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LITHO-AND BIOSTRATIGRAPHY OF THE CENOMANIAN-EARLY TURONIAN SUCCESSION AROUND THE GULFS OF SUEZ AND AQABA, EGYPT

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ABSTRACT

Lithological and biostratigraphical studies on three Cenomanian-early Turonian succession at Wadi Watir, west of the Gulf of Aqaba and at Gebel Qabeliat and Gebel Ataqa, east and west of the Gulf Suez, respectively have been carried out.

The Cenomanian Galala Formation is subdivided here into there members namely; the Abu Had (a sequence of fine siliclastics and carbonates), the Mukattab (a sequence comprising hard carbonate beds) and the El Hadida (a predominantly dolomitic limestone, marl and kaolin bed) members, corresponding tentatively to the previously established subdivision of the Raha Formation in west-central Sinai. The El Hadida Member (Galala Formation) differs from its chronologically equivalent Ekma Member (Raha Formation) in its carbonate nature instead of the Ekma Member.

The Cenomanian facies of the Raha/Galala Formation suggest an environment ranging from shallow marine to supratidal settings. However, the overlying facies of the early Turonian Abu Qada Formation showed relatively more deeper environment particularly at Wadi Watir and at Gebel Ataqa due to their enrichment in planktonic foraminifera in the former and the presence of ammonites in the latter.

At Gebel Qabeliat section, the Cenomanian rocks are separated from the Turonian by a hiatus in sedimentation. This unconformity surface is evidenced by the presence of glauconitic, silty limestone facies. Meanwhile, at Gebel Ataqa, continental sedimentation is demonstrate by the presence of a relatively thick kaolin bed indicating a warm humid climate with good drainage system.

Keywords: Cenomanian-early Turonian-Gulf of Suez-Gulf of Aqaba-Raha Formation-Galala Formation.

INTRODUCTION

The Cenomanian succession in the Gulf of Suez region has attracted the attention of many workers particularly who are interested in the field of petroleum geology. This interest has increased due to the fact that the Sadot gas field in northern Sinai, is located in Cenomanian limestone and dolomite beds. Since the beginning of this century, several publications have dealt with the litho- and biostratigraphy of the Cenomanian rocks of Egypt (e.g. Barron, 1907; Ball, 1916; Hume *et al* ., 1920; Moon and Sadek, 1923, 1925; Omara, 1956; Ghorab, 1961; Ansary *et al.*, 1962; El Dakkak,1973, 1974; El Shinnawi and Sultan, 1973 Wasfi and Hataba, 1984 and Cherif *et al.*, 1989).

The aim of this work is to carry out a detailed litho-and biostratigraphic studies on the Cenomanian-early Turonian at three different localities for correlation purpose. The samples were collected from Sheikh Attia section at the entrance of Wadi Watir west of the Gulf of Aqaba and from Gebel Qabeliat in west-central Sinai as well as from Gebel Ataqa (Wadi Maghra El Hadida) west of the Gulf of Suez (Fig. 1). The study is also carried out to identify rock types, depositional environments and to delineate both the lateral and vertical changes in the facies and faunal content.

The Cenomanian Raha Formation (Ghorab, 1961) at Wadi Watir section represents a complete marine sedimentary cycle and comprising from base to top; the Abu Had (Ghorab, 1961), Mukattab

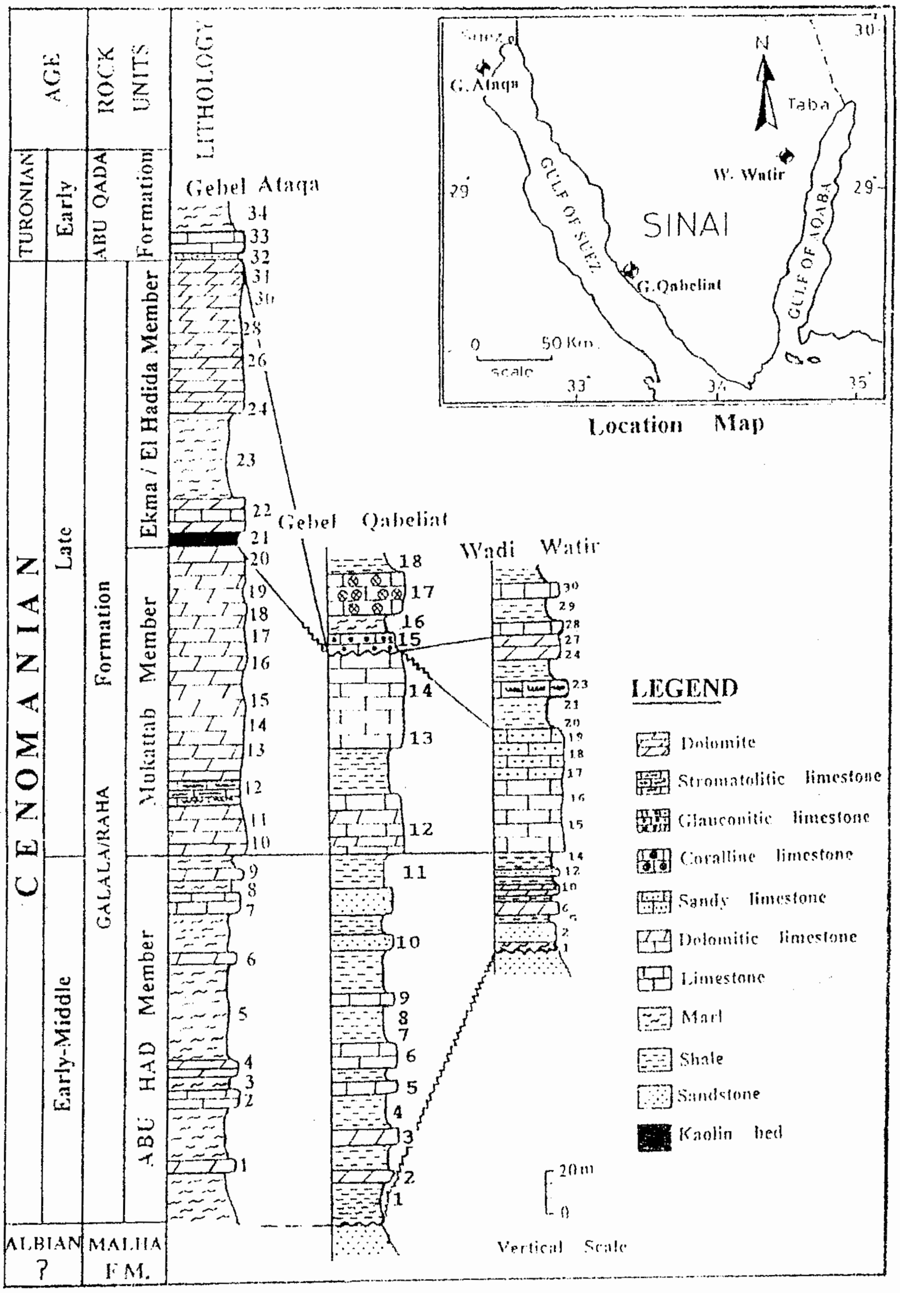


Fig. 1 : Correlation chart for the studied sections and location map

(Cherif *et al.*, 1989) and Ekma (Cherif *et al.*, 1989) members. This formation is represented by a lower clastic member, a thick middle carbonate member and an upper clastic member. It is conformably overlain by the early Turonian Abu Qada Formation (mainly limestone and shales) and unconformably underlain by the Albian? sandstones of the Malha Formation (Abdallah and Adindani, 1963).

