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

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Key words: Carbonates, Egypt (Western Desert - Bahariya Oasis), Eocene (Plateau Limestone), Lagoonal environment, microfacies, reefal environment, sedimentology, shallow marine environment.

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:
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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.

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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, *Opeculian, 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 N2 and N7). It is made up of fossil shells (≈ 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 N3, N6, Q1, Q2, Q3, Q6, Q8, Q12, Q13, Q14 and H2). The texture is made up of fossil shells (≈ 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
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 H1). It is
composed of fossil shells (≈ 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 N4, N5, Q9 and Q6). 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 segregations 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 Q3, 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 Q12, 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 N6, 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 N7, ordinary light, X 200.
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Fig. (5) See text
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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 Q3, 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 H1, 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 Q5, 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 Q8, 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)
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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.

ACKNOWLEDGEMENTS

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REFERENCES


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

عمر عز الدين حلمي، محمد حمود أبو زيد، نعيمة سعد

يتضمن هذا البحث دراسات متنوعة وتفصيلية على مكونات النبق والكازون والحمارة الصخرية التابعة للعصر الأيوسيني والموجودة في الهضبة الشمالية للواحات البحرية وذلك بهدف التعرف على التغيرات السححية الرأسية، وكذلك ظروف الترسيب البيئية الفردية.

وقد دلت نتائج تلك الدراسات على أن الخصائص الصخرية والعضوية لهذه المكونات الصخرية الثلاثة تختلف اختلافاً بانياً، فقد تم التعرف على إحدى عشر نوعاً من السححات الدقيقة موزعة بين تلك المكونات الصخرية توزيعاً غير متجانساً و Lime mudstone و Crystalline Carbonate (dolostone) Packstone و Wackestone

وتتميز حدود بين المكونات الصخرية الثلاثة بتفاوت حادة في كل من نوع النسيج الصخري ونسبة وتركيب المحتوى غير الكربيونات والطاقة الحركية للمياه التي تم ترسيب الصخور تحت تأثيرها.

وتشير نتائج الدراسات إلى أن صخور المكونات الثلاثة كانت جزءاً من رصيف صخري جيري تكون على رف بحري ضحل، وأن معظم تلك الصخور قد ترسب تحت تأثير تقليل مائي خفيف نسبياً، وتميزت فترات من تاريخ بعض أجزاء الرصيف الصخري بنشاط خيري كثيف أدى إلى تكوين رواسب شعابية، كما أدت تقدمات وتقهيرات بسيطة للبحر في ذلك الزمن - وخاصة عند حدود المكونات الصخرية - إلى تكوين لاعونات خلف الأجسام الشعابية بصورة متقطعة تم فيها ترسيب الطبقات الغنية بالجبس والفقيرة في الأحافير.

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