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Pleistocene coral reefs of southern Sinai, Egypt: Fossil record, facies analysis and diagenetic alterations

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ABSTRACT. *The Pleistocene coral reefs of southern Sinai constitute three reef units. They exhibit different elevations above the present sea level and occur predominantly in narrow outcrops, in which the vertical succession of facies can be studied. 30 scleractinian, 7 gastropod, 10 bivalve and 3 echinoid species were identified. Four microfacies types were recorded, ranging from wackestone to boundstone. Semiquantitative distribution of identified fauna and quantitative composition of skeletal and non-skeletal grains in the three reef units are documented. The quantitative composition of skeletal grains from thin sections indicates upward gradual reduction in the number of biota. The aragonitic biotas were particularly altered either by partial or complete leaching with subsequent or concomitant calcite precipitation or neomorphism.*
Carbon and oxygen isotope values of samples from the studied reefal units indicate that dolomite was formed as cement from marine and meteoric waters in a mixing zone.
Scleractinian corals and the associated fauna as well as facies distribution suggest that the Pleistocene coral reefs of southern Sinai were formed on the upper reef slope and in lagoonal and beach environments.

INTRODUCTION

Southern Sinai is a triangular area which borders the Gulf of Suez and Aqaba and faces the Red Sea. It is located at the triple junction between the African plate, the Arabian plate and the Sinai subplate.

The coral reefs in the Gulf of Aqaba are amongst the northernmost reefs in the world. Many studies have been carried out on ecology, morphology, sedimentary facies, systematics and growth history of the modern fringing coral reefs along Sinai coasts (Walther 1888, Hume 1906, Friedman 1968, Loya & Slobodkin 1971, Mergner 1971, Mergner & Schuhmacher 1974, Gvirtzman & Buchbinder 1978, Sheppard & Sheppard 1991, Heiss et al. 1993). Other studies on diagenesis, dating and sedimentology of the Pleistocene coral reefs have been carried out by Goldberg (1970), Nir (1971), Gvirtzman & Friedman (1977), Abou Khadra & Darwish (1988), Al-Rifaiy & Cherif (1988), Youssef (1988), Gvirtzman et al. (1992), Strasser et al. (1992) and ElAsmar & Attia (1996).

The marine terraces along the Red Sea coast and the Gulf of Aqaba exhibit different elevations above the present sea level (Cimiotti 1980, Hotzl et al. 1984, Al-Rifaiy & Cherif 1988, Dullo 1990). In the Gulf of Aqaba, these terraces form narrow outcrops in which the vertical succession of facies may be studied (Dullo 1990), in contrast to the Red Sea where the terraces are wider and thus suitable for lateral facies study (El-Sorogy 1994).

The ages obtained by Th/U method enable comparing the coral reef sequence in Sinai to the global oxygen isotope stages (Chappell & Shackelton 1986) as well as to the classical models of Quaternary sea-level oscillations developed from Barbados (Mesolella et al. 1969) and New Guinea (Bloom et al. 1974).

The purpose of the present study is to investigate the scleractinian corals and associated fossils, facies and diagenetic alterations of the Pleistocene reefs of southern Sinai, Egypt.

MATERIALS AND METHODS

The study area lies along the Sinai coast between Ras Mohamed and Taba. Four representative stratigraphic sections have been measured at Ras Mohamed, Umm Sid, Shark Bay and Wadi El-Malaha (Fig. 1). Samples from the different reef terraces were taken. 82 thin sections were prepared to establish the quantitative composition of skeletal and nonskeletal grains (point counting) and to examine microfacies associations. Most of the samples are very porous and therefore were impregnated with a hardening agent and resin under vacuum. Thin sections of corals were stained for identification of aragonite using Feigl's solution (Friedman 1959) and high-magnesium calcite using titan yellow (Winland 1971). Selected samples were analyzed for their stable isotope analysis. Additional samples were investigated using the SEM.

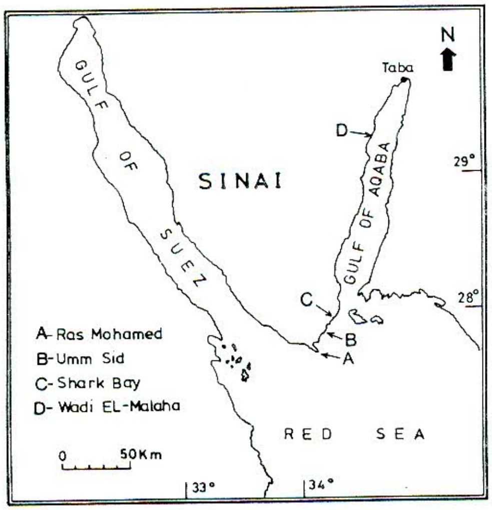


Figure 1. Location map of studied sections.

GEOLOGIC SETTING AND BIOFACIES ANALYSIS

The marine Pleistocene terraces of southern Sinai were formed during interglacial periods, with high sea levels in which water exchange was efficient (Gvirtzman et al. 1992). This occurred under the influence of several interrelated factors: tectonic movements, eustatic sea-level fluctuations, variations in salinity, temperature and sediment load of the ocean water, and varying input of freshwater and terrigenous sediments (Strasser et al. 1992).

Gvirtzman et al. (1992) identified three uplifted fossil reefs in southern Sinai. The youngest one is dated at about 141,000-61,000 years B.P., the middle unit at about 250,000-170,000 years B.P. and the oldest unit at about 330,000-290,000 years B.P. In the area of Naama Bay, Strasser et al. (1992) identified two reef cycles. The younger one is dated between 140,000 and 60,000 years B.P., corresponding to the last interglacial period of isotope stage 5 (Hays et al. 1976). The older reef cycle is dated between 380,000 and 270,000 years B.P. and corresponds to the interglacial period of isotope stage 9. The reef cycle corresponding to isotope stage 7 occurs only as a relic.

Three coral reef units are well preserved along the Sinai coast. They occur at different levels above the present sea level. The morphology, biotic associations and sediments of these Pleistocene reefs are comparable to their recent counterparts. Lithologically, these reefs are formed of algal and coral limestone. The primary frame-builders are scleractinian corals, crustose coralline algae and milleporids. The secondary builders are encrusting foraminifers, bivalves, gastropods, echinoids, bryozoans, alcyonarian corals and serpulids.

It is noteworthy that the studied reef units are locally disrupted and tilted by still active faults and form a discontinuous strip along the coast, interrupted in front of wadi mouths. These drainage systems were already active during glacial lowstands of sea level, leading to deep erosion patterns, where reefs are replaced by gravels of alluvial fans. Corals in such special environments are missing the appropriate substrate (Dullo 1990).

The width of each reef unit is variable. It ranges from 5 to 75 m with vertical relief towards the sea (Fig. 2). The contacts between reef units are in many cases not easy to see.

1) Ras Mohamed section

Three coral reef units can be recognized (Fig. 2) with width ranging from 100 to 150 m. The lower (youngest) unit exhibits two prominent morphological steps at elevations 2 and 5 m above present sea level. The middle unit has one morphological step at elevation 8.5 m above present sea level. The upper unit reaches 29-31 m above present sea level. The stratigraphic base of the upper unit is tilted limestone, characterized by frequent pectinids (*Chlamys senatoria*) and irregular sea urchins (*Clypeaster reticulatus* and *Laganum depressum*).

Each of the lower and middle units is composed of two vertically superposed subunits while the upper one is composed of four subunits. These subunits are separated from each other by beach sands and coarse calcarenites and show a shallowing upward, i.e., they start with coral communities of the reef slope, followed upward by back reef and beach sediments.

