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SEDIMENTOLOGICAL AND PALEO-ENVIRONMENTAL STUDIES ON THE EOCENE LIMESTONES IN THE NORTHERN PLATEAU OF BAHARIYA OASIS, WESTERN DESERT, EGYPT

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ABSTRACT

Detailed investigation of the three Eocene formations in the Northern Plateau revealed remarkable differences in their biogenic and lithologic characters. Eleven different microfacies associations have been recognized. Lime mudstone, wackestone, packstone and crystalline carbonate (dolostone) are the rock textures existing. They show distinctive and significant distribution among the three formations.

The Eocene limestones represent a carbonate bank (biostrome) developed on a shallow marine shelf. They were deposited under gently to slightly agitated water conditions. During parts of the life history of the bank, intense vital activity had dominated in places and a reefal environment prevailed. Minor regressions and transgressions of the sea, which were more remarkable at all formation boundaries, resulted in the occasional development of restricted, back-reef lagoons.

INTRODUCTION

Bahariya Oasis represents one of the most important occurrences of the Eocene rocks in the Western Desert, Egypt. These rocks, which are designated "Plateau Limestone" (Said, 1962), cover an extensive tract particularly in the northern plateau of the oasis where they are encountered both in the walls of the escarpments and in the isolated hills within the depression. The oasis had been subjected to uplifting that gave rise to a major anticline the core of which is occupied by the older Cretaceous formations. To the north of the oasis, the "Plateau Limestone" directly overlies the Bahariya Formation (Lower Cenomanian). To the south, it overlaps the Lower Maestrichtian Chalk, while in the middle part of the oasis it covers the El-Hefhuf Formation (Campanian).

Several successions of the Eocene rocks in the Bahariya Oasis were measured by various workers (e.g. Ball & Beadnell, 1903; Hermina *et al.*, 1957; El-Bassyony, 1961 and 1972; El-Akkad & Issawi, 1963; Said & Issawi, 1964). The different units were given different names (Table 1). Said & Issawi (1964) subdivided the "Plateau Limestone" in the area north of the oasis into the following three rock units:

Top 3. The El-Hamra Formation (Late Lutetian-Bartonian)
2. The Qazzun Formation (Late Lutetian)
1. The Naqb Formation (Early Lutetian)

The three formations differ from each other in lithology and field appearance. The Naqb Formation overlies with an angular unconformity the Bahariya Formation. The formation consists of a succession of limestone beds with a few marl and clay interbeds. The Qazzun Formation conformably overlies the Naqb Formation and is represented by nummulitic limestones which are occasionally siliceous and dolomitic. The El-Hamra Formation overlies the Qazzun Formation with apparent conformity and is made up of limestones with a few clastic intercalations.

The purpose of the present study is to investigate in detail the vertical facies changes in the Eocene formations and to provide an integrated environmental interpretation for the whole succession.

FIELD AND LABORATORY WORK

Three stratigraphic successions representing the Naqb Formation, the Qazzun Formation, and the El-Hamra Formation were measured and sampled in their type localities (Fig. 1). The lithological and paleontological characters of the collected samples were determined through megascopic and microscopic investigations, and by carrying out insoluble residue and chemical analyses. The petrographic investigation comprised a detailed modal analysis of the different allochemical and orthochemical components of the limestones. The measured successions were then correlated with one another on micro-lithostratigraphical bases and a composite succession has been compiled.

