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Paleontology and depositional environments of the Pleistocene coral reefs of the Gulf of Suez, Egypt

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With 7 figures and 1 table

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Abstract: The Pleistocene coral reefs at Gebel Zeit and Ras Gemsha (western side of the Gulf of Suez) form terraces of different elevations above the present sea level. The identified 30 species of bryozoans, corals and molluscs are of strongly Indo-Pacific affinity. Many coral specimens show no alteration of their primary microstructure, but a few are affected by early meteoric diagenesis. The differences in Sr, Ca and Mg among coral families and their relation to diagenetic alterations are documented. The reconstructed depositional environments reach from upper reef slope to back-reef and water-depths from 1 to 50 meters.

Zusammenfassung: Die pleistozänen Korallenriffe des Gebel Zeit und Ras Gemsha (W-Seite des Golfes von Suez) bilden mehrere Terrassen über dem heutigen Meeresspiegel. Die 30 bestimmten Arten von Korallen, Mollusken und Bryozoen gehören alle zur Indo-Pazifischen Provinz. Die primären Mikrostrukturen vieler Korallen zeigen keine diagenetischen Veränderungen, aber andere sind von früher meteorischer Diagenese erfaßt worden. Die bei den Korallen-Familien unterschiedlichen Gehalte an Sr, Ca und Mg sowie deren Bedeutung für verschiedenes Verhalten bei der Diagenese werden dokumentiert. Die Ablagerungsbereiche der untersuchten Korallenriffe reichen vom oberen Riffhang bis zum Hinterriff, während die Wassertiefen zwischen 1 und 50 m schwanken.

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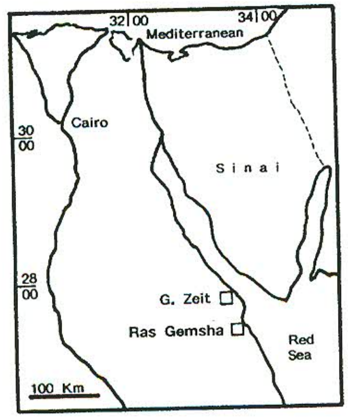

Fig. 1. Location of G. Zeit and Ras Gemsha.

Introduction

Uplifted Pleistocene coral reefs occcur widespread along the coasts of the Red Sea. The morphology, biological associations and sediments of these Pleistocene limestone are homologous with those of the adjacent modern environment. Age, diagenesis, stable isotopic composition and patterns in seasonal growth band deposition of these reefs were discussed by several authors in the last decades (Gvirtizman & Friedman 1977, Dullo 1984, 1986, 1990, Abou Khadrah & Darwish 1986, Al-Rifaiy & Cherif 1988 Andres & Radtke 1988, Klein et al. 1990, Strasser et al. 1992, Heiss & Dullo 1997, El-Sorogy 1997 among others).

Gebel Zeit is an uplifted block of Precambrian granitic basement rocks of ca 30 km length. It is located at 50 km north of Hurghada (fig. 1), along the western side of the Gulf of Suez, Egypt. At least three fossil beach levels of Pleistocene age are present in the study area at maximum elevations of 65 m, 50 m, 15 m and a Holocene reef at 2 m (Heiss & Dullo, 1997). At the 15 m level there is an excellently preserved fossil raised reef. Based on absolute dating with U/Th and ESR, this reef grew during the maximum of the last interglacial period, stage 5e, Eemian, 125,000 YBP (Andres & Radtke 1988; Bosword & Taviani 1996).

At Ras Gemsha, south of Gebel Zeit, the coral reefs rest on non-fossiliferous, thick evaporites and oolitic sandstone. These evaporites similar to those found in Gebel Tanka on the eastern side of the Gulf of Suez, which may be a result of the hypersaline conditions which was prevailing in this region during the last glaciation in Europe (ABED, 1982).

The studied lower (youngest) reef unit is easily traced allover the study area along the coast. It exhibits two prominent morphological terraces at elevations 10 and 15 m above present sea level with abundant scleractinian corals, as well as well preserved pelecypods and gastropods.

The main targets of the present work are the systematic paleontology, bio- and paleobiogeography of the Pleistocene coral reefs at Gebel Zeit and Ras Gemsha area on the western side of the Gulf of Suez, as well as their paleoecological and diagenetic implications.

Material and methods

Two stratigraphic sections were sampled, at Gebel Zeit and Ras Gemsha (fig. 1). Twenty five thin sections were prepared for microfacies analysis. The very porous samples, especially corals have been impregnated with resin under vacuum for producing thin sections. The microstructure and diagenitic alteration of the scleractinians were studied by means of thin sections and SEM, using fresh fractures, cleaned with distilled water and pressured air. The carbonate mineralogy was analyzed using X-ray fluorescence and Atomic Absorption and Spectrophotometer (in the laboratories of Building Materials Research Institute and of the Nuclear Materials Authority, Cairo).

Paleontology

The classification used in the present work is that of MOORE (1953-1969). The studied materials are deposited in the Department of Geology, Zagazig University, Egypt. Instead of detailed description, short diagnoses are given for all studied taxa and their geographical distribution and habitats are discussed in detail.

Phylum **Bryozoa EHRENBERG, 1831**

Order Cyclostomata BUSK, 1852
Family Crisidae JOHNSTON, 1847

Genus *Crisia* LAMOUROUX, 1816

Type species: *Sertularia eburnea* LINNAEUS, 1758.

Crisia elongata Milne-Edwards, 1838 — Fig. 2/1

1838 *Crisia elongata*. – Milne-Edwards, p. 203, pl. 7, fig. 2.
1987 *Crisia elongata* Milne-Edwards. – Ziko & Hamza, p. 502. figs. 2-3.
1992 *Crisia elongata* Milne Edwards. – Ziko, Hamza & El-Dera, p. 296, figs. 1-2.
1995 *Crisia elongata* Milne-Edwards. – Ziko & El-Sorogy, p. 82, fig. 1/2.
1996 *Crisia elongata* Milne-Edwards. – Ziko, p. 126, fig. 2/1-2.

Material: Five well preserved cellariform zoaria, Gebel Zeit.
Diagnosis: Zoarial internode slender, long, turned first outsides then inwards. Peristome circular, thin salient. Ovicell large, inflated, isolated, sacciform.

Distribution and Habitat: Eocene of France, North America; Oligocene of Germany, France, Italy; Miocene of Egypt, Italy, Hungary, Poland, CSSR, Austria; Pliocene of Italy; Pleistocene of the Red Sea coast. Recent of Atlantic, Mediterranean, Red Sea, Pacific in Borneo and Japan. Depth range 0-59 m (Vavra 1977; Ziko & El-Sorogy 1995; Ziko 1996).

Range: Eocene-Recent.

Order Cheilostomata Busk, 1852
Family Scrupocellariidae Levinsen, 1909

Genus *Scrupocellaria* Van Benden, 1845

Type species: *Sertularia scrupusa* Linnaeus, 1758.

Scrupocellaria elliptica (Reuss, 1848) — Fig. 2/2

1848 *Bactridium ellipticum*. – Reuss: p. 56, pl. 9, figs. 7, 8.
1965 *Scrupocellaria elliptica* (Reuss). – Souaya: p. 1137, pl. 137, figs. 7-8.

Fig. 2. 1: *Crisia elongata* Milne-Edwards, frontal view of one zoarial segment with ovicell, Gebel Zeit, bar scale = 558 µm. **2:** *Scrupocellaria elliptica* (Reuss), celluliferous side of a zoarium, Ras Gemsha, bar scale = 558 µm. **3:** *Stylophora pistillata* (Esper), side view of a colony, Ras Gemsha, bar scale = 12 mm. **4:** *Acropora clathrata* (Brook), side view of a branch, Gebel Zeit, bar scale = 10 mm. **5:** *Acropora horrida* (Dana), side view of a branch, Ras Gemsha, bar scale = 10 mm. **6:** *Montipora spongiosa* (Ehrenberg), side view of a branch, Ras Gemsha, bar scale = 10 mm. **7:** *Coscinaraea columna* (Dana), top view of a colonial part, Ras Gemsha, bar scale = 5 mm. **8:** *Fungia* (*Fungia*) *fungites* (Linnaeus), upper surface of a corallum, Gebel Zeit. Scale bar = 12 mm.

