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FACIES ANALYSIS AND PALEOENVIRONMENTAL RECONSTRUCTION OF THE THEBES FORMATION (LOWER EOCENE) SEQUENCE ALONG THE RED SEA COAST BETWEEN QUSIER AND HURGHADA, EGYPT.

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The Eocene Thebes Formation had been subjected to detailed field and petrographic analysis to evaluate the stratigraphy, depositional facies, paleoenvironment and sedimentological history of the Thebes Formation carbonates. Four surface stratigraphic sections located in the Eastern Desert have been studied in detail. These sections are distributed from south to north: Gebel Hamadat, Wadi Syatin, Gebel Wasif, and Wadi Malha sections. The carbonate succession of Thebes Formation rests conformably on the siliciclastic shales of the Esna Formation at all sections except at Wadi Malha, where there is an unconformity separates between Esna and Thebes formations.

Sedimentologically, four sedimentary facies belts have been detected. These are tidal flats, bank, continental slope and open marine facies belts. The tidal flat facies are dominated by limemudstone with wackestone intercalations. Bank facies is composed mainly of intact and fragmented fine nummulites, gastropods, pelecypods, operculines, and echinoderm bioclasts. The nummulites bank is well represented at Hamadat and Syatin sections by nummulitic lime mudstone to wackestone, besides other less dominant microfacies as nummulitic floatstone with wackestone matrix, pelecypodal floatstone, mollusca and operculines floatstone. Continental slope facies is mostly represented by wackestone microfacies that intercalated with lime mudstone of tidal flat facies. Open marine facies is represented by foraminiferal lime mudstone and calcareous shale except at Malha section where it is missing.

The studied succession shows regressive trend where the open marine facies at base of succession grade upward into deep and then shallow subtidal facies at the top. The oyster limestone facies dominates the upper part indicating shallowing upward conditions.

Keywords: Sedimentary basin, Lower Eocene Thebes Formation, Eastern Desert, Tidal flats, Bank facies, Continental slope facies, Open marine facies.

1. INTRODUCTION

Eocene outcrops cover about one-fifth of the surface area of Egypt. As well, the Eocene rocks assume several thousand meters in thickness and are almost exclusively made of carbonates with varying amounts of clastics (Said, 1990). The Thebes Formation is one of the thickest (~340 m) and regionally extensive outcropping lithostratigraphic units of Egypt (Snavely et al., 1979). It extends throughout central and southern Egypt forming hills and plateaus that dominate the Egyptian landscape. It represents part of the extensive carbonate platform developed along the southern margin of the Tethyan Ocean (Said, 1962).

The study area is located in the Eastern Desert, Egypt between Latitude 25º 30”, 28º 00” North, and Longitude 33º 00”, 35º 00” East, which extends for around 150Km along the Red Sea cost (Fig. 1). The good exposure and widespread distribution of Thebes Formation outcrops give opportunity to study the depositional history of an extensive mosaic of time-conformable carbonate lithofacies deposited in shelf setting (Snavely, 1985).

The Eocene rocks have been extensively studied in the Eastern Desert. Most of these studies are focused on their lithological and paleontological aspects while detailed analysis of the sedimentological characteristics is limited (Table 1). Basic previous studies include the works of Zittel (1883);Said (1960, 1962, 1971, 1990); Bishay (1961); Omara et al. (1970); Abdel Kreem and Abdou (1979); Snaveley et al. (1979); Issawi et al. (1981); Abu Khadra et al. (1987, 1994); Bandel and Kuss (1987); El Ayyat (1989); Keheila et al. (1990); Darwish and El Araby (1993); Boukhary et al. (1998); Kuss et al. (2000); Khalifa et al. (2005); El Ayyat and Obaidalla (2005, 2016, 2019); Morsi and Scheibner (2009); and Höntzsch et al. (2011).

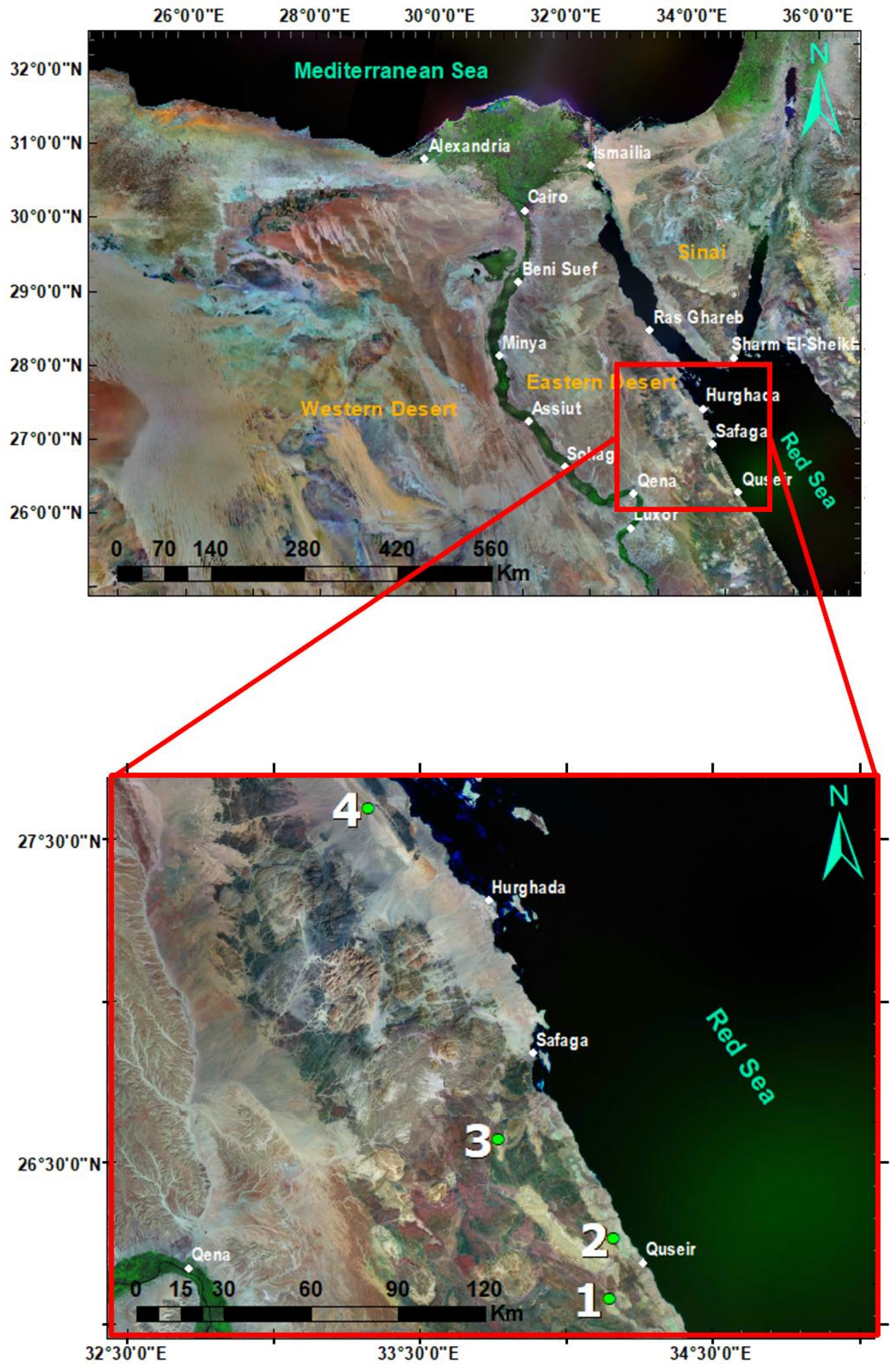

Fig. 1: Location map of the study area showing the measured sections (**1**. Gebel Hamadat; **2**. Wadi Syatin; **3**. Gebel Wasif; **4**. Wadi Malha).

Table 1: Lithostratigraphic correlation of the different proposed rock units of Early Paleogene in the Eastern Desert and the surrounding areas.

Placeocene	Early Eocene	Middle Eocene	Age / Author and Locality
Tarawan Formation	Southern Galala Formation; Thebes Formation		Bandel and Kuss (1987) Kuss and Lepping (1989) Gulf of Suez
	Useit Formation		Barakat et al. (1986) Abu Khadra et al. (1987) west Sinai and Southern Galala
Esna Formation	Serai Formation		Bandel et al. (1987) north of Wadi Qena
	Southern Galala Formation		Abdalla et al. (1971) Southern Galala
Esna Formation	Farafra Formation	Middle Eocene rocks	Abdel Kareem and Abdou (1979) Galala Plateaus
Dakhla Fm; Sudr Fm; Tarawan Fm; Esna Formation	Thebes Group: Serai Formation; Abu Rimth Formation	Mokattam Group: Observatory Formation	Hermina and Lindenberg (1989) NE Desert and Red Sea coast
Tarawan Fm; Esna Fm	Thebes Formation		Keheila (2000) Galala Plateaus
Tarawan Formation	Thebes Formation; MiniaFormation; Ibrahimi Formation		
El Egma Group			Darwish and Al Araby (1993) Gulf of Suez
Esna Formation	Thebes Formation; Samalut Formation; Waseiyat Formation	Mokattam Fm Rod El Awad Fm	
	El Egma Group: Waseiyat Formation; Rod El Awad Formation		Zalat and Eweda (1998) west central Sinai
Esna Formation	Thebes Formation	Mokattam Fm Samalut Fm	Issawi and El Hainnawi (1981) Wadi Feiran, Sinai
Esna Formation	Thebes Formation	Khaboba Fm Darat Fm	Viotti and El Demerdash (1969) Wadi Nukhul, Sinai
Esna Formation	Southern Galala Formation; Thebes Formation		Höntzsch et al. (2011) Galala Mountains
Dakhla Formation; Esna Formation	Thebes Formation		El Ayyat and Obaidalla (2016) North Eastern Desert
Esna Formation	Thebes Formation		N The Present Study S

2. SCOPE OF THE PRESENT STUDY

This work aims to determine the lithological characteristics of a number of carbonate outcrops in the study area; provide a comprehensive view of the paleoenvironment as well as reconstruct the sedimentological history of the Eocene carbonates in the study area. The objectives also include determining the vertical relationship between the carbonate of Thebes Formation and siliciclastics of underlying Esna Formation.

