Alfarama Journal of Basic & Applied Sciences

Faculty of Science Port Said University

https://ajbas.journals.ekb.eg
ajbas@sci.psu.edu.eg

http://sci.psu.edu.eg/en/

January 2023, Volume 4 , Issue I

DOI:10.21608/ajbas.2022.140511.1104

ISSN 2682-275X

Submitted: 24-05-2022
Accepted: 14-08-2022

Pages: 132- 154

Microfacies Analyses, Depositional Interpretation and Sequence Stratigraphic Delineation of the Miocene Rocks at Cairo-Suez Road, Egypt

Hatem F. Hassan[1], Amer A. Shehata[1], Raafat M. Morsy[1, *]

Geology Department, Faculty of Science, Port Said University, Port Said, 42522, Egypt.

***Corresponding author:** raafat3030@yahoo.com

ABSTRACT

Facies analysis and depositional environment investigation coupled with the sequence stratigraphy gave a precise picture on the depositional framework and evolution of any succession. This study is ground on litho- and microfacies analysis and stratigraphical investigation to conclude the depositional and sequence stratigraphic framework of the Miocene rocks units along the Cairo-Suez Road. The studied depositional sequences of Burdigalian-Langhian age can be differentiated into two main stratigraphic units; A lower siliciclastic unit revealing lagoonal (intertidal lagoons, intertidal estuarine), and inner ramp facies, termed as Gharra Formation, and lies unconformably over the Oligocene continental sediments of Gebel Ahmar Formation. This unit is conformably overlain by the middle Miocene marine-nature sediments of Genefe Formation., revealing middle, to outer ramp facies. This depositional sequence was initiated as a result of the Miocene sea first advance over northern Egypt, including the study area. Retrogradational parasequences were stacked successively to evolve the lowstand system tract (LST), followed by the transgressive surface (TS), that matched the contact between Gharra, and Genefe formations. A deeper accommodation zone was formed as a result of the middle Miocene sea level rise, due to a tectonic subsidence, resulting in the deposition of Genefe Formation over the transgressive surface (TS), representing the transgressive system tract (TST).

Key Words:

Gharra, Genefe, sequence stratigraphy, siliciclastic-carbonate, Burdigalian, Langhian, Cairo-Suez district, Egypt.

1. INTRODUCTION

The siliciclastic-carbonate sequences are significant since they serve as a transitional zone between carbonate-dominated subtropical zones and siliciclastic temperate strata. The siliciclastic-carbonate sequences are defined by two factors: paleotopographic variations and tectonic events [1]. The Miocene in the North Eastern desert has also been explored in prior studies by [1,2,3,4,5,6], among of these [7] exhibits relations, where The transgression and regression stages are revealed in many locations (e.g. Gebel Gharra, Gebel Homiera, and Gebel Geneifa) which are unconformably either underlain by Oligocene or overlain by the post-Miocene strata. Whereas the Miocene sediments are classified into two formal units, Gharra Formation, or the lower clastic dominated facies, and Genefe Formation or the upper carbonate dominated facies. [8] interpreted that, the cyclic sedimentation, lateral facies, and thickness variations of the Miocene succession in Cairo-Suez district are caused by block faulting along renewed tectonic activities. on the other hand [9] suggested that the Miocene shallow water siliciclastics and carbonates in the Cairo–Suez district, were deposited within the epeiric ramp based upon lithofacies and biofacies documentation. The lateral facies change is well represented in Wadi Hagul as studied by [10] which exhibits different lithofacies characteristics than other basins, where the middle Miocene represents a reefal limestone within a rimmed carbonate shelf. In addition [11] outlined four major sequence boundaries within sedimentation cycles of lagoonal to outer-shelf settings based on the study of calcareous tube-dwelling encrusting polychaetas fossils. Therefore, the overall goal of this paper was twofold, clarify the depositional interpretation and interpret the sequence architecture of the Miocene rocks at Cairo -Suez Road, Egypt.

The objective of this study is to clarify the depositional interpretation, microfacies analysis, and sequence stratigraphic delineation of the Miocene rocks at Cairo -Suez Road, Egypt.

2. Material and Methods:

Five lithologic sections (Fig. 1) were chosen to be inspected in detail in the field, reported on, and sampled.

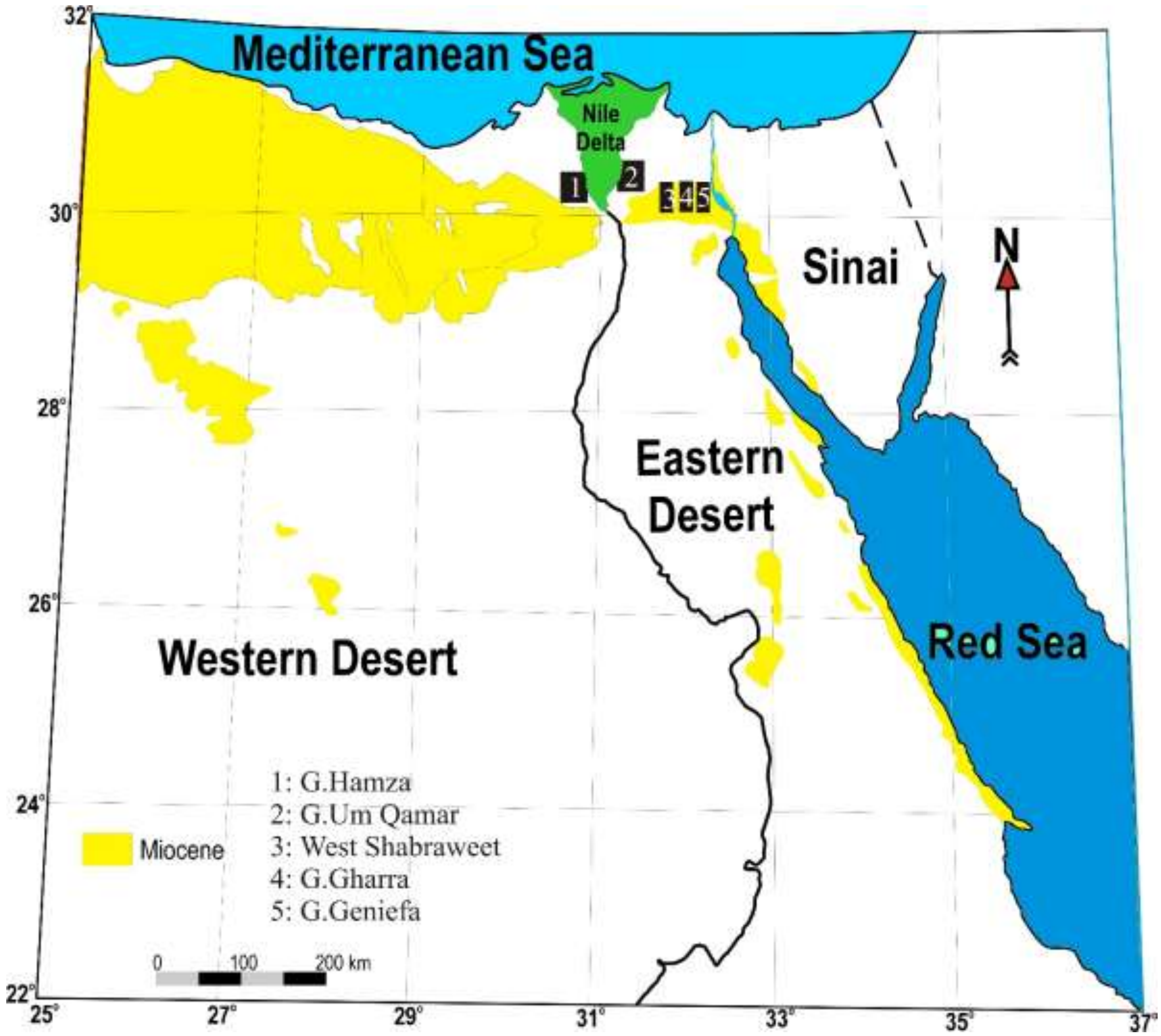
Between longitudes 31° 36′ E and 32° 46′ E, and latitudes 30° 05′ N and 30° 17′ N, the study area is located. It is bordered on the north by the Cairo-Ismailia road (Um Gdam slopes), on the south by the Cairo-Suez route (Gebel Ataqa), on the east by the Great Bitter lakes, and on the west by the city of 10th Ramadan. (Fig.1).

