EOCENE STRATIGRAPHY, FACIES, SEQUENSES AND DEPOSITIONAL HISTORY IN SHABRAWEET AREA, NORTH OF SUEZ, EASTERN DESERT, EGYPT.

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ABSTRACT

The Eocene rocks in Shabraweet area comprise the Lower, Middle and Upper Eocene stages. Each stage consists of only one rock unit; the Minia Formation, the Mokattam Formation and the Maadi Formation, respectively. The Minia Formation shows angular unconformity relationship with the underlying Cretaceous rocks and disconformity relationship with the overlying Mokattam Formation. The Maadi Formation is also unconformably overlying the Mokattam Formation and is separated from the underlying Oligocene sediments by a conglomeratic bed.

Eighteen microfacies associations are recorded in the rocks units. Five constitute a clastic facies (polymictic conglomerates, calcareous quartzarenites, lithic quartzarenites, ferruginous quartzarenites and claystone), ten constitute a limestone facies(lime mudstone, sandy lime mudstone, alveolinid wackestone, ostracoda foraminifera wackestone, sandy Somalina wackestone, foraminiferal wackestone, sandy miliolidae packstone, dolomitic oyster packstone, miliolidae grainstone and algal miliolidae grainstone) and three constitute a dolostone facies(sandy dolostone, dolostone and sandy dedolostone).

Two types of cycles are recorded in the study area; the first one is shallowing upward with several varieties (in pure clastic facies, in mixed clastic- carbonate and in pure carbonate facies). The other cycles are deepening upward in pure clastic facies, recorded only at the base of the Maadi Formation. Three depositional sequences are recognized in the study area. They are sequence1, sequence 2 and sequence3 represented the Lower Eocene, the Middle Eocene and the Upper Eocene, respectively. These sequences are separated by sequence boundaries represented by unconformity surfaces

The Minia Formation was deposited in a shallow marine environment. The Mokattam Formation was deposited in shallow tropical and subtropical zones, with normal salinity water and fair high rate of sedimentation. The Upper Eocene was deposited in shallow agitated water with high influx of clastics.

1- INTRODUCTION AND PREVIOUS WORK

The Shabraweet region covers an area of about 300Km^2. It is limited from the east by the Ismalia- Suez road and from the west by the tributaries of Wadi Abo Talh and by Gebel Um-Kathieb. It is bounded from the north and south by the plain of the Great Bitter Lake. It lies between Latitudes 30°15′ and 30° 21′N. and Longitudes 32° 13′ and 32° 20′E (Fig.1). The exposed rocks in the study area range from Lower Cretaceous to Recent.

The regional stratigraphy of the Eocene of Sabraweet area has been studied by different authors (e.g. Barron, 1907; Blanckenhorn, 1921; Barthoux, 1922; Foly, 1941; Fawzi, 1959a; Faris and Abbass, 1961; Said, 1962; Barakat and Abu Khadra, 1971; Barakat and Aboul Ela, 1972; Al-Ahwani, 1982; Helal, 1990 and Mostafa & Hassan, 2004).

The present study focuses on the Eocene rock stratigraphy, facies development, sequences and depositional history. Two stratigraphic sections of the Eocene sequence were measured, sampled and described reflecting coeval environments along east-north direction. More than one hundred thin sections were prepared and examined for their composition texture and microfossil assemblages. The petrographic description of the sandstones follows Pettijohn et *al.* (1973). The terminology of limestones and dolostones is based on the classification of Dunham (1962). Calcite was distinguished from dolomites by staining technique of Friedman, (1965).

2- STRATIGRAPHY

The Eocene rocks show the widest distribution in the north Eastern Desert of Egypt. These rocks are cropping out at the Southern and Northern Galala plateaux, Gebel Ataqa and Gebel Shabraweet which represents the extreme northern Eocene outcrops in the Eastern Desert. The Eocene succession in the study area is subdivided into two Lower Eocene, Middle Eocene and Upper Eocene rocks.

2.1. Lower Eocene rocks

The Lower Eocene rocks in the Shabraweet area is represented by the Minia Formation.

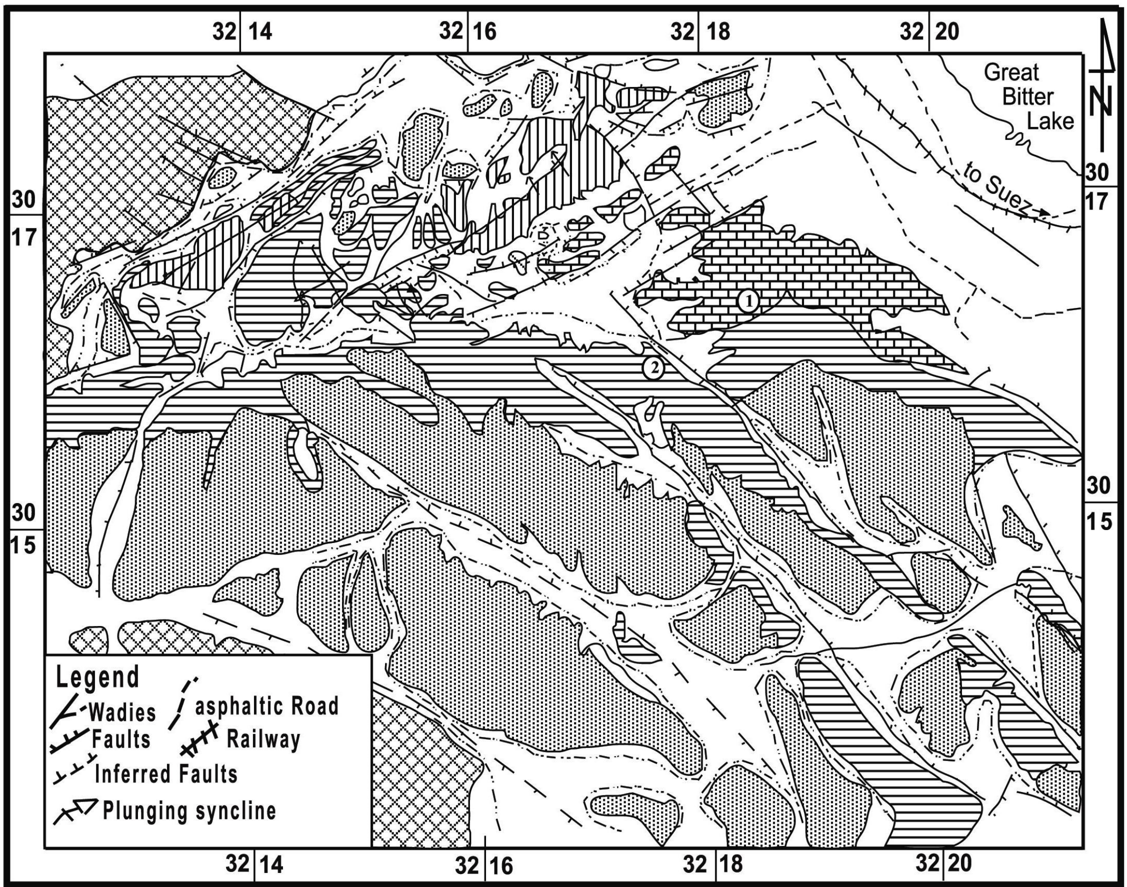


Fig.(1)Geological map of Sabraweet area (after AL-Ahwani,1982, with modifications).

Lower& Middle Eocene · Oligocene · (1) El Goza El Hamra section · 0 — 1 Km.
Cretaceous · Upper Eocene · Miocene · (2) Darbet El Houity section

2.1.1. Minia Formation (Late Ypresian):

In the study area, the Minia Formation shows angular and disconformable relationship with the underlying Turonian- Santonian strata and the overlying Mokattam Formation, respectively. The lower contact with the Turonian-Santonian strata is an angular unconformity surface. The discontinuity of sedimentation from the Cretaceous to the Eocene was controlled by ENE-WSW structural high that belong to the Syrian Arc system (Shukri, 1954). The unconformity surface zone is represented by a thick bed of conglomerate and conglomeratic clay and sandstone. The conglomerate consists of dolomitic limestone and flint pebbles with different shapes and sizes in a sandy matrix of brownish colour. The upper contact with the Mokattam Formation is evidenced by a conglomeratic bed representing a disconformity surface.

The Minia Formation was recorded and studied in detail in the Nile Valley by Bishay (1961 & 1966),(Amer *et al.*, 1970, Kenawy and El-Baradei (1977), Keheila (1978&1983), Khalifa, (1981), Youssef *et al.* (1982) , Boukhary and Abdel Malik, (1983), Philobbos and Keheila (1991), Soliman *et al.* (1998), Hassaan *et al.* (1990) Helal (1996) , Sheleby *et al.* (2000) and Abu El- Ghar *et al.* (2005).

In the study area, the Minia Formation decreases in thickness from 100m in the El-Goza El-Hamra section in the east to 6m in the southwest El-Goza El-Hamra section. In the southwest of El-Goza El-Hamra section, the Minia Formation resembles the upper part of this formation in the El-Goza El-Hamra section. The lower part of the Minia Formation is made up of yellowish brown to pink, hard, compact limestone with some recrystallized calcite crystals filling thin fissures. The limestone is highly fossiliferous with *Alveolina frumentiformis.* The middle part of the formation consists of ferruginated, highly gypsiferous and saliferous claystone and marl intercalations with thin whitish yellow limestones. The limestone is compact and hard, sandy or marly, with thin calcite veins, showing burrowing. The limestone is thinner than the claystone and marl. It is fossiliferous with benthonic foraminifera; ostracoda and do not contain *Alveolina frumentiformis.* The upper part of the Minia Formation consists of varicoloured compact saliferous claystone, reddish brown, grey, greenish grey with some black spots, intercalated with grey sandy claystone and siltstone. There are several bands of cobble, boulder,

pebble and coarse sand in fine grained matrix of clayey sandstones. It is fossiliferous with plant fossils (*Charophyta*). Southwest El Goza El Hamra, the upper part of the Minia Formation consists of clastic facies (siltstone, sandy clay and topped by conglomerate). The siltstone is yellow with some violet patches attaining a thickness of about 2.5m. The claystone is brown to grey in colour, sandy, saliferous and unfossiliferous measuring about 2.5m in thickness. The conglomerate is composed of boulders, cobbles and pebbles embedded in a brownish sandy matrix with thickness reaching 1.0m.

