Diversity, growth forms and rhodolith distribution: factors controlling the fabric of coralline algae of the Lower Miocene deposits, Cairo – Suez District, Egypt

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Abstract

The Lower Miocene deposits in Gabal Gharra, Cairo – Suez District, unconformably overlies the Oligocene and Eocene deposits. They consist predominantly of regressive and transgressive mixed siliciclastic / carbonate sediments of shallow marine environments. The Lower Miocene deposits are represented lithostratigraphically by the Gharra Formation that comprises four members, from base to top: Agrud, Sadat, Hommath and Genefe members. Two measured sections were described and investigated: Gabal Gharra section and Gabal Agrud section. The coralline red algae are highly abundant in Sadat and Genefe members as fragments, crusts and rhodoliths. Larger foraminifera, corals, echinoids, bivalves, gastropods, bryozoans, benthic and planktonic foraminifers, dasyclades are also present. These two members consist of dolomitized bioclastic packstone, grainstone to floastones / rudstone with rhodoliths (up to 3cm in size). The systematic study led to the recognition of 14 coralline algal species. *Lithophyllum* sp. dominates the coralline associations at the generic level, followed by *Mesophyllum* spp, *Lithothamnion* spp and *Spongites* spp. The vertical distribution of the coralline red algae in the two concerned sections allowed to subdivide the Lower Miocene sequence into two local coralline algal zones, from base to top: *Lithophyllum ghorabi* Zone (including the Sadat Member) and *Mesophyllum iraqense* Zone (covering the Genefe Member). The rhodoliths populations in the two sections were analyzed in terms of their size, shape, massiveness, symmetry, algal growth forms, algal species diversity, epibionts and borings. These parameters reflect environmental differences between the two studied sections. A comparison of the two the analyzed rhodoliths populations show common features, but also significant differences are recorded. The rhodoliths populations of Gabal Gharra were formed under low energy conditions characterized by porous rhodoliths with higher primary porosity, less frequent epibionts, more boring and thick coralline algal thalli as well as greater asymmetry. On the contrary, in Gabal Agrud the analyzed rhodoliths population was formed in high energy conditions of shallower water marine environments and characterized by more mobile, symmetrical rhodoliths, more frequent epibiont, thin coralline thalli.

Keywords: *Lower Miocene, Gabal Gharra, Agrud, coralline algae, rhodoliths, Egypt.*

Introduction

The Miocene rocks are commonly distributed in Cairo – Suez District are overlying unconformably the non - marine siliciclastic sediments (reddish to brownish sands, sandstones and gravels) of the Oligocene age (Sadek, 1926 & Metwalli, 1963 & Said, 1990). These Miocene rocks crop out as laterally – extensive exposures and occupies the low areas surrounding the Eocene topographic highs such as Gabal Ataqa, Gabal Oweibed, Gabal Abu Treifyia and El Galala El Baharyia plateau. These sediments represent a general transgressive / regressive sequence with shallow marine siliciclastics at base and shallow – water algal limestone associations characteristic of modern temperate platforms at top. Numerous papers have been carried out on these Miocene rocks of that area and most of them concerned with the stratigraphy with little emphasis on their microfossill content. Among the authors who dealt with are Sadek (1926, 1959); Macfayden (1930); Metwalli (1963); Souaya (1961, 1963; Cherif (1966, 1980); Ghorab & Marzouk (1966) Hamam (1966); Said & Metwalli (1966); Abdallah & Abdel Hady (1968); Farag & Sdaek (1968), El Gamal (1971), Al Ahawani, (1977); Cherif & Yehia (1977); Hamza (1977); Hermina *et. al*. (1989); Said (1990); Ismail & Abdel Ghany (1999), Abdel Ghany & Piller (1999), Nebelisick & Kroh (2002), Abel Ghany (2003) and Hamad (2008). The first detailed work on the coralline red algae of Gabal Gharra was carried out by Souaya (1963) who described and illustratted 13 species of coralline algae and established two loacal algal subzones from base to top: *Archaeolithothamnium cyrenicum* Raineri and *Lithophyllum ghorabii* Souaya. El Gamal (1971) studied extensively the Miocene algal - bearing deposits in some localities in northern Egypt and among these are the area of Cairo – Suez district and showed the presence of numerous coralline red algae within this Miocene deposits. Imam & Refaat (2000) studied also the Miocene deposits at Wadi Abura, southern Sinai and recognized fifteen coralline red algal species and subdivided the

Miocene sequence into two local algal zones, from base to top: *Lithothamnium undulatum* and *Mesophyllum sancti-dionysii* zone.

Geological setting

The Lower Miocene deposits in Cairo – Suez district and especially in both Gabals Gharra and Agroud are represented by alternative regressive and transgressive deposits of siliciclastcs and carbonate sediments. The present work focused on the study of these two measured sections that previously mentioned. The lithostratigraphic study revealed that the only rock unit recorded in this area is the Gharra Formation that in turn subdivided into four members (El Gamal, 1971) from base to top as follows: Agrud, Sadat, Hommath and Genefe members.

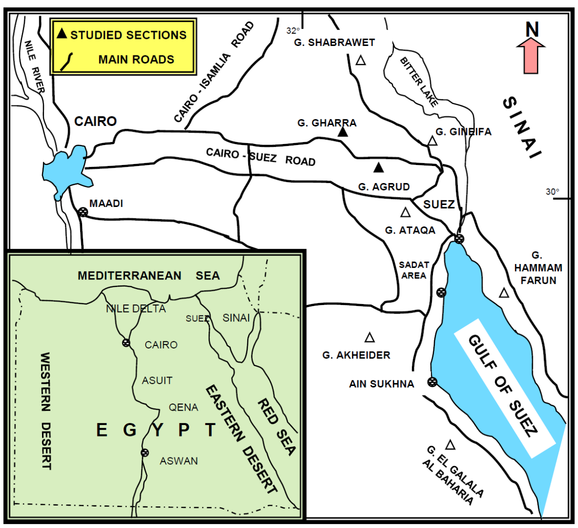

Figure 1. Location map showing the studies sections

Gharrra Formation

This rock unit was first described by Ghorab & Marzouk (1967) in Gabal Gharra in the Cairo – Suez district to designate the marine Miocene deposits in that area. El Gamal (1971) in his studies on the Miocene reefal limestone rocks of some sections in northern Egypt informally subdivided the Gharra Formation into four members. These members are described in details in the following paragraphs from base to top:

Agroud Member: This member was first described and informally established by El Gamal (1971) to designate the lower subdivision of the Gharra Formation in the Cairo – Suez District. Lithologically this member is composed mainly of siliciclastic deposits unconformably overlies the Oligocene rocks and underlies the Sadat Member. Lithologically, it is represented by coarse-grained sandstone, siltstone and calcareous sandstone interbedded with sandy limestone thin beds. This interval terminated upward with horizontal laminated siltstone alternating with fine sandstones and coal seams. Ismail & Abdel Ghany (1999) studied the planktonic foraminiferal content of this member and recorded the following species: *Globigerinella* sp. *Globigerinoides altiaperturus, Gs. parawoodi, Gs. immaturus, Gs. primordius, Gs. trilobus,* and *Gs. quadrilobatus* that assigned this member to the Lower Miocene (Burdigalian) age. He also confirmed their age assignment with the help of the calcareous nannoplanktonic *Helicosphaera ampliaperta* (NN4 of Martini, 1971). Nebelsick & Kroh (2002) studied the macrofaunal content of this unit and showed that it was flooded with great accumulation of complete and fragmented skeletal remains of *Parascutella* spp., *Parascutella deflersi* along with *Amphiope bioculata, Clypeaster acclivis* and *Echinolampas ampla* that strongly assigned this unit to the Lower Miocene (Burdigalian age). Moreover, the present author studied the sandy limestone interbeds and some of the mudstone ones in Gabal Gharra and showed the presence of planktonic and benthonic association represented mainly *Catapsydrax unicavas, Dentoglobigerina venezuelana, Globigerina angustiumbilicata Globigerina ciperoensis, Globigerinoides primordius and Globigerinoides trilobus* with the benthic species *Lepidocyclina undosa, Lepidocyclina canelli, Elphidium* sp., *Heterostegina* sp, *Siphonina tenuicarinata, Miogypsina* sp. that mark the zone M1 of Berggren *et. al.* (1995). The presence of cross – bedded sandstone, bioturbated siltstone and fossiliferous sandy limestone thin beds suggested that this member was deposited under fluvial / fluviomarine to shallow marine environments.

Sadat Member (algal – bearing unit): This member was informally first established by El Gamal (1971) to designate the lower part of the Gharra Formation in the Cairo – Suez district. It conformably overlies the Agrud Member and conformably underlies the Hommath Member. Lithologically, it composed predominantly of white to yellowish white, hard, algal to reefal limestone highly fossiliferous with remarkable coralline algal nodules (forming 30 – 50 % of the rock). Bivalves, bryozoans, serpulids, gastropods, echionoids and isolated solitary and colonial corals are also recorded. The present author noted that this member is made up of several rhodoliths horizons (made up of accumulation of rhodoliths, coralline crusts and marine bryozoans) alternating with thin beds of sandy limestone. These rhodolith horizons thicken in Gabal Gharra (25m) rather than in Gabal Agrud (9m). The member is also highly fossiliferous with large benthonic foraminifera such as *Miogypsina* spp., *Heterostegina* spp. and reworked *Leipdocyclina* spp (Cherif, 1963). Recently, Ismail & Abdel Ghany (1999) studied in details their microfaunal content and showed the presence of the following large benthic foraminifers: *Operculina complanata, Heterostegina heterostegina, Miogypsina intermedia* and dated this member to Lower Miocene age (Burdigalian). The present author carefully studied this member and showed that it contains primarily larger benthonic foraminiferal species including *Miosorites americanus, Neorotalia mexicana, Stillostomella caribbea, Heterostegian sp., Planostegina costata, P. heterostegian and Operculina complanata* that assigned this member to M2 – M3 zones of Berggren *et. al*. (1995). Among the macrofaunal content recognized are *Ostrea plicatula, Ostrea verleti, Ostraea frondosa, Clypeaster intermedius,* and *Clypeaster subdecagonus.* These macro and microfaunal content assinged this unit to the Lower Miocene (Burdigalian) age. The lithological and microfaunal contents as well as the rhodoliths coralline algal association strongly indicate that this member was deposited in shallow marine warm water environments favorable for reef growth.