RESULTS AND DISCUSSIONS

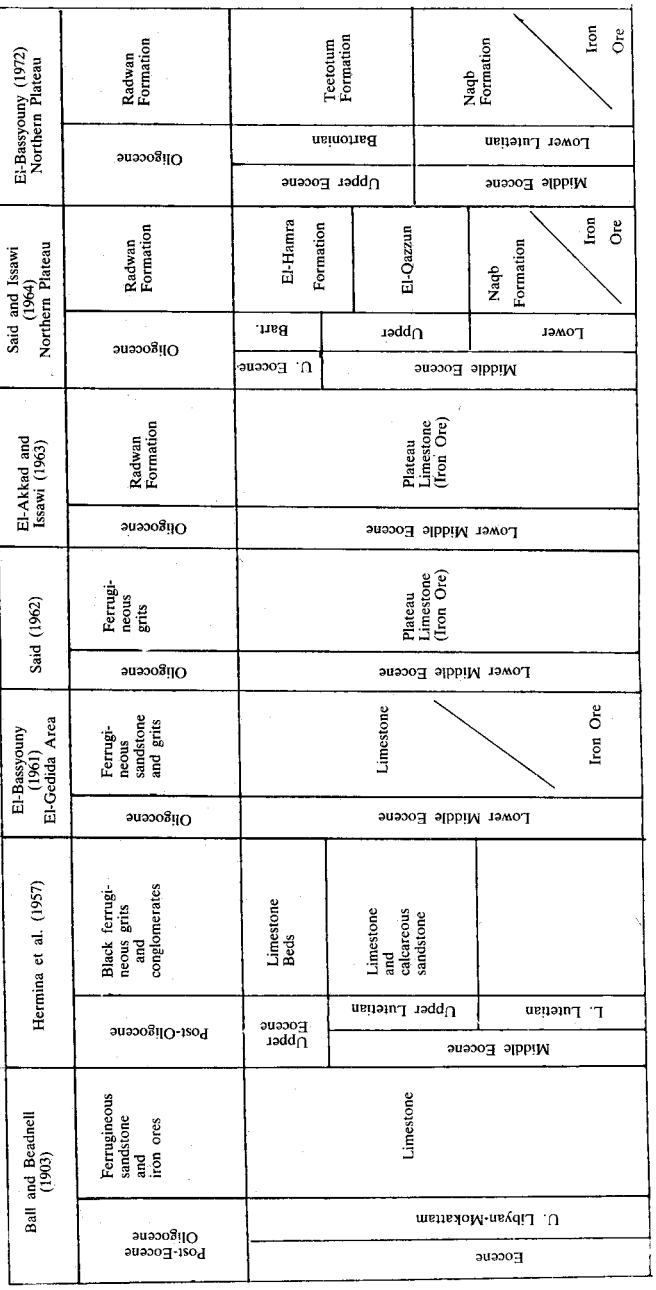
A. Stratigraphical Microfacies

Detailed investigation of the Eocene formations revealed remarkable differences in their lithologic and biogenic characters, and showed the presence of various microfacies associations. Fig. 2 presents the description of the composite succession in which the names of the reported microfacies associations, based on the terminologies adopted by Folk (1959), are given between brackets.

1. The Naqb Formation

The Naqb Formation is made up of a succession of pure limestone beds intercalated at the middle part of the formation with dolostones. The limestones are micritic, sparitic and intraclastic at the base, ferruginous in parts, with chalcedony replacing fossil shells and forming geodes. The insoluble residue percentage is markedly low throughout the whole formation. Three microfacies associations are identified; these are (from base to top): fossiliferous dolosparite, intra-dolomicrite, and molluscan bio-dolomicrite. The fossils which constitute these associations are: different agglutinated foraminifers, *Nummulites,* Bryozoa, Mollusca, echinoid spines and plates, ostracods and Algae. The dolostones are microcrystalline, with sparry calcite filling voids and fractures, and contain very few unidentifiable organic remains.

Table 1:
Stratigraphy of the Eocene rocks in Bahariya Oasis according to several authors.



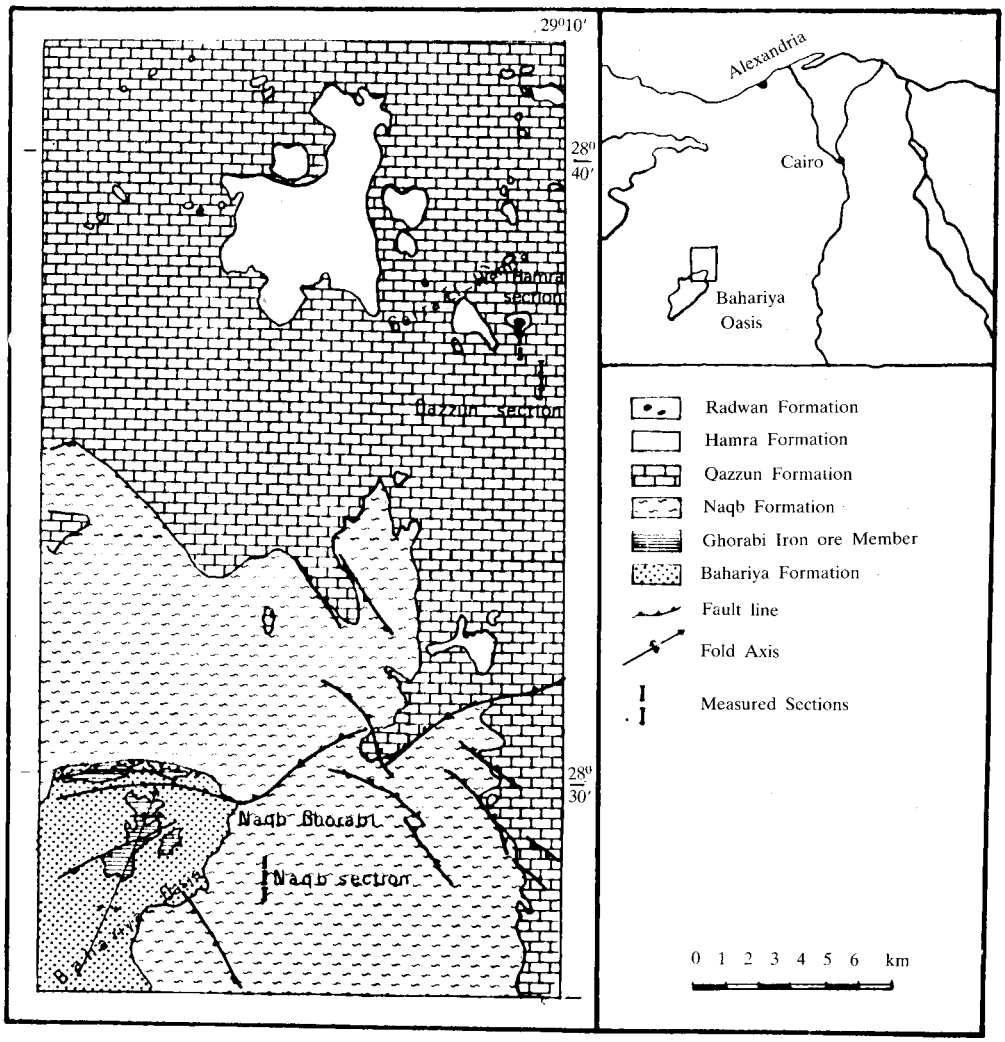


Fig. (1) Simplified geologic map of the Northern Plateau of Bahariya Oasis (Said and Issawi, 1964) showing location of studied sections.