3. MATERIALS AND METHODS

To achieve the previous goals; four surface sections have been measured and described in detail (Fig. 2). The sampling space varies from 20cm in shales to more than 1 m in carbonates according to the outcrop condition and the degree of alteration. About 150 microscopic thin sections have been made and examined under the microscope. Detailed petrographic analysis (following Dunham, 1962; Embry and Klovan, 1971) and water energy index (following the methods described by Leighton and Pendexter, 1962; Plumley et al., 1962) have been carried out. Staining technique of Katz and Friedman (1965) was followed to differentiate the dolomites in the samples. General legend for symbols used in this study is presented in Figure3.

Photomicrographs of thin sections have been taken with a camera Zeiss MC 80. Paleoecologic interpretation and basin evolution have been attempted based on the fossil content, litho- and microfacies associations, tectonic behavior of the region and previous related studies. Information from Early Paleogene successions in adjacent areas have been integrated and compared to elucidate the paleogeographic setting of the studied basin and to reconstruct a more precise depositional history. These data form the basis of the regional interpretation of uplift, erosion, sedimentation and renewed subsidence by throwing more light on the syn-depositional tectonism.

4. GEOLOGICAL SETTING

The Lower Eocene carbonate covers about 200,000 km^2 of the Egyptian country. The majority of these carbonates are concentrated in two great limestone plateaus, the extensive El-Maaza Plateau of central Egypt and the smaller Egma Plateau in the Sinai (Snavely,1985). Less than one percent of these carbonates outcropping east of Red Sea hills as part of the Upper Cretaceous-Lower Tertiary sedimentary sequences. It is represented by small isolated outcrops preserved within two elongate structural basins, the Gulf of Suez graben, and the Duwi Trough (west of Qusier-Safaga coastal plain, Lawrence and Meguid, 1978) where the study area belongs. The Duwi Trough is located about 100 km south of the southern entrance to the Gulf of Suez. It is a structural basin, named by Lawrence and Meguid (1978). The Duwi Trough extends approximately 100 km southeast to northwest, between Quseir and Safaga cities, and is about 40 km wide. To the southeast, southwest and northwest, it is bounded by the uplifted Precambrian through Mesozoic granitic and metamorphic terrain of the Red Sea Hills. To the northeast it dips beneath the surface of the Red Sea, where, it is covered by Miocene through Pleistocene sediments along the Red Sea coast.

In Qusier-Safaga area, the Cretaceous-Eocene sedimentary sequence is preserved as isolated outcrops. These outcrops occupy the trough of the synclinal-like folds between uplifted elongate blocks of older basement rock (Said, 1990). The preserved sedimentary strata is distributed as isolated outcrops few kilometers in length, elongated parallel to their bounding faults (Snavely,1985). The sediments in this district are affected by a series of predominantly northwest-trending normal faults typical of the Red Sea regional extensional regime. The basement complex with its overlying Cretaceous-Eocene sediments in that region was subjected to intense deformation which resulted in series of highly tilted fault blocks running in north-northwest direction (Said, 1990). This caused elevation of the area and absence of the Upper Eocene and Oligocene deposits.

In the northern sections, the Early Paleogene sedimentary succession has depositional setting vary from an inner shelf to basin transect. The Esna Formation represents an interval of uppermost Paleocene to Lower Eocene basinal marl, shale and followed by alternating chalky marl, dolomitized limestone, chert and calcareous sandstone of the Thebes Formation (Hermina and Lindenberg, 1989). The deposition of the northern sections took place within a marine basin of primarily neritic depths with intermittent rapid deeper water sedimentation. Exposures at the northern sections, specifically Gebel Wadi Malha site, exhibit slump and slide structures of different types. The formation of shallow water environments and slopes steep enough to generate slump structures may be the result of Early Eocene uplift of fault blocks. This would allow carbonate platform sediments to coexist adjacent to deeper basinal sediments and periodically be deposited downslope into the basin. Thebes Formation unconformabally overlies Esna Formation with major erosive discontinuity surface mostly related to the Late Paleocene paleo-relief.

Carbonate facies of Thebes Formation in the studied area are similar to those recognized in the Nile Valley with except the interbedded allochthonous carbonate debris flows and skeletal turbidites derived from local, structurally controlled paleo relief surrounded the Duwi Trough sedimentary basin (Snavely,1985).

5. LITHOSTRATIGRAPHY

5.1. Esna Formation

Said (1962) introduced Esna Formation as formal rock unit to describe nearly 104m thick succession of green-grey to green shale and marl exposed at Gebel Oewina at Esna City, Upper Egypt.

The present study deals with the uppermost part of Esna Formation to delineate the nature of contact between Thebes and Esna formations. The Esna Formation consists mainly of calcerous shale to marl at the base of studied sections. The contact between the Esna and Thebes formations is graditional contact at all sections except at Wadi Malha where there is an unconformity contact between Thebes and Esna formations.

5.2. Thebes Formation

Although, several names were proposed by several authors (e.g., Hermina and Lindenberg 1989; Darwish and El Araby, 1993; Höntzsch et al., 2011) to describe the Eocene carbonates under study, Thebes Formation was the widely accepted and commonly used name. Thebes Formation first introduced by Said (1961) to describe nearly 290m thick succession of limestone with many flint bands that overlies the Esna Formation at Gebel Gurnah, Luxor. It consists of massive limestone, chalky and marly limestone with occurrence of scattered or banded chert nodules at the base and nummulites and operculines banks at top. Although Thebes Formation has been elevated to group level by the authors of the new geological map of Egypt, this work uses it as formational name to designate the Eocene carbonate facies of the studied area.

In the study area, Thebes Formation records its maximum thickness at Hamadat section (about 105m) while at Syatin, Wasif and Wadi Malha sections, it attains about (75, 72, and 65 m) respectively. This variation in thickness may be related to differences in sedimentation rates and/or post-depositional erosion related to tectonic movement.

Lithologically, Thebes Formation at the study area composed mainly of laminated to thinly bedded fine-grained limestone interbeds with minor calcareous shales. Scattered nodules, beside concretions or bands of chert (flint) are represented through the succession but became more common in the upper portion.

Thebes Formation overlies Esna Formation with conformable to unconformable relationship. The unconformable contact mostly related to the Late Paleocene paleo-high. Several discontinuity surfaces were recorded within Thebes Formation especially at Wadi Malha section.

In the present study, the Thebes Formation is assigned to Early Eocene (Early Ypresian) following Said (1960, 1971), El Naggar (1970), Abd El Razik (1972), Issawi (1972), Kenawy (1972), Mansour and Philobbos (1983) and Keheila (2000); and Early to Middle Eocene by Haggag (1992) and El-Ayyat and Obaidalla (2005).

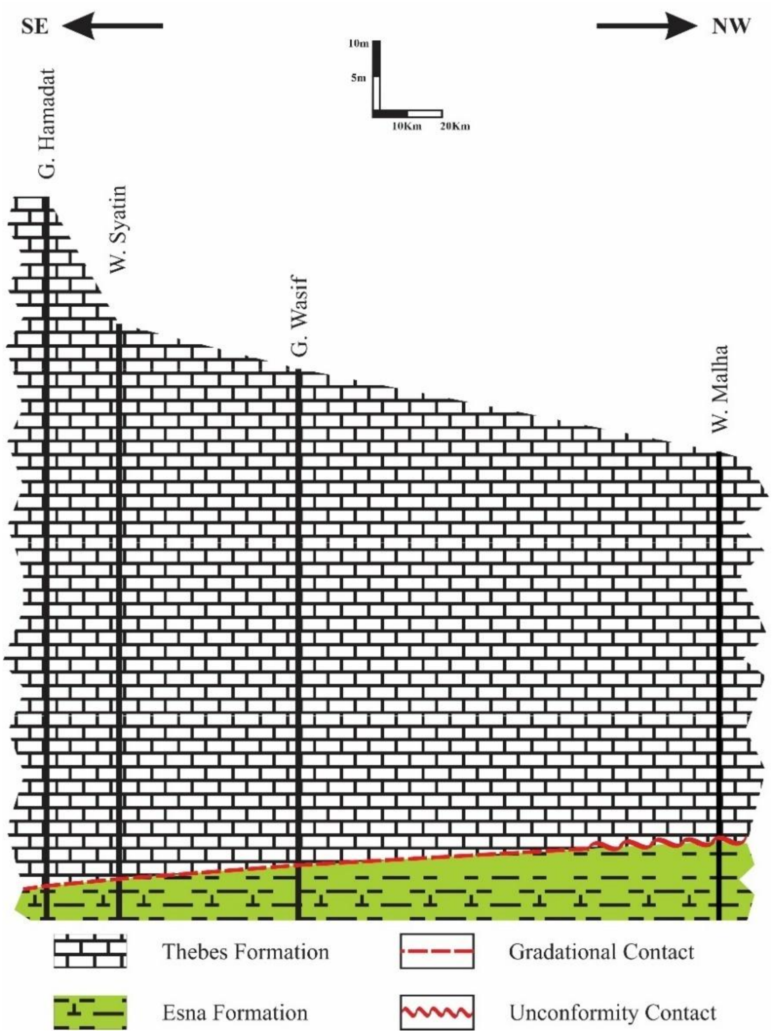

Fig. 2: Lithostratigraphic correlation of the studied sections.

