب سيناء - مصر

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[2] المركز الإقليمي للمساحة الجيولوجيه المصرية بقنا - مصر

يقدم هذا البحث تحليلاً طباقياً لتتابع الكريتاوي العلوي بمنطقة جبل مسبع سلامه-جنوب غرب سيناء- حيث أمكن تقسيم هذا التتابع إلى أربع وحدات صخرية هي متكون الراحه يعلوه متكون أبو قعده ثم متكون الوطا فمتكون المطله .

وإعتماداً على توزيع الحفريات الكبيره أمكن تقسيم التتابع إلي أربع نطاقات حيوية هي :

١- نطاق *Ilymatogyra africana-Exogyra olisiponensis* المتواجد في متكوني الراحه وأبوقعده والذي يدل على عمر سينوماني متأخر .

٢- نطاق *Vascoceras proporium* المصاحب للجزأ العلوي من متكون أبو قعده ويشير إلى العمر التوروني المبكر .

٣- نطاق *Choffaticeras* المتواجد في متكون الوطا والذي يدل أيضاً على التوروني المبكر .

٤- نطاق *Pycnodonte proboscideum* وتم تعريفه متكون المطلة مشيراً إلى العمر السانتوني .

ولقد تم مقارنة هذه النطاقات بمثيلاتها من بعض المناطق وتم إستنتاج فترات الإنقطاع في الترسيب hiatuses حيث تم التعرف على فترتي إنقطاع كبيرتين قبل وبعد التوروني المبكر ممثلتين في عدم الترسيب أثناء السينوماني المتأخر جداً لفترة قصيرة نسبياً ولفترة طويلة شملت التوروني المتأخر والكونياسي وذلك بالإضافة لعدد من أسطح عدم التوافق التي تم ملاحظتها متخللة تتابعات السينوماني المتأخر والتوروني المبكر .

ويعتقد أن المنطقة قد تأثرت بالنشاط البركاني المصاحب للحركة اللارمادية Laramide Orogeny والتي تسببت بدورها في رفع المنطقة خلال أزمنة التوروني المتأخر والكونياسي وعدم الترسيب .