2. The Qazzun Formation

The Qazzun Formation is composed of a succession of limestone beds intercalated at the middle part of the formation with thin dolostone layers. The limestones are micritic, occasionally sparitic, invariably highly sandy and argillaceous, rarely pelletal, glauconitic and conglomeratic in parts. The insoluble residue percentage is remarkably higher than in Naqb Formation particularly in two horizons in the lower half of the formation. Seven microfacies associations are recognized; these are (from base to top): shelly biomicrite, sandy echinodermal bryozoan biomicrite, shelly *Nummulites* biosparite, sandy sparite, globigerinid biomicrite, pel-dissparite, and molluscan biomicrite. The fossils which constitute these associations are: miliolides, other small benthonic forams, *Nummulites,* corals, Bryozoa, Mollusca, echinoid spines and plates, smooth ostracods and Algae. The dolostones are microcrystalline, slightly argillaceous, with recrystallized *Nummulites* (ghosts), Bryozoa, Mollusca, and other unidentifiable shell fragments.

3. The El-Hamra Formation

The El-Hamra Formation is made up of a succession of limestone beds intercalated at the upper part of the formation with sandstones. The limestones are mainly micritic, invariably sandy, argillaceous and glauconitic. The insoluble residue percentage is remarkably low in the lower part of the formation but shows drastic increase upwards. Molluscan nummulitic biomicrite is the only microfacies association reported in this unit. The fossils which constitute this association are: miliolids, *Operculian, Nummulites gizehensis,* Bryozoa, Mollusca (oysters), Echinoidea and Algae. The sandstones are fine to medium-grained, subangular to subrounded, argillaceous, slightly calcareous, glauconitic, with bone fragments.

B. Petrography

The investigated carbonate rocks are texturally classified according to the scheme adopted by Dunham (1962). This scheme proved to be valuable in the present study as the identified textures show distinctive and significant distribution in the three Eocene formations. These textures are: lime mudstone, wackestone, packstone and crystalline carbonate (dolostone). Figs. 3 and 4 show the vertical distribution of the different textures in the succession and the variation in their allochemical and orthochemical components.

1. Lime mudstone

(Fossiliferous dolomitized sparite, dolomitized micrite)

This texture is encountered only at the lower and upper parts of the Naqb Formation (samples N_2 and N_7). It is made up of fossil shells ($\approx$ 1.5 to 6.5%) embedded in a micritic, partly dolomitic matrix which, at the base of the formation, is recrystallized into sparite. The lime mudstones are very slightly sandy and argillaceous. Iron oxides occur as spots and patches and replace fossil shells in parts.

2. Wackestone

(Intra-dolomitized micrite, Molluscan bio-dolomitized micrite, shelly-biomicrite, Sandy echinodermal bryozoan biomicrite, Shelly *Nummulites* biosparite, Globigerinid biomicrite, Pel-dissparite, Shelly *Nummulites* biomicrite).

The wackestone is the most widespread texture in the Eocene formations. It comprises two laminae in the Naqb Formation, most of the Qazzun Formation, and the middle part of the El-Hamra Formation (samples N_3, N_6, Q_1, Q_2, Q_3, Q_6, Q_8, Q_{12}, Q_{13}, Q_{14} and H_2). The texture is made up of fossil shells ($\approx$ 10-38%) set in a micritic matrix which is highly dolomitic in the Naqb Formation. The matrix is recrystallized into sparite in the middle part of the Qazzun

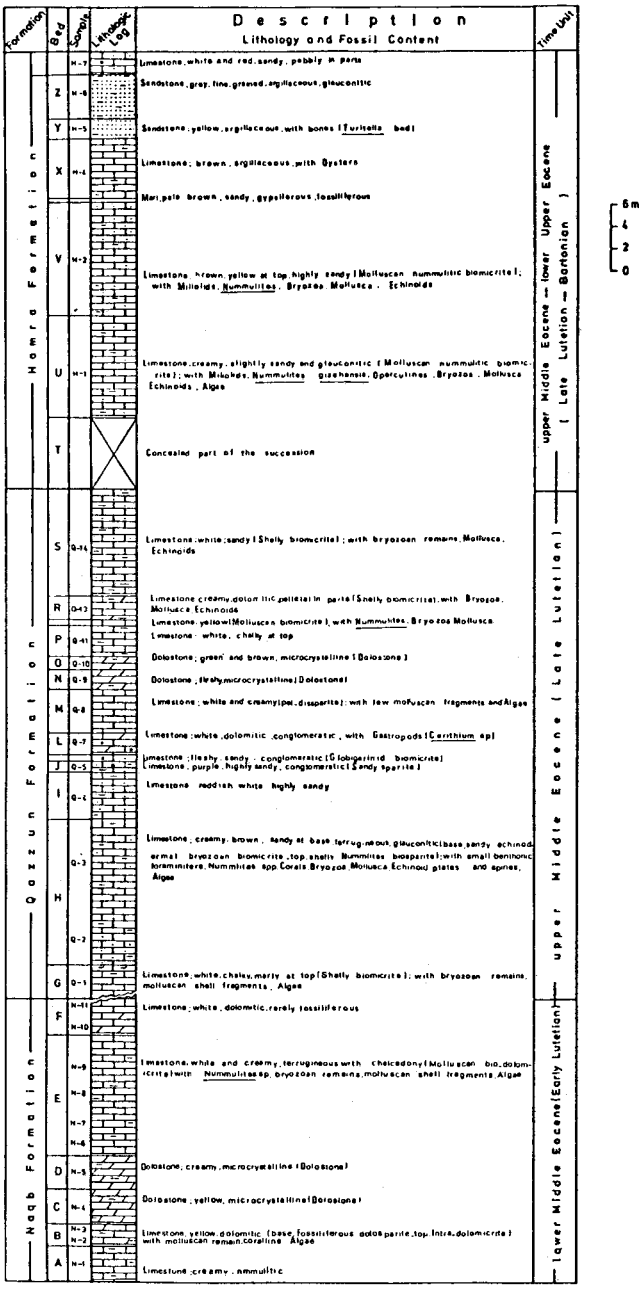


Fig. (2) Composite stratigraphic columnar section of the Eocene rocks in Bahariya Oasis.