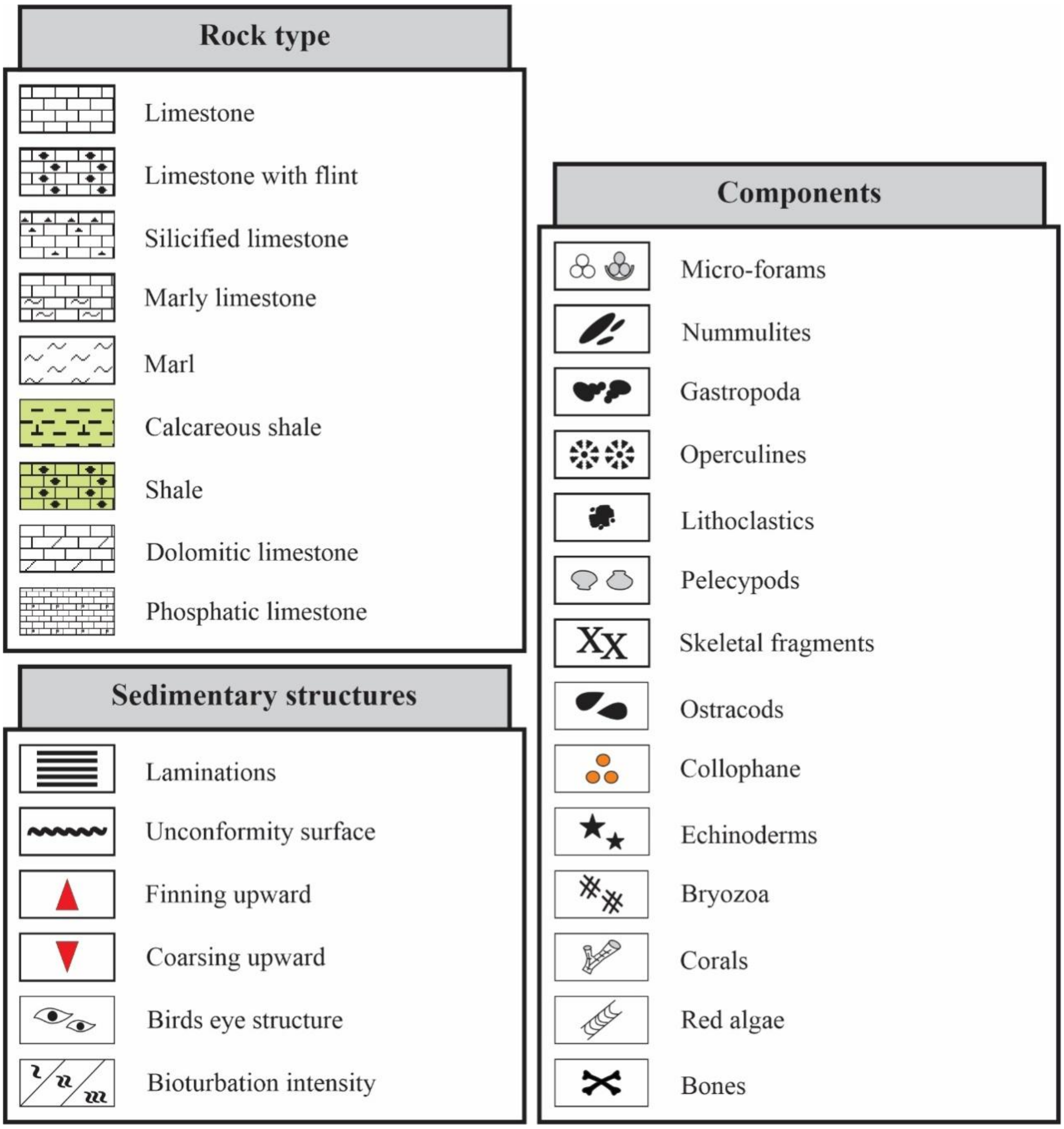

Fig. 3: Legend of symbols used in the present study.

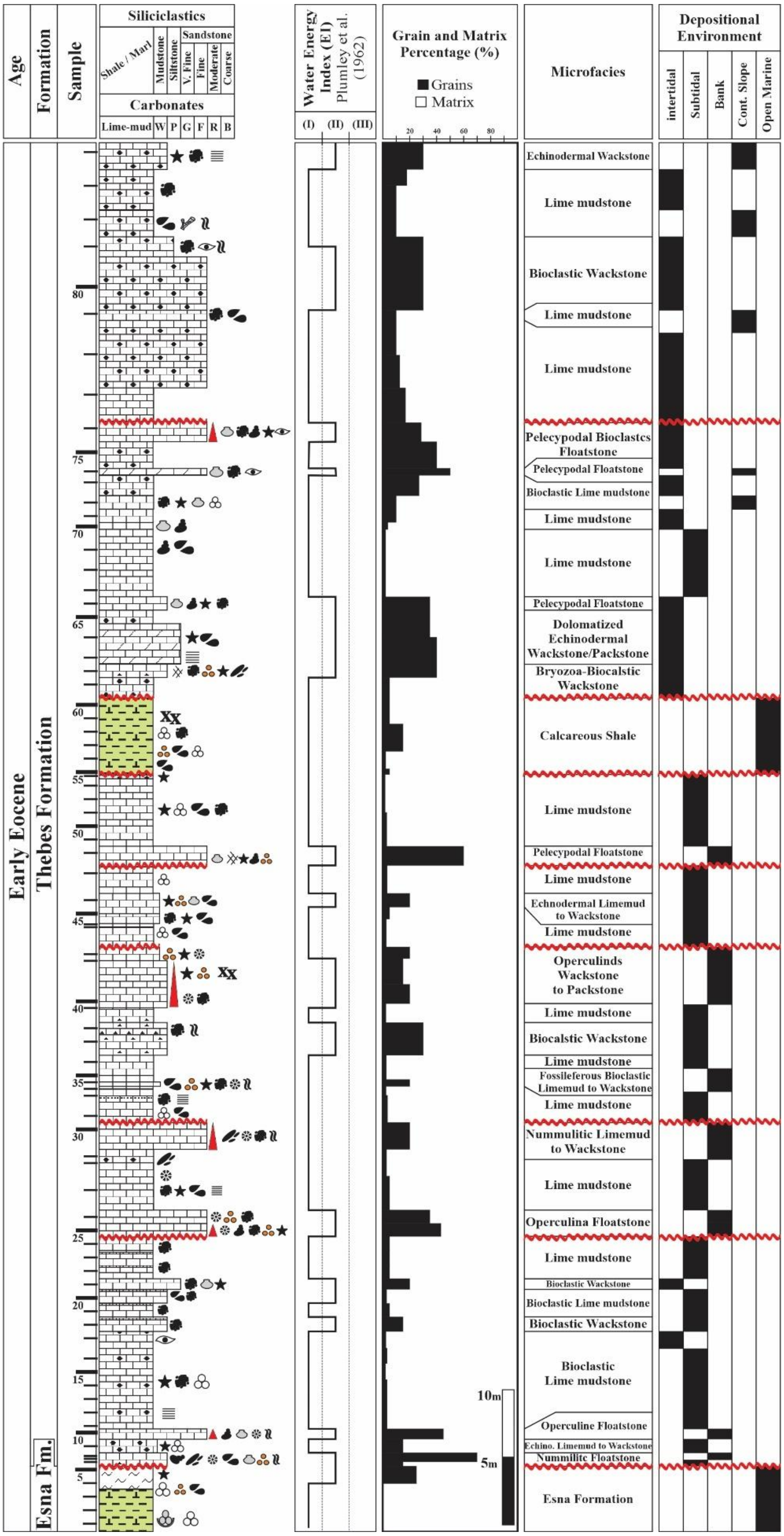

Fig. 4: Vertical distribution of the main components, depositional textures, energy index (EI) and sedimentary environments of the Thebes Formation at Hamadat section (Legend in Fig. 3).

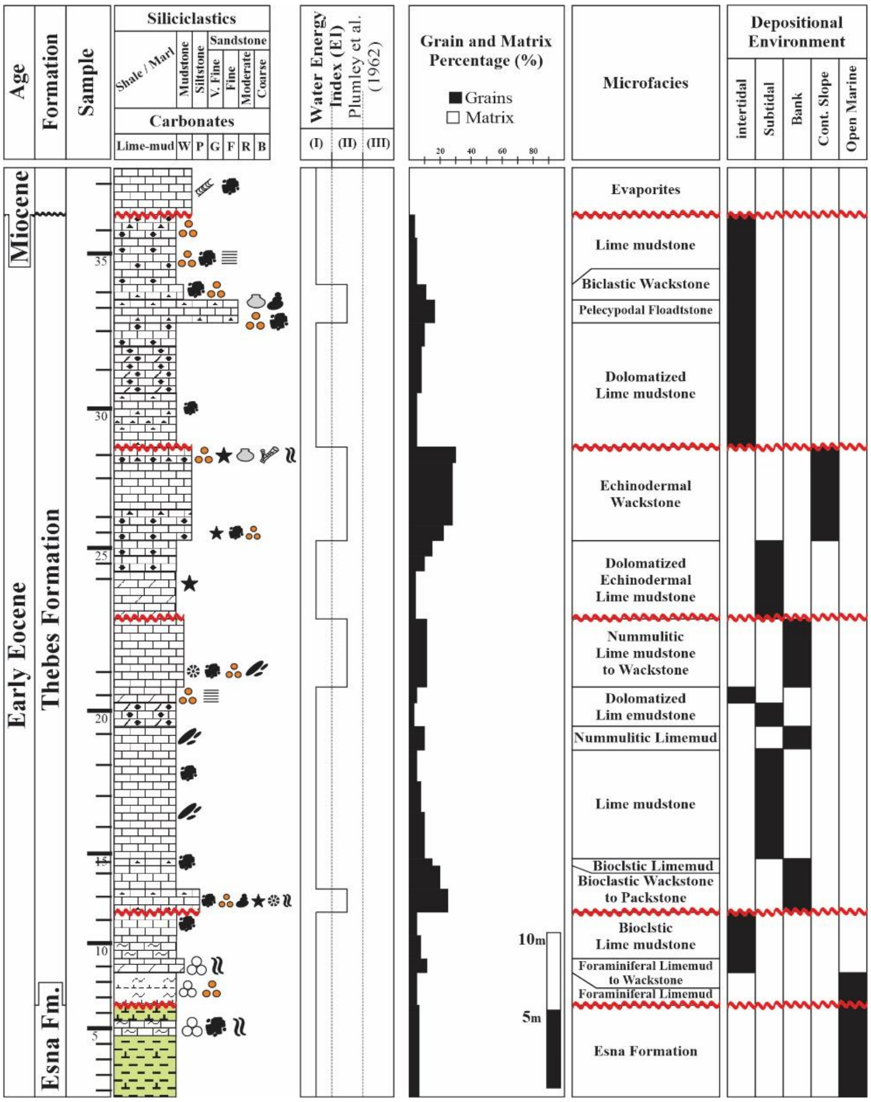

Fig. 5: Vertical distribution of the main components, depositional textures, energy index (EI) and sedimentary environments of the Thebes Formation at Syatin section (Legend in Fig. 3).