The studied surface sections include:

1- Um Qamar Succession Latitude 30° 36′ N, Longitude 30° 16′ E
2- Gebel Hamza succession Latitude 30° 14′ N, Longitude 31° 38′ E
3- Suez succession Latitude 30° 12′ N, Longitude 32° 46′ E
4- Genefa succession Latitude 30° 05′ N, Longitude 32° 19′ E
5- Gebel Gharra succession Latitude 30° 11′ N, Longitude 32° 12′ E

These successions were investigated multiple times for the presence of diverse rock units and their stratigraphic relationships with other units. Bed-contacts, bed-geometry pattern, the thickness behavior, characteristic sedimentary structures of Miocene Epoch sedimentary facies, and microfacies examinations were investigated. A total of 75 representative spot samples reflecting the sedimentary facies in the Miocene strata studied were obtained. The acquired data and samples were subjected to laboratory tests.

The Bed-contacts, bed-geometry pattern, the thickness behavior, characteristic sedimentary structures were investigated. According to [12, 13, 14, 15], a microscopic research was conducted on 35 thin sections reflecting the various Early–Middle Miocene lithofacies in the study area. In the meantime, for the siliciclastic microfacies, [16, 17, 18] were used.



(Fig 1) Geologic map of the study area showing the examined surface sections.

2.1 Lithostartigraphy

Two rock units compose the lithostratigraphy of the Miocene in the studied sections, as arranged from base to top as follows;

2.1.1 Gharra Formation [20] Early Miocene (Burdigalian)

[8] First used the term Gharra Formation to describe a 120-meter of arenaceous, detrital limestone with shale and sandstone unit of shallow marine shelf section of Gebel Gharra in the Cairo-Suez district, to the early Miocene deposits as described by [19].

In the studied sections, Gharra Formation unconformably overlies the Oligocene Gebel Ahmar Formation, and conformably underlies the Burdigalian Genefe Formation (Plate 1.1, 1.6, 1.7).

Gharra Formation is encountered in all of the examined sections, and is composed of Mudstone or shale with sandstone interbeds, with slight shaly sand intercalations,

(Plate 1.6, 1.8), with Sandstone of yellow Color form lens-shape bodies (e.g. West Shabraweet section) (Plate 1.2), or may be even and exhibiting high angle tabular planar cross stratifications (Plate 1.5), with yellow colors, while shales exhibit varicolored, yellow, and grey to greyish green colors, with gypsum compact intercalations, and are extremely fissile (Plate 1.6, 1.7).

Gharra Formation shows up lateral lithologic variation where sandstone beds thinning out towards south east (Figure 2), while shale interbeds persist throughout the entire sections studied. It assumes various thicknesses within the investigated sections, varies from 1.5 meters in Geniefa to 22 meters in Gebel Gharra (Figure 2).

Age assignment of Gharra Formation based on (fossil content, and stratigraphic position from previous studies) dates it back to early Miocene (Burdigalian) [19, 20,21]. Meanwhile, in the studied sections, the Gharra Formation is dated to the early Miocene (Burdigalian) based on its stratigraphic position.

The Gharra Formation is equivalent to Rudies Formation in the Gulf of Suez [20] and to Nukhul Formation [20] in southwestern Sinai. It is also correlated with Moghra and Gebel Khashab formations in the northwestern desert (Fayoum-Abu Rawash district) (Table1).

2.1.2 **Genefe Formation** [19]

[19, 26] used the term Genefe Formation to describe the early Miocene sequence in Cairo-Suez district. Genefe Formation is a carbonate unit with minor facies variations. From the Gulf of Suez entrance eastward, it grades into the Hommath Formation, which is grit-marl facies. Previous researches [27,28], have shown that the Genefe Formation is of middle Miocene age (Marine Facies of Miocene), Hommath Formation [10, 20, 23, 29, 30], and Miocene Middle Series [1, 2, 31, 32].

Genefe Formation in the studied sections conformably overlies Gharra Formation of early Miocene age (Burdigalian) (Plate 1.1, 1.6, 1.7).

Lithologically, Genefe Formation is a limestone unit, and is described as; sandy limestone in some sections, with clay interbeds, and is highly fossiliferous with echinoids (Plate3.4), bivalves (*Pecten sp*.) (Plate1.3), and *nummulites*. It is capped by a layer of fossiliferous compacted pink to buff limestone (plate1.1, 1.8).

As it assumes varying thicknesses in the analyzed sections, Genefe Formation shows a steady drop in thickness throughout the study area in northwesterly direction with maximum thickness of 28.8m at Geniefa locality, to being completely absent at west Shabraweet locality, like a wedge (Figure 2).

Although Genefe Formation is rich in its fossil content such as: bivalves, corals, and echinoids, but as a result of the integration of its faunal content, the age assignation of Genefe Formation is complex matter, however, in the studied sections Langhian was assigned to be the age of Genefe Formation, according to its fossil content e.g: *Miogypsina sp. Quniquelequline sp.* (Plate 3.5) and *Uvigerina sp,* and according to the previous literature [21, 26, 27]

Genefe Formation is equivalent to Hommath Formation in Wadi Hagul, and to the upper parts of Sadat Formation in the Gulf of Suez [23], lower parts of Gemsa Formation [25], which runs along the western edge of the Gulf of Suez basin, as well as the Kareem Formation [20], which represents early Serravallian marine facies in the Gulf of Suez (Table1).

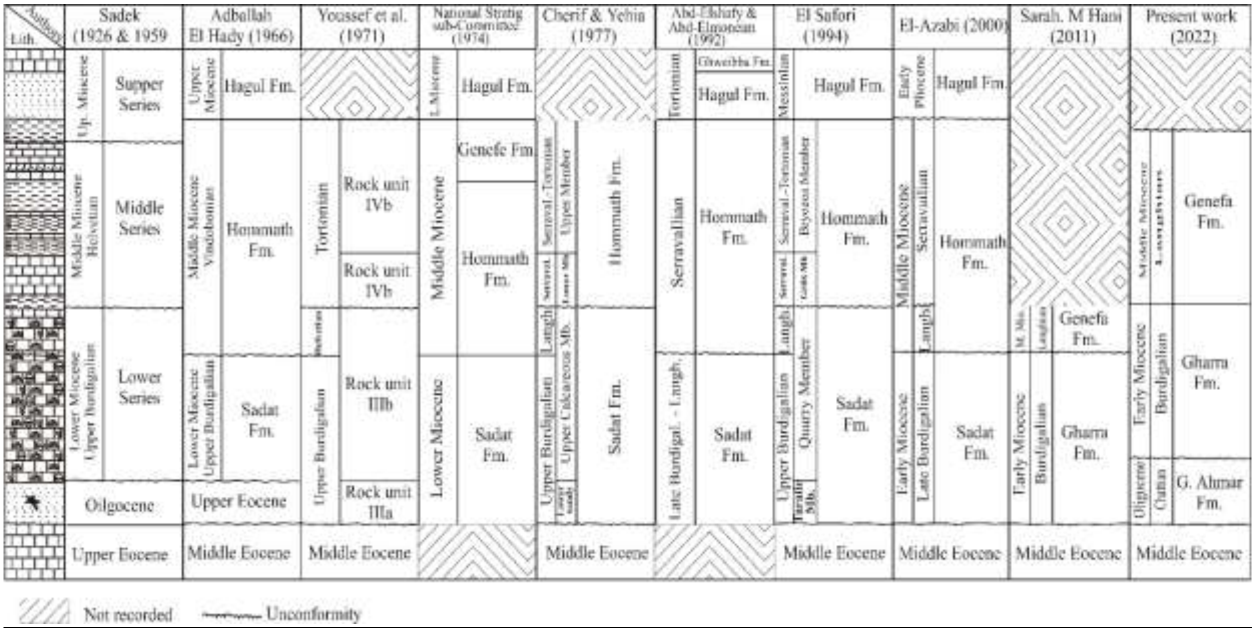


Table (1): Stratigraphic nomenclatures of the Miocene rock-units in the Gulf of Suez region (Modified after 21)