The effect of tectonism is more prominent at Ras Mohamed than in other studied areas. Large blocks comprising several facies units slide down as rock fall which may have been caused by earthquakes common in this region.

2) Umm Sid section (14 km northeast of Ras Mohamed)

The Pleistocene reefs constitute three units (Fig. 2) with a width ranging from 100 to 120 m. The lower unit forms two morphological terraces with elevations 3 m and finally to 4.5 m above present sea level. The succession starts with a planation at 1.5 m above present sea level. At this level, there is a fossil wave notch and/or correlating deposits of the ancient shore line. The middle unit exhibits two morphological terraces with elevations 6.5 and 8.5 m above present sea level with well developed coral on coral onlap onto the upper unit. The upper unit reaches 18-21 m above present sea level. The stratigraphic base of the upper unit merges into alluvial fans.

Each of the lower and middle reef units is formed of two subunits, while the upper one is composed of four subunits. The sequence of these subunits is shallowing upwards. However, the vertical development within the depositional sequence of the second terrace of the lower unit is difficult to see in the field due to huge gravel accumulations.

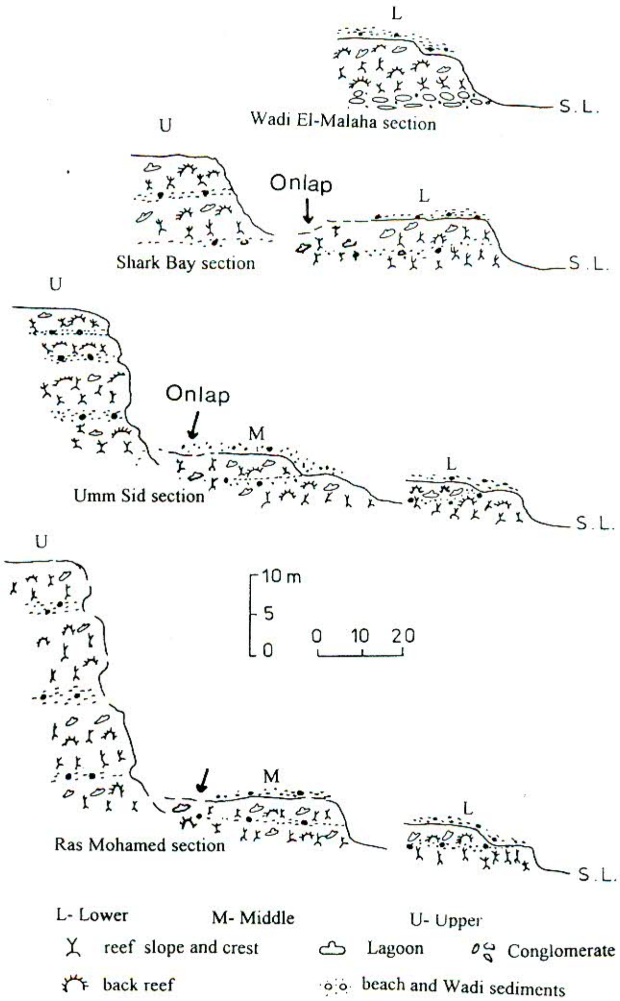


Figure 2. Sketch of the three coral reef units and their facies developments.

3) Shark Bay section (28 km north of Ras Mohamed)

Two reef units can be recognized (Fig. 2), with a width of 75 to 100 m. The lower unit reaches 5 to 8 m above present sea level and exhibits a well developed onlap onto the uplifted and partly eroded upper reef unit which is elevated 10-13 m above present sea level. The upper unit disconformably overlies the tilted Tertiary substrate. However, it may be eroded down at some places to the level of the lower unit.

The lower reef unit starts with a coral community of the upper slope then shallows upwards into immature siliciclastic beach sands. A second sequence starts with a reef slope community, then is composed of back reef and lagoon sediments, and is capped by gravels of fluviatile origin. Transgressive and regres-

sive sequences within the same reef unit may occur as a result of erosional and constructional processes during slight rises or still stand of sea level (Dullo 1983, Strasser & Davaud 1986). These regressive and transgressive patterns are also governed by terrigenous sediment input (Vail et al. 1984).

The upper unit appears correlable with the middle unit at Ras Mohamed and Umm Sid areas. It is composed of at least two small subunits, separated by beach sands. Each unit starts with a coral community of reef slope and continuously shallows upward to coral rock and back reef sediments. This shallowing upward trend indicates diminishing water depth, which was controlled by a combination of changes in sea level, subsidence rate and sediment accumulation (Strasser et al. 1992).

4) Wadi El-Malaha section (52 km south of Taba)

Only the lower unit occurs and represents the Pleistocene reefs in the area between Taba and Nuwiba (Fig. 2). The width of this unit is 50 to 75 m. It rests on a 1 to 1.75 m thick hard, varicolored conglomeratic bed. Clasts are pebbles and cobbles sometimes reaching boulder size, cemented by calcareous material and sometimes contain pelecypod and gastropod molds. This unit is found between Quaternary unlithified terrestrial-fluviatile gravels related to the mountainous hinterland while slopes gently towards the sea and interfingers with coastal sabkha and beach sediments. It is elevated 6.5 to 9.5 m above present sea level. The vertical sequence starts with a coral community of reef slope and continues regressively upwards to reef crest and coral rock. Then it follows again sediments of upper reef slope and fossil shore which are capped with a conglomerate bed like the one of the base.

FOSSIL RECORD AND MICROFACIES ANALYSIS

30 scleractinian species, 7 gastropods, 10 bivalves and 3 echinoids have been identified (Fig. 3). These faunas are mostly comparable to their recent counterparts.

Most of the identified fauna are badly preserved. In his study on the Quaternary fauna from Gebel Tanka, eastern side of the Gulf of Suez, Sinai Peninsula, Abed (1982) studied systematically thirty-seven macroinvertebrate species from two Quaternary raised beaches. Some of Abed's collection are mentioned in this study.

The reefal carbonate rocks also yielded abundant foraminifers such as *Textularia, Quinqueloculina, Triloculina, Sorites, Amphisorus, Amphistegina, Planorbulina, Borelis, Gypsina, Cibicides, Discorbis, Eponides, Eurycheilostoma, Peneroplis, Acervulina, Miniacinna, Homotrema*. Furthermore articulate coralline algae are present as skeletal grains.

All identified species (Fig. 11-12) are recorded from the Indo-Pacific bioprovince, except *Acropora pharaonis* and *Coscinaraea monile*, which are recorded also from the Atlantic bioprovince.

Facies patterns in the Pleistocene reef terraces along the Red Sea coast exhibit lateral and vertical changes over short distances (Dullo 1990). These changes reflect either transitions within the depositional environment, or they are

