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RESEARCH PAPER

# Larger foraminifera from the Miocene Gharamul Formation, Gebel Abu shaar El Qibli, Gulf of Suez region, Egypt: new insights into biozonation and palaeoenvironmental significance

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**Abstract**
The foraminiferal contents of the Miocene deposits exposed in two sections in Wadi Bali and Wadi Kharaza, Gebel Abu Shaar El Qibli plateau, Western side of the Gulf of Suez, Egypt were carefully studied for their benthic and planktonic foraminiferal content. Based on their lithofacies variations and microfaunal content, three rock units were studied, from base to top as follows: Abu Gerfan Formation, polymictic conglomerates (Early Miocene, Aquitanian), the overlying Gharamul Formation (carbonate and mixed siliciclastic-carbonate) (Middle Miocene, Burdigalian to Lnghian), and evaporates of Gemsa Formation (Middle Miocene, Serravallian age) are reported. Detailed smaller, larger and planktonic foraminiferal investigations led to the recognition of three foraminiferal zones from base to top: 1) *Miogypsina complnata* / *Nonion granosus* Zone (Zone SBZ 24), comprising the Abu Gerfan Formation that ascribed to Early Miocene Aquitanian age, 2) *Miogypsina globulina* zone (SBZ 25) representing the lower unit of Gharamul Formation, and correlated with the Early Miocene, Burdigalian age and lastly *3) Borelis melo melo* Zone (SBZ 26) of Middle Miocene, Langhian age covering the upper part of Gharamul Formation. The Middle Miocene interval of Gharamul Formation is ascribed to the Langhian for first time where *Operculina complanata* (Defrance) and *Borelis melo melo* (Fichtel and Moll) are the main time-specific diagnostic taxa recognized in this interval. For the first time, planktonic foraminifera are documented from the Gharamul Formation in Gebel Abu Shaar El Qibli plateau being characterized by the occurrence of planktonic foraminifera such as *Globigerina praebulloides*, *Globigerina* ciperoensis, *Globigerinoides altiaperturus*, *Globigerinoides trilobus* and *Globigerinoides subquadratus*. This association characterises the *Borelis melo melo* interval Zone. The variation in lithology and foraminiferal assemblages will be discussed here and reflects the variety of environmental settings characterizing the studied Miocene sequence, indicating an overall shallowing-upward trend, from continental to subeqous fan delta facies of Abu Gerfan Formation to platform reefal facies and restricted lagoon-salina conditions represented by evaporites of Gemsa Formation.

**Keywords:** Early Miocene, Biostratigraphy, Gharamul Formation, Gebel Abu Shaar El Qibli, Gulf of Suez, Egypt.

## Introduction

Gebel Abu Shaar El Qibli is Precambrian horst block of the Esh El Mellaha range (Fig.1) where the Miocene rocks form discontinuous exposures and unconformably overlie the Precambrian rocks and underlie the Pliocene rocks. Their contacts with surrounding rocks are easily traceable due to remarkable lithologic variations. Its geological setting has been discussed by many authors among them Gregory, 1906; Hume, 1916; Burchette, 1988, James et al., 1988, Purser et al., 1990; Cofer et al., 1984; E1-Haddad et al., 1984; Rouchy et al., 1983; Monty et al., 1987;

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Aïssaoui et al., 1986; Coniglio et al., 1988; James et al. (1988), Burchette (1988), Clegg et al., 1998; and Bosence et al., 1998; Purser et al. (1996, 1998), Cross et al. (1998), Clegg et al. (1998), Perrin et al. (1998), Perrin (2000), El Sorogy (2001), and Cross and Bosence (2008).

Roucky (1981) recoreded two main types of sediments regime constituting Gebel Abu Shaar El Qablei area, first the carbonate deposits comprising the rocky plateau and the second is the evaporites deposites surrounded the plateau footslopes. El-Haddad et al. (1984) studied the Miocene rocks of G. Abu Shaar and identified three principal facies: 1) platform interior facies located on the plateau and consists of chalky dolomites, carbonates, silicates, algal domes, algal laminites, green sandy marls and sandstones, 2) platform edge facies along the eastern periphery and consists of dolomitized mudstones, wackestones, packstones and boundstones and 3) talus facies, spectacular, steeply inclined beds (40˚-60˚) along the eastern margin, and is composed of two district units; the lower is purely carbonate rich in molluscs, coral stromatolitic domes and the upper is essentially dolomitic with subordinate sandy green marls and sandstones, and its bedding is very irregular and locally slumped. Cofer et al. (1984) and James et al. (1988) showed that the Esh El Mellaha carbonate sequence could be correlated with the basal carbonate section of the Rudeis Formation in the subsurface of the Zeit Bay area. Khalifa et al. (1984) referred that the Miocene carbonates sequence exposed at Gebel Abu Shaar El Qibli area is only represented by the Um Mahara Formation (Middle Miocene).

Burchette (1988) introduced another concept and stated that Gebel Abu Shaar plateau is developed in three phases, generating three distinct sedimentary sequences linked to the tectonic development of the fault block. The initial platform succession (sequence 1), platform accretion (sequence 2) and younger carbonate (sequence 3). These three sequences correspond respectively with the Kharaza, Esh El Mellaha, and Bali members of Coniglio et al. (1988) and James et al. (1988).

The Egyptian General Petroleum Corporation "EGPC" (1964) devised a modern nomenclature with the names of type locality. In this classification marine Miocene rocks are differentiated into two major groups namely: Gharandal and Ras Malaab.


**Figure 1.** a. Google earth image showing the location of the studied Gebel Abu Shaar El Qibili, Gulf of Suez region, Egypt, b. Location map showing the locations of the studied sections, Abu Shaar El Qibili plateau, western side of the Gulf of Suez region, Egypt

The clastic Gharandal Group is subdivided from base to top into Nukhul and Rudeis formations. On another hand, the upper dominantly evaporitic Ras Malaab Group is represented from bottom upwards by Kareem, Belayim, south Gharib and Zeit formations, respectively (Table. 1).

The National Stratigraphic Sub-Committee "NSSC" (1974) modified the latter classification and added the clastic-rich Kareem Formation in the lower Gharandal Group. Also, They divided the non-marine Miocene and coastal facies after Ghorab and Marzouk (1967) into four main formations from base to top; Abu Gerfan, Gharamul, Gemsa and Sarbut El-Gamal Formations, respectively. In addition, they added that Abu Gerfan and Gharamul Formations are the coastal equivalent of Gharandal Group, while Gemsa and Sarbut El-Gamal Formations are the marginal equivalent of the Ras Malaab Group.

According to the classification of "NSSC" (1974), the Miocene rocks exposed at Gebel Abu Shaar El Qibli area are represented by three distinct formations from base to top; Abu Gerfan, Gharamul and Gemsa. These formations were adopted and described in details in Gebel Abu Shaar El Qibli by Ahmed & El-Aaser (1994), Kamh (2008) and more recently Hamad & Orabi (2021).

Since there has been little studies pertaining to study the benthic and larger foraminifera, the biofacies and palaeoenvironmental analyses of the Gharamul Formation outcropping in Gebel Abu Shaar El Qibli, Western side of the Gulf of Suez, Egypt, the principal objectives of this paper are (1) to describe the microfacies types of the studied section pertaining to the Gharamul Formation (2) to present brief systematic description on the distribution and abundance of the of the major coralline red algae and benthic foraminifera and (3) to decipher the main depositional palaeoenvironments prevailed during of the deposition of Gharamul Formation. To achieve the above points four the main objectives of the present study are, in addition to a lithostratigraphical classification, to establish a high-resolution biostratigraphical classification based on both planktonic and benthic foraminifera of the Miocene carbonate platform in Gharamul Formation outcropping in Gebel Abu Shaar El Qibli, Western side of the Gulf of Suez, Egypt. Our biostratigraphical analysis is based mainly upon comparisons of the larger benthic and small planktonic foraminiferal assemblages recorded from the study area with the well-known assemblages of the western Tethys and circum-Mediterranean areas, which puts the Lower Miocene strata of in Gebel Gharamul a global biochronological framework.and to to decipher the main depositional palaeoenvironments prevailed during of the deposition of Gharamul Formation

| Epoch | | Stage | Wynd, 1965 | Adams & Bourgoise,1967 | | Cahuzac and Poignant, 1997 | Laursen et al., 2009 | Hewaidy et al., 2020 | Present study, Hamad, 2024 |
|---|---|---|---|---|---|---|---|---|---|
| Miocene | Middle Miocene | Langhian to early Serravallian | Not studied | | | Borelis melo melo | Not studied | Borelis melo melo Zone | Borelis melo melo Zone |
| | Early Miocene | Burdigalian | Borelis melo curdica | Borelis melo group Meandropsina iranica | | Borelis melo group Miogypsina | Borelis melo Curdica Borelis melo melo | Miogypsian Zone | Miogypsina cf. globulina Zone |
| | | Aquitanian | Austrotrillina howchici Peneroplis evolutus Zone 59 | Elphidium sp. Miogypsian / Archaias asmaricus Archaias hensoni | Miogypsinoides, Archaias Valvu linides | Austrotrillina howchici Miogypsina, Miogypsinoides deharti | Miogypsia sp., Elphidium sp., Peneroplis farsensis | Not studied | Miogypsinioide Complanata / Nonion granosus Zone |