Plate 1

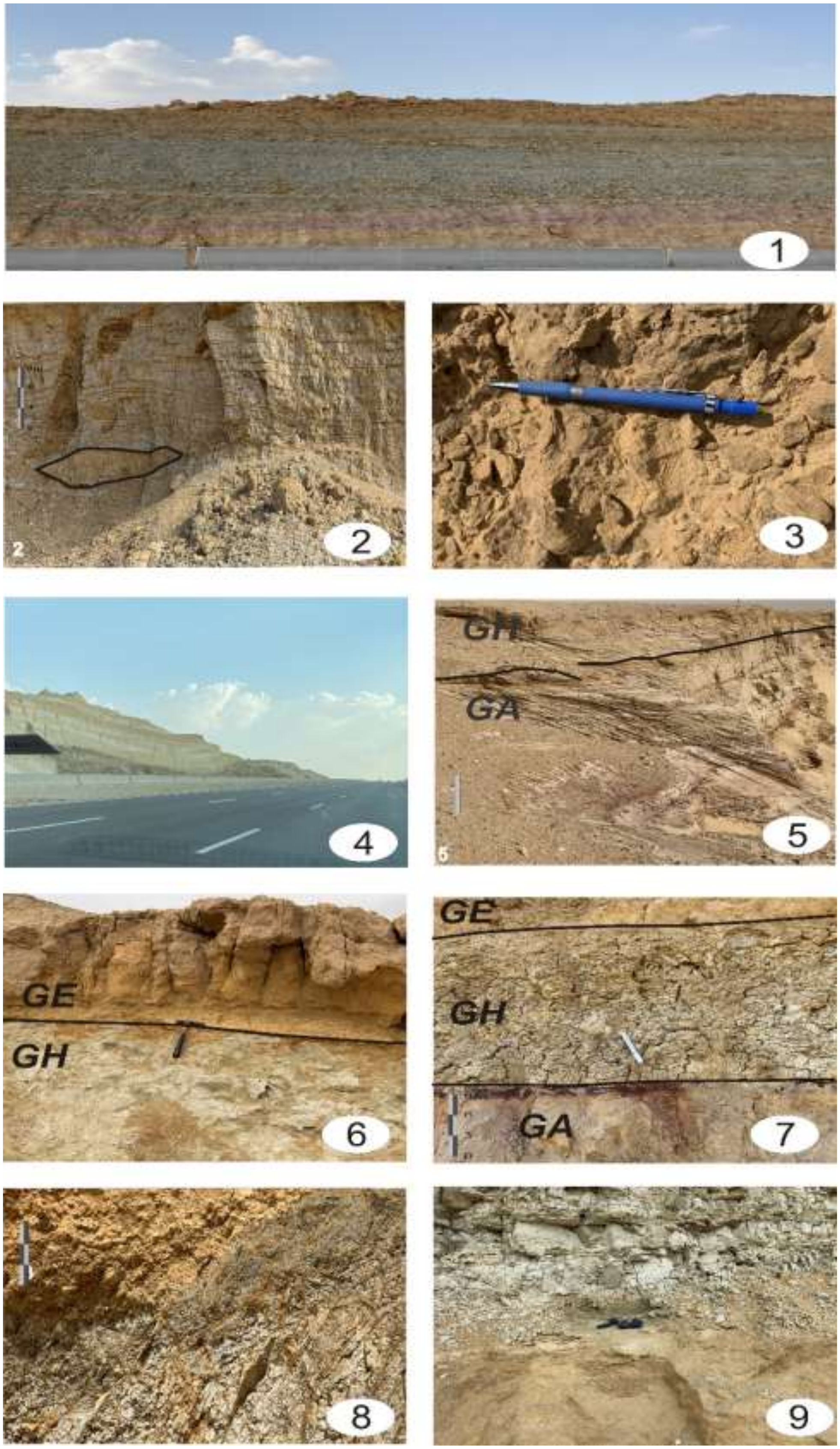


Plate 1

Fig 1. General view of Gebel Gharra lithologic succession looking to the north.

Fig 2. Sand lens of Gharra Formation, west Shabraweet section.

Fig 3. External cast fossil of *Pecten sp.*
Fig 4. Synclinal fold of the studied Miocene succession.
Fig 5. View of the contact between Gebel Ahmar (GA) Formation represented by the red ferruginous sandstone, and Gharra Formation (GH) represented by grey shale, and showing 6 sets of high angle tabular cross stratification, also a reverse fault is present in this picture which is an evidence of the structural deformation.
Fig 6. A close up view of the contact between Gharra Formation (GH) which is represented by the grey shales in the picture followed conformably by the yellow compact limestone of Genefe Formation (GE).
Fig7. Close up shot of the Gebel Ahmar Formation (GA) – Gharra Formation (GH) contact, Gebel Ahmar Formation is represented by red ferruginous sand stone, followed by the varicolored shales of Gharra Formation.
Fig 8. Gharra Formation, mudstone, and sandstone, West Shabraweet section.
Fig 9. Gharra Formtion, Mudstone, Gebel Gharra section.

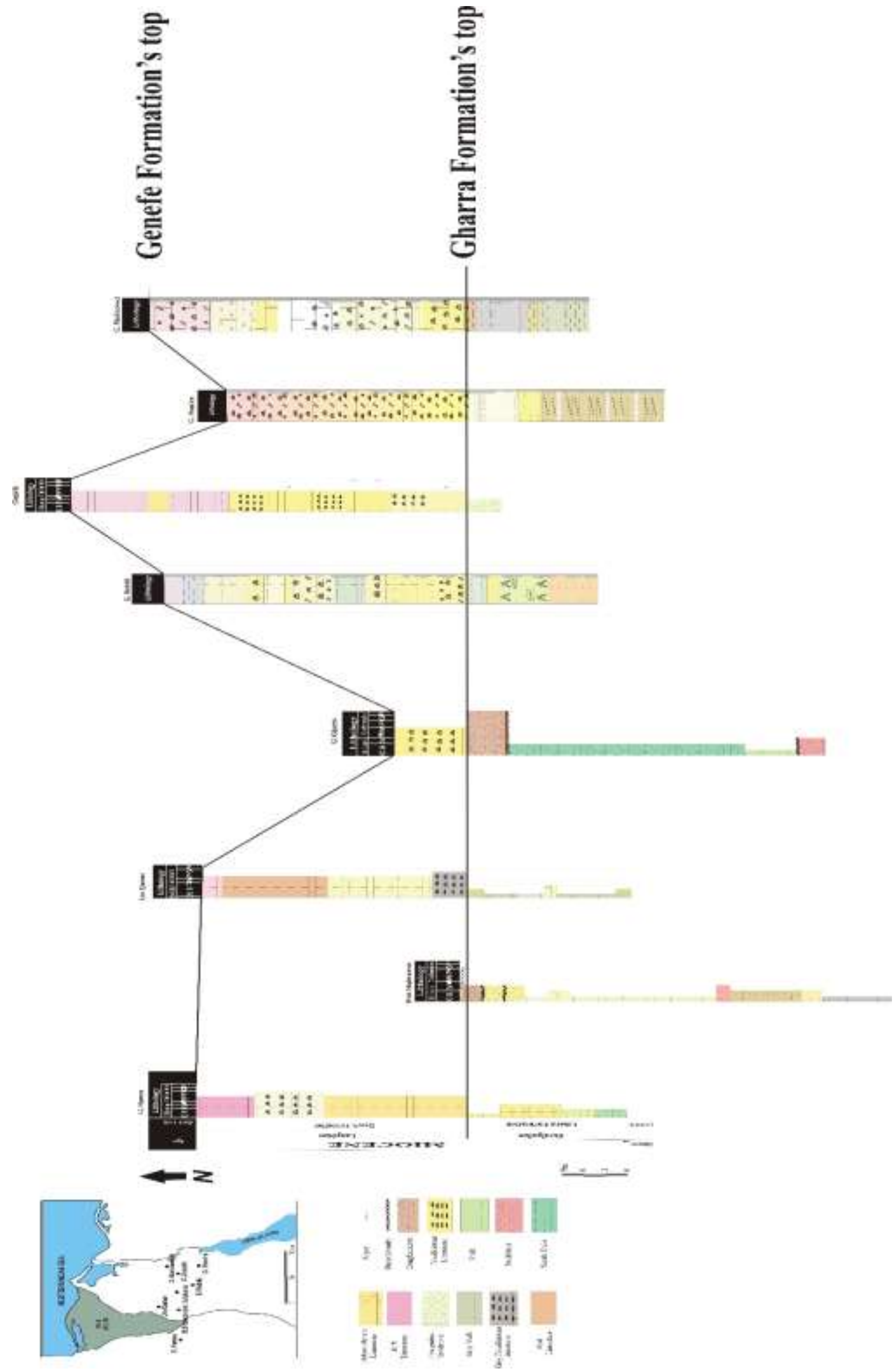


Figure (2) Correlation between the studied successions with the top surface of Gharra Formation as datum, and in North-East direction

Correlation:

Genefe Formation rests conformably over Gharra Formation (Plate 1.1, 1.6, 1.7), and thins eastward and becomes more shaly as westward, Gharra Formation's lithology is sandier, whereas eastward the thickness, and the sand percentage decreases.
Gharra formation rests unconformably over Gebel Ahmar Formation (Plate 1.5, 1.7) Thickens eastward, it's nearly not found to the west in west Shabraweet section, while westward it thickens and the faunal content also increases including corals, bivalves such as (*Pecten sp.*) (Plate 1.3).