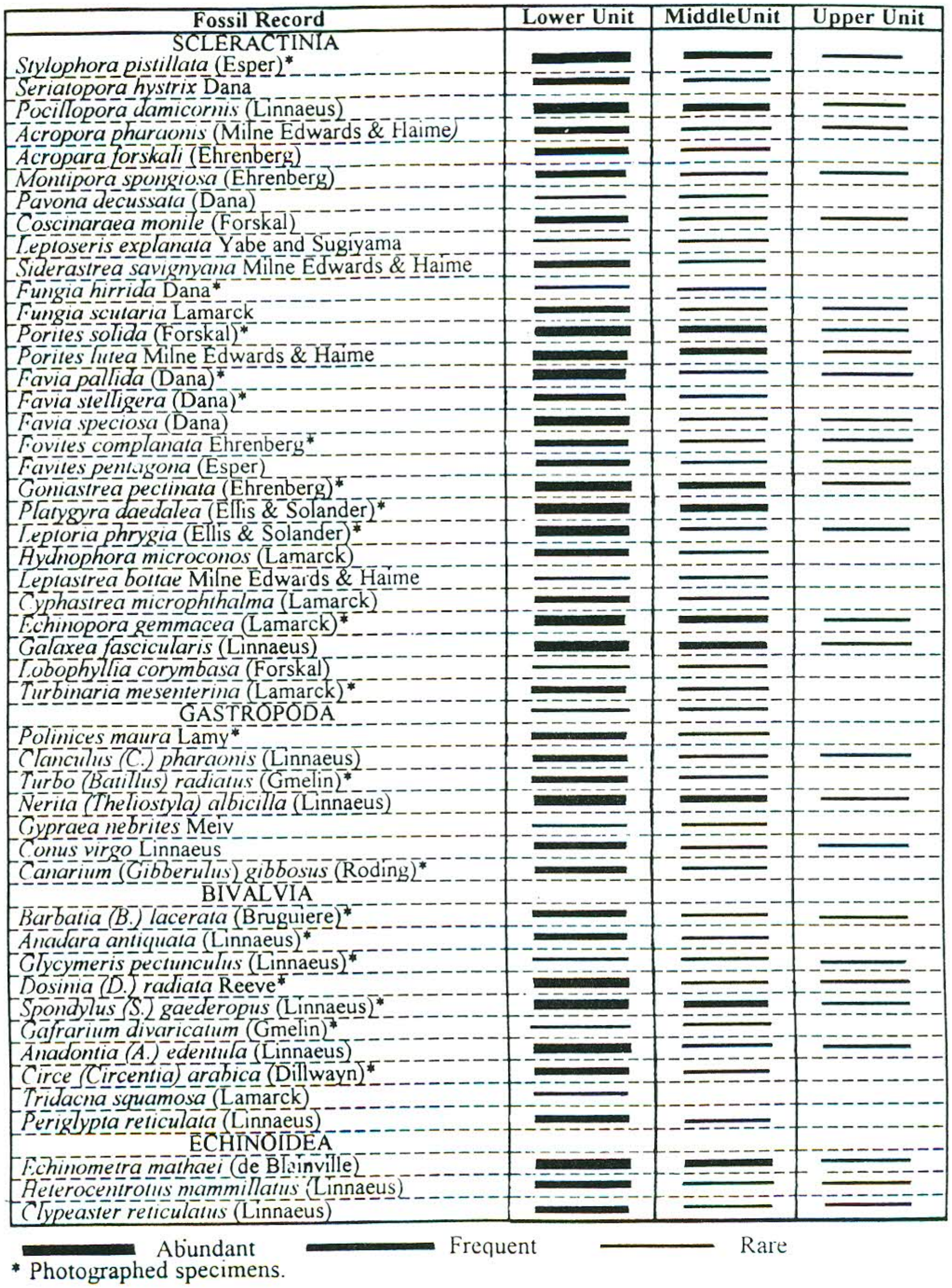


Figure 3. Semiquantitative distribution of scleractinian coral, gastropod, bivalve and echinoid species in the studied reefal units.

related to minor or major sea level fluctuations. Also the tectonic displacement lead to distinct terrace steps.

Microfacies nomenclature in the present study follows the system introduced by Dunham (1962) and Embry & Klovan (1972) as well as the energy index classification of Plumely et al. (1962). Four microfacies types were identified. The model of their distribution is summarized in Figure 4.

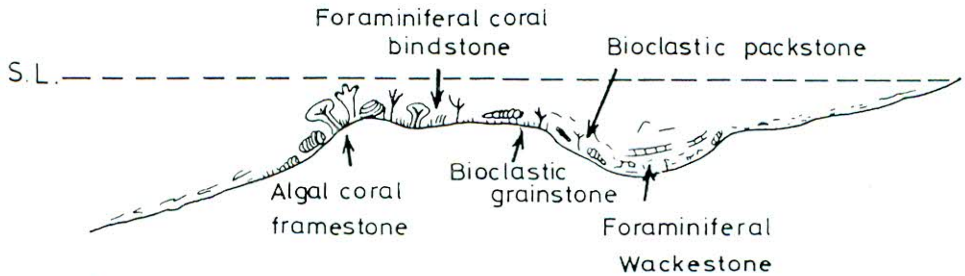


Figure 4. Distribution model of the recorded microfacies types.

1) Foraminiferal wackestone (Fig. 6/3). This type is composed of biomorphs and rare bioclasts rooted in micrite. It is particularly rich in foraminifers (*Carpenteria, Amphistegina, Miniacina* and smaller miliolids and textulariids) and rare coral fragments and quartz grains. This microfacies type was deposited in shelf lagoon with open circulation in quiet water below normal wave base (Flügel 1982).

2) Bioclastic packstone (Fig. 6/4). This microfacies consists of abundant detritus of frame building and reef-dwelling organisms, calcareous algae, scleractinian corals, foraminifers, molluscs and echinoids. These coated and warm bioclasts are badly-sorted, embedded in micrite matrix and act as essential rock builders. This facies is typical of reef flank, the dominant particles were formed in a high energy environment on shoals and have moved down local slopes to be deposited in quiet water.

Figure 5

1 Wave notch in the lower reef unit at Ras Mohamed.

2 Coral community of the upper reef slope with *Fungia scutaria* (F) and *Siderastrea savignyana* (S). Lower reef unit at Ras Mohamed.

3 Upper part of the upper reef unit at Ras Mohamed.

4 Lower reef unit at Umm Sid.

5 Upper reef unit at Umm Sid.

6 Close up of the upper reef unit at Umm Sid showing massive *Favia pallida* (F) in life position.

Figure 6

1 Coral community of the upper reef slope with branching *Pocillopora damicornis* (D), *Galaxea vascicularis* (V) and *Porites solida* (S). Lower reef unit at Shark Bay.

2 Lower reef unit at Wadi El-Malaha, resting on a conglomeratic bed.

3 Foraminiferal wackestone. Fragments of *Carpenteria* sp. (C) and few fine quartz grains, all embedded in micritic matrix. Upper reef unit, Ras Mohamed, crossed nicols.

4 Bioclastic packstone. Fragments of coralline algae (Co), scleractinian corals (Ss), molluscs and foraminifers. Lower reef unit, Wadi El-Malaha, crossed nicols.

5 Bioclastic grainstone. Algal and molluscan fragments bound by sparitic cement with high porosity. Upper reef unit, Skark Bay, crossed nicols.

6 Foraminiferal coral bindstone. Sessile foraminifers *Carpenteria* sp. act as sediment binder with *Porites* sp. (P) Lower reef unit, Ras Mohamed, crossed nicols.