The age of the Minia Formation was originally assigned to the Middle Eocene by different authors (Said, (1960, 1962 & 1971); Bishay, (1966); Amer *et al.* (1970); Keheila, (1978); Youssef *et al.* (1982); Aref, (1982); Mansour and Philobbos, (1983); Abdel Shafy *et al.* (1984); Kenawy *et al.* (1988) and Hassaan *et al.*(1990). More recently however, Boukhary *et al.* (1982) analyzed the nummulites of the Minia Formation and concluded that this formation must be dated back to the Late Ypresian (Cuisian). Since that time, several geologists have supported this view e.g. Boukhary and Abdel Malik, (1983); Strougo, (1986); Strougo *et al. (*1990); Helal, (1996 & 1999) and Sheleby *et al.* (2000). In the present work and in accordance with the aforementioned studies the Minia Formation is considered here at the Late Ypresian age.

2.1.2. Mokattam Formation (Late Lutetian):

The Mokattam unit was given by Zittel (1883); Said, (1962) and Barakat *et al.* (1970). In the investigated area, the Mokattam Formation overlies unconformably the Minia Formation. The unconformity surface is formed of highly reworked pebbles of limestone, brown flint and sandstone embedded in a highly ferruginated sandy clay matrix that is poorly cemented and partially friable. It attains in study area a thickness of about 2.0m (Fig. 2). Mokattam Formation is separated from the overlying Maadi Formation by an unconformity surface.

The thickness of the Mokattam Formation decreases from the east at El Goza El Hamra section (67m) to the southwest El Goza El Hamra section (7.0m). Mokattam Formation is differentiated into three distinct facies. The lower part is made up of clastic facies represented by claystone, marl and sandstone. The claystone is sandy, brown to reddish violet, greenish grey in colour, soapy touch with some gypsum veins, saline, compact and barren from fossils. The marl is yellow, full with larger foraminifera (*Somalina stefaninni*) and compact. The sandstone is yellow to yellowish brown, coarse grained, massive and hard. The middle part is composed of massive and hard, sandy and marly limestone which is yellow, brown, grey, brownish-yellow in colour and porous, fossiliferous with gastropods, pelecypods, foraminifera (*Miliolidae* sp. and *Somalina* sp.) and ostracods. The upper part consists of limestone and dolostone. The limestone is compact and hard, dolomitic, sandy, dirty brownish yellow, fossiliferous with gastropods, pelecypods, ostracods and benthonic foraminifera. The dolostone is brownish grey, porous, ledge-forming, massive and very hard. Both middle and upper parts of the formation are recorded only in El Goza El Hamra section.

The age of the Mokattam Formation was originally assigned to the Middle Eocene (Late Lutetian) by different authors (Said, 1962; Barakat *et al*. 1970 and Bassiouni *et al.* 1987). In the present work, the Mokattam Formation is dated to Late Lutetian, which come in accordance with the latest studies.

2.2. Upper Eocene rocks

The Upper Eocene rocks are represented by only one stratigraphic rock unit, the Maadi Formation, which described as follows:-

2.2.1. Maadi Formation (Upper Eocene):-

The term "Maadi Formation" was introduced by Said (1960) to describe the sandy claystone, claystone and ferruginated, gypsiferous, sandy limestones with brown dolomite (90 m. thickness) exposed east of Maadi, southeast of Cairo (type locality). It is correlated with the Mokattam Stage (Zittel, 1883), *Carolia* Stage (Blanckenhorn, 1900) and Upper Mokattam (Hume, 1911; Fourtau, 1912 and Cuvillier, 1924). At the type section, the Maadi Formation overlies the Mokattam Formation and underlies the Oligocene sediments (Said, 1962).

In the area under study, the Maadi Formation exhibits an unconformable relationship with the underlying Middle Eocene Mokattam Formation. The unconformity surface is represented by a thick conglomeratic bed (5.0m) that consists of limestone fragments, brown flint pebbles, and pebbly sand and sandy clay. The Maadi Formation underlies unconformably the Oligocene fluviatile sediments with an angular unconformity. The Maadi Formation decreases in thickness from the west at Darbet El Houity section (105m) to the east at El Goza El Hamra section (25m).

The lower part of the Maadi Formation consists of brownish yellow conglomerate with pebbles and coarse sand grains, boulders, cobbles and granules. It is overlain by siltstone with some pebbles and claystone. The claystone is sandy, grey to greyish green, compact and topped by reddish brown, saliferous, with thick gypsum veins. This part is nearly barren of fossils, except the presence of some plant fossils such as charophyta gyrogonites.

The middle part of the formation is composed of intercalations of marls and limestones. The marl is sandy, brownish yellow, greenish yellow, deeply weathered, unfossiliferous and compact. It represents a base of the shallowing upward cycle. The limestone is massive and very hard, sandy, marly, whitish yellow, brownish yellow, greyish brown, ledge forming, fossiliferous with gastropods, pelecypods, echinoderms, benthonic foraminifera, algae, bryozoa and ostracods. The limestone represents the top of the shallowing upward cycle.

The upper part of the Maadi Formation consists of limestone intercalated with sandstone, claystone and dolostone. The limestone is massive and hard, sandy, ledge forming, greyish yellow, brownish yellow, grey, pale violet, whitish yellow in colour, porous, with thin calcite threads crowded with oysters. The sandstone is massive and hard, grey, with armored elongated siliceous nodules. The claystone is sandy, brown to reddish brown, saliferous and compact. The dolostone is greyish brown, cavernous, compact and hard. This part is distinct with the presence of several oysters.

The age of the Maadi Formation was originally assigned to the Late Eocene by different authors (Said, 1962; Barakat *et al.* 1970 and Bassiouni *et al.* 1987). In the present work, the Maadi Formation is dated Late Eocene, which comes in accordance with the latest studies.

3. MICROFACIES ASSOCIATIONS

Eighteen microfacies associations distributed as the follow: five clastic lithofacies, ten carbonate microfacies, two dolostone microfacies and only one dedolostone lithofacies.

3.1. Clastic lithofacies:

3.1.1-Polymictic conglomerate:- Cong.

This lithofacies is detected from the lowermost part of the Mokattam and Maadi formations measuring a cumulative thickness of about 2.0m and 5.0m, respectively. The rocks of this lithofacies are yellowish-grey in colour, with pebble to boulder sized lithoclasts and hard. It represents the unconformity contact between the Mokattam and the Maadi formations.

It is composed mainly of quartz, rock fragments and clays as matrix. Quartz grains (25%) have different grades of size (fine, medium to very coarse sand sized). Most grains are monocrystalline (few grains are polycrystalline), straight extinction, angular to subangular, moderately sorted, and high sphericity, few are cracked. They are randomly distributed allover the rock. Rock fragments that are derived from sedimentary rocks are lithoclasts and chert. Lithoclasts are made up of limestone and dolostone. Chert grains that have coarse sand sized and chalcedonic quartz are often pore-fill. Most grains are oval in shape, well-rounded and high sphericity. Chalcedonic quartz is also present as overgrowth silica cement around the quartz grains. The binding material inbetween all components is a clay matrix.

3.1.2- Calcareous quartzarenites (Pl.1-E):- Ca. QA

Calcareous quartzarenites are recognized from the lower and uppermost parts of the Maadi Formation at south Darbet El-Houity section and the lower part of the Mokattam Formation at Gebel El Goza El-Hamra section. It measures a thickness of about 2.0m, 3.0m and 5.0m, respectively. It overlies lithic quartzarenites, dolostone and claystone and usually underlies claystone. The rock belongs to this lithofacies is reddish brown, saliferous, with cross bedded structure and hard.

In thin section, the rock is made up of quartz grains embedded in calcareous cement. The quartz grains reach more than 90% of the rock attaining the very coarse sand size (1.0-2.0mm). They are angular to subangular and poorly sorted. Quartz grains are monocrystalline, showing straight extinction, occasionally with inclusions. Quartz grains have suffered from partial replacement by calcite along its borders. The binding material that occurs in between quartz grains is lime mud matrix and isopachous calcite cement which have undergone recrystallization around and perpendicular to the grains.

3.1.3- Lithic quartzarenites (Pl.1-F):- Lith. Qa.

Rocks of this microfacies type are distinguished from the basal part of the Maadi Formation. It measures a thickness of about 2.0m. It overlies the polymictic conglomerate and underlies the calcareous quartzarenites lithofacies (Fig.2). The rocks belonging to this microfacies are brownish yellow in colour, coarse grained, thin bedded, ferruginous, massive and hard.

The rock is made up of quartz grains (55%), lithoclasts (35%) and binding material (10%). Most of quartz grains are monocrystalline, with straight extinction, subangular to subrounded, with inclusions and cracked.