2.2 Microfacies Analysis, and depositional trends

This study was carried out on 25 thin sections for the microfacies analysis.

2.2.1 Microfacies types and facies interpretation

The following microfacies were discovered after microscopic examination of eleven thin sections from the Gharra Formation and twenty thin sections from the Genefe Formation.:

Table (1): The microfacies associations encountered in the different Miocene rock units in Cairo-Suez district.

Age	Rock unit	Microfacies association	No. of thin sections	Thin Section
Langhian	Genefe Formation	**3-** Dolomitic algal biomicrite wackstone	11	H9, H11, H16, H4, H7, H15 Sh10, Sh13, H9′, H13′, H14′
		2- Sandy dolomitic algal packstone	1	H11
		1- Dolomitic fossiliferous calcareous quartz arenite	1	Gr8
Burdigalian	Gharra Formation	**7-** Quartz greywack	1	8
		6- Dolomitic biomicrite rudstone	1	Gr5
		5- Sandy dolomitic biomicrite packstone	1	Gr4
		4- Dolomitized microsparite packstone	1	H1
		3- Algal sandy biosparite grainstone	1	H1′
		2- Mudstone	3	H4
		1- Ferruginous calcareous quartz arenite	4	H2, H3, H5, H6

A. Tidal flat Facies

Representing the middle part of Genefe Formation at Um Qamar section, as a 2m layer of yellow, high angle tabular X-stratified fossiliferous sandstone unit.

A.1. Dolomitic fossiliferous calcareous quartz arenite

This microfacies is describing the lower part of Genefe Formation, it's recorded within Um Qamar section (Sample no. Gr8) (Plate 2.1).

The main component of this microfacies is the quartz grains which forms about (90%) of the sample, a very small amount of polycrystalline quartz grains is encountered and they display strong undlose extinction, whereas most of the quartz grains are monocrystalline, and display even to slight undlose extinction, the quartz grains are moderately sorted, sub-rounded to rounded, while the grain to grain contacts are found to be point, and line contacts. Bioclastic fragments form about (10%) of the sample, represented by red coralline algae, and echinoid spines.

All of these components are bind together by a microsparitic matrix.

Dolomitization is the main diagenetic process that took place over the microsparite matrix, as well as medium compression reflected by the point, and line grain to grain contacts.

This microfacies can be compared to the SMF18 deposited in the tidal flat quiet water below normal wave base [12, 32].

B. Lagoonal backreef facies:

Its representable to the middle, and upper parts of Gebel Hamza, and composed of 5m of yellow sandy limestone, in the middle of Gharra Formation, and is overlain, and underlain by yellowish green sandy shale beds.

B.1. Ferruginous calcareous quartz arenite microfacies association:

This microfacies describes the middle & upper parts of Gebel Hamza section which is represented by a sandy unit (Sample no. H3, H5 Hamza section) (Plate2.5). This microfacies is composed of hard, yellowish brown sandstone, and display even bed geometry.

It's composed of Quartz grains (92%) (0.5 to 1mm size), poorly to moderately sorted. Most of the grains are monocrystalline with either even extinction or undlose. The polycrystalline grains are of less presence in the samples, and they are of undlose extinction. Almost all of the grains are sub rounded to sub angular, their boundaries are covered with iron oxides, and the grains shows point contacts. Microcline is the second in order in presence, most of the microcline crystals are altered. All of these allochems are cemented by calcareous muddy matrix.

Compaction is the main diagenetic process, as concluded from the grain to grain relations.

This microfacies can be compared to the SMF9 deposited in the (E) lagoonal back-reef area with open circulation (inner ramp); quiet water below normal wave base [12, 32].

C. Inner ramp facies:

Representing the upper parts of Gharra Formation, at Gebel Hamza section as a 2m bed of sandy yellowish green mudstone, 2m of greenish white muddy sandstone at Geniefa locality, and 1m of green shales at Gebel Um Qamar section, all of these Sediments display lesoidal bed geometry.

C.1. Mudstone microfacies association

This microfacies describes the middle & upper parts of Gebel Hamza section which is represented by a sandy unit (Sample no. H4 Hamza section) (Plate3.1). It's represented by Greenish grey friable to compact thinly bedded, highly fissile shales and mud stones, in some parts it's sandy, and in other parts it's gypsiferous, while the bed geometry is lensoidal, it's entirely composed of fine-grained silica with rare quartz grains, all cemented with muddy matrix.

This microfacies can be compared to the SMF3 deposited in the (E: D) lagoonal back-reef area with open circulation (inner ramp - middle ramp); quiet water below normal wave base [12, 32].

C.2. Algal sandy biosparite/ Sandy bioclastic grainstone

It's represented by the lower part of Geniefa section (Sample no. H1′) (Plate 2.4).

It's mainly composed of yellow, hard fossiliferous sandy limestones. This microfacies is mainly composed of bioclastic fragments (nearly 80%) especially bivalves (Pecten sp.), and echinoid spines. Quartz grains are also present in this microfacies (nearly 20%), monocrystalline grains are sub rounded and rounded, while polycrystalline grains are angular to sub rounded, the quartz grains are medium to coarse in size (0.2:1mm), while the orthochems represented by sparite patches, and rare dolomites may also be present.

Diagenesis of micrite into sparite is the present diagenetic process.

This microfacies can be compared to the SMF5 deposited in the (E) lagoonal back-reef area with open circulation (inner ramp); quiet water below normal wave base [12, 32].

C.3. Dolomitized microsparite packstone microfacies association

This microfacies describes the middle parts of Gebel Hamza section (Sample no. H1 Hamza section) (Plate 3.3).

The microfacies is represented by thinly bedded yellow limestone.

It's majorly composed of sparry shell fragments (Pecten sp.) within dolomitic microsparite matrix, the bioclasts are represented by pelecypod. As a result of dolomitization, and Quartz corrosion due to calcareous matrix, and the rare sparite patches formation; neomorphism may have been present. Dolomitization took place resulting in the formation of fine-grained dolomite grains in the fine ground mass, even the dolomitization may have reached the shell debris resulting in the replacement of the shell fragments in some parts.

This microfacies can be compared to the SMF5 deposited in the (E) lagoonal back-reef area with open circulation (inner ramp); quiet water below normal wave base [12, 32].

C.4. Sandy dolomitic biomicrite/ Sandy dolomitic bioclastic packstone

This microfacies is representable to the lower part of Gebel Um Qamar section (Sample no. Gr4) (Plate 3.4). It's composed of highly fossiliferous, yellow, compacted limestone. The main constituent of this microfacies is the bioclastic fragments which forms about (70%), including bivalves shell debris which are strongly dolomitized, echinoidal spines, as well as coralline algae (Rodless). Quartz grains form about (20%) of this microfacies, and these grains are ranging in size from fine to coarse, all of these components are held together by micritic matrix, which may be partially neomorphosed into micro sparite.

Diagenesis is represented by the neomorphism of micritic matrix into microsparite.

This microfacies can be compared to the SMF5 deposited in the (E) lagoonal back-reef area with open circulation (inner ramp); quiet water below normal wave base [12, 32].

D. Middle ramp facies:

Represented by the upper part of Gharra Formation at Um Qamar locality, as a 1m layer of yellowish green compacted sandy shales, and 1m lensoidal bed of yellow sandstone, at the upper part of West Shabraweet section.

D.1. Dolomitic biomicrite/Dolomitic bioclactic rudstone

This microfacies is recorded in the lower part of Gebel Um Qamar section (Sample no. Gr5) (Plate 2.2). This microfacies is composed of highly fossiliferous, yellow, compacted limestone rich in shell fragments.

The main component of this microfacies is the bioclastic fragments, including bivalves shell debris oyster debris, as well as coralline algae (Rodless). Quartz grains and glauconite represent the terrigenous input, all of these components are held together by micritic matrix, which may be partially neomorphosed into micro sparite, which somehow have been dolomitized by zoned fine crystalline dolomite rhombs.

Dolomitization is the main diagenetic process within this microfacies.

This microfacies can be compared to the SMF6 deposited in the (E: D) lagoonal back-reef area with open circulation (inner ramp – middle ramp); quiet water below normal wave base [12, 32].

D.2. Quartz greywacke

This microfacies is presented in the upper part of West Shabraweet section (Sample no. 8)

It's composed of yellow to green, glauconitic sandstones (Plate 3.2).