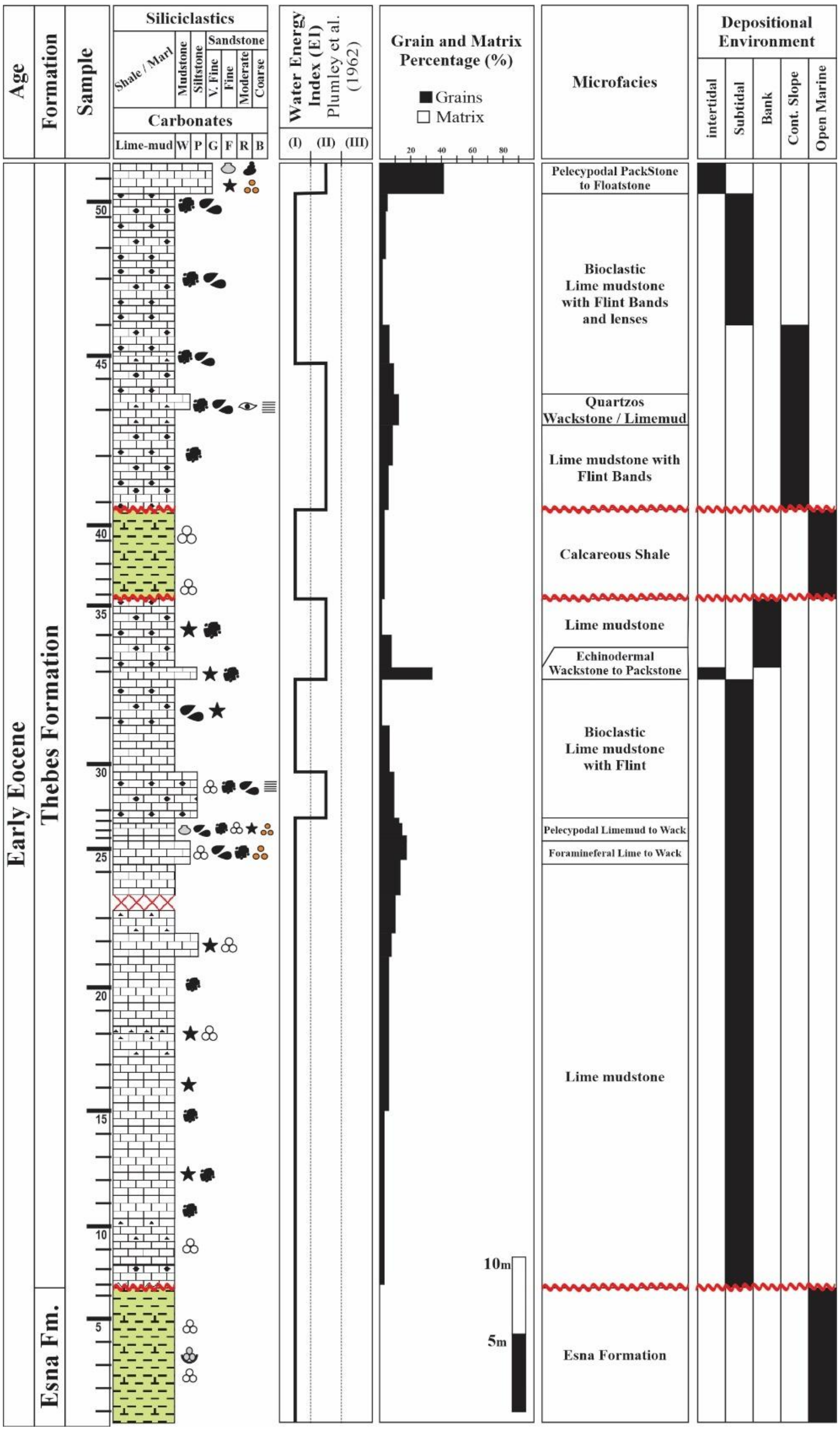

Fig. 6: Vertical distribution of the main components, depositional textures, energy index (EI) and sedimentary environments of the Thebes Formation at Wasif section (Legend in Fig. 3).

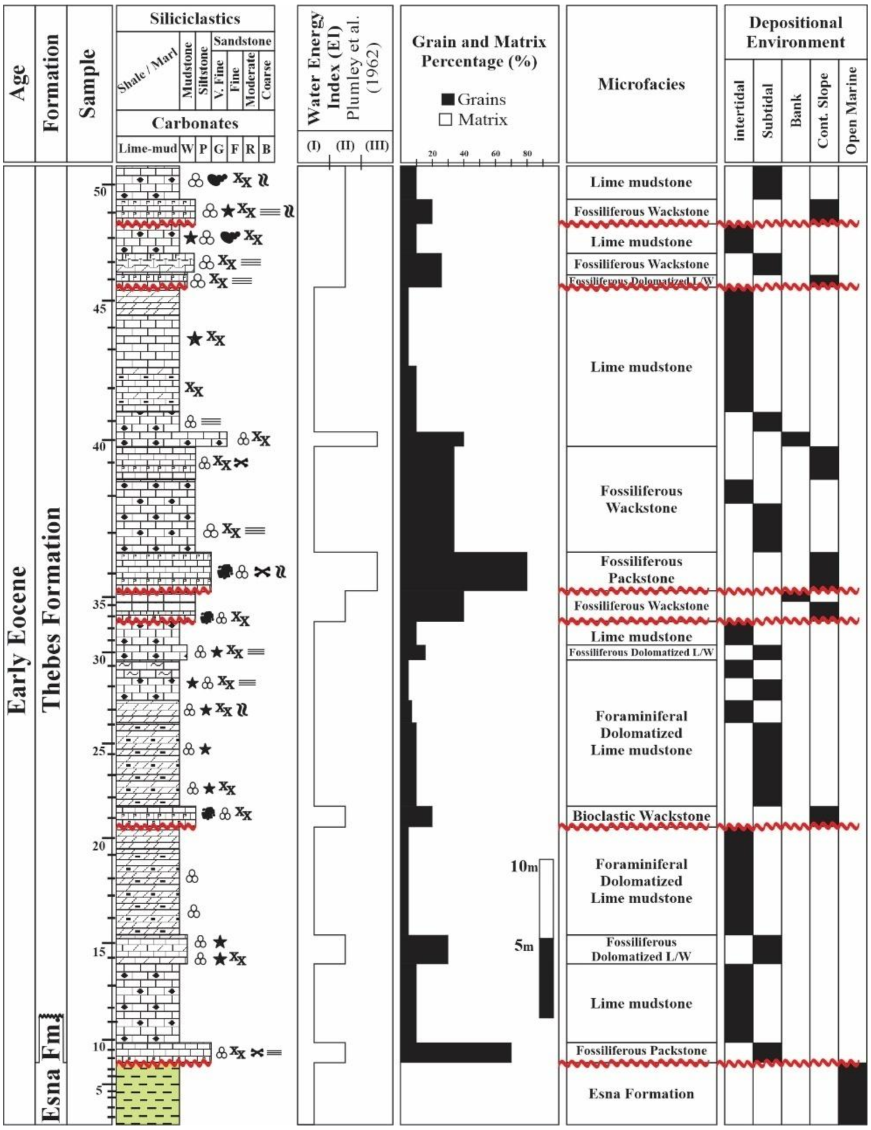

Fig. 7: Vertical distribution of the main components, depositional textures, energy index (EI) and sedimentary environments of the Thebes Formation at Wadi Malha section (Legend in Fig. 3).

6. FACIES ANALYSIS AND PALEOENVIRONMENTS

Detailed field and petrographic analyses for the studied succession in four localities revealed the predominance of tidal flats, bank, continental slope and open marine depositional environments. Each environment is distinguished by its lithology, faunal content, sedimentary structures and bedding types (Figs. 4-7).

6.1. Tidal flats

Occurrence*:* The tidal flat facies has been detected overall the study area. It is considered as the main building facies of Thebes Formation. Its thickness ranges between about 60 m at Wasif and Hamadat sections, and about 35 m at Syatin and Malha sections.

Description: The prevailing rock types are white thin laminated to papery lime mudstone with scattered chert nodules (2-20 cm diameter) and bands **(Plate A1)**. This lime mudstone facies ranges from pure to dolomitized limemud and may be silicified at certain horizons especially at the upper parts. Both vertical and horizontal bioturbation is recorded within the sediments of this facies. At the upper part of this facies the papery limestone grades into concretionary limestone **(Plate A2)** with more flint nodules.

In thin section, two types of dolomite rhombus can be identified **(Plate A3)**. The first type is fine-grained rhombs ranging from 10 to 50 µm. The second type isless abundant. The allochemes are mainly fragmented parts of echinoderms, gastropoda and foraminiferal chambers. Sometimes, the allochemical elements are found arranged in thin layers intercalating the pure lime mudstone **(Plate A4)**. Several microfacies associations are distinguished in the tidal flat facies. The main microfacies building 80% of Thebes Formation are lime mudstone microfacies. This microfacies is intercalated by thin beds of wackestone at Hamadat and Syatin sections. Echinodermal limemudstone-wackstone and echinodermal wacke to packstone **(Plate A5)** also recorded with moderate to strong dolomitization. The upper part of Thebes Formation at Hamadat and Syatin sections includes pelecypodal floatstone **(Plate A6)** with wackestone matrix.