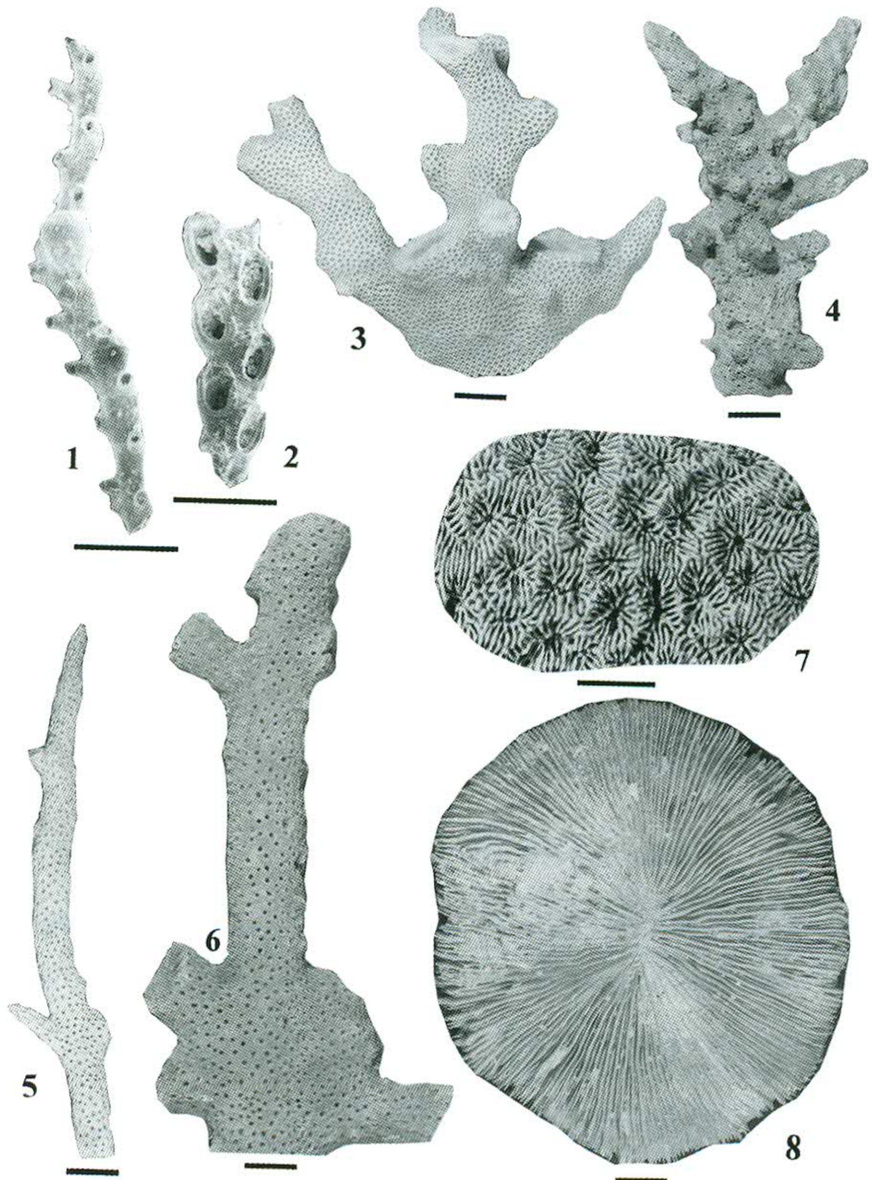

Fig. 2 (Legend see p. 340)

1974 *Scrupocellaria elliptica* (Reuss). – David & Pouyet: p. 130, pl. 2, fig. 3.
1988 *Scrupocellaria elliptica* (Reuss). – Moissette: p. 106, pl. 16, figs. 5, 8.
1995 *Scrupocellaria elliptica* (Reuss). – Ziko & El-Sorogy: p. 84, fig. 4/ 3-5.
1996 *Scrupocellaria elliptica* (Reuss). – El Dera: p. 98, pl. 10, figs 2-4.

Materials: Three well preserved erect zoaria, of cellariiform colonies, Gebel Zeit and Ras Gemsha.

Diagnosis: Zoarial segment bearing eight zooecia arranging in biserial: alternating manner. Zooecia articulated, distinct, elliptical, separated from each other by relatively wide grooves. Mural rim with two circular spines at the midline of interior opesia.

Distribution and Habitat: Oligocene of France, Italy; Miocene of Egypt, France, Austria, Poland, Portugal, Algeria; Pliocene of Portugal; Pleistocene of USA and Egypt; Recent of Atlantic off Brazil and Canada, East Atlantic at Cap Verde Island, Mediterranean, Pacific and Arctic. (Moissette 1988; Ziko & El-Sorogy 1995; Ziko 1996).

Range: Eocene-Recent.

Phylum **Cnidaria Hatschek, 1880**

Order Scleractinia Boure, 1900
Family Pocilloporidae Gray, 1842

Genus *Stylophora* Schweigger, 1819

Type species: *Madrepora pistillata* (Esper, 1795).

Stylophora pistillata (Esper, 1795) Fig. 2/3

1795 *Madrepora pistillata*. – Esper: p. 73, pl. 60.
1879 *Stylophora pistillata* (Esper). – Klunzinger, p. 62, pl. 7, fig. 3, pl. 8, fig. 2.
1983 *Stylophora pistillata* (Esper). – Scheer & Pillai, p. 22, pl. 2, figs. 3-5.
1991 *Stylophora pistillata* (Esper). – Sheppard & Sheppard, p. 41, pl. 9-11, figs. 14 a-c.
1997 *Stylophora pistillata* (Esper). – El-Sorogy, p. 32, fig. 11/1.
1998 *Stylophora pistillata* (Esper). – Gameil, p. 175, fig. 3/1.

Material: Eight branches, Ras Gemsha and Gebel Zeit.
Diagnosis: Calices are 0.7-1.2 mm in diameter, arranged but scattered irregularly and usually closely. Corallites have mostly well developed six primary septa and a small columella.

Distribution and Habitat: Pleistocene of the Red Sea coast and Sinai; Recent of the Indo-Pacific, from Red Sea to Fiji and Samoa, but not known

along the coast of India. Recorded from shallow reef crest to at least 50 m deep (PILLAI & SCHEER 1976, SCHEER & PILLAI 1983; SHEPPARD & SHEPPARD 1991; EL-SOROGY 1997).

Range: Pleistocene-Recent.

Family Acroporidae VERRILL, 1902

Genus *Acropora* OKEN, 1815

Type species: *Millepora muricata* LINNAEUS, 1758.

Acropora clathrata (BROOK, 1891) Fig. 2/4

1984 *Acropora clathrata* (BROOK). – VERON & WALLACE, p. 360, figs. 889-899.
1991 *Acropora clathrata* (BROOK). – SHEPPARD & SHEPPARD, p. 55, pl. 24, fig. 31.

Material: Fifteen branches, Ras Gemsha and Gebel Zeit.
Diagnosis: Corallum ramose, brachlets anastomose strongly with noticeably rounded and more smooth radial corallites, septa in two cycles.

Habitat: Red Sea and Arabian Sea. This species is widespread in clear but sheltered areas (SHEPPARD & SHEPPARD 1991).

Acropora horrida (DANA, 1846) Fig. 2/5

1984 *Acropora horrida* (DANA). – VERON & WALLACE, p. 251, figs. 602-612.
1991 *Acropora clathrata* (DANA). – SHEPPARD & SHEPPARD, p. 57, fig. 37.

Material: Four branches, Ras Gemsha and Gebel Zeit.
Diagnosis: Corallites are cylinderical. The axial corallites measure 1-1.3 mm in diameter with a large funnel-shaped opening having 12 Septa. The prominent radials are 1 mm in diameter. Septa vary in different calices.

Habitat: Red Sea, Gulf of Suez and Arabian Sea. It is a shallow water species, in sandy and lagoonal habitats. In some areas it is widespread down to 5m deep (SHEPPARD & SHEPPARD 1991).

Genus *Montipora* DE BLAINVILLE 1830

Type species: *Montipora verrucosa* QUOY & GAIMARD, 1833.

Montipora spongiosa (EHRENBERG, 1834) Fig. 2/6

1879 *Montipora spongiosa* (EHRENBERG). – KLUNZINGER, p. 38, pl. 5, fig. 10, pl. 6, fig. 3, pl. 10, fig. 10.

1983 *Montipora spongiosa* (EHRENBERG). – SCHEER & PILLAI, p. 54, pl. 10, figs. 9, 10.
1991 *Montipora spongiosa* (EHRENBERG). – SHEPPARD & SHEPPARD, p. 47, fig. 21.

Material: Fifty well preserved branched colonies, from the uppermost part of the studied coral reefs at Ras Gemsha .
Diagnosis: Calices from 0.6-1 mm in diameter. First cycles of septa thickened. The papillae are developed at the underside of the corallites. The surface shows a tight set of reticulum with fine echinulations.

Habitat: Red Sea, Arabian Sea (SHEPPARD & SHEPPARD 1991; SCHEER & PILLAI 1983).

Family *Siderastreidae* VAUGHAN & WELLS, 1943

Genus *Coscinaraea* EDWARDS & HIME, 1848

Type species: *Astrea monile* FORSKÅL, 1775.

Coscinaraea columna (DANA, 1846) Fig. 2/7

1980 *Coscinaraea columna* (DANA). – VERON & PICHON, p. 92, figs. 152-157.
1991 *Coscinaraea columna* (DANA). – SHEPPARD & SHEPPARD, p. 81, figs. 71 a-c.

Material: One encrusting massive colony, Ras Gemsha.
Diagnosis: Calicular structure is very similar, 2-3 mm in diameter, corallites very shallow to completely superficial. Septa considerably more beaded. 12-15 major septa reach the columella.

Habitat: It is common in the clear water of the Arabian Sea and Red Sea, at 10 m deep in a coastal embayment (SHEPPARD & SHEPPARD, 1991).

Fig. 3. 1: *Fungia* (*Danafungia*) *corona* DOEDERLEIN, upper surface of a corallum, Gebel Zeit. **2:** *Fungia* (*Danafungia*) *validae* VERRILL, upper surface of a corallum, Gebel Zeit. **3:** *Galaxea fascicularis* (LINNAEUS), top view of a colonial part, Ras Gemsha. **4:** *Echinopora lamellosa* ESPER, top view of a colonial part, Ras Gemsha. **5:** *Blastomussa merleti* (WELLS), top view of a colonial part, Ras Gemsha. **6:** *Lobophyllia corymbosa* (FORSKÅL), top view of a colonial part, Gebel Zeit. **7:** *Favites peresi* FAURE & PICHON, top view of a colonial part, Gebel Zeit. **8:** *Favites pentagona* (ESPER), top view of a colonial part, Gebel Zeit. Scale bar = 10 mm.

