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PALEOECOLOGIC STUDY OF THE MIDDLE – UPPER EOCENE ROCKS IN EAST FAYOUM DEPRESSION, WESTERN DESERT, EGYPT.

By

Abdallah, A. M.*, Helal, S. A.** and Abdel Aziz, S.M.**

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Abstract

The reconstruction of the paleoenvironmental conditions that prevailed during the deposition of the Middle and Upper Eocene sediments which exposed at the Fayoum – Nile divide are based on the quantitative and qualitative aspects of the identified Foraminifera and Ostracoda, as well as the consideration of the encountered lithofacies. The important paleoecologic parameters used in this study include Planktonic / Benthonic ratio (P/B ratio); Triangular plot diagram; Abundance patterns of foraminiferal and ostracods families and Arenaceous / Calcareous benthic foraminiferal ratio (A/C ratio).

It is concluded that the exposed Eocene rock units; Gehannam and Birket Qarun formations were deposited under varying marine conditions ranging from the inner to outer neritic environments. A shallowing upward tendency from the Middle to the Late Eocene is detected.

* Geology Department, Faculty of Science, Cairo University.

** Geology Department, Faculty of Science, Cairo University, Fayoum Branch.

Introduction

The eastern part of the Fayoum depression is made up of low desert ridge which has (5-12 km width and 50 km length). It separates the Fayoum depression form the Nile Valley between Girza and Shaklufa sections and called the Nile-Fayoum Divide (Fig. 1).

Previous studies of the Fayoum depression include Beadnell (1905); Hume (1912); Cuvillier (1926); Iskander (1943); Ansary (1955; Said (1962); Abdel Kireem (1971); Ismail & Abdel Kireem (1971); Strougo (1979, 1986 & 1992); Shamah (1981, 1990 & 1994); Bassiouni *et al.* (1984); Abdel Kireem (1985); Haggag (1985, 1989, 1990 & 1992); Samir (1986); Swedan (1986 & 1992); El Badry & Eid (1987); Abdel Ghany (1990); Allam *et al.* (1991); Boukhary *et al.* (1993); Shamah *et al.* (1994); Haggag & Bolli (1995 & 1996); Haggag & Luterbacher (1995); Abdallah *et al.* (1997); Saber (1998); Elewa *et al.* (1998) ,Omar (1999) and Helal (2002) .

All the above mentioned studies are concerned with the stratigraphical, sedimentological and paleontological aspects of the study area. The paleoecologic and paleoenvironmental conditions prevailing during the Middle and Late Eocene are not previously studied; the cause that initiated the idea of this study.

Lithostratigraphy

Seven stratigraphic surface sections are measured along the ridge area separating the Fayoum depression from the Nile Valley. These are from north to south 1-Girza section Lat. 29° 27` N. and Long. 31° 08` E., 2-El

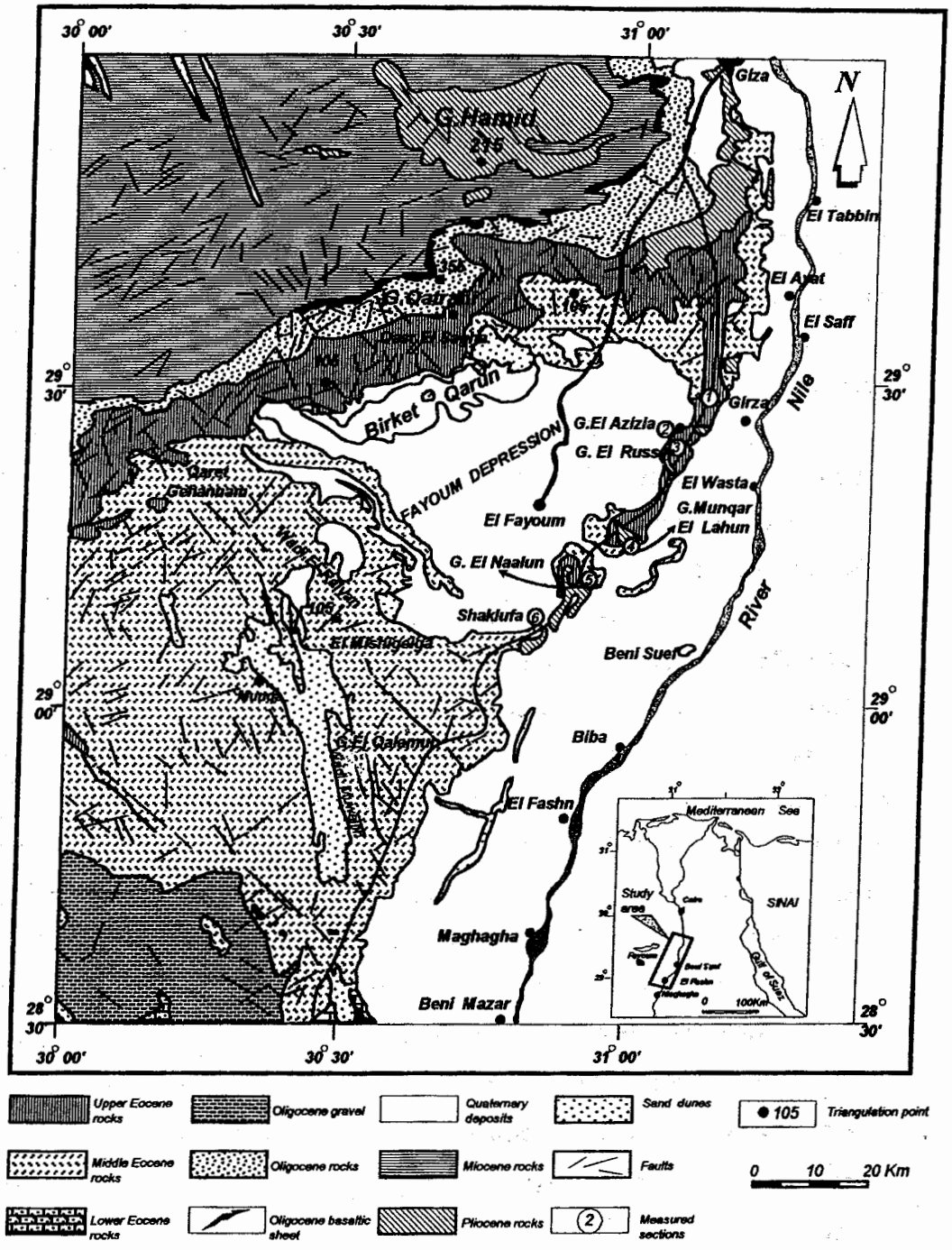


Fig.(1) Geological map of the study area (modified after Conoco ,1987)

Azizia section Lat. 29° 26` N. and Long. 31° 06` E., 3-Gebel El Russ section Lat. 29° 20` N. and Long. 31° 04` E., 4-Gebel Munqar El Lahun section Lat. 29° 16` N. Long. 30° 54` E., 5-Gebel El Naalun section Lat. 29° 12` N. and Long. 30° 53` E., 6-Shaklufa section Lat. 29° 08` N. and Long. 30° 51` E. and 7-Gebel El Qalamun section Lat. 28° 54` N. and Long. 30° 35` E. (Fig. 1).

The exposed sedimentary rocks in the area under study range in age from Middle Eocene to Pliocene (Fig. 1). The exposed rocks are represented by the following rock units from younger to older as follows:

5- Helwan Formation (Late Pliocene)

4- Umm Raqaba Formation (Late Pliocene)

3- Kom el Shelul Formation (Middle Pliocene)

▪▪▪▪▪▪▪▪▪▪ Unconformity ▪▪▪▪▪▪▪▪▪▪

2- Birket Qarun Formation (Late Eocene)

1- Gehannam Formation "Ravine beds" (Middle/Late Eocene)

These rock units are carefully sampled and investigated for their microfaunal content. The Pliocene rocks are devoid of microfauna. The Eocene rock samples (261) yields, generally, a rich and diversified fauna including Foraminifera (benthic and planktic) and Ostracoda that represent the data base for this study. The following paragraphs, a brief description of the studied lithologies and their microfaunal content.

1- Gehannam Formation (Middle – Late Eocene)

This formation was first known as Ravine Beds by Beadnell (1905) and Said (1962) renamed it as Gehannam Formation. These beds are consist of marls, claystones, sands with occasional limestones intercalations .

The Gehannam Formation occurs at Griza (44 m thick.), El Azizia (37.5m thick), El Russ (5.5 m thick), Munqar El Lahun (22m thick), Naalun (45m thick) and Shaklufa (18.5 m thick). The base is unexposed and the formation is unconformably overlained by the Pliocene rocks at Girza and by the Birket Qarun Formation at El-Azizia, El Russ, Munqar El Lahun, Naalun and Shaklufa Sections.

The details of the lithologic columns, the correlation, and the location of the samples are shownin fig.2. the studied samples yielded rich and diversified formainiferal (Planktic and bcnthic) and Ostracoda communities, these faunal contents are introduced in tables 1a-d.

2- Birket Qarun Formation (Late Eocene).

This unit was first named the Birket Qarun Series by Beadnell (1905). The formal name, Birket Qarun Formation was introduced by Said (1962). This formation consists of calcareous sandstones, sandy claystones, calcareous mudstones and sandy limestones. It occurs at El Azizia (33m thick), El Russ (19.5m thick) Munqar El Lahun (32.5 m thick) and Naalun (22.5m thick).

The Birket Qarun Formation conformably overlies the Gehannam formation and unconformably underlies the Pliocene Helwan and Um Raqaba formations. The encountered lithologies and the location of the samples are shown in fig 2. The Birket Qarun Formation is barren of Planktic Foraminifera. The recovered

microfauna include benthic Foraminifera (small and large) and Ostracoda which are listed in tables 1a- d .