PLATE (A)

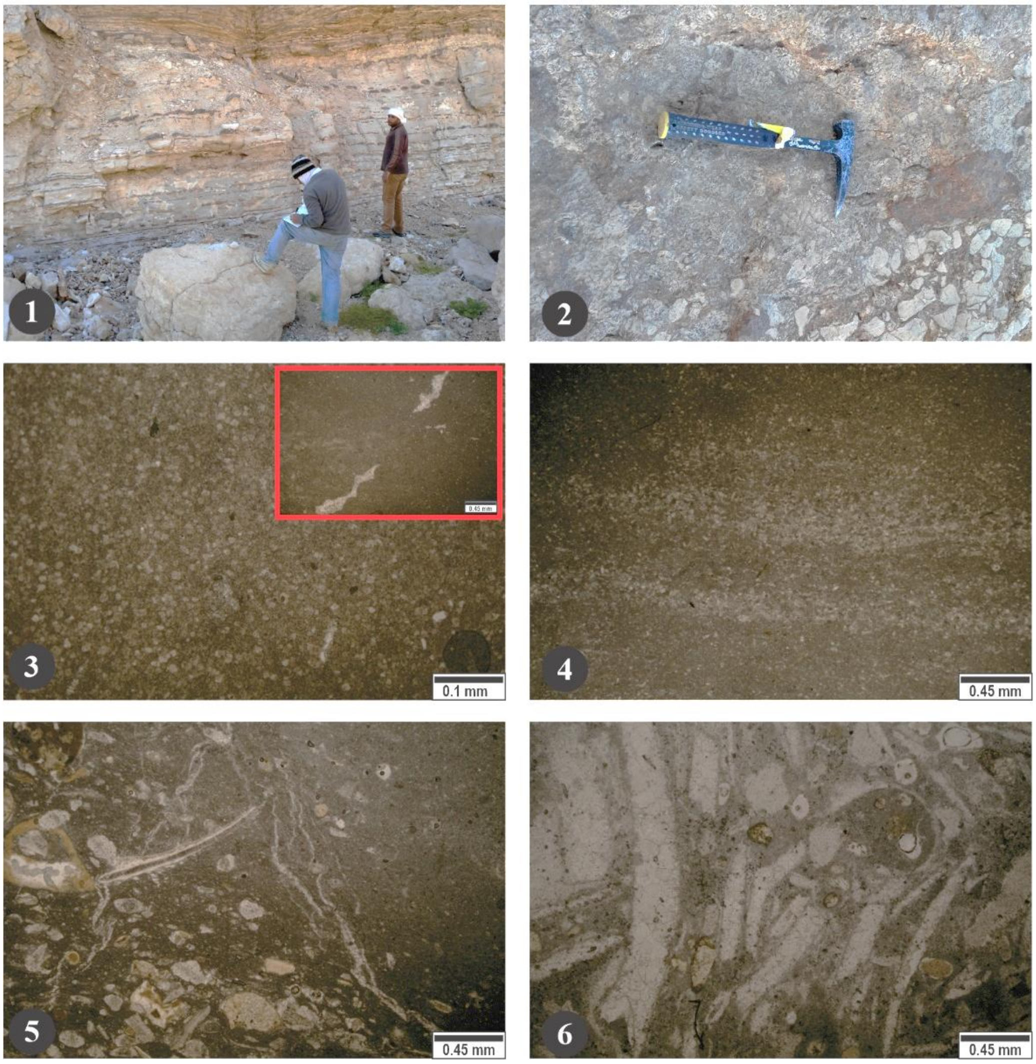

Plate A. (1). Field view showing the white laminated to papery limestone with scattered chert nodules and bands, Wasif section. (2). Field view showing the concretionary limestone, the upper parts of Hamadat section. (3). Photomicrograph showing the dolomitization of tidal flat facies, Hamadat section. (photo inset) Microscopic photo showing the bird's eye structure which characterize the tidal flat environment. (4). Photomicrograph showing the lamination structure formed by the intercalation of the allochemical and lime mudstone bands, Syatin section. (5). Photomicrograph showing echinodermal lime mudstone-wackstone with moderate to strong dolomitization, Hamadat section. (6). Photomicrograph showing the pelecypodal floatstone facies, the upper part of Hamadat section.

Interpretation: There are several criteria supporting the tidal flat origin of these sediments as: the common bird's eye structure (Plate A3, photo inset), frequent dolomitization of lime mudstone and common bioturbation. The faunal elements are restricted and represented by fragmented echinoderm and gastropoda. The planktic foraminifera are rare or nearly absence. It is only represented by fragments and broken chambers because planktic foraminifera increase in deep water away from the shelf. The broken foraminifera could not be used as indicator to paleoenvironment.

Occurrence of two different sizes of dolomite rhombus suggesting the secondary origin (replacement) of dolomite. It is believed that during compaction, the smectite which is a major clay mineral component of the interbedded shales, converts into the more stable illite. This results in release of Mg^{+2}(McHargue and Price, 1982). This Mg^{+2}replaces Ca^{+2} to form dolomite. The sediments of this facies were deposited in quiet water conditions (EI = I) intermitted by short intervals of agitated water (EI = II).

6.2. Bank facies belt

Occurrence: This facies is well exposed in the southern parts of the study area at the lower part of Hamadat (13 m thick) and Syatin (8.75 m thick) sections. It decreases in thickness in the northern part of the study area **(Plate B1)**, where it measures only (4 m thick) at the middle part of Wasif section and (1.5 m thick) at Wadi Malha section.

Description: It is exposed as hard, medium to thick bedded, laminated dark grey limestone. Sedimentary structures are represented by burrow and bioturbation. Bioturbated wackestones and packstones dominate the sequence, but mudstones are also abundant.

Microscopically, this facies is composed mainly of intact and fragmented fine nummulites (1-1.4 cm in diameter), the smaller A-forms dominate over the larger B-forms with bimodal grain size distribution. In addition to nummulites, other faunal elements are represented as gastropods (2-34%), pelecypods (up to 50%), operculines (up to 21%), echinoderm bioclasts (1-10%) and bifoliate bryozoa (1-5%). The main microfacies are nummulitic lime mudstone-wackestone **(Plate B2)**, nummulitic floatstone with wackestone matrix **(Plate B3)**, pelecypodal floatstone **(Plate B4)**, mollusca and operculines floatstone **(Plate B5)**, and operculines wackestone to packstone **(Plate B6)**.

Interpretation: The restriction of fauna which dominated by nummulites and other larger foraminifera, mullasca, echinoderms is evident criteria to nummulites bank environment. The little micro or macrofauna associated with nummulites, suggesting that deposition took place in a nutrient-poor environment (oligotrophic) and/or in an environment with significant hydrodynamic sorting. Many of these sediments are located above erosive or burrowed firm ground bases. The nummulite tests and fragments show rare evidences of boring, suggesting they were originally deposited in a continuously agitated environment.

Occurrence of nummulites, in association with other larger foraminifera are indicators to neritic and shelf ramp facies. The sediments of this facies was deposited in quiet to intermittently agitated water conditions (E=I-II).

PLATE (B)

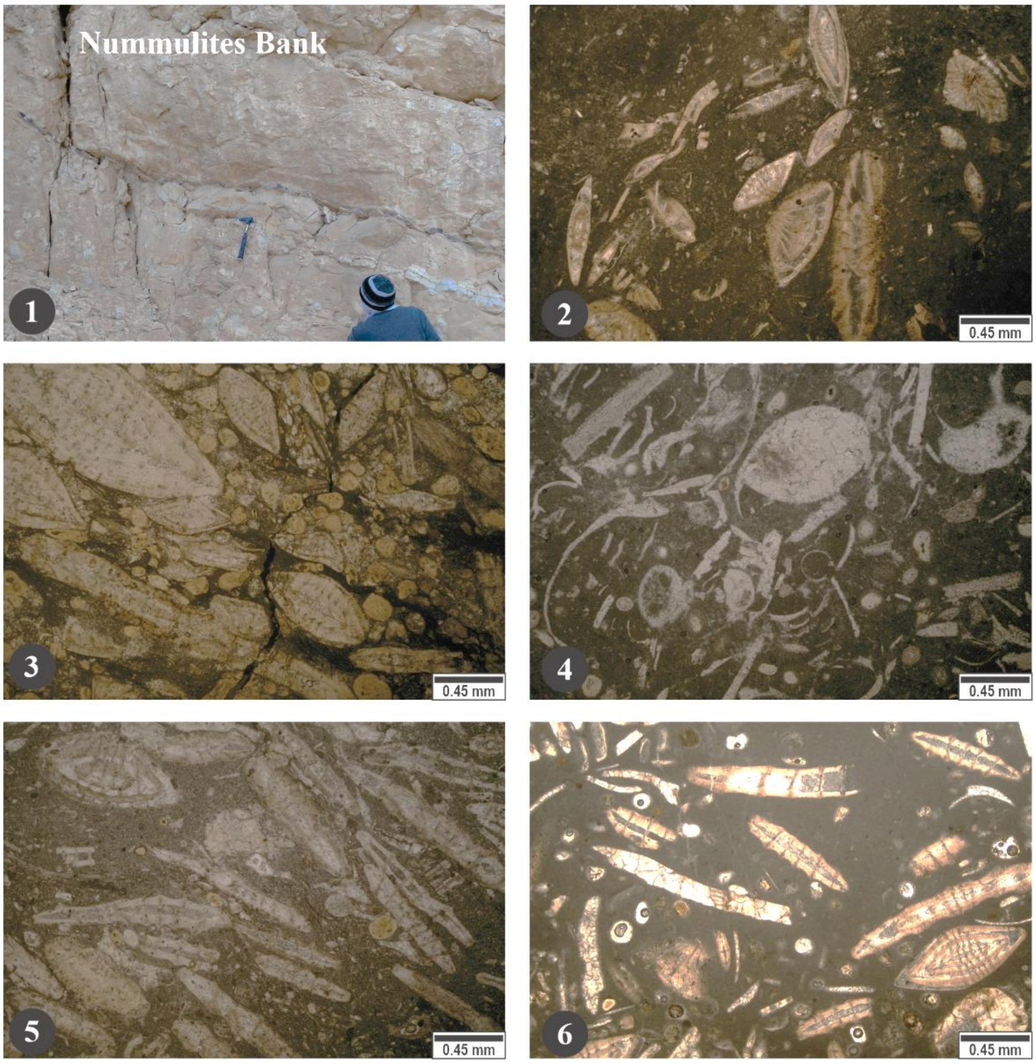

Plate B. (1). Field view showing the nummulites bank facies at the lower part of Thebes Formation, which is well exposed in the southern parts, Hamadat section. (2). Photomicrograph showing nummulites wackestone of bank environment, Hamadat section. (3). Photomicrograph showing nummulitic floatstone with wackstone matrix, Hamadat section. (4). Photomicrograph showing pelecypodal floatstone, Hamadat section. (5). Photomicrograph showing mollusca and operculines floatstone, Hamadat section. (6). Photomicrograph showing operculines wackestone to packstone, Hamadat section.