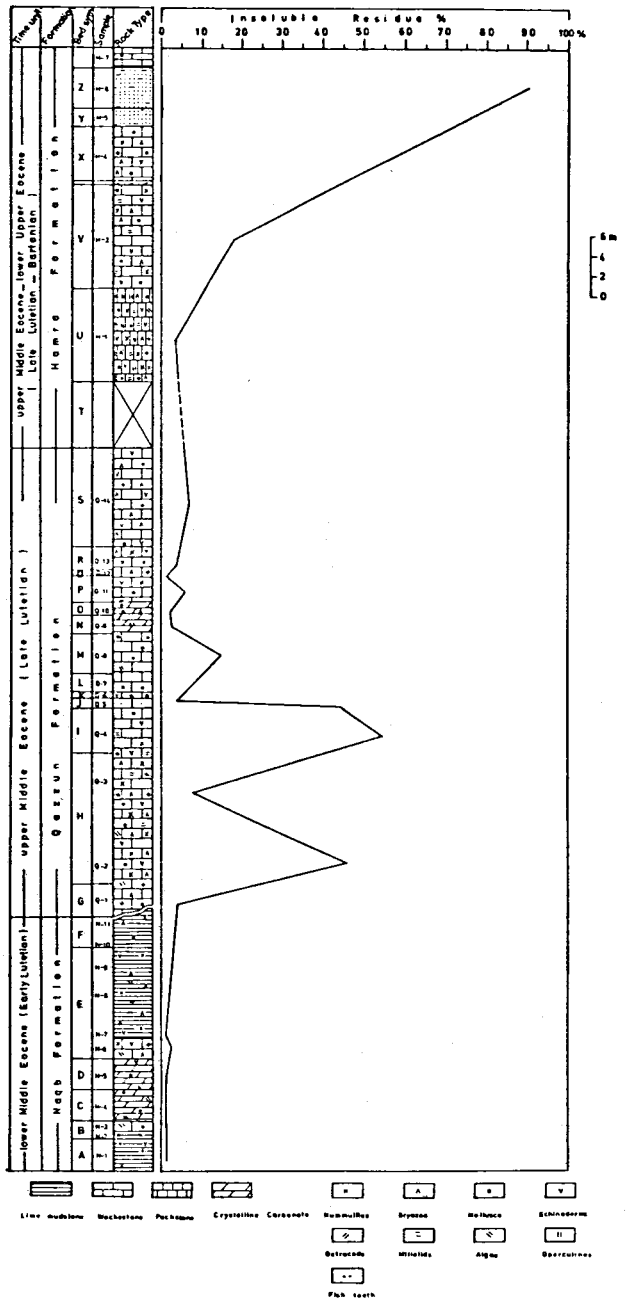


Fig. (3) Vertical variation in the texture and insoluble residue of the Eocene rocks in Bahariya Oasis.

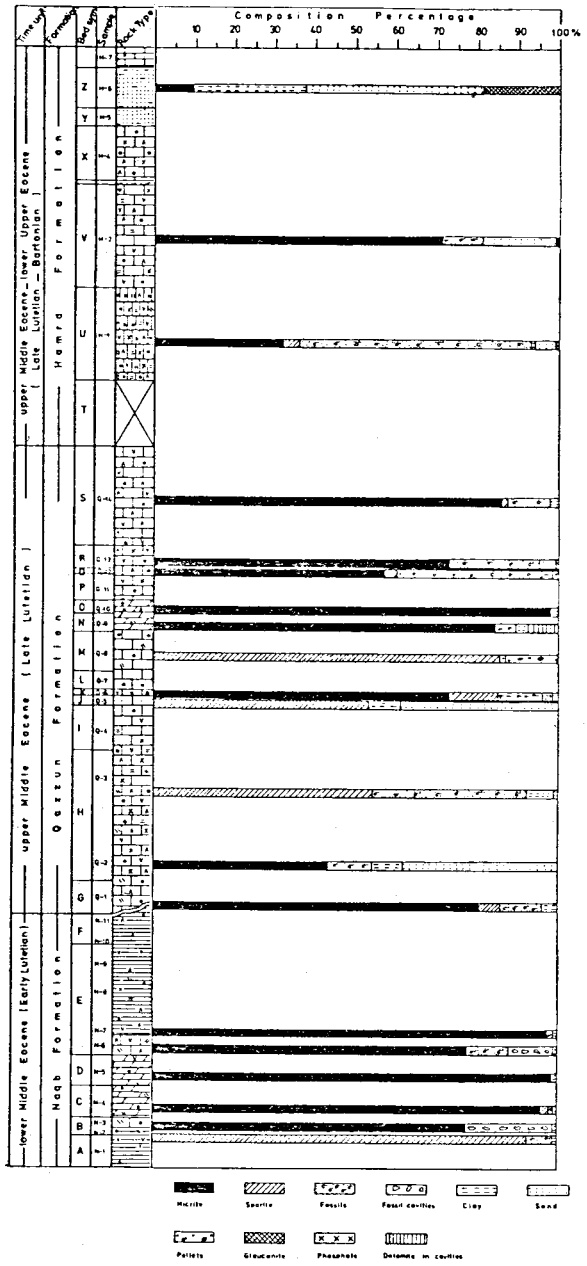


Fig. (4) Percentage — constituent of the Eocene formations of the Bahariya Oasis.