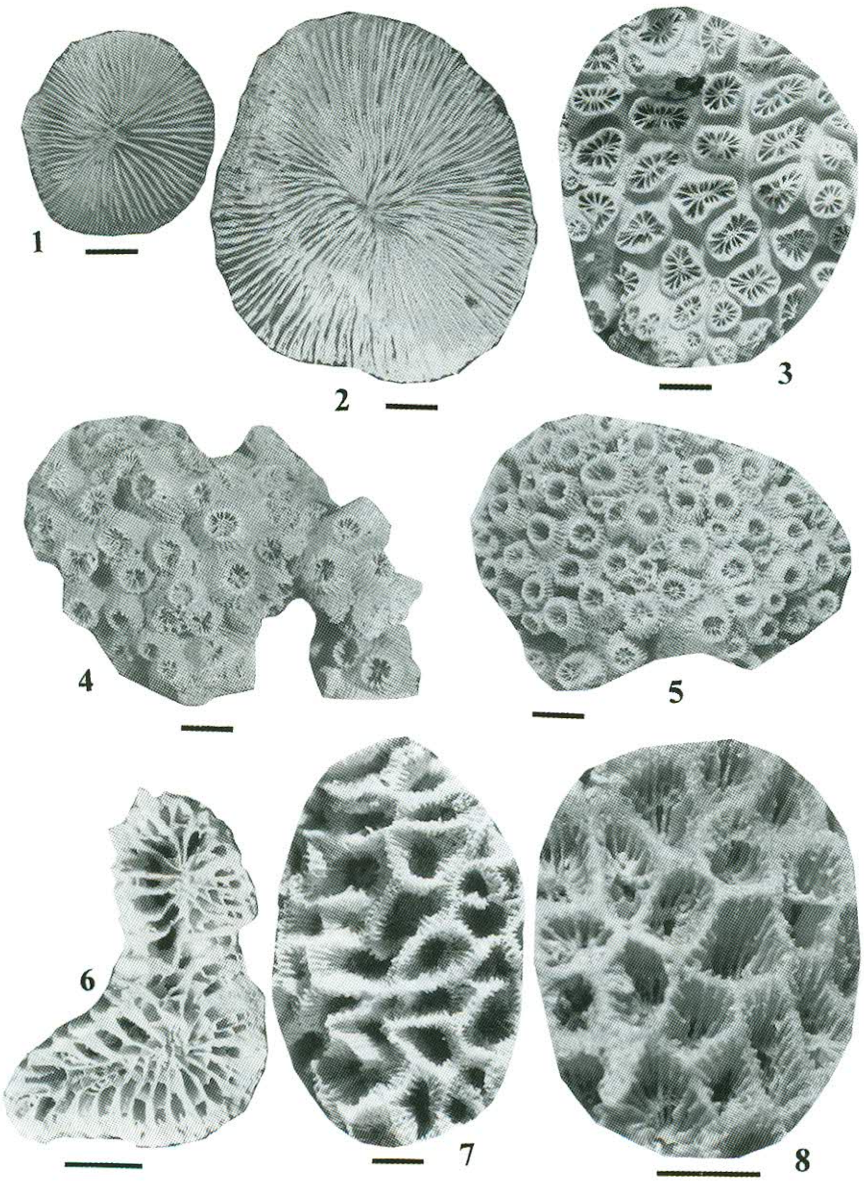

Fig. 3 (Legend see p. 344)

Family Fungiidae DANA 1846

Genus *Fungia* LAMARCK, 1801

Type species: *Madrepora fungites* LINNAEUS, 1758.

Fungia (*Fungia*) *fungites* (LINNAEUS, 1758) Fig. 2/8

1979 *Fungia fungites* (LINNAEUS). – SCHUHMACHER, p. 234, figs. 26-27.
1983 *Fungia fungites* (LINNAEUS). – SCHEER & PILLAI, p. 84, pl. 20, figs. 1-5.
1991 *Fungia* (*Fungia*) *fungites* (LINNAEUS). – SHEPPARD & SHEPPARD, p. 101, fig. 94.
1993 *Fungia fungites* (LINNAEUS). – ZIKO, HAMZA, ZALAT & EL-SOROGY, p. 331, pl. 2, figs. 6-7.

Material: Four preserved coralla, Gebel Zeit.
Diagnosis: Coralla are circular and flat, septa with triangular and small dentations. Costal spines regular, tall and sharp.

Distribution and habitat: Pleistocene of the Red Sea coast and Sinai; Recent of the Red Sea, Gulf of Aden, East Africa, Seychelles, Maldives, Singapore, Philippines, Japan, Great Barrier Reef, Marshall islands, Somoa, Tuamotu Archipelago. This species is very common in sandy, rubble and hard substrate areas, down to at least 35 m (SCHEER & PILLAI 1983, SHEPPARD & SHEPPARD 1991).

Range: Pleistocene-Recent.

Fungia (*Danafungia*) *corona* DOEDERLEIN, 1901 Fig. 3/1

1980 *Fungia* (*Danafungia*) *corona* DOEDERLEIN. – VERON & PICHON, p. 136, figs. 218-221.
1991 *Fungia* (*Danafungia*) *corona* DOEDERLEIN. – SHEPPARD & SHEPPARD, p. 101, fig. 95.

Material: Two well preserved coralla, Gebel Zeit.
Diagnosis: Coralla are circular, septa have large, coarse, and regular teeth. Costae are widely spaced and alternate in size.

Habitat: Red Sea. It is found on gently sloping reef slopes and rubble (SHEPPARD & SHEPPARD, 1991).

Fungia (*Danafungia*) *validae* VERRILL 1864 Fig. 3/2

1980 *Fungia* (*Danafungia*) *validae* VERRILL. – VERON & PICHON, p. 143, figs. 232-233.

1991 *Fungia (Danafungia) validae* VERRILL. – SHEPPARD & SHEPPARD, p. 102, fig. 99.

Material: Two well preserved coralla, Gebel Zeit.
Diagnosis: Septa fairly thick and their teeth are very large and irregular.

Habitat: Red Sea, in sheltered areas (SHEPPARD & SHEPPARD 1991).

Family Faviidae GREGORY, 1900

Genus *Favia* OKEN, 1815

Type species: *Madrepora fragum* ESPER, 1795.

Favia stelligera (DANA, 1846) Fig. 4/1

1977 *Favia stelligera* (DANA). – VERON, PICHON & WIJSMAN-BEST, p. 20, figs. 16-22.
1983 *Favia stelligera* (DANA). – SCHEER & PILLLAI, p. 105, pl. 26.
1997 *Favia stelligeria* (DANA). – EL-SOROGY, p. 32, pl. 11/4.
2000 *Favia stelligera* (DANA). – ZALAT, HAMZA. ZIKO & EL-SOROGY, p. 240, pl. 1, figs. 1-2.

Material: Two massive placoid colonies, Ras Gemsha.
Diagnosis: Calices circular and 2.5-3.5 mm in diameter. Three cycles of septa well developed major ones with paliform lobes.

Distribution and habitat: Pleistocene of the Red Sea coast. Recent of the Red Sea, East Africa, Seychelles, Maldives, Singapore, Philippines, Japan, Great Barrier Reef, Somoa, Tuamotu Archipelago, Ceylon, Maldives, Indonesia, Japan, Taiwan, New Caledonia. This species has a strong preference to very shallow water in sheltered sites such as protected fringing reefs, rarely found deeper than 6 m. (SCHEER & PILLAI 1983; SHEPPARD & SHEPPARD 1991; ZALAT et al. 2000).

Range: Pleistocene-Recent.

Genus *Favites* LINK, 1807

Type species: *Madrepora abdita* ELLIS & SOLANDER, 1786.

Favites pentagona (ESPER, 1794) Fig. 3/8

1977 *Favites pentagona* (ESPER). – VERON, PICHON & WIJSMAN-BEST, p. 68, figs. 122-127.
1983 *Favites pentagona* (ESPER). – SCHEER & PILLAI, p. 118, pl. 29.

1991 *Favites pentagona* (Esper). – Sheppard & Sheppard, p. 126, pl. 91, figs. 136 a-b.

Material: One massive cerioid colony, from the upper unit, Gebel Zeit.
Diagnosis: Calices from 4-7 mm in diameter. Calice outlines are angular rather than circular (commonly five-sided as the name suggests).

Habitat: Red Sea, Arabian Sea, East Africa, Ceylon, Maldives, Indonesia, Japan, Taiwan, New Caledonia. It is found on the reef flats as well as reef slopes, in lagoonal and exposed sites. (Scheer & Pillai 1983; Sheppard & Sheppard 1991).

Favites peresi Faure & Pichon, 1978 Fig. 3/7

1978 *Favites peresi* Faure & Pichon. – Faure & Pichon, p. 107, pl. 1-5.
1983 *Favites peresi* Faure & Pichon. – Scheer & Pillai, p. 113, pl. 28.
1991 *Favites peresi* Faure & Pichon. – Shepppard & Sheppard, p. 129, pl. 93, figs. 140.

Material: Two well preserved massive colonies from the upper unit, Gebel Zeit.
Diagnosis: Cerioid, polygonal calices with acute wall, 10 to 20 mm in diameter and 6-10 mm deep. Septal number varies according to the size of the calices, the first two cycles reach the columella.

Habitat: This is a common member of the high diversity faviid zone at mid-depths on bare reef slope of the Red Sea, and Madagascar. It is very rarely found on exposed reef crests, reef flats or sites covered by sediment (Scheer & Pillai 1983; Sheppard & Sheppard 1991).