Table (1a) The identified Planktonic Foraminifera from the studied sections

(X: Gehanam Formation O: Birket Qarun Formation

Species	Girza section	El Azizia section	El Russ section	Munqar El Lahun section	El Naalun section	Shakluf section
a- Planktonic Foraminifera:						
Globigerinatheka index index (Finlay)	X	X	X			X
Gka. mexicana mexicana (Cushman)	X					X
Gka. mexicana barri Brönnimann	X					X
Gka. index tropicalis (Blow & Banner)	X		X		X	
Gka. index rubriformis (Subbotina)	X					
Gka. index aegyptiaca Haggag & Bolli	X		X			
Gka subconglobata subconglobata (Shutskaya)						X
Turborotalia cerroazulensis cerroazulensis (Cole)	X		X		X	X
Tur. c. pomeroli (Toumarkine & Bolli)	X		X	X	X	X
Tur. c. cocoaensis (Cushman)	X					X
Tur. Pseudoampliapertura (Blow & Banner)	X	X	X	X	X	X
Acarinina bullbrooki (Bolli)					X	
A. spinuloinflata (Bandy)					X	X
Pseudohastigerina micra (Cole)					X	
Truncorotaloides rohri Brönnimann & Bermudez					X	X
Tr. topilensis (Cushman)					X	X
Tr. libyaensis El Khoudary					X	X
Globigerina linaperta Finlay	X	X	X	X	X	X

Table 1a cont.						
G. ampliapertura Bolli	X		X	X	X	X
G. cryptomphala Glaessner	X			X	X	
G. baconica Samuel					X	X
G. corpulenta Subbotina	X			X		X
G. tripartita Koch	X	X	X	X		X
G. yeguaensis Weinzierl & Applin	X	X	X	X	X	X
G. eocaena Gümbel	X	X	X	X	X	X
G. hagni Gohrbandt	X	X			X	X
G. pseudovenezuelana Blow & Banner						X
Globigerinita echinata africana Blow & Banner	X					
G. howei Blow & Banner	X	X	X			

Table (1b) The identified Benthonic Foraminifera from the studied sections

Species	Girza section	El Azizia section	El Russ Section	Munqar El Lahun section	El Naalun section	Shaklufa section
b- Benthonic Foraminifera:						
Lenticulina chitanii (Yabe & Asano)	X	X	X	X O	X	X
L. depressa (Asano)		X		O	X	
L. yaguatensis (Bermudez)	X	X	XO	X		X
L. alabamensis Cushman		X				
L. mayi (Cushman & Parker)	X					
Cancris subconicus (Terquem)	X	X	O	XO	X	X
C. auriculus (Fichtel & Moll)	X	X	XO		X	X

Table 1b cont.						
C. turgidus (Cushman & Todd)	X			X		X
Textularia halkyardi Lalicker	X	X	O			
T. fahmyi Anan	X	X		X	X	X
T. adamsi (Lalicker)	X	X		X	X	
T. agglutinans d'Orbigny	X		O	X		
T. communis (d'Orbigny)			O		X	X
T. recta Cushman				O		
Quinqueloculina seminula Linné	X	X	O	XO		X
Q. ludwigi Reuss		X	O			
Q. triangularis d'Orbigny	X					
Spiroloculina tenuissima Reuss	X		X		X	X
S. dorsata Reuss	X				X	
S. canaliculata d'Orbigny		X		X		
Bulimina jacksonensis Cushman	X	X	XO	XO	X	X
B. truncana Gümbel	X	X	XO	XO	X	X
B. inflata Seguenza					X	
B. elegans d'Orbigny			O			
Uvigerina mediterranea Hofker	X	X	XO	X	X	X
U. seriata Cushman & Jarvis	X	X	XO	XO	X	
U. spinicostata Cushman & Jarvis	X			X		
U. szakalensis Majzon	X		X	XO		
U. farinosa Hantken				XO		
U. woodringi obsoleta Bermudez	X			XO		
U. cocoaensis Cushman			X			X
U. continuosa Lamb						X
U. jacksonensis Cushman						X
U. multistriata Hantken						X

Table 1b cont.						
U. nuttalli Cushman & Edwards						X
Nonion planatum Cushman & Thomas	X		X		X	X
N. scaphum (Fichtel & Moll)			O	X O		
N. acutidorsatum Ten Dam	X		O			
N. belridgensis Barbat & Johnson			X			
N. microumbilicatus Le Roy			O	X	X	
N. trompi Ansary		X				
Nonionella auris (d'Orbigny)	X	X	O	X O	X	
N. longicamerata Bandy					X	
N. maadiensis Ansary			X			
Marginulinopsis costata (Batsch)		X			X	
M. tuberculata (Plummer)	X	X			X	
M. brantlyi (Garrett)	X	X				X
Bolivina pulchra (Terquem)		X	XO	X O	X	X
B. moodysensis Cushman & Todd	X					
B. nobilis Hankten		X				
B. cookei Cushman		X				
B. oblique Barbat & Johnson			O		X	
B. carinata Terquem	X			X O		
Lagena costata (Williamson)				X	X	
L. apiculata (Reuss)				X		
L. hispida Reuss		X		X		
L. isabella (d'Orbigny)				X		
L. sulcata (Walker & Jacob)				X		
L. laevis (Montagu)				X		
L. globosa (Montagu)				X		
L. striata (d'Orbigny)	X	X		X	X	

Table 1b cont.						
L. hexagona (Williamson)				X	X	
Globulina gibba (d'Orbigny)		X		X	X	
G. inaequalis Reuss		X		X		
Saracenaria barnardi Ansary	X		X	X		X
S. gibba (Costa)				X	X	
S. moresiana Howe & Wallace	X			X	X	
Laevidentalina soluta (Reuss)		X	X			
L. jacksonensis (Cushman & Applin)		X		X	X	
L. cooperensis (Cushman)		X				
L. wilcoxensis (Cushman)					X	
L. halkyardi (Cushman)				X		
L. herculea (Gümbel)	X					
Nodosaria communis (d'Orbigny)				XO		X
N. vagina (Stache)			X			
N. stipitata costulata Reuss	X			X	X	X
Cibicides lobatulus (Walker & Jacob)	X	X	O	XO	X	X
C. mabahethi Said		X		X	X	
C. westi Howe		X		X		X
C. mississippiensis ocalamus Cushman		X		X		X
C. pygmeus (Hankten)			O	XO		
C. proprius (Brotzen)		X				
C. crassidiscus Bandy			X			
Cibicidina fletcheri (Galloway & Wissler)	X	X		XO	X	
Anomalinoides fayoumensis (Ansary)	X	X	X	X	X	
Eponides ellisorae Garrett	X	X	X	XO	X	X
E. praecinctus (Karrer)				XO	X	
Pararotalia audouini (d'Orbigny)	X		X	XO	X	

Table 1b cont.						
Angulogerina abbreviata (Terquem)	X		O	X		
Guttulina irregularis (d'Orbigny)	X	X			X	
Glandulina laevigata d'Orbigny	X					X
Palmula ansaryi Anan					X	
Elphidium excavatum (Terquem)		X				
E. ancestrum le Calvez		X				
Fursenkoina sequamosa (d'Orbigny)	X		O			
Pyramidulina vertebralis (Batsch)	X					
P. elegantissima d'Orbigny	X					
P. affinis Reuss					X	

Table (1c) The identified Ostracoda from the studied sections

Species	Girza section	El Azizia section	El Russ Section	Munqar El Lahun section	El Naalun section	Shaklufa section
c- Ostracoda:						
Cytherella münsteri Roemer	X	X	X	X O	X	X
Costa ducassae Bassiouni *et al.*	X	X	X	X	X	X
C. crassireticulata Bassiouni	X	X			X	X
C. humboldti Bassiouni	X	X	XO	X O		
C. mokattamensis Bassiouni					X	X
Ruggieria (Keijella) glabella Bassiouni	X	X	O	XO	X	X
Brachycythere ismaili Bassiouni	X	X	XO	O	X	X
B. omarai (Cronin & Khalifa)	X			X		
Loxoconcha pseudopunctatella Cronin & Khalifa	X	X	X O	X	X	X

Table 1c cont.						
Asymmetricythere yousefi Bassiouni	X	X	XO	X	X	X
A. hiltermanni Bassiuoni		X	O	X	X	X
Leguminocythereis sadeki Bassiouni	X	X	XO	X	X	X
L. africana Bassiouni	X	X		O		
Trachyleberis nodosus nodosulcatus Bassiouni	X	X	O	XO	X	X
T. n. reticulatus Bassiouni		X				
Reticulina heluanensis (Bassiouni)	X	X	XO	XO	X	X
Limburgina moosi Bassiouni		X	O	XO	X	X
Hermanites libyaensis El Waer		X		X	X	X
Bairdia gliberti (Keij)	X		O	XO	X	X
Novocypris eocenana Ducasse		X	O	XO	X	X
Cativella qurnensis Bassiouni			O		X	X
Bradleya oertlii Ducasse				XO		
Xestoleberis subglobosa (Bosquet)			X	XO	X	X
Bythoceratina bassiounii n. sp.	X	X				

Table (1d) The recorded Larger Foraminifera from the studied sections

Species	Girza section	El Azizia section	El Russ Section	Munqar El Lahun section	El Naalun section	Shaklufa section
d- Larger Foraminifera:						
Nummulites beaumonti d'Archiac & Haime					X	
N. discorbinus (Schlotheim)					X	X
N. striatus (Bruguiere)	X	X	X	X		X
N. ptukhiani Kacharava	X					
N. bullatus decrouezae Boukhary					X	
N. aff. Pulchallus Hantken					X	
Operculina schwageri Silvestri	X	X	X	X	X	X

Paleoecology

Review of the available literature dealing with the depositional environments of the Middle to Upper Eocene rocks of Egypt indicate that no studies are carried out for the area of the present study.

The paleoenvironmental conditions that prevailed during the deposition of the Gehannam and Birket Qarun formations at the studied sections are deduced by using several paleoecologic parameters.The important paleoecologic parameters used in this study include: Planktonic / Benthonic ratio (P/B ratio); Triangular plot diagram; Abundance patterns of foraminiferal and ostracodes families; Arenaceous / Calcareous benthic foraminiferal ratio (A/C ratio).