Formation. The wackestones are invariably argillaceous and sandy. Aggregates, pockets and veinlets of sparry calcite are occasionally reported in the micritic varieties. Microcrystalline chalcedony is present forming geodes, replacing fossil shells, and developing spherulites inside the large *Nummulites* shells. Phosphatic fragments are encountered in the upper part of the Qazzun Formation.

3. Packstone
(Shelly *Nummulites* biomicrite)

This texture is encountered only at the base of the El-Hamra Formation (sample H_1). It is composed of fossil shells ($\approx$ 57%), some of which are recrystallized, embedded in a micritic, occasionally sparitic, slightly argillaceous and glauconitic matrix. The texture contains scattered detrital fine quartz.

4. Crystalline carbonate
(Dolostone)

This texture is reported at the middle parts of both the Naqb and the Qazzun Formations (samples N_4, N_5, Q_9 and Q_0). It is composed of a dominant microcrystalline matrix in which the fossils and larger fossil fragments are recrystallized or represented by voids or casts. The texture displays many features indicating a secondary, diagenetic origin. Recrystalization during dolomitization greatly altered the primary textures. Some dolomitized limestones are marked by mottles or seggregations of coarser dolomite rhombs in a matrix of finer, commonly less dolomitized material. This may indicate an incomplete second phase of dolomitization controlled by original porosity differences related to the presence of algal fronds and other fossils.

A. Wackestone

A part of a bryozoan fragment together with a shell (now fibrous calcite) set in a sparitic matrix. Sample Q_3, ordinary light, X 250.

B. Wackestone

Several entire *Nummulites* tests embedded in a lime mud matrix which contains much comminuted fossil debris (Mollusca, Echinoidea, ostracodes, and Algae) together with a few phosphate fragments and detrital quartz. Note spherulites of chalcedony inside the large *Nummulites* tests. Sample Q_{12}, ordinary light, X 4.

C. Wackestone

Ill-sorted fossil debris set in a matrix of dolomitic lime mud. The fossils are: planktonic foraminifers, mollusca (gastropod showing the pelletal filling material in the gastropod chambers) and ostracods. Some of the fossil shells are diagenetically replaced with chalcedony. Sample N_6, ordinary light, X 5.

D. Crystalline carbonate

An exceedingly fine anhedral mosaic of dolomite evidently formed by profound dolomitization of a lime mudstone. The light small islands are remains of the original cryptocrystalline structure. Sample N_7, ordinary light, X 200.