**Table 1.** Comparison of previous Miocene biostratigraphic zonation schemes

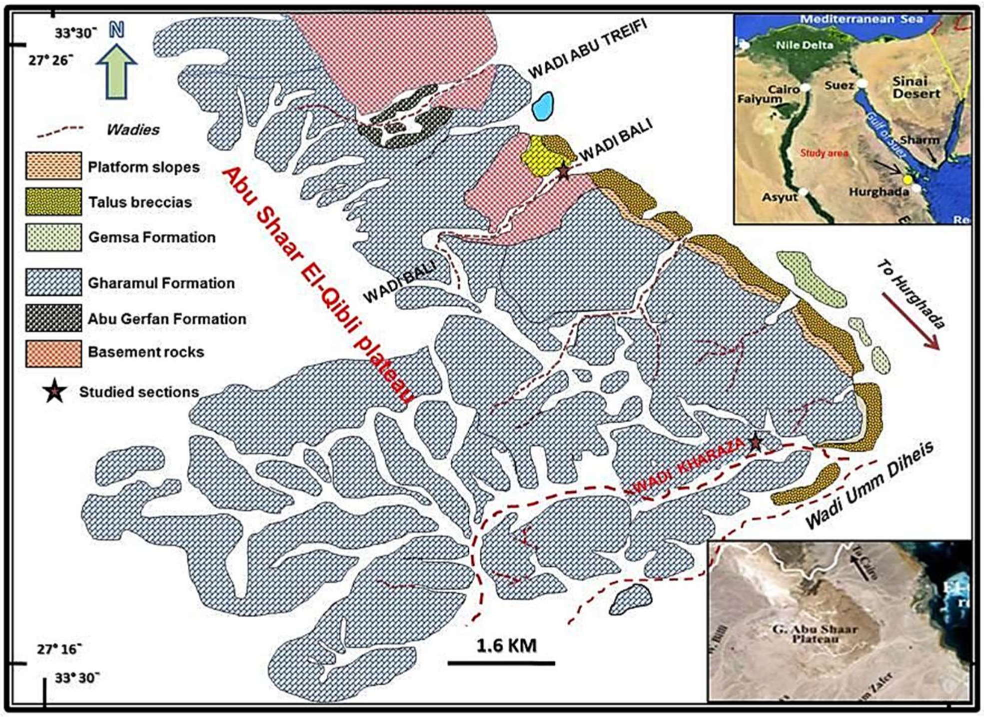


**Figure 2.** Simplified Geological map showing the different Miocene formations at Gebel Abu Shaar El Qibli plateau, western side of the Gulf of Suez, Egypt (modified after Ahmed & El-Aaser, 1994)

## Geologic setting and lithostratigraphy

The Miocene rocks are exposed in the study area as small outcrops at Gebel Abu Shaar El Qibli, as low lying hills scattered in the Quaternary deposits. The Miocene rocks in the study area are mainly represented by the elevated rectangular plateau of Gebel Abu Shaar El-Qibli (100 km2) at the southern limit of the Precambrian horst block of the Esh El Mellaha range. Many authors have been studied the stratigraphy and sedimentology of this area such as (Burchette, 1988, James et al., 1988, and Purser et al., 1990, Cofer et al., 1984; E1-Haddad et al., 1984; Rouchy et al., 1983 and Monty et al., 1987; Aïssaoui et al., 1986, Coniglio et al., 1988, Clegg et al., 1998, and Bosence et al., 1998). On the basis of coral faunas, a Miocene age was given for G. Abu Shaar by Gregory (1906) and Hume (1916). Rouchy (1981) has noted that two main types of sediments comprising G. Abu Shaar area. They are the carbonate sediments building up the rocky plateau and evaporites deposited around the plateau foot slopes. El-Haddad et al. (1984) studied the Miocene rocks of Gebel Abu Shaar and identified three principal facies, they are arranged as follow: 1) platform interior facies located on the plateau and consists of chalky dolomites, carbonates, silicates, algal domes, green sandy marls and sandstones, 2) platform edge facies along the eastern periphery and consists of dolomitized mudstones, wackestones, packstones and boundstones, and 3) talus facies, spectacular, steeply inclined beds along the eastern margin, and composed of two distinct units; the lower one is purely carbonate rich in molluscs, coral, stromatolitic domes and the upper is essentially dolomitic with subordinate sandy green marls and sandstones and its bedding is very irregular and locally slumped.

The Egyptian General Petroleum Corporation "EGPC" (1964) established other nomenclature with the names of type locality. In this classification marine Miocene rocks are differentiated into two groups namely: Gharandal and Ras Malaab groups. The lower clastic Gharandal Group is subdivided from base to top into Nukhul and Rudeis formations. On the other hand, the upper group is evaporitic Ras Malaab Group is represented from bottom to top by Kareem, Belayim, South Gharib and Zeit formations, respectively. They also divided the non-marine Miocene and coastal facies of Ghorab and Marzouk (1967) into four main formations from base to top as follows; Abu Gerfan, Gharamul, Gemsa and Sarbut El-Gamal Formations, respectively. In addition, they added that Abu Gerfan and Gharamul formations are the coastal equivalent of Gharandal Group, while Gemsa and Sarbut El-Gamal formations are the marginal equivalent of the Ras Malaab Group. According to the classification of "NSSC" (1974), the Miocene rocks exposed at Gebel Abu Shaar El Qibli area are represented by three distinct formations from base to top; Abu Gerfan, Gharamul and Gemsa (Fig. 3). These formations were adopted and described in details in Gebel Abu Shaar by Ahmed and El-Aaser (1994).But in the present study the present authors focused their work on Gharamul Formation only.

Burchette (1988) introduced another concept and stated that G. Abu Shaar plateau is developed in three phases, generating three distinct sedimentary sequences linked to the tectonic development of the fault block. The initial platform succession (sequence 1), platform accretion (sequence 2) and younger carbonate (sequence 3). These three sequences correspond respectively with the Kharaza, Esh El Mellaha, and Balih members of Coniglio et al. (1988) and James et al. (1988).

**Abu Gerfan Formation**

It was first established by Ghorab and Marzouk (1967). In its type locality, it overlies pre-Miocene rocks and underlies the Gharamul Formation. In the study area, this formation sporadically distributed within troughs along the eastern scarp of Gebel Abu Shaar El Qibili, particularly around Wadi Abu Treifi and south of Wadi Bali. Abu Gerfan Formation represents the basal Miocene rock unit at Gebel Abu Shaar El Qibili where it overlies unconformably the Precambrian basement rocks and underlies the Gharamul Formation. It is composed of 20-30 m thick undedded polymictic bouldery conglomeratic beds alternating with argillaceous limestone and coralline algal dolostone, which were deposited in environments ranging from non-marine to subaqueous fan delta, shore environments (Ahmed and El-Aaser, 1994).

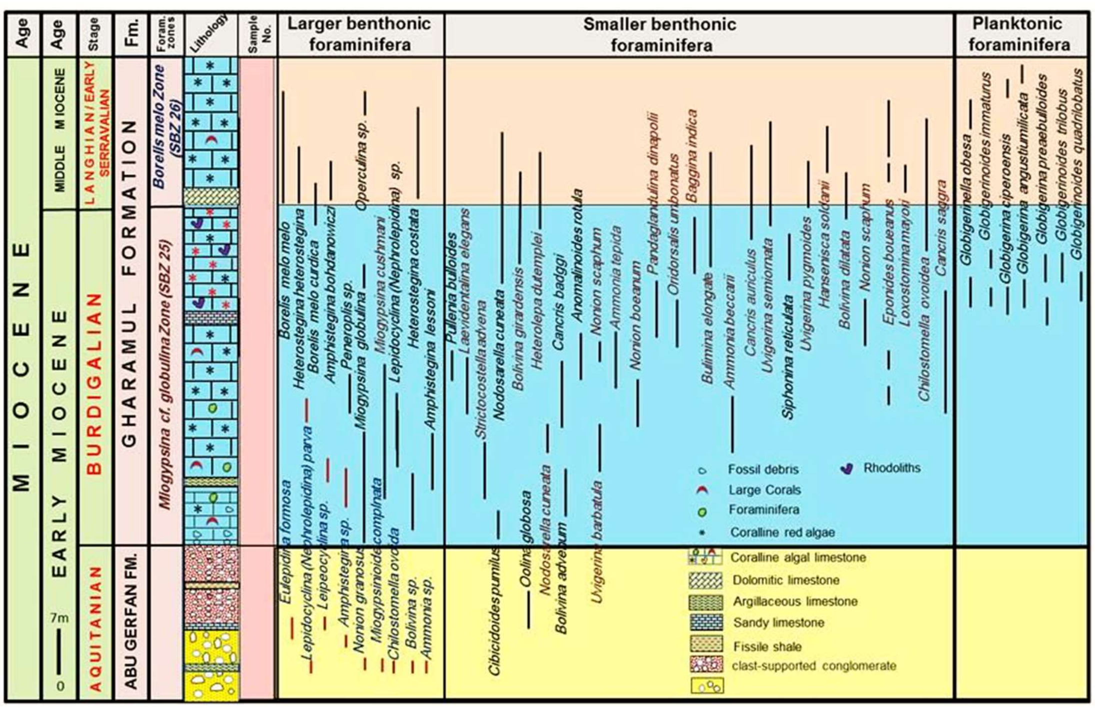

**Figure 3.** Distribution chart of the benthonic and planktonic foraminiferal species recorded in the Miocene succession at Gebel Abu Shaar El Qibli , Gulf of Suez region, Egypt

The conglomerates are poorly-sorted with a wide grain size ranging from granule up to boulder (Pl.1, Figs, 1 & 2). They consist of sheet like beds and lenses organized in overlapping sets (from 3-5 meters thick) and composed mainly of carbonate, chert and basement clasts tightly-packed in a sandy lime mud matrix. The polymictic conglomerates are usually intercalated with a few argillaceous limestone interbeds.