1- Gehannam Formation:

The Gehannam Formation is composed mainly of claystones and fossiliferous limestone, sandy limestone and argillaceous limestone beds. The claystone beds of this formation at Gebel Girza, Gebel El Russ and Gebel Shaklufa sections contain high concentration of benthonic and planktonic foraminifera as well as high content of ostracodes. The limestone beds are highly fossiliferous containing *Nummulites spp.* and *Operculina spp.*

The planktonic / benthonic (P/B) ratio at Gebel Girza reaches to about (60%); at Gebel El Russ section (38%) and at Gebel Shaklufa section (45.7%) indicating outer neritic environment (Boersma, 1978) (Fig. 3A-C). On the triangular plot diagram most of the samples of this formation at the three studied sections are located at the suborder Rotaliina corner to show its predominance on the other two suborders. At Girza section the Rotaliina ranges from (57% - 100%); Textulariina (0% - 35%) and Miliolina (0% - 15%). At Gebel El Russ section the Rotaliina ranges from (97.4% - 100%); Textulariina (0%) and Miliolina (0% - 2.6%). At Gebel Shaklufa section the Rotaliina ranges from (80% - 100%); Textulariina (0% - 8.6%) and Miliolina (0% - 11.7%) denoting shelf sea of normal salinity (Murray, 1973) (Fig. 4A-C). The described benthonic foraminiferal species from the Gehannam Formation at Girza section belong to 18 families. The frequency percent of these families are Vaginulinidae (25.96%); Buliminidae (15.52%); Uvigerinidae (12.10%); Bagginidae (11.77%); Textulariidae (7.10%); Bolivinidae (6.63%); Hauerinidae (4.71%); Eponididae (3.38%); Polymorphinidae (2.95%); Alfredinidae (2.10%); Cibicididae (1.66%); Nonionidae (1.49%); Spiroloculinidae (1.39%); Glandulinidae (1.33%); Nodosariidae (0.80%) Rotaliidae (0.50%); Lagenidae (0.36%) and

Fursenkoinidae (0.30%). The frequency percent of the recorded benthonic foraminiferal species at Gebel El Russ section are Vaginulinidae (29.13%); Uvigerinidae (27.96%); Buliminidae (15.53%); Bolivinidae (10.87%); Nonionidae (3.30%); Rotaliidae (3.11%); Alfredinidae (2.72%); Bagginidae (2.33%); Spiroloculinidae (1.75%); Nodosariidae (1.55%0; Eponididae (0.97%) and Cibicididae (0.78%). At Gebel Shaklufa section, the frequency percent of the identified benthonic foraminiferal species are Buliminidae (32.51%); Uvigerinidae (20.51%); Vaginulinidae (20%); Bagginidae (6.15%); Cibicididae (4.62%) Hauerinidae (4.21%); Nodosariidae (3.38%); Bolivinidae (2.46%); Textulariidae (1.85%); Nonionidae (1.23%); Spiroloculinidae (1.13%); Eponididae (1.03%) and Glandulinidae (0.92%) (Fig. 5A-C).

The arenaceous / calcareous ratio for the Gehannam Formation at Gebel Girza section is represented by the value (14.94%); at Gebel El Russ section (0%) and at Gebel Shaklufa section (6.04%) indicating outer neritic environment (El Deeb & El Gammal, 1997).

According to Haynes (1981) the presence of families Bagginidae, Nonionidae, Anomalinidae and Buliminidae are more indicative for the outer shelf and bathyal environments. Also, the genera *Bolivina*, *Bulimina* and *Uvigerina* are more abundant on the outer shelf and the uppermost continental slope (Murray, 1973 and Boltovskoy *et al.*, 1980). The occurrence of costate uvigerinid and buliminid (*Bulimina jacksonensis*) faunas are more indicative for outer neritic depths (Barr & Berggren, 1980). According to Murray (1970, 1971) *Cancris* and *Cibicides* are typical shelf genera. The occurrence of *Uvigerina spp.* indicates relatively low oxygen depositional environment; where it is normal marine genus characteristic for deeper waters (Smith, 1963; IngleE *et al.*, 1980 and Lutze, 1980). The

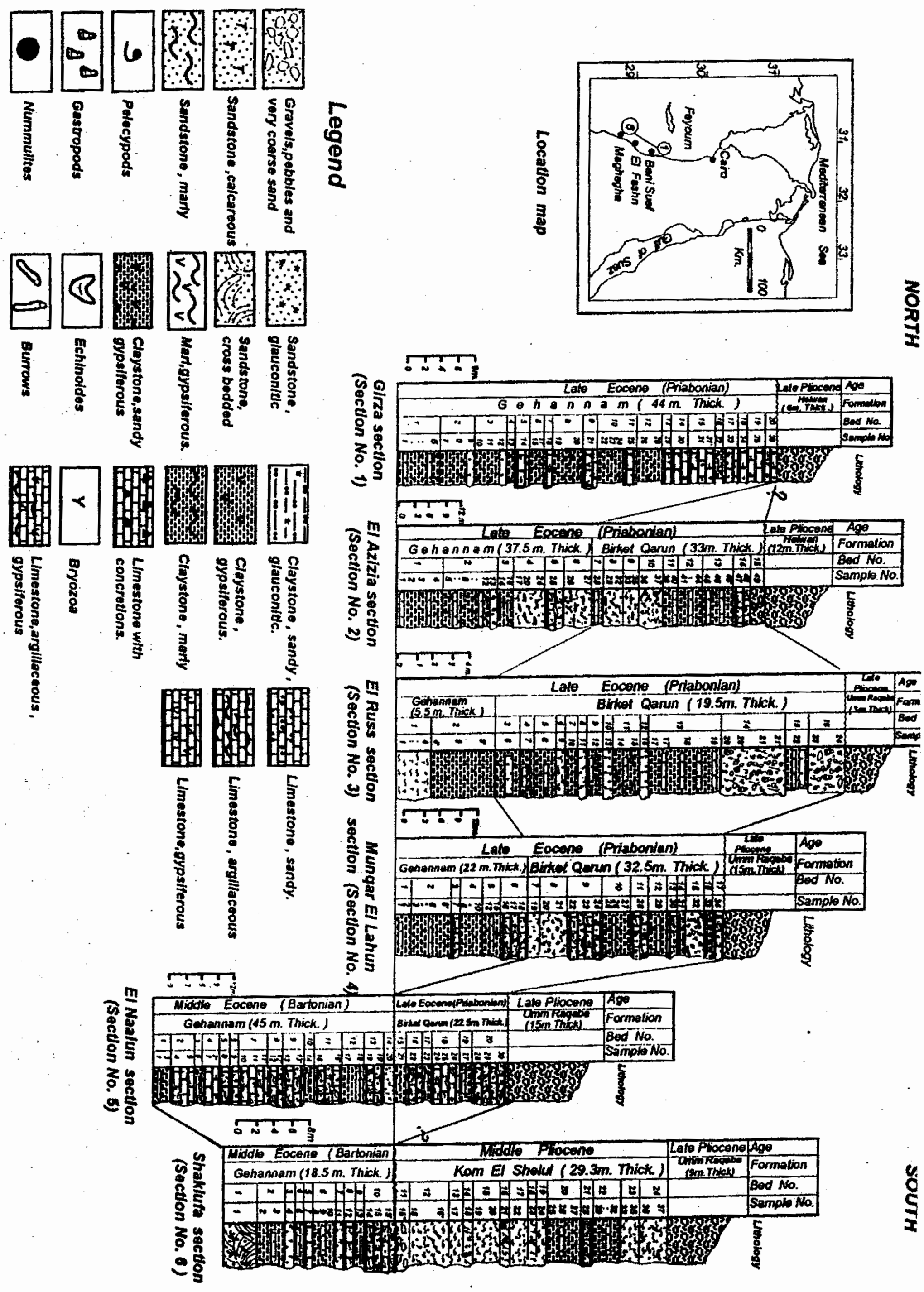


Fig.(2) Correlation chart of the studed sections ; Fayoum area.