Hommath Member: This member was first described and established by El Gamal (1971). It overlies conformably the Sadat Member and underlies the Genefe Member of the Gharra Formation in the Cairo – Suez district. It measures 5 m in thickness in Gabal Gharra and and nLower 50m in Gabal Agrud. Lithologically this member composed mainly of siliciclastic sediments that composed predominantly of sandstone, siltstone and claystone with thin interbeds of fossiliferous sandy limestone. Ismail & Abdel Ghany (1999) studied the planktonic foraminiferal content of this member and recorded the following species: *Globoquadrina dehiscens, Globigerinoides altiaperturus, Gs. parawoodi,* and *Gs. trilobus that* assigned this member to the Lower Miocene (Burdigalian) age. This member is barren of any coralline algae unless few reworked fragmented crusts occurred in the sandy limestone interbeds.The presence of cross – bedded sandstone, bioturbated siltstone and fossiliferous sandy limestone thin beds suggested that this member was deposited under fluvial / fluviomarine to shallow marine environments.

Genefe Member: This member was first established and described by Ghorab & Marzouk (1967) in Gabal Genefe. It represents the topmost part of the Gharra Formation in the Cairo – Suez district. It attains 20 m thick in Gabal Gharra and 26 m in Gabal Agrud. Lithologically this member composed mainly coralline algal limestone with sandy limestone thin beds as well as very thin layers of dark greenish gray claystone. Ismail & Abdel Ghany (1999) studied the planktonic foraminiferal content of this member and recorded the following species: *Globoquadrina dehiscens, Globigerinoides altiaperturus, Gs. parawoodi, Gs. trilobus, Gs. bisphericus, Gs. obliquus, Gs. primordius,* and *Globigerina ciperoensis* that assigned this member to the Lower Miocene (Late Burdigalian) age.

Table 1. Lithostratigraphic correlation chart showing the different Miocene rock units in Cairo-Suez road, Egypt.

Age	Sadek 1926&1959	Abdallah & Abdel Hady 1966	National Start. Sub- committee 1976	Said, 1990 G. Gharra	Ismail & Abdel Ghany 1999	Present work Hamad, 2018
Upper Miocene	Upper Series M3	Hagul Formation	Hagul Formation			
Middle Miocene	Middle Series M2	Hommath Formation	Genefe Formation Hommath Formation	Genefe Formation	Hommath Formation	Hommath Formation
Early Miocene	Lower Series M1	Sadat Formation	Sadat Formation		Gharra Formation Sadat Formation	Gharra Formation

In the author opinion the presence of the *Globigerinoides primordius* is doubtful as this species has very short stratigarphic range and never accompanied with the *Globigerinoides bisphericus* and *Globigerinoides obliquus.* The lithological and macrofaunal contents as well as the rhodoliths coralline algal association strongly indicate that this member was accumulated in shallow marine warm water environment favourable for reef growth.

Experimental and methods

The studied materials come mainly from the Lower Miocene (Burdugalian) coralline algal limestones of both the Sadat and the Genefe members of the Gharra Formation, Gabals Gharra and Agrud, Cairo – Suez District. These coralline algal limestones are up to 40 m thick in both of the two units and were deposited on a mixed carbonate – siliciclastic ramp. They are known from other parts of the Cairo – Suez district as in Sadat area, Gabal Homiyera and Gabal Geneifa. A detailed study of the paleoecology and facies of the algal limestone is in preparation by the author. Thin sections were analyzed and studied. Samples were taken whenever corallines and rhodoliths appeared in the surface outcrops. Ten polished slabs were prepared and studied with the help of a lens or ordinary binocular microscope. The cell and conceptacle dimensions were measured according to the figures presented by Woelkerling *et al*., (1993) and Rasser & Piller, (1999). Measurements were made by a microscope at magnification of 500x to the nearest 1µm. The terms of the diagnostic anatomical and taxonomic features of Woelkerling, (1988) and the growth forms Woelkerling *et al.*, (1993) are adopted in the present work.

Morphology and mode of occurrence of the coralline algae

Coralline red algae (Corallinaceae, Rhodophyta) are important paleoenvironmental indicators. Their associations and growth form types, in combination with petrographic and sedimentological data can be used to determine the environment of deposition and the genesis of the sediments in which they occur (Johnson, 1960; Adey, 1979; Bosence, 1983; Martin *et al*. 1993 and Nebelsick *et al*. 2003, Bassi, 2005). Coralline algae are the most important components in the Lower Miocene algal limestone of both Sadat and Genefe members as they contribute up to 80% of the main framework of these facies. In the studied material the coralline red algae show great diversity where at least 10 genera and 28 species were recognized. The most important genera are *Lithophyllum Lithothamnion, Mesophyllum, Sporolithon, Spongites* and *Lithoporella.* These coralline algae mostly occur as in situ crusts on the corals and other skeletal elements, loose branches and rhodoliths forms being lengthing mainly to family Corallinaceae. Both of the crustose non-geniculate corallines (subfamily Meloisioideae, forming more than 90% of the components) and the (geniculate corallines) articulated coralline algae (subfamily Corallinoideae, 10%) frequent and abundant especially in the lower Sadat Member of Gharra Formation. The green alga of Family Codiaceae (Cholorophyta division) is rarely recorded, being represented by only one genus, *Halimeda* sp. The coralline diversity of the studied material is moderately high where twenty-three taxa of coralline algae were recognized and described. The algal association is dominated by shallow water coralline algae of lithophylloids (*Lithophyllum)* intercalated with intervals dominated by melobesoids (*Mesophyllum* and *Lithothamnion*), with minor sporolithaceans (*Sporolithon*) and subordinate mastophoroids (*Spongites* and *Neogoniolithon*) that predominate in algal association of slightly deep sediments. Both the *Lithophyllum prelichenioides* and *Lithophyllum ghorabi* reach more than 30% of the stuied coralline algae. The *Lithophyllum* spp. and *Mesophyllum* spp. are the main components of the algal associations and chiefly dominant than the other coralline algae. *Lithothamnion* spp. and *Sporolithon* spp. are relatively rare and existed as fragmented specimens. *Lithoporella* spp. occurs as monostromatic crusts that highly exited and commonly encrusting in situ and fragmented corals and large benthonic foraminifers as well as other coralline red algae. This type of coralline algae is commonly occur as abraded, fragmented grains which may be derived from attached crusts and are either micritized that prevent the taxonomic identification. They usually form free crusts but relatively scarce and mainly associated with isolated coral colonies or form algal bank that pave the solid substrates. The other form is branched thalli, which existed as loosely packed branches. The main growth form types observed in the studied materials are:

Coralline algal branches

The coralline algal branches include two types of growth forms. The first one is represented by isolated, branched unfragmented algal thalli and the second one is depicted by the unfragmented multilayer aggregates that is composed commonly of coralline algae. This type of coralline algal branches is differentiated from the main rhodoliths (most abundant growth forms) by two prominent variations, firstly the less sizes they have (less than 2 cm) and secondly by the unidirectional growth pattern. This type of growth form (coralline algal branches) is extensively developed in the upper Genefe Member of the Gharra Formation (bioclastic grainstone facies) and less abundant in the lower Sadat Member of the same formation.

Attached coralline crustose forms

The attached coralline crustose forms are defined as unfragmented, dorsoventrally organised layers of encrusting coralline algae (Rasser, 2000). The attached coralline crustose forms are differentiated on the basis of the number of the constituting species into two types. The first type is represented by mono – layered crusts that directly overgrowing on bioclastic fragments, where *Lithophyllum* spp. and *Lithoporella* sp. are the most dominant algal type in the studied materials. The mono – layered algal crusts consist mainly of *Lithophyllum prelichenioides* (most abundant species and outnumbering any other *Lithophyllum* spp.) and *Lithophyllum ghorabi* (the second most abundant species which mainly associated with bryozoans and coral colonizes) as well as *Lithophyllum pseudoamphiroa* Johnson. The second type is showed in the presence of multilayered crusts that grow over corals, bryozoans, or larger foraminifers. This type of coralline red algal crusts occurred commonly in the form of superimposed undulating crusts of 300 –500 μm thick and usually alternating with encrusting foraminifers forming short protuberances and short branches (Pl. 3, Fig. 1). They occurred also as encrusting the large benthonic foraminifers such as *Amphistegina* spp. and *Heterostegina* spp. and rapped also the bryozoans and echinoids plates and the colonial corals as well.

Rhodoliths

The rhodoliths are unattached nodules with size of greater than 2 cm (Adey, 1986) and consists of more than 50% of nongeniculate encrusting coralline algae (Bosellini & Ginsburg, 1971; Bosence, 1983). Moreover, they sometimes defined by the occurrence of different growth directions in order to separate them from coralline branches. The rhodoliths are commonly found in the intratidal pools (Wehrmann *et al*. 1995) down to more than 200m (Adey & Macintyre, 1973; Bosence, 1983; Littler *et al*., 1991) Water energy is expected to be an important ecological factor for rhodoliths distribution as it can control the occurrence of the herbiverous animals (Steneck, 1985) and influence the growth forms and taxonomic succession (Bosellini & Ginsburg, 1971; Braga & Martin, 1988; Bosence, 1991).The rhodoliths are remarkably occurred in the Lower Miocene deposits in Gababl Gharra in the form of unattached algal nodules having size ranges from 2 cm up to maximum diameter 6 cm and predominantly consists of nongeniculate encrusting coralline red algae. These rhodoliths are characterized also by different types of growth forms. Most of the rhodoliths are spheroidal to discoidal and laminar – concentric with remarkable amount of sediments or cement between crusts. One of them is characterized by domination of the *Lithophyllum*, Lithothamnion*, Mesophyllum Sporolithon* and, together with minor *Spongites* and rarely *Lithoporella.* Sometime intergrowing with these previous coarlline red algae inside the rhodoliths are serpulids, bryozoans and vermetids as well as encrusting foraminifers. The nucleus of this type is composed mainly of bioclastics in the form of fragmented corals or mollusk shell fragments. The other rhodoliths type is exclusively built up of *Lithophyllum and Lithoporella* crusts. It is noteworthy of mention that several growth phases inside the rhodoliths can be distinguished separated by intraerosional surfaces that cut across the former set of laminae. It is laso noted that some bioclastics are also incorporated between the laminae and made up of unattached nodules of non-geniculate laminar, encrusting thalli and foralgaliths in which thin encrusting coralline thalli are intergrown with encrusting larger foraminifera.