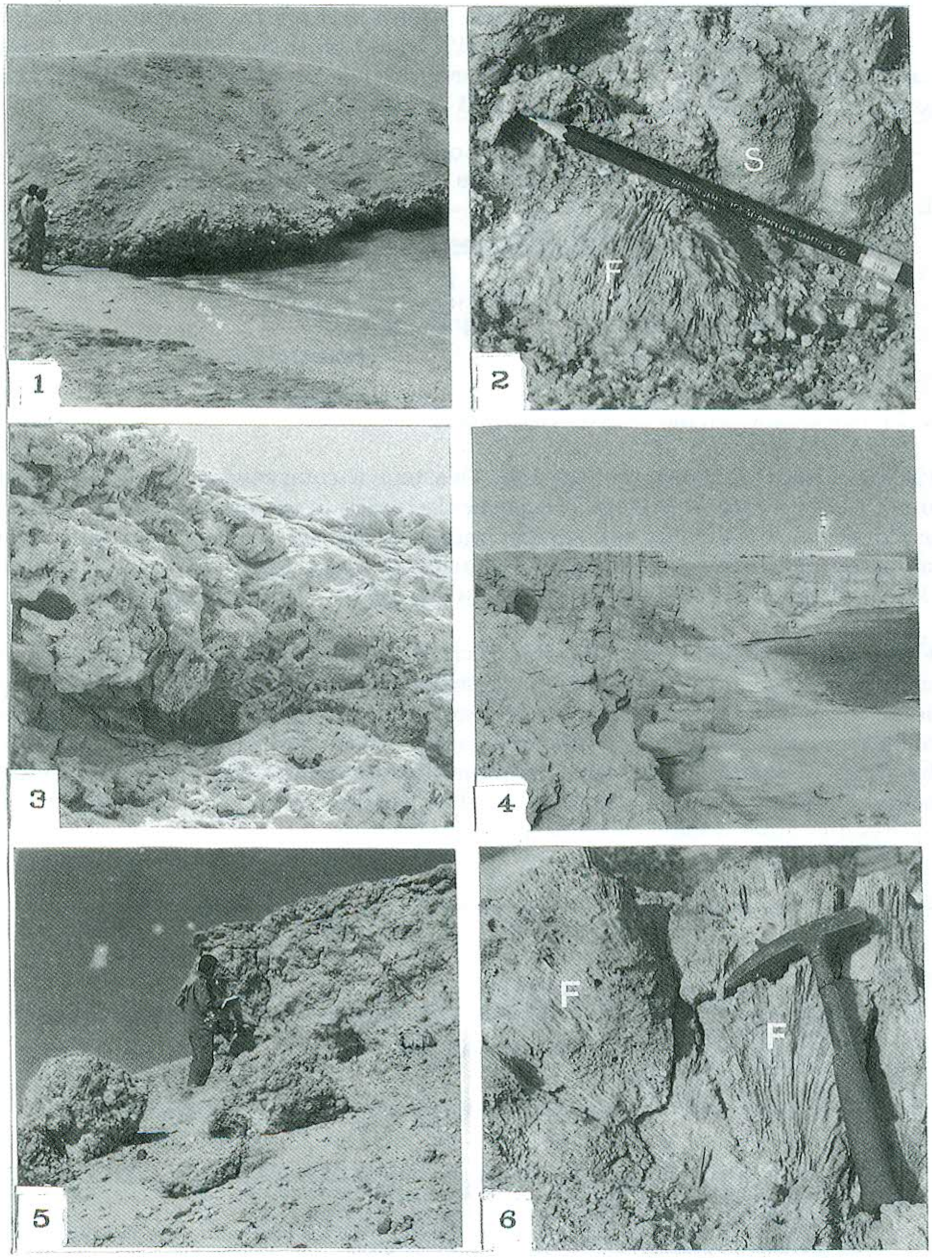
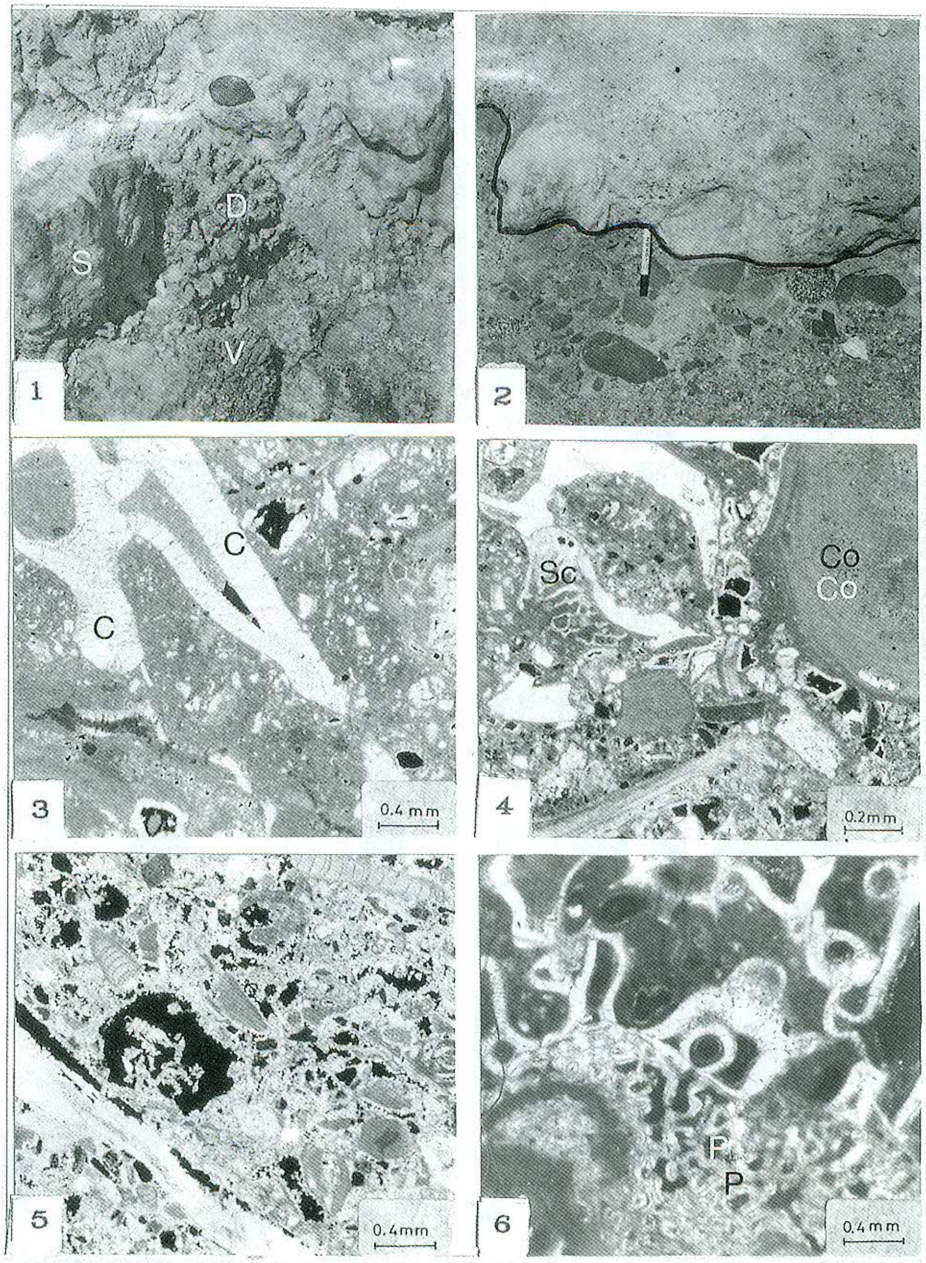