These conglomerates represent the proximal deposits of coastal alluvial fans which have formed adjacent to high hinterlands along the western margin of the Miocene basin or along the scarp edge delineating the emerged palaeostructural highs which were formed within the basin (Burchette, 1988, Ahmed and El-Aaser, 1994 and Gawthorpe et al., 1994, and El-Azabi, 1997). They have been formed as successive debris flow deposits derived from the weathering products of the surrounding basement rocks and pre-Miocene high hinterlands (Pl.1, Fig. 2). There is a lateral facies change from the conglomerate facies to sandstone facies. The sandstones occur as white to yellowish white lenses composed of feldspar, quartz and rock fragments. On the other hand, siltstones are also found as lenses in lower parts of the alluvial fans. In addition, two beds of coralline algal dolostone are found interbedded within Abu Gerfan calstics.

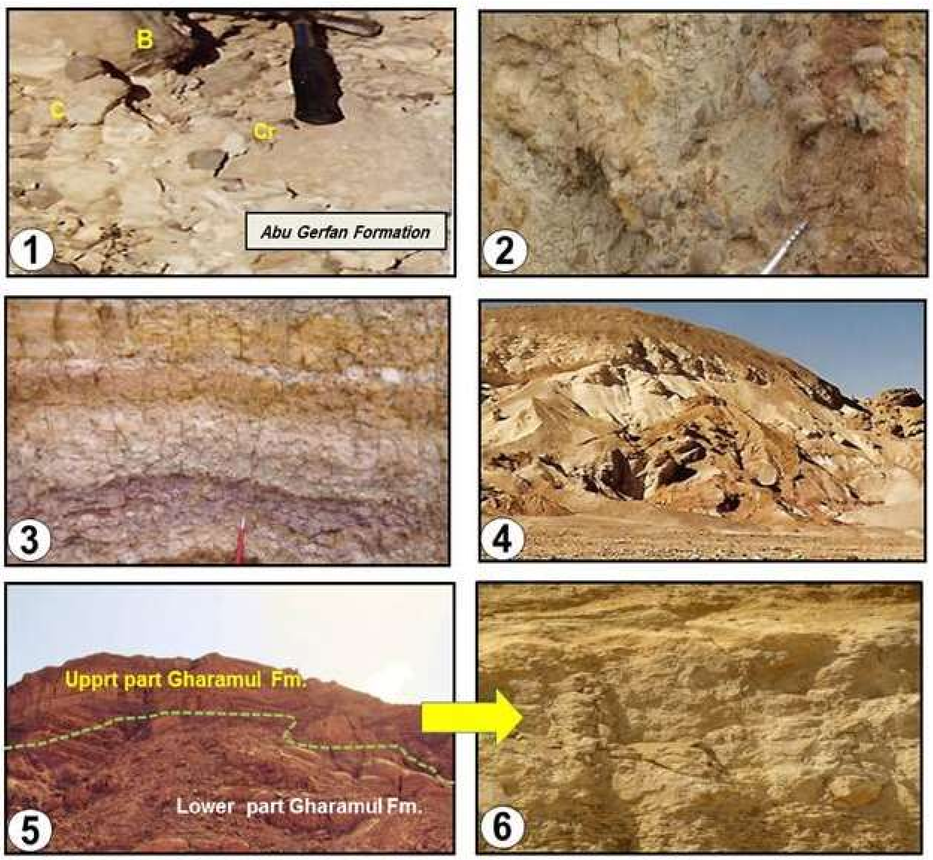


**Plate 1.** 1 & 2: Field photographs showing grain supported, polymictic conglomerates, texturally immature composed of poorly sorted, subangular to subrounded basement clasts (B), carbonate (Cr), chert (c) embedded in calcareous sandy argillaceous matrix, Abu Gerfan Formation, Wadi Bali. 2: Poorly-sorted carbonate and chert clasts embeded in a sandy argillacous lime matrix, Abu Gerfan Formation. 3. A thick bed of sandy argillaceous limestone interbedded with the matrix supported polymictic conglomerates, Abu Gerfan Formation, Wadi Bali. 4. Lower part of Gharamul Formation at entrance of Wadi Bali. 5: coralline algal dolomitic limestone beds at the entrance of Wadi Kharaza, Gharamul Formation (lower and upper part of Gharamul Formation) and hard colonial algal reefal limestone (Upper part), 6: Field photographs showing colonial reefal platform margin of upper part of Gharamul Formation at Wadi Kharaza

Abu Gerfan Formation is non-fossiliferous except the intercalated limestone beds, which are enriched in non-diagnostic molluscs coral fragments and lagre benthonic foraminifera.

**Gharamul formation**

It was first established by Ghorab and Marzouk (1967) and is represented by reefal coralline alga limestones that overlain Abu Gerfan Formation and underlain Gemsa Formation. Gharamul Formation varies in thickness from 50 to 110 m at Gebel Abu Shaar and shows lateral variations. It is mainly composed of algal dolostone with few beds of clastics. Ahmed and El-Aaser (1994) subdivided the carbonate facies of Gharamul Formation into two main facies; platform edge and platform interior, where these two facies are equivalent to the facies described by El-Haddad et al. (1984). Platform edge facies: the horizontal and inclined carbonate beds of the platform edge facies are located along the eastern and southeastern edges of Gebel Abu Shaar and composed of coralline reef lenses and shallow platform slope deposits. The entrance of Wadi Kharaza and the eastern margin of Wadi Billi are the most perfect occurrences of the exposed coral reef bodies in the study area (Pl. 1, Fig. 3). The coral reef beds reach up to 6 m thick approaching laterally the form of broad lenses embedded in bioclastic dolostones (Ahmed and El-Aaser, 1994). Platform interior facies: volumetrically this facies is the most important one. It comprises sequences up to 100 m thick made up of bedded fossiliferous and/or nonfossiliferous dolostones, sandstones and green shales (Pl. 1, Fig. 4). The platform interior facies, especially along both sides of Wadi Billi and W. Kharaza is rich in burrowing pelecypods such as *Pectinids* and *Lucinids* (Ahmed and El-Aaser, 1994, Kamh, 2008).

**Materials and Method**

About 60 samples of mostly carbonate rocks (notably, limestone, corallin algal limestone) and a few mixed siliciclastic-carbonates (marly limestone and sandy allochems limestone, evaporites (mainly gypsum), cherts and hybrid sandstones were collected from three surface outcrops through out the Gebel Abu Shaar El Qibili Gharamul area (Fig. 1) namely Wadi Abu Treifia, Wadi Bali and Wadi Kharaza sections. All samples were collected at a maximum interval of 1 m; within lithologic facies changes and where the samples were more closely spaced and diffent in facies. Composition, sedimentary structures, bed thickness and macrofossil content (notably bivalves, gastropods and echinoids) were defined and described using terms proposed by Tucker (2011).The majority of the hard samples collected were subsequently processed for thin-section preparations, with several lithologies being documented. Their litho and bioclastic components are generally expressed using terms recommended by Flügel (2010). Twenty samples of soft lithologies were crushed and disaggregated byhydrogen peroxide solution and washed through a 63-m sieve. Particular attention was given to the foraminiferal specimens, as they are the main group in the study material. Only a few dozen of small and large benthic foraminifera per sample showing good preservation were picked, identified and stored in cardboard slides. Taxonomic classification was based on Loeblich and Tappan (1968) and Adams and Bourgeois (1989). Larger and smaller benthonic foraminifera are the main means for the stratigraphic zonation of carbonate sediments. Planktonic foraminifera are rare in Gharamul Formation, making correlation with the planktonic zonation is difficult. Therefore, biostratigraphic zonation is mainly based on the larger and smaller benthic foraminifera which are very abundant and have high diversity in the studied sections. The biostratigraphical contents of Gharamul Formation were described by Wynd and reviewed by Adams and Bourgeois (1989).