According the presence or absence of nucleus, two main types of rhodoliths are evident. (1) Non – nucleated rhodoliths and (2) Nucleated rhodoliths. The first type is represented by non - geniculate rhodoliths that suggested here to be formed through overturned coralline crusts and this type is less frequent in the studied materials and rarely recorded in the Sadat Member of Gharra Formation at Gabal Gharrra. The second type, nucleated rhodoliths, is differentiated in this study on the basis of the nucleus formed it and is classified here into two subtypes. The first one is represented by typical rhohodliths with nuclei of fragmented corals or molluscan shell fragments (Pl.1, Fig. 2), and are dominated with coralline red algae, mostly of melobesioide coralline such as *Lithophyllum* spp., *Lithothamnion* spp., together with minor *Lithoporella* sp., *Mesophyllum* sp. and rarely *Sporolithon* spp. Serpulids, bryozoans, vermitids and encrusting foraminifers can all be found intergrowthing coralline inside these rhodoliths. Such type of bioclastic association is typical of shallow water – temperate marine platforms (Bosence, 1990 and Rasser & Piller, 1999). The second type of rhodolith is serpulids nodules, consists exclusively of nuclei of serpulids worm tubes (Pl. 3, Fig. 1) and encrusting with *Mesophyllum* spp. (mainly of *Mesophyllum sanctidionysi* and *Mesophyllum laffittei*. With *Lithophyllum* spp. and rarely *Lithoporella* sp). The algae were sometimes occurred as individual algal nodules of coarse rhodoliths (3- 5 cm) composed mainly of overturned coralline, but this type is very rare. The presence of rhodoliths indicate depth ranges from 70 – 90 m (Adey & MacIntyres, 1973; Adey, 1979).

Main characteristics of the rhodoliths

The rhodoliths have investigated with respect to several criteria that commonly control the final pattern of the rhodoliths. These criteria are controlled and related primarily to the environmental factors. Among these criteria are shape and size of the rhodoliths, their internal structure, the diversity of algal species, massiveness, associated microbiota (epibionts and borings) and the algal thallus thickness. The analyzed rhodoliths in both Gabal Gharra and Gabal Agrud revealed some significant differences in the studied rock materials indicating that these analyzed rhodoliths populations were developed in two different environmental conditions during their growth.

Shape and size of Rhodoliths: This factor constituted an important role in the studied Lower Miocene samples. The investigation of the rhodoliths revealed the predominance of three main shapes (spheroidal, ellipsoidal and discoidal shapes). The first and second shapes are most easily transported than discoidal one (Bosence, 1983).

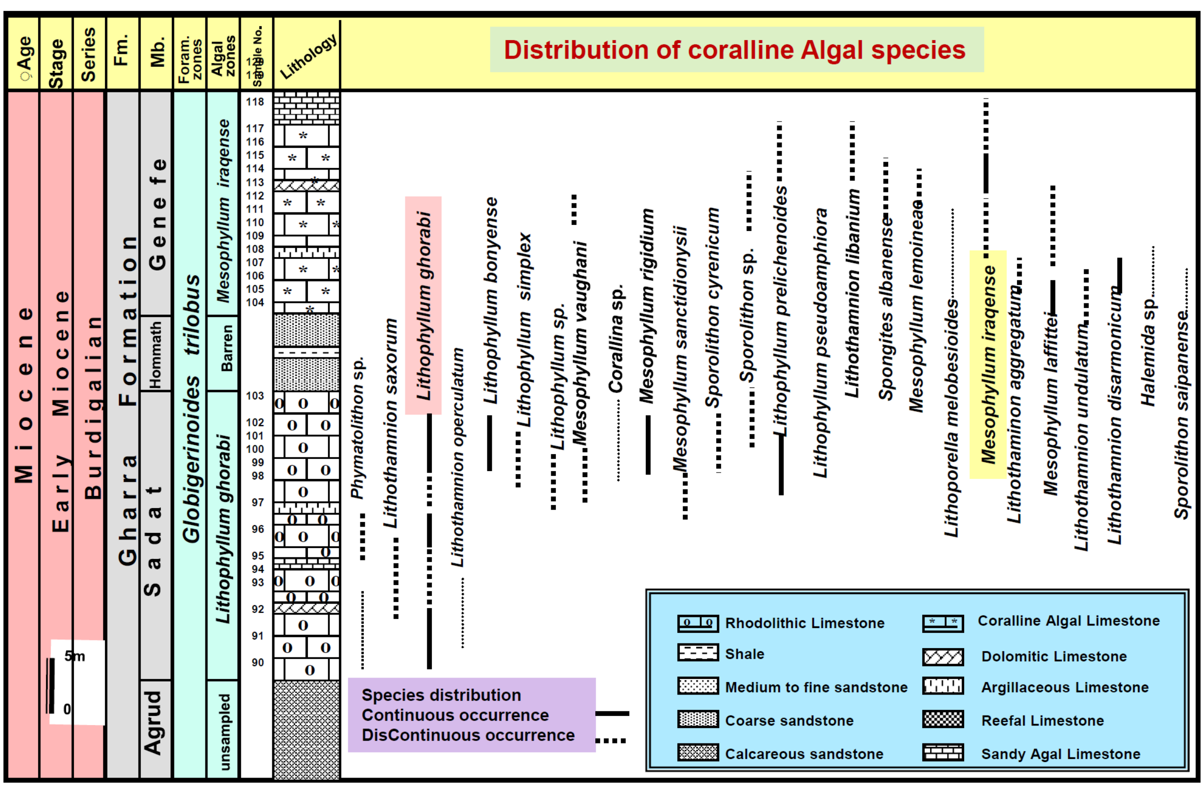

Figure 2. Stratigraphic distribution of the Lower Miocene coralline red algae in Gabal Gharra, Cairo - Suez road, Egypt.

But, it is noteworthy to mention that the shape itself is quite useless as the criterion because certain rhodoliths externally susceptible to rolling and clLower show unidirectional growth, thus evidencing their stability. The shape is also controlled largely by the size of the nucleus that tends to be very large compared to the algal covering. Bosence (1983) mentioned that algal covering and the nucleus as well as the complexity of rhodoliths increase with the increasing of depth. In the field, it is observed that small sizes (2 – 4 cm) and discoidal shape (flat shape) are commonly recorded in Sadat Member of Agrud area denoting low energy and less depth. But the larger sizes (4 – 6 cm) and spheroidal to elliposidal shapes are predominately recorded in the previous member in Gabal Gharra indicating high-energy environments with greater depth.

Massivenss of rhodoliths: concerning this character, there are three types of rhodoliths could be discriminated in the studied materials, they are: (1) porous rhodoliths with great amount of primary growth framework voids between crustose and branching coralline algae (2) massive rhodoliths, compact with low primary porosity and (3) badly preserved rhodoliths with secondary porosity that are transported from other pre – existing rocks especially the Eocene rocks. In the present study the main target will be focused on the first two types as they constitutes the main bulk of the studied samples and also there are clear distinctions between these types also in distribution in their occurrences among the studied samples. The first type commonly occurred in lower Sadat Member and useless in the overlying Genefe Member of Gabal Gharra. Whereas the second type is commonly recorded in the Sadat Member of Gabal Agrud.

Algal species diversity of rhodoliths: This character is depended mainly on the total coralline algal species identified in the studied materials. About twenty-eight coralline algal species have been recognized in Gabal Gharra and about twenty two ones are recorded in Gabal Agrud. There are two remarkable types of rhodoliths on the basis of their algal species diversity.

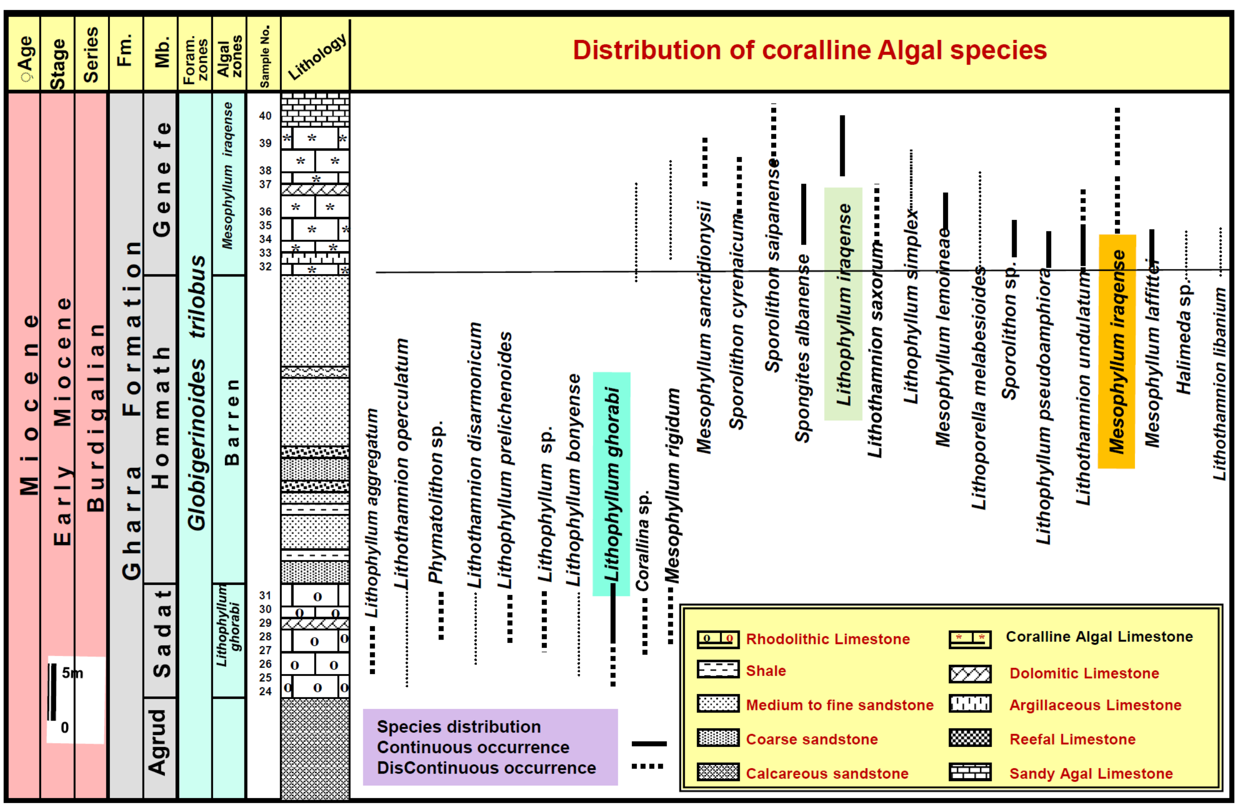

Figure 3. Stratigraphic distribution of the Lower Miocene coralline red algae in Gabal Agrud, Cairo - Suez road, Egypt

The first type is the monospecific rhodoliths that commonly composed of one species such as *Lithophyllum ghorabi* or *Mesophyllum lemoineae* or *Lithophyllum prelichenoides* and this type constitutes rare samples in the studied sections and this type is dominated in Sadat Member of Gabal Agrud. The other type is represented by multispecific rhodoliths (commonly formed of more than one species) and usually dominated with four to five coralline algal species. It usually shows successive different growth stages (laminar / columnar to branching growth forms) of the different algal species. This type is commonly dominated in the Sadat Member of Gharra Formation at Gabal Gharra.