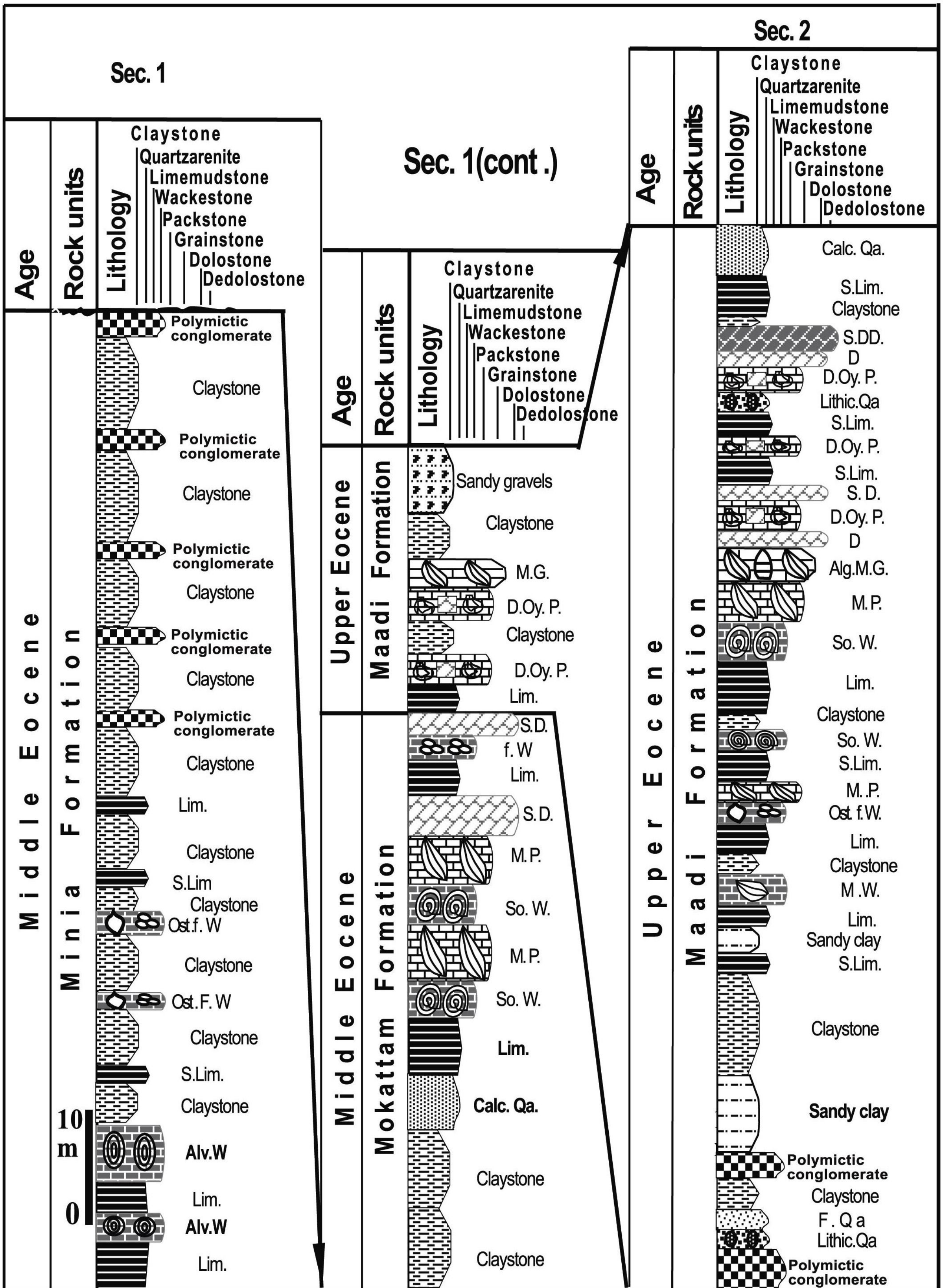
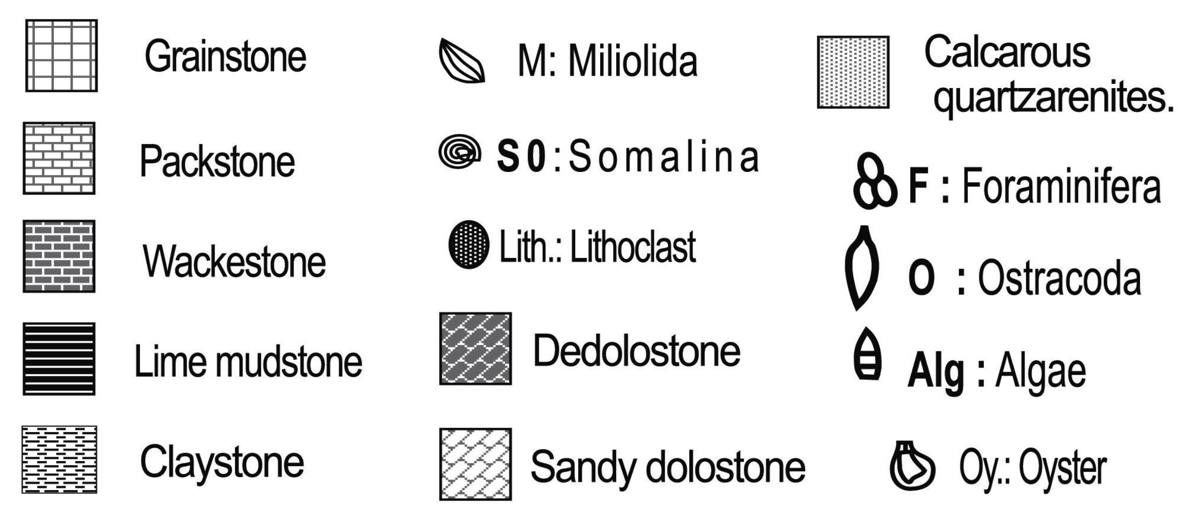


Fig. (2): L ithofacies distribution of Gebel El Goza El- Hamra, SE Gebel Shabraweet (Sec1) and south Darbet El- Houity section,SW Gebel Shabraweet(Sec.2). (For location see fig.1 and for legend see fig.3&4)



Fig(3):Symbols applied in the measured sections.

They are of coarse sand-size (0.5-1.0 mm) and show serrated contact with either each other. Few grains show polycrystalline and wavy extinction. Lithoclasts are composed of fine quartz grains embedded in a ferruginated clay matrix. They are commonly dark brown in colour, rounded and oval in shape. The binding material inbetween quartz grains and lithoclasts is a ferruginous clay matrix.

3.1.4-Ferruginous quartzarenites (PL.2-A):- F.QA.

Ferruginous quartzarenites are recorded from the lowermost part of the Maadi Formation at Darbet El Houity section attaining a thickness of about 2m. The rock enclosing this lithofacies is yellow to brownish yellow, coarse grained with ferruginous concretions.

Microscopically, the rock consists mainly of quartz grains and iron oxides as matrix. Quartz grains are the major component forming about 65% of the rock. It has variable sizes ranging from fine to coarse grained (o.2mm- o.6mm), subangular to subrounded in shape, with low sphericity and moderately sorted. Quartz grains are monocrystalline without inclusions and show straight extinction. The binding material between quartz grains that is a ferruginous material (may be hematite), appears as patches of reddish brown iron oxide.

3.1.5- Claystone:-

The claystone lithofacies is compact, grey to yellow in colour, sandy, with gypsum veinlets, that indicates deposition in fairly shallow marine conditions, receiving clastic sediments from a nearby landmass.

3.2. Carbonates microfacies:

3.2.1- Mudstone microfacies:-

Mudstone microfacies are distributed in the Minia, Mokattam and Maadi formations. They don't only occur at the base of depositional cycles (shallowing upward) but they are also found as a cap for cycle based with claystone. They comprise the following associations:-

3.2.1.1- Lime mudstone (Pl.2-B):- Lim.

Lime mudstone microfacies associations are distinguished from the lower and middle parts of the Minia Formation attaining a thickness of about 1.5m to 2.0m. It is also recorded in the middle part of the Mokattam Formation and the middle part of the Maadi Formation, measuring about 2.0m and 5.0m, respectively. In the field, the rock is limestone, grey, with calcite threads, marly, fine grained and compact.

Plate 1

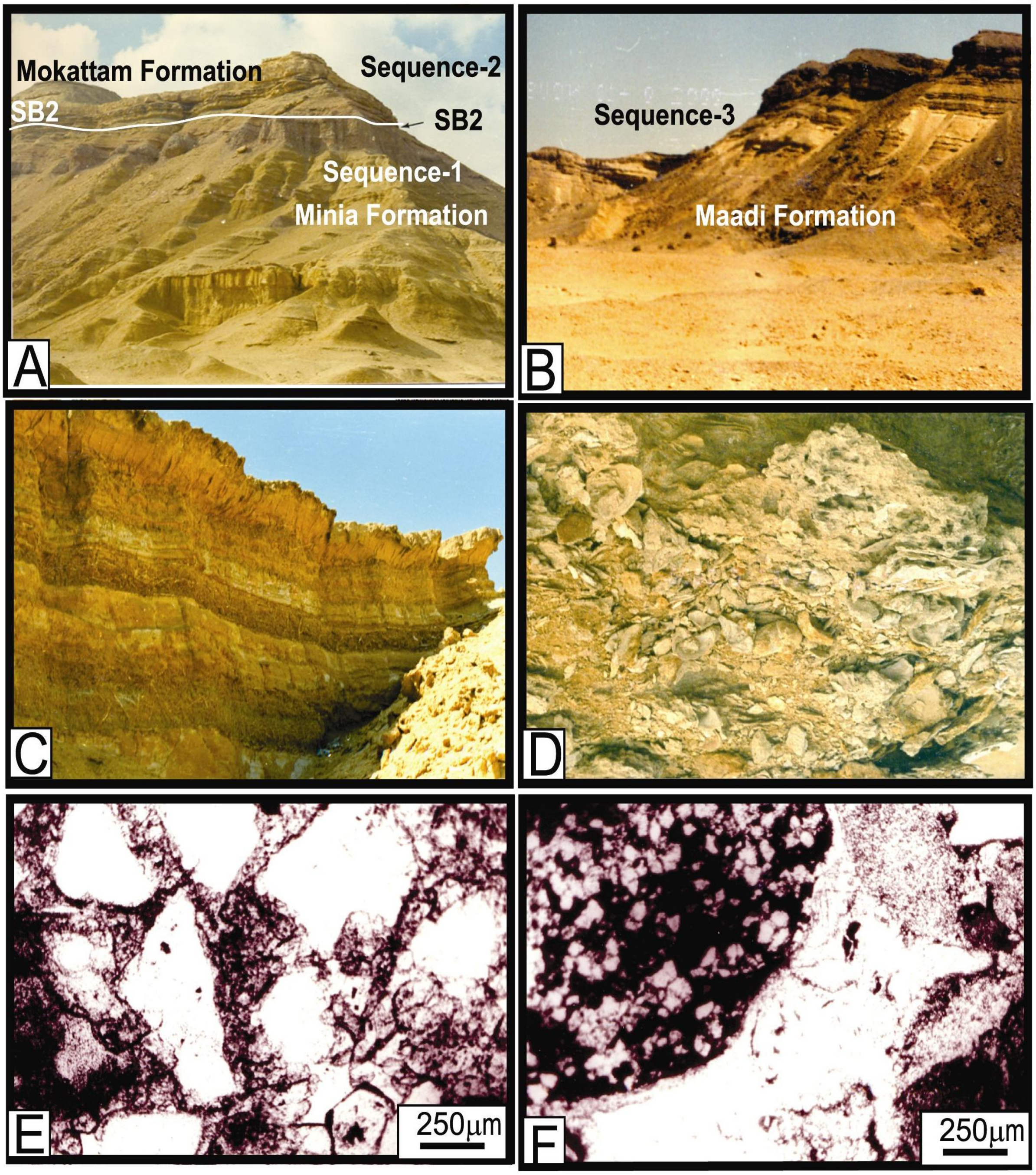


Fig.(A): Field photograph showing the Sequence boundary(SB 2) between the Minia Formation (Sequence 1)and Mokattam Formation(Seuence 2) at Gebel El Goza El Hamra(sec.1). Fig.(B): Field photograph showing the Upper Eocene Maadi Formation (Sequence 3), at south Darbet El Houity (sec.2). Fig.(C)Field photograph showing the shallowing upward cycles through the middle part of sequence 2) at Sec.1.Fig(D) Field photograph showing the Oyster bank in the Maadi Formation.Fig.(E): Calcareous quartzarenites consisting of monocrystalline, subrounded to subangular quartz grains being embedded in calcite and dolomite cement, Ordinary Light. Fig.(F): Litharenites showing subrounded to rounded lithoclast with low sphericity and monocrystalline, Ordinary Light.