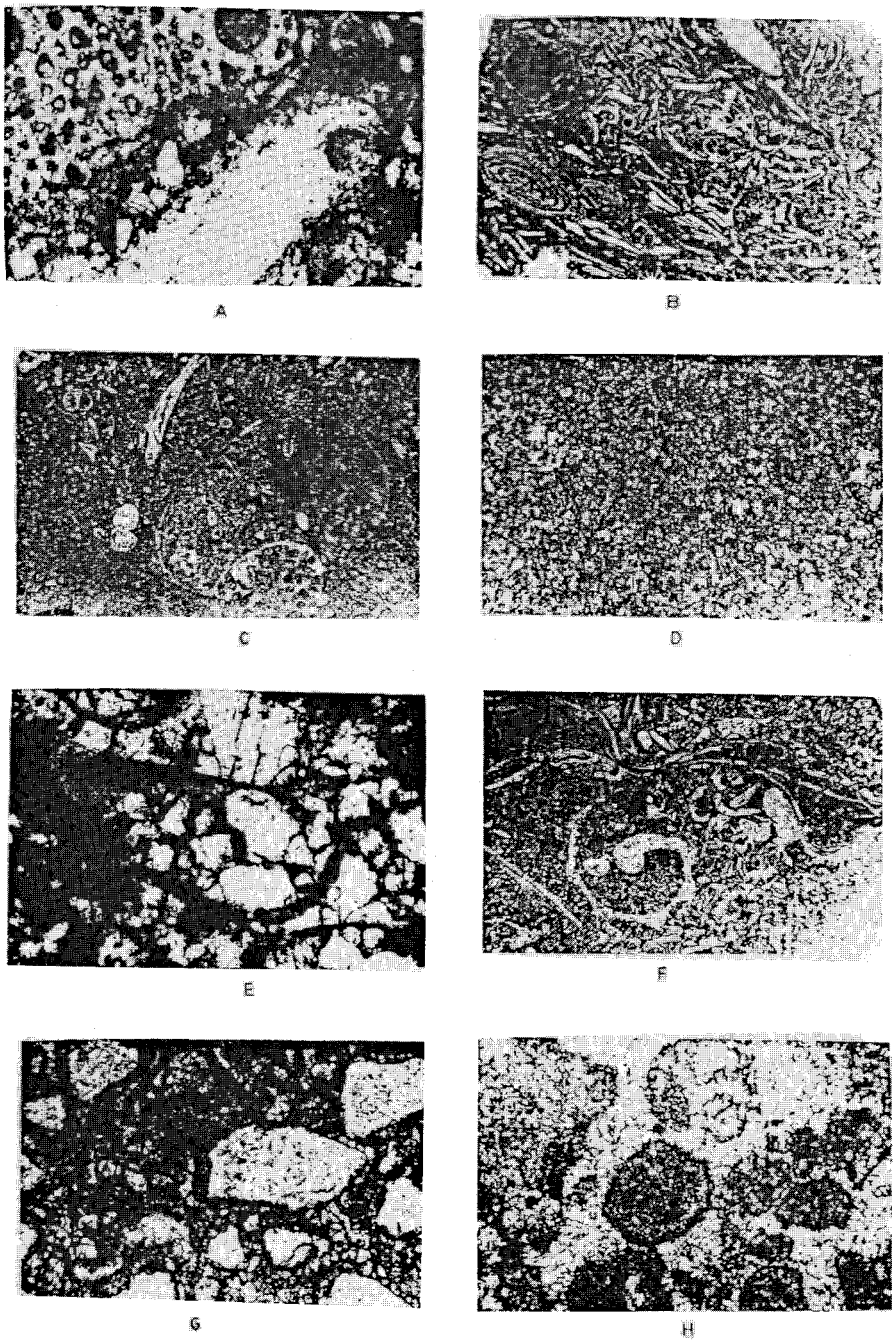


Fig. (5) See text

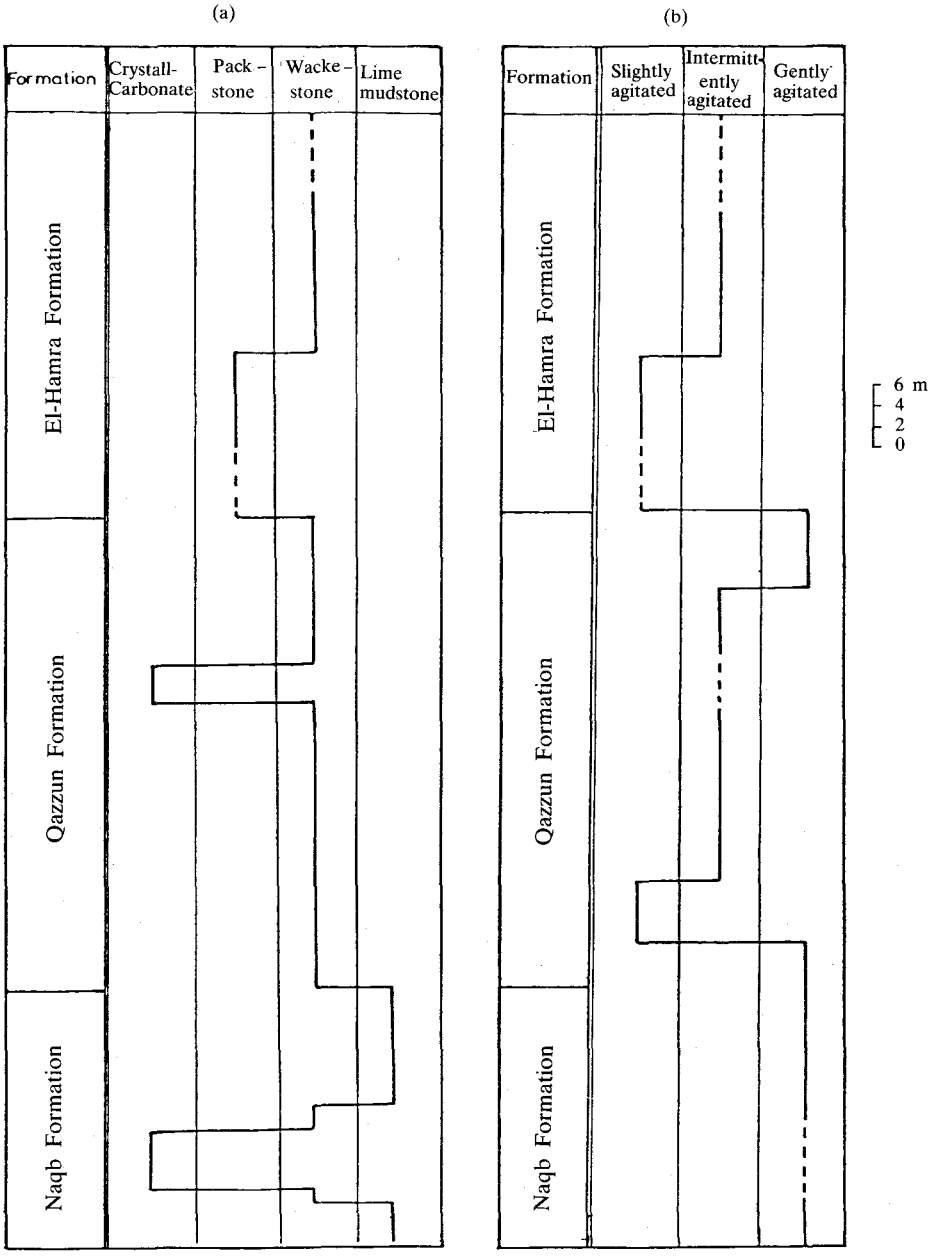


Fig. (6) Vertical variation in the depositional texture (a) and water energy (b) of the Eocene formations.

E. Wackestone

Clear sparry calcite cementing and infilling the cavities of partially micritized shell fragment (? echinoid plate). Sample Q_3, ordinary light, X 250.

F. Packstone

Fossil debris cemented with micritic, partially sparitic matrix. The allochems include *Nummulites,* bryozoan and molluscan fragments, echinoid spines and plates together with carbonate detritus of unknown origin. Note lack of assortment of fossil debris, diversity of the fossil types represented, and the dense dark micritic rims on some of them. Sample H_1, ordinary light, X 4.