The quartz grains of medium size (0.2:0.5mm) form about (40%) of this sample, whereas glauconite forms (50%) of the microfacies. Quartz grains are monocrystalline with even to undlose extinction, sub rounded to rounded, very well sorted, Glauconite pellets are fine to medium in their size (0.2:0.5mm).

Diagenesis is represented by the iron oxides staining to the rock unit.

This microfacies can be compared to the SMF18 deposited in the (C: B) lagoonal back-reef area with open circulation (middle ramp); quiet water below normal wave base [12, 32].

E. Outer ramp Facies:

Representable of the upper parts of Gebel Hamza section, as a 4m layer of faint yellow to gray fossiliferous limestone, middle parts of Geniefa section, as a 3m bed of yellow, highly fossiliferous limestone, and the top part of Gebel Gharra succession, as a 6m layer of pink limestone.

E.1. Sandy dolomitic algal biomicrite /Sandy dolomitic algal Packstone

This microfacies is representable of the upper part of Genefe Formation at Gebel Hamza locality (Sample no. H11) (Plate 2.6). It's composed of marly, highly fossiliferous limestone.

The main constituent of this microfacies is considered to be the red coralline algae representing (nearly 50%) of the sample, bivalves shell debris, echinoid spines, and other skeletal grains also occur, most of the skeletal bioclastic fragments are preserved, whereas some of them are affected by dolomitization; changing their internal structure. Terrigenous input is expressed as mono crystalline quartz grains forming (nearly 10%) of the sample, and they were found to be sub rounded to rounded. These components are held together by micritic matrix.

Dolomitization is the main diagenetic process that took place over the bioclastic fragments.

This microfacies can be compared to the SMF18 deposited in the (C: B) lagoonal back- reef area with open circulation (middle ramp – outer ramp); quiet water below normal wave base [12, 32].

E.2. Dolomitized algal biomicrite/ Dolomitized algal wackstone /mudstone

This microfacies is encountered in Gebel Gharra section (Samples no. Sh10, Sh13), Geniefa section (Samples no. H9′, H13′, H14′), representing the upper part of Genefe Formation.

This microfacies is composed of pink, hard limestone. The main constituent of this microfacies is the coralline algae that forms up to (70%) of the rock framework. The terrigenous input is rare; however, it's mainly represented by quartz grains, and decreases upward within this microfacies. The binding material is a micritic matrix, which to some extent is dolomitized, and neomorphosed.
Dolomitization is the main diagenetic process that took place over the micrite matrix
(Plate 2.3).
It's can be compared to the SMF5 deposited in the (C: B) lagoonal back- reef area with open circulation (middle ramp – outer ramp); quiet water below normal wave base [12, 32].

Plate (2)

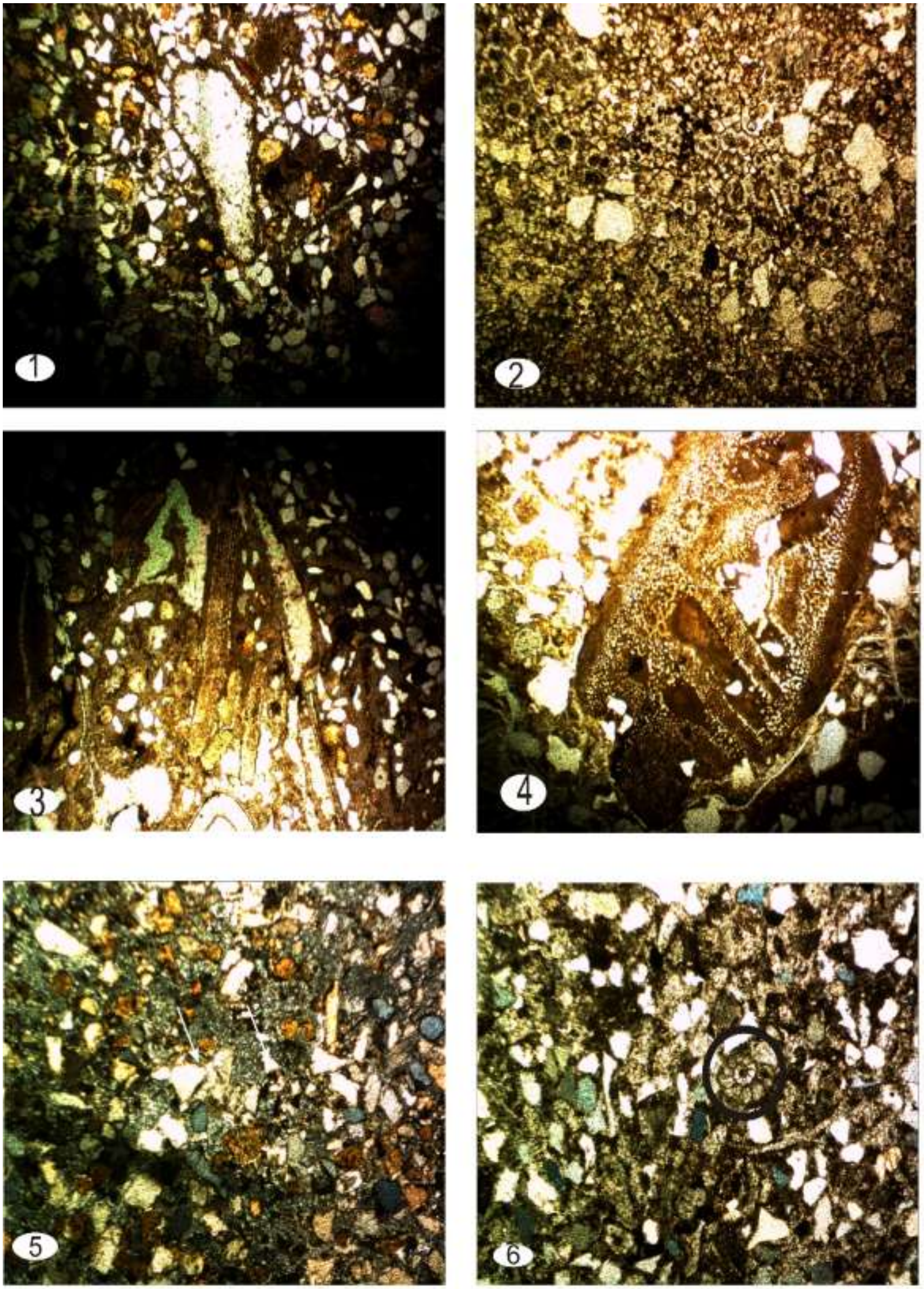

1
2
3
4
5
6

Plate 2

Fig. 1. Dolomitic calcareous fossiliferous calcareous quartz arenite microfacies, Gebel Gharra section, Genefe Formation, 50x magnification, ppl.

Fig. 2. Dolomite rhombs scattered in sparite cement, Gebel Gharra section, Genefe Formation, 45x magnification, ppl.

Fig. 3. Dolomitic algal biomicrite wackstone microfacies, Gebel Gharra section, Genefe Formation, 45x magnification, ppl.

Fig. 4. Coralline red algae (*Sporolithon sp*.), Gebel Gharra section, sample (Sh13), Genefe Formation, 45x magnification, xpl.

Fig. 5. Ferruginous calcareous quartz arenite microfacies, 50x magnification, xpl.

Fig. 6. Benthic foraminifera, (*Anomalinoides sp*.), Sandy algal pack stone microfacies, Gebel Gharra section, Genefe Formation, 50x magnification, xpl.