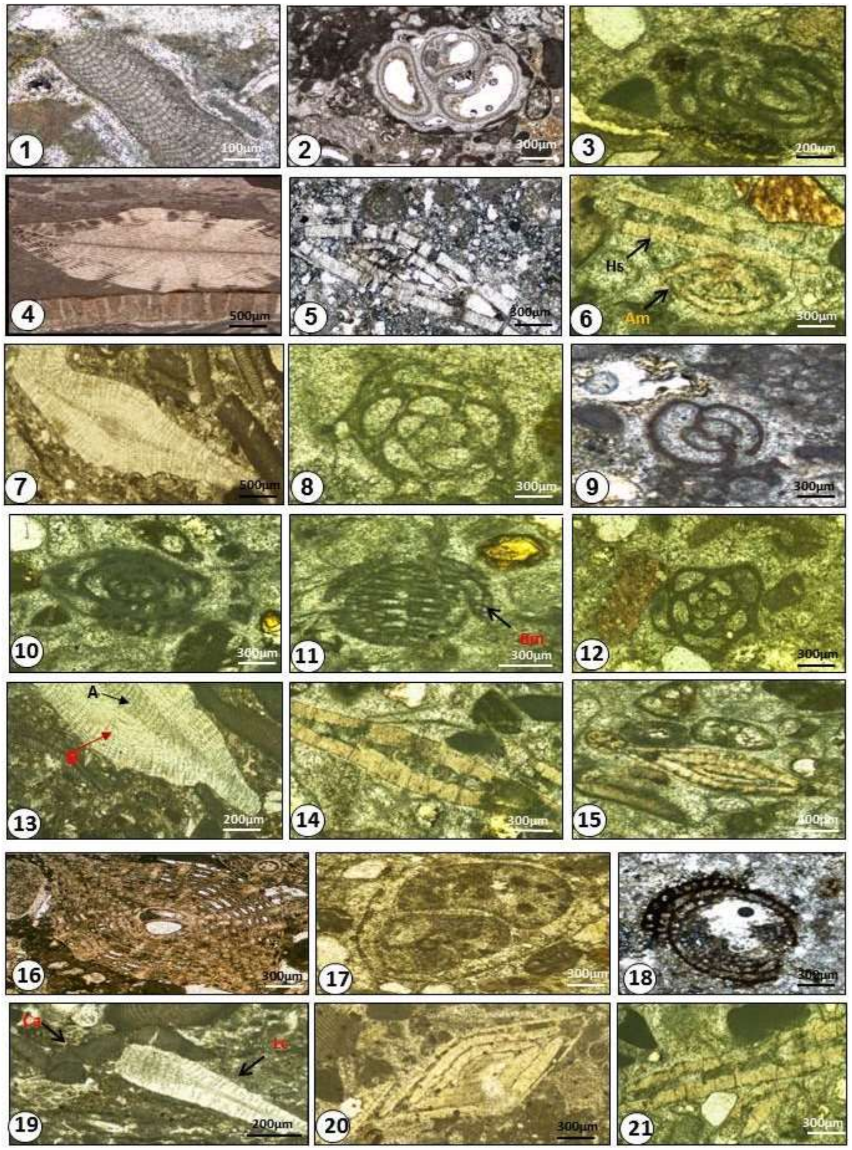


**Plate 2.** 1. Coralline red algae *Lithophyllum* sp. upper part of Gharamul Formation, Wadi Kharaza, sample No. 48. 2. *Valvulinid* sp. Filled with sparry calcite cement, Abu Gerfan Fm., Wadi Bali, sample No. 12. 3. *Austrotrillina sp* lower part of Gharamul Fm., Wadi Kharaza, sample No. 32. 4. *Eulepidina sp.*, Abu Gerfan Fm., Wadi Bali, sample No. 17. 5. *Amphistegina sp.* (Am), Gharamul Formation Wadi Kharaza, sample No. 44. 6. *Heterostegina heterostegina (Hs) and Amphistegina lessonii (Am),* Gharamul Fm., Wadi Kharaza, sample No. 54,. 7. *Lepidocyclina (Nephrolepidina) parva*, axial section, Gharamul Fm., Wadi Kharaza*,* sample No. 54. 8. *Austrotrilina sp.*, Gharamul Fm., Wadi Kharaza. sample No. 57. 9. *Pyrgo sp.*, Gharamul Formation, Wadi Kharaza, sample No. 55. 10. Large miliolid, Gharamul Fm., Wadi Kharaza, sample No. 50. 11. *Borelis melo melo* (Fichtel and Moll) (Bm), upper part of Gharamul Fm., Wadi Kharaza, sample no. 55. 12. *Austrotrillina ? sp.,* Wadi Kharaza, sample No. 50 .13. *Lepidocyclina (Nephrolepidina)* sp. (B), encrusting with coralline red algae, coralline sp.(A). 14. *Operculina complanata,* upper part of Gharamul Fm., Wadi Kharaza, sample no. 55. 15. *Amphistegina* sp. Gharamul Fm., Wadi Kharaza, sample no. 45. 16. *Lepidocyclina (Nephrolepidina) parva* Oppenoorth, upper part of Gharamul Fm., Wadi Kharaza, sample 48. 17. *Pyroga* sp. upper part of Gharamul Fm., Wadi Kharaza, sample no. 55. 18. *Borelis melo.*, upper part of Gharamul Fm., Wadi Kharaza, sample no. 54. 19. *Lepidocyclina (Nephrolepidina)* sp. (Lc) with coralline red algae (Ca), upper part of Gharamul Fm., Wadi Kharaza, sample no. 55. 20. *Amphistegina sp.,* upper part of Gharamul Fm., Wadi Kharaza, sample no. 55. 21. *Heterostegina heterostegina,* enlarged section, Gharamul Fm., Wadi Kharaza*,* sample No. 59.