Figure 5. *(Legend on page 23).*



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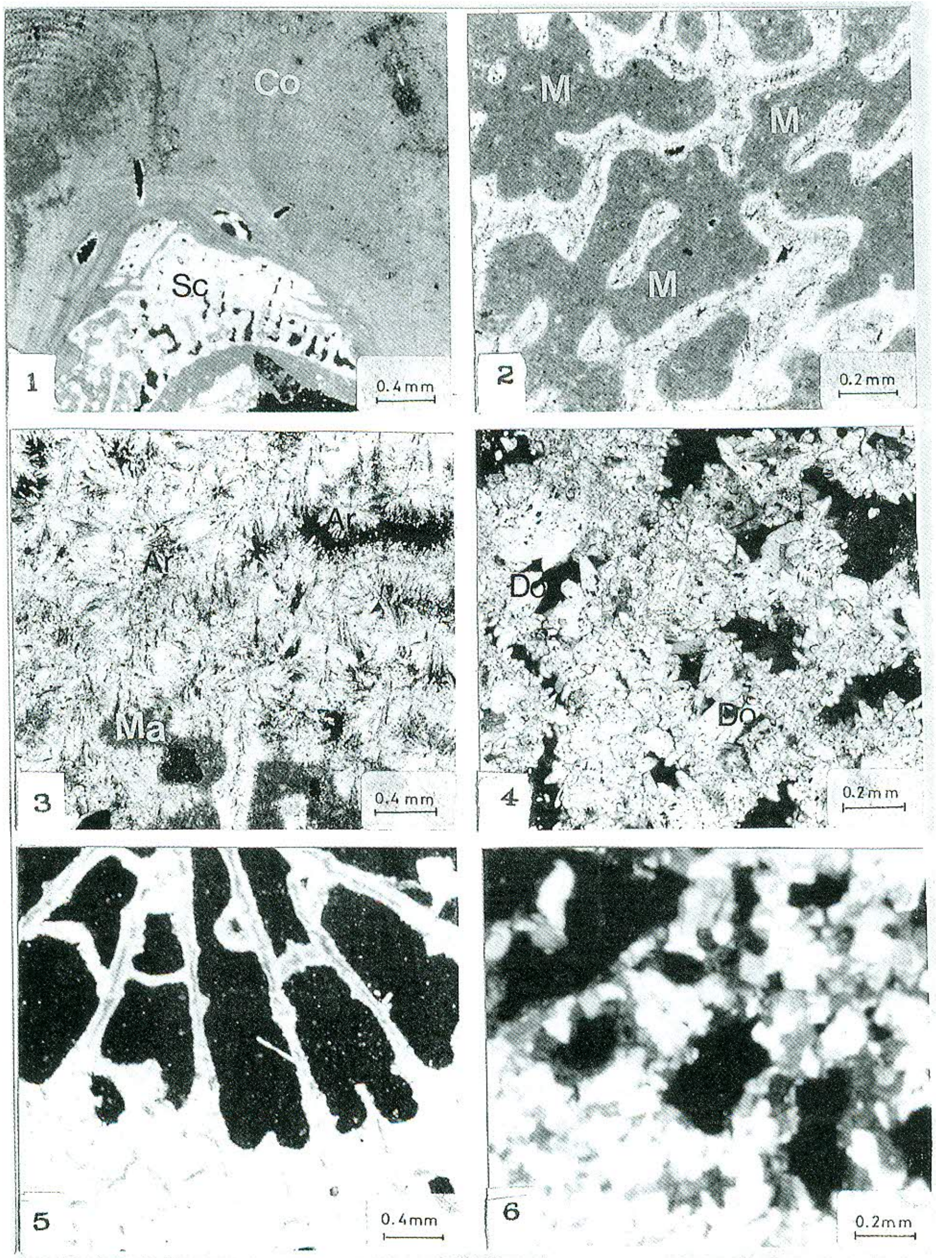


Figure 7. *(Legend on page 27).*

3) Bioclastic grainstone (Fig. 6/5). This is made up of coated and abraded, moderately sorted, polymictic fragments of calcareous algae, bivalves, foraminifers and corals. These bioclasts are cemented by sparite and act as essential rock building constituents. This facies type represents winnowed platform edge sands, the area of constant wave action at or above wave base.

4) Boundstones (Fig. 6/6, Fig. 7/1). Two sub-microfacies types were recorded: Foraminiferal coral bindstone (Fig. 6/6), where sessile benthonic foraminifers act as sediment binders with scleractinian coral. The second is algal-coral framestone (Fig. 7/1) where in situ coralline algae (*Lithothamnium, Lithophyllum, Lithoporella,* etc.) and scleractinians act as framebuilders. High magnesium calcite (micrite) totally filled the coral cavities. This facies type represents an in situ organic build-up formed in a shallow, warm and agitated water environment.

DIAGENETIC ALTERATIONS

The rate of diagenetic alteration is a valuable key to distinguish between Quaternary reefs of different ages (Dullo 1984, 1986). The basic structure of all scleractinians is the trabecula, which consists of a bar or a rod of skeletal aragonite. These bars form the light-weight porous skeleton. The ultrastructure of the trabecula is composed of aragonite fibers arranged in a spherulitic cluster, which is the sclerodermites.

The present study is based on the quantitative composition of skeletal and non-skeletal grains in the field as well as in thin sections of the three reef units (Fig. 8). Particular attention is given to two scleractinian species *Porites solida* and *Favia pallida*, whose diagenetic evolution is affected by both external environmental factors and internal skeletal parameters.

Lower reef unit

The selected species *Porites solida* and *Favia pallida* exhibit no alteration of the primary microstructure (Fig. 7/3, 5).

Two types of marine cements are recorded in the lower unit. Aragonite cement (Fig. 7/2-3), in the form of needles 30-200 µm long and 2-10 µm wide, which grew in the interseptal cavities either syntaxially on the trabecular structure of coral or on micritic envelopes composed of Mg-calcite are formed by micropores on the surface of the coral skeleton. High magnesium calcite (micrite) (Fig. 7/2-3) in the form of semi-opaque, fine rhombic crystals 2-15 µm, may totally fill coral cavities.

Figure 7

1 Algal coral framestone. The coralline algae (Co) and scleractinian corals (Sc) act as frame builders. Lower reef unit, Umm Sid, crossed nicols.

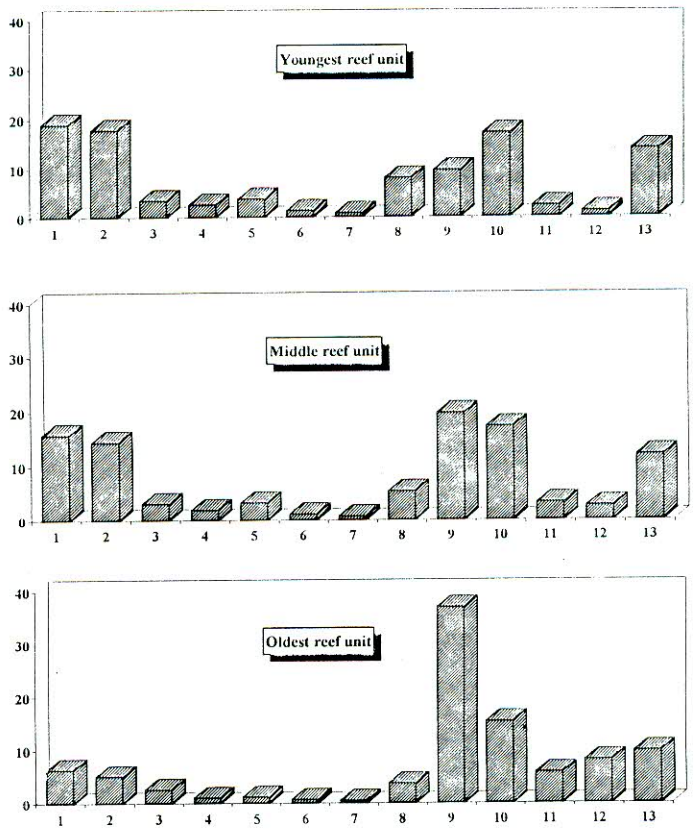
2 Phreatic high magnesium pelleted micrite (M) totally filling the coral cavities. Note the partial leaching of trabecular centers. Lower reef unit, Shark Bay, crossed nicols.

3 Marine aragonite (Ar) and high magnesium calcite (Ma) cements locally present in leached trabecular centers of coral. Lower reef unit, Umm Sid, crossed nicols.

4 Dog-tooth sparry cement (Do) of low-magnesium calcite with locally altered microstructure. Middle reef unit, Ras Mohamed, crossed nicols.