At Gebel Qabeliat, the Raha Formation (Cenomanian) consists of alternating dolomite, shale and sandstone beds. It is separated from the overlying early Turonian rocks (Abu Qada Formation) by a hiatus in sedimentation corresponding to the Ekma Member (Cherif *et al.*, 1989) and unconformably underlain by the Malha Formation. The Abu Qada Formation is made up of glauconitic sandy limestone, marl, coralline dolomitic limestone and shales.

At Gebel Ataqa, the Cenomanian rocks belonging to the Galala Formation (Abdallah and Adindani, 1963), is similarly classified in the present work into three rock units; the Abu Had, Mukattab and El Hadida members. The El Hadida Member is introduced for the first time in this work to designate a sequence of dolomitic limestone, marl and kaolin bed that normally weathered into white, fine powder. It is differs from its chronologiclly equivalent Ekma Member in its carbonate nature instead of the clastic nature of the Ekma Member. This member is erected to replace Ekma in the western side of the Gulf of Suez. On the other hand the Mukattab members is identical in the both formations (Raha and Galala). These members resemble tentatively the classification of the Raha Formation which was previously introduced by (Cherif *et al.*, 1989) in west central Sinai.

At Gebel Ataqa the Malha Formation is unexposed in the studied section. Meanwhile, the Galala Formation is conformably overlain by a thick succession previously named Maghra El Hadida Formation by Akkad and Abdallah (1971). However, it is interesting to note that the lower part (about 55 m thick) of that formation yields ammonites of early Turonian age. Following Kerdany and Cherif (In Said, 1990), the lower part of the Maghra El Hadida Formation is ascribed to the Abu Qada Formation in the present study.

A total of 71 rock samples were collected from the three studied sections (Fig. 1) representing the Galala/Raha and Abu Qada formations. Particular attention was only given to the Cenomanian rocks for a detailed litho-and biostratigraphic studies. The Malha Formation is not considered here. The selected rock samples were thin sectioned, stained and examined under the polarizing microscope. The classifications of Folk (1959) and Dunham (1962) were used in describing composition and texture of the rocks. In each sample, the foraminiferal species were identified, and a total of 250 individuals of benthic forams were counted to provide sufficient representation for each population. The identification of foraminifera in thin sections (plate 4) is based on that showed in Schroeder and Neumann (1985).

LITHO-AND BIOSTRATIGRAPHY

Based on the petrographic study (plates 1-3) and the faunal content, each formation of the three studied Cenomanian-early Turonian sections will be discussed here separately;from base to top:

1. Raha/Galala Formation (Cenomanian)

1.1. Abu Had Member(early-middle Cenomanian)

At Waid Watir, this member is composed of alternating sandstones, shales, marl and dolomite beds. The petrographic study showed that these sandstones are represented by two lithofacies types:

a) Medium-grained quartz arenite (samples 2, 12) : It is composed of subanglular to subrounded quartz grains, highly fractured and cemented by iron oxides (pl. lc).

b) Coares-grained glauconitic quartz arenite(sample4; pl. Id) : It is formed of rounded to subrounded quartz grains cemented by calcareous material (ferroan dolomite) with some scattered granules. The quartz grains are highly fractured, mostly monocrystalline and sometimes have an undulose extinction. However, few quartz grains are polycrystalline.

The shales are yellowish white to yellow, moderately hard, flaky, highly fissile, sandy in parts, glauconitic and ferruginated. The marly beds are pale yellow,moderately hard and highly fossiliferous.

c) The dolomite facies (samples 6, 8, 10,) : It is formed mainly of fine-grained dolomite with some coarse-grained calcitic patches and few scattered large dolomite rhombs. The latter exhibits zoning with dark iron-oxide core and clear outer rim. Both the vuggy and intercrystalline porosities are common in these rocks.

The Abu Had Member at Wadi Watir attains a thickness of

27.2m and yields the following arenaceous forams : *Thomasinella punica* Schlumberger, *T. aegyptia* Omara, *T.fragmentaria* Omara, *Ammobaculites agrestis* Cushman and Applin, *A. impexus* Eicher, *Ammomarginulina paterella* Eicher, *Haplophragmoides gilbreti* Eicher, *H. globosa* Lozo , *Trochammina boehmi* Franke, *T. wetteri* Stelk and Wall, *T. inflata* (Montagu), *Spiroplectammina arabica* Said and Barakat, *S. laevis* (Roemer), *S. macfadyeni* Said and Barakat, *Marsonella oxycona* (Reuss) and *M. orbigini* Cuviller and Szakall.

In addition to the arenaceous forams few calcareous species represented by *Serrovaina beadnelli* (Said and Barakat) and *S. minutus* (Said and Kenawy) were recorded there.

At Gebel Qabeliat, the Abu Had Member is formed mainly of alternating carbonate and siliciclastic beds. The petrographic investigation has shown that the carbonate beds can be classified into the following lithofacies :

a) Dolomite facies (samples 2,3) : It is composed of medium to coarse-grained, euhedral to subhedral rhomb-shaped dolomite crystals. It is generally characterized by varing crystal sizes and shapes and has irregular crystal boundaries and patchy grain-size distribution. Some areas are irregularly stained with iron oxides and many dolomite rhombs contain iron-oxide inclusions to appear cloudy and dark-coloured (pl. 2 a).

b) Molluscan wackestone facies (samples 6,9) : It is composed of long pelecypod shells or shell fragments supported by a matrix of carbonate mud with some coarse-grained spary patches and microsparitic mosaics. The sediment is cut by thin veins and minor fractures which were secondary filled with coarse-grained ferroan and non-ferroan calcite. Some euhedral dolomite crystals are clearly visible in channel-like fractures. These dolomite rhombs are highly ferruginous with very clear zoning. Some skeletal grains were leached and some pores were later filled with iron-oxides and secondary gypsum.

In the upper part of this member, the sequence is dominated by fossiliferous calcareous sandstone, shales, marls and limestones yielding oyster banks of *Ilymatogyra (Afrogyra) africana* (Lamarck), *Amphidonte (Ceratostreon) flabellatum* (Goldfuss) and *Exogyra (Costagyra) olisiponensis* (Sharpe).

The Abu Had Member at Gebel Qabeliat reaches about 88 m thick and contain abundant arenceous foraminifera such as : *Haplophragmoides fraseri* Wickenden, *Thomasinella punica* Schlumberger, *T. fragmentaria* Omara, *T. aegyptia* Omara, *Trochammina boehmi* Franke and *Hemicyclammina evoluta* Hamaoui.

At Gebel Ataqa, the Abu Had Member is composed of yellowish green marls, dolomite and limestone beds. petrographically, the identified carbonate lithofacies include :

a) Silty dolomite facies (samples 1,4,6): It is consist mainly of fine-grained dolomite with few coarse, euhedral dolomite crystals. Detrital quartz silt-particles, angular to subangular, are scattered throughout. The lower part of this facies (sample 1) is characterized by dessication cracks which were probably originated by repeated wetting and drying. Meanwhile, the middle part (sample 4) is highly porous; intercrystalline, vuggy and mouldic porosities are the main types. In the upper part (sample 6; pl. 1b) the silty dolomite is composed of alternating silty laminae and carbonate mud which is diagenetically replaced by fine-grained dolomite crystals. Laminoid fenestrae are associated with algal stromatolites and silt quartz grains.

b) Molluscan packstone/grainstone facies (sample 2) : The grains supporting this facies include bioclasts (mainly pelecypods and gastropods), intraclasts (doloclasts), pelloids and few ooids. Few angular to subangular, quartz silt particles and large rhomb dolomite crystals scattered throughout. Some voids are filled with sparry calcite crystals.

c) Foraminiferal packstone facies (sample 7) : The bioclasts of this facies comprise a large number of benthic foraminifera (e.g *Praealveolina cretacea* pl.4, fig.6) and few micro-gastropods embedded in a micritic fine-grained carbonate material.