The rock consists entirely of micrite and microspars. The micrite matrix has less than 4μm in size. It is partially recrystallized into microspars. Fe- oxide patches occur in the micrite matrix occur as red spots. In some cases, the micrite has been recrystallized into spary calcite, which indicates dissolution in fractures and veinlets due to the aggrading neomorphism process.

3.2.1.2- Sandy lime mudstone (Pl.2-C):- S.Lim.

Sandy lime mudstone microfacies is identified in the middle part of the Minia Formation attaining a thickness of about 2m. It is also found in the lower and the upper parts of Maadi Formation, measuring about 4.0m and 8.0m, respectively. The rocks belonging to this microfacies are yellow, grey, sandy, with gypsum veinlets and calcite threads, marly, fine grained and compact.

The rock consists entirely of micrite, allochems and quartz grains. It is partially recrystallized into microspars or occasionally appears as"dismicrite". Fe- oxide patches occur in the micrite matrix as sporadic red spots. In some cases, the micrite is transversed by some veinlets that are filled with spary calcite which indicate dissolution and precipitation in fractures. Microspars have been created by the aggrading neomorphism process. Quartz grains that form about 15% of the rock have medium to coarse sand size. They are monocrystalline, with straight extinction, subangular to rounded and randomly distributed all over the rock.

3.2.2- Wackestone microfacies:-

The wackestone microfacies associations show a wide distribution in the Minia, Mokattam and Maadi formations. They mostly overlie the lime mudstone microfacies or the claystone in the shallowing upward cycles. They occur in the middle part of this type of cycle but in some cases they form the lowermost part of the cycle. They are mainly overlain by the packstone or grainstone facies. It is also recorded as a cap for the cycle overlying the claystone lithofacies.

3.2.2.1- Alveolinid wackestone (Pl.2-D):- Alv.W.

Alveolinid wackestone is represented only by two beds near the lowermost part of the Minia Formation at Gebel El Goza El Hamra section, attaining a thickness of about 10 m. It overlies the lime mudstone microfacies. It represents a cap of the shallowing upward cycle with a thickness of about 2.5 m and 5m. In the field, the rock is massive and hard limestone, yellowish brown to pink, with calcite veins and fossiliferous with elongate alveolines.

Petrographically, this microfacies consists of about 10-15% skeletal particles scattered throughout a micritic matrix. The foraminiferal shells form about 10% of the rock; they are represented mainly by alveolinids (up to 8%), orbitolites (2.5%) and miliolids (up to 1.5%). Other components are algae (1%), echinoids (up to 2%) and intraclasts (up to 5%). They are very coarse sand sized to pebbly sized (1.5mm-4mm), micritized and have preferred orientation. The aggrading and degrading recrystallization processes are the main diagenetic features that are exhibited in this association.

3.2.2.2- Ostracoda foraminiferal wackestone (Pl.2-E):- Ost.f.W.

This association represents a cap of the shallowing upward cycle. It overlies the claystone lithofacies. It is recorded in the middle part of both Minia and Maadi formations at Gabel El Goza El Hamra and Darbet El Houity sections. They attain a thickness of about 1.5 and 5.0m, respectively. In the field, the rock is massive limestone, whitish yellow, grey, argillaceous, fossiliferous and gypsiferous.

Petrographically, the rock is formed of skeletal particles embedded in a micrite binding material. About 15-20% skeletal particles consist of ostracoda, foraminifera and echinoids. The ostracoda (articulated and disarticulated) form about 10% of the rock. They have medium to coarse sand size ranging from 0.3 to 0.7mm and with oval shape. The foraminiferal shells form about 8% of the rock; they are represented mainly by coiled and uncoiled, fine to medium sand sized (0.2mm- 0.4mm) and well sorted benthonic forms. Echinoids are found with less percentage (up to 2%) in the rock. They are represented by spines, knobs and osciles. The skeletal particles are scattered randomly throughout the rock. The binding material between the ostracoda, benthonic foraminiferal shells and echinoids is micrite. Some micrite have been recrystallized due to aggrading neomorphism.

3.2.2.3- Sandy Somalina wackestone (Pl.2-F):- S.So.W.

Sandy Somalina wackestone microfacies occurs in the middle part of both the Mokattam Formation at Gebel El Goza El Hamra (Sec.1) and the Maadi Formation at South Darbet El Houity (Sec.2) with thicknesses of about 3-4m and 2-5m, respectively. It overlies the lime mudstone facies. The rock is massive and hard

Plate 2

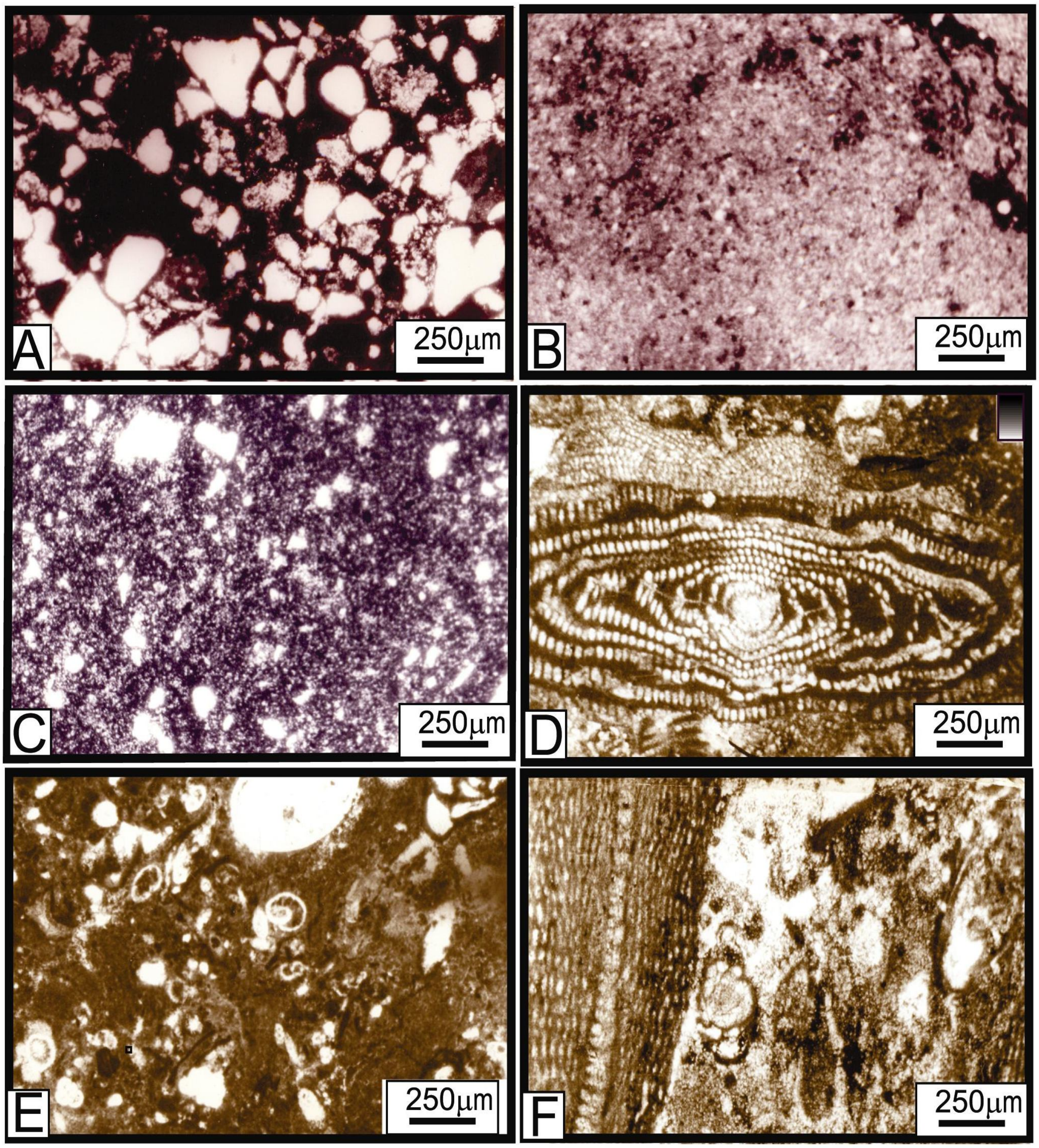


Fig.(A): Ferruginous quartzarenites showing subrounded to subangular quatrz grains ebmedded within ferruginous material, Ordinary Light.. Fig.(B): Lime mudstone showing microcrystalline micrite less than 4Mm and very fine quartz grains, Ordinary Light. Fig.(C) Sandy lime mudstone showing two classes of sizes, with ill sorted and monocrystalline quartz grains, Ordinary Light. Fig(D)Alveolinid wackestone showing *Alveolina frumentiformis* **embeded in amicritic matrix,Ordinary Light. Fig(E)Ostracoda foraminifera wackestone with coiled and uncoiled foraminifera and ostracod forms.Ordinary Light. Fig(E) Somalina wackestone in which** ***Somalina*** **sp. is embedded in a micritic matrix,Ordinary Light.**

limestone; yellow, brownish yellow to brown in colour, marly, sandy, fossiliferous with foraminifera, echinoderms and mollusca.

Under the microscope, this facies consists of about 10-15% skeletal particles, 5% quartz grains and micrite as a binding material. The skeletal particles consist mainly of *Somalina stefaninii* (8%), miliolids (*Hauerina* sp.), *Dictyconus aegyptiensis* and Ostracoda spp. (5-7%) of the rock. Quartz grains are subangular, monocrystalline attaining a medium to fine sand size. Both skeletal particles and quartz grains are embedded in micrite. This microfacies was deposited in quiet water environment in a shelf lagoon with somewhat low energy water, receiving small amount of detrital sand grains.

3.2.2.4- Foraminiferal wackestone (Pl.3-A):- F.W.

Foraminiferal wackestone microfacies occurs only in the upper part of the Mokattam Formation measuring about 2m in thickness. It caps the shallowing upward cycle overlying the lime mudstone and underlying the sandy dolostone. In the field, the rock is compact limestone, brown, marly, fossiliferous with miliolids.

Under the microscope, this facies consists mainly of benthonic foraminifera and coiled mollusca forming about (15%) of the rock. The Miliolida is the main component of benthonic foraminifera having fine sand size. It is *Triloculina* sp., globular in shape. The chambers are filled with sparry calcite due to recrystallization. They range in size from fine sand size to coarse sand size and embedded in micrite. They are distributed randomly allover the rock. The micritic binding material between the skeletal particles has been recrystallized into microspars in the veins and fissures.

3.2.3- Packstone microfacies:-

3.2.3.1- Sandy miliolidae packstone (Pl.3-B):- S. M.P.