Plate (3)

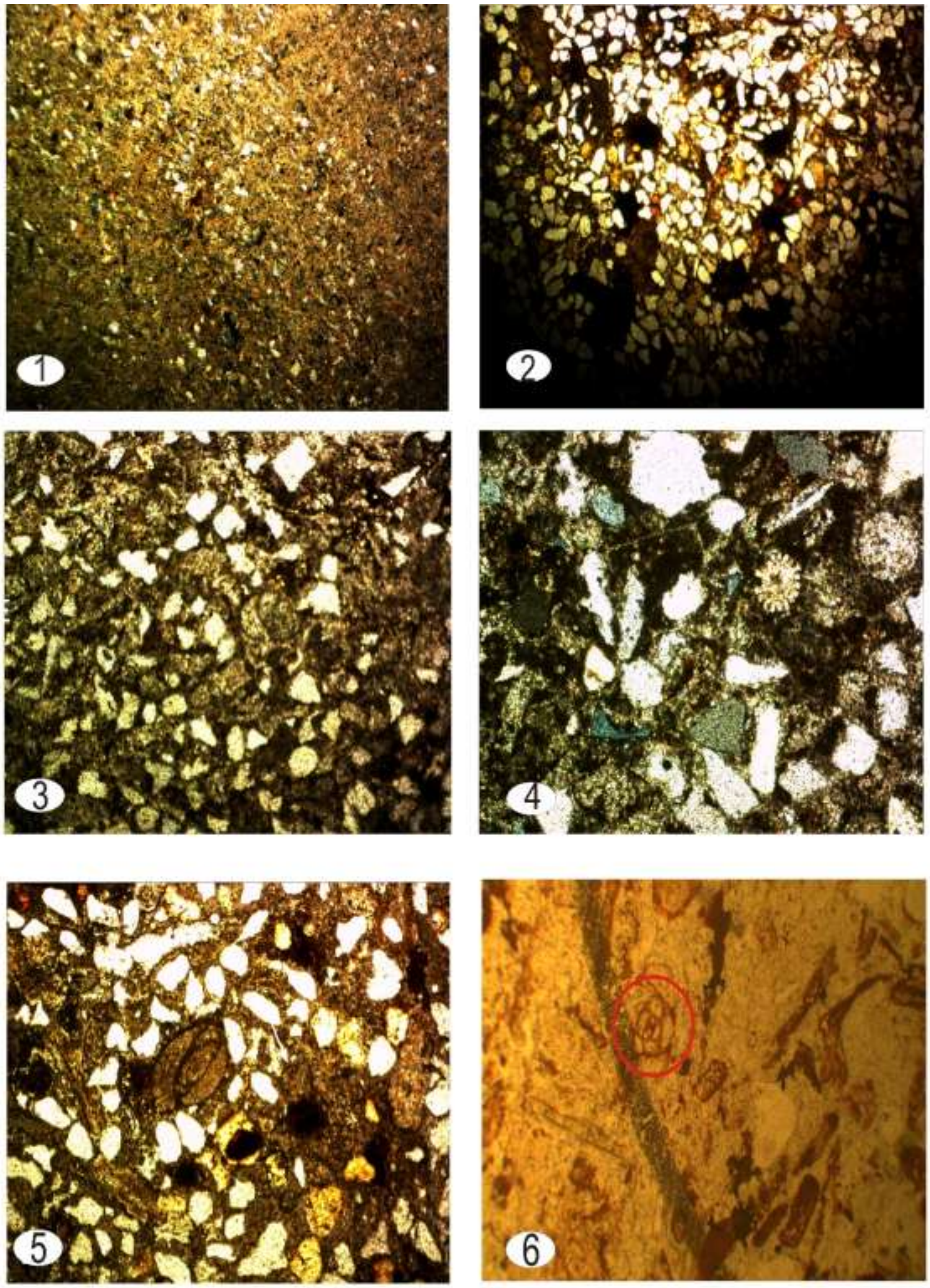


Plate 3

Fig. 1. Mudstone, Mudstone microfacies Gebel Gharra section, Genefe Formation, 50x

magnification, ppl.

Fig. 2. Quartz grains, Quartz Greywack microfacies, 100x magnification, ppl.

Fig. 3. Sandy dolomitic biomicrite packstone microfacies, Gebel Gharra section, Genefe Formation. 50x magnification, ppl.

Fig. 4. Echinoid spine, and calcite filling, Sandy algal packstone microfacies, Gebel Gharra section, Genefe Formation, 100x magnification, xpl.

Fig. 5. Different forms of skeletal grains, foraminifera (*Quniqueleqeline sp*.) and bivalve oyster shell debris in dolomitic micrite matrix; Sandy dolomitic algal biomicrite microfacies; Geneva section, sample (H19), Genefe Formation, 25x magnification, xpl.

Fig. 6. Different forms of skeletal grains, foraminifera (*Quniqueleqeline sp*.) and bivalve oyster shell debris in dolomitic micrite matrix; Sandy dolomitic algal biomicrite microfacies; Geneva section, sample (H19), Genefe Formation, 45x magnification, ppl.

2.2.2 Early-Middle Miocene depositional trends:

The Miocene platform sediments investigated along the northern Cairo-Suez road were separated into two major units: a lower clastic unit (Gharra Formation) and an upper carbonate unit (Genefe Formation).

A. Clastic dominated unit:

This unit is known as the Gharra Formation, and it is made up of several para sequences, each of which is made up of thinly bedded mudstones/shales with cross bedded sandstones at the bottom.

This facies is topped by a sandy limestone unit with fossiliferous mudstone interfingers, fossiliferous sandstones near the top containing pectinids, and coralline worm tubes.

The uppermost part of the Gharra Formation in the Gebel Hamza section can be described as thinly bedded glauconitic sandstone, in contrast to all other localities, which contain shales/mudstone with small benthic foraminifera such as *Miogypsina sp. Quniquelequline sp.* (plate3.5) and *Uvigerina sp,* but no macrofossils. The depositional trends of the upper clastic dominated unit range from the intertidal foreshore facies (intertidal lagoons, intertidal estuaries) to the inner ramp facies, which expresses the deepest bathymetrical level zone during the deposition of this unit

B. Carbonate dominated unit:

Genefe Formation is made up primarily of reefal and dolomitic limestones that are rich in fossils such as *Uvigerina sp.* Which is abundant on the outer shelf, and the uppermost continental slope [34, 35], *Miogypsina sp.,* oysters, and coralline red algae.

This unit differs from the upper clastic unit in that it is of deeper marine facies and ranges from middle to outer ramp facies.

3.2. Sequence stratigraphy:

Field and laboratory examinations of Miocene sediments across the research area show that both units (Gharra and Genefe formations) form one incomplete depositional sequence that began and developed as a result of the first Miocene sea's advance across the study area.

3.2.1. Sequence boundaries:

The examined depositional succession (Gharra and Genefe Formations) lies unconformably over the Oligocene continental sediments of the Gebel Ahmar Formation, forming a type 1 [36] sequence boundary. All of the sequence boundaries analysed within the sections reveal a tectonically controlled SB1 type sequence boundary (fig 4).

The end of the Oligocene epoch has seen a significant period of subaerial emergence, as well as continental depositional events, especially in Egypt's northeastern sections, which covers the study area. These variables allowed for the creation of the type 1 boundary and the lower parts of Gharra's and Genefe's depositional sequences.

The Burdigalian-Aquitanian unconformity surface can be correlated with this unconformity surface [37].

3.2.2. Low stand system tract:

During the early Miocene, a sea level rise occurred over northern and northeastern Egypt, including the study area, which began to be submerged under shallow water, representing intertidal foreshore conditions, which continued throughout the time of Gharra Formation deposition, as a low stand wedge that extended southward over northern Egypt, displaying a fining upward upward succession., starting with high energetic sandstones (Fossiliferous quartz arenites), moving upward, the deposition progresses to the inner ramp mudstone/shale facies, which includes intertidal lagoons, tidal flat, and intertidal estuarine sediments, and finally to sandy grainstone, sandy biosparite, and inner ramp facies.

3.2.3. Transgressive surface (TS):

A depositional surface was discovered all across the research area as a result of the marine invasion.

The contact between the Gharra and Genefe formations was discovered to represent the transgression surface in the study area, indicating a shift in para sequences with sea level rise, as well as the deposition of the outer ramp facies, rather than the inner ramp sediments, and shallow foreshore.

The middle Miocene is correlated with the age of this transgression surface.

3.3.4. Transgressive system tract (TST):

The middle Miocene was characterized by a rise in sea level and the deposition of deeper marine facies, which began with the deposition of the Genefe Formation, forming the transgressive system tract sediments, just at the top of the transgressive surface in the research area, establishing a fining upward succession, that has been deposited within middle, and outer ramp zones, beginning with quartz arenites (Ferruginous, and Dolomitic) microfacies association, deposited within the middle ramp.

As a result of a sea level rise across northern Egypt, a transgression phase succeeded the transgressive surface (TS), resulting in the deposition of consecutive aggradational sequences along with reef build-ups (Sandy dolomitic algal packstone facies).

The maximum flood surface (MFS) is represented by the (Dolomitic algal biomicrite facies) toward the top of Genefe Formation, which comprise the deepest marine facies within the transgressive system tract, although we can't rest assured because the top surface of Genefe Formation is eroded in all of the studied sections, which could have happened as a result of a general uplift.