Internal structures of rhodoliths: This factor is of great importance in the whole period of the rhodolith growth stages. Therefore, the degree of the asymmetrical rhodoliths commonly reflects the immobility of the rhodoliths. Two types of internal structure are observed, the first one is the asymmetrical rhodoliths and it is composed mainly of one staged growth (unidirectional growth) built predominantly of laminar coralline algae. This type denoting typical of stable position during the whole period of rhodoliths growth. Several samples of this type are recorded in Gabal Agrud. The other type is the symmetrical rhodoliths and built mainly of multistaged growth zones (laminar to branching / laminar, columnar to branching) and this type indicate low energy conditions where number of species (algal covering) overcome the size of the nucleus and also denoting typical of unstable position during the whole period of rhodoliths growth. This type commonly recorded in the Sadat Member of Gharra Formation in Gabal Gharra.

The thickness of the thallus: Sometimes the algal rhodoliths internally show a different thallus thickness during their growth. The rhodoliths usually exhibit thick thalli followed by thin one in the same structure. Others are composed mainly of thick thallus. The predominance of the thick thalli rhodoliths is more frequent and commonly concentrated in the Sadat and Genefe Membrs of the Gharra Formation of Gabal Gharra. Where in Gabal Agrud, the other type (thin – thalli dominated rhodoliths) is more frequent. This character (the thickness of the thallus) is relatively significant and shape an outstnding role in the formation of rhodoiths. Steneck (1985), Rasser & Piller (2002) and Nebelsick *et al*. (2003) showed that there was a relationship between the environments and the thallus thickness and showed also that thin crusts usually developed and grew faster than thick one.

Epibionts & borings: Most of the studied rhodoliths are externally covered with epibionts such as sepulids, bryozoans (chielostomatous and cyclostomatous) and encrusting larger foraminifers (*Amphistegina* sp. *Miogypsina* sp. and *Heterostegina* sp.) and this character is insignificant in the genesis of the rhodoliths but indicate to great extent the mutual relationship between the rhodoliths growing and the associated microfauna. It is noteworthy of mention that the rhodoliths are more heavily encrusted in the Sadat Member of the Gharra Formation in Gabal Agrud than in Gabal Gharra. The other striking character of the rhodoliths is the boring of other organisms such as the bivalved *Lithophaga* spp. That noted in some of the rhodoliths in Gabal Gharra. This feature suggested periods of non-growing of the rhodoliths. Some authors believe that degree of the perforation is a function for the duration of the exposition (Bosence, 1985, Rasser, 1999, Rasser & Pillar, 2004, Hamd, 2008, 2009; Hamad *et al*., 2015; Renema *et al*., 2015).

Systematic paleontology (description of the main coralline algal taxa)

The terminology according to the revision of Woelkerling, 1988 using "core filaments" instead of “hypothallus” and “peripheral filaments” instead of “perithallus” is adopted. Moreover, the taxonomic features of Braga *et al.* 1993 and the different growth forms of Woelkerling *et al.* 1993, are adopted in the taxonomy and identification of the present fossil material. In the following paragraphs the main characteristic coralline algal species that characterize every morphological type will be discussed from their arrangement and characters of the core filaments and peripheral filaments (shape of cells and their arrangement), shape of the reproductive organs (conceptacles and sporangia) and different growth forms for algal thalli.

Division: Rhodophyta Wettstein, 1901
Class: Rhodophyceae Rabenhorst, 1851
Order: *Corallinales Silva & Johansen,*
Family: Corallinaceae Lamouroux, 1849
Subfamily: *Lithophylloideae Setchell, 1943*
Genus *Lithophyllum* Philippi, 1837

Lithophyllum ghorabi Souaya, 1963.
(Plate 1, Figure 1)

Description: Branching form varying in thickness from 580 – 770 µm, The core filaments is thick (180 –320 µm thick) composed of regular co - axial rectangular cells measuring 11- 27 µm in diameter and 20 – 44 µm in length where the cells becomes smaller toward the peripheries. The peripheral filaments (300 - 430µm) are composed also of rectangular cells measuring 25 – 32 µm in length and 10 - 19µm in diameter. The specimen under consideration resembles to some extent the the thalli of Souaya (1963a) but differs in that it has not reproductive organs (Conceptacles).

Lithophyllum pseudoamphiroa Johnson, 1964
(Plate1, Figure 2)

Description: a single fragment composed of very thick crustose form. The thallus commonly encrusts the other bioclastic constituents. The core filaments (260 – 580 µm thick) is well developed and thick walled. It composed of concentric co -axial arched layers of cells measuring 24 – 41 µm in length and 15 – 21 µm in diameter. Cells become thick in the middle part and thin towards the peripheries. The peripheral filaments are relatively thick (180 – 430 µm thick). The peripheral cells are thick walled also, arranged in rows of grid pattern. Conceptacles are very poorly preserved, no measurements were taken.

Lithophyllum prelichenioides Lemoine, 1917
(Plate 1, Figure 7)

Description: crustose to long branched forms composed of uniform core filaments and variably thick peripheral filaments. The core filaments are composed of regular coaxial cell rows. These cells are 10 –13 µm in length and 15 – 19 µm in diameter. The peripheral filaments consist of rectangular cells. Cells are 15 –23 µm in length and 13 – 17 µm in diameter. Conceptacles are not observed in the studied materials.

Lithophyllum simplex Johnson, 1964
(Plate 2, Figure 3)

Description: Two fragments of thallus composed exclusively of peripheral filaments (300 µm thick) are recorded. Cells are of thick walled, measuring 19 – 23 µm in length and 10 – 13 µm in diameter, arranged in regular rows of fan – like appearance. The core filaments are not developed and if occurred, it shows external layer of small cells that could be interpreted as embryonic peripheral filaments. Conceptacles are not observed in the studied materials.

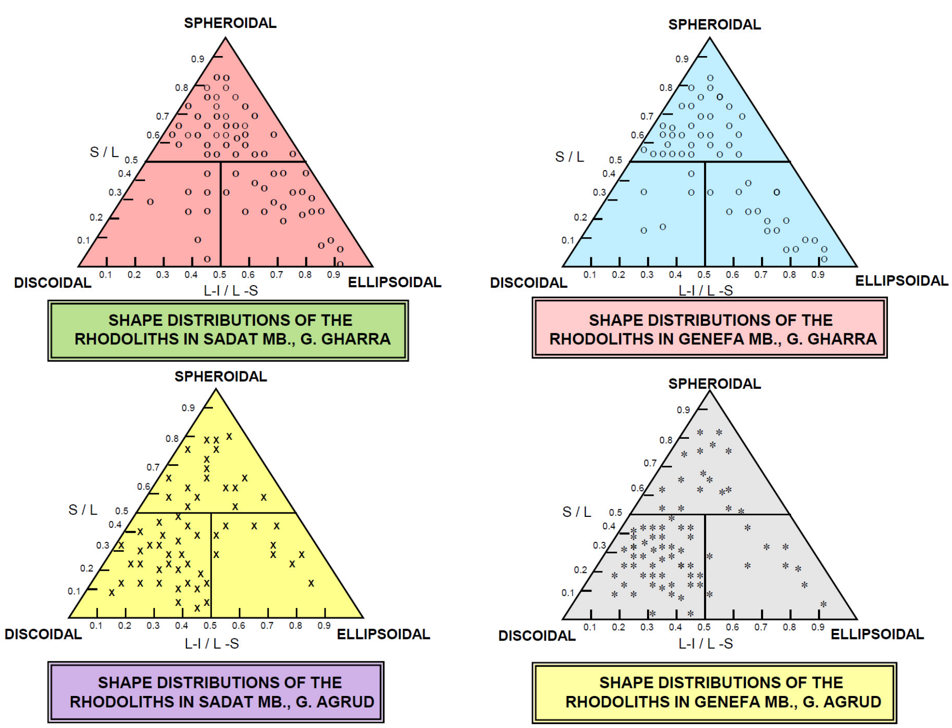

Figure 4. Shape distribution of the rhodoliths populations in Gebel Gharra and Gebel Agrud, Cairo - Suez road, Egypt.

Lithophyllum sp.
(Plate 2, Figure 5)

Description: Crustose thallus with mamillae varies in thickness from 300 to 500 µm, commonly encrusting fragmented corals and bryozoa. The core filaments are thin (150 – 220 µm thick) and composed of concentric coaxial arched layers where the cells become thick in the middle part and thin towards the peripheries. Cells are 15 – 23 µm in length and 9 – 13 µm in diameter. The peripheral filaments are relatively thick (350 – 460 µm) with rectangular cells 12 – 16 µm in length and 10 – 14 µm in diameter. Conceptacles are observed in some thin sections, measuring 240 – 410 µm in diameter and 120 – 180 µm in height.