The Abu Had Member of Gebel Ataqa reaches about 85m thick and yields banks of *Ilymatogyra (Afrogyra) africana* (Lamarck), *Exogyra (Costagyra) olisiponensis* (Sharpe) and *Hemiaster humei* Fourtau.

In addition to the *Prealveolina cretacea* identified in thin section, the separated arenaceous foraminifera includes : *Haplophragmoides excavatus* Cushman and Waters, *H. globosa* Lozo, *H. olusaensis* Cushman and Goudkoff,*Spiroplectammina macfadyeni* Said and Barakat, *S. regalis* Said and Barakat, *Hemicyclammina evoluta* Hamaoui, *H. sigali* Hamaoui, *Ammomarginulina paterlla*

Eicher and *Thomasinella punica* Schlumberger.

1.2. Mukattab Member (late Cenomanian)

This member was intorduced by Cherif *et al.*, (1989) to designate a cliff formed mainly of calcareous sequence in west-central Sinai.

At Wadi Watir, this member reaches about 30m in thickness and comprises the following carbonate lithofacies:

a) Lime mudstone facies (sample 15) : It is consist of fine-grained calcitic matrix with few bioclasts and quartz grains. Fractures and void spaces produced by mouldic porosity are filled with secondary sparry calcite.

b) Foraminiferal packstone/grainstone facies (sample 16): This facies is highly rich in foraminiferal species with few echinoid and shell fragments. Calcitic matrix is mostly replaced by coarse-gained calcite crystals. Mouldic and intergranular porosities are secondary replaced by coarse mosaic calcite crystals.

c) Silty packstone facies (samples 17,19): The grains supporting this facies include bioclasts, intraclasts and pelliods. The whole components are embedded in ferruginous micritic, binding material. Fractures and interparticle porosities are filled with coares-grained calcite crystal. In the upper part of this facies (sample 19) some fractures are filled with secondary silica.

The foraminiferal species separated from this member include : *Trochospira avenimelechi* Hamaoui and Saint Marc, *Pseudorhipidionina casertana* De Castro, *Biconcava bentori* Hamaoui and Saint Marc, *Nezzazata simplex* Omara, *N. convexa* (Smout), *N. gyra* (Smout). *N. conica* (Smout) and *Quinqueloculina cf. sandiegoensis* Sliter. In addition species of *Chrysalidina gradata* D,Orbigny, *Pseudolituonella reicheli* Marie, *Pesudorhipidionina casertana* De Castro, *Massilina* sp. *Hedbergella* sp. and P*seudedomia drorimensis* Reiss identified in thin section.

At Gebel Qabeliat, the Mukattab Member reaches about 50m in thinkness and consists of highly crystalline limestone and dolomitic limestone. The following lithofacies are recognized :

a) Molluscan dolomitized wackestone facies (sample 12) : The bioclasts are composed mainly of long pelecypod shells with laminated structure. They are embedded in dolomitic microsparite mosaic with coarse-grained recrystallized calcite patches. Two generations of dolomite crystals are recognized; the first is characterized; by a very large ferroan-dolomite crystals with clear zoning and the second includes small dolomite crystals. Some secondary pores are filled with sparry calcite cement.

b) Bioclasts grainstone facies (sample 13) : The grains are mainly bioclasts (pelecypods, gastropods, echinoids, bryozoas and algae) with some pelloids, all embedded in a fine-grained micrite. Evidences of burrowing, dessication cracks and algal lumping are noticed. Fractures and pores are filled with large, well zoned, dolomite rhombs that stained with iron oxides. However, some voids are filled with large, sparry calcite crystals.

c) Packstone facies (sample 14; pl.2d) : In this lithofaacies, the allochems include echinod plates and spines, pelloids, bryozoas and unknown, highly crystallized bioclasts. The grains are supported by a matrix of carbonate mud in which some pores are filled with coarse sparry calcite. Evidence of boring (sometimes filled with dolomite rhombs) is also seen.

No foraminiferal species are recorded in the washed residues of this member, except some Nezzazatinae which are recognized in thin sections.

At Gebel Ataqa, this member reaches about 70 m in thickness and consists of algal limestone, and dolomite. The recorded lithofacies include:

a) Stromatolitic wackestone facies (sampl 12) : The grains consist of few pelecypod shells with scattered pelloids embedded in a fine-grained micrite. Algal laminations are alternating with carbonate mud in which few quartz grains and some scatered dolomite rhombs are present. Some gypsum nodules and iron oxide spots are common.

b) Dolomite facies (samples 14-17) : This lithofacies is composed of an alternating coarse to fine-grained dolomite crystals. The original calcite matrix has been wholly replaced by dolomite. In coarse-grained varieties euhedral rhomb- shaped dolomite crystals indicate partial repacement of calcite. Medium-grained dolomites are characterized by idiotopic to mesotopic texutres (pl. la). Dolomicrites with very small crystal sizes are characterized by fenestral and denderitic shape porosity filled with manganese oxides. However, several types of porosity are recorded in these facies (intercrystalline,fenestral and vuggy).

c) Dedolomite facies (sample 20; pl. 2c) : Evidence of dedolomitization has been observed in this facies. The former dolomite crystals are replaced by calcite, usually by the action of oxidizing meteoric water, leading to rhomb-shaped crystals of calcite, which are usully filled with brown inclusions of iron oxides. Micritic calcite material occurs between the rhomb-shaped areas.

The Mukattab Member at Gebel Ataqa yields the following mega-invertebrates : *Ilymatogyra (Afrogyra) africana* (Lamarck), *Amphidonte (Ceratostreon) flabellatum* (Goldfuss) and *Exogyra (Costagyra) olisiponensis* (Sharpe). As well as it yields the following foraminiferal species : *Ammobaculites mosbyensis* Eicher, *A. fragmentarius* Cushman, *A. agrestis* Cushman and Applin, *A. subplanatus* Cushman and Deaderick, *A. plummerae* Loeblich, *A. rowei* Banner, *A. subcretaceus* Cushman and Alexander, *A. difformis* Hamaoui, *A. albertensis* Stelck, *Haplophragmoides colusaensis* Cushman and Goudkoff, *H. calculus* Cushman and Waters, *H. bulloides* (Beissel), *H. excavatus* Cushman and Waters, *Trochammina wetteri* Stelk and Wall. *Ammomarginulina paterella* Eicher, *Spiroplectammina macfadyeni* Said and Barakat, *Biconcava bentori* Hamaoui and *Trochospira avenemelechi* Hamaoui and Saint-Marc, in addition to *Orbitolina (Orbitolina) concava* (Lamarck) which is idenified in thin section.

1.3. Ekma / El Hadida Member (late Cenomanian)

The Ekma Member was intorduced by Cherif *et al.*, (1989) and its facies represent a regressive phase particulary in west central Sinai. It overlies the hard, cliff-forming Mukattab limestone at Wadi

Watir section, but it is absent at Gebel Qabeliat as a result to either continental erosion or to non-deposition episode (Cherif *et al.*, 1989).

At Gebel Ataqa section, the El Hadida Member is overlies the Mukattab Member and represents a phase of continental sedimentation.

At Wadi Water, this member reaches about 24m in thickness and yields no foraminifera. The identified carbonate lithofacies include the following :

a) Stromatolitic mudstone facies (sample 23; pl. 3a) : This facies composed of few, small bioclasts embedded in a fine-grained micrite. Algal stromatolites associated with dessication cracks are recorded. Some fractions and small rounded vugs are the main types of porosity.

b) Dolomicrite facies (sample 24) : It is represented by very small dolomite crystals with small vuggy pores.