G. Sandy sparite

Large subangular to subrounded quartz and chert grains together with small silt-sized particles of quartz set in an argillaceous sparitic matrix. Note a thin irregular zone of neomorphic microspar surrounding some quartz grains. Sample Q_5, ordinary light, X 200.

H. Wackestone

A coarsely crystalline carbonate matrix in which spherical pellets are embedded. Some of these pellets are degraded by recrystallization. Sample Q_8, ordinary light, X 200.

C. Environmental Interpretations

Fig. 6 shows the vertical variation in the depositional texture of the investigated Eocene samples and the water energy of the depositional medium as determined from the grain-matrix ratio (Leighton & Penedexter, 1962). From this figure, the following observations are outlined:-

a. There are remarkable differences in the textural characteristics between the three Eocene formations. The Naqb Formation represents a small-scale cyclic sedimentation of lime mudstone and wackestones, the Qazzun Formation was wholly deposited as wackestone, while the El-Hamra Formation is represented by packstone in its lower part and wackestone in the upper part.

b. There is a general increase in the water energy of the depositional environment upwards in the succession. The Naqb Formation was wholly deposited below the wave base in a relatively quiet, or still-water environment, while the Qazzun and the El-Hamra Formations were invariably slightly affected by the wave action during deposition in a shallower, more turbulent environment.

c. Drastic changes in the percentage of insoluble residue (Fig. 3), depositional texture, and water energy are seen at the boundaries of the three formations.

d. It is most probable that the secondary dolostones reported at the middle parts of both the Naqb and the Qazzun Formations were originally wackestones as they were deposited under conditions resembling those of the overlying and underlying wackestones. Moreover, it can be inferred that the concealed part of the succession is composed of packstone as it forms the base of the El-Hamra Formation the lower part of which is made up of the same rock type.

The nature of the fossil content and the lithologic and facial characters of the Eocene formations together with the above-mentioned water energy characteristics strongly suggest that these rocks represent a carbonate bank on a shallow marine shelf. This is indicated by the

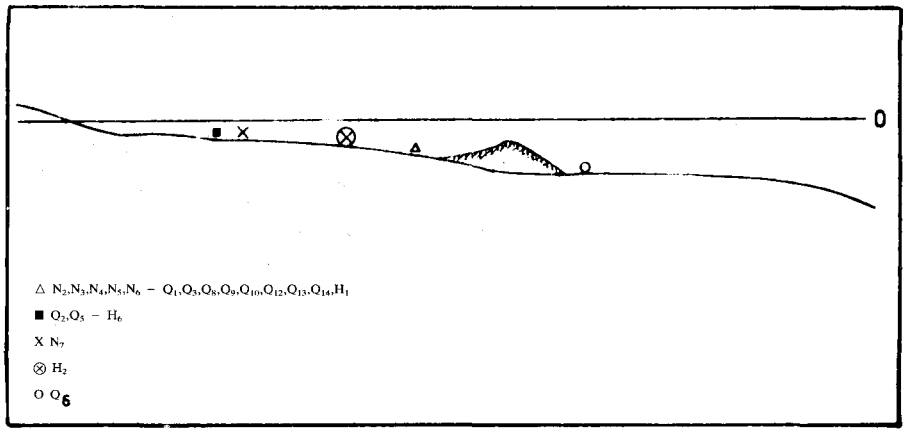


Fig. (7) Plot of Eocene samples on the marine profile (Blondeau, 1972)

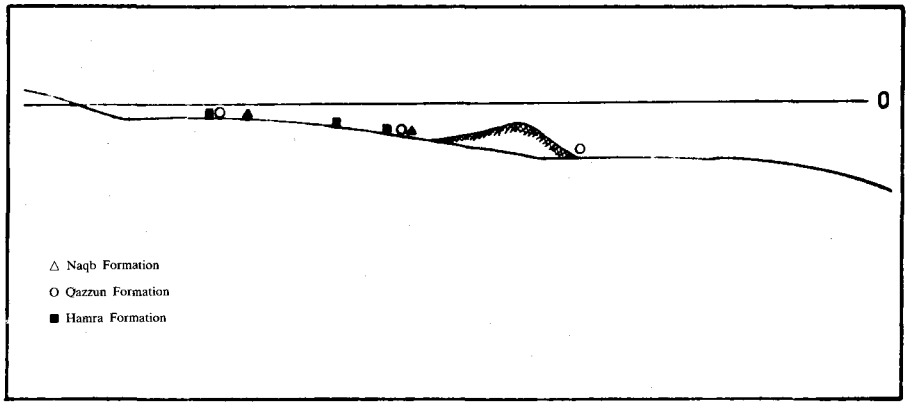


Fig. (8) Plot of Eocene formations on the marine profile (Blondeau, 1972)

high fossil diversity and abundance (Neal, 1969), the dominance of passive organisms (Heckel, 1974), and the absence of criteria of high water turbulence (Heckel, 1974 & Wilson 1975). Plotting of the Eocene samples on the marine profile adopted by Blondeau (1972) confirms deposition in a shallow water environment (Figs. 7 and 8).

The highly fossiliferous zones frequently encountered in the Eocene succession are believed to represent deposition in the bank margin subenvironment. This is characterized by high concentration of the carbonate-precipitating organisms due to the normal salinity and the high oxygenation associated with wave action and nutrients from the marine basin.