Sandy miliolidae packstone microfacies is found in the middle part of both the Mokattam Formation (Sec.1) and the Maadi Formation (Sec.2) with thicknesses of about 4-5m and 2m-4m, respectively. It overlies Somalina wackestone or ostracoda foraminiferal wackestone and underlies sandy dolostone or algae miliolidae grainstone in the shallowing upward cycles. In the field, the rock is massive and hard limestone, yellow to brown, fossiliferous with miliolida, small gastropods and pelecypods.

The rock consists mainly of skeletal particles, quartz grains and lime mud matrix. The skeletal particles form about 35% of the rock. They consist mainly of miliolidae (25%) and algae, bryozoa, ostracoda, echinoid remains and *Dictyconus* sp (10%). The shells of most skeletal particles are filled with micrite but few of the chambers are filled with sparite due to recrystallization. Quartz grains (8%) are fine to medium sand sized, subrounded and monocrystalline. Parts of the binding material have been recrystallized into microsparite grains due to aggrading neomorphism.

3.2.3.2- Dolomitic oyster packstone (Pl.3-C):- D. Oy.P

Dolomitic oyster packstone microfacies is recorded in the upper part of the Maadi Formation (Upper Eocene) at Gebel EL Goza El Hamra (Sec.1) and south Darbet El Houity (Sec.2). It represents a cap of the shallowing upward cycles. It overlies the lime mudstone or claystone facies. It also underlies sandy dolostone facies (Fig.2).

The thickness of this microfacies varies from cycle to cycle between 1.5 and 3.5m (Fig.2). In the field, the rock is massive and very hard limestone, dolomitic, greyish yellow, pale yellow, brownish yellow, fossiliferous with several oyster banks.

Under the microscope, the rock consists mainly of skeletal particles, dolomites, quartz grains and binding material. About 45% of the skeletal particles are composed of pelecypods (Oysters). They have fine to coarse sand sizes (0.2mm-0.8mm) and are curved in shape. The majority of these shell fragments are well preserved, showing the original foliated microstructure with their original aragonitic texture. Most of them have been recrystallized into microsparite due to aggrading neomorphism, and have preferred orientation generally parallel to the bedding plane. About 25% of the rock dolomite rhombs are unzoned, fine sand sized (0.13mm- 0.25mm), with dark core and light outer rims, xenotopic fabric, equigranular texture. Quartz grains are less abundant than dolomite rhombs, forming about 5% of the rock, with medium sand size (0.2-0.3 mm) and subangular to subrounded, monocrystalline and moderately sorted. The binding material between the skeletal particles and Quartz grains is micrite. Parts of the micrite have been recrystallized into microspars, which fills the intergranular spaces.

Plate 3

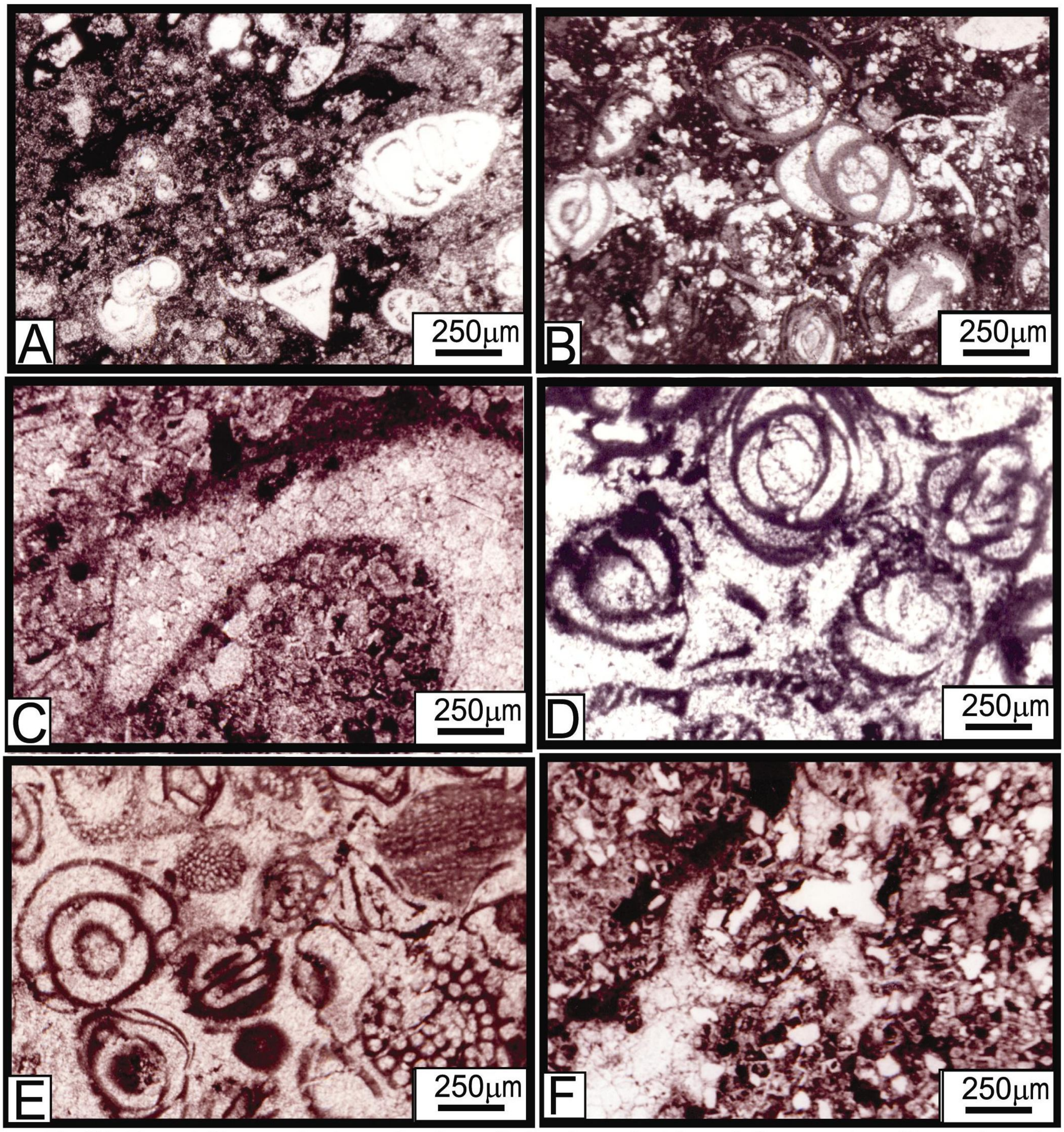


Fig.(A): Foraminifera wackestone showing coiled and uncoiled foraminifera species with quartz grain embedded ina micritic matrix, Ordinary Light. Fig.(B): Sandy miliolida packstone showing chambers filled with sparites due to recrystallization, Ordinary Light. Fig.(C) Dolomitic oyster packstone in which mollscan fragments have been recrystallized to sparry calcite and dolomite rhombs scattered through the rock, Ordinary Light. Fig(D)Miliolida grainstone showing miliolida sp packed in a microsparite cement, Ordinary Light. Fig(E)Algal miliolida grainstone in which skeletal particles are embedded in a sparite cement,Ordinary Light.Fig(F) Sandy dolostone in which dolomite rhombs show dark core and lighter outer rim and with subangulr-subrounded quartz grains,Ordinary Light.

3.2.4- Grainstone microfacies:-

3.2.4.1- Miliolidae grainstone (Pl.3-D):- M.G

Miliolidae grainstone occurs in the middle part of the Maadi Formation at sec.2 and attaining a thickness of about 2m. The rock is yellow, fossiliferous with mollusca and miliolida, compact and hard.

Microscopically, the rock consists mainly of skeletal particles and sparry calcite as cement. Miliolids are the main component of skeletal particles, where they form about 65% of the rock. The shells of miliolids are fine to coarse sand size (0.12-0.6mm). The majority of the chambers of these skeletal particles are filled with spary calcite. They are rounded, oval in shape and scattered allover the rock. The binding material between the skeletal particles is sparry calcite cement, which fills the intergranular spaces. The original micritic matrix was removed away by the action of waves and currents in a turbulent shallow environment.

3.2.4.2- Algal miliolida grainstone (Pl.3-E):- Alg.M.G.

Algal miliolidae grainstone microfacies is represented only in the middle part of the Maadi Formation at Darbet El Houity (Sec.2) with a thickness of about 3m. It caps the shallowing upward cycle and overlies the miliolidae packstone. The rock is compact and very hard limestone, brown to greyish brown, fossiliferous with miliolids, algae and crowded with echinodermata and mollusca.

Microscopically, the rock consists mainly of skeletal particles, quartz grains and sparry calcite cement. The skeletal particles form about 80% of the rock and are represented by miliolids (55%), algae (15%) and (10%) echinoderms (Stems, spines and osciles). They have fine to medium sand sizes (0.12-0.5mm). The majority of these shells are well preserved, showing the original foliated microstructure with their original aragonitic texture. Most of them are micritized, but some of them are filled with spary calcite due to aggrading neomorphism. Quartz grains are less abundant than skeletal particles forming about 10% of the rock, with medium sand size (0.25-0.35 mm), subangular to subrounded and moderately sorted, straight extinction and monocrystalline grains. The binding material between the skeletal particles and quartz grains is sparry calcite cement, which fills the intergranular spaces.

3.3. Dolostone lithofacies

There are two dolostone lithofacies types as follows:

3-3-1- Sandy dolostone (Pl.3-F):- S.D

Sandy dolostone is recorded in the lower part of the upper part of the Mokattam Formation and the Maadi Formation at Sec.1 and Sec.2. They measure about 3.5m, 2m and 1.5m thicknesses, respectively. It caps the shallowing upward cycle, overlying lime mudstone, dolomitic miliolidae packstone and miliolidae packstone. The rocks belonging to this lithofacies are compact and hard dolostone, calcareous, grey, brownish yellow, unfossiliferous and porous.

In thin section, the rock is composed mainly of dolomite rhombs and quartz grains. Dolomite rhombs are the most common, forming about 70% of the rock. They range in size from 5 to l0μm with dark core and light outer rims, xenotopic fabric, equigranular texture. Quartz grains constitute about 9% of the rock, with two modes of size; the first is fine sand (0.15- 0.2 mm) and the second is medium sand size (0.25-0.35 mm). They are subrounded to subangular, with low sphericity and moderate sorting. Most of the quartz grains are monocrystalline; some are polycrystalline without inclusions and with straight extinction. The binding material between the dolomite rhombs and quartz grains is microcrystalline dolomites calcareous matrix.

3.3.2- Dolostone (Pl.4-A):- D

Dolostone lithofacies is encountered in the upper part of the Maadi Formation overlying the dolomitic miliolidae packstone and algal miliolida packstone. It attains a thickness of about 2m. In the field, the rock belonging to this lithofacies is massive and very hard dolostone, brownish yellow and cavernous.