At Gebel Ataqa section, the El Hadida Member reaches about 65m think and it is made up of dolomitic limestone with some gypsum intercalation, marl and thick (3m) kaolin bed at the base which is normally weathered into white, fine powder. No foraminiferal species are recorded from this member. The recognized carbonate lithofacies include the following :

a) Dolomitic grainstone facies (sample 22; pl. 3c) : The grains consist of several types including pelloids, ooids, bioclasts and intraclasts. The whole components are cemented by sparry calcite mosaic, with some patches of dolomitized micritic matrix. Mouldic and itergranular porosities are recognized, although some pores are filled with sparry calcite cement.

b) Recrystallized dolomite facies (samples 24-27) : The dolomite rhombs of this facies range from very fine to very coarse crystal sizes. The very fine grained dolomites are usually associated with gypsum nodules and halite vugs while the very coarse grained variety is characterized by non-ferraon dolomite with xenotopic and mesotopic textures. These dolomites are highly porous with abundant vuggy and intercrystalline porosities. At the upper part of this member (sample 27), some very coarse-grained, dedolomitized rhombs are recognized there (pl. 2 b)

2- Abu Qada Formation (early Turonian)

At the Gulf of Suez region, Ghorab (1961) established this rock unit, where it overlies the Raha Formation (Cenomanian). The Abu Qada Formation consists mainly of shales, marls and limestone beds and it represents a phase of increasing sea level. At Wadi Watir, this rock unit lies conformably on the Raha Formation (Orabi, 1992) and unconformably overlain that formation at Gebel Qabeliat (Cherif *et al.*, 1989).

Although Akkad and Abdallah (1971) established Maghra El Hadida Formation (Turonian) as a new rock unit conformably overlies the Galala Formation at Gebel Ataqa, however, Kerdany and Cherif (In Said, 1990) assigned the lower part (about 55m) of this formation to the Abu Qada Formation, where it yields ammonites of early Turonian age. However the early Turonian Abu Qada Formation is only considered in the present work.

ENVIRONMENTAL INTERPRETATION

The Cenomanian facies demonstrate a sequence of environment ranging from shallow marine to supratidal settings. The overlying early Turonian facies of the Abu Qada Formation, however, suggest a relatively more deeper environment particularly in the area of Wadi Watir and at Gebel Ataqa. This conclusion is attributed to the enrichment of the early Turonian carbonate facies of Wadi Watir by planktonic foraminifera and echinoids in the carbonate rocks of Gebel Ataqa. Unlikely, the presence of glauconitic, silty limestone and coralline boundstone (pl. 3b) at Gebel Qabeliat points to more shallower environment. Figures 2-4 show the distribution of different genera in the three studied sections

For the purpose of the present work, the depositional environments for each member of the Cenomanian succession and the early Turonian Abu Qada Formation in the three studied areas will be discussed here separately from base to top :

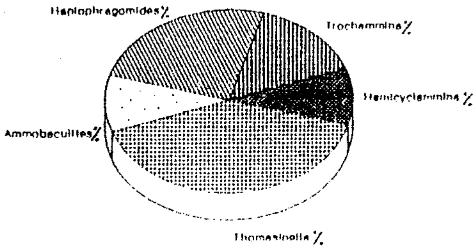
1. Raha/ Galala Formation (Cenomanian)

1.1. Abu Had Member

At Wadi Watir, the base of this member consisits of reddish medium-grained quartz arenite with ferruginous cement grading upward to coarse-grained quartz arenite cemented by ferroan dolomite. The red colour of the clasts indicates their through oxidation prior to deposition and burial, and therefore this interval is interpreted as an exposure surface, developed during a period of offlap on the platform. The overlying coarse-grained sandstone with

Fig.(2) Foraminiferal distribution in Gebel Qabeliat

Gebel Qabeliat
Abu Had Member



C
Gebel Qabeliat
(Total distribution)

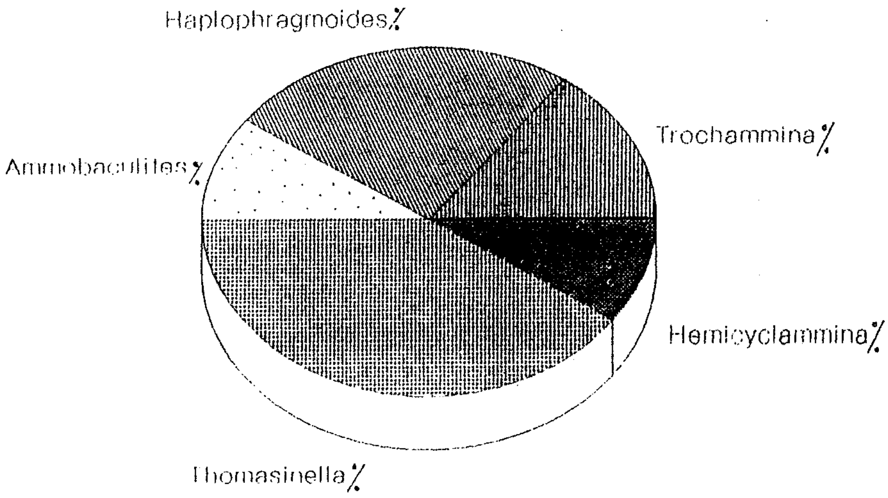


Fig.(3) Foraminiferal distribution in Gebel Ataqa

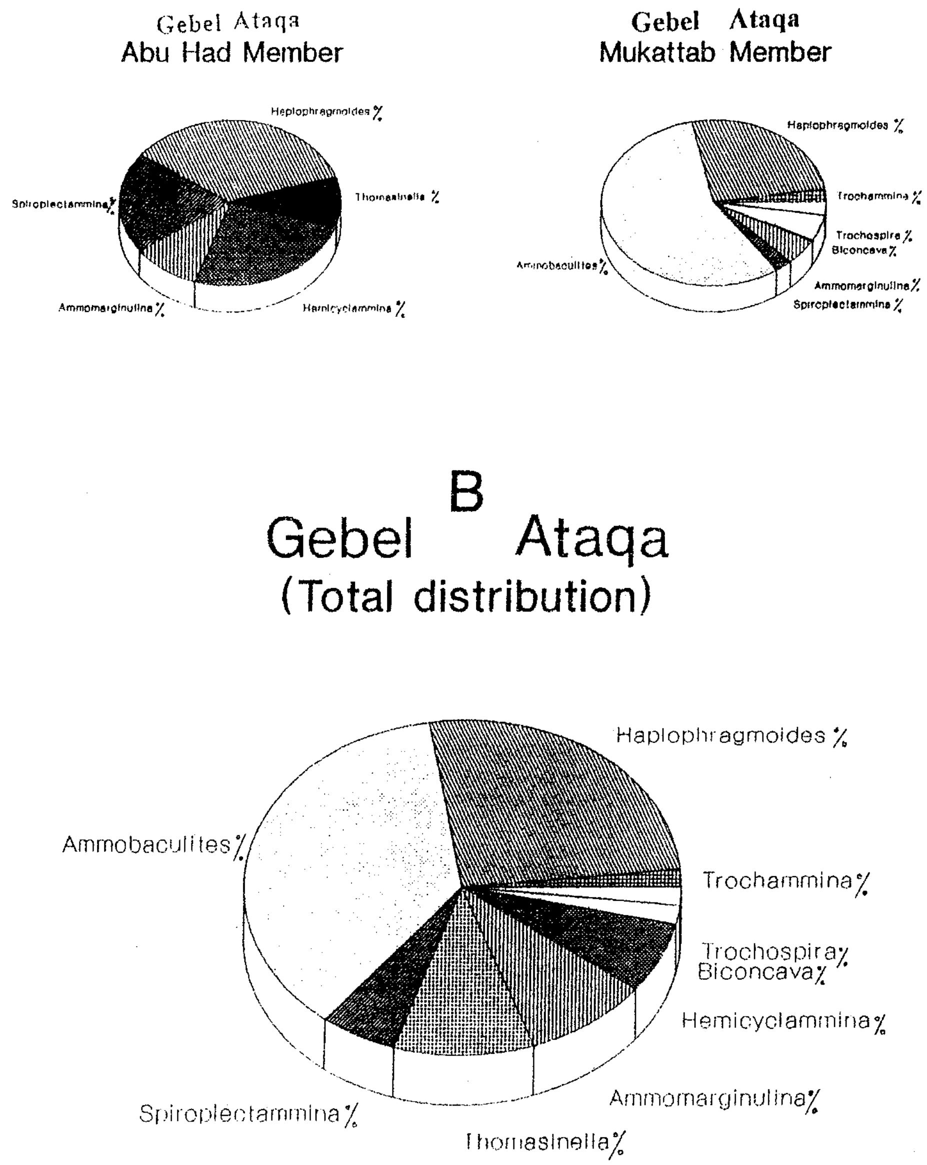
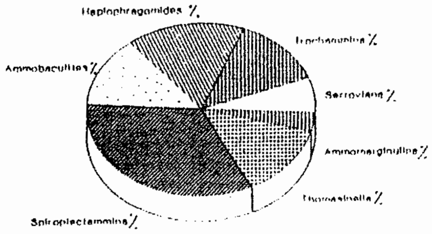
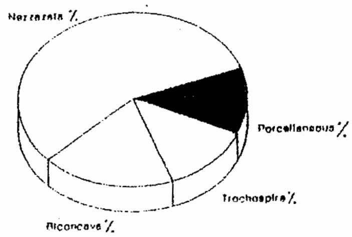