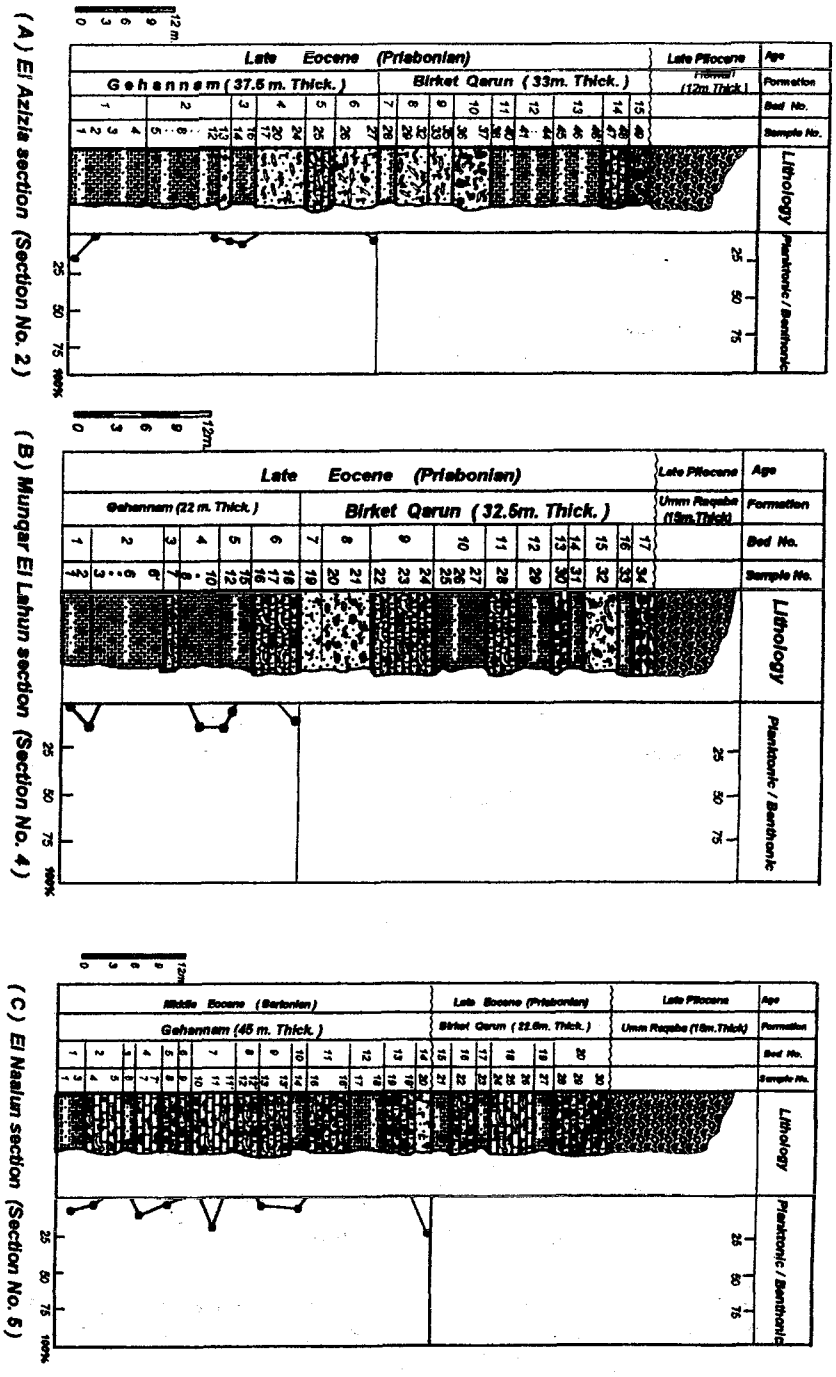
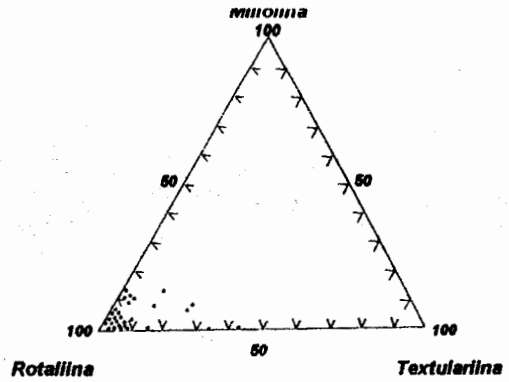
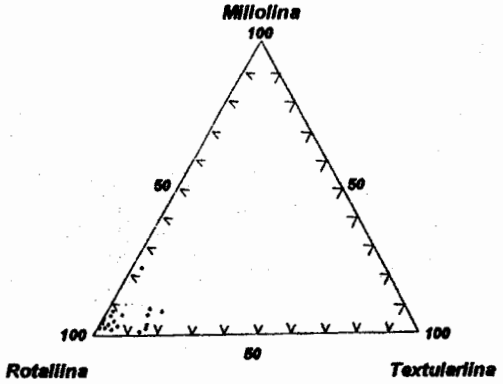


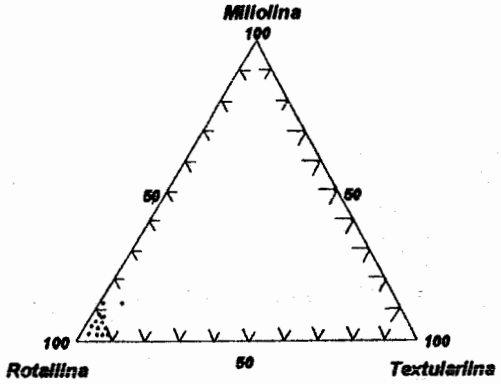
Fig.(3) Planktonic /Benthonic (P/B) ratio of the Gehannam Formation at (A)El Azizia, (B)Gebel Munqar El Lahun and (C) Gebel El Naalun sections .



(A) Girza section

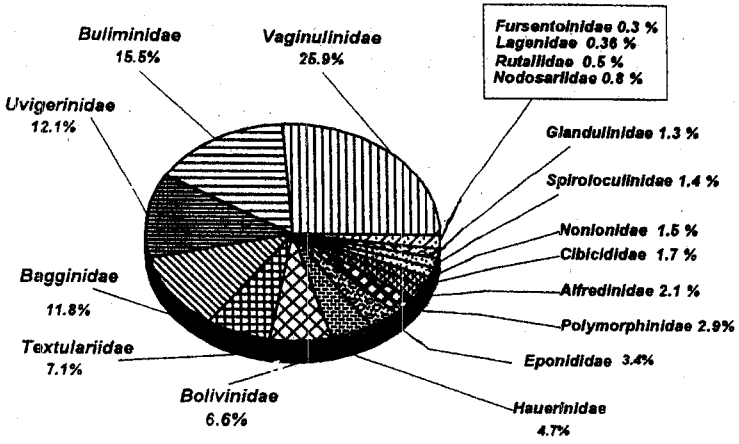


(B) El Russ section

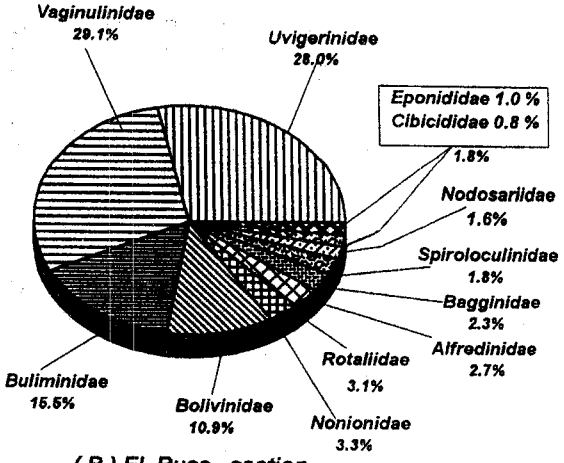


(C) Shaklufa section

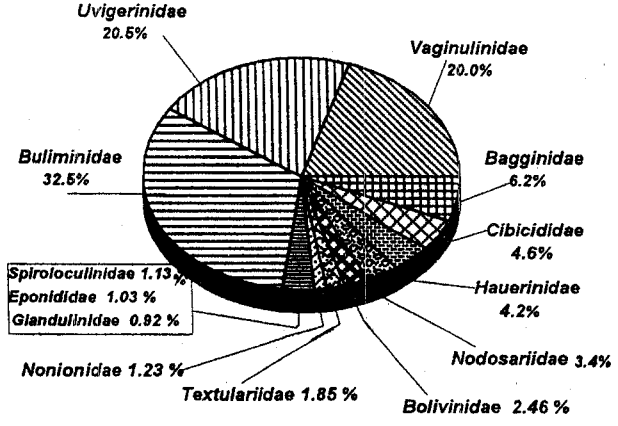
Fig.(4)Triangular plot diagrams for the foraminiferal content of the Gehannam Formation at (A) Gebel Girza , (B) Gebel El Russ and (C) Gebel Shaklufa sections



(A) Girza section



(B) El Russ section



(C) Shaklufa section

Fig.(5)Individual no.% of the indentified Benthonic Foraminifera throughout the Gehannam Formation at (A) Gebel Girza, (B)El Russ and (C) Shaklufa sections.

presence of rare and small size *Nummulites spp.; Operculina spp.* and the *Pararotalia audouini* within the sandy limestone beds at Gebel Girza, Gebel ElRuss and Gebel Shaklufa sections represent shallow neritic environments (Barr & Berggren, 1980). Also, the occurrence of macrofossils such as *Ostrea spp.* and *Turritella spp.* at the topmost part of the Gehannam Formation at Gebel Shaklufa section indicate shallowing upward tendency.

The identified ostracodes from the Gehannam Formation at Gebel Girza section are represented by the families Trachyleberididae (53.27%); Brachycytheridae (16.37%); Campylocytheridae (12.32%); Loxoconchidae (7.80%); Cytherellidae (5.37%); Bythocytheridae (4.31%) and Bairdiidae (0.21%). At Gebel El Russ section, the recorded ostracodes are represented by the families Trachyleberididae (50.58%); Campylocytheridae (19.54%); Brachycytheridae (14.94%); Cytherellidae (6.90%); Loxoconchidae (4.60%) and Xestoleberididae (3.45%). The described ostracodes at Gebel Shaklufa section are represented by Trachyleberididae (63.68%); Campylocytheridae (10.64%); Brachycytheridae (10.14%); Loxoconchidae (5.91%); Bairdiidae (5.07%) and Cytherellidae (4.56%) (Fig. 6A-C).

According to Bassiouni *et al.*, (1984) the presence of the genera; *Loxoconcha*, *Bairdia* and *Krithe* may reflect inner neritic and deeper marine conditions. They considered the presence of highly ornamented trachyleberid genera as indicative of typical marine, most probably shallow littoral to outer neritic. The occurrence of the families Trachyleberididae; Bythocytheridae; Cytherellidae; Bairdiidae and Loxoconchidae indicate inner to outer neritic environments (Whatley, 1988). Bassiouni *et al.*, (1994) mentioned that the typical species for the open platform environment are *Loxoconcha vetustopunctatella, Leguminocythereis sadeki* and *Costa crassireticulata* associated with the assemblage *Limburgina moosi, Trachyleberis nodosus*

reticulatus, Acanthocythereis salahii, Bairdia sp., Reticulina heluanensis, Ruggieria (Keijella) glabella, Costa humboldti,? Bythocypris mereirensis, Brachycythere (Digmocythere) ismaili and *Asymmetricythere yousfei*. The recorded assemblage from the Gehannam Formation at Gebel Girza, Gebel El Russ and Gebel Shaklufa sections is very similar to this association. Consequently, the recorded ostracodes assemblage may be considered as indicating for outer neritic depths in accordance with the obtained results from the foraminiferal analysis.

The Gehannam Formation at Gebel El Azizia, Gebel Munqar El Lahun and Gebel El Naalun sections is characterized by its rare content of planktonic foraminifera.