Subfamily Mastrophoroideae Setchell, 1943
Genus *Lithoporella* (Foslie) Foslie, 1909
Lithoporella melobesioides (Foslie) Foslie, 1909
(Plate 1, Figure 8)

Description: Thick unistratose thallus of multilayered (multiple overgrowth), representing the basal primigenous filaments. The crusts are superimposed on each other, each single layer consisting of large rectangular palisade cell except around the conceptacles where the thalli are thick. Cells are 42 - 58 µm in length and 14 – 23 µm in diameter. The conceptacles are circular measuring 80 – 120 µm in height and 70 – 130 µm in diameter.

Genus *Spongites* Kützing, 1841
Spongites albanense Lemoine, 1924
(Plate 2, Figure 3)

Description: Irregular crustose thalli (0.5 – 1.9 mm thick). Thallus composed of irregular peripheral filaments with rectangular cells measuring 10 – 19µm in length and 9-12 µm in diameter and indistinct basal core filaments with cells measuring 13 – 25µm in length and 12 - 17µm in diameter. Conceptacles are observed measuring 290 – 430 µm in diameter and 160 – 180 µm in height with single short thick opening. This species ascribed before to *Lithophyllum albanense*, but the tissue of this taxon shows clear and abundant cell fusions and therefore belongs to subfamily Mastrophoroideae and not to the Lithophylloideae.

Spongites sp.
(Plate 2, Figure 5)

Description: Crustose thalli encrusting bioclastics and other coralline algae. The core filament unistratose with cells having 15 – 35µm in length and 11 – 22 µm in diameter. The peripheral filaments show cells with irregular cell walls. The cell sizes are 10 –21 µm in length and 10 -17 µm in diameter. The tetra / bisporangial conceptacles uniporate with cylindrical pores. Conceptacles are 250 – 360 µm in diameter and 140 – 150 µm in height.

Subfamily Melobesioideae Bizzorzero, 1897
Genus *Lithothamnion* Heydrich, 1897
(Former name: Lithothamnium Rhilippi, 1837)
Lithothamnion aggregatum Lemoine, 1939
(Plate 1, Figure 3)

Description: Warty to fructicose plants. The protuberances are up to 13 mm long and 4 mm in diameter.

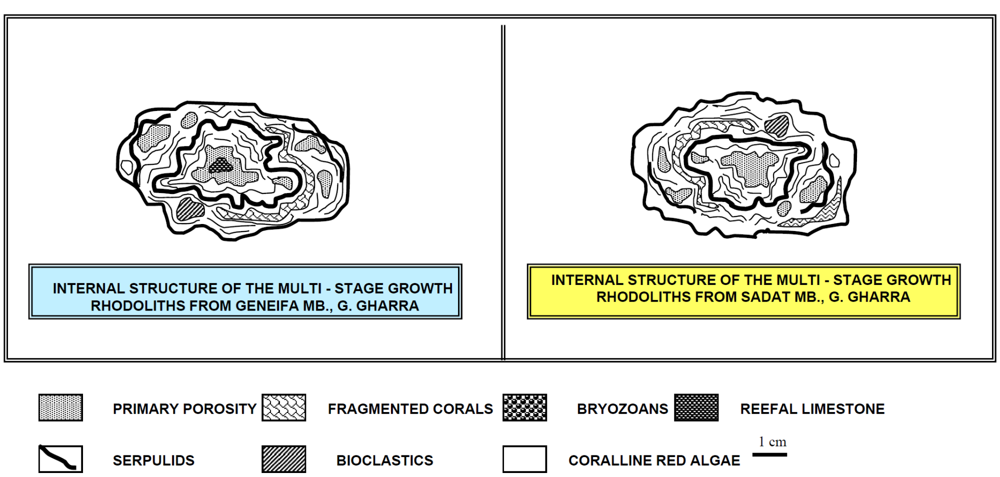

Figure 5. Schematic diagrams showing the internal structure of multi- staged growth rhodoliths, Sadat Member, Gharra Formation, Gebel Gharra

The core filaments are plumose with monomerous thallus. Cells have slightly arched, rectangular shape and measure 7 – 14 µm in diameter and 9 - 22 µm in length. The peripheral filaments are well developed in the form of zonations, consist of irregular lenticular growth zones. Cells are 7 – 10 µm in diameter and 9- 12 µm in length.

Lithothamnion operculatum Conti, 1950
(Plate 1, Figure 5)

Description: Crustose thalli mammillae. The core filaments are thin to modertaely developed, usually absent consisting of rounded to nLower rectangular cells measuring 11 – 16 µm in length and 8 –11 µm in diameter. The peripheral filaments consist of irregular growth zones. Cells arranged in fairly regular vertical rows. They are 8 – 18 µm in diameter and 9- 15 µm in length. Conceptacles are wide and flat, abundantly occurred, measuring 190 – 500 µ in diameter and 110 – 140µ in height.

Lithothamnion saxorum Capeder, 1900
(Plate 2, Figure 6)

Description: Crustose thalli of plumose basal core filaments and well-developed peripheral filaments. The core filaments consist of upward curved cell rows of rectangular shape measuring 12 – 27 µm in length and 10-15 µm in diameter. The peripheral filaments are composed of regular tissue with pronounced vertical cell threads and growth zones. Cells are 10 – 18 µm in length and 7-11 µ in diameter. Conceptacles are rare and measure 260 – 320 µm in diameter and 110 - 140 µ in height.

Lithothamnion undulatum Capeder, 1900
(Plate 2, Figure 7)

Description: Thalli in the form of crusts with warty protuberance of undulating appearance or branches. The basal core filaments predominantly curve towards the dorsal. The core portion is relatively thin 50 – 90 µm. Cells are 7 – 12 µm in diameter and 10 - 15 µm in length. The peripheral filaments show tissue of well developed, contorted appearance and lenticular growth zones. Conceptacles abundant, strongly varied in shape and size. Most frequently ellipsoidal, 290 – 420 µm in diameter and 140 – 170 µm in height

Genus *Mesophyllum* Lemoine, 1928
Mesophyllum iraqense Johnson, 1964
(Plate 2, Figure 8)

Description: Simple crusts provided with short mamillae or short massive columns, or long slender branches. The core filaments consisting of cells measuring 7 – 11 µm in diameter and 15 - 22 µm in length.

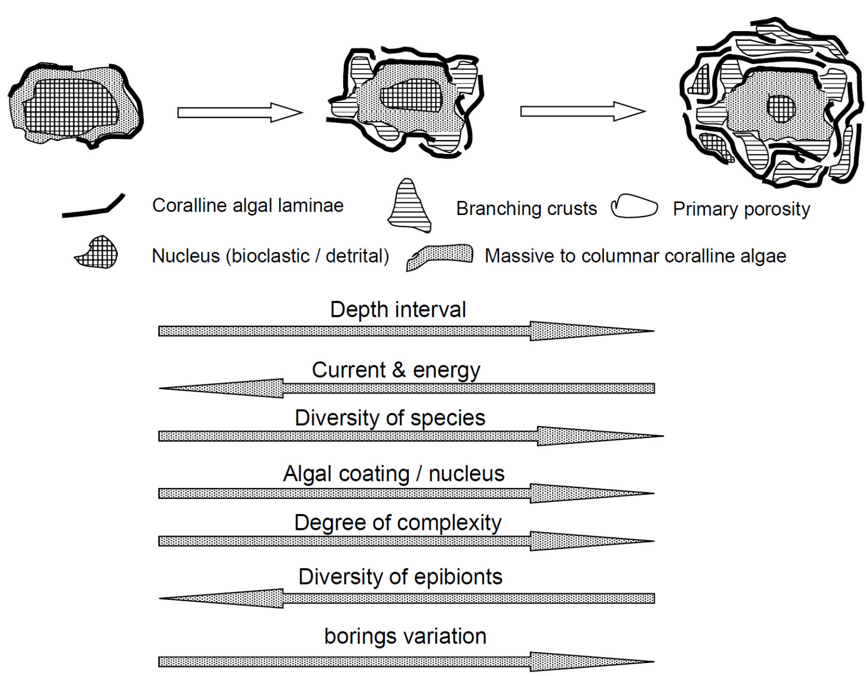

Figure 6. Conceptual model for rhodolith development in both Gabal Gharra and Gabal Agroud, Cairo - Suez road, Egypt. Modified from Braga & Martin (1989)

The marginal peripheral filaments are sometimes worn with rare conceptacles of minute sizes. The cells of the peripheral filaments are 9 – 13 µm in diameter and 15 - 20 µm in length. This species is commonly recorded in the studied materials and contributes in the forming of the rhodoliths.

Mesophyllum lemoinaea Souaya, 1963
(Plate 2, Figure 4)

Description: Thallus crustose, relatively thin, commonly 300 – 500 µm thick. The core filaments are poorly developed with cells not arranged in regular rows and gradually passing to the peripheral filaments. Irregularly peripheral filaments often lenticularly owing to the presence of conceptacles. Their cells are 7 – 11 µm in diameter and 15 - 22 µm in length. Conceptacles embedded and distributed in the peripheral part of the growth zone in the peripheral filaments they are measuring 240 – 430 µm in diameter and 130 – 190 µm in height. This species sometimes grow freely over the other coralline algae with alternative layers of *Lithoporella* spp. and bryozoans.

Mesophyllum sanctidionysii Lemoine, 1939
(Pl. 2, Fig. 2)

Description: Several mammillae crusts composed of partly developed core filaments and strongly zoned peripheral filaments with numerous conceptacles. The cells of the core filaments are 8 – 10 µm in diameter and 15 - 18 µm in length. The peripheral filaments are composed of strong lenticular growth zones with cells measuring 8 – 12 µm in diameter and 17 - 21 µm in length. Conceptacles embedded in the center of each growth zone, measuring 220 – 400 µm in diameter and 140 – 180 µm in height.

Mesophyllum rigidum Mastrorilli, 1967
(Pl. 1, Fig. 6)

Description: Thallus forming mammillate crusts with short stubby branches. The core filaments is basal and zoned with rectangular cells having sizes 23 – 38 µm in length and 10 - 12 µm in diameter. The peripheral filaments with strong lenticular growth zones composed of subquadrate cells 8 – 12 µm in length and 10 – 12 µm in diameter. Conceptacles are large, multipored, commonly oval in section, measuring 340 – 580 µm in diameter and 160 – 240 µm in height.