Fig.(4) Foraminiferal distribution in Wadi Watir

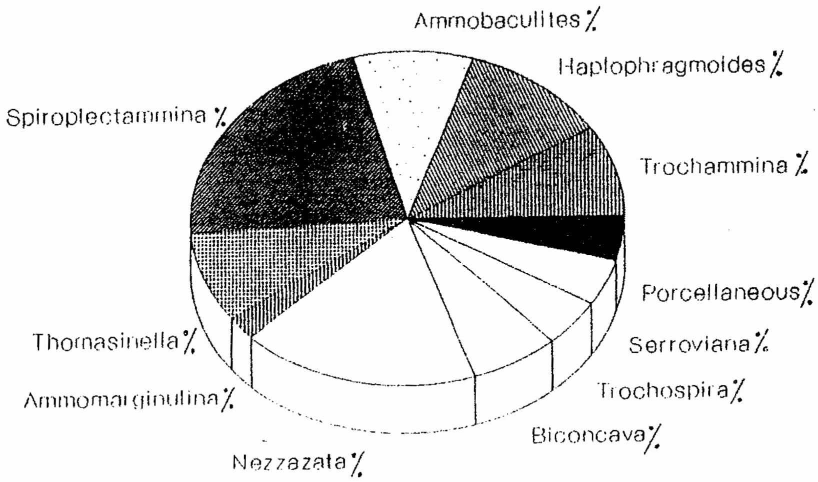
Wadi Watir
Abu Had Member



Wadi Watir
Mukattab Member



A
Wadi Watir
(Total distribution)



calcareous cement and scattered glauconite granules imply a renewed shallow marine onlap on the platform.

The middle and upper part of this member is dominated by a sequence of very fine to fine crystalline dense dolostones seldom have any recognizable faunal constituents and exhibit sedimentary features that are indicative of coastal sabkha environments. The presence of some coarse-grained calcitic patches and few scattered large dolomite rhombs are linked to recrystallization through diagenetic process. However, the dominance of *Thomasinella* spp. and *Ammobaculites* sp. at some soft horizons in this member suggests tidal flat to marsh environment (Parker and Athearn, 1959; Phleger, 1960; Bandy, 1963). The predominance of agglutinated foraminifera (≈ 93% of the total forams) with some calcareous hyaline species (Fig. 2) suggests a hyposaline marshes (Murray, 1971). On the other hand, the presence of some calcareous tests (*Surroviana)* in the upper most shaly part of this member implies that these shales were deposited during a relatively deeper episodes, inner shelf (Murray, 1971).

At Gebel Qabeliat, the Abu Had Member consists of alternating carbonate and siliciclastic beds. The carbonates are represented by medium to coarse-grained dolomite and molluscan lime-wackestone facies which are frequently burrowed. These dolomitized mudstone and burrowed wackestone facies are indicative of protected lagoonal to subtidal environments.

The secondary dolomite shows evidences of having formed at or slightly above the normal high tide, but not in an area so dessicated that evaporites were able to from. On the other hand, the limestones are a lighter-coloured bioclastic wackestone that is extensively mottled with burrows, reflecting renewed subtidal deposition.

In marked contrast to the carbonate horizons, the intercalated shales are yellowish, green sandy in parts. No calcareous fauna are recorded in this member, however, agglutinated taxa of *Thomasinella* spp., *Trochammina* sp. and *Haplophragmoides* sp. are present. These forms suggest littoral, brackish water and marshy environment (Murray, 1971). The absence of calcareous tests and the enrichment of this member with agglutinated formas is probably attributed to the effect of postmortem disslution in brackish water (Apthorpe, 1980).

At Gebel Ataqa, the Abu Had Member is predominated by a silty dolomicrite facies intercalated by a molluscan and foraminiferal packstone facies. However, the contacts between dolomicrite and the limestone units above and below are usually sharp.

The silty dolomites occur as irregularly laminated, alternating light and dark gray dolomicrite bands containing stromatolites. Mud cracks are present, indicating periodic desiccation at that time. The existance of stromatolitic structure, fenestral fabrics and mud cracks points to deposition in a peritidal mud flat setting. The intercalated lighter-coloured bioclastic packstone facies that are extensively mottled with burrows reflect renewed subtidal deposition.

The dominance of some aggutinated foraminiferal fauna such as *Haplophragmoides* spp. in the upper most part of this member indicates deposition in cold water at shallow depths (Glaessner, 1945); and probably water of less than normal marine salinity (Eicher, 1967) and lower pH (Bandy, 1956).

Figs. (2-4) show that the Abu Had Member at Gebel Qabeliat and Gebel Ataqa sections has higher percentage of agglutinated foraminifera compared to that of Wadi Watir section which has some calcareous benthonic forams. This suggests that subsidence was less active in the former two areas than the area of Wadi Watir where the depth of the sea was relatively high.

1.2. Mukattab Member

At Wadi Watir, the lower part of this member consists of homogeneous, lime mudstone with few quartz grains suggesting a protected lagoonal environment. It is succeeded upward by a foraminiferal packstone and silty packstone facies containing bioclastic debris and intraclasts embedded in a ferruginous micrite, recording a renewed marine onlap into the area. The recognized sedimentary features in these facies are indicative of shallow water depositional environments. The presence of the faunal Nezzazatinea association, further, suggests a sublittoral environment in a warm sea (Hamaoui in Schroeder and Neumann, 1985)

At Gebel Qabeliat, the Mukattab Member is dominated by a highly crystalline, fossiliferous limestone and dolomitic limestone facies. These fossiliferous rocks suggest a shallow-water origin. The subtidal deposition of these facies is demonstrated by a variety of primary depositional fabrics such as parallel laminations and by faunas. However, at the middle part of the sequence, features such as burrowing, desscation cracks and algal lumping suggest some periodic desication at this horizon. In addition, the bioclastic carbonate grainstone facies is inter-preted to represent a shallow subtidal shoal agitated by current and wave action.