Fig. 4. 1: *Favia stelligera* (Dana), top view of a colonial part, Ras Gemsha. **2:** *Platygyra daedalea* (Ellis & Solander), top view of a colonial part, Ras Gemsha. **3:** *Clanculus* (*Clanculus*) *pharaonium* (Linnaeus), top view, Ras Gemsha. **4:** *Luria* (*Basilitroma*) *isabella* (Linnaeus), apertural view, Gebel Zeit. **5:** *Conus generalis* Linnaeus, apertural view, Ras Gemsha. **6, 7:** *Arca imbricata* (Bruguière), 6 internal view of left valve, 7 external view of the same, Ras Gemsha. **8, 9:** *Barbatia* (*Barbatia*) *lacerata* (Bruguière), 8 internal view of left valve, 9 external view of the same, Ras Gemsha. **10, 11:** *Anadara antiquata* (Linnaeus), 10 internal view of right valve, 11 external view of the same, Ras Gemsha. **12, 13:** *Glycymeris pectenculus* (Linnaeus), 12 internal view of left valve, 13 external view of the same, Gebel Zeit. Scale bar = 10 mm.

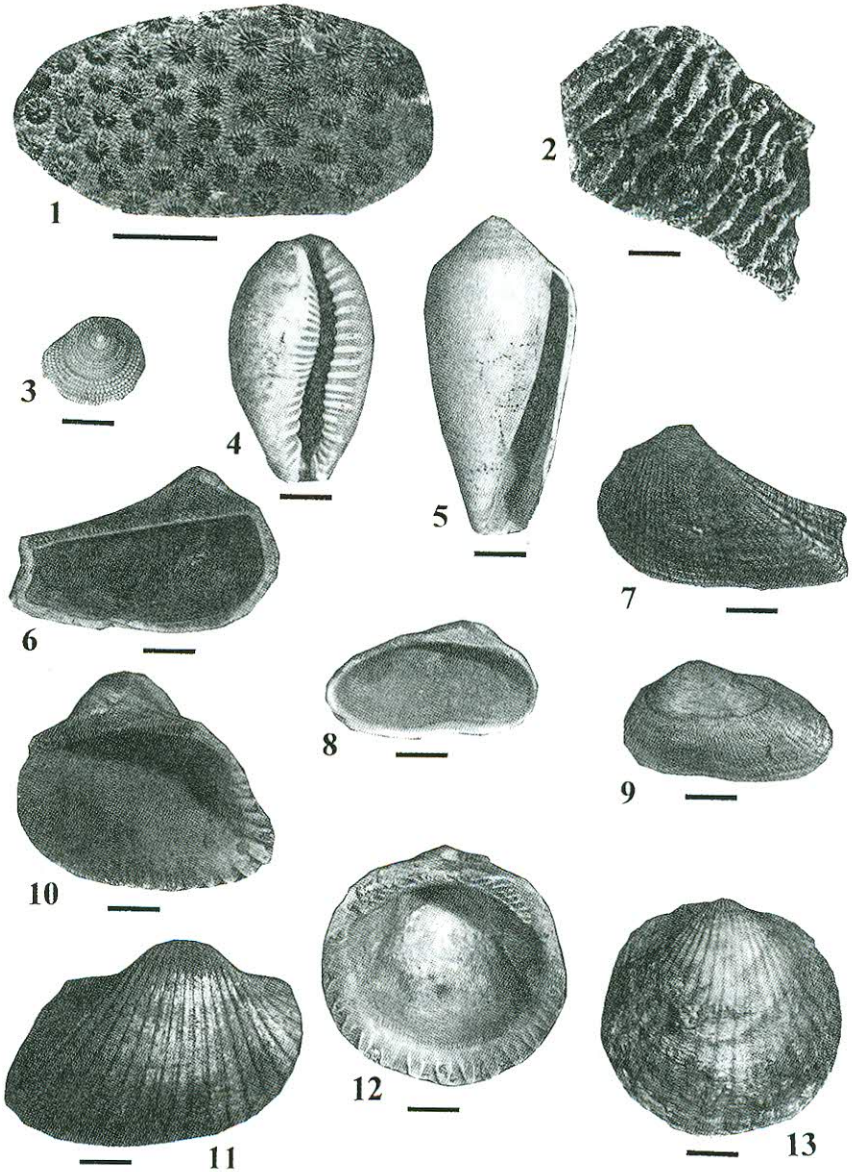

Fig. 4 (Legend see p. 348)

Genus *Platygyra* EHRENBERG, 1834

Type species: *Madreopora* (*Platygyra*) *lamellina* EHRENBERG, 1834.

Platygyra daedalea (ELLIS & SOLANDER, 1786) Fig. 4/2

1977 *Platygyra daedalea* (ELLIS & SOLANDER). – VERON, PICHON & WIJSMAN-BEST, p. 98, figs. 190-196.
1991 *Platygyra daedalea* (ELLIS & SOLANDER). – SHEPPARD & SHEPPARD, p. 132, pl. 97, fig. 148.
1983 *Platygyra daedalea* (ELLIS & SOLANDER). – SCHEER & PILLAI, p. 123, pl. 30, fig. 6.
1997 *Platygyra daedalea* (ELLIS & SOLANDER). – EL-SOROGY, p. 32, fig. 11/8.
2000 *Platygyra daedalea* (ELLIS & SOLANDER). – ZALAT, HAMZA, ZIKO & EL-SOROGY, p. 243, pl. 2, fig. 2.

Material: Five fully meandroid, massive colonies, Ras Gemsha.
Diagnosis: The valleys are wider than the separating walls, 5-7 mm width and 5-8 mm depth. Septa alternating in size, edges dentate. Columella trabecular and continuous.

Distribution and habitat: Pleistocene of the Red Sea coast. Recent of the Red Sea into the Pacific as far east as Samoa and Cook islands. It is a fairly common species in mid-depths on fore-reef slopes of the Red Sea, Arabian Gulf, and Arabian Sea. (SCHEER & PILLAI 1983; SHEPPARD & SHEPPARD 1991; ZALAT et al. 2000).

Range: Pleistocene-Recent.

Genus *Echinopora* LAMARCK, 1816

Type species: *Madrepora lamellosa* ESPER, 1795.

Echinopora lamellosa ESPER, 1797 Fig. 3/4

1977 *Echinopora lamellosa* ESPER. – VERON, PICHON & WIJSMAN-BEST, p. 183, figs. 366-374.
1983 *Echinopora lamellosa* ESPER. – SCHEER & PILLAI, p. 136, pl. 32.
1991 *Echinopora lamellosa* ESPER. – SHEPPARD & SHEPPARD, p. 141, pl. 108, figs. 163 a-b.
2000 *Echinopora gemmacea* ESPER. – ZALAT, HAMZA, ZIKO & EL-SOROGY, p. 245, pl. 3, fig. 3.

Material: One ramose colony, Ras Gemsha.
Diagnosis: Calices rounded, 3-6 mm in diameter, and in general spaced about a corallite diameter apart. The primary septa are markedly exsert and bear paliform lobes. 12 to 16 septa reach the columella.

Distribution and habitat: Pleistocene of the Red Sea coast and Sinai; Recent common species in the Red Sea, East Africa, Seychelles, Maldives, Singapore, Philippines, Japan, Great Barrier Reef, Somoa, Tuamotu Archipelago, Ceylon, Maldives, Indonesia, Japan, Taiwan, New Caledonia, Chagos, Fiji. It occurs on steep reef slopes, generally below 15 m (SHEPPARD & SHEPPARD, 1991; ZALAT et al. 2000).

Range: Pleistocene-Recent.

Family Oculinidae GRAY, 1847

Genus *Galaxea* OKEN, 1815

Type species: *Madrepora fascicularis* LINNAEUS, 1758.

Galaxea fascicularis (LINNAEUS, 1767) Fig. 3/3

1956 *Galaxea fascicularis* (LINNAEUS). – MOORE, p. 412, fig. 311/2.
1980 *Galaxea fascicularis* (LINNAEUS). – VERON & PICHON, p. 204, figs. 336-347.
1983 *Galaxea fascicularis* (LINNAEUS). – SCHEER & PILLAI, p. 142, pl. 34.
1991 *Galaxea fascicularis* (LINNAEUS). – SHEPPARD & SHEPPARD, p. 106, pl. 70, fig. 109.
2000 *Galaxea fascicularis* (LINNAEUS). – ZALAT, HAMZA, ZIKO & EL-SOROGY, p. 246, pl. 3, fig. 7.

Material: Three phaceloid colonies, Ras Gemsha and Gebel Zeit.
Diagnosis: Corallites 7 to 15 mm in diameter. Septa in 4 to 5 cycles, depending on the size of the calyx.

Distribution and habitat: Pleistocene of the Red Sea coast; Recent of the Red Sea and Arabian Sea to Samoa, generally uncommon on clear water reef slopes where its range is 5-20 m. It may be extremely abundant in turbid areas, in water less than 5 m deep. (SCHEER & PILLAI 1983; SHEPPARD & SHEPPARD 1991; ZALAT et al. 2000).

Range: Pleistocene-Recent.

Family Mussidae ORTMANN, 1890

Genus *Blastomussa* WELLS, 1961

Type species: *Bantamia merleti* WELLS, 1961.

Blastomussa merleti (WELLS, 1961) Fig. 3/5

1975 *Blastomussa merleti* (WELLS). – CHEVALIER, p. 327, pls. 29, fig. 6, pl. 30, figs. 5-7.

1980 *Blastomussa merleti* (Wells). – Veron & Pichon, p. 234, figs. 393, 767.
1983 *Blastomussa merleti* (Wells). – Scheer & Pillai, p. 149, pl. 35, figs. 5-6, 10-11.
1991 *Blastomussa merleti* (Wells). – Sheppard & Sheppard, p. 111, pl. 74, figs. 113 $_{a-c}$.

Material: Two phaceloid colonies, Ras Gemsha.
Diagnosis: Calices from 4-9 mm in diameter. Septa contain few strong but blunt spines, commonly one on each near the wall.