6.3. Continental slope facies belt

Occurrence: This facies is well represented all over the study area, where it measures6m thick at Hamadat, about 6 m thick at Wadi Malha, about 5.5 m thick at Syatin, and about 2m thick at Wasif.

Description: this facies consists mainly of lime mudstone that may change laterally into echinodermal wackstone at certain levels. It is represented by foraminiferal wackestone to packstone at Wadi Malha section. The sediments are slightly to moderately bioturbated. Slide and slump features were detected as remarkable features. The recorded slump and slide sediments can be distinguished into three types:

- Synsedimentary slump-folded beds **(Plate C1)**
- Slide blocks rest on large intraformational truncation surface (slump scars) inargillaceous and cherty limemudstone to wackestone
- Slump channel lag deposits (turbidites). **(Plate C2)**

The synsedimentary slump-folded beds include well visible micro folds; convolute thin laminae, disrupted and discontinuous very thin beds. These structures have been recorded mainly inrecrystallized, unfossiliferous, pure lime mudstone beds.

Microscopically, this facies is composed mainly of fragmented planktic foraminifera (1-30 %), pelecypods (to 2%), ostracoda (1-5%), echinoderm bioclasts (up to 28%), corals (1-2%) and fragments of unknown fossils (1-5%). Different microfacies have been recorded in this facies belt such as, echinodermal wackstone **(Plate C3),** and lime mudstone to wackestone **(Plate C4).**

Interpretation: The bedding planes are mainly deformed, which suggest plastic deformation during transport **(Plate C1)**. Slump and slide features are developed as a result of down slope, short periods of catastrophic gravitational sliding and slumping on steep ramp which subjected to tectonic subsidence and progressive tilting (El Ayyat and Obaidalla, 2005).The dominance of planktic foraminifera; relatively small size of the planktonic and benthonics; and relatively high P/B ratio beside the sedimentary structure suggest deposition in upper bathyal zone (continental slope setting).The sediments representing this facies were probably deposited under intermittently (EI=II) agitated water conditions.

PLATE (C)

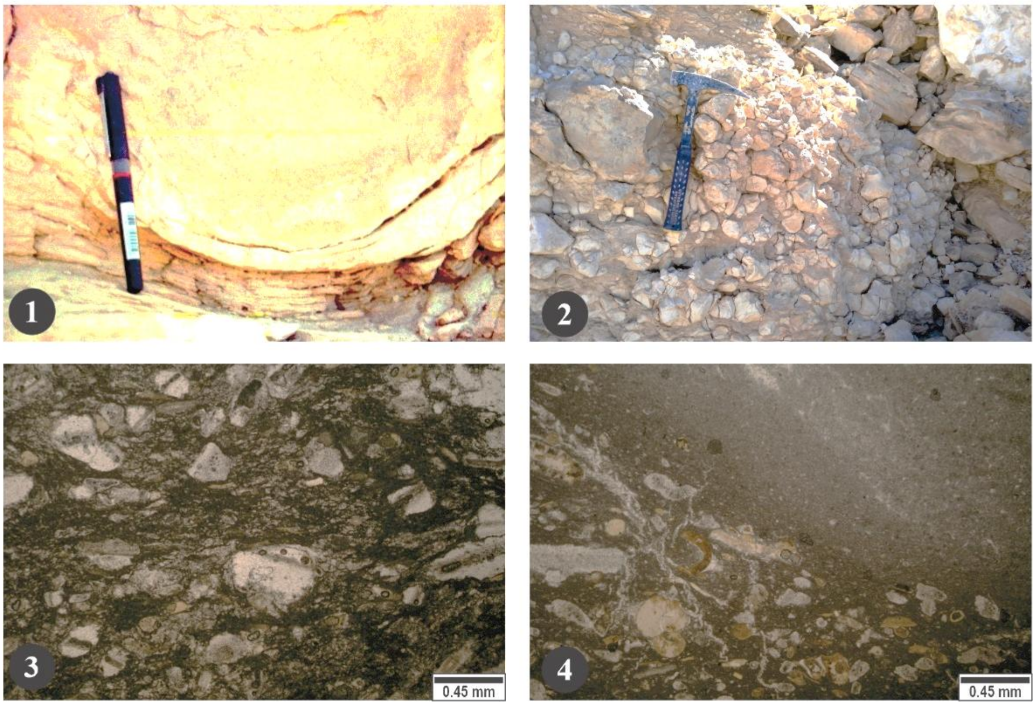

Plate C. (1). Field view showing synsedimentary slump-folded beds. The bedding is intensively deformed, suggesting plastic deformation during transport, W. Mallha section. (2). Field view showing the coarse detritus on carbonate slope where the turbidity currents and debris flow are the dominant transport mechanism, Hamadat section. (3). Photomicrograph showing the echinodermal wackstone facies, Syatin section. (4). Photomicrograph showing lime mudstone to wackestone facies, Wasif section.

6.4. Open marine facies belt

Occurrence: The sediments of this facies belt is relatively restricted in the occurrence, where it is mainly recorded at the lower part of the Thebes Formation near the contact between Esna and Thebes formations **(Plate D1)** and as two bands of calcareous shale to marl intercalating the middle part of Hamadat (5m thick), and Wasif (4.5m thick).It is represented at Hamadat by about 11 m thick, Syatin by about 2 m thick and Wasif by about 6 m thick. It is completely absent at Wadi Malha section.

Description: The sediments of this facies is represented mainly by laminated to thinly bedded- fine grained limestone and calcareous shale. Scattered nodules or concretions of flint (chert) also represented throughout but increase in the upper portion. Petrographically, this facies contains planktonic foraminifera (3-10 %) and benthic foraminifera (up to 3%) beside ostracoda (up to 7%) and unknown fragments (1-5%). A limited number of microfacies has been recorded in this facies such as, calcareous silt to marl, and foraminiferal limemud to wack (Plate D2).

PLATE (D)

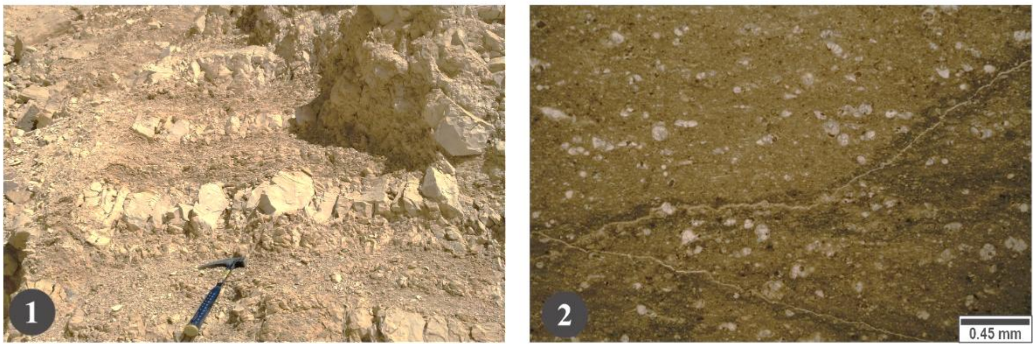

Plate D. (1). Field view showing the intercalated marl and shale deposits at the gradational contact between Esna and Thebes formations, Syatin section. (2). Photomicrograph showing the foraminiferal limemud to wacky representing the open marine environment, Syatin section.

Interpretation: The thin bedded to laminated nature of this facies suggest a very low energy depositional environment. The little occurrence of benthonic fossils and trace fossils suggest that this facies was formed in deep calm water, in an open marine environment, normally below the range of current activity. The preservation of horizontal laminations is related to absence of burrowing organisms. The sediments of this facies were probably deposited under calm water conditions (E=I).

7. SEDIMENTOLOGICAL HISTORY

The geological history of the Egyptian Paleogene is dominated by tectonic events, which began as Late Cretaceous tectonism and continued steadily or episodically in the Paleogene (Said, 1990). Boukhary and Abdel-Malik (1983) believed that the alternation of shallow and comparatively deeper facies exhibited by the Eocene deposits in Egypt is possibly related to the relief of the depositional basin in which they accumulated. Abu Khadra et al. (1987) recorded syn-tectonic Lower and Middle Eocene limestone facies in the Southern Galala and suggested that the central part of Gulf of Suez was tectonically active site during the Eocene period. In the northeast of Assiut (Nile Valley), Keheila (2000) believed in the presence of northeast elongated submarine paleohigh, separated by a synform trough during Late Ypresian. By analogy, and alsofrom the paleogeographical relationships between the different facies types under study, it is assumed that the Syrian Arc System tectonism had its impact on the sedimentary facies and paleogeography of the Lower Eocene sedimentary basin in Red Sea cost. It became clear that tectonism has had a significant control over sedimentation, although tectonism is only superimposed locally onto more regional sea-level changes.

The study area was developed on a passive margin basin during the intermediate closing phase of the Neotethys. The studied sections show a gradual passage from relatively deeper marine to shallow marginal marine facies, without evidence for a talus slope or significant slope break, suggesting deposition on a gently inclined ramp. The lateral and vertical evolution of facies of the Lower Eocene reflects repeated transgressions and regressions due to the combination of tectonic movements and sea level changes. Contacts between each facies are gradational, suggesting migration of the depositional environments.