The planktonic / benthonic ratio at Gebel El Azizia section reaches about (14%); at Gebel Munqar El Lahun (13%) and Gebel El Naalun (23.8%) indicating middle neritic environment (Hewaidy, 1994) (Fig. 7A-C). On the triangular plot diagram most of the samples are located at the corner of the suborder Rotaliina. At Gebel El Azizia section the Rotaliina ranges from (79% - 100%); Textulariina (0% - 5.2%) and Miliolina (0% - 15.7%). At Gebel Munqar El Lahun section the Rotaliina ranges from (76% - 100%), Textulariina (0% - 16.2%) and Miliolina (0% - 8.1%). At Gebel El Naalun section the Rotaliina ranges from (71.3% - 100%), Textulariina (0% - 23%) and Miliolina (0% - 18.6%) attesting shelf sea of normal salinity (El Dawy, 1997) (Fig. 8A-C). The frequency percent of the identified benthonic foraminiferal species at Gebel El Azizia section is represented by Vaginulinidae (36.31%); Uvigerinidae (18.36%); Bolivinidae (7.20%); Eponididae (6.87%); Cibicididae (5.84%); Elphidiidae (4.44%); Bagginidae (4.35%); Nonionidae (2.90%); Nodosariidae (2.57%); Textulariidae (2.10%); Polymorphinidae (1.87%); Alfredinidae (1.82%); Buliminidae

(1.68%); Lagenidae (1.26%); Spiroloculinidae (1.03%); Hauerinidae (0.98%) and Glandulinidae (0.42%). At Gebel Munqar El Lahun section the frequency percent of the recorded

benthonic foraminifera from the Gehannam Formation are Uvigerinidae (21.28%); Cibicididae (12.48%); Vaginulinidae (9.94%); Buliminidae (9.69%); Bagginidae (7.54%); Lagenidae (6.78%); Bolivinidae (6.52%); Textulariidae (3.86%); Nonionidae (3.67%); Eponididae (3.61%); Rotaliidae (3.36%); Hauerinidae (2.91%); Nodosariidae (2.60%); Glandulinidae (2.15%); Polymorphinidae (1.58%); Alfredinidae (1.20%) and Spiroloculinidae (0.83%). At Gebel El Naalun section the frequency percent are Vaginulinidae (22.18%); Uvigerinidae (21.89%); Nodosariidae (7.66%); Textulariidae (6.59%); Bagginidae (6.25%); Cibicididae (5.61%); Nonionidae (5.35%); Bolivinidae (4.83%); Buliminidae (4.71%); Spiroloculinidae (4.22%); Eponididae (4.08%); Lagenidae (2.17%); Glandulinidae (1.71%); Alfredinidae (1.42%); Rotaliidae (0.90%) and Polymorphinidae (0.43%) (Fig. 9A-C).

The arenaceous / calcareous (A/C) ratio for the Gehannam Formation at Gebel El Azizia section is represented by the value (8.11%), at Gebel Munqar El Lahun section (10.12%) and Gebel El Naalun section (12.36%) indicating middle neritic environment (EL Ashwah & El Deeb, 2000).

According to Murray *et al.*, (1981) the presence of *Cancris subconicus, Cibicides lobatulus, Guttulina problema, Epistominella spp., Nonion spp.* and *Globulina spp.* attest inner to middle shelf conditions. The occurrence of *Cibicides lobatulus* and *Elphidium clavatum* indicate inner shelf environment with depth up to (45m) (Ellison & Nichols, 1976). The presence of *Textularia agglutinans* indicates shallow water depth where this species is common and widely distributed at depths (3 – 35m) and the

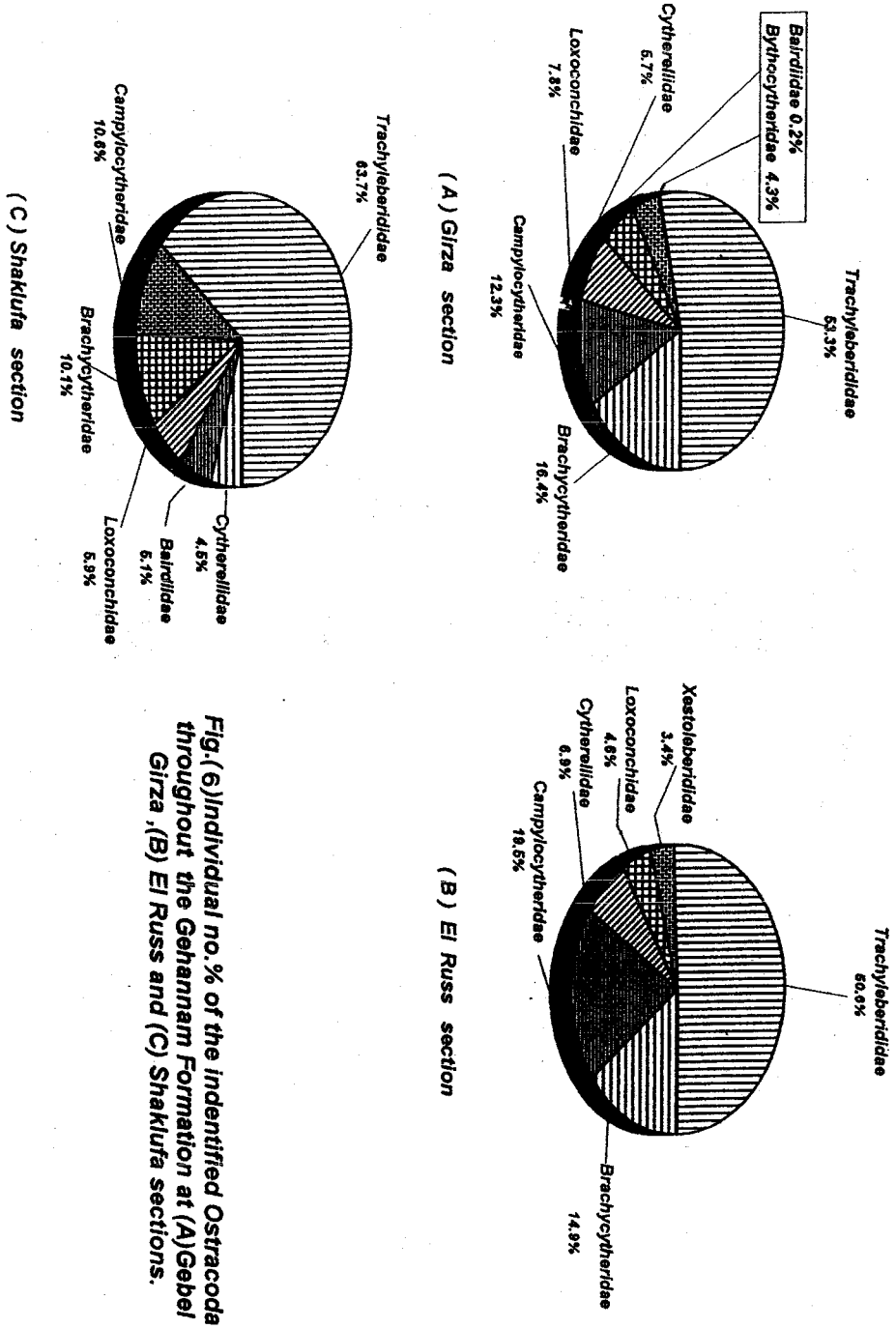


Fig.(6)Individual no.% of the indentified Ostracoda throughout the Gehannam Formation at (A)Gebel Girza ,(B) El Russ and (C) Shaklufa sections.

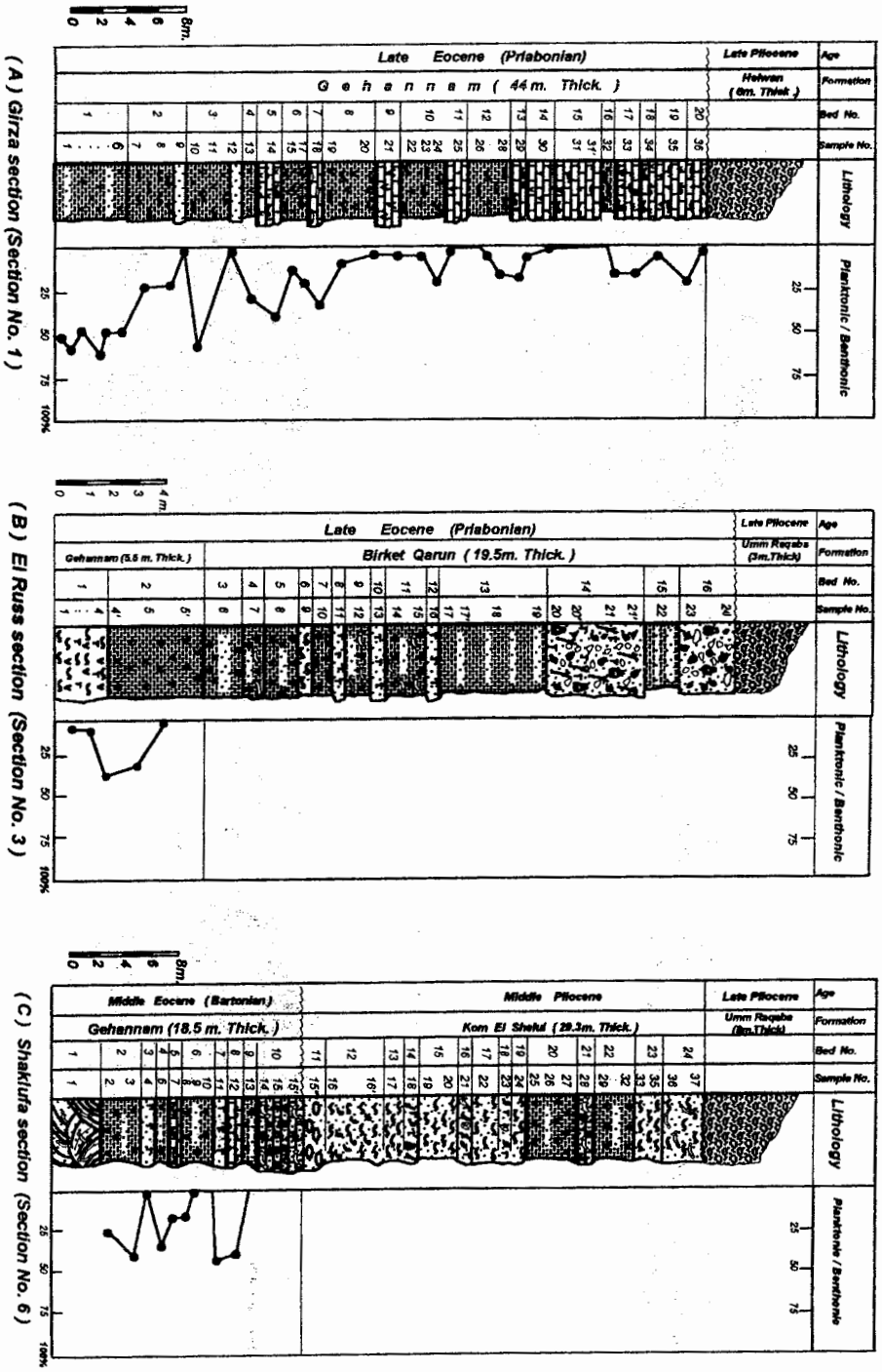
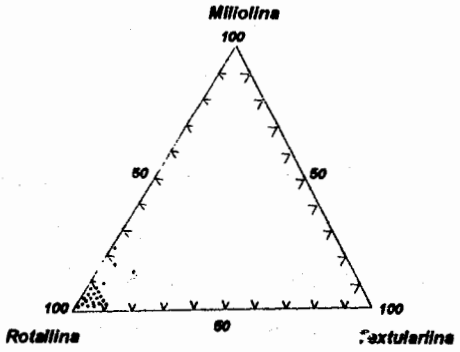
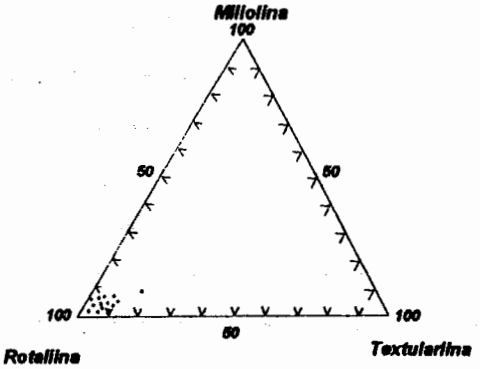