Parts of the Qazzun and the El-Hamra Formations, however, display several distinctive criteria of reefal facies and show evidence of considerable water turbulence. This suggests that during parts of the life history of the bank intense biogenic development had dominated in places and the wave resistant character of true organic reefs was approached. The high porosity of these reef rocks favoured diagenetic dolomitization which is detected in parts of the succession.

During the deposition of the Eocene formations, minor transgressions and regressions of the sea occurred. These were more remarkable at all formation boundaries. They resulted in the occasional development of restricted, back-reef lagoons. The gypsiferous, rarely fossiliferous beds (base of the Qazzun Formation and top of El-Hamra Formation) were mostly deposited in these lagoons where the increase in salinity resulted in a decrease in organic contribution to the sediment and a rise in the proportion of chemically-precipitated carbonate and sulfate.

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REFERENCES

BALL, J. and **H.J.L. BEADNELL.** 1903. Bahariya Oasis, its topography and geology. Egypt. Surv. Dept., Cairo.

BLONDEAU, A. 1972. Les Nummulites, Vuibert edit., Paris, 200 pp.

DUNHAM, R.J. 1962. Classification of carbonate rocks according to depositional texture. In W.E. Ham (ed.), Classification of carbonate rocks. AAPG Bull., Mem. 1, p. 108-121.

EL-AKKAD, S. and **B. ISSAWI.** 1963. Geology and iron ore deposits of the Bahariya Oasis. Geol. Survey. Egypt, Cairo, Paper no. 18, pp. 300.

EL-BASSYONY, A.A. 1961. Preliminary report on a new discovery of iron ore deposits in the Bahariya Oasis (El-Gedida Area). Geol. Surv. Egypt.

EL-BASSYONY, A.A. 1972. Geology of the area between Gara El-Hamra, Ghard El-Maharik and El-Harra (northeastern Plateau), Bahariya Oasis, Egypt. M.Sc. Thesis, Cairo University.

FOLK, R.L. 1959. Practical Petrographic classification of limestones. AAPG Bull., V. 43: 1-38.

HECKEL, P.H. 1974. Carbonate buildups in the geologic record: A review, p. 90-154 in Laporte, L.F. (ed.), Reefs in time and space (Selected examples from the recent and ancient). Tulsa, Oklahoma, Soc. Econ. Paleontologists and Mineralogists, Spec. Pub. no. 18, pp. 256.

HERMINA, M.H. and others. 1957. Final geological report on geology of Bahariya Oasis. Unpublished report no. 261, Sahara Petroleum, Co.

LEIGHTON, M.W. and **C. PENEDEXTER.** 1962. Carbonate rock types. In W.E. Ham (ed.), Classification of carbonate rocks. AAPG Bull., Mem. 1: 33-61.

NEAL, W.J. 1969. Carbonate facies and paleogeography of the Plackjack Creek Formation (Pennsylvanian), Missouri. Jour. Sed. Petrology, v. 38, no. 1: 34-48.

SAID, R. 1962. The geology of Egypt. Elsevier Publ. Co., Amsterdam-New York, 377 pp.

SAID, R. and **B. ISSAWI.** 1964. Geology of Northeastern Plateau, Bahariya Oasis, Egypt, Geol. Surv. Egypt, Cairo, Paper no. 29, 41 pp.

WILSON, J.L. 1975. Carbonate facies in geologic history. New York, Springer Verlag, 471 pp.

دراسات رسوبية وبيئية قديمة على الصخور الجيرية التابعة للعصر الأيوسيني بالهضبة الشمالية للواحات البحرية ، الصحراء الغربية (مصر)

محمد عز الدين حلمى ، محمد محمود أبو زيد ، نعيمة سعد

يتضمن هذا البحث دراسات متنوعة وتفصيلية على متكونات النقب والكازون والحمرة الصخرية التابعة للعصر الأيوسيني والمتواجدة في الهضبة الشمالية للواحات البحرية وذلك بهدف التعرف على التغيرات السحنية الرأسية ، وكذلك ظروف الترسيب البيئية القديمة .

وقد دلت نتائج تلك الدراسات على أن الخصائص الصخرية والعضوية لهذه المتكونات الصخرية الثلاثة تختلف إختلافا بينا ، فقد تم التعرف على إحدى عشر نوعا من السحنات الدقيقة موزعة بين تلك المتكونات الصخرية توزيعا غير متجانسا وهو ما يميز أيضا توزيع الأنسجة الصخرية التى تم حصرها وهى Lime mudstone و Wackestone و Packstone (dolostone) Crystalline Carbonate .

وتتميز الحدود بين المتكونات الصخرية الثلاثة بتغيرات حادة في كل من نوع النسيج الصخري ونسبه وتركيب المحتوى غير الكربوناتى والطاقة الحركية للمياه التى تم ترسيب الصخور تحت تأثيرها .

وتشير نتائج الدراسات إلى أن صخور المتكونات الثلاثة كانت جزءا من رصيف صخرى جيري تكون على رف بحرى ضحل ، وأن معظم تلك الصخور قد ترسب تحت تأثير تقليب مائى خفيف نسبيا ، وتميزت فترات من تاريخ بعض أجزاء الرصيف الصخري بنشاط حيوي كثيف أدى إلى تكوين رواسب شعابيه ، كما أدت تقدمات وتقهقرات بسيطة للبحر في ذلك الزمن ـ وخاصة عند حدود المتكونات الصخرية ـ إلى تكوين لاغونات خلف الأجسام الشعابية بصورة متقطعة تم فيها ترسيب الطبقات الغنية بالجبس والفقيرة في الأحافير .