Sedimentological and paleontological studies have shown that a standard Bahamian type platform model cannot be fully applied to this ancient siliciclastic-carbonate succession. The gentle dip of the sequence suggests that the sediments were deposited on a homoclinal ramp. The rare occurrence of reef building organisms in subtidal are as despite the favorable conditions is likely characteristic of ramps. Louks et al. (1998) put forward a ramp model which is favored in this paper. A ramp interpretation predicts that facies will shift laterally as a result of only a modest rise in sea level and will generally interfinger with each other. This differs from the shelf platform model, which proposes that a mild sea level rise would cause an aggradation of the various facies with less interfingering. The absence of dasycladacean algae suggests a deeper ramp setting below fair-weather wave base. True storm structures are absent; probably the area lay on the outer limits of wave action and in addition the area has been extensively bioturbated.

The fine-grained terrigenous lithologies may represent a deposit of a low energy, deep subtidal, distal ramp setting well below fair weather wave base. This is based on the following characteristics: the dominance of fine-grained siliciclastics and micrite; the excellent lateral continuity of bedding; macro-and microfauna; the absence of shallow-water sedimentary structures and in situ benthonic fauna. The presence of burrows, attest to normal oxygenic conditions prevailing at times in the surface sediment layer, but conditions did not allow benthic colonization. The water energy levels are interpreted as having been very low to low, resulting in sedimentation due to the settling of carbonate mud and argillaceous shales, muds and fine silt from suspension, with the exception of occasional high-energy storm events which introduced sediments from shallower water.

The ramp (Fig. 9) is classified into tidal flats, bank, continental slope and open marine zones. The pattern of sedimentation and facies changes may be controlled by paleotopography that were inherited from the Late Paleocene/Early Eocene tectonism. This resulted from the reactivation of the Syrian Arc Fold System. The sedimentation pattern, types and thickness of the sediments accumulated in the studied basin have controlled by the paleo structures in addition to the repeated sea level changes and clastic supply. The wide variation in thickness of the different facies suggests that deposition occurred on a highly undulating sea bottom of the shelf setting and also suggests continuous sedimentation in a subsiding basin. The depositional evolution of sedimentary basins in the studied area is summarized in Figure 8 as follows:

Stage (1): From the close of the Paleocene through the beginning of the Eocene it was an interval of high stand sea level. This result in a marine transgression gradually inundated the northeast Afro -Arabian shelf and removed proximal sources of fine-grained terrigenous clastics from the vicinity of the study area, resulting in the gradual transition from shales, to marls, to chalk with time. The marine transgression during this interval resulted in deposition of pelagic sediments of upper Esna Formation over the study area.
Preexisting basement topography in the northern of the study area at Wadi Malha caused an overall thinning of the Esna shale in that region. No evidence of positive bathymetry to the south is noted at this time (Fig. 8).

Stage (2): The inception of pelagic carbonate deposition in the study area near the beginning of the Eocene found the basin well aerated and containing an active infauna. Continued rise in sea level resulted in the establishment of oxygen-depleted basinal conditions that inhibited further development of a benthonic fauna.

At this time also, carbonate platforms had developed at southeast of the studied basin, suggesting that tectonic uplift had affected the basin flanks. A diverse assemblage of shallow-water skeletal organisms developed on the platform -margin and were periodically redeposited into the basin by gravity induced mass flow.

This stage characterized by intermittent deposition of open marine and bank sediments. These sediments were intercalated by shallow marine tidal flat facies at the southern part of the study area (Hamadat and Syatin). The sediments of this stage was represented mainly by shallow water tidal flat deposits at the northern sections (Wasif and Malha).Thebes Formation overlies Esna Formation with remarkable unconformity at Malha section suggesting uplift affected the northern part of the study area during Early Eocene mostly as a reactivation of the Syrian arc system.

Episodic upwel1ing of basinal waters onto the northern platform slope caused periods of high organic productivity in this area and the concentration of both skeletal and authigenic phosphate grains within numerous sandy carbonate intervals here (Fig. 8).

Stage (3): Sedimentation persisted in the study area but became less continuous. Intermittent cycles of deposition and nondeposition resulted in the development of intercalated sequences of laminated chalk and nodular limestone.

General shallowing of sea level was prevailed during deposition of upper part of Thebes Formation. This may be related to eustatic fall. This shallowing led to widespread deposition of the tidal flat deposits over the study area.

Carbonate sands continued to be reworked off-bank from the north, while a more restricted, oyster-dominated fauna became established on the southern platform as a result of gradual regional shallowing. Nodular limestones forming on the slopes of both carbonate platforms periodically slumped and were transported into the sedimentary basin by means of submarine debris flows.

Gradual shallowing continued, and oyster-rich molluscan epifauna began to become established on the basin floor itself (Fig. 8).

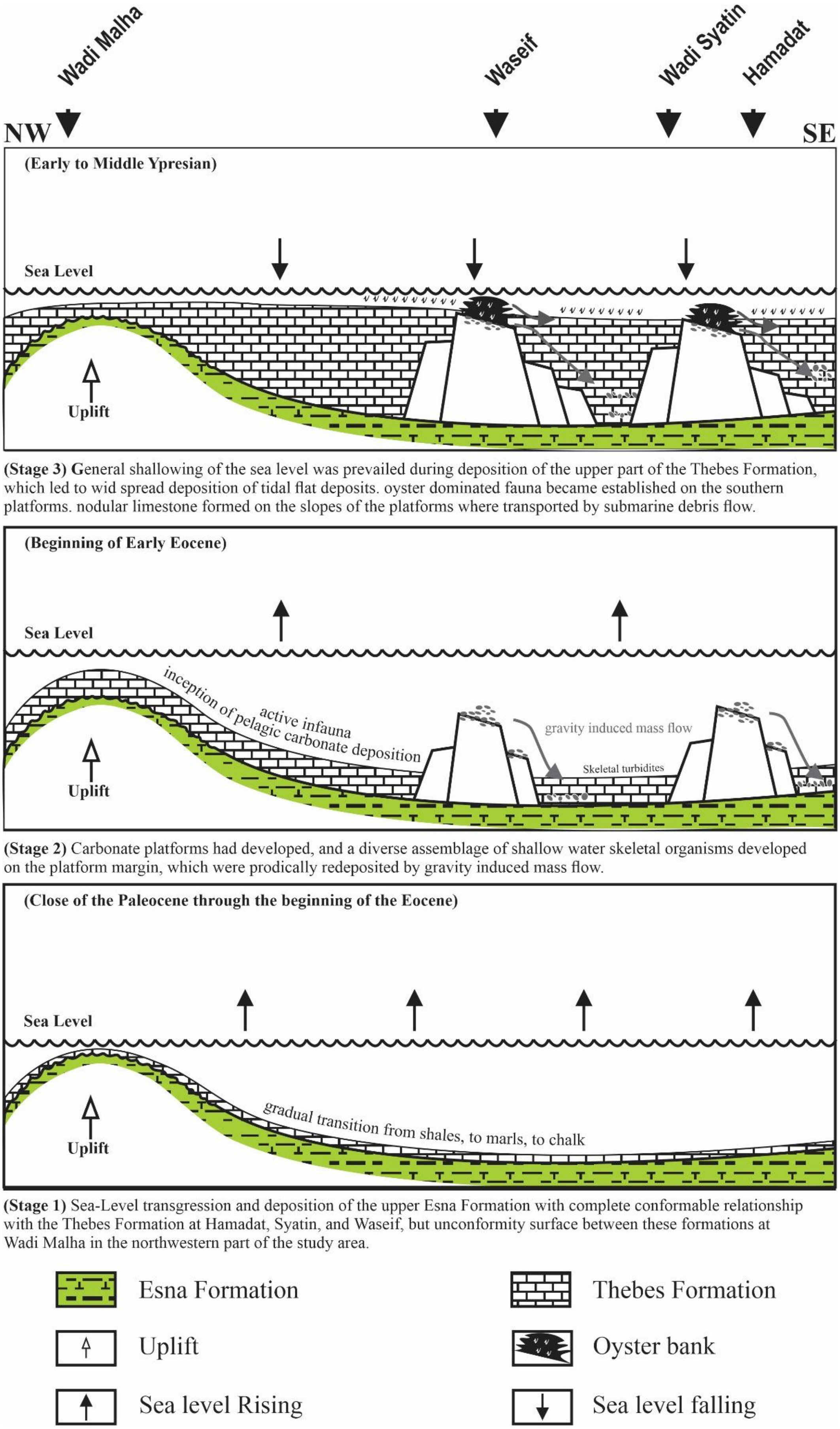

Fig.8 The depositional evolution of sedimentary basins in the studied area.