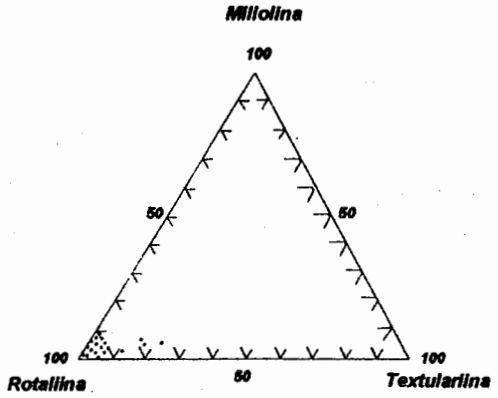
Fig.(7) Planktonic / Benthonic (P / B) ratio of the Gehannam Formation at (A) Girza , (B) Gebel El Russ and (C) Gebel Shaklufa sections



(A) El Azizia section



(B) Munqar El Lahun section



(C) El Naalun section

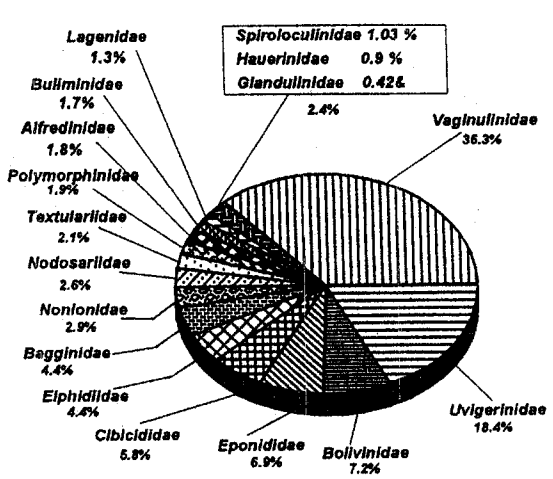
Fig.(8)Triangular plot diagrams for the foraminiferal content of the Gehannam Formation at (A) Gebel El Azizia ,(B) Gebel Munqar El Lahun and (C) Gebel El Naalun sections

presence of *Quinqueloculina seminula* denotes shallow inner shelf environment where this species was recorded at depth (0.5 – 27m) (Aref & Madkour, 2000). The occurrence of the families Rotaliidae and Nummulitidae together with Elphidiidae, Cibicididae and Miliolidae suggest shallow marine conditions (El Deeb, 1982). According to Gevirtz *et al.*, (1971) *Cibicides lobatulus* lives between (45-63m) and *Elphidium spp.* lives between (0-18m). Also, *Nonion scaphum* was recorded at water depths (30-70m) indicating an inner shelf environment with normal salinity (Hughes, 1977). The occurrence of *Uvigerina spp.* indicates relatively low oxygen depositional environment. It is normal marine genus characteristic for deeper water and also able to live in shallow muddy environment (Smith, 1963; Ingle *et al.*, 1980 and Lutze, 1980). The following assemblage *Textularia agglutinans*; *T. communis*; *Quinqueloculina laevigata*; *Q. seminulum*; *Spiroloculina elegantisma*; *Pararotalia calcar*; *Elphidium advenum* and *E. crispum* were recorded from the shallow water (subtidal zone) along the Red sea shore by (Ouda & Obaidalla, 1998). According to Murray *et al.*, (1981) *Quinqueloculina impressa*; *Q. juleana*; *Q. ludwigi*; *Q. seminulum*; *Triloculina trigonula*; *Discorbis propinqua*; *Elphidium laeve*; *E. sp.*; *Pararotalia curryi*; *P. inermis*; *P. spinigera* and *Angulogerina muralis* assemblages are of slightly brackish to normal marine, inner shelf environment. The occurrence of *Pararotalia spinigera* and *Elphidium excavatum* indicate shallow neritic depths (Selima, 1989). The presence of *Nummulites spp.* and *Operculina spp.* suggest inner to middle neritic environment (Blondeau, 1972 and Aigner, 1981). The occurrence of *Pararotalia audouini* and *Nummulites spp.* indicate inner to middle neritic environment (Barr & Berggren, 1980). The assemblage that marked by the following genera *Quinqueloculina*, *Trochammina*, *Siphonina*, *Nonionella*,

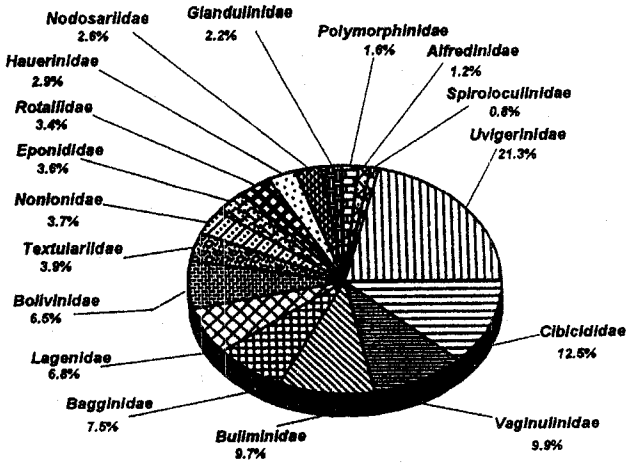
Textularia, *Lenticulina* and *Eponides* are of inner to middle shelf environments (Boersma, 1978). From this discussion, all these information attest that the Gehannam Formation at Gebel El Azizia, Gebel Munqar El Lahun and Gebel El Naalun sections was deposited in middle neritic environment.

The recorded ostracodes from the Gehannam Formation at Gebel El Azizia section are represented by the families Trachyleberididae (62.02%); Campylocytheridae (13.66%); Brachycytheridae (8.40%); Loxoconchidae (7.72%); Bythocytheridae (4.78%) and Cytherellidae (3.42%). The described ostracodes at Gebel Munqar El Lahun section are represented by the families Trachyleberididae (50.56%); Campylocytheridae (9.59%); Cytherellidae (8.88%); Loxoconchidae (8.17%); Cyprididae (7.67%); Bairdiidae (7.27%); Xestoleberididae (3.94%); Hemicytheridae (2.12%) and Brachycytheridae (1.82%). At Gebel El Naalun section, the identified ostracodes from the Gehannam Formation are represented by the families Trachyleberididae (58.17%); Campylocytheridae (8.21%); Brachycytheridae (6.84%); Cytherellidae (6.46%); Bairdiidae (6.08%); Loxoconchidae (5.70%); Xestoleberididae (5.10%) and Cyprididae (3.42%) (Fig. 10A-C).

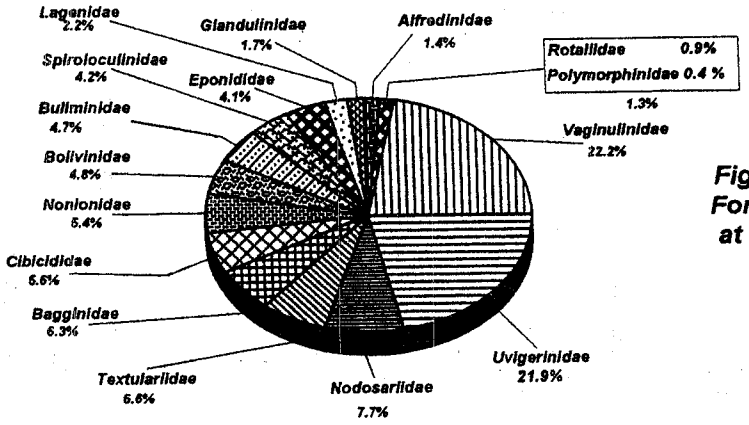
The presence of highly ornamented trachyleberid genera indicate shallow littoral to outer neritic environment (Bassiouni *et al.*, 1984). The occurrence of *Loxoconcha vetustopunctatella, Leguminocythereis sadeki, Costa crassireticulata, Limburgina moosi, Trachyleberis nodosus reticulatus, Bairdia gliberti, Reticulina heluanensis, Ruggieria (Keijella) glabella, Costa humboldti, Brachycythere (Digmocythere) ismaili* and *Asymmetricythere yousfei* indicate open platform environment (Bassiouni *et al.*, 1994). According to El Waer (1992) the occurrence of *Asymmetricythere, Hermanites, Heptaloculites, Isobuntonia,*



(A) El Azizia section



(B) Munqar El Lahun section



(C) El Naalun section

Fig.(9)Individual no.% of the indentified Benthonic Foraminifera throughout the Gehannam Formation at (A) Gebel El Azizia,(B)Munqar El Lahun and (C) El Naalun sections.