4. Conclusion:

The (Siliciclastic-Carbonate) marine Miocene sequence overlying the Oligocene continental sediments of Gebel Ahmar Formation, exposed at northern Cairo-Suez district is a transgressive sequence, represented by the Burdigalian siliciclastic Gharra Formation, that conformably underlies the Langhian carbonate Genefe Formation, and microfacies studies revealed the following units:

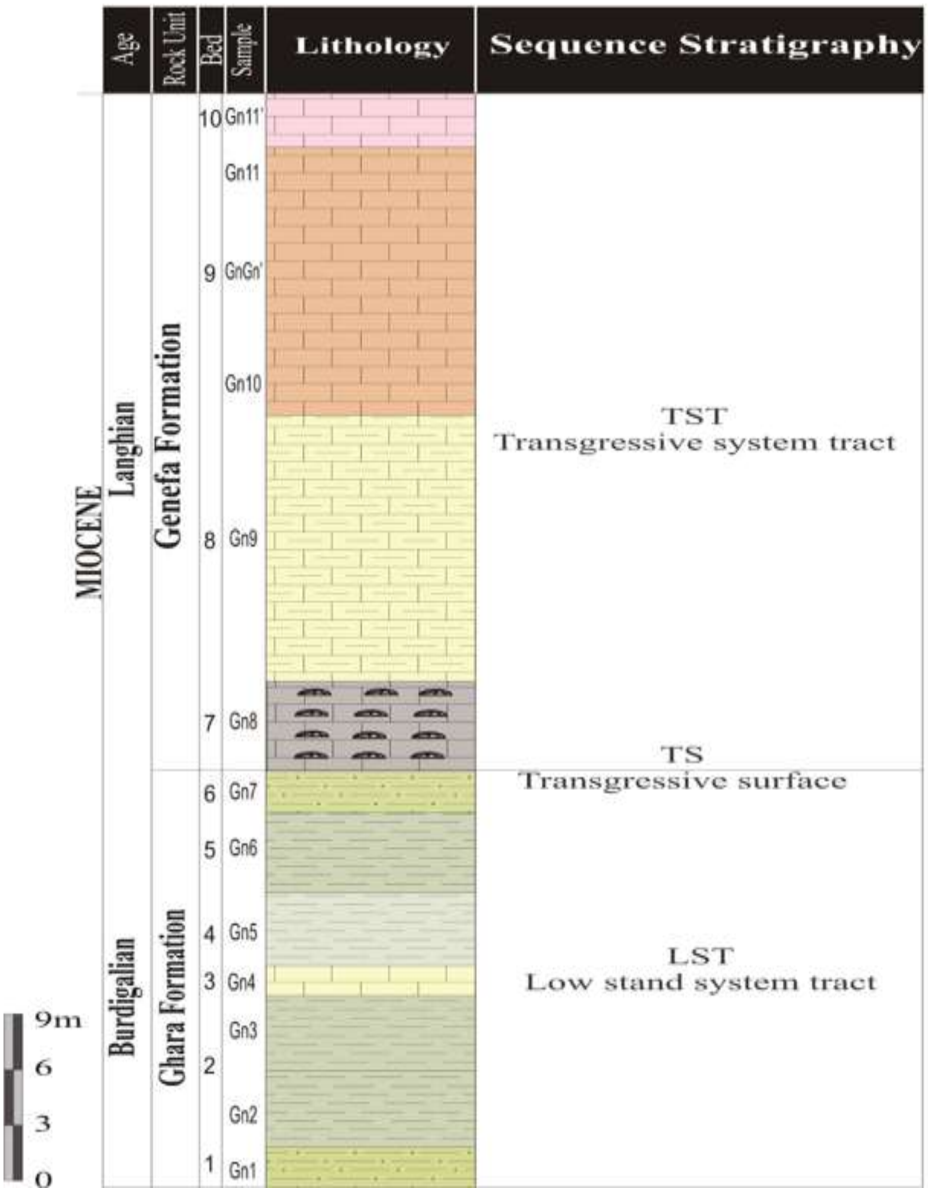


Figure (4) Sequence stratigraphic boundaries within the study area

4.1. Clastic dominated unit:

This unit is made up of recurrent para sequences that include cross-bedded sandstones, shales, and mudstones, and an oyster-rich sandy limestone with sandstone and mudstone intercalations on top.

The depositional trends span from intertidal foreshore facies (intertidal lagoons, estuaries) to inner ramp facies, which is represented by the Gharra Formation in our study.

4.2. Carbonate dominated unit:

Genefe Formation represents this unit, which is primarily composed of algal and dolomitic limestones. These limestones are highly fossiliferous, with *Uvigerina sp., Miogypsina sp.,* oysters, and coralline red algae which indicates deposition at warm water conditions. Its depositional trends are deeper than those of the clastic dominated unit, ranging from middle ramp to outer ramp, which is deeper than the depositional trends of Gharra Formation.

The deposition began as a result of a marine transgression over the study area, which was a marine transgression over previously deposited continental Oligocene sediments of the Gebel Ahmar Formation, with a type 1 SB, accompanied by the transgressive surface that indicates the contact between the Gharra and Genefe formations, which defined the transition in the deposition into retrogrdational/aggradational nature as a result of the marine transgression.

The middle Miocene was defined by a rise in sea level that caused the deposition of deeper marine facies as a consequence of tectonic subsidence, resulting in Genefe Formation being deposited above the transgressive surface.

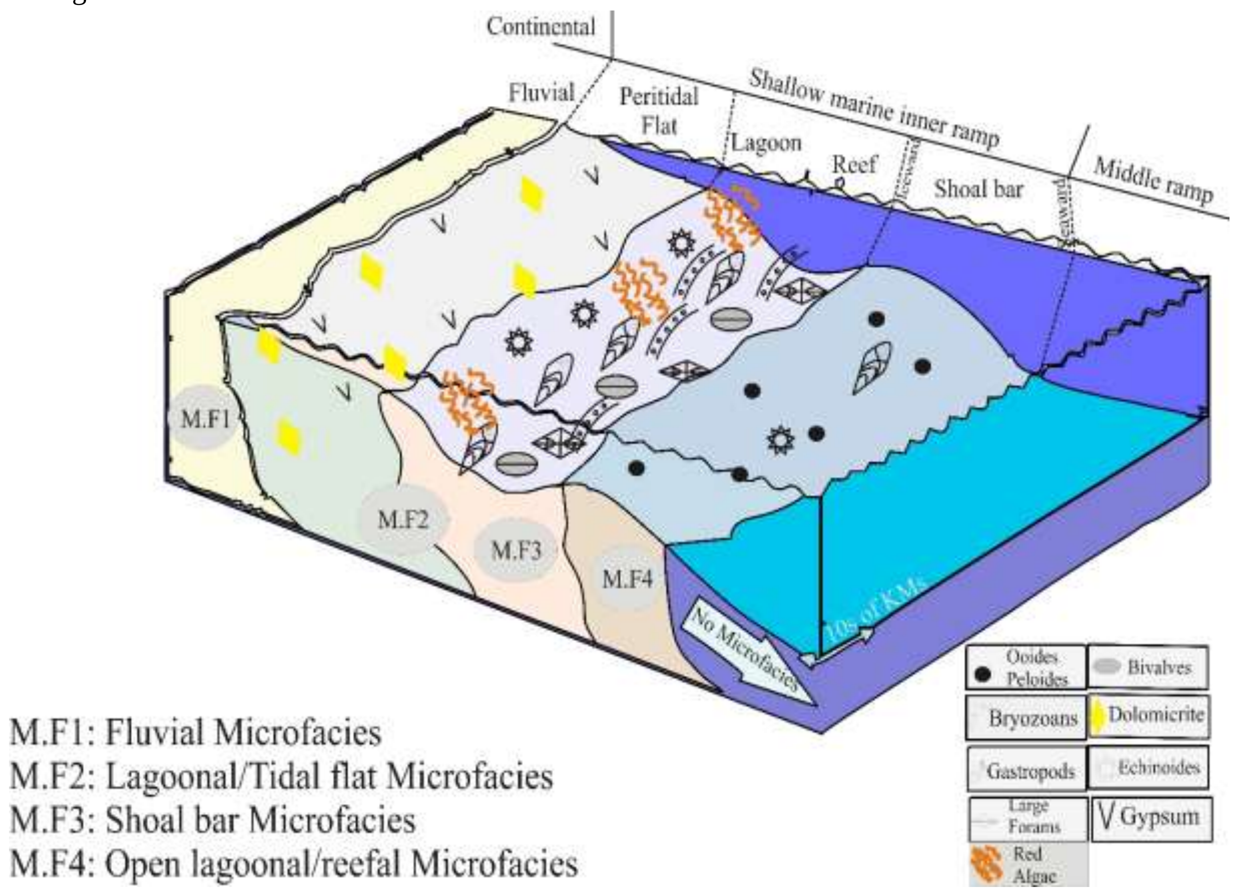


Figure (5) Depositional model of the study area

REFERENCES

[1] Sadek, A., 1968. Contribution to the Miocene stratigraphy of Egypt by mean of Miogypsinids. -Proc. 3rd Afr. Micropaleontol. Colloq., Cairo, pp: 509-514.