Under the microscope, the rock consists mainly of dolomite rhombs and ferruginous material as binding material. The dolomite rhombs form about 80% of the rock ranging in size from medium to coarse sand size (0.5mm-1mm). It has dark core and light outer rims, xenotopic fabric, equigranular texture, subhedral crystal outlines. The rock is stained with iron oxides. Some quartz grains are scattered throughout the binding material.

3.4. Dedolostone lithofacies:

3-4-1. Sandy dedolostone (Pl.4-B):- S.DD

Plate 4

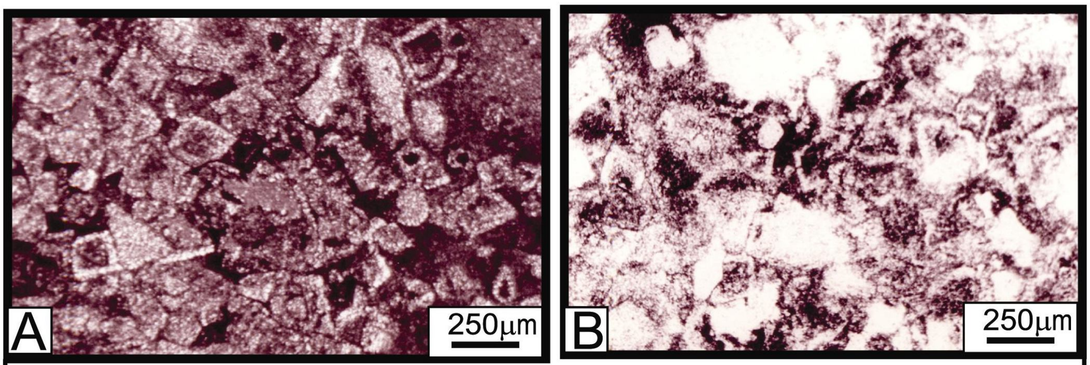


Fig.(A): Dolostone with crystals showing dark core and lighter outer rim, xenotopic fabric, equigranular texture dolomite rhombs are stained with iron oxides, Ordinary Light. Fig.(B): Sandy dedolostone showing calcite crystals replacing the dolomite rhombs. Relics of dolomite rhombs within the calcite crystals, Ordinary Light.

Sandy dedolostone is detected from the upper part of the Maadi Formation at Darbet El Houity section reaching a thickness of about 2.5m. It represents a cap of the shallowing upward cycle overlying the dolomitic miliolidae packstone. The rock is massive and very hard dolostone, sandy, yellow to yellowish grey and porous.

Petrographically, the rock is composed of dolomite rhombs (15%), quartz grains (20%) with blocky calcite (35%). The dolomite rhombs are fine to medium grained (70-120μm). They have anhedral to subhedral crystal outlines and show a xenotopic to hypidotopic texture with equigranular fabric. The rhombs are stained with iron oxide and with a dark core, where their outer periphery is is rimmed with clear zone. Quartz grains are angular, poorly sorted with low sphericity. They are monocrystalline with straight extinction. The calcite crystals replace the dolomite rhombs showing relics of dolomite rhombs within the calcite crystals.

4. Cyclicity

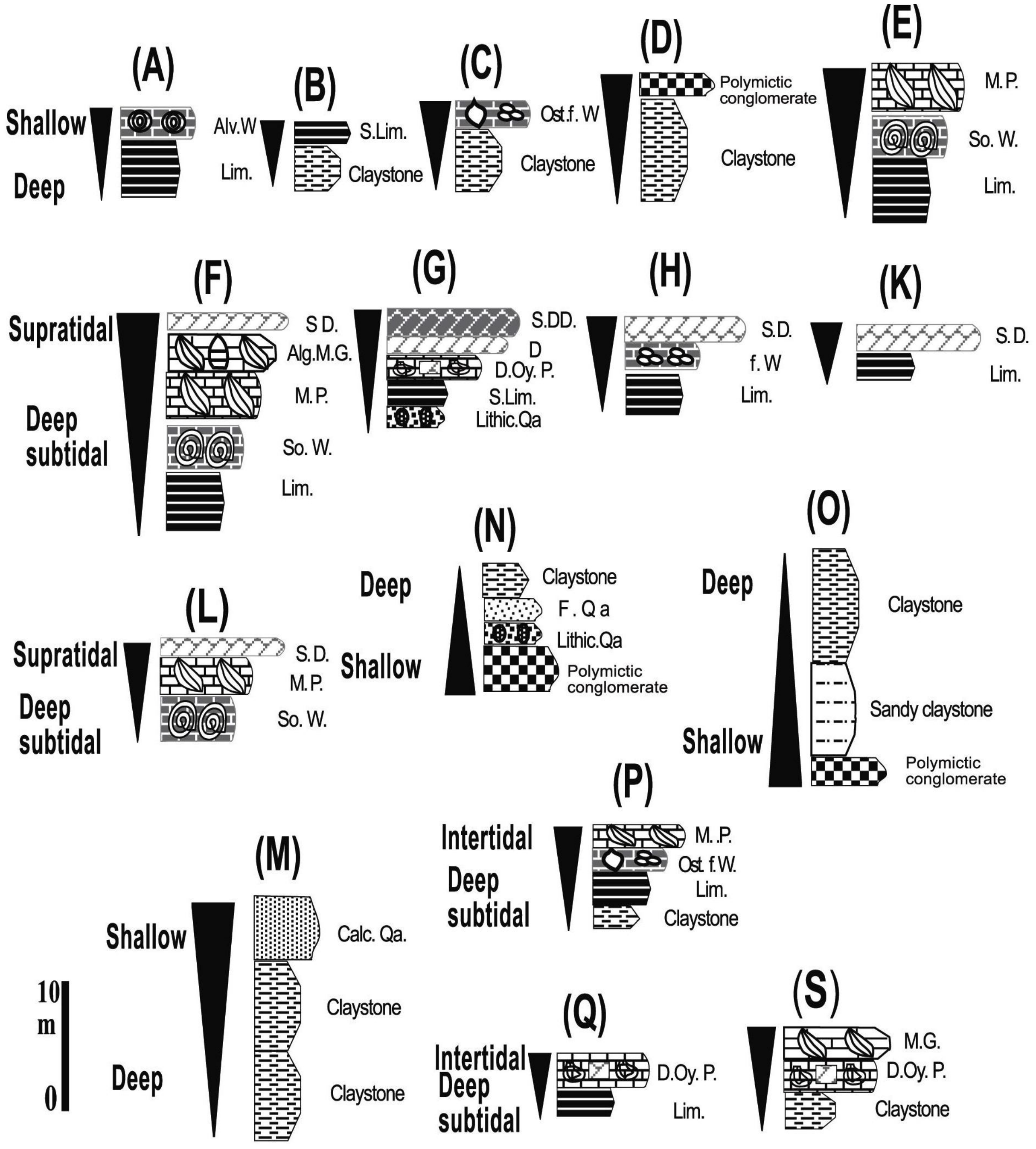
The depositional cycles are defined as a group of rock strata which are arranged in a certain order where the uppermost bed of the cycle represents either shallower or deeper conditions than the underlying bed (Sloss, *et.al.,*1949,).

4.1. Shallowing upward cycles:

Shallowing upward cycles comprise a group of rock strata which differ in their lithological constituents and are arranged in the order that the uppermost bed of the cycle represents a shallower environment than its basal bed (Grotzinger, 1986). In the present work, the shallowing-upward cycles are widely distributed and occur in pure siliciclastics, pure carbonates and mixed siliciclastics-carbonate facies. Each cycle starts with claystone, gypsiferous claystone and lime mudstone and ends by quartzarenites, wackestone, packstone and dolostone (Fig.4). Such cycle has different terms, e.g. regressive cycles (Matthews, 1974) and emergence cycles (Khalifa, 1996).

4.1.1. Shallowing-upward cycles in pure clastic facies:

Shallowing-upward cycles in pure clastic facies are common in the upper part of the Minia Formation at Sec.1 and the lower part of both the Mokattam and Maadi formations (Sec.1&2). This cycle consists of claystone, gypsiferous claystone at the base followed upward by calcareous litharenites, sandy gravels/ conglomerates (Figs.4D & M). The thickness of claystone is usually greater than the sandstones which is characterized by vertical burrowing in the calcareous quartzarenites. This type of shallowing upward cycles may gave rise to sudden lowering of sea level.



S: Sandy
M: Miliolida
D: Dolostone
P: Packstone
f: Foraminifera

Qa: Quartzarenite
DD: Dedolostone
W: Wackestone
F: ferruginous
Calc: Calcareous

▼ : Shallowing upward cycle
▲ : Deepening upward cycle
G: Grainstone
Lim: Lime mudstone

Alv: Alveolina
Ost: Ostracoda
Oy: Oyster
Alg: Algae
So: Somalina

Fig.(4): Shallowing upward and deepening upward cycles in the study area. Notice, Shallowing upward in pure clastic facies(D and M); in mixed clastic- carbonate facies (B,C,G,P and S) and in pure carbonate(A,E, F, H,K L and Q). Deepening upward cycles in pure clastic facies(N and O).(For lithofacies symbols see Fig.3)

4.1.2. Shallowing-upward cycles in mixed siliciclastics - carbonate facies:

Shallowing-upward cycles in mixed siliciclastics-carbonate facies occur in the middle part of the Maadi Formation (Sec.1&2) and the middle part of the Minia Formation (Sec.1). This cycle consists of claystone at the base followed upward by lime mudstone, wackestone, packstone and grainstone (Figs.4B, C, G, P & S). The thickness of claystone is usually less than that of limestones. The greater thickness of claystone indicates more subsidence and vice versa for cycles in which the subtidal facies are overlain by intertidal facies (presence of vertical burrowing in ferruginous calcareous quartzarenites). They are capped by facies representing the supratidal environment (presence of grainstone and packstone).

4.1.3. Shallowing-upward cycles in carbonate facies:

Shallowing-upward cycles in carbonate facies are well observed in the lowermost part of the Minia Formation (Sec.1) and in the middle part of the Mokattam Formation (Figs.4A, E, F, H, K, L& Q). These cycles consist of lime mudstone (deeper subtidal) overlain by wackestone (intertidal to shallow subtidal). This type of cycles is common in the Oligocene-Miocene at Ras Banas, Red Sea coast Egypt (Khalifa *et al.*, 2003) and also found in the Upper Eocene of northern part of Fayoum Province (Abu El Ghar, 2005). It also comprises lime mudstone at the base followed upward by Somalina wackestone, miliolidae packstone and sandy dolostone.