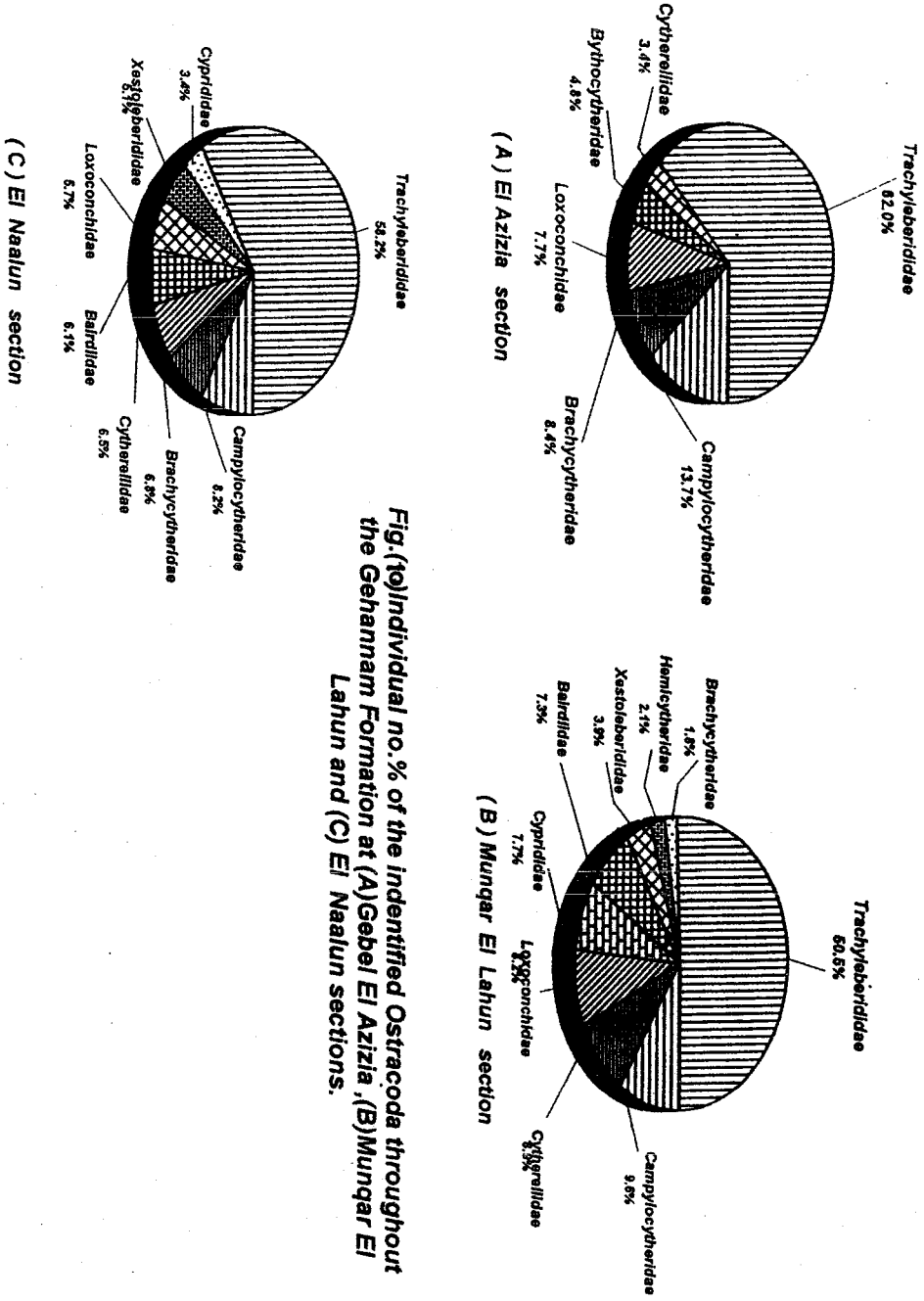


Fig.(10)Individual no.% of the indentified Ostracoda throughout the Gehannam Formation at (A)Gebel El Azizia ,(B)Munqar El Lahun and (C) El Naalun sections.

Leguminocythereis, Schizocythere, Pokornyella, Urocythereis, Cytheropteron (thick shelled), *Flexus, Loxoconcha* and *Cytherella* (punctate forms) indicate inner neritic environment. The presence of the families Trachyleberididae, Bythocytheridae, Cytherellidae, Bairdiidae, Loxoconchidae, Hemicytheridae, Cyprididae and Xestoleberididae indicate inner to outer neritic environment (Whatley, 1988). Hence the recorded ostracode association beside the consideration of the foraminiferal community were considered as indicative of deposition in inner to middle neritic environment.

2- Birket Qarun Formation:

The Birket Qarun Formation consists mainly of sandstones, sandy claystones and fossiliferous sandy limestone beds.

At Gebel El Russ and Gebel Munqar El Lahun sections, the Birket Qarun Formation is completely barren of planktonic foraminifera. The recovered fauna are represented by benthonic foraminifera and ostracodes. The benthonic foraminifera and ostracodes are concentrated in the lower two thirds of the studied formation. While, the upper third is marked by the presence of recurring banks of larger foraminifera (*Nummulites* and *Operculines*) and macrofossils such as (*Carolia placunoides, Ostrea* (*Turkostrea*) *multicostata* and *Turritella spp.*).

The planktonic / benthonic ratio at Gebel El Russ and Gebel Munqar El Lahun sections is represented by zero value (P/B = 0%) indicating shallow inner to shallow middle shelf environments (EL Ashwah & El Deeb, 2000) (Figs. 3B & 7B). On the triangular plot diagram most of the studied samples of the Birket Qarun Formation at Gebel El Russ and Munqar El Lahun sections are aggregated at the corner of Rotaliina. At Gebel El Russ section the Rotaliina ranges from (74.5% - 100%); Textulariina (0% - 19%)

and Miliolina (0% - 14.3%). At Gebel Munqar El Lahun section the Rotaliina ranges from (86.6% - 100%); Textulariina (0% - 6.7%) and Miliolina (0% - 6.7%) indicating shelf sea of normal salinity (Samir, 1986) (Fig. 11A-B). The frequency percent of the recorded benthonic foraminiferal species at Gebel El Russ section are represented by Cibicididae (29.42%); Buliminidae (16.36%); Uvigerinidae (13.46%); Nonionidae (9.76%); Hauerinidae (6.38%); Textulariidae (5.86%); Bagginidae (5.54%); Vaginulinidae (5.28%); Eponididae (4.22%); Bolivinidae (2.46%) and Fursenkoinidae (1.19%). At Gebel Munqar El Lahun section, the frequency percent are Cibicididae (29.58%); Uvigerinidae (22.19%); Vaginulinidae (13.56%); Eponididae (10.17%); Nonionidae (9.41%); Bagginidae (6.32%); Bolivinidae (2.47%); Buliminidae (2%); Rotaliidae (1.69%); Textulariidae (1.39%) and Hauerinidae (1.23%) (Fig. 12A-B).

The arenaceous / calcareous ratio of the Birket Qarun Formation at Gebel El Russ is represented by the value (10.74%) and at Gebel Munqar El Lahun by the value (4.06%) indicating middle shelf environment (Hewaidy, 1994).

According to Boersma (1978) the following genera *Quinqueloculina*, *Trochammina*, *Siphonina*, *Nonionella*, *Textularia*, *Lenticulina* and *Eponides* are of inner to middle shelf environment. The occurrence of *Cancris subconicus*, *Cibicides lobatulus*, *Guttulina problema*, *Epistominella spp.*, *Globulina spp.* and *Nonion spp.* indicate inner to middle shelf environments (Murray *et al.*, 1981). The presence of *Cibicides lobatulus* and *Elphidium clavatum* indicate inner shelf environment with water depth up to (45m). (Ellison & Nichols, 1976). According to Gevirtz *et al.*, (1971) *Cibicides lobatulus* lives between (45-63m) and *Elphidium spp.* lives between (0-18m). Also, *Nonion scaphum* was recorded at water depth (30-70m)

indicating an inner shelf environment with normal salinity (Hughes, 1977). The presence of *Quinqueloculina impressa*; *Q. juleana*; *Q. ludwigi*; *Q. seminulum*; *Triloculina trigonula*; *Discorbis propinqua*; *Elphidium laeve*; *E. sp.*; *Pararotalia curryi*; *P. inermis*; *P. spinigera* and *Angulogerina muralis* associations are of inner shelf environment (Murray *et al.*, 1981). The occurrence of the following genera *Ammobaculites; Clavulina; Quinqueloculina; Pyrgo; Triloculina; Globulina; Guttulina; Cancris; Praeglobobulimina; Nonionella; Cibicidina; Anomalinoides; Eponides; Textularia; Nonion;*

Spiroloculina; Discorbis; Pararotalia; Elphidium; Angulogerina, Miliola; Spiroplectinella; Nummulites; Spiroplectammina and *Reussella* indicate inner to middle shelf environment (El Dawy, 1997). The following assemblages *Textularia agglutinans*; *T. communis*; *Quinqueloculina laevigata*; *Q. seminulum*; *Spiroloculina elegantisma*; *Pararotalia calcar*; *Elphidium advenum* and *E. crispum* were recorded from the shallow water (subtidal zone) along the Red sea shore (Ouda & Obaidalla, 1998). The presence of *Nummulites spp.* and *Operculines spp.* suggest inner to middle neritic environment (Blondeau, 1972 and Aigner, 1981). The occurrence of *Pararotalia audouini* and *Nummulites spp.* indicate inner to middle neritic environment (Barr & Berggren, 1980). The above discussion indicated that the foraminiferal associations of the Birket Qarun Formation at Gebel El Russ and Gebel Munqar El Lahun sections are of inner to middle neritic environment.