At Gebel Ataqa, this member consists mainly of algal stromatolitic limestone and dolomite having various crystal sizes of dolomite rhombs. The presence of stromatolitic wackestone with algal lamination and scattered quartz grains suggests that these limestones are deposited in the intertidal zone. The intertidal areas are characterized by a well laminated carbonates contain various types of stromatolites. These laminations are distinctive of the algal-flat environment where they are subsequently buried by supratidal sediment and dolomitized.

On the other hand, the fine grained dolomites of sabkha origin that having different sizes of dolomite rhombs are attributed to recrystallization processes. The very fine crystalline nature of these dolomites, the presence of evaporite nodules and the rounded shape of porosity indicate their deposition in a supratidal to intertidal environments. The presence of *Ammobaculites* spp. in this member suggests a brackish-water environment as these species are known to be a detritvore preferring organic rich sediments (Bandy, 1956; Ellison and Murray, 1987).

The presence of Nezzazatinae in the Mukattab Member of the three studies sections represents a phase of slight increase in depth of the sea over all the areas. On the other hand, the presence of some planktonic foraminifera in thin sections at Wadi Watir, may point to subsequent connection to the open sea. Meanwhile, the presence of agglutinated foraminiferal species in the sediments of Gebel Ataqa section suggests more shallower environment than that prevailed at Wadi Watir section.

1.3. Ekma / El Hadida Member

The facies association of the Ekma and El Hadida members in the studied localities represents a phase of regression of the sea. The absence of foraminifera with occasional presence of oysters, suggests that this member was laid down in a very shallow infra-littoral environment or in a tidal flat setting. Moreover, at Gebel Qabeliat the Ekma Member seems to be suffered from erosion or to non-deposition episode.

At Wadi Watir section, the carbonate facies of the Ekma Member are represented by stromatolitic mudstone and dolomicrite facies. The presence of algal stromatolite limestone with dessication cracks and the absence of foraminifera in this part of the member points to periods of subaerial exposure in a tidal flat environment. On the other hard, the overlying dolomicrite facies,with some rounded pores filled with gypsum, represents a phase of regression and deposition in a supratidal or sabkha environment.

At Gebel Ataqa, the base of the El Hadida Member is dominated by a thick kaolin bed (about 3 meters in thickness) that normally weathered into white, fine powder. This bed represents a phase of continental deposition in warm, and humid climate with good drainage system. In marked contrast to the kaolin bed, the overlying dolomitic grainstone facies with abundant bioclasts and ooids reflects renewed subtidal deposition in high energy platform. The overlying recrystallized, originally fine-grained dolomite facies with gypsum nodules and halite vugs, indicates a supratidal sabkha environment. Extensive evaporation along sabkha areas causes concentration of brines and precipitation of gypsum and halite which are considered toxic elements unfavourable for living of foraminifera.

2. Abu Qada Formation (early Turonian)

The facies association and faunal content of the Abu Qada Formation at the three studied localites exhibit sedimentary features that are indicative of relatively more deeper environment than that prevailed during the Cenomanian and therefore, represents a renewed phase of transgression. At Wadi Watir, this formation is represented by fossiliferous limestone and shale interbeds rich in planktonic foraminifera, while at Gebel Ataqa it consists of fossiliferous calcareous sandstone and marl beds with ammonite species and echinoids.

Apparently, the unconformity surface recognized between the late Cenomanian Mukattab Member and the overlying early Turonian Abu Qada Formation at Gebel Qabeliat is evidenced by the presence of glauconitic, silty limestone facies (Pl. 3d). This errosional surface is overlain by a sequence of fossiliferous marl, coralline limestone and shales which reflect renewed subtidal deposition of early Turonian marine transgression.

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PLATE 1

a- Photomicrograph showing medium- grained, recrystallized dolomite with intercrystalline porosity. Sample 17, Mukattab Member, Gebel Ataqa, C.N., X30.

b-Photomicrograph showing a highly porous silty dolomicrite with fenestral and mouldic porosities. Sample 6, Abu Had Member, Gebel Ataqa, C.N., X30.

c- Photomicrograph showing a medium- grained, ferruginous, quartz arenite. Some quartz grains are highly fractured. Sample 2, Abu Had Member, Wadi Watir section, C.N., X30.

d- Photomicrograph showing a coarse- grained, quartz arenite cemented by ferroan dolomite. Sample 4, Abu Had Member, Wadi Watir section, C.N., X30.

PLATE 2

a- Photomicrograph showing dolomite rhombs occur as euhedral crystals with ferruginous dark - coloured, cloudy centers and clear outer rim. Sample 3, Abu Had Member, Gebel Qabeliat, C.N., X60.

b- Photomicrograph showing very coarse- grained dedolomitized carbonates with vugy and intercrystalline porosities. Sample 27, El Hadida Member, Gebel Ataqa, C. N., X60.

c- photomicrograph showing dedolomite (former dolomite is replaced by calcite) usually formed by the action of oxidizing meteoric waters and leading to rhomb- shaped calcite crystals with dark inclusions of iron oxides. Sample 20, Mukattab Member, Gebel Ataqa, C.N., X60.

d- Photomicrograph showing wackestone facies with clear intragranular and mouldic porosities. Sample 14, Mukattab Member, Gebel Qabeliat, C.N., X30.

PLATE 3

a- Photomicrograph showing algal, stromatolitic lime mudstone. Note wavy lamination. Sample 23, Ekma Member Wadi Watir section, C.N., X30.

b- Photomicrograph showing coralline limestone, the internal structure of corals is partialy filled with sparry calcite crystals. Sample 17, Abu Qada Formation, Gebel Qabeliat, C.N., X30.