Habitat: Red Sea, Aldabra, Madagascar, Great Barrier Reef, New Caledonia. It favours small crevices or steep parts of the reef slopes and may be recorded down to at least 50 m depth in fairly dark and cryptic conditions as well as in moderatly lit areas, very rarely encountered in shallow or exposed conditions (Scheer & Pillai 1983; Sheppard & Sheppard 1991).

Genus *Lobophyllia* de Blainville, 1830

Type species: *Madrepora corymbosa* Forskål, 1775.

Lobophyllia corymbosa (Forskål, 1775) Fig. 3/6

1879 *Mussa corymbosa* (Forskål). – Klunzinger, p. 6, pl. 1, figs. 4, 9.
1980 *Lobophyllia corymbosa* (Forskål).–Veron & Pichon, p. 274, figs. 472-475.
1983 *Lobophyllia corymbosa* (Forskål). – Scheer & Pillai, p. 146, pl. 34.
1991 *Lobophyllia corymbosa* (Forskål). – Sheppard & Sheppard, p. 116, pl. 79, fig. 119.
2000 *Lobophyllia corymbosa* (Forskål). – Zalat, Hamza, Ziko & El-Sorogy, p. 246, pl. 3, fig. 9.

Material: Two phaceloid well preserved colonies, Gebel Zeit.
Diagnosis: Corallites essentially monocentric, with occasional di- or tricentric valleys. Valleys 3-4 cm long and 2-2.5 cm wide.

Distribution and habitat: Pleistocene of the Red Sea coast. Recent from the Red Sea eastward to Tahiti. It is particularly abundant in sheltered localities, often adjacent to or on sandy back-reef areas. It is also common among the coral rubble accumulating on fringing reef slopes. (Scheer & Pillai 1983, Sheppard & Sheppard 1991; Zalat et al. 2000).

Range: Pleistocene-Recent.

Phylum **Mollusca Cuvier, 1795**

Class Gastropoda Cuvier, 1797
Family Trochidae Rafinesque, 1815

Genus *Clanculus* MONTFORT, 1810

Type species: *Trochus pharaonius* LINNAEUS, 1758.

Clanculus (*Clanculus*) *pharaonium* (LINNAEUS, 1758) Fig. 4/3

1900 *Clanculus* (*Clanculus*) *pharaonium* (LINNAEUS). – NEWOTEN, p. 559, pl. XX, fig. 4.
1982 *Clanculus* (*Clanculus*) *pharaonium* (LINNAEUS). – ABED, p. 167, pl. VIII, fig. 4.
1982 *Clanculus* (*Clanculus*) *pharaonis* (LINNAEUS). – EL-SHAZLY, p. 112, pl. 12, figs. 2-3.
1990 *Clanculus* (*Clanculus*) *pharaonis* (LINNAEUS). – EL-SOROGY, p. 147, pl. 14, figs. 1-2.
1998 *Clanculus* (*Clanculus*) *pharaonius* (LINNAEUS). – GAMEIL, p. 534, pl. 1, figs. 3-4.

Material: Twenty one well preserved shells, Ras Gemsha.
Diagnosis: Shell of small size, trochoid form, spire low, sutures depressed, body whorl large. Surface ornamented with granulose tuberculated spinal cords.

Habitat and distribution: Pleistocene raised beaches of the Red Sea coast and Sinai; Recent of the Red Sea, Gulf of Aqaba, Gulf of Suez and Arabian Gulf (NEWOTEN 1900; EL-SHAZLY 1982; BOSCH et al. 1995; GAMEIL 1998).

Range: Pleistocene-Recent.

Family Cypraeidae FLEMING, 1828

Genus *Luria* JOUSSEAUME, 1884

Type species: *Luria lurida* (LINNAEUS, 1758).

Luria (*Basilitroma*) *isabella* (LINNAEUS, 1758) Fig. 4/4

1982 *Cypraea isabella* LINNAEUS. – ABED, p. 272, pl. VII, figs. 2a, b.
1982 *Luria* (*Basilitroma*) *isabella* (LINNAEUS, 1758). – EL-SHAZLY, p. 145, pl. 15, figs. 4-5.
1990 *Luria* (*Basilitroma*) *isabella* (LINNAEUS, 1758). – EL-SOROGY, p. 162, pl. 15, figs. 2-3.
1998 *Luria* (*Basilitroma*) *isabella* (LINNAEUS, 1758). – ABD EL- FATTAH, p. 112, pl. 23, figs. 2.
1998 *Luria* (*Basilitroma*) *isabella* (LINNAEUS, 1758). – GAMEIL, p. 537, pl. 1, figs. 18-19.

Material: Two well preserved shells, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of small to moderate size, large curved, inner lip very gently convex, well developed teeth.

Habitat and distribution: Pleistocene raised beaches of the Red Sea coast; Recent of the Red Sea, Indo-Pacific, Zanzibar, Arabian Gulf. (Cox 1927; El-Sorogy 1990; Bosch et al. 1995; Gameil 1998).

Range: Pleistocene-Recent.

Family Conidae Adams 1849

Genus Conus Linnaeus, 1758

Type species: *Conus marmoreus* Linnaeus, 1758

Conus generalis Linnaeus, 1758 — Fig. 4/5

1982 *Conus generalis* Linnaeus. – El-Shazly, p. 135, pl. 16, fig. 10.
1989 *Conus generalis* Linnaeus. – Al-Rifaiy & Cherif, p. 394, pl. VIII, fig. 2.
1990 *Conus generalis* Linnaeus. – El-Sorogy, p. 165, pl. 15, figs. 10-11.
1998 *Conus generalis* Linnaeus. – Abd El-Fattah, p. 117, pl. 3, figs.9-11.

Material: Two well preserved shells, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of moderate size, obconical, short spire, sutures flush, body whorl large, longitudinal. Surface ornamented with smooth yellowish colour bands.

Habitat and distribution: Pleistocene raised beaches of the Red Sea coast. Recent of the Red Sea, Ceylon, East Africa, Philippines, New Caledonia, Aden (Newoten 1900; El-Sorogy 1990; Al-Rifaiy & Cherif 1989).

Range: Pleistocene-Recent.

Class Bivalvia Linnaeus, 1758
Family Arcidae Lamarck, 1809

Genus *Arca* Linnaeus, 1758

Type species: *Arca noae* Linnaeus, 1758.

Arca impricata Bruguière, 1789) — Fig. 4/6, 7

1927 *Arca impricata* (Bruguière). – Cox, p. 242, pl. IX, figs. 17-18.
1982 *Arca impricata* (Bruguière). – El-Shazly, p. 48, pl. 2, figs. 4-5, 8, pl. 9, figs. 1, 7.
1990 *Arca impricata* (Bruguière). – El-Sorogy, p. 102, pl. 8, figs. 4-5.
1998 *Arca impricata* (Bruguière). – Gamiel, p. 538, pl. 2, figs. 1-2.

Material: One right and three left valves, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of small size, trapezoidal, umbo located above the anterior third of the hinge, integripalliate, surface ornamented with concentric growth lines increase ventrally, crossed by very fine radial ribs. The ribs becoming more developed in the posterior part.

Habitat and distribution: Pleistocene sediments of the Red Sea; Recent of the Gulf of Suez, Gibuti, Aden, Zanzibar, Madgascar, Indian Ocean, Philippine, Australia, (NEWOTEN 1900; EL-SHAZLY 1982; GAMEIL 1998).

Range: Pleistocene-Recent.

Genus *Barbatia* GRAY, 1892

Type species: *Arca barbatia* LINNAEUS, 1758.

Barbatia (*Barbatia*) *lacerata* (BRUGUIÈRE, 1789)
Fig. 4/8, 9

1972 *Barbatia lacerata* (LINNAEUS). – HAMZA, p. 75, pl. 1, fig. 3.
1982 *Barbatia* (*Barbatia*) *lacerata* (BRUGUIÈRE). – EL-SHAZLY, p. 43, pl. 1, figs. 1-3, pl. 9, fig. 2.
1997 *Barbatia* (*Barbatia*) *lacerata* (BRUGUIÈRE). – EL-SOROGY, p. 32, fig. 12/4.
1998 *Barbatia* (*Barbatia*) *lacerata* (BRUGUIÈRE). – GAMIEL, p. 538, pl. 2, figs. 3-4.

Material: One right and one left valve, Ras Gemsha.
Diagnosis: Shell of moderate size, highly prosogyrate, integripalliate, Surface ornamented with numerous very fine radial ribs crossed by fine concentric growth lines.

Habitat and distribution: Pleistocene of the Red Sea coast; Recent of Red Sea, Zanzibar, Gibuti, Philippine, Farsan Islands and the Arabian Gulf (AL-AWADI 1980; EL-SHAZLY 1982; GAMEIL 1998).

Range: Pleistocene-Recent.

Genus *Anadara* GRAY, 1874

Type species: *Arca antiquata* LINNAEUS, 1758.

Anadara antiquata (LINNAEUS, 1758) Fig. 4/10, 11

1972 *Anadara antiquata* (LINNAEUS). – HAMZA, p. 70, pl. 1, figs. 4-4a.
1982 *Anadara* (*Anadara*) *antiquata* (LINNAEUS). – ABED, p. 252, pl. IV, figs. 3 a, b.

1982 *Anadara antiquata* (LINNAEUS). – EL-SHAZLY, p. 252, pl. IV, figs. 3 a, b.
1990 *Anadara antiquata* (LINNAEUS). – EL-SOROGY, p. 106, pl. 9, figs. 1-3.
1997 *Anadara antiquata* (LINNAEUS). – EL-SOROGY, p. 32, fig. 12/10.