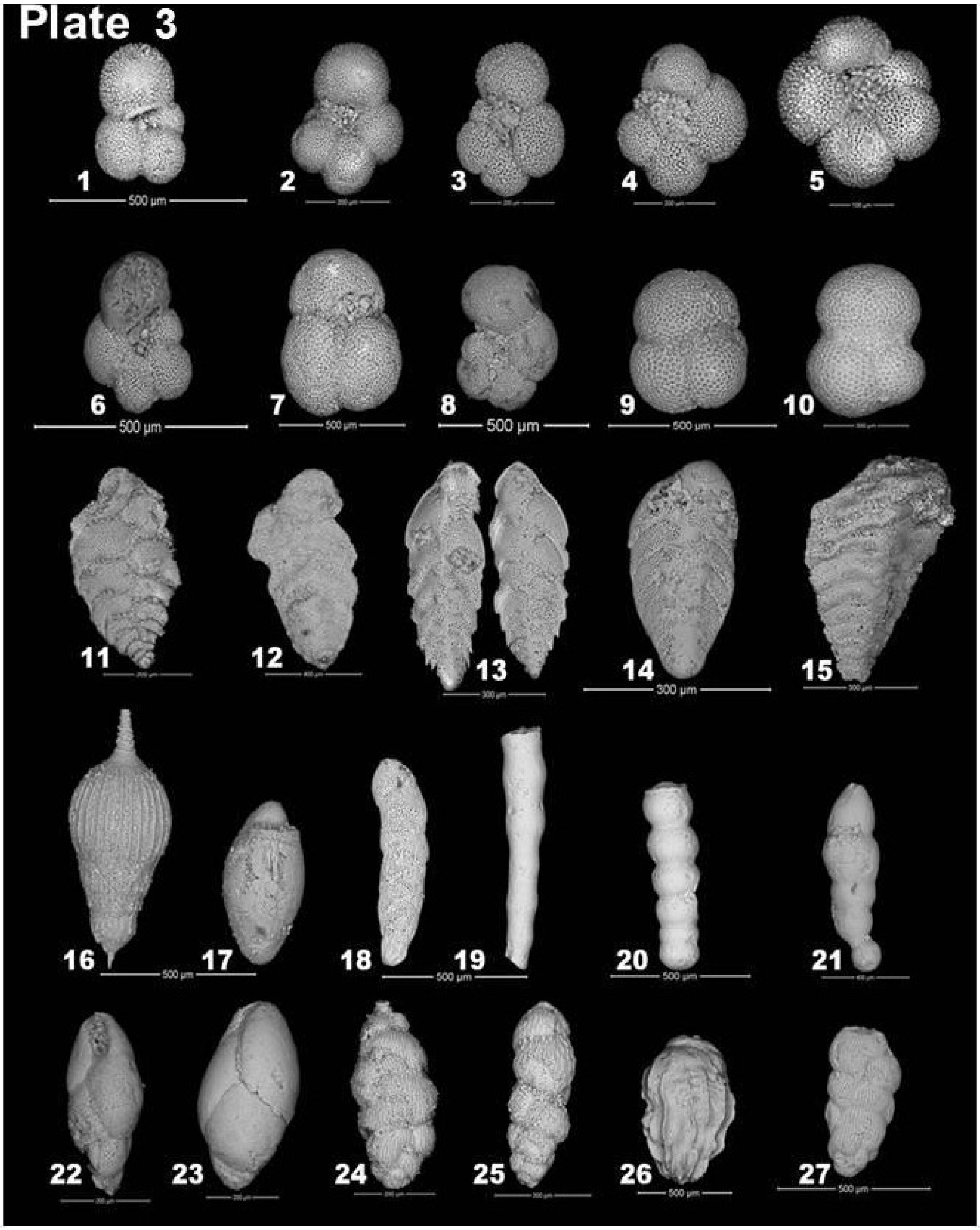


**Plate 3.** 1. *Globigerina praebulloides* Blow & Banner, sample No. 37. 2. *Globigerina ciperoensis* Bolli, sample No. 44. 3. *Globigerina* cf. *ciperoensis* Bolli*,* sample No. 47. 4. *Globigerina ciperoensis* Bolli, sample No. 44. 5. *Globigerina angustiumbilicata* Bolli, sample No. 41. 6. *Globigerina* cf. *angustiumbilicata* Bolli, sample No. 41. 7.*Globigerinoides quadrilobatus* d'Orbigny, sample No. 40. 8. *Globigerinella obesa* (Bolli), sample No. 43. 9. *Globigerina falcoensis* Blow, sample No. 40. 51. 10. *Globigerina tilobus* Reuss, sample No. 43. 11. *Bolivina alazaensis* Cushman, sample No. 45. 12. *Bolivina girardensis* Ranken, sample No. 55. 13 . *Bolivina bramletti* Kleinpell, sample No. 40. 14. *Bolivina dilatata* Reuss, sample No. 44. 15. *Bolivina churchi* Kleinpell &Tipton, sample No. 34. 16. *Amphicoryna striata* (d Orbigny), sample No. 49. 17. *Chilostomella ovoidea* Reuss, sample No. 48. 18. *Loxostomina mayori* Cushman, sample No. 54. 19. *Stilostomella* sp., sample No. 47. 20. *Stelostomella advena* (Cushman & Laiming), sample No. 53. 21. *Nodosarella cuneata* Loeblich & Tappan, sample No. 55. 22. *Bulminia alazensis* Cushman*,* sample No. 55. 23. *Bulimina elongata* (d'Orbigny), sample No. 55. 24. *Uvigerina neudorfensis* Papp & Turnovsky, sample No. 32. 25. *Uvigerina barbatula* Macfadyen, sample No. 52. 26. *Uvigerina semiornata d'Orbigny,* sample No. 51. 27. *Uvigerina barbatula* Macfadyen, sample No. 52

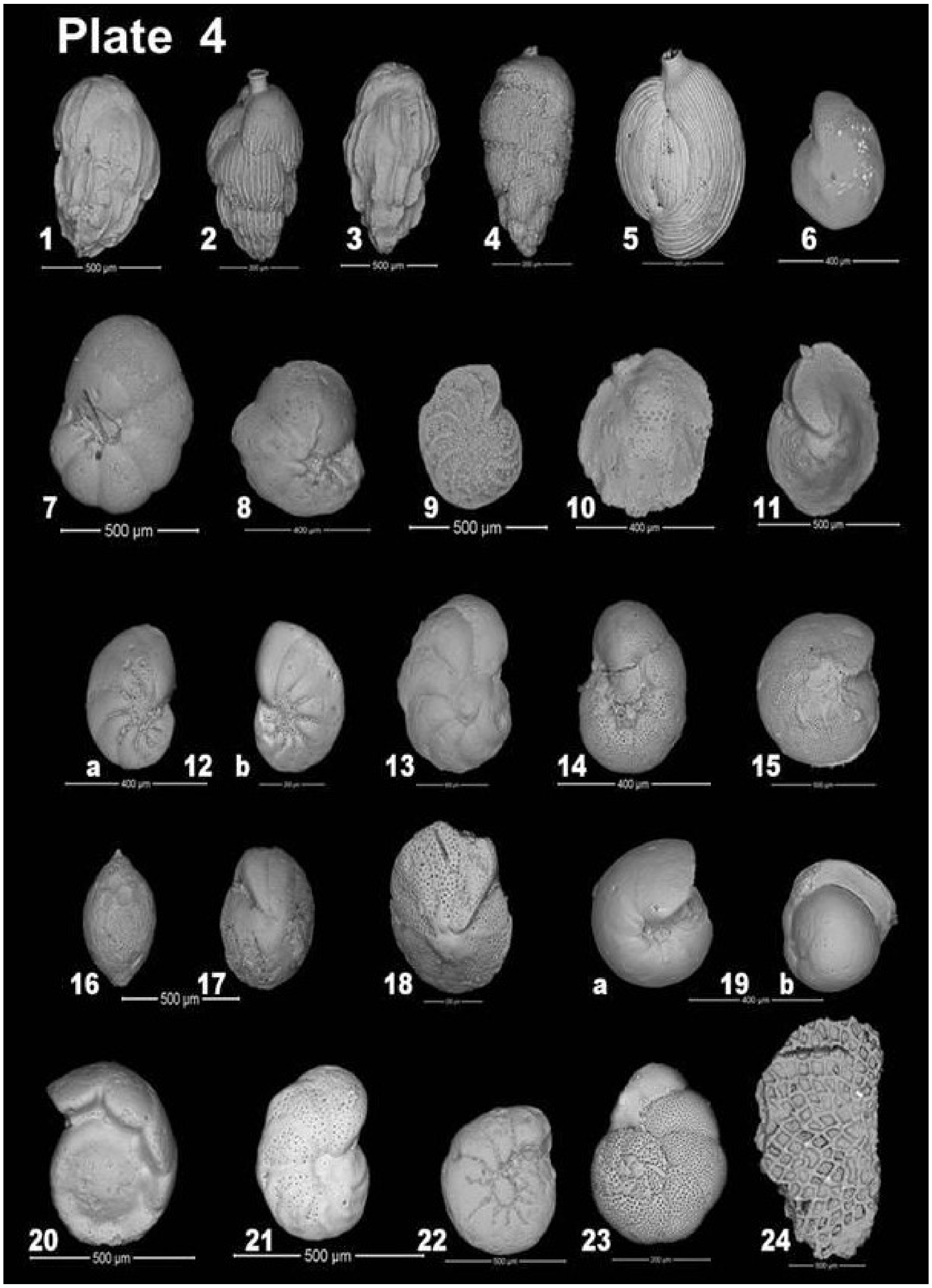


**Plate 4.** 1. *Uvigerina gallowayi* (Cushman), sample No. 51. 2. *Uvigerina semiornata* d'Orbigny, sample No. 50. 3. *Uvigerina pgymoids* (Papp & Turnovesky) , sample No. 51. 4. *Uvigerina ba rbatua* Macfyden, sample No. 40. 5. *Triloculina striata* d'Orbigny, sample No. 53. 6. Gyroidina leavigata d'Orbigny, sample No. 55. 7. *Cancris baggi* Cushman & Kleinpell, sample No. 40. 8. *Cancris planus* Cushman & Todd, sample No. 54. 9. *Elphidium macellum* (Fitchel & Moll), sample No. 40.10. *Siphonina reticulata* (Czjzck), sample No. 41. 11. *Eponides boueanus* d'Orbigny, sample No. 41.12. *Nonion boeanum* d'Orbigny, sample No. 54. 13. Discorbinella montereyensis (Cushman & Martin), sample No. 50.14. *Hanzawia cushmani* (Natall), sample No. 45. 15. *Heterolepa* sp., sample No. 49. 16. *Oolina globosa* (Montagu), sample No. 45. 17. *Cibicides refugens* De Montfort, sample No. 40. 18. *Cibicidoides pumilus* (Flinger & Lipps), sample No. 38 19. *Pullenia bulloides* (Reuss), sample No. 36. 20. *Gyroidina soldanii* d'Orbigny, sample No. 39 21. *Valvulineria miocenica* Cushman, sample No. 29 22. *Ammonia beccarii* (Linne), sample No. 28. 23.*Hanzawaia cushmani* Nattull, sample No. 36 24. *Miogypsina cushmani* (Vaughan), sample No. 40.

## Foraminiferal biostratigraphy

About 48 outcrop samples were collected at close intervals and examined in order to determine the ages of the Miocene rock units recorded in the studied area. Ages were established on biostratigraphic analysis of the large and smaller benthonic as well as planktonic foraminiferal assemblages. The Miocene foraminiferal biostratigraphy presented in this work based on the ranges and assemblages of the larger and smaller benthonic foraminifers and on the presence and distribution of the planktonic foraminifers. Detailed foraminiferal investigations of the studied Miocene sequence in Gebel Abu Shaar El Qibli area led to the recognition of three foraminiferal zones from base to top: *Miogypsina complanata l Nonion granosus Assemblage Zone*, *Miogypsina globulina* zone (early Miocene, Burdiglian age) covering the lower parts of Gharamul Formation Abu Shaar El Qibli and *Borelis melo melo* zone (Middle Miocene, Langhian age) respectively. These biozones are discussed whereas the distribution charts of these foraminiferal species are also given in figures 3, 4, and 5, where the most diagnostic foraminiferal species are presented in two plates (Plates 1 & 2 & 3). In the following are the main foraminiferal zones recognized in the Miocene succession from base to top:

## Larger Foraminiferal Biostratigraphy

***Miogypsina complanata l Nonion granosus Assemblage Zone:*** This zone is defined on the basis of the less abundance of the two nominated zonal taxa (*Miogypsina complanata* / *Nonion granosus*) and spanned the interval from the first occurrence of shallow marine *Nonion granosus* and *Miogypsina complanata* to the first occurrence of *Miogypsina globulina*. It occupies the Abu Gerfan Formation from sample 22 to 30 (Fig. 3). The interval of this zone is characterized by low to moderate diversity of both genera and species. The benthonic foraminifers are very rare and associated commonly with the clays and argillaceous limestone interbedd with the polymictic conglomerates, being represented mainly by non – diagnostic minute benthonic foraminiferal tests that makes it difficult to delineate its biozone. Among the planktonic foraminiferal taxa recorded are *Globigerina ciperoensis* Bolli, *Gg. angustiumbilicata* Bolli, *Gg. praebulloides* Bolli, *Cassigerinella chipolensis* Cushman.