4.2. Deepening upward cycles:

Deepening upward cycles comprise a group of rock strata which differ in their lithological constituents and are arranged in the order that the uppermost bed of the cycle represents a deeper environment than its basal bed (Grotzinger, 1986). Such cycle has different terms, e.g. transgressive cycles (Matthews, 1974) and submergence cycles (Khalifa, 1996).

In the present work, the deepening upward cycles occur in the pure siliciclastics facies in the lower most part of the Maadi Formation (Sec.2). Each cycle starts with polymictic conglomerate followed upward with lithic quartzarenites, ferruginous quartzarenites and ends by claystone (Figs.4N&O). The deepening upward cycles are usually recognized in the areas that are subjected to sudden subsidence. Miall, (1981) showed the deepening upward cycles in the basin- wide associated with tectonic events. Hence, the deepening upward cycles were controlled by external factors or allocyclic mechanism. In the Maadi Formation, the basal part of cycles (polymictic conglomerate) was formed during the initiation of tectonic events and the formation of the Cretaceous, Lower and Middle Eocene rocks. These rocks are considered the main source of conglomerates at the basal part of the cycle. This was followed by ceased faulting and low relief of the Cretaceous, Lower and Middle Eocene rocks that gave rise to the deposition of the litharenite forming the top of cycle. Repetition of these mechanisms can lead to superposition of the submergence and/or fining upward cycles.

5. Sequence stratigraphy:

Sedimentary sequence is a common term in literature since the work of Sloss *et al*. (1949). A sequence is a relatively conformable succession of genetically related strata bounded by unconformities and their correlative conformities ((Mitchum, 1977; Van-Wagoner *et al*, 1988 & 1990).

Detailed studies of the Eocene succession in the Shabraweet area lead to the recognition of four sequence boundaries which are marked by angular unconformities and presence of conglomeratic beds. Depending on these sequence boundaries, the Eocene succession in the Shabraweet area could be subdivided into three depositional sequences. The detailed study of facies changes and their depositional environments indicated sequences that were defined by cycles.

5.1. Sequence boundaries:

5.1.1. Cretaceous- Lower Eocene sequence boundary (SB1):

In Gebel Shabraweet, this boundary is represented by angular unconformity surface traced between the Cretaceous rocks (Turonian- Santonian strata) and the Lower Eocene (Minia Formation). The discontinuity of sedimentation from the Cretaceous to the Eocene was controlled by ENE-WSW structural high that belong to the Syrian Arc system (Shukri, 1954). The unconformity surface zone is represented by a thick bed of conglomerate and conglomeratic clay and sandstone. The conglomerate consists of dolomitic limestone and flint pebbles with different shapes and sizes in a sandy matrix of brownish colour. Said (1962) believed that the Eocene rocks follow on top of the Turonian-Santonian strata of Gebel Shabraweet with an angular unconformity. Al Ahwani (1982) detected this boundary between the (Turonian- Santonian strata) and the Minia Formation at Gebel Shabraweet.

5.1.2. Late Ypresian (Minia Formation) - Late Lutetian (Mokattam Formation) sequence boundary (SB2):

This sequence boundary of is easily traced in Gebel EL Goza El Hamra where the Minia Formation is overlain unconformably by the Mokattam Formation (Pl.1.A). The unconformity surface is evidenced by a conglomeratic bed measuring about 2.5m in a thickness. Al Ahwani (1982) and Helal (1990) detected this unconformity between the Minia Formation and the Mokattam Formation at Gebel Shabraweet.

5.1.3. Middle Eocene - Upper Eocene sequence boundary (SB3):

The Middle - Upper Eocene sequence boundary (SB3) is represented by unconformity surface between the upper part of the Mokattam Formation (Middle Eocene) and the overlying Upper Eocene (Maadi Formation) (Fig.4). This boundary is marked by a thick conglomerate bed (5m) at South Darbet El Houity southwest Gebel Shabraweet. Al Ahwani (1982) and Helal (1990) detected this unconformity between the Minia Formation and the Mokattam Formation at Gebel Shabraweet. Kostandi (1963) considered that the lower boundary of the Upper Eocene is taken at the disappearance of all the typical Lutetian large foraminifera, the most of which is the *Nummulites gizehensis*.

5.1.4. Upper Eocene-Oligocene sequence boundary (SB4):

The Upper Eocene-Oligocene sequence boundary (SB4) is represented by an unconformity surface which separates the Upper Eocene (Maadi Formation) and the Oligocene deposits at the southern part of Shabraweet area. Al Ahwani (1982) also detected this unconformable relationship between the topmost part of the Maadi Formation (brown and hard siliceous limestone) and the Oligocene gravels.

5.2. Depositional sequences:

5.2.1. Depositional sequence-1(S1):

This sequence is bounded by sequence boundaries (SB1 and SB2) within Gebel El Goza El Hamra. The lower part consists mainly of two pure carbonate shallowing upward cycles. Each cycle is based with deep subtidal lime mudstone and capped with shallow subtidal alveolinid wackestone.

The middle part consists of six shallowing upward mixed siliciclastic-carbonate cycles, each of which consists of claystone at the base followed by lime mudstone, sandy lime mudstone or ostracoda foraminiferal wackestone at the top (Fig. 4). This part may form during the portion of base level rise when the rates of rise outpace the sedimentation rates, which resemble transgressive systems tract described by Catuneanu, (2002). The cycles of the upper part differ from that occurring in the middle part, where they are capped with sandy gravels or Polymictic conglomerate.

5.2.2. Depositional sequence-2(S2):

This sequence forms the Mokattam Formation. It is bounded at the top by sequence boundary (SB3). The lower part consists of siliciclastic facies at the base of the Mokattam Formation. It includes thick coarsening-upward cycle. It consists of clays at the base and calcareous quartzarenites at the top. The lower part is topped by middle part which displays transition from siliciclastic facies to carbonate facies. The middle part built up of deep subtidal lime mudstone with shallow subtidal somalina wackestone, miliolidae packstone as intertidal subenvironment. The upper part consists of two shallowing upward cycles. Each cycle is based with lime mudstone and is capped with sandy dolostone which indicating high frequency sea level changes.

5.2.3. Depositional sequence 3(S3):

This Depositional sequence is bounded by unconformity surfaces. It builds up of the Maadi Formation between the sequence boundary (SB3) and the sequence boundary (SB4). The lower part comprises two fining upward cycles, each of which begins with polymictic conglomerate at the base, followed by lithoclastic quartzarenites and ferruginated quartzarenites and claystone at the top. The middle part is composed of four shallowing upward clastic-carbonate cycles. Each cycle consists of claystone, sandy claystone or sandy lime mudstone at the base, followed by miliolidae wackestone, Somalina wackestone, ostracoda foraminiferal wackestone, miliolidae packstone, algal miliolidae grainstone and dolostone at the top. The upper part consists of shallowing upward cycles. It is capped with sandy dolostone (which indicating high frequency sea level changes) and dedolostone, which is a good indicator of percolation of meteoric water during intermittent subaerial exposure. This phenomenon was noticed in the carbonate platforms (Molina, et al., 1999).

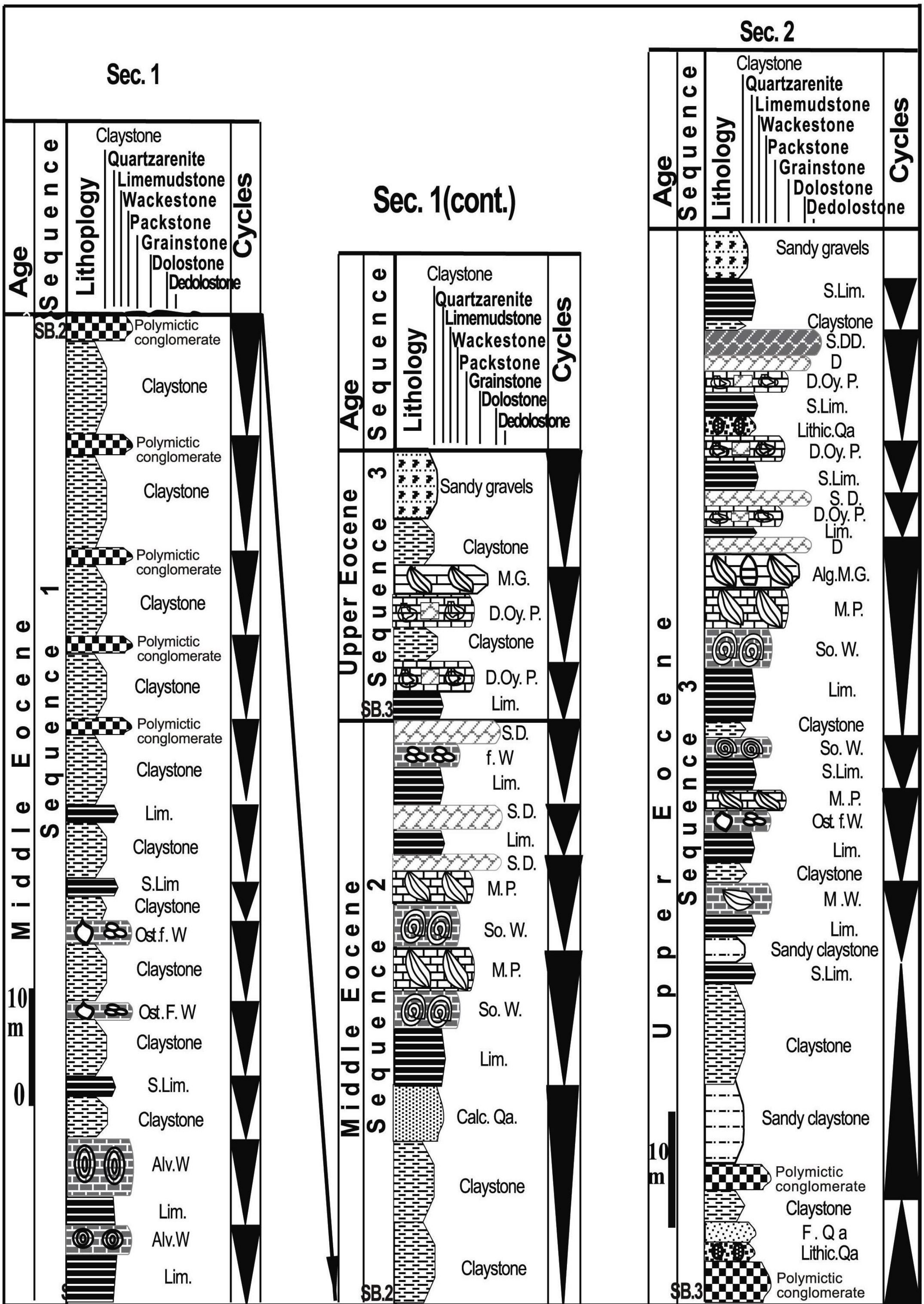


Fig.(5):Sequence stratigraphy and cyclicty of the Eocene rock units at Southeast and Southwest Gebel Shabraweet, Eastern Desert, Egypt.(For lithofacies symbols see Figs.3&4)

6. DEPOSITIONAL HISTORY

1. Depositional environment of the Minia Formation:

According to the study of the lithology, microfacies associations, stratigraphic position and sedimentary structures of the Minia Formation, it can be indicated that the Minia Formation was deposited in a shallow marine environment.