Material: Four right and six left valves, Ras Gemsha.
Diagnosis: Shell of moderate size, trapezoidal, prosogyrate, umbo located above the anterior third of the dental plate, integripalliate. Surface ornamented with well developed divided radial. ribs crossed by concentric threads, the radial ribs separated by narrow interspaces.

Distribution and habitat: Pliocene of Java, Kenya; Pleistocene of Java and Red Sea raised beaches, Kenya; Recent of the Arabian Gulf. (NEWOTEN 1900; COX 1927, AL-RIFAIY & CHERIF 1989).

Range: Pliocene-Recent.

Family Glycymeridae NEWOTEN, 1922

Genus *Glycymeris* DA COSTA, 1778

Type species: *Arca orbicularis* DA COSTA, 1778.

Glycymeris pectenculus (LINNAEUS, 1758)

Fig. 4/12, 13

1900 *Glycymeris pectenculus* (LINNAEUS). – NEWOTEN, p. 547, pl. XXI, fig. 7.
1972 *Glycymeris pectenculus* (LINNAEUS). – HAMZA, p. 78, pl. 1, figs. 5a, b.
1982 *Glycymeris pectenculus* (LINNAEUS). – ABED, p. 254, pl. V, figs. 1 a, b.
1982 *Glycymeris pectenculus* (LINNAEUS). – EL-SHAZLY, p. 51, pl. 2, figs. 7-8.
1990 *Glycymeris pectenculus* (LINNAEUS). – EL-SOROGY, p. 108, pl. 9, figs. 6-7.
1997 *Glycymeris pectenculus* (LINNAEUS). – EL-SOROGY, p. 32, fig. 12/9.

Material: Four right, four left valves and one double valved shell, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of moderate size, orbicular, equilateral, orthogyrate. Surface ornamented with well developed radial ribs, crossed by concentric threads, the radial ribs separated with interspaces which are as wide as the radial ribs, radial ribs not developed laterally.

Habitat and distribution: Pliocene sediments of the Red Sea;. Pleistocene raised beaches of Zanzibar, Red Sea and Sinai. Recent of the Red Sea, Zanzibar, Gulf of Aqaba, Suez, Java, Gibuti and Philippine. (NEWOTEN 1900; ABED 1982; EL-SHAZLY 1982, EL-SOROGY 1997).

Range: Pliocene-Recent.

Family Spondylidae GRAY, 1826

Genus *Spondylus* LINNAEUS, 1758

Type species: *Spondylus gaederopus* (LINNAEUS, 1758).

Spondylus (*Spondylus*) *gaederopus* (LINNAEUS, 1758)
Fig. 5/1, 2

1969 *Spondylus gaederopus* (LINNAEUS). – MOORE, p. 380, figs. 99, 1 c, f.
1982 *Spondylus* (*Spondylus*) *gaederopus* (LINNAEUS). – EL-SHAZLY, p. 53, pl. 2, figs. 10-12.
1989 *Spondylus* (*Spondylus*) *gaederopus* (LINNAEUS). – AL-RIFAIY & CHERIF, p. 380, pl. III, figs. 3, 4.
1990 *Spondylus* (*Spondylus*) *gaederopus* (LINNAEUS). – EL-SOROGY, p. 113, pl. 9, fig. 18, pl. 10, figs. 1-2.
1997 *Spondylus* (*Spondylus*) *gaederopus* (LINNAEUS). – EL-SOROGY, p. 32, fig. 12/5.

Material: One right and one left valve, Ras Gemsha.
Diagnosis: Shell large, oval, equilateral, cardinal area large, rounded muscle scar. Surface ornamented with spinose primary striation with secondary ones in the interspaces inbetween.

Habitat and distribution: Pleistocene raised reefs of the Red Sea coast Recent of the Indian Ocean, Arabian Gulf and Mediterranean. (AL-AWADI 1980; EL-SOROGY 1990; AL-RIFAIY & CHERIF 1989).

Range: Pleistocene-Recent.

Family Chamidae LAMARCK, 1809

Genus *Chama* LINNAEUS, 1758

Type species: *Chama lazarus* LINNAEUS, 1758.

Chama pacifica (BRODERIP, 1835) v Fig. 5/3, 4

1982 *Chama* cf. *pacifica* (BRODERIP). – EL-SHAZLY, p. 100, pl. 8, figs. 2, 6, 10, pl. 10, fig. 3.
1990 *Chama* cf. *pacifica* (BRODERIP). – EL-SOROGY, p. 122, pl. 11, figs. 6-7.

Material: Two right and eight left valves, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of moderate size, oval, cardinal area large, pachydont, two large, oval, raised muscle scars. Surface ornamented with pitted concentric lines.

Habitat and distribution: Pliocene and Pleistocene sediments of the Red Sea coast; Recent of the Arabian Gulf (AL-AWADI 1980; EL-SOROGY 1990).

Range: Pliocene-Recent.

Family Carditidae FLEMING, 1820

Genus *Cardites* LINK, 1807

Type species: *Chama antiquata* (LINNAEUS, 1758).

Cardites antiquata (LINNAEUS, 1758) Fig. 5/5, 6

1969 *Cardites antiquata* (LINNAEUS). – MOORE, p. 556, figs. 56/1.
1982 *Cardites antiquata* (LINNAEUS). – EL-SHAZLY, p. 79, pl. 5, figs. 7, 9, 11, 12, pl. 10, fig. 5.
1990 *Cardites antiquata* (LINNAEUS). – EL-SOROGY, p. 127, pl. 11, figs. 14-15.

Material: Three left and two right valves, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of small to moderate size, elongate, trapezoidal, prosogyrate, integripalliate. Surface ornamented with well developed radial ribs, separated by narrow interspaces, all radial ribs and interspaces crossed by concentric threads.

Habitat and distribution: Pliocene and Pleistocene sediments of the Red Sea coast; Recent of the Mediterranean Sea, Ceylon, Farsan Island, Arabian Gulf. (EL-SHAZLY 1982; EL-SOROGY 1990).

Range: Pliocene-Recent.

Family Veneridae RAFINESQUE, 1815

Genus *Dosinia* SCOPOLI, 1757

Type species: *Dosinia* (*Dosinia*) *concentria* (BORN, 1878).

Dosinia (*Dosinia*) *radiata* (REEVE, 1850) Fig. 5/7, 8

1900 *Dosinia radiata* (REEVE). – NEWOTEN, p. 555, pl. XXI, fig. 5.
1982 *Dosinia* (*Dosinia*) *radiata* (REEVE). – EL-SHAZLY, p. 83, pl. 6, figs. 1-3.

Fig. 5. 1, 2: *Spondylus* (*Spondylus*) *gaederopus* (LINNAEUS), 1 internal view of right valve, 2 external view of the same, Ras Gemsha. **3, 4:** *Chama pacifica* (BRODERIP), 3 internal view of left valve, 4 external view of left valve, Gebel Zeit. **5, 6:** *Cardites antiquata* (LINNAEUS), 5 internal view of right valve, 6 external view of the same, Gebel Zeit. **7, 8:** *Dosinia* (*Dosinia*) *radiata* (REEVE), 7 internal view of right valve, 8 external view of the same, Ras Gemsha. **9, 10:** *Circe* (*Circentia*) *arabica* (DILLWYN), 9 internal view of right valve, 10 external view of the same, Gebel Zeit. Scale bar = 10 mm.

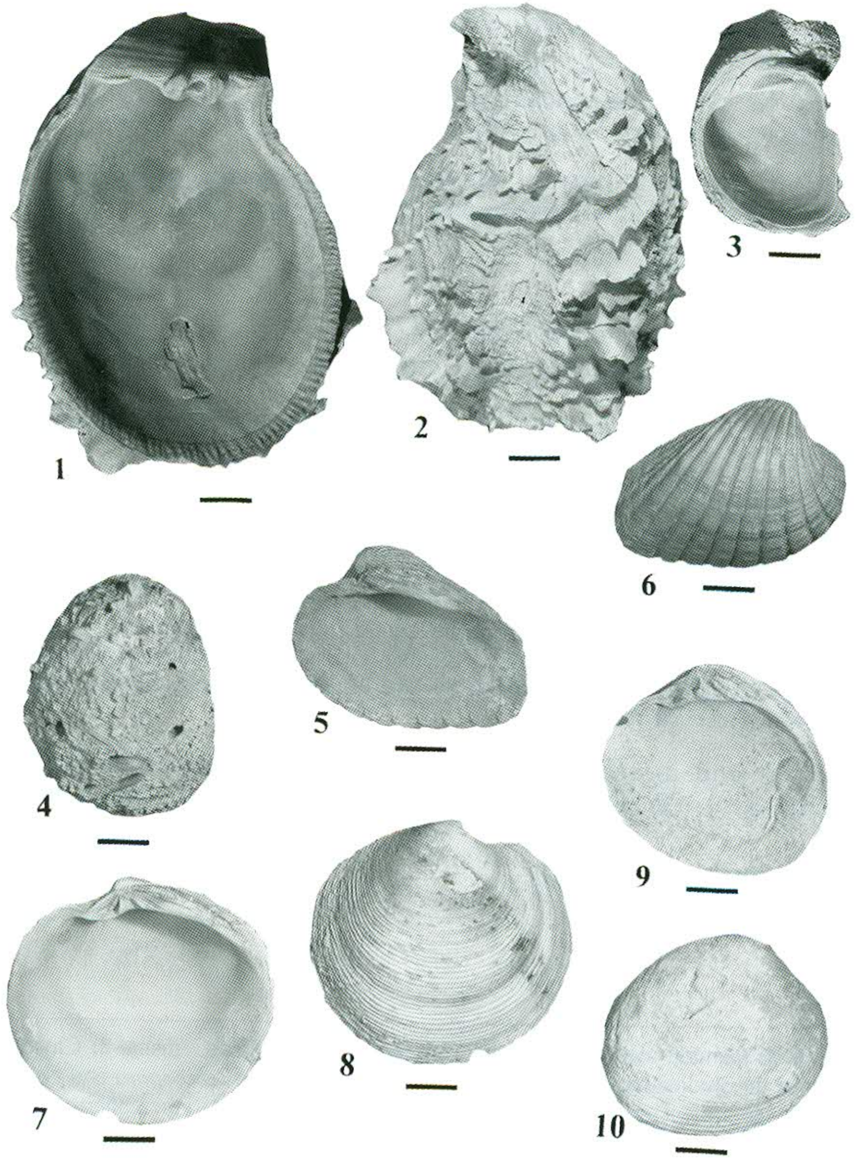

Fig. 5 (Legend see p. 358)

1990 *Dosinia* (*Dosinia*) *radiata* (REEVE). – EL-SOROGY, p. 134, pl. 12, figs. 12, 13.
1997 *Dosinia* (*Dosinia*) *radiata* (REEVE). – EL-SOROGY, p. 32, fig. 12/6.