c- Photomicrograph showing dolomitic grainstone facies, Note vague

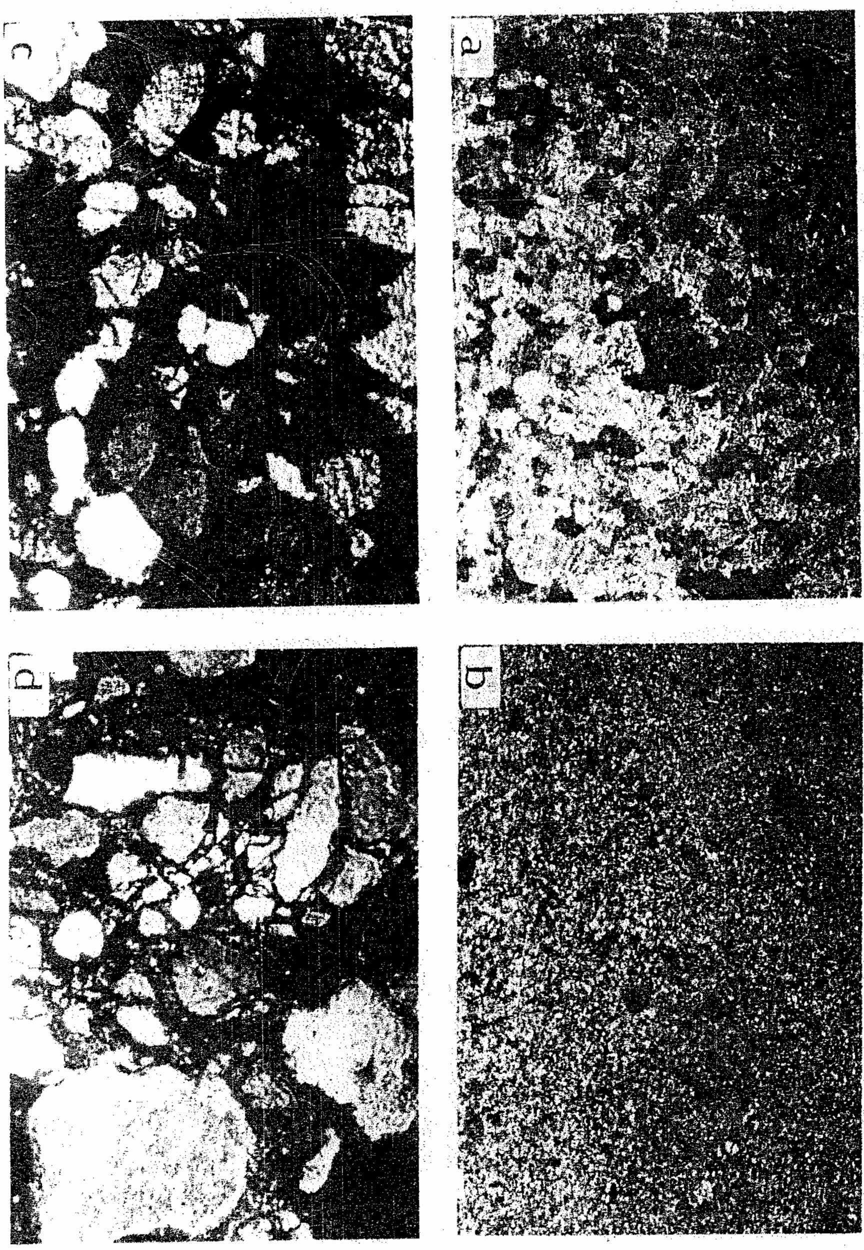

PLATE 1

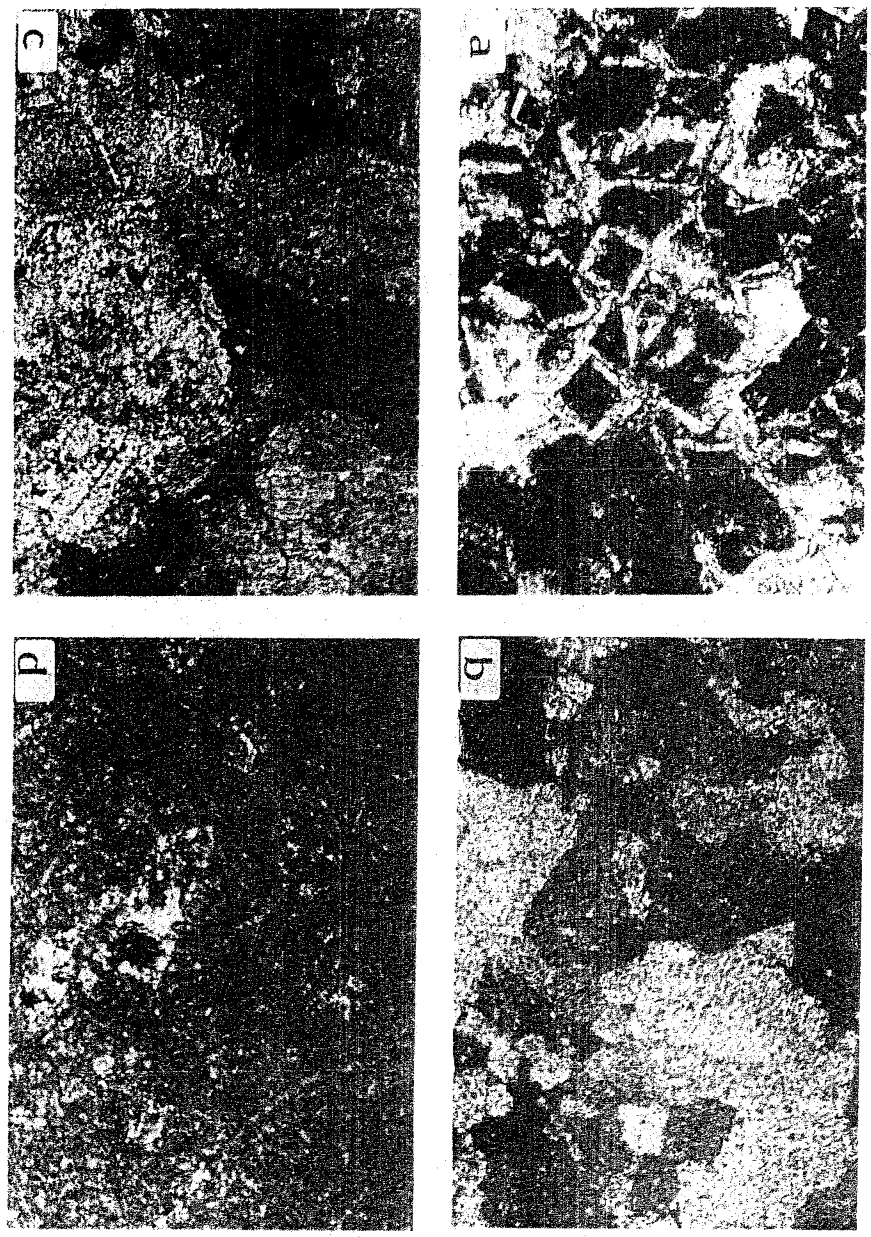

PLATE 2

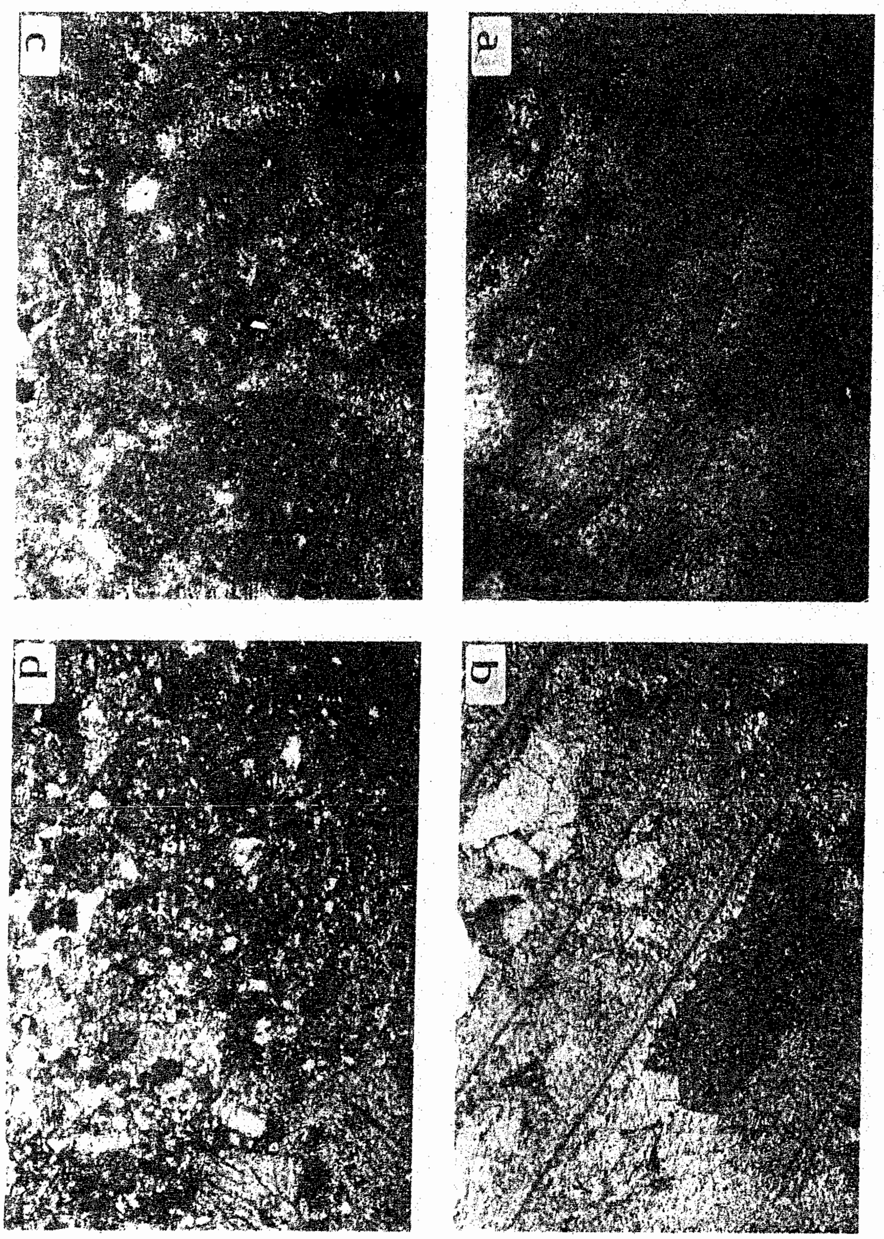

PLATE 3

appearance of grains due to dolomitization effect. Sample 22, El Hadida Member, Gebel Ataqa, C.N., X30.

d- Photomicrograph showing silty glauconitic limestone. Note glauconite granules and iron oxide stains. Sample 15, Abu Qada Formation, Gebel Qabeliat, C.N., X30.