5 Unaltered microstructure of *Favia pallida* with the trabecular centers. Lower reef unit, Ras Mohamed, crossed nicols.

6 Microstructure of *Favia pallida* completely altered by neomorphism, dissolution and cementation. Upper reef unit, Ras Mohamed, crossed nicols.



1- Scleractinians and hydrozoans
2- Coralline algae
3- Foraminifers
4- Echinoderms
5- Aragonitic molluscs
6- Calcitic molluscs
7- Bryozoans
8- Unknown Biog. alloch.
9- Cement
10- Micrite
11- Peloids
12- Terrigenous particles
13- Porosity

Figure 8. Quantitative composition of skeletal and non skeletal grains, including cement, micrite and porosity for the three reefal units.

Figure 9

1 Marine aragonite cement often grows as syntaxial prolongations of the fan shaped sclerodermites of *Porites solida*. Lower reef unit, Wadi El-Malaha, SEM.

2 Chalky layer of partly dissolved aragonite, rimming the open trabecular centers. Lower reef unit, Ras Mohamed, SEM.

3 Open trabecular centers, subsequently filled with equant calcite, indicating soltition precipitation processes. Middle reef unit, Umm Sid, SEM.

4 Meteoric cementation (Me). Blocky and dog-tooth calcite crystals grew on substrate of micritic linings (Mi). Upper reef unit, Ras Mohamed, SEM.

5 Microstructure of *Porites solida* completely altered by dissolution and subsequent cementation. Upper reef unit, Umm Sid, SEM.

6 Dolomite rhombs developed as cement within septa of *Favia pallida*. Lower reef unit, Shark Bay, SEM.

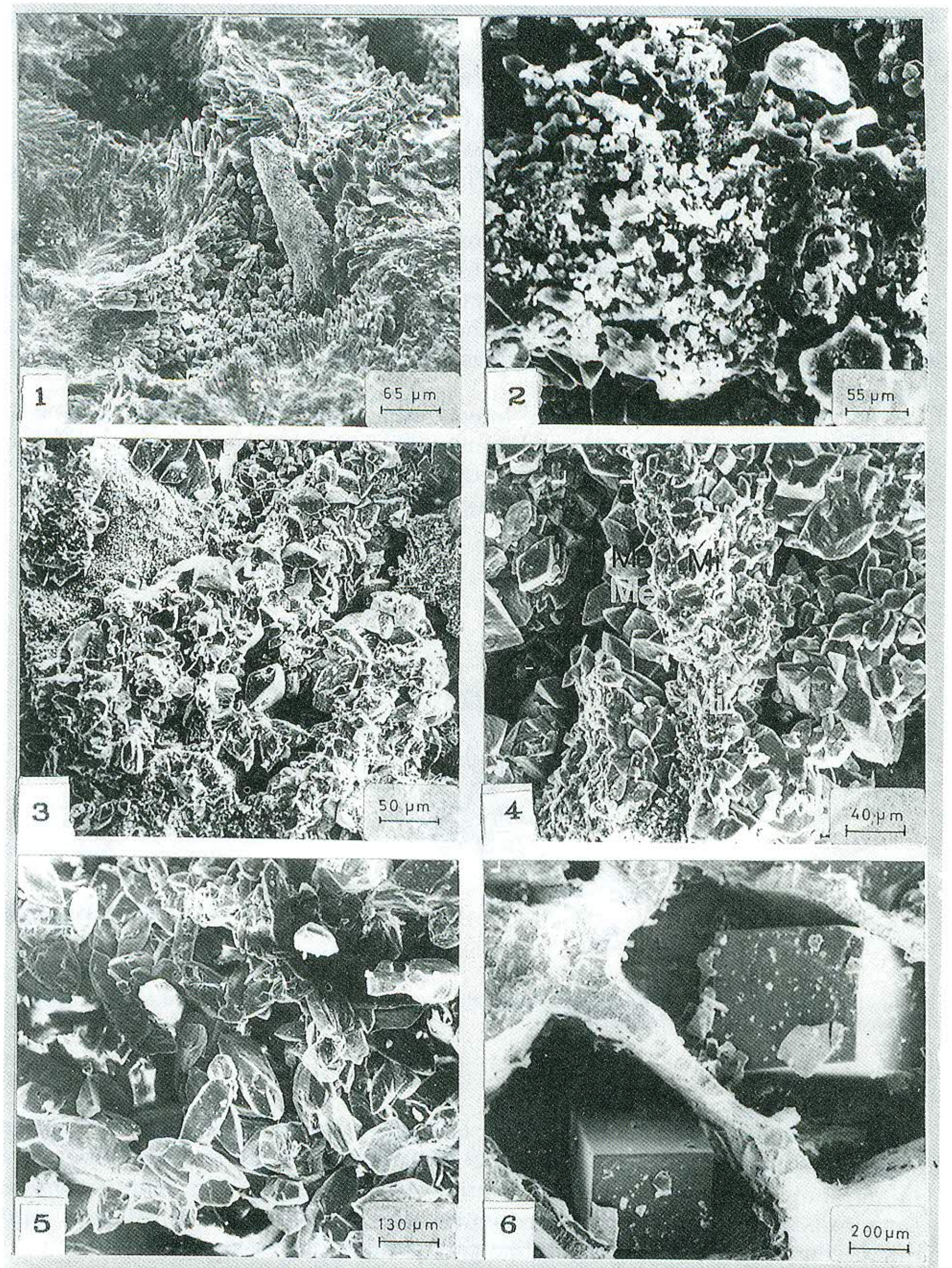


Figure 9. *(Legend on page 28).*

Some *Porites* samples especially at Ras Mohamed show meteoric leaching in the form of open trabecular centers (Fig. 7/2) rimmed predominantly by a chalky layer of partly dissolved aragonite (Fig. 9/2) which consists of randomly oriented skeletal aragonite needles (James 1974).

Stable isotope values of samples from the youngest unit plot between +2.38 and +1.11‰ $\delta^{13}C$ PDB and between -3.40 and -4.74‰ $\delta^{18}O$ PDB (Fig. 10). These values are comparable with those of normal marine limestones locally affected by fresh water diagenesis (Hudson 1977) and with those reported by Moore (1985) for burial cements.

Patches of the lower unit are dolomitized, where dolomite develops as a cement within coral cavities (Fig. 9/6). Similar dolomite cements have been described by Aissaoui et al. (1986) from Mururoa atoll and by Ward & Halley (1985) in northeastern Yucatan where they are interpreted as having been formed from marine waters. The isotopic values of dolomitized samples are shown (Fig. 10).

The diagenetic fabrics of the lower unit appear correlatable to stage II (introduction of marine cements, decomposition of marine cements and decomposition of organic tissue in submergent reefs) of Gvirtzman & Friedman (1977) and to stage 2 (marine-cemented organic skeleton) of El Asmar & Attia (1996).

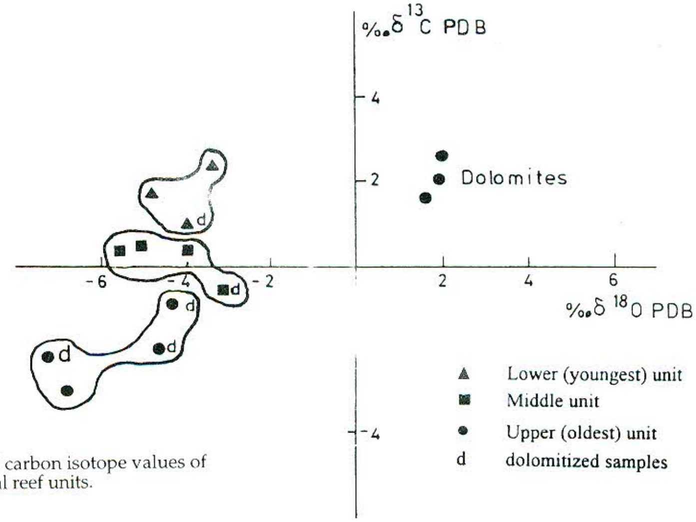


Figure 10. Stable oxygen and carbon isotope values of samples from the studied coral reef units.