Material: One right and one left valvee, Ras Gemsha.
Diagnosis: Shell of moderate size, orbicular, two subequal adductor muscle scars, prosogyrate, sinupalliate. Surface ornamented with concentric growth lines.

Habitat and distribution: Pleistocene raised beaches of the Red Sea coast; Recent of the Red Sea (Newoten 1900; El-Sorogy 1990).

Range: Pleistocene-Recent.

Genus *Circe* SCHUMACHER, 1817

Type species: *Venus arabica* DILLWYN, 1817.

Circe (*Circentia*) *arabica* (DILLWYN, 1817) Fig. 5/9, 10

1969 *Circe* (*Circentia*) *arabica* (DILLWYN). – MOORE, p. 672.
1982 *Circe* (*Circentia*) *arabica* (DILLWYN). – EL-SHAZLY, p. 84, pl. 6, figs. 7-9.
1990 *Circe* (*Circentia*) *arabica* (DILLWYN). – EL-SOROGY, p. 135, pl. 12, figs. 15-16.
1997 *Circe* (*Circentia*) *arabica* (DILLWYN). – EL-SOROGY, p. 32, p. fig. 12/8.

Material: Two right and two left valves, Ras Gemsha and Gebel Zeit.
Diagnosis: Shell of moderate size, orbicular, two subequal adductor muscle scars, prosogyrate, pallial sinus very small. Surface ornamented with concentric growth lines which increase ventrally.

Habitat and distribution: Pleistocene raised beaches of the Red Sea coast; Recent of the Red Sea and Indo-Pacific (NEWOTEN, 1900; EL-SOROGY 1997).

Range: Pleistocene-Recent.

Fig. 6. 1: General view of the Pleistocene coral reefs at Ras Gemsha. **2:** Close-up view of the studied reefal limestone at Gebel Zeit, showing *Echinopora* and *Favites* colonies in life position. **3:** *Acropora* and *Seriatopora* colonies in the uppermost part of the studied reefal limestone at Ras Gemsha. **4:** Sea shell accumulation, above the Pleistocene coral reefs of Ras Gemsha. **5:** Sandy bioclastic wackestone, transverse section in echinoid spine, alcyonarian corals and other fossil fragments, fine to medium quartz grains. Gebel Zeit. **6:** Sandy algal bindstone, the red algal filaments act as frame-builders for moderatly rounded quartz grains and some bioclasts. Gebel Zeit. Scale bar = 0.4 mm.

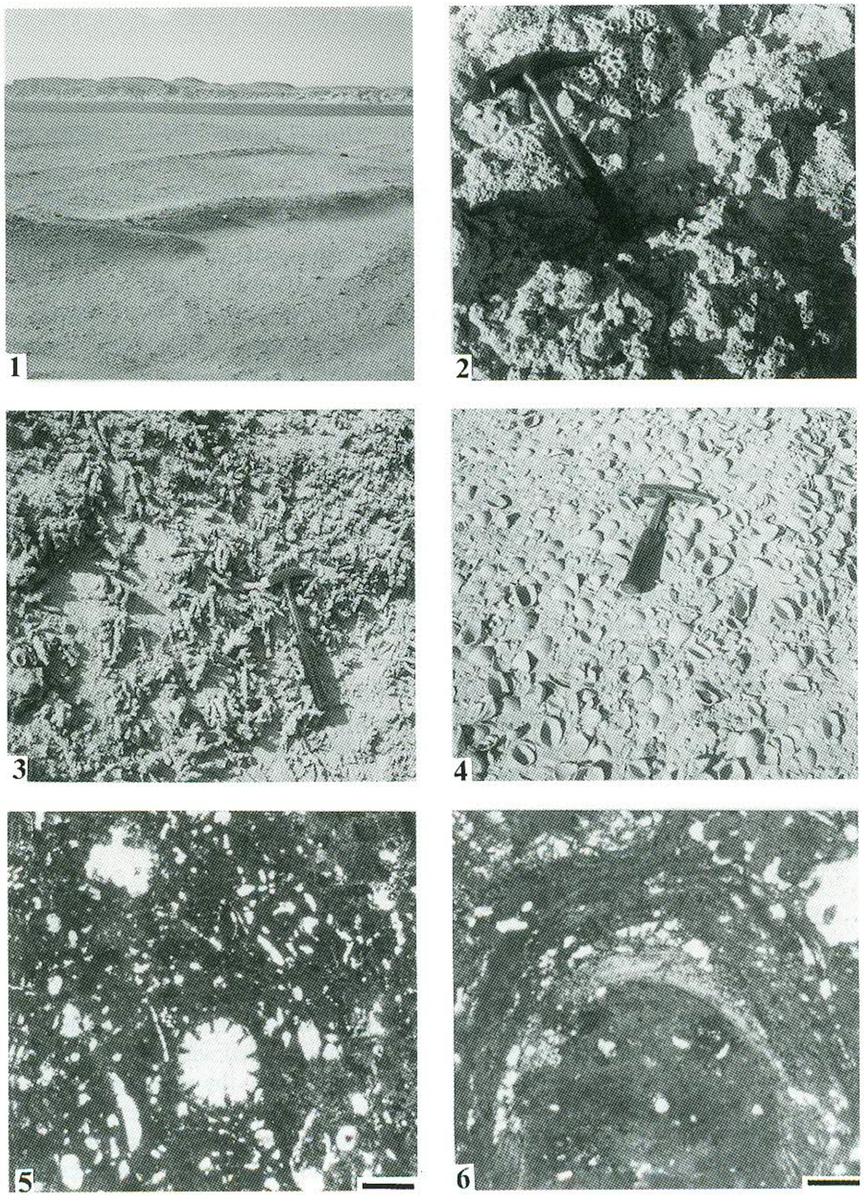

Fig. 6 (Legend see p. 360)

Facies and environments

Facies analysis:

The studied reef unit at Rash Gemsha (fig. 6/1, 3, 4) rests on a 0.50 to 1.25 m thick hard, fossiliferous, varicoloured conglomeratic bed. Clasts are cemented by calcareous material and contain well preserved bivalves, gastropods and coral debris. The primary frame-builders are scleractinian corals (Acroporidae, Poritidae, Faviidae,....) in life position and crustose coralline algae (*Lithophyllum* sp., *Lithothamnium* sp., *Lithoporella* sp.). The secondary builders are encrusting foraminifers, bivalves, gastropods, alcyonarian corals and serpulids. The foraminiferal assemblages obtained by washing are very similar to those described from the modern reefs of Mauritius Island, Indian Ocean (Montaggioni, 1982). They include *Heterostegina depressa, Amphistegina lessonii, Elphidium crispum, Miniacina* sp., *Textularia agglutinans, Quinqueloculina* sp. and *Triloculina*. sp.

Bryozoans are very rare and accumulated on the bottom as carbonate sands, in and around reefs. They are not principal frame-builders in the studied reefs, unlike scleractinian corals and red algae. Cuffey (1977) in his study on bryozoan contribution to reefs, stated that, most of bryozoans inhabit the undersides of the corals and other associated fauna (hidden encrusters) and as fillers of cavities within the reefs, they contribute some calcareous skeletal material to the reef mass.

The vertical sequence shows shallowing upward development, starting at the base with a coral assemblage of the upper reef slope community, and grades into the coral rock zone. This shallowing sequence indicates diminishing water depth. It is capped by a veneer of weakly consolidated shore gravels containing intertidal fossils.

Fig. 7. 1: Coralline framestone; the skeleton of *Porites* sp. acts as frame-builder, about half of the interskeletal pores are empty, the others filled with marine cements. Ras Gemsha, scale bar = 0.4 mm. **2:** Coralline framestone; the skeleton of *Favites* sp. acts as frame-builder, all the interskeletal pores are empty. Gebel Zeit, scale bar = 0.4 mm. **3:** Spherulitic aragonite of sclerodermites forming the trabecular structure of *Favites* sp., Ras Gemsha, scale bar = 20 µm. **4:** Marine aragonite cement, on partially altered trabecular structure of *Porites* sp. Gebel Zeit, scale bar = 20 µm. **5:** Unaltered trabecular structure of *Favites* sp., Ras Gemsha, scale bar = 15 µm. **6:** Typical chalky appearance of trabecular structure due to meteoric diagenesis of *Porites* sp. Gebel Zeit, scale bar = 20 µm.