The recorded ostracodes from the Birket Qarun Formation at Gebel El Russ section are represented by Trachyleberididae (54.05%); Cytherididae (23.68%); Cyprididae (5.06%); Bairdiidae (5.06%); Brachycytheridae (4.45%); Campylocytheridae (4.05%) and Loxoconchidae

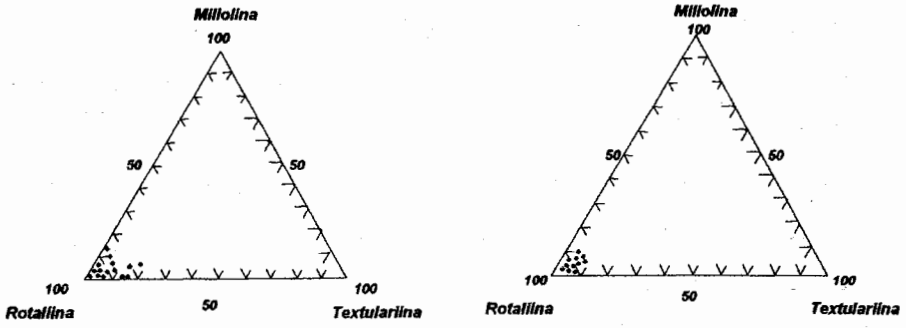


Fig.(11) Triangular plot diagrams for the Birket Qarun Formation at (A) Gebel El Russ and (B) Gebel Munqar El Lahun sections

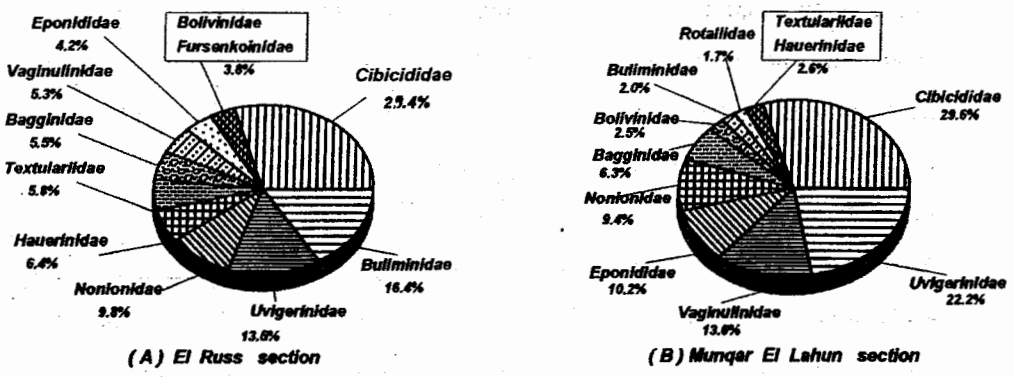


Fig.(12) Individual no.% of the recorded Benthonic Foraminifera from the Birket Qarun Formation at (A) Gebel El Russ and (B) Gebel Munqar El Lahun sections

(3.64%). At Gebel Munqar El Lahun section the described ostracodes are represented by Trachyleberididae (67.62%); Bairdiidae (11.45%); Cypridídae (7.93%); Cytherellidae (6.83%); Campylocytheridae (2.06%); Xestoleberididae (1.90%); Brachycytheridae (1.10%) and Bythocypridídae (1.10%) (Fig. 13A-B).

According to Bassiouni *et al.*, (1984) the presence of highly ornamented trachyleberid genera indicate shallow littoral to outer neritic environment. Also, the occurrence of *Limburgina moosi*, *Trachyleberis nodosus reticulatus, Reticulina heluanensis, Ruggieria (Keijella) glabella, Costa humboldti,? Bythocypris mereirensis, Brachycythere (Digmocythere) ismaili, Asymmetricythere yousefi, Cytherella sp.* and *Bairdia sp.* indicate deposition under normal marine and well oxygenated environment (winnowed platform edge sands) as adopted by (Bassiouni *et al.*, 1994). According to Whatley (1988) the presence of the families Trachyleberididae, Bythocytheridae, Cytherellidae, Bairdiidae, Cypridídae, Loxoconchidae and Xestoleberididae denote inner to outer neritic environment. The presence of *Asymmetricythere, Hermanites, Heptaloculites, Isobuntonia, Flexus, Leguminocythereis, Schizocythere, Pokornyella, Loxoconcha, Urocythereis, Cytheropteron* (thick shelled) and *Cytherella* (punctate forms) attest inner neritic environment (El waer, 1992). These data indicate that the ostracodes of the Birket Qarun Formation at El Russ and Munqar El Lahun sections is of inner to shallow middle neritic environment.

The upper third of the Birket Qarun Formation at Gebel El Russ and Gebel Munqar El Lahun sections is marked by the high concentration of *Nummulites spp.* and *Operculines* indicating inner to middle neritic environment (Blondeau, 1972 and Aigner, 1981), the presence of macrofossils such as *Carolia placunoides, Ostrea multicostata* and *Turritella*

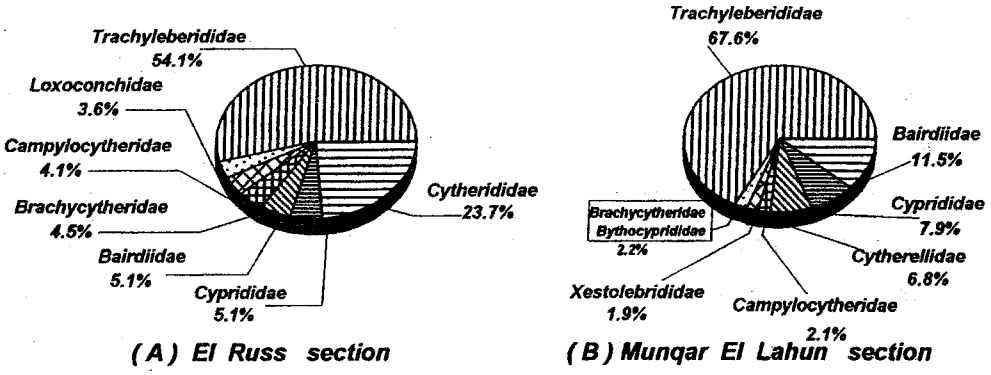


Fig.(13)Individual no.% of the identified Ostracoda from the Birket Qarun Formation at (A)Gebel El Russ and (B) Gebel Munqar El Lahun sections

spp. indicate shallow water depth (Dubarr, 1958). Also, the living members of the genus *Turritella* are gregarious and most common in tropical, inner neritic environment on a variety of substrates (Petuch, 1976; Saul, 1983 and Allmon, 1988). Nesbitt (1995) stated that "constituents of the *Turritella – Solena* assemblage reflect a sandy, inner neritic environment shallower than 50m". According to Rhoads (1975) the presence of straight subvertical and vertical burrows indicate very shallow if not intertidal environment. The preceding data indicate that the upper third of the Birket Qarun Formation at Gebel El Russ and Gebel Munqar El Lahun sections was deposited at inner neritic environment.

At Gebel El Azizia and Gebel El Naalun sections, the Birket Qarun Formation is completely barren of planktonic foraminifera, small benthonic foraminifera and ostracodes.

This formation is distinguished by the presence of recurring banks of larger foraminifera (*Nummulites spp.* and *Operculines*) suggesting inner to middle neritic environments (Blondeau, 1972 and Aigner, 1981). The occurrence of macrofossils such as *Carolia placunoides, Ostrea multicostata, Turritella spp.* and *Echinolampus spp.* indicate shallow water depth (Dubarr, 1958). Also, the Recent oyster banks occur at 1-3m depth in embayments with seasonally variable salinities (Nesbitt, 1995). The living members of the genus *Turritella* are most common in tropical, inner neritic environment on a variety of substrates (Petuch, 1976; Saul, 1983 and Allmon, 1988). The occurrence of straight subvertical and vertical burrows at Gebel El Azizia section indicate very shallow if not intertidal environment (Rhoads, 1975). The above stated information indicate that the Birket Qarun Formation at Gebel El Azizia and Gebel El Naalun sections was deposited at inner neritic environments.

In conclusion, all the above mentioned environmental parameters indicate that the Birket Qarun Formation at Gebel El Russ and Gebel Munqar El Lahun sections were deposited in inner to middle neritic environments based on the recorded benthonic foraminifera and ostracodes. At Gebel El Azizia and Gebel El Naalun sections the Birket Qarun Formation were deposited in inner neritic environment based on the recorded molluscan fauna.

Summary and Conclusion

The Eocene rocks in east Fayoum depression is represented by two formations, the Gehannam Formation (Middle – Late Eocene) and the Birket Qarun Formation (Late Eocene). The foraminiferal and Ostracoda content of 210 rock samples collected from six stratigraphic sections are evaluated quantitatively and qualitatively.

Paleoecologically, the Gehannam Formation at Gebel Girza, Gebel El Russ and Gebel Shaklufa sections was deposited in outer neritic environment with shallowing upward tendency. At Gebel El Azizia, Gebel Munqar El Lahun and Gebel El Naalun sections the Gehannam Formation was deposited in inner to middle neritic environments. The Birket Qarun Formation at El Russ and Munqar El Lahun sections was deposited in inner to middle neritic environments. At Gebel El Azizia and Gebel El Naalun sections the Birket Qarun Formation was deposited in inner neritic environment.

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