Middle reef unit

The transition to the middle unit is marked by meteoric phreatic influence and increase of cementation as in Ras Mohamed and Umm Sid. Some *Porites solida* show complete alteration of microstructure (Fig. 7/4). Some colonies of *Favia pallida* show open trabecular centers which later became filled with equant calcite (Fig. 9/3) indicating a solution precipitation processes.

The diagenetic fabrics of the middle unit appear correlatable to stage III (leaching of sclerodermites under subaerial conditions) of Gvirtzman & Friedman (1977).

Isotope values of calcified samples from the middle unit plot between -1.56 and +0.63‰ $\delta^{13}C$ PDB and between -5.50 and -3.11‰ $\delta^{18}O$ PDB. These values suggest fresh water influence (meteoric cements, Saller 1984).

Upper reef unit

This unit is interpreted as being altered in a meteoric diagenetic environment, which was characterized by complete leaching, leading to molds which were later filled with spar cement, and intercrystalline leaching with concomitant precipitation (neomorphism). This led to a drastic destruction of the fossil record in this unit (Fig. 8). *Porites solida* and *Favia pallida* show completely altered microstructures (Fig. 7/6, Fig. 9/6).

Some colonies of *Favia pallida* show relics of aragonitic structure incorporated into low magnesium calcite crystals (Sandberg 1985).

Dissolution is selective according to the microstructures of the organisms (Gvirtzman & Friedman 1977, Constantz 1968, Dullo 1986, Strasser et al. 1992). Aragonitic skeletons are numerically more reduced than Mg-calcite skeletons (Fig. 8). Echinoderms are not so much reduced in number. This is possibly a result of the early diagenetic formation of single calcite crystals (Richter 1984, Dullo 1990) which resist leaching by having a small reaction surface.

Low magnesium calcite cement (Fig. 9/4) commonly occurs in the form of dog tooth and blocky crystals, which may have be derived from dissolved marine cement or from leached parts of the biogenic skeleton. Porosity is reduced due to increased cementation. The newly formed low magnesian calcite crystals cross beyond the original coral boundaries (border crossing crystals) indicating a fresh water phreatic origin (Dullo 1987).

Isotope values of samples from the upper unit plot between -3.33 and -1.29‰ $\delta^{13}C$ PDB and between -7.23 and -4.33‰ $\delta^{18}O$ PDB (Fig. 10). These negative values suggest fresh water influence (meteoric cements, Saller 1984).

The upper unit contains slightly and also completely dolomitized samples. The isotope values of the latter plot between +2.53 and -1.29‰ $\delta^{13}C$ PDB and between +1.63 and +2.00‰ $\delta^{18}O$ PDB (Fig. 10). These values indicate a mixing-zone dolomitization as proposed by Ward & Halley (1985) for the Upper Pleistocene reefs in Yucatan. See also discussions in Coniglio et al. (1988) and Strasser et al. (1992).

The diagenetic fabrics of this unit appears correlatable to stage IV (precipitation of low magnesian calcite by meteoric fresh waters) of Gvirtzman & Friedman (1977) and to stage 3 (meteoric-cement calcite skeleton) of El Asmar & Attia (1996).

SUMMARY AND CONCLUSIONS

1) The Pleistocene coral reefs of southern Sinai constitute three reef units. They have different elevations above present sea level and occur predominantly in narrow strips in which the vertical succession of facies could be studied.
2) 30 scleractinian, 7 gastropod, 10 bivalve and 3 echinoid species have been identified. The semiquantitative distribution of these fauna along the three recorded units was documented (Fig. 3).

3) Four microfacies types have been recorded: Foraminiferal wackestone, bioclastic packstone, bioclastic grainstone and boundstone (Fig. 4). The quantitative composition of skeletal and non-skeletal grains from thin sections is also examined (Fig. 5). Skeletal grains shows upward gradual reduction in the number of recognizable biota especially aragonitic ones, either by partial or complete leaching with subsequent or concomitant calcite precipitation or neomorphism. This caused the gradual diagenetic alteration of the Pleistocene reefal units.

4) *Porites solida* (Suborder Fungiina) is altered faster than *Favia pallida* (Suborder Faviina). This difference in the rate of diagenetic alteration depends on the microstructure and microarchitecture and their relation to the reactive surface area (Constantz 1986). Also, it depends on the degree of intercrystalline porosity within the sclerodermites and therefore the tightness of fiber packing and arrangement which vary within the different suborders of the stony corals (Dullo 1987).

5) Isotope values of samples from the studied reefal units indicate that dolomite was formed as cement from meteoric-marine waters.

6) The study of scleractinians and associated fauna and facies analysis, combined with field observation revealed that the Pleistocene coral reefs of southern Sinai, Egypt, were formed in the upper reef slope to lagoonal and beach environments.

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Figure 11

1 *Stylophera pistillata* (Esper). Lower unit, Ras Mohamed.
2 *Fungia horrida* Dana. Upper unit, Umm Sid.
3 *Porites solida* (Forskål). Lower unit, Wadi El-Malaha.
4 *Favia stelligera* (Dana). Lower unit, Ras Mohamed.
5 *Favia pallida* (Dana). Lower unit, Shark Bay.
6 *Goniastrea pectinata* (Ehrenberg). Middle unit, Umm Sid.
7 *Favites complanata* (Ehrenberg). Lower unit, Shark Bay.
8 *Platygyra daedalea* (Ellis & Solander). Upper unit, Shark Bay.
9 *Leptoria phrygia* (Ellis & Solander). Middle unit, Umm Sid.
10 *Echinopora gemmacea* (Lamarck). Lower unit, Ras Mohamed.
11 *Turbinaria mesenterina* (Lamarck). Middle unit, Wadi El-Malaha
Bar scale of figures = 20 mm.

Figure 12

1 *Turbo (Batillus) radiatus* (Gmelin). Apertural view. Middle unit, Ras Mohamed.
2 *Polinices maura* Lamy. Apertural view. Lower unit, Wadi El-Malaha.
3 *Canarium (Gibberulus) gibbosus* (Röding). Apertural view. Lower unit, Ras Mohamed.
4 *Barbatia (B.) lacerata* (Bruguière). Left valve, internal view. Upper unit, Umm Sid.
5 *Spondylus (S.) gaederopus* (Linnaeus). Right valve, internal view. Upper unit, Ras Mohamed.
6 *Dosinia (D.) radiata* Reeve. Right valve, external view. Lower unit, Shark Bay.
7 *Gafrarium divaricatum* (Gmelin). Left valve, internal view. Middle unit, Ras Mohamed.
8 *Circe (Circenita) arabica* (Dillwayn). Left valve, internal view. Upper unit, Umm Sid.
9 *Glycymeris pectunculus* (Linnaeus). Right valve, internal view. Upper unit, Ras Mohamed.
10 *Anadara antiquata* (Linnaeus). Right valve, internal view. Lower unit, Wadi El-Malaha.
Bar scale of figures = 20 mm