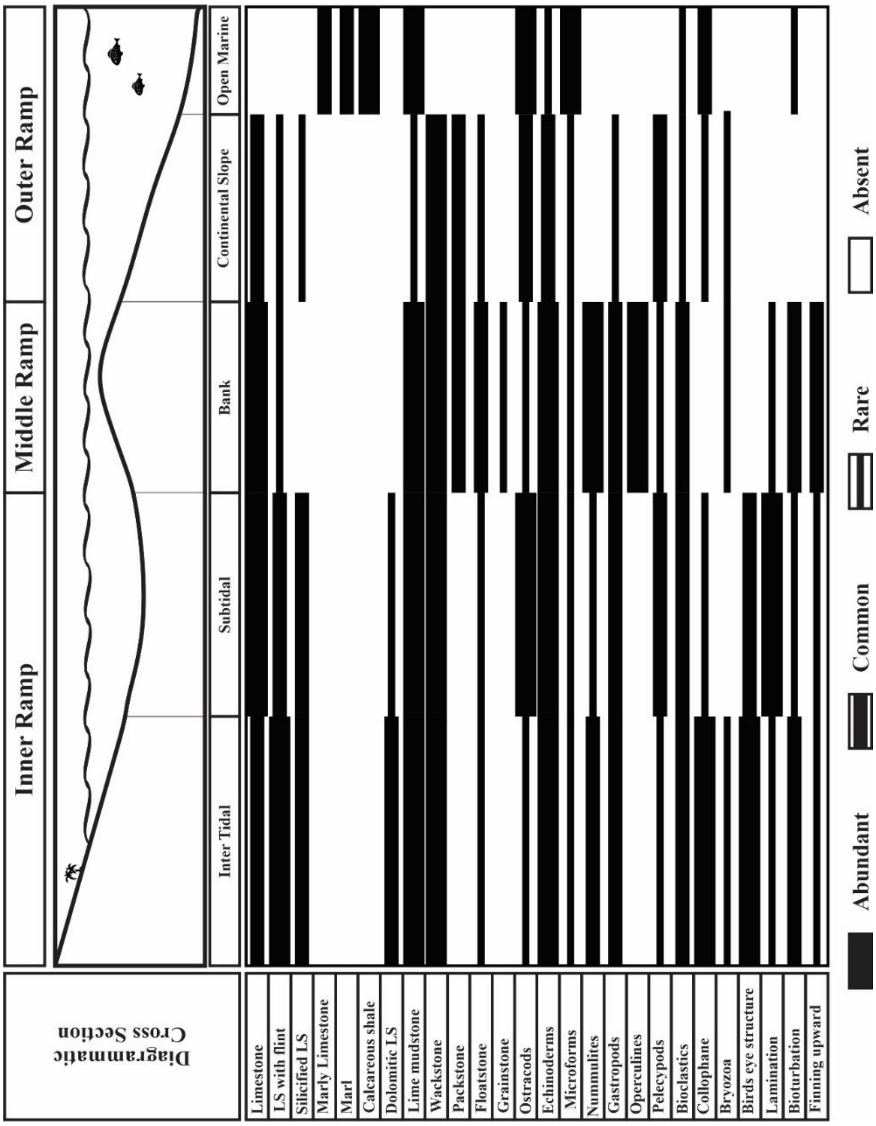

Fig. 9. Facies model of the Lower Eocene sedimentary sequence in the study area, demonstrating the distribution of the main ortho- and allo-chemical components, depositional textures and primary sedimentary structures.

SUMMARY AND CONCLUSIONS

The good exposure and widespread distribution of Eocene Thebes Formation in central and northern Egypt give opportunity to study, in detail, facies analysis and paleoenvironment reconstruction of this formation. Lithostratigraphically, the carbonate succession of the Thebes Formation rests conformably and unconformably over the siliciclastics of the Esna Formation. The contact ranges from gradational contact at the southern sections (Hamadat, Syatin, and Wasif) to sharp contact with obvious unconformity at Wadi Malha section.

Sedimentologically, detailed field investigations and petrographic analysis led to recognize four main sedimentary facies belts.

Tidal flat facies belt, most carbonates of this facies are bioclastic and foraminiferal lime mudstones intercalated by thin beds of wackestones. The pure papery lime mudstone is intercalated by thin fossiliferous layers of pelecypodal lime mudstone at Wasif section. Quiet to slightly agitated water conditions (EI=I-II) was suggested for the deposition of this carbonates.

Bank facies belt, this microfacies is less represented than tidal flat facies. It is well represented at the lower half of Hamadat and Syatin sections. Its texture is dominated by nummulitic lime mudstone to nummulitic floatstone with wackestone matrix, beside the less common pelecypodal, mollusca and operculine floatstone and foraminiferal grainstone. Several criteria supported the nummulite bank facies of deposition as, occurrence of many of these sediments above erosive or burrowed firm ground bases, the restriction of fauna which dominated by nummulites and other larger foraminifera. The water conditions during deposition of this microfacies was probably intermittently agitated (E=II).The occurrence of nummulites, in association with other larger foraminifera are indicator to neritic depth.

Continental slope facies belt, this facies shows deformed bedding planes, which suggest plastic deformation during transport. Slump and slide features are developed as a result of down slope. The main microfacies associations are lime mudstone that may range into echinoderm wackestone at certain levels, also foraminiferal wackestone and foraminiferal wacke to packstone is recorded at Malha section the sediments representing this microfacies were probably deposited under intermittently (EI=II) agitated water conditions.

Open marine facies belt, it is represented by foraminiferal lime mudstone and calcareous shale except at Malha section where it is absent. The fine-grained-thinly bedded nature of these sediments reflects deposition in quiet water conditions (EI=I). The relative abundance of planktonic foraminifera is indicator open marine environment away from shelf.

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التحليل السحني و البيئة القديمة لتتابع متكون الطيبة (الإيوسين السفلي) علي طول ساحل البحر الأحمر ما بين القصير و الغردقة

تهدف هذه الدراسة الي القاء المزيد من الضوء علي تتابع الكربونات لمتكون الطيبة (الايوسين) بالصحراء الشرقية لمصر من ناحية السحن وبيئات الترسيب وكذلك التاريخ الترسيبي للحوض ولتحقيق تلك الاهداف تم اختيار ٤ قطاعات صخرية تغطي مساحة ١٥٠ كم٢ علي طول الساحل الغربي للبحر الاحمر مابين مدينتي القصير والغردقة. هذه القطاعات الصخرية مرتبة من الجنوب الي الشمال كالتالي: ١ . قطاع جبل حماضات، ٢. قطاع وادي السياتين، ٣. قطاع جبل وصيف، ٣. قطاع وادي مالحة. هذة القطاعات تم قياسها ووصفها في الحقل وتم تجميع ٢٢٦عينة صخرية كما تم عمل ١٢٩ قطاع ميكروسكوبي رقيق منها.

ومن خلال الدراسة الطباقية أمكن تمييز وحدتين صخريتين أساسيتين في المنطقة وهما الجزء العلوي من متكون الإسنا ويعلوها متكون الطيبة، وتفصلهما علاقة توافق ظاهري في الثلاث قطاعات الجنوبية بينما يفصلهما سطح تعرية وعدم توافق بالجزء الشمالي (قطاع وادي المالحة).

وقد تم دراسة الصخور الجيرية بالمنطقة من الناحية الترسيبية تفصيليا وذلك من خلال دراسة ميكروسكوبية تحليلية تم فيها تقدير النسب المئوية لجميع مكونات الحجر الجيري العضوية والغير عضوية في لوحة رقم ٩، كما تم تحديد أنسجة الترسيب المختلفة وكذلك تغيرات معامل الطاقة للمياه أثناء الترسيب في لوحات رقم ٤,٥,٦,٧.

تم تحديد ٤ أنواع رئيسية من سحن الصخور الجيرية مرتبطة بأربع بيئات ترسيب رئيسية وفيما يلي إستعراض لهذه السحن:

١.سحنة مسطحات المد والجزر Tidal flat facies

تعتبر هذه السحنة من أكثر السحن إنتشارا وتمثيلا بمتكون الطيبة بمنطقة الدراسة.وتتكون في مجملها من حجر جيري مارلي يحتوي علي فتات وأثار الحفريات.وتعكس هذه السحنه ظروف ترسيب بحرية هادئةquiet water conditions وتحتوي علي حفريات بحرية هائمة منقولة reworked planktonic foraminifera

٢. سحنة المسطح النيموليتي Nummulites bank facies
الجزء الأعظم من هذه السحنه تم تسجيله بالجزء الجنوبي من منطقة الدراسة بقطاعات الحماضات والسياتين بينما تواجده محدود بالقطاعات الشماليةز

تتكون هذه السحن من حجر جيري نيموليتي سميك التطبق thick-bedded nummulitic limestone يكتظ بأصداف النيموليت ذات الحجم المتوسط والكبير. ويعزي تكوين هذه السحنة الي بيئة تميزت بطاقة مياه هادئة الي متوسطة quiet to intermittenly agitated water conditions

٣. سحنة المنحدر القاري continental slope facies

هذه السحنه أظهرت وفرة من الفورامنفيرا، كما تظهر بها عدة شواهد علي الانزلاق والهبوط المرتبط بالترسيب علي المنحدرات. وتعتبر هذه السحنه ترسبت في بيئة تميزت بطاقة مياه متوسطة intermittently agitated water conditions

٤. سحنة المياة العميقة Open marine facies

تمثيل هذه السحنة محدود بمتكون الطيبة بينما تعتبر السحنة الأساسية البانية لمتكون الإسنا وتتمثل بالطفلة الجيرية الغنية بالفورامنفيرا الهائمة. يعزي تكوين هذه السحنة الي الترسيب في بيئة تتميز بطاقة مياه هادئة quiet water conditions

كما أمكن تلخيص التاريخ الترسيبي لتتابع الايوسين بمنطقة الدراسة بالشكل رقم ٨ في عدة مراحل كالتالي:

المرحلة الأولي:

منذ نهاية العصر الباليوسيني وحتى بداية العصر الأيوسيني حدث ارتفاع في مستوى سطح البحر. أدى إلى غمر الجزء الشمالي من قارة أفريقيا بما فيها منطقة الدراسة ، مما أدى إلى ترسيب الجزء العلوي من طفلة الإسنا و الجزء السفلي من متكون الطيبة ممثلاً بـ طفلة خضراء و مارل ثم طباشير. و أدي الرفع الموجود في حوض الترسيب في شمال منطقة الدراسة بوادي مالحة الي تمثيل طلفة الإسنا بسمك قليل.

المرحلة الثانية:

في بداية العصر الإيوسيني كان حوض الترسيب جيد التهوية ويحتوي على كائنات حية نشطة عاشت في تلك البيئة. في هذا الوقت أيضًا ، تطورت أرصفة الكربونات في جنوب شرق الحوض المدروس ، مما يشير إلى أن الارتفاع التكتوني قد أثر على جوانب الحوض. مما أدي الي نشأة مجموعة متنوعة من الكائنات الحية ذات الهياكل الصلبة في المياه الضحلة على قمة هذه الأرصفة و التي حدث لها تعرية ثم نقل الي داخل حوض الترسيب عن طريق تدفق الكتلة الناجم عن الجاذبية.

المرحلة الثالثة:

مع نهاية الإيوسين السفلي سادت حالة من تقهقر مستوي سطح البحر بشكل عام أثناء ترسب الجزء العلوي من تكوين طيبة. قد يكون هذا مرتبطًا بإنخفاض عالمي في مستوي سطح البحر تحت هذه الظروف إستمر ترسيب الكربونات متزامناً مع نمو أرصفة المحاريات سواء علي قمم الأرصفة البحرية أو في منطقة المد و الجذر نتيجة لضحالة مستوي سطح البحر.