PLATE 4

1- *Pseudedomia drorimensis* Reiss, Hamaoui & Ecker, Mukattab Member (Raha Formation), Wadi Watir, subequatorial section, X60.

2- *Orbitolina (Orbitolina) concava* (Lamarck), Mukattab Member (Galala Formation), Gebel Ataqa, axial section, X40.

3- *Pseudorhipidionina casertana* (De Castro), Mukattab Member (Raha Formation), Wadi Watir, oblique subequatorial section, X80.

4-*Biconcava bentori* Hamaoui & Saint-Marc, Mukattab Member (Galala Formation), Gebel Ataqa, subeqatorial section, X80.

5-*Pesudolitunella reicheli* Marie, Mukattab Member (Raha Formation), Wadi Watir, axial, X60.

6- *Praealveolina cretacea* (D.Archiac), Abu Had Member (Galala Formation), Gebel Ataqa.

a- Oblique transverse section cutting a zone with two rows of secondary chamberlets, X80.

b- Axial section, X60.

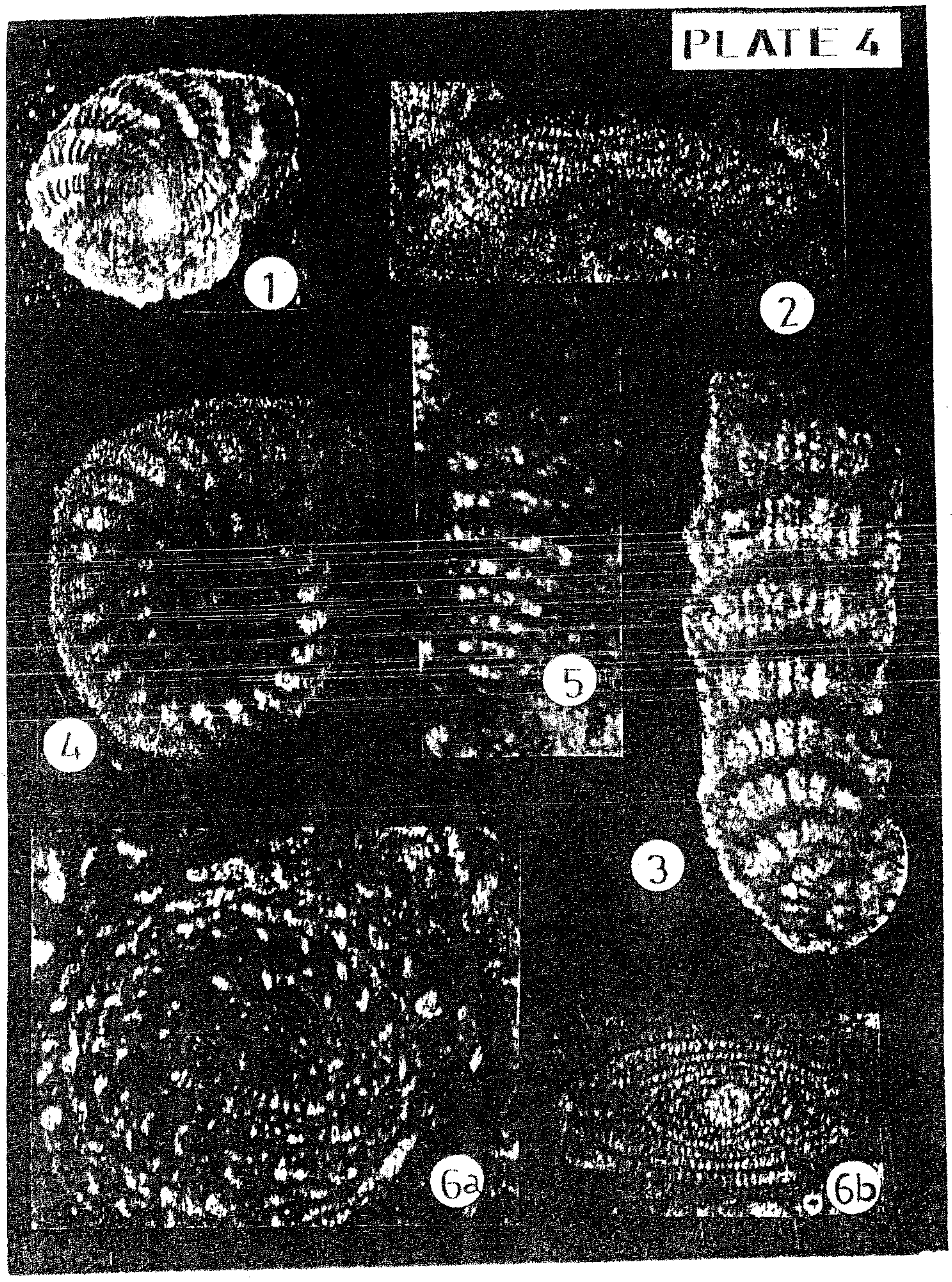
PLATE 4
1
2
3
4
5
6a
6b

ليثوبيو استراتجرافى لتتابع السينومانى - التورونى المتقدم حول خليجى السويس والعقبة - مصر

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يتناول البحث دراسة التتابعات الليثولوجية والبيواستراتجرافية للسينومانى - التورونى المتقدم لثلاثة قطاعات سطحية جمعت من وادى وثير (خليج العقبة) جبل قابليات وجبل عتاقة (خليج السويس) وقد امكن تقسيم تكوين الجلالة بجبل عتاقة الى ثلاثة اعضاء هى عضو ابوحاد (صخور فتاتية وكربوناتية) وعضو مقطب (صخور كربوناتية) وعضو الحديدة (حجر جيرى دولوميتى ومارل وكاولين) وهذا التقسيم يتشابه مع تقسيم تكوين الراحة السابق فى منطقة غرب وسط سيناء مع وجود اختلاف فى المحتوى الليثولوجى لعضو الحديدة عن عضو عكمة (صخور فتاتية).

وبدراسة البيئات القديمة امكن استنتاج ان بيئة ترسيب كل من تكوين الراحةوتكوين الجلالة (سينومانى) تتراوح بين البيئات البحريةالضحلة ومنطقة المد (supratidal) بينما تدل بيئة ترسيب تكوين ابو قاعدة (تورونى متقدم) على انه اعمق نسبيا عند كل من قطاع وادى وثير ونظرا لوفرةالفورامنيفرا الهائمة وجبل عتاقة لوجود الأمونيات فى الطبقات السفلى منه بينما لوحظ عند جبل قابليات وجود سطح عدم توافق بين السينومانى و التورونى المتقدم ممثل فى عدم ترسيب او تاكل عضو عكمة(سينومانى علوى) .