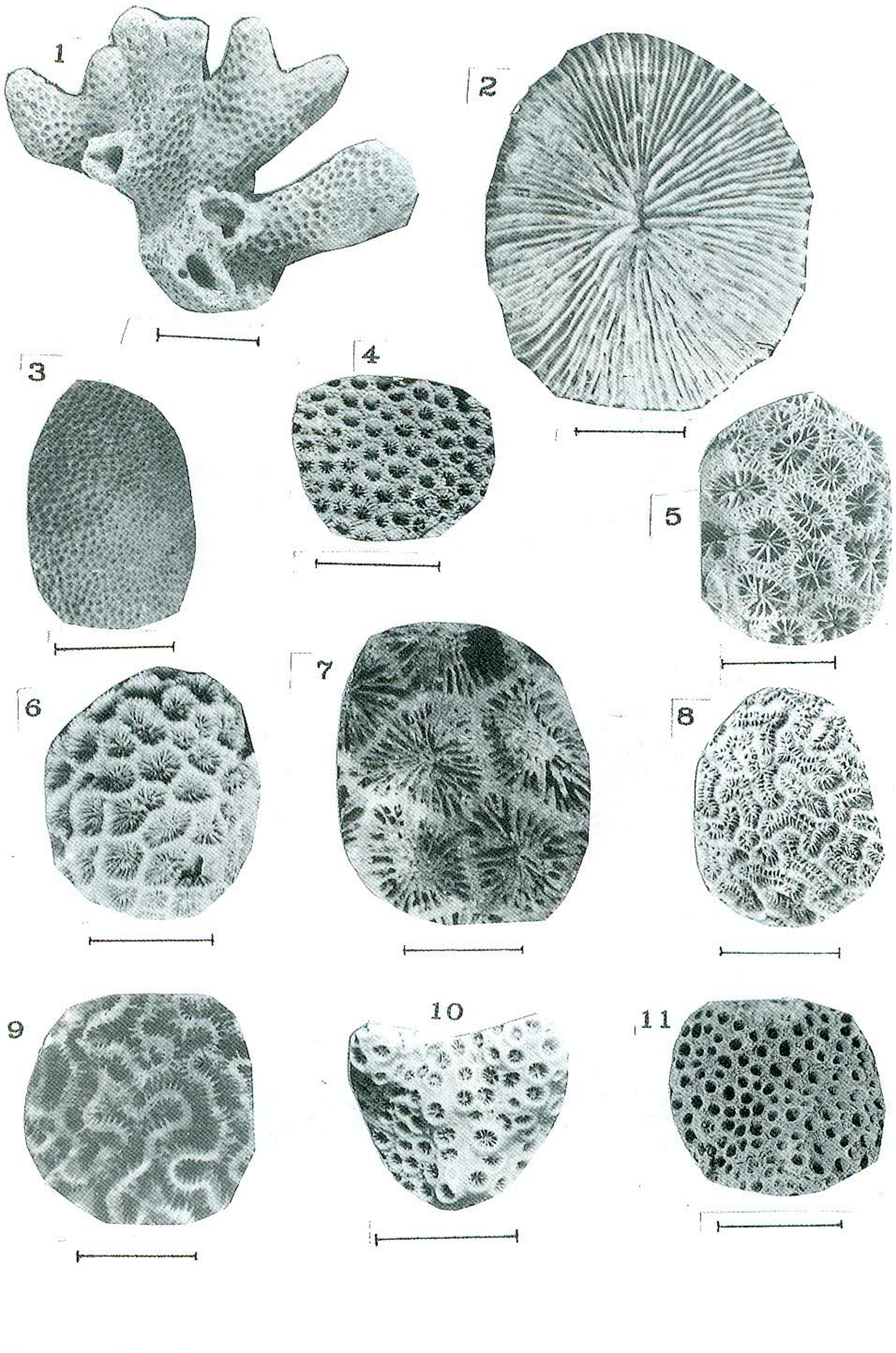

Figure 11. *(Legend on page 32).*

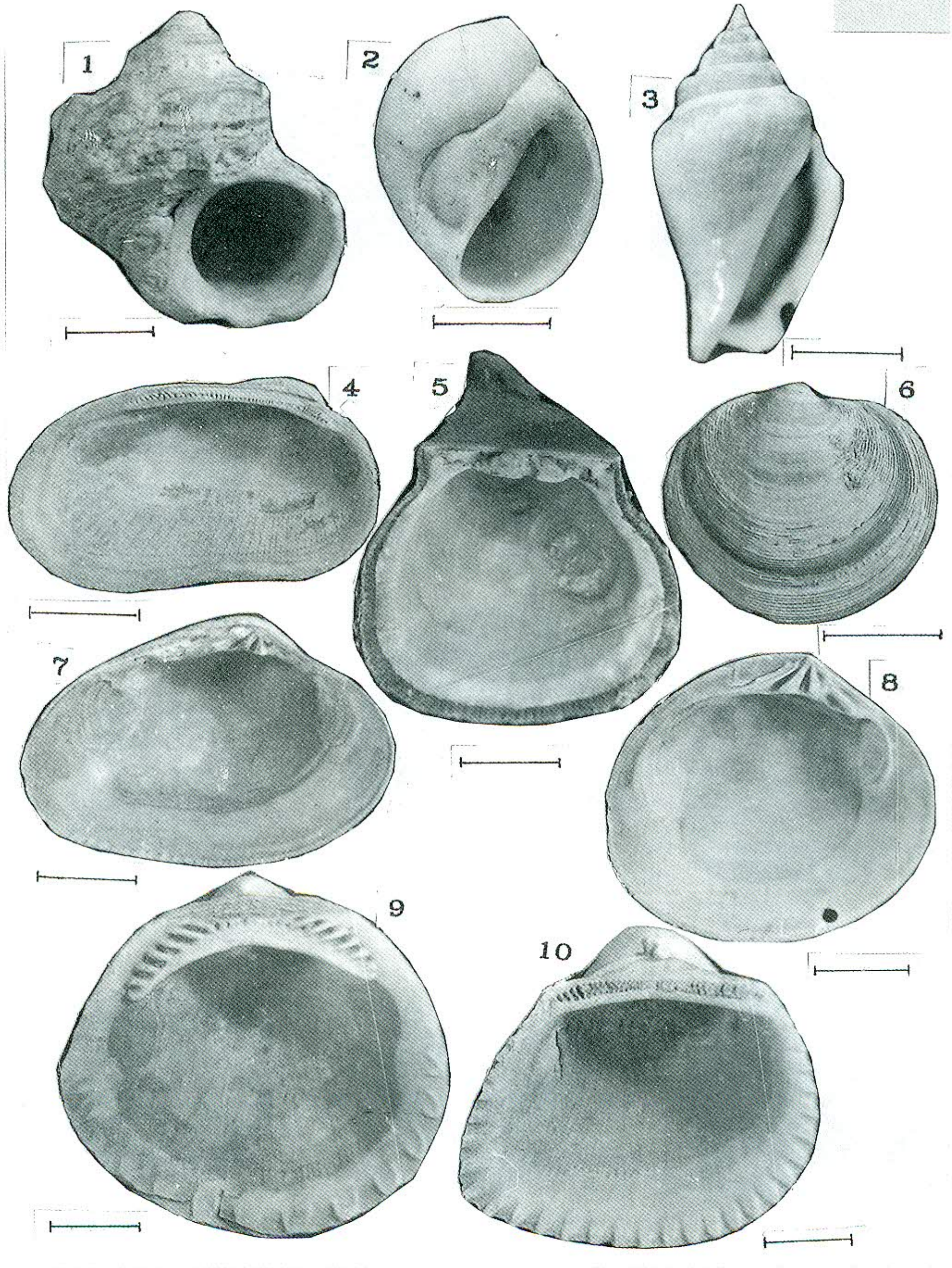

Figure 12. *(Legend on page 32).*

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