It seems that the Minia Formation in the present area was deposited under normal marine conditions as evidenced by the high average percentage of the large foraminifera (alveolines, orbitolites and miliolids). Alveolines are usually growing under normal marine salinity conditions (Hottinger, 1977). The Orbitolites exhibit the same paleoecological conditions as alveolines, while the miliolids are flourishing in normal marine to slightly hypersaline water.

The organic sedimentary structures are rare and represented only by the vertical and inclined burrows. Rhoads (1967) in his study of burrowing organisms showed that the vertical burrows characterize the intertidal substrate and horizontal burrows characterize the subtidal substrate.

The microfacies associations recognized in the Minia Formation in the study area are: lime mudstone, sandy lime mudstone, alveolina wackestone, ostracoda foraminiferal wackestone, claystone, sandy gravels and polymictic conglomerates. The vertical arrangement of the present facies shows shallowing upward cycles (Fig.3). Two pure carbonate shallowing upward cycles are recognized in the lower part, each cycle begins with lime mudstone and capped by alveolinid wackestone.

The middle part consists of six mixed clastic-carbonate cycles, each cycle is based with claystone and capped by sandy lime mudstone, lime mudstone or ostracoda foraminiferal wackestone. The upper part on the other hand comprises five pure clastic shallowing upward cycles; each cycle is composed of claystone at the base and capped by sandy gravels and/or polymictic conglomerates.

The lower part of the Minia Formation consists mainly of carbonate cycles, each cycle is composed of lime mudstone at the base and capped with alveolinid wackestone. Khalifa (1996) stated that the emergence (shallowing upward) cycles of pure carbonate usually occur in the outer shelf facies. The large foraminifera are important elements of benthonic communities in the shallow tropical and subtropical zones. The restriction of these Foraminifera to the photic zone is due to the fact that these foraminifera enclose symbiotic algae (Hallock, 1981). The Minia Formation in the study area was deposited in shallow water conditions with water depth not exceeding 20 m as evidenced by the presence of the alveolines, orbitolites, miliolids and algae. This is also indicated by the common micrite envelopes which refer to < 40 m water depth (Swinchatt, 1969). Ross (1969) stated that the alveolines prefer living in the shallow water with a depth ranging from 20 to 80 m, but they can live in shallow water of 5-15 m.

The presence of ostracoda in the ostracoda foraminiferal wackestone microfacies indicates a shallow subtidal to restricted lagoonal environment and miliolids are indicative of very shallow water with hypersaline affinity. They are recoded in the intertidal (backshore and foreshore) in Quaternary sediments at Sharm El Sheikh (Khalifa, 2003)

The fossiliferous claystone (ostracods and foraminifera) with grey and brownish yellow colour is mainly deposited below wave-base at depths in excess of 20- 50m (Tucker, 1981).

The upper part of the Minia Formation consists of five pure clastic coarsening-upward cycles; each cycle is based with claystone and capped by sandy gravels and conglomerates. Such cycle is deposited in a very shallow marine environment (mostly littoral zone) due to presence of an assemblage of *Charophyta spp.* Grambast (1974) glue that the charophetes are fresh or brackish water green plants that are considered as a group of green algae. Wray (1977) showed that charophetes gyrogonites may be transported from their place of origin and deposited in marginal marine settings. The repetition of these cycles indicates oscillation of sea water level and mainly controlled by the allocyclic mechanism that proves high frequency sea level fluctuations. This interpretation is in harmony with the works of Rust and Koster (1984) and Sopena and Sanchez-Moya (1997) who suggested that the coarse upward succession was deposited immediately after fault movements.

2. Depositional environment of the Mokattam Formation:

The Mokattam Formation is subdivided into three parts. The lower part which is composed mainly of only one thick pure clastic shallowing upward cycle, based with thick claystone and capped by calcareous quartzarenites, indicates a continuous high influx of detrital clastic grains by intertidal – subtidal stream. As this transgression comes from the south (no Eocene sediments are recorded in the northern part of the area (Al Ahwani,1982). The lateral equivalent to the south is represented by more open, calm conditions with less rates of detrital influxes. Such facies are recorded in the Wadi Awlad El Shelikh area by Gharieb, (2003), indicates the continuous influx of clastics by intertidal–subtidal stream. More transgression took place during the middle part which includes two pure carbonate shallowing upward cycles. These cycles starts with deep subtidal facies (lime mudstone and Somalina wackestone), followed by shallow subtidal to intertidal facies (miliolidae packstone) and ends with intertidal/ supratidal facies (sandy dolostone. The presence of larger foraminifera and miliolids, such as *Somalina sp*., indicates the shallow tropical and subtropical zones, normal salinity and fair high rate of sedimentation. The upper part of the Mokattam Formation is composed of three microfacies, lime mudstone, foraminifera wackestone at the base (deep subtidal zone) and sandy dolostone at the top(intertidal to supratidal zone) showing progradational stacking pattern. This may reveal the variability in sea level changes during its regression making the ends of the depositional sequence.

3. Depositional environment of the Maadi Formation (Upper Eocene):

The Upper Eocene (Maadi Formation) in south Darbet El Houity section shows two types of cycles, the lower deepening upward (submergence) cycles begin with thick conglomeratic bed followed by lithic quartzarenites, ferruginous quartzarenites and end by claystone. These cycles that represent the lower part, invade the area with highly agitated water by the sea leading to intensive erosion of the older rocks. The repetitions of fining upward cycles indicate intermittent pulsating phase of deposition in shallow agitated water with high influx of clastics. Hassan and Hassanein (1989) pointed out that after the deposition of the Middle Eocene, a contemporaneous regression of the Tethys continued, accompanied with elevation during which the Upper Eocene sediments were deposited. It is believed that the sediments of the lower part were deposited in shallow sea retreating to the north, which was receiving detritus from the exposed hinterland. The influx of detrital material became exceptionally high during the Late Eocene when large rivers seem to have discharged in the sea. These cycles probably represent fluvial deposition, formed during the tectonic events, which probably forms a thick fan-like facies. The fining upward cycles may reflect highly episodic tectonic control that led to the deposition of the polymictic conglomerate fan at the base. This was followed by flash flooding during intensive rainfall depositing the litharenite at the top of the cycle. The repetitions of fining upward cycles indicate intermittent pulsating phases of tectonic uplift followed by flash flooding events. Sopena and Sanchez-Moya (1997) who suggested that the fining upward sequence was produced as the source area becomes degraded during post tectonic evolution.

The middle part is composed of four mixed clastic-carbonates shallowing upward cycles. The microfacies of these cycles are deep subtidal (claystone, sandy claystone and lime mudstone), shallow subtidal (Somalina wackestone, ostracoda foraminifera wackestone, miliolidae packstone and algal miliolidae grainstone) and intertidal/ supratidal (dolostone). The miliolids (*Quinqueloculina* and *Triloculina*) prevail over inner shelf and in open gulfs, in warm shallow tropical and sub tropical waters at depths from zero to about 100m (Luczkowska,1974). Ostracods are considered to be controlled by water depth, salinity and turbulence (Bate, 1971). The presence of the varied types of algae and foraminifera suggests rather shallow, clear water of open circulation and normal salinity (Bowman, 1978).

The upper part of the Maadi Formation that occurs at Gebel El Goza El Hamra and south Darbet El Houity, forms five microfacies, claystone, lime mudstone, foraminifera wackestone and lithic-quartzarenites at the base, followed by dolomitic oyster packstone and capped by miliolidae grainstone, dolostone and sandy dedolostone. Several oyster embankments with thick shells indicate that the upper part of the Maadi Formation is deposited in a very shallow subtidal to intertidal marine environment with normal to hypersaline waters. Such oyster bank of the Maadi Formation at Gebel Homret Schaibon reflects very shallow subtidal marine facies (Gharieb, 2003). El Hefnawi (1990) showed that such facies of the Maadi Group in the Mokattam area indicates shallow marine condition. The miliolidae grainstone and sandy dedolostone are diagenetic features in the limestone and dolostone respectively. The replacement occurs usually near the earth surface within mixing meteoric water under low temperature and pressure (Chafetz, 1972). The fresh water remove Mg ion that hamper the coarsening of calcite crystals (Folk and Land, 1975).

7. CONCLUSIONS

1- Two stratigraphic sections (Gebel El Goza El Hamra and south Darbet El Houity) of the Eocene sequence at the Shabraweet area were measured, sampled and described reflecting coeval environments along east-north direction. The lithostratigraphy of the study area is arranged from base to top as: 1- The Minia Formation, 2- Mokattam Formation and 3- The Maadi Formation. The Minia Formation is showing unconformity relationship (angular unconformity surface) with the underlying Cretaceous rocks and the overlying Mokattam Formation. The Maadi Formation also unconformably overlies the Mokattam Formation and unconformably underlies the Oligocene sediments by conglomeratic beds.

2- Eighteen microfacies associations are recorded in the studied units. They are distributed as the following, five clastic facies (polymictic conglomerates, calcareous quartzarenites, lithic quartzarenites, ferruginous quartzarenites and claystone), ten limestone facies (lime mudstone, sandy lime mudstone, alveolina wackestone, ostracoda foraminifera wackestone, sandy Somalina wackestone, foraminiferal wackestone, sandy miliolidae packstone, dolomitic oyster packstone, miliolidae grainstone and algal miliolidae grainstone) and three dolostone facies (sandy dolostone, dolostone and sandy dedolostone).

3- Two types of cycles are recorded in the study area; the first one is the shallowing upward cycles with several varieties (in pure clastic facies, in mixed clastic-carbonate and in pure carbonate facies). The other cycles are deepening upward cycles in pure clastic facies and recorded only at the base of the Maadi Formation.

4- The Eocene rocks include three depositional sequences. They are sequence-1; sequence-2 and sequence-3 representing the Lower Eocene, the Middle Eocene and the Upper Eocene, respectively. These sequences are separated by four sequence boundaries represented by unconformity surfaces.

5- The Minia Formation was deposited in shallow marine environment. The Mokattam Formation was deposited in the shallow tropical and subtropical zones, normal salinity water and fair high rate of sedimentation. The Upper Eocene Maadi Formation was deposited in shallow agitated water with high influx of clastics.

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