[2] Sadek, H., 1959. The Miocene in the Gulf of Suez region (Egypt). -Egy. Geol. Surv. Egypt, 118p.

[3] Sadek, H., 1926. The geography and geology of the district between Gabal Ataqa and El-Galala El-Bahariya (Gulf of Suez)-Egy. Geol. Surv., Cairo, 40, 120 p.

[4] Macfadyen, W.A., 1930. Miocene foraminifera from the clysmic area of Egypt and Sinai. Geological Survey Egypt, 149 p.

[5] Cherif, O.H., 1966. The Geology of the Sadat area, Southwest of Suez, Egypt. M. SC. Thesis, Ain Shams University, Cairo, 242p.

[6] Cherif, O.H., 1980. Remarques sur I'utilisation des Miogypsines et des Operculines pour la chronostratigraphie du Miocenedu Nord du Desert Arabique (Egypte). 6th African Micropalieontology Colloquium, Tunis, 3, pp: 325-335. DOI:http://pascalfrancis.inist.fr/vibad/index.php?action=getRecordDetail&id=9431762

[7] El Sorogy, A.S., Abd El-Shafy, E. Abd ElMoneim, M. and Mowafi, A., 2005. Stratigraphy, paleontology and depositional environments of some exposed Miocene sediments in Cairo-Suez District, Egypt. Jour. Paleontol. 5:223-251. DOI:https://d1wqtxts1xzle7.cloudfront.net/41425579/STRATIGRAPHY__PALEONTOLOGY_AND_DEPOSITIONAL-with-cover-page

[8] Said, R., 1962. The Geology of Egypt. -El Sevier, 377p.

[9] Tawfik.M, El-Sorogy.A, Mowafi.A, Al-Malky.M (2015). Facies and sequence stratigraphy of some Miocene sediments in the Cairo–Suez District, Egypt, Journal of African Earth Sciences, Volume 101, January 2015, Pages 84-95. DOI: 10.1016/J.JAFREARSCI.2014.08.016

[10] El Azabi, M. H., 2000. Sedimentary facies, paleoenvironments and facies development of the Miocene-Pliocene sequences in the Sadat Wadi Hagul stretch, Northwest Gulf of Suez and their time correlatives in the adjacent basins, Egypt- Proc. 5th Internat. Conf. Geol. Arab world, Fac. Sci., Cairo Univ, 3: 1135- 1174.

[11] Vinn, Olev, Haitham M. Ayyad, Abdel Galil A. Hewaidy, Naser A. Al-Labaidy 2022. Sequence stratigraphy of the Miocene siliciclastic–carbonate sediments in Sadat Area, north-west of Gulf of Suez: Implications for Miocene eustasy. DOI: 10.1002/gj.4406

[12] Wilson, J. L., 1975. Carbonate facies in geologic history. -Springer, Verlag, Berlin, 471pp. DOl: 10.1007/978-1-4612-6383-8

[13] Flügel, E. 2010. Microfacies of Carbonate Rocks, Analysis, Interpretation and Application. Berlin, Springer-Verlag, 976p. DOI: https://doi.org/10.1007/978-3-642-03796-2

[14] Dunham, R. J., 1962. Classification of carbonate rocks according to depositional texture. In. Ham, W.E. (ed.) Classification of carbonate rocks. A symposium, A.A.P.G. Mem. 1: 108- 121. DOI: https://doi.org/10.1306/M1357

[15] Tucker, M.E., Wright, V.P., 1990. Carbonate Sedimentology. Blackwell, Oxford, 482 pp.

[16] Folk, R.L., 1974. Petrology of Sedimentary Rocks: Austin, TX, Hemphill Press, second edition, 182 p.

[17] Pettijohn, F. J. 1975. Sedimentary rocks. Harper and Row, New York, 286 pp.

[18] Pettijohn, F. J.; Potter, P. E., & Siever, R., 1987. Sand and sandstone. Springer-Verlag New York, Heidelberg, Berlin, 532 p.

[19] Said, R., 1990. The Geology of Egypt. - Balkema, Rotterdam 734 p.

[20] National Stratigraphic Subcommittee of the Geological Sciences of Egypt (NSSC), 1974. Miocene rock stratigraphy of Egypt. –Egy. J. Geol., 18(1): 1-59.

[21] Hassan, H.F. and Hany, S.M., 2012. Sequence stratigraphic analysis of the carbonate-siliciclastic Miocene sediments, North Eastern Desert, Egypt, Journal of Petroleum and Mining Engineering (JPME), 15 (2) 84-103. DOI: 10.21608/JPME.2015.42546

[22] El Akkad, S. E. and Dardir, A., 1966. Geology of the Red Sea coast between Ras Shagra and Mersa Alam with short note on exploratory work at Gabal El Rusas lead-zinc deposits. Geol. Surv. Egypt, 35: 67p.

[23] Abdallah, A. M. M. and Abd El Hady, F. M., 1966. Geology of Sadat area, Gulf of Suez. Egypt. -Egy. J. Geol., 10: 1-24.

[24] Samuel, M. D. and Saleeb-Roufaiel, G. S., 1977. Lithostratigraphy and petrographic analysis of the Neogene sediments at Abu Ghusun, Um Mahara area, Red Sea coast, Egypt. -Beitr. Zur Lithologie, Freiburg. Forsch. 323(c): 47-56.DOI:http://pascalfrancis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCALGEODEBRGM7720281454

[25] Ghorab M. A. and Marzouk, I. M., 1967. A summary report on the rock stratigraphic classification of the Miocene non-marine and coastal facies in the Gulf of Suez and Red Sea coast. -Internal Report 601, General Petrol. Co., Cairo.

[26] El Shazly, S. H. and Saber, S. G., 1999. Facies and macro paleontological studies of the marine Miocene sediments at Gabal Homeira, Cairo-Suez district, Egypt- Egy. J. Geol., 43(2): 317-341.

[27] Abdel Wahab S. and M. El Belassy (1987). Sedimentology of the Lower-Middle Miocene sequence in Gebel El Hamza Gebel Um Qamar area, Cairo Ismailia road, Egypt- Bull Fac. Sci., Cairo Uni., Egypt, 55: 445:480.

[28] Farag I. A. M. and A. Sadek 1966. Stratigraphy of Gebel Homeira area, Cairo-Suez district. J. Geol. U. A. R., 10 (2): 107-124.

[29] Abd-Elshafy E. and M. Abd-Elmoneim 1992. Lithostratigraphy of the Miocene rocks in the area between Gabal Ataqa and the northern Galala, Eastern Desert, Egypt. Bull. Fac. Sci., Zagazig Univ., 14(2): 290-303.

[30] El Safori Y. A. 1994. Stratigraphy and paleontology of some Miocene exposures on the western side of the Gulf of Suez, Egypt. -Unpublished ph.D. Thesis, Ain Shams Univ.: 278 p.

[31] Said R. 1971a. Explanatory notes to accompany the geological map of Egypt. –Egy. Geol. Surv. Egypt, Paper 56,123pp.

[32] Said R. 1971b. The Geological Survey of Egypt: History and organization. -Geol. Surv. Egypt, paper 55, 26pp.

[33] Flugel, E. 2004. Microfacies of Carbonate Rocks Analysis Interpretation and Application. 976 p., Springer-Verlag, Amsterdam. DOI: 10.1007/978-3-662-08726-8

[34] MURRAY, J. W. 1973. Distribution and ecology of living benthic foraminiferids. Crane Russak & Co., New York. xiii + 274 p.
DOI: doi.org/10.4319/lo.1973.18.6.1011a

[35] Boltovskoy, Demetrio & Riedel, W.R.. (1980). Polycystine radiolaria from the southwestern Atlantic Ocean plankton. Rev. Esp. Micropaleontol.. 12. 99-146.

[36] Vail, P. R., Todd, R. G. and Sangree, J. B., 1977. Seismic Stratigraphy and Global Changes of Sea Level: Part 5. Chronostratigraphic Significance of Seismic Reflections: Section 2. Application of Seismic Reflection Configuration to Stratigraphic Interpretation Memoir, 26: 99–116.

[37] Guiraud, R., Bosworth, W., Thierry, J., Delaplanque, A., 2005. Phanerozoic geological evolution of northern and central Africa: an overview. Journal of African Earth Sciences 43, 83–143. DOI: 10.1016/j.jafrearsci.2005.07.017