Mesophyllum vaughani (Howe), Lemoine, 1928
(Pl. 2, Fig. 1)

Description: Regular spine like branch composed of completely of peripheral filaments with strong irregular growth zones. The zonal boundaries are almost never parallel to each other. The peripheral filaments composed of subquadrate cells with no conceptacles. Cells are most commonly 8 – 12 µm in diameter and 15 - 19 µm in length

Family Sporolithaceae Verheij, 1993
Genus *Sporolithon* Heydrich, 1897
(Former name: *Archaeolithothamnium* Rothpletz, 1891)
Sporolithon sp.

Description: Crustose dorsiventeral and monomerous thalli with rounded protuberance measuring 180µm in height. The ventral core filaments is commonly thin plumose with cell filaments measuring 14 – 23 µm in length and 10 – 12 µm in diameter. The peripheral filaments are usually regular 15 – 27 µm in length and 10 - 13 µm in diameter, where cell fusion are scarce. Tetra / biosporangial conceptacles arranged in sori , the sori consists of 14 – 35 tetra / biosporangia that sometimes arise from layer of elongated cells. The shape of conceptacles are elongated ellipsoidal measuring 100 – 120 µm in height and 50 – 75 µm in diameter.

Subfamily Corallinoideae Foslie,1898
Genus Corallina Linnaeus, 1759
Corallina sp.

Description: several fragments of segmented stems are observed (300m thick) composed exclusively of core filaments, cells are 40 – 55µm in length and 8 –14µm in diameter. Peripheral filaments weakly developed on the margins of segments. Conceptacles are not observed in the present specimens.

Phyllum: Chlorophyta Pasher, 1914
Class: Cholorophyceae Kutzing, 1843
Order: Siphonals Wille, In Warming, 1884
Family: Codiaceae Zanardini, 1843
Genus: *Halimeda* Lamouroux, 1812
Halimeda sp
(Pl.1, Fig. 4)

Description: Thallus strongly branched and calcified with elliptically elongated segments of about 0.5 to 1.9 mm in diameter and 1.5 – 2.6 mm in length. Filaments slightly oblique with non – distinctive layers.

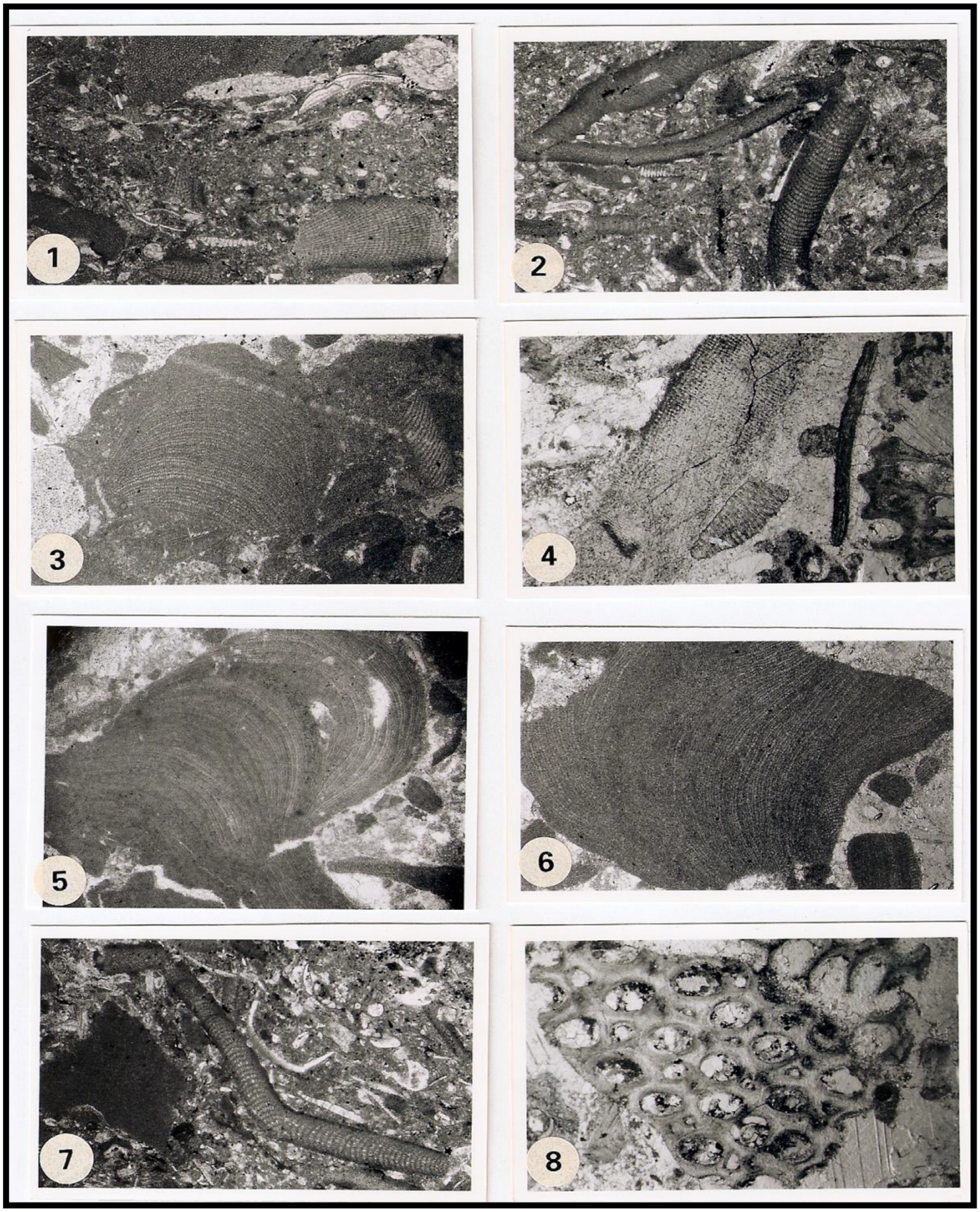

Plate 1. Fig. 1. Lithophyllum ghorabi Souaya, Single branche showing coaxial core filaments embedded in micrite matrix, sample 103, Sadat Mb., Gharra Fm., Gabal Gharra, x80. Fig. 2. Lithophyllum pseudoamphiora Johnson, coaxial core filaments, sample 95, Sadat Mb., Gharra Fm., Gabal Gharra, x60. Fig. 3. Lithothamnium aggregatum Lemoine, warty protuberance of peripheral filaments, sample 40, Sadat Mb., Gharra Fm., Gabal Gharra, x80. Fig. 4. Halimeda sp. layers of palisads cells with circular conceptacle, sample 83, Sadat Mb., Gharra Fm., Gabal Gharra, x50. Fig. 5. Lithothamnium operculatum Lemoine, warty protuberance of peripheral filaments with conceptacle, sample 40, Sadat Mb., Gharra Fm., Gabal Gharra, x80. Fig. 6. Mesophyllum rigidum Mastrorilli, Peripheral filaments showing oval - shaped conceptacles in irregular grid peripheral thalli, sample 28, , Sadat Mm., Gharra Fm., Gabal Agrud. Fig. 7. Lithophyllum prelichenoides Johnson, branche of coaxial core filaments, sample 95, Sadat Mb., Gharra Fm., Gabal Gharra, x60. Fig. 8. Lithoporella melabesioideae (Foslie) Foslie, encrusting dimerous layers of palisads cells with circular conceptacle, sample 83, Sadat Mb., Gharra Fm., Gabal Gharra, x50.