It is noteworthy of mention that *Miogypsina* taxa played an important role in the age assignment of this zone. Drooger (1954; 1963; 1993) related the *Miogypsina* group (*M. intermedia* Drooger, *M. cushmani* Cushman, *M. complanata* Schlumberger, *M. globulina* (Drooger) to Burdigalian age and equated to planktonic zone not older to N6. Souaya (1961 &1963) and Cherif (1966; 1980) recorded *Miogypsina intermedia* Drooger associated with *Operculina complanata*, *Heterostegina heterostegina* from the Miocene deposits of Cairo – Suez road of Egypt and assigned the rocks to early Miocene (Burdigalian) age. Nassif *et al*., (1992) recorded the same assemblage of the nominated zone in the Miocene sequence of Wadi Feiran, southwest Sinai, Egypt and assigned the assemblage to an early Miocene (Burdigalian) age. Moroever, Abdel Ghany & Piller (1999) recorded the *Miogypsina intermedia, M. cushmani* and *M. mediterranea* from the early Miocene Gharra and Sadat formations in some sections in Cairo – Suez district, Egypt and assigned to late Burdigalian age. Imam & Refaat (2000) recorded also this zone from the early Miocene deposits of Wadi Abura and Gebel Hammam Sayidna Musa, southern Sinai, Egypt and dated it to an early Miocene (Burdigalian) age. Boudaghar *et al*. (2000& 2001) described some such large benthonic foraminiferal assemblage from early Miocene (Burdigalian) sections in Boreno and neraby countries.

Hamad (2009) recorded this association from the Eraly Miocene deposits of Sadat Formation, Sadat area, NW Gulf of Suez region. From the foregoing discussion, thelower part of Al Faidiyah Foramtion that encompasses this zone is frankly assigned to early Miocene (Burdigalian) age on the basis of the *Miogypina* spp. and the rare occurrence of *Globigerina* spp. Consequently, this zone could be matched with N5 / N6 of Blow (1969) and correlated to the *Globigerinoides altiaperturus* /*Catapsydrax dissimilis* zone of Iaccarino (1985) in the Mediterranean region. It is noteworthy of mention that no evidences of Aquitanian depsits were recorded in the studied area where neither of the *Miogypsina tani* Drooger (larger benthonic foraminifera) nor the *Globiquadrina dehiscens dehiscens* (planktonic foraminifera) zones are not recorded denoting that the Miocene transgrssion started earlier at the Late Burdigalian time. It is interesting to mention that some striking environmental foraminiferal species characterize this zone.The co – occurrence of *Bolivina tumida, Nonion scaphum, Uvigerina gallowayi* and *Miogypsina spp*. and thelow P/B ratio indicate shallow marine environments (Douglas, 1979; Van der Zwaan & Jorissen, 1991; Murray 1991, Christopher *et al,* 2007). Moreover, the co – occurrence of the *Ammonia beccarii* and the *Elphidium* sp. aswell as *Heterolepa dutemplei* are taken as evidence of shallow marine shelf environments less than 10m (Lipps*et al.* 1979; Boersma, 1983; Jorissen, 1991; Murray, 1991; Abul Nasr & Salama 1999). Another feature supportshallow marine shelf environments for the lower part of Al Faidiyah Formation (*Elphidium macellum* /*Miogypsina intermedia* zone) is the occurrence of oyster and molluscan shell fragments in the lower calcareoussandstone and the polymictic conglomerate beds that indicate near shore environment (Friedman & Sanders, 1978). All these environmental features assert that the *Elphidium macellum* / *Miogypsina intermedia* zone was deposited in very shallow inner shelf marine environments.

***Miogypsina globulina* Zone (SBZ 25):** In the present study, the lower boundary of this zone (Cahuzac and Poignant,1997) is defined by the first occurrence of *Miogypsina globulina* and *M. cf. intermedia*, while its upper boundary is delimited by the extinction of all *Miogypsina* species (Ogg *et al.,* 2016) and also is delfined on the first occurrence of *Borelis melo melo and Heterostegina spp.*. The lower boundary of the SBZ 25 Zone was defined by the FO of *Miogypsina globulina,* whose stratigraphical range as same as that of *Miogypsina cf. intermedia* (Cahuzac and Poignant 1997 and Hakyemez and Toker, 2010). Where *Miogypsina globulina* is regarded as a common global index for the Burdigalian Stage (Özcan & Less, 2009) and aged to Early Miocene (Burdigalian). Stratigraphically, It is recorded in the lower unit of the Gharamul Formation at Gebel Abu Shaar El Qibli section (Fig. 3). The thickness of this biozone assigned to42metres in the Gebel Abu Shaar El Qilbli section.

The most significant large benthic foraminifera recorded in this zone are *Miogypsina cushmani, Miogypsina (Lepidosemicyclina) polymorpha, Miogypsina cf. mediterranea, Miogypsina spp., Miogypsinoides spp., Nephrolepidina sp. are associated with Miogypsina cf. intermedia* in this zone. However, the SBZ 25 Zone was determined tentatively based on the occurrences of *Miogypsina globulina*, *Miolepidocyclina burdigalensis and Miogypsina* sp.where the smaller benthonic foraminifers are represented by *Ammonia beccarrii*(Linnaeus), *A. tepida* (Cushman), *A. parkinsonia* (d'Orbigny), *Amphistegina lessonii* (d'Orbigny), *Cibicides lobatulus* (Walker & Jacob), *Discorbis* sp., *Elphidium crispum* (Linnaeus), *Elphidium decipiens* (Costa ), *Gypsina* sp., *Nonion commune* (d'Orbigny), *Oridorsalis umbonatus* (Reuss,), *Peneroplis evolutus* (Henson,), *Planorbulina* sp., *Pyrgo* sp., *Quinqueloculina* sp., *Rosalina* sp.,*Sphaerogypsina globulus* (Reuss, 1848), *Spiroluculina* sp., *Spiroplectinella wright* (Silvestri), *Stomatorbina concentrica* (Parker & Jones,), *Triloculina tricarinata* (d'Orbigny, 1826) and *T. trigonula* (Lamarck,). The most important coralline red algae of this zone are the *Lithoporella melobesioides* (Foslie), *Lithothamnion* sp. and *Mesophyllum* sp., as well as the ostracods *Chrysocythere* aff. *naqibi* (Khalaf), *Cytheretta* sp., *Cyprideis* sp., *Miocyprideis ovalis* (Khalaf), *Sagmatocythere* sp. and *Xestoleberis* aff. *glabrescens*(Reuss,).

It is noteworthy of mention that *Miogypsina* taxa played an important role in the age assignment of this zone. Drooger (1952 and 1993) assigned the *Miogypsina* group which includes (*Miogypsina intermedia*, *M. cushmani*, *M. globulina* and *M. complanata*) to the

Burdigalian Age. The presence of the larger benthic foraminifera *Miogypsina cf. intermedia* that is widely distributed throughout the Tethys Ocean and known to be restricted to the late early Miocene, Burdigalian age ( Wildenborg, 1991; Drooger, 1993; Cahuzac and Poignant, 1997; Özcan *et al*., 2009). Furthermore, recently geologic time scale workers correspond the first occurrence of *Miogypsina cushmani* to the base of Zone M4 and corresponds the last occurrence of *Miogypsina* to the top of M4 zone or (SBZ-25).