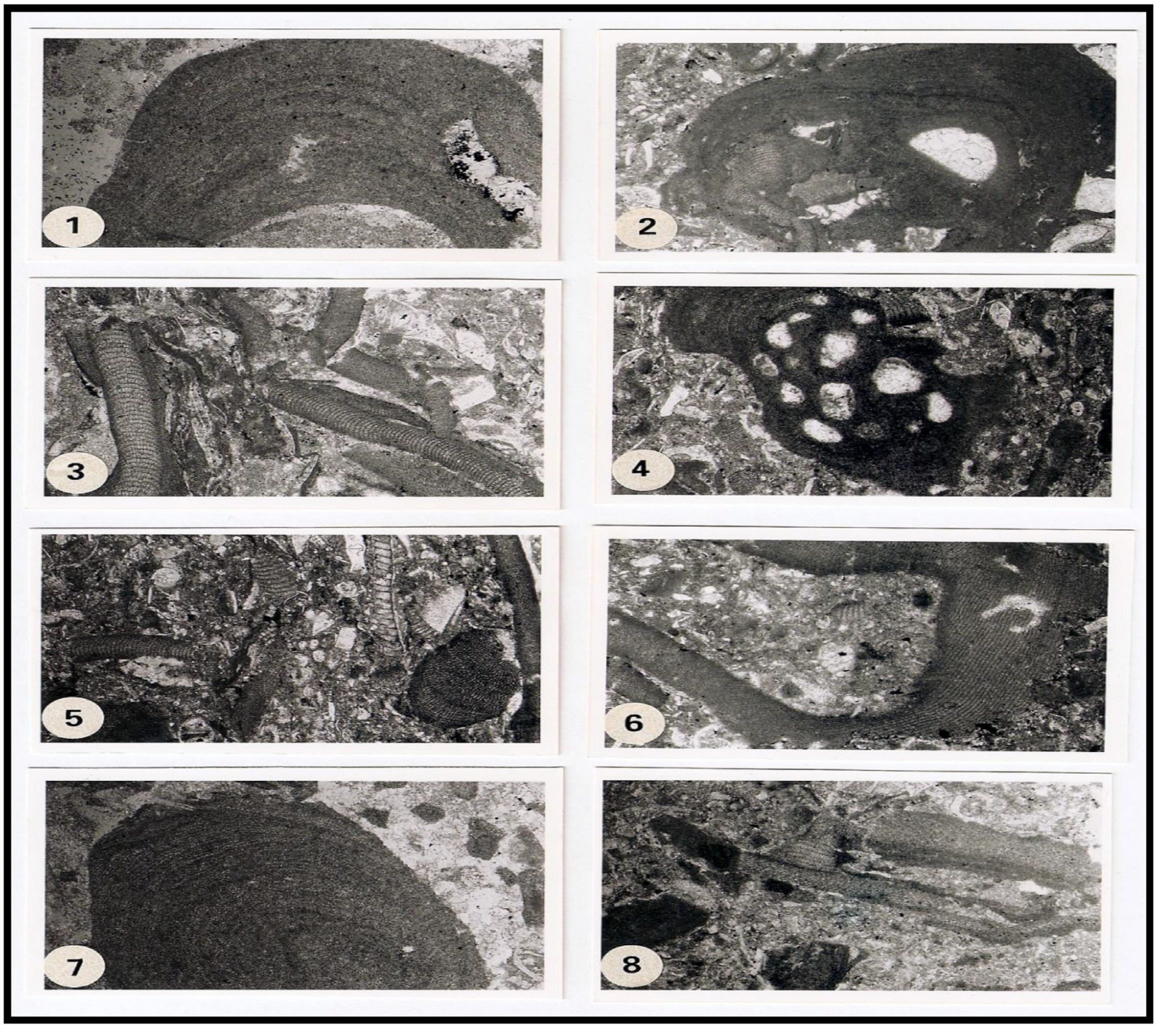

Plate 2. (All the figured specimens are magnified as x50, unless otherwise noted), Fig. 1. Mesophyllum vaughani (Howe) Lemoine, Warty protuberance of poorly developed core filaments at base with peripheral filaments, sample 98, Sadat Mm., Gharra Fm., Gabal Gharra. Fig. 2. Mesophyllum sanctidionysi Lemoine, long branch protuberance with large conceptacles, sample 98, Sadat Member, Gharra Formation, Gabal Gharra. Fig. 3. Spongites albanensis (Lemoine), Bifurcating layered to foliose crusts of Peripheral filaments showing bean - shaped conceptacles in irregular grid, sample 103, Sadat Mm., Gharra Fm., Gabal Gharra. Fig. 4. Mesophyllum lemoine Lemoine, long branch protuberance with large conceptacles, sample 98, Sadat Member, Gharra Formation, Gabal Gharra. Fig. 5. Spongites sp., Peripheral filaments showing bean - shaped conceptacles in irregular grid, sample 103, Sadat Member, Gharra Formation, Gabal Gharra. Fig. 6. Lithothamnion saxorum Capeder, postigenous filaments with conceptacle, sample 69, Sadat Mb., Gharra Fm., Gabal Agrud, x60. Fig. 7. Lithothamnion undulatum Capeder, fragement of branche thalli showing protuberance with conceptacle, sample 69, Sadat Mb., Gharra Fm., Gabal Agrud, x60. Fig. 8. Mesophyllum iraqense Johnson, warty protuberance of coaxial core filamnets and outer peripheral filaments, sample 103, Sadat Member, Gharra Formation, Gabal Gharra. Lithophyllum bonyense Johnson, branched to columnar thalli showing thin monomerous thin thalli, sample 93, Sadat Mb., Gharra Fm., Gabal Gharra, x40

Summary and cnclusions

The study of the coralline red algae from the Lower Miocene deposits of both Sadat and Genefe members of the Gharra Formation in two stratigraphic sections namely Gabal Gharra and Gabal

Agrud, Cairo – Suez District, led to the recognition of twenty four coralline algal species belonging maily to nine genera and two subfamilies of the Phyllum Rhodophyta. The recognized species have been taxonomically studied and their occurrence is also mentioned. The Lower Miocene rhodoliths from both Gabals Gharra and Agrud were formed in an open platform environments subjected to the influence of sporadic storms. Internally, the rhodoliths are composed of delicate laminar coralline growths that are predominant together serpulids, bryozoans, and encrusting foraminifers. The algal association comprises the following genera: *Lithophyllum, Lithothamnion, Mesophyllum* and rare *Sporolithon, Spongites and Lithoporella.* The investigations showed that the most dominant genera are *Lithophyllum* spp. and represented maily by *Lithophyllum ghorabi, Lithophyllum prelichenoides, Lithophyllum pseudoamphiora* and *Lithophyllum* sp. These species are occurred encrusting different skeletal fragments such as large foraminifera, coral fragments and other reworked coralline red algae. Concerning the relative abundance of the other genera, *Lithothamnion* spp. and *Mesophyllum* spp. are recorded in more or less frequencies. They represented mainly by *Lithothamnion saxorum, Lithothamnion saipanense, Mesophyllum lemoineae, Mesophyllum laffittei, and Mesophyllum sanctidyonesii*. The Sporolithons spp. are rarely occurred in the studied materials and reprsented by few species such as *Sporolithon cyrenicum and Sporolithon sp*. The monostromatic *Lithoporella* sp. is commonly recorded. The geniculate coralline algae are represented by *Corallina* sp. only where the green algae of the family Codiaceae is rarely recorded being represented by only one genus, *Halimeda* sp. The stratigraphic distribution of the identified species led to subdivide the Lower Miocene section into two main local coralline algal zones, from base to top: *Lithophyllum ghorabi* Zone and included the Sadat Member while the other zone is *Mesophyllum iraqense* and covered the Genefe Member.

The study also showed that five factors contributing the formation rhodoliths and their coralline algal thalli, among them are the shape, size, massiveness, and internal structures of the rhodoliths, algal species diversity and the thallus thickness as well as the predominance of epibiont and borings. A comparison of the two the analyzed rhodoliths populations from the Lower Miocene deposits in both of the studied two sections shows common features, but also of significant differences. The most significant differences are: The rhodoliths populations of Gabal Gharra formed under low energy conditions (quite water environments) and characterized by porous rhodoliths with higher primary porosity, less frequent epibionts, more boring and thick coralline algal thalli as well as greater asymmetry. On the contrary, in Gabal Agrud the analyzed rhodoliths population were formed in high energy conditions of shallow water marine environments and characterized by more mobile, symmetrical rhodoliths, more frequent of epibiont, thin coralline thalli.

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References

Abdallah, A. M., Abdel Hady, F. M. 1968. Geology of Sadat area, Gulf of Suez. Journal of Geology of the United Arab Repulic, 10 (1): 1 –22.

Abdel Ghany, O., 2003. Lower Miocene startigraphy of the Gabal Shabrawet area, North Eastern Desert, Egypt. Journal of African Earth Sciences, 34: 203–212

Abdel Ghany, O., Piller, W. E., Toleiks, R., 1996. Nummulitide Foraminiferen (gattung: Planostegina) im Unter – und Mittle Miozaen der Paratethys und des mediterranen Raumes. Sediment96, Sedimenttologentreffen, 1, Wien, 11p.

Adey, W. H., MacIntyre, I. G., 1973. Crustose coralline algae: A re – evaluation in the geologic sciences. Geological Society of American Bulletin, 84: 883 – 904.

Al Ahawani, M. M., 1977. Geology and sedimentology of the eastern part of Cairo – Suez district (Agroud area). M. Sc. Thesis, Faculty of Science, Cairo University, 240p.

Bassi, D., 1995. Curstose Coralline algal pavement from Late Eocene, Colli Berici of Northern Italy. Riv. Italiana Paleont. Strat. , 101: 81 – 92.

Bassi, D., 1998. Coralline algal facies and their paleoenvironments in the Late Eocene of Northern Italy. Facies, 39: 179 – 202.

Basso, D., Fravega, P., Vanucci, G. 1997. The taxonomy of Lithothaminum ramossimum (Gumbel non Reuss) Conti and Lithothamnium operculatum (Conti) Conti (Rhodophyta, Corallinaceae). Facies, 37: 167 – 182.

Berggren, W. A., Kent, D. V., Swisher, C. C., Aubry, M. P. 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W. A., Kent, D. V., Aubry, M. P., & Hardenhol, J. Eds. , Geochronology, time scales and Golbal stratigraphic correlation: SEPM Special Publication, 54: 129 – 212.

Bosence, D. W. J., 1983. Coralline algae from the Miocene of Malta. Paleontology, 26 (1): 147 – 173.

Bosence, D. W. J., 1990. Coralline algae: mineralization, taxonomy and paleocology. In: Riding, J. (ed.). *Calcareous Algae and Stromatolites*. Springer Verlag, Heidelberg.

Braga, J. C., Martin, J. M., 1988. Neogene coralline red algal growth forms and their paleoenvironments in the Almanzora river valley (Almeria, Spain). Paleogeogr., Paoeclimatol., Paleecol., 67: 285 – 305.

Buchbinder, B., 1987. Systematic and paleoenvironments of the calacreous algae from the Miocene deposits of Israel. Marine Micropaleontology, 42 (2): 321 – 342.

Capeder, G., 1900. Caperder, Contribuzione alio studio dei Lithothamnion terziari. Malpighia, 14: 172–182, pl. 6.

Cherif, O. H. 1966. Geology of the Sadat area, southwest of Suez, Egypt. M. Sc. Thesis, Ain Shams, 242p.

Cherif, O. H. 1, Yehia, M. A. 1977. Stratigraphy of the area between Wadi Gimal and Wadi Hommath, Gulf of Suez, Egypt. Egyptian Journal of Geology, 21 (2): 185 – 202.

Conti, S., 1945. Le Corallinacee del calcare miocenico (Leithakalk) del bacino diVienna.-Inst. Geol. Univ. Genova Pub. Quad., 1-2, ser. A, 1-68

Edgell, H. S., Basson, P. W., 1975. Calcareous algae from the Miocene of Lebanon. Micropaleontology, 21 (2): 165 – 184.

El Gamal, M. M., 1971. Paleontoloical and Stratigraphical studies on some Miocene reefal facies in Egypt with special emphasis on the calcareous algae. Ph. D. Thesis, Faculty of Science, Cairo University, 209p.

El Sayed, A. A. Y, Fahmy, S. E., Imam, M. M., 1988. Startigraphy and microfacies of the Miocene sequence at Gabal Sarbut El Gamal, West - Central Sinai, Egypt. N. Jb. Geol. Palaeont. Abh., 177 (2): 225 – 242.

Farag, I. A. M. & Sadek, A., 1968. Stratigraphy of Gabal Homeira area, Cairo – Suez district. Journal of Geology of the United Arab Repulic, 10 (2): 107 – 124.

Ghorab, M. A., Marzouk, I. M., 1967. A summary report on the rock stratigraphic classification of the Miocene non – marine and coastal facies in the Gulf of Suez and Red sea coast. Internal Report 601, General Petroleum Company, Cairo.

Gischler, E., Pisera, A., 1999. Shallow water rhodoliths from Belize reefs. N. Jb. Geol. Palaont. Abh. , 214 (1/2): 71-93, Stuttgart.