In Egypt, Souaya (1961 &1963) and Cherif (1966) recorded *Miogypsina intermedia* from the Miocene deposits of Cairo-Suez district and assigned the rocks to the Burdigalian, Early Miocene. Ouda (1998) described *Miogypsina globulina, Miogypsina intermedia* and *M. cushmani* from the Miocene deposits of the northern Western Desert and assigned to Early Miocene, late Burdigalian. Abdelghany and Piller (1999) recorded the *Miogypsina intermedia* and *M. cushmani* from the early Miocene Gharra and Sadat formations in Cairo-Suez district and assigned to late Burdigalian age. Imam and Refaat (2000) recognized these species from the early Miocene deposits of Wadi Abura and Gebel Hammam Sayidna Musa, southern Sinai and assigned the studied deposits to early Miocene, Burdigalian age. Abdelghany (2002) recorded the *Miogypsina intermedia* from Gebel Shabrawet area north Eastern Desert and assigned to early Miocene, Burdigalian age. Hamad (2009) recorded *Miogypsina globulina, Miogypsina cushmani* and *M. intermedia* from the lower part of the Sadat Formation, Sadat area, Cairo-Suze district during his studies on the coralline red algae and assigned them to early Miocene (early Burdigalian). Hamad (2013) recorded *Miogypsina intermedia* from the Miocene sequence of Wadi Zaqlum, Sirte basin in Libya and assigned to Burdigalian age. Hamad and Elgaml (2015) recorded these large benthonic foraminifera *Miogypsina globulina, M. intermedia* and *M. cushmani* from Bir Haliyfia and Gebel Zeita and assigned the Miocene rocks to early Miocene, Burdigalian age. *Hewaidy et al. (2020)* described *Miogypsina cushmani and M. intermedia* from the Miocene deposits of the Sadat, Formation in Sadat area on the west side of the Gulf of Suez, Egypt, and assigned to late Burdigalian age according to the occurrence of *Miogypsina cushmani* and *Miogypsina intermedia.*

From the foregoing discussion, the lower part of the Gharamul Formation that encompasses this zone is assigned to the Burdigalian age where the last occurence of the *Miogypsina* cf.*globulina* (Michelotti) marks the contact between the Aquitanian and Burdigalian age. The biozone SBZ 25 is definedby the total range of *Miogypsina* cf. *globulina* (Michelotti), and according to Cahuzac and Poignant (1997) SBZ 25 closely corresponds to the Burdigalian stage. This zone could also be matched with N6 of Blow (1969) and to the uppermost part of *Globigerinoides altiaperturus / Catapsydrax dissimilis* Zone of Iaccarino (1985) in the Mediterranean region. It is noteworthy of mention that some striking environmental features characterize this zone. First, the presence of *Bolivina arta, Nonion scaphum, Uvigerina gallowayi* and *Miogypsina spp*. which indicate neritic environments (Douglas, 1979; Murray 1991) The comon occurrence of *Miogypsina* cf. *globulina* (Michelotti) and other miogypsinides in the lower part of the Gharamul Formation may indicate a water depth of less than 60 m with normal salinity (Murray, 2008). Moreover, the co-occurrence of the *Ammonia beccarii* and the *Elphidium spp*. points also to shallow marine shelf environments (Lipps *et al*. 1979; Boersma, 1983; Murray, 1991; Abul Nasr & Salama 1999). The occurrence of the oyster and molluscan shell fragments in the lower coralline limestone beds in the lower part of the Gharamul Formation supports the shallow marine shelf environments too. These environmental features indicate that the *Miogypsina globulina* zone may be deposited in a shallow (inner neritic) marine environment.

***Borelis melo melo* Zone (foraminiferal Zone SBZ 26):** The *Borelis melo melo* zone of Cahuzac and Poignant (1997) is defined in the present study by the total range of the nominated zonal taxon, where its lower boundary is delineated on the first occurrence of *Borelis melo melo* Fichtel & Moll and the upper boundary is marked by its extinction and and the disappearance of *Miogypsina* spp. Ogg et al. (2016)., This zone is encountered in the studied sections covering the upper part of Gharamul Formation covering the stratigraphic interval from sample 51 to 59. Two distinct spherical subspecies of *Borelis melo* are recognized including *Borelis melo melo* (Fichtel and Moll) *and Borelis melo curdica* (Reichel) recorded only from the upper part of the Gharamul Formation (Fig. 3).It is characterized by the abundance of larger foraminifera such as *Borelis melo melo* Fichtel & Moll, *B. melo curdica* (Reichel), *Amphistegina lessonii* Brady, *Operculina carpenteri* Silvestri, *Heterostegina costata costata* d'Orbigny, *H. heterostegina heterostegina* Silvestri, H. *heterostegina praecosta* Papp & Kupper, *Lepidocyclina (Nephrolepidina) parva.*. Among the benthonic foraminifera recorded in this zone are: *Ammonia beccarii* Linne`, Elphidium minutum (Reuss), *Hansenisca soldanii*, *Eponides boueanus*, *Nodosarella cuneata*

The careful investigation of the dolomitic limestone interbeds and the thin white cream - coloured chalky limestone beds yielded low diversified planktonic foraminiferal association represented by: *Globigerinoides trilobus* (Reuss), Gs. *immaturus* Le Roy, *Gs. sacculifer* Brady, *Gs. subquadratus* Bronimmann, *Globigerina ciperoensis* Bolli, *Gg. praebulloides* Blow, *Globorotalia obesa* Bolli, *Gr. siakensis*, *Cassigerinella chipolensis* Cushman & Ponton. These planktonic foraminiferal assemblages indicate relatively deeper water environment than the *Borelis melo* association (shallow marine environment) and hence suggest progressive deepening of water. This zone could be correlated with the standard planktonic foraminiferal zone N8 and N9 of Blow (1969) and also to the *Praeorbulina glomerosa* and *Orbuina suturalis* zones of Iaccarino (1985), Foresi et al. (1998) and Betzler & Chapronière (1993) in The Mediterranean region. Consequently, this zone is assigned to Middle Miocene (Langhian to Early Serravallian) time.

It is noteworthy to mention that *Borelis melo melo* (Fichtel & Moll) is the most conspicuous large benthonic foraminiferal species recorded in this zone. Many authors have discussed the biostratigraphic and paleoenvironmental significance of this taxon as Middle Miocene index species. It was first described by Colem (1958) who recorded this taxon with the *Orbulina* spp. in the Middle Miocene strata that overlying the *Miogypsina mediterranea* beds of Majorca in Spain. Eames *et al.* (1962) recorded it associated with *Globorotalia fohsi fohsi / Orbulina* spp. zone and considered it as index large foraminiferal species marking the beginning of the Middle Miocene boundary. Reiss & Givertzmann (1966) showed that the presence of *Borelis melo* in The Middle to Upper Miocene Ziqlag Formation of Israel and attributed to zone N9 of Blow (1969). Bizon et al. (1968) and Clarke & Blow (1959) reported that Borelis melo ranges stratigraphically from base of zone N9 to Recent deposits. James & Wynd (1965) placed the FO of *Borealis melo* in the Burdigalian. Of this species, two subspeciesJames & Wynd (1965) placed the FO of *Borealis melo* in the Burdigalian.

Of this species, two subspecies. James & Wynd (1965) and Bignot & Guernet (1976) Hottinger (1977) placed the FO of *Borealis melo* in the Burdigalian. Of this species, two subspeciesare recognised: *Boreli melo melo* and *B. melo curdica*. The former evolved into the latter, which has a more complex structure of incipient attic chamberlets, a Y-shaped septula and external apertures (Jones et al., 2006). It is often difficult to differentiate these; in those cases, they are referred to as *Borelis melo* group (e.g., Daneshian & Cheghini, 2007). In the Indo-Pacific Province, *Borelis melo melo* starts in planktonic foraminiferal zone M1a (early Aquitanian) and continues up to M6 (late Langhian). However, its stratigraphical range in the Med-iterranean Province is from the beginning of M5b (early Langhian) up to PL1 (early Pliocene) (Jones et al., 2006). *Borelis melo curdica* appears in the Indo-Pacific Province in the middle of zone M5 (early Burdigalian) and becomes extinct near the top of M6 in the upper Langhian. In the Mediterranean Province, it ranges from the middle Burdigalian (upper M3) tothe late Langhian (Jones et al., 2006).

In Libya, Barr & Weegar (1972) recorded this species in Al Jabal Al Akhdar as a marker for the Middle Miocene beds. In Egypt, Souaya (1963a) recorded the *Borelis melo with the Miogypsina* in the middle Miocene of Gabal Gharra, Cairo-Suez district. Souaya (1963b) recognized also the *Borelis melo* from the middle Miocene- Pliocene in the Red sea. Youssef et al. (1971) recorded the *Borelis melo* from the upper part of the Sadat Formation in the Sadat area and attributed it to Langhian ageSouaya. Szczechura and Abd-Elshafy (1988) recorded the *Borelis melo* fromthe Hommath Formation in Bir El-bada area at the western side of the Gulf of Suez and assigned toMiddle Miocene age Moreover, Imam et al. (1997) recorded this taxon from the Middle Miocene deposits of SarbutEl-Gamal Formation, west central SinaiImam (1997 & 1999 a, b) also defined this taxon in the Middle Miocene Al Jaghboub Formation in Al Bardia area, NE Libya. Imam & Refaat (2000) recorded also this taxon from the Middle Miocene Hammam Faroun Member of Belayium Formation and gave it a definite zone in Gebel Hammam Sayidna Musa and Wadi Abura, southern Sinai, Egypt. Imam (2002) recorded the Borelis melo zone from the middle Miocene Marmarica Formation in the Salum area, Western Desert, Egypt. Later on, Ouda (1998) recorded the *Borelis melo* from the Miocene successions in the north Western Desert. He considered the *Borelis melo* as a diagnostic taxon for the lateLanghian-Serravallian age. Abul Naser et al. (2009) recorded this taxon from the Middle Miocene Hammam Faroun Member of Belayium Formation, between Wadi Sudr and Wadi Wardan, Gulf of Suez region. Hewaidy et al., (2020) recognized two distinct subspecies of *Borelis melo* are *Borelis melo melo* (Fichtel and Moll) and *Borelis melo curdica* (Reichel), in the Sadat and Hommath formations. And showed that the presence of these two species suggests that the upper part of the Sadat Formation and the whole Hommath Formation is of Langhian-Serravallian age**.** From the above mentioned discussion, the presence of *Borelis melo melo* Fichtel & Moll *and Borelis melo curdica* (Reichel),in the Upper part of Gharamul Formation suggests that this part is assigned to Middle Miocene, Langhian-Serravallian age.

## Paleoecological interpretation

Foraminifera are the most abundant marine protozoa in the epipelagic and the upper mesopelagic realms. Because of the complexity and diversity of habitats, especially in the shallow benthic realm, foraminifera show high biodiversity resulting from their different ecological requirements (Barbeiri et al., 2006). Based on the type of distribution and paleoecological conditions, the faunas were grouped into three large foraminifera zone (Figs. 6 and 7). The first zone Assemblage *Miogypsina complanata l Nonion granosus Assemblage Zone* is dominated by larger benthonic foraminifera along with shallow water benthic foraminifera as *Elphidium, Rotalia and Textularia*. Their occurrence were recoreded in the matrix of the ploymictc conglomerates of Abu Gerfan Foramtion where it is represented by wackestone-packstone (Fig. 6A). The second zone is *Miogypsina globulina* zone (SBZ 25) is represented by *Miogysinides and Lepidocyclinids with Operculinides, Heterostegina sp., Spiroclypeus sp.*. The texture is wackestone to packstone. The third biozone is *Borelis melo melo* Zone (foraminiferal Zone SBZ 26) is characterized by co-occurrence of larger hyaline and imperforated forms (Fig. 7AeD). Hyaline foraminifera were dominated by Borelis, Miogypsinoides, Lepidocyclina sp., Amphistegina sp., Operculina sp., Miogypsina sp., Archaias sp., Planorbolina sp., Peneroplis sp.,

In *Miogypsina complanata l Nonion granosus Assemblage Zone*, with a shallow, marginal marineenvironment exposed to salinity fluctuations (brackish or closemarine value) dominated by small benthic foraminifera (Ammoniaspp. and Elphidium sp.), and finally to the near shore, well-lit, highlytranslucent, high energy conditions in an inner ramp setting dominated by B. melo curdica, M. iranica and P. evolotus abundant benthonic foraminifera represent a more shallow offshore environment, The absence of light-dependent biota such as corallinacea and LBF indicates that these fauna developed under aphotic conditions in an inner ramp setting.

The high muddy carbonate matrix indicates low turbulence water (Murray, 1973; Nebelsick et al., 2000). *Miogypsina globulina* zone (SBZ 25) is characterized by the dominance of large discoidal tests of Lepidocyclinids (Eulepidina) and Nummulitids. Fine siliciclastic particles are also present in the texture. The large sized lepidocyclinids and discoidal flat tests (Eulepidina) are typical for a low energy environment with a low light on the inner ramp (Hallock, 1985; Hallock and Glenn, 1986). The predominance of large foraminifera may indicate a highly oligotrophic palaeoenvironment dominated by K-strategists (Bassi, 2005). The sediments of *Borelis melo melo* Zone (foraminiferal Zone SBZ 26) suggest that different degrees of water turbulence were involved in the creation of the packstone grainstone texture. Abundance of larger benthic foraminifera suggests shallow, well-illuminated, warm, oligotrophic waters with suitable substrate (Hottinger, 1983; Murray, 1991; O'Connell et al., 2012) and normal marine salinity. The mixture of large rotalids and the sea grass associated bioclasts (porcellaneous forms and small rotalids) indicates meso-euphotic conditions (Pomar et al., 2014). The grainstones represent a higher degree of turbulence with mobile substrate and fauna indicating well-lit conditions (Nebelsick et al., 2000), which is also shown by robust and thick tests of foraminifera (Fournier et al., 2004). In shallow waters, where light limitation is not problematic, LBF can produce thick tests, which protect the test from mechanical damage due to the increased hydrodynamic energy in shallow waters (Hohenegger, 2000). the predominance of Ammonia and ostrea indicates a eutrophic environment with normal marine conditions that were only exposed to short-term salinity fluctuations (Reuter and Brachert, 2007).
The presence of bryozoans together with microfossil assemblages with their relatively high diversity in some samples might suggest that the environmental conditions changed from unstable with salinity fluctuations to more stable conditions and the normal salinity (Filipescu et al., 2014). The abundance of Ammonia and the occurrence of Textularia and heterotrophic organisms in the microfacies may indicate increased nutrient input (Sen Gupta, 1999; Mateu-Vicens et al., 2008). The dominance ofporcellaneous larger foraminifera in Assemblage 5 indicates highenergy conditions in the well-lit, highly translucent, shallow part of the photic zone (Bassi and Nebelsick, 2010). The low turbidity isascribed to the high diversity of the porcelaneous foraminiferalfauna, which develops in meso-to-oligotrophic settings at a shallowdepth (Hallock, 1984, 1988; Reiss and Hottinger, 1984; Buxton and Pedley, 1989; Romero et al., 2002; Barattolo et al., 2007). The dominance of imperforate foraminiferal tests may indicate a slightly hypersaline depositional environment (Hallock & Glenn, 1986, Brandano et al., 2009). Based on the occurrence and morphology of foraminifera,our paleoecological interpretation shows a gradient change fromdeep offshore, low energy conditions in aphotic zones dominated by planktonic foraminifera to a deep, turbid, low-light setting in theoligophotic zone dominated by Eulepidina (elephantine, dilatata, sp.) and Nummulitids (Heterostegina sp., Operculina sp., O. complanata,Spiroclypeus sp., S. blankenhorni). Following this, the conditionschange again to deeper parts of the inner ramp dominated by M. complanatus, N. viennoti, Lepidocyclina sp., operculina sp. And Archaias sp., then to Assemblage 4 (Fig. 8)

## Conclusions

The present study deals with the Lithostratigraphy and biostratigraphy of the Miocene succession Gebel Abu Shaar El Qibli plateau, Western side of the Gulf of Suez, Egypt . The material of this study consists of 60 samples which were collected from two surface stratigraphic surface sections, namely from north to south: Wadi Balih, and Wadi Khoriza surface sections (29º 33¯ N and 32º 55¯W). Lithostratigraphyically, the studied succession is divided into two formations from base to top as follows: Abu Gerfan and Gharamul formations.The Miocene successions of the present study has been subdivided into three biostratigraphic zones, according to the biostratigraphic range of the identified larger and smaller benthonic foraminiferal species.

Biostratigrphically, three larger and smaller benthonic foraminiferal zones of world and regional extention have been recognized according to Cahuzac & Poignant 1997. These biozones are from base to top as follows: *Miogypsina complanata l Nonion granosus* Assemblage Zone (early Miocene, Aquitanian age) equated with Abu Gerfan Formation, *Miogypsina globulina* zone (early Miocene, Burdiglian age) covering the lower parts of Gharamul Formation and *Borelis melo melo* zone (Middle Miocene, Langhian age) covering the upper parts of Gharamul Formation respectively in Gabal Abu Shaar El Qibli plateau.

Larger foraminiferal species identified in one level of the Gabal Abu Shaar El Qibli plateau sections clearly indicate that the Abu Gerfan Formation is comparable with the SBZ 24 (Aquitanian age) and Gharamul formation is equated with SBZ25 and SBZ25 of early Miocene, Burdiglian to Langhian age. The larger foraminiferal zones SBZ 24 and SBZ 25, identified in the Bir El Haleifiya and Beir Haleifiya sections, also indicate an Early Miocene age of the Nukhul Formation. In the Cahuzac and Poignant SBZ (1997) the SB 25 Zone corresponds to the Burdigalian and its lower boundary is defined by the FO of *Miogypsina globulina* (Fig. 6). In this study, since *Miogypsina globulina* was recorded, SBZ 25 was recognized by the occurrence of *Miogypsina intermedia* whose range is the same as that of *Miogypsina globulina* (Cahuzac & Poignant 1997).

The Miocene sequence in the area of Gabal Abu Shaar El Qibli plateau , Gulf of suez region, Egypt showed the coexistence of larger and planktonic foraminifera in the shallow to deep water sediments. Thus, both a well defined biostratigraphic framework was established and stratigraphic ranges of some larger foraminifera were calibrated with planktonic foraminiferal zones throughout the Miocene interval. The MMi 1 Zone, corresponding to the lowest part of the early Miocene ( Aquitanian), was identified in the studied sequence due to the existence of *Globigerinoides primordius* which is generally rare in the Mediterranean region. The Aquitanian corresponds to the SB 24 Zone (Cahuzac & Poignant 1997) (Fig. 3), was recorded only in Bir El Haleifiya section with the occurrence of *Miogypsina* sp. However, *Miolepidocyclina* sp. accompanied with *Miogypsina* sp. in the same level indicates the upper part of the SBZ 24 (Upper Aquitanian). Moreover, the planktonic foraminiferal assemblage represents the MMi 2b Zone, whose lower part corresponds to the upper part of the SBZ 24.

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