Hamad, M.M. 2008a. Foraminiferal biostratigraphy of Lower Oligocene – Middle Miocene sequence in Banighazi area, Northeastern Libya. Egyptian Journal of Plaeontology, 8: 87 – 111

Hamad, M. M., 2008b. Coralline red algae from the Lower Miocene Wadi Wizer, Red Sea area, Egypt. International Journal of Algae. 10 (2): 83 -110.

Hamad. M. M., 2009. Coralline red algae and Foraminiferal biostratigraphy from the Lower Miocene Sadat Formation, Sadat area, Northwest of the Gulf of Suez, Egypt, Egyptian Journal of Paleontology, 9: 183 – 212.

Hamad. M. M., 2013. Biostratigraphy and paleoecology of the Miocene sequence along the stretch of Qabilt ash Shurfah to Wadi Zaqlum sections, Sirte Basin, Libya. Australian Journal of Basic and Applied Sciences, 7(10): 513-531.

Hamad, M. M., El Gammal, R., Maryam, N. 2015: Coralline Red Algae from the Lower Miocene Qom Formation, Bagh Section, Northern Isfahan, Iran. Australian Journal of Basic and Applied Sciences, 9(33): 467-480.

Hamam, K. A. 1966. Stratigraphy and Paleontology of the area south west of Suez. M. Sc. Thesis, Faculty of Science, Ain Shams University, Cairo, 199p.

Hamza, F. H., 1992. Contribution to the Neogene biostratigraphy of the eastern part of Egypt. Middle East Research Center, Ain Shams University, Earth Science Series 6: 151 – 166.

Hermina, M., Klitzsch, E., and List, F. K. (1989). Stratigraphic Lexicon and Explanatory Notes on the Geologic map of Egypt 1: 500.000 – Conco Inc., 263p.

Imam, M. M., 1991. Geological studies on the Miocene sequence in the area between Wadi El Tayiba and Wadi Sidri, West – Central Sinai, Egypt. Unpublished Ph. D. Disseration, Faculty of Science, Cairo University, Egypt, 265p.

Imam, M. M., 1996. Coralline red algae from the Middle Miocene deposits of Gabal Gushia, West – Central Sinai, Egypt. N. Jb. Geol. Palaont. Abh., 199 (1): 1-15, Stuttgart.

Imam, M. M., 1997. Planktonic foraminiferal biostratigraphy of the Miocene Sequence in the area between Wadi El Tayiba and Wadi Sidri, West - Cenrtral Sinai, Egypt. Journal of African Earth Sciences, 25 (3): 435 – 451.

Imam, M. M., 1999a. Lithostratgraphy and planktonic foraminiferal biostratigraphy of the Late Eocene – Middle Miocene sequence in the area between Wadi Al Zeitun and Wadi Al Rahib, Al Bardia area, northeast Libya. Journal of African Earth Sciences, 28 (3): 619 – 639.

Imam, M. M., 1999b. Lithostratgrphy, microfacies and depositional environments of the Miocene Sequence in the area between Wadi El Tayiba and Wadi Sidri, west cenrtral Sinai, Egypt. N. Jb. Geol. Palaont. Abh. 7: 409 – 439.

Imam, M. M., Refaat, A. A., 2000. Stratigraphy and Microfacies analysis of the Miocene Sequence in the area between Gabal Hammam Sayidna Musa and Wadi Abura, southern Sinai, Egypt. N. Jb. Geol. Palaont. Abh. 7: 385 – 409.

Johnson, J. H. 1964. Miocene coralline algae from northern Iraq. *Micropaleontology*, 10 (4): 477 – 485.

Johnson, J. H. 1965. Tertiary red algae from Borneo. Bull. British Mus (Natural History), Geology, 11 (6): 257 – 280.

Kumar, G, Ajanta, S., Suman, S., 2014. Diversity of Middle Eocene Coralline Red Algae from the Prang Limestone

(Shella Formation) of Jaintia Hills, Meghalaya, NE Himalaya, India with special emphasis on palaeoenvironment Chinese Science Bulletin ·58 Suppl. I : 118‒125

Kundal, M. P. and Humane, S. K. (2012): Geniculate coralline algae from the Lower Miocene Godhra Formation of the Kachchh offshore basin, western India. Jour. Pal. Soc. India, 57: 143-151.

Kundal, P., Milind P., Humane, S. K. 2016. Nongeniculate Coralline Algae from Lower Middle Miocene Offshore Sequence of Kachchh Basin, Western India: Paleoenvironmental Significance. Journal Geological Society of India*,* 88: 39-46.

Kützing, M., 1841. The crustose Corallinaceae. Oceanogr. Mar. Biol., Ann. Rev., 1: 31-37, table 1.

Lamouroux, M., 1816. Structure anatomique des Melobesiees. Application a laclassification. Monaco, Inst. Oceanogr., Ann., 2 (2): 1-21 5, pls. 1-5, text-figs. 1–105.

Lemoine, M. P., 1917. Contributionsa I'etude des Corallinacee sfossiles. IV.Surlapresence de Lithophyllum amphiroaeformis Rothpl. dansI'Albien de Vinport (Landes). Soc. Geol. France, Bull., ser. 4, 17(3-5): 280-283.

Littler, M. M., Littler, D. S., Hanisak, M. D. 1991. Deep water rhodoliths distribution, productivity, and growth form history at sites of formation and subsequent degradation. Jorunal of Marine Biology and Ecology, 150: 163 – 182.

Mastrorilli, 1967. Nuovo contribute a110 studio delle Corallinacee dell'Oligocene LiguroPiemontese: i reparti della Tavoletta Ponzone.-Ibidem, 5 (2): 153406.

Metwalli, M. H. 1963. The study of some Miocene sediments in the Cairo – Suez district- M. Sc. Thesis, Faculty of Science, Cairo University, 198p.

Montaggioni, L. F. 1979. Environmental significance of the rhodolites from the Mascarene reef province, Western Indian Ocean. Bull. Centr. Rech. Explor. – Prod. Elf Aquitaine, 3: 713 – 723.

Moussavian, E., Kuss, J., 1990. Typification and status of *Lithothamnium aschersonii* Schwager, 1883 (Corallinaceae, Rhodophyta) from the Paleocene limestones of Egypt. A contribution to the synonymy and priority of the genera *Archeolithothamnium* Rothpletz and *Sporolithon* Hedydrich. Berliner geowissenschaftliche Abhandlungen, 120: 929 – 943.

Nebelsick, J., Kroh, A. 2002. The stormy path from life to death assemblages: The Formation and preservation of Mass accumulations of fossil sand dollars. *Palaios*, 17: 378 – 393.

Nebelsick, J., 1992. Echinoid distribution by fragment identification in the Northern Bay of Safaga, Red Sea. Palaios, 7: 316 – 328.

Nebelsick, J., Rasser, M. W., Bassi, D., 2003: The Development of Facies Patterns of Middle Eocene to Lower Oligocene Circum-Alpine, Shallow Water Carbonate Environments. In: Prothero, D.R. (ed.) Greenhouse to Icehouse: The Marine Eocene-Oligocene Transition (Columbia Univ. Press).

Rasser, M. W. & Piller, W. E., 2004. Crustose algal frameworks from the Eocene Alpine Foreland. Paleogeography, Paleoclimatology, Paleoecology, 206: 21–39.

Rasser, M., Piller, W. E., 1994. Re- documentation of Paleocene coralline red algae of Austria, described by Lemoine (1930). Beitrage zur Palaontologie, 19: 219 – 225.

Renema, W., Warter, V., Novak, V., Young, Y., Marshall, N., Hasibuan, F., 2015: Age of Miocene fossil localities in the Northern Kutai Basin (East Kalimantan, Indonesia): Palaios, 30: 26–39.

Rosler, A; Vedrana, P., Novak, V., Willem, R. & Braga, J. C., (2015): Coralline algae from the Miocene Mmahakam Delta (East Kaliman tan, Southea st Asia), Palaios, 30: 83–93

Sadek, H. 1959. The Miocene in the Gulf of Suez region, Egypt. Geological Survey of Egypt. 8: 1 – 18.

Said, R., 1990. Cenozoic. In: Said, R. (Ed.), the Geology of Egypt. A. A. Balkema, Rotterdam, pp. 451 – 486.

Said, R., Metwalli, H., 1966. Foraminifera of some Miocene sediments of the Cairo – Suez District – Egyptian Journal of Geology, 7 (1): 29 – 65.

Souaya, F. J. 1963a. On the Foraminifera of Gabal Gharra (Cairo – Suez District) and some other Miocene samples, Journal of Paleontology, 37 (2): 433 – 457

Souaya, F. J. 1963b. Micropaleontology of four sections south of Qusier, Egypt, Micropaleontology, 9 (3): 233 – 266.

Souaya, F. J. 1963c. On the calcareous algae (Melobesoideae) of Gabal Gharra (Cairo – Suez District) with local zonation and some possible correlations. Journal of Paleontology, 37 (6): 1204 – 1216.

Steneck, R. S., 1985. Adapation of crustose coarlline algae to herbivory: patterns in space and time, In: Toomey, D. F. & Nitecki, M. H. (eds.), Paleoalgology Contemporary research and applications, 352 – 366, Springer Verlag, Berlin.

Verhij, E. 1993. The genus *Sporolithon* (Sporolithaceae fam. Nov., Corallinales, Rhodophyta) from the Spermonde Archipelago, Indonesia. Phycologia, 32: 148 – 196.

Wehrmann, A., Freiwals, A. & Zanki, H. 1995. Formation of cold – temperature water multispecies rhodoliths in intertidal gravel pools from Northern Brittany, France. Senckenbergiana maritima 26 (1&2): 51 – 71. Frankfurt.

Wettstein, V. A., 1901. The Corallinaceae of the Siboga Expedition. Siboga Exped., Monogr., 61: 1-110, pls. 1–16.

Woelkerling, W. J. 1988. *The Coralline Red Alage:* An Analysis of the Genera and subfamilies of the Nongeniculate Corallinaceae. Oxford University Press, 268pp.

Woelkerling, W. J., Irvine, L. M., Harvey, A. S., 1993. Growth forms in non - geniculate coralline red algae (Corallinales, Rhodophyta). *Austeralian Systematical Botany*, 6: 277 –293.
Wray, J. L., 1977. *Calcareous algae*. Elsevier Pub. Company, Amsterdam. 185pp.