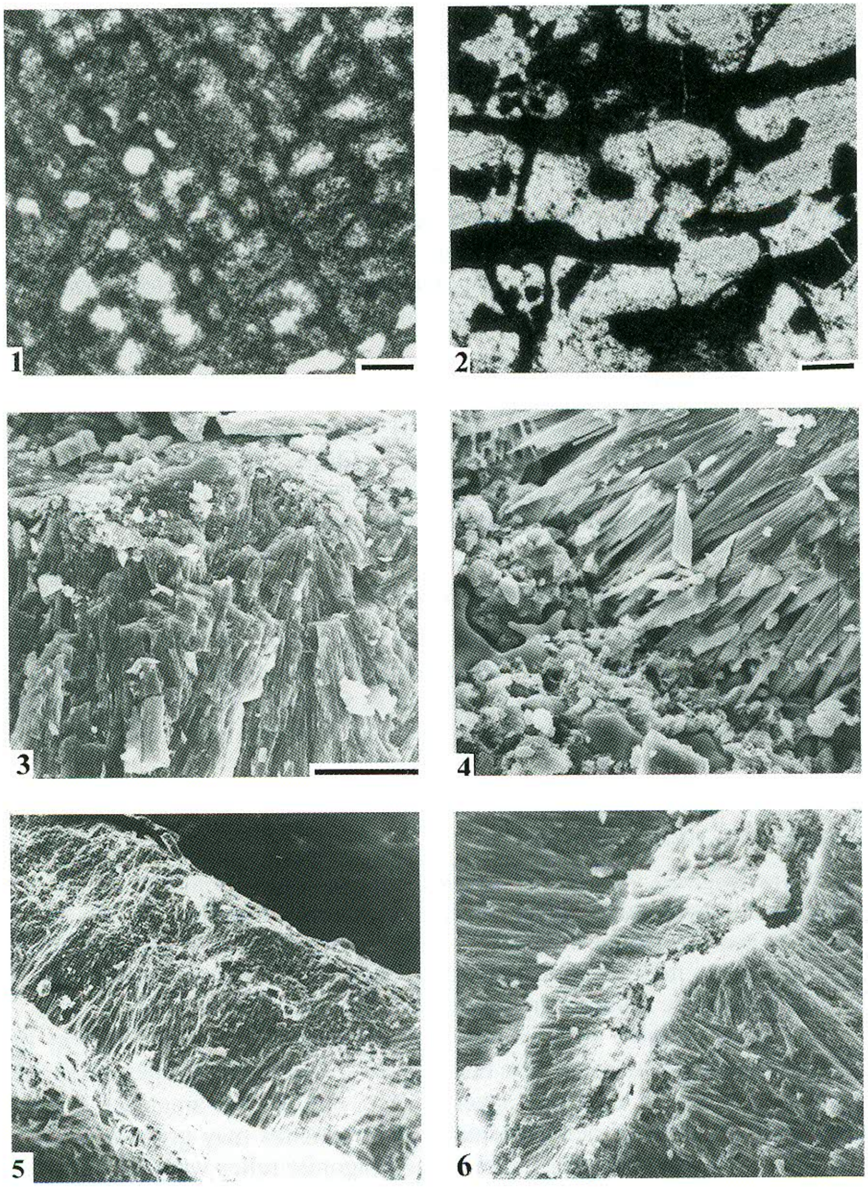

Fig. 7 (Legend see p. 362)

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). Three microfacies types were identified:

Sandy bioclastic wackestone (Fig. 6/5):

This type is composed of bioclasts and rare biomorphs, rooted in micrite. It is particularly rich in alcyonarian corals, echinoid fragments (spines), scleractinian corals, molluscan fragments and foraminifera. Non-carbonates are fine to medium, rounded to subangular quartz grains.

Sandy algal bindstone (Fig. 6/6):

This microfacies type is composed of badly preserved calcareous red algae (*Lithothamnium* sp.), which act as sediment binder of scleractinian fragments and planispiral foraminiferal tests. Noncarbonates are represented by fine to medium, rounded to subangular quartz grains.

Scleractinian framestone and/or bafflestone (Fig. 7/1, 2):

The scleractinian corals *Porites* spp., *Favia* sp., *Favites* spp., *Echinopora* sp., *Stylophora* sp., *Acropora* spp., *Montipora* sp., etc. act as frame-builders. In parts, the branches of dendroid corals act as sediment bafflers (bafflestone). This microfacies type is similar to the SMF 7 facies belt 5 of of Flügel (1972) and Wilson (1975).

Diagenetic patterns:

Many investigated *Porites* and *Favites* samples show no alteration of their primary microstructures, and marine aragonite cement (fig. 7/3-5), which occur as needles filling the skeletal pores and rest either on the trabecular structure or on micritic envelopes. Also peloidal Mg-calcite in the form of semi-opaque, fine rhombic crystals entirely fill the coral cavities.

Few samples show early meteoric leaching. This process starts in the center of the trabecular structure (James 1974) and results in open trabecular centers, rimmed by a chalky layer of partly dissolved aragonite needles (fig. 7/6). In addition, newly formed blocky calcites may grow around the remaining aragonite needles, resulting in aragonite relics within fresh water calcites (Sandberg & Hudson 1983 and Dullo 1986).

In the upper terraces, few *Porites* specimens show minor leaching of the trabecular centers and replacement by low-Mg calcite. These diagenetic patterns of the studied reef unit are correlatable to stage III (leaching of

Table 1. Chemical analysis of selected corals.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Cl	Mn_2O_3	TiO_2	P_2O_5	Total	$CaCO_3$	$MgCO_3$	Ca	Mg	Sr
Acroporidae	1.51	0.43	0.29	44.52	1.19	4.22	0.01	1.09	1.34	0.04	0.32	0.04	55.87	79.50	2.49	31.80	0.71	5220
	1.63	0.44	0.40	44.92	1.03	4.84	0.08	1.01	1.00	0.07	0.29	0.02	55.22	80.21	2.16	32.09	0.67	5500
	1.09	0.74	0.20	43.75	0.97	4.35	0.07	1.09	1.34	0.01	0.36	0.09	55.87	78.13	2.03	31.25	0.58	6413
Poritidae	1.32	0.36	0.18	43.25	2.20	3.68	0.13	1.12	2.19	0.07	0.28	0.03	54.08	77.22	4.62	30.89	1.32	4905
	1.32	0.76	0.11	42.11	2.233	3.11	0.19	1.73	2.22	0.05	0.31	0.06	54.21	75.20	4.68	30.08	1.34	4840
	0.67	0.21	0.09	45.10	1.46	5.50	0.06	0.40	0.58	0.09	0.05	0.01	54.97	80.53	3.62	32.21	0.87	5116
Faviidae	0.60	0.16	0.05	47.84	0.61	1.14	0.06	0.79	1.10	0.08	0.03	0.08	52.50	85.16	1.28	34.17	0.36	8336
	0.24	0.03	-0.04	47.83	0.45	1.11	0.01	0.92	1.29	0.01	-0.04	0.09	51.55	85.40	0.94	34.16	0.16	8634
	0.24	0.08	-0.03	49.84	0.243	1.35	0.04	0.12	1.15	0.04	-0.05	0.02	51.78	89.00	0.51	35.60	0.14	8660

sclerodermities under subaerial conditions), of GVIRTZMAN & FRIEDMAN (1977).

The difference of the rate of diagenetic alteration in the studied scleractinians (*Porites* and *Favites*) may depend on the primary microstructure and microarchitecture, as noted by CONSTANTZ (1984) for *Acropora palmata* and *Acropora cervicornis*. Thus, taxonomic differences seem to influence the rate of diagenetic alteration.

Chemistry:

Chemical analysis of some major oxides and strontium for selected coral samples of Poritidae, Acroporidae and Faviidae are illustrated in table 1, in order to study the relationship between their concentrations in coral skeletons with diagenesis.

SiO_2 and Al_2O_3 have low values (tab. 1) in all the studied corals, they mainly occur in clay minerals in the coral cavities. Also SO_3^{--}, Na_2O_3 and Cl^- have low values (tab. 1). Their presence is due to anhydrite/gypsum and halite, mostly concentrated by surface processes.

The concentrations of strontium in the present samples vary from 4840 to 8860 ppm. Its content is higher in faviids (average 8543 ppm) than in acroporids (average 5711 ppm) and in poritids (average 4955 ppm). The concentration of strontium in our samples agrees with that of Quaternary ones of SCHROEDER et al. (1970) and FRIEDMAN & BRENNER (1977).

The data (tab. 1) show that Sr^{++} content increases with increasing Ca^{++} and decreases with creasing Mg^{++} due to the impact of diagenesis, Strontium is progressively eliminated towards the older fossil reefs. Fresh water dissolved the skeletal aragonite and removed strontium. Consequently the concentration of strontium is much lower in the calcite that precipitated progressively where the framework of the coral reefs had been dissolved. This conclusion is agreement with FRIEDMAN & BRENNER (1977).

The degree of intercrystalline porosity in the sclerodermites and therefore the tightness of fiber packing and arrangement vary within the different suborders of the stony corals.The Faviidae (Suborder Faviina) exhibit a tight packing of aragonite fibers, which restricts intercrystalline porosity to a minimum, in contrast to the Poritidae (Suborder Fungiina), which are characterized by a loose arrangement (CONSTANTZ 1986 and DULLO 1987). The Acroporidae (Suborder Astrocoeniina) have an intermediate position. Owing to the small size of the crystallites comprising the polycrystalline fibers, the reaction surface area is large, but the packing of the fibers reduces intercrystalline porosity. The different patterns are well documented in a different rate of diagenetic alteration (DULLO 1986 and EL-SOROGY 1997).

Paleoecology:

The paleoecologic interpretation depends on the scleractinian corals (colonial growth-forms and their relation to light, temperature and depth) and on the crustose coralline algae which form the primary frame-builders of the studied coral reefs.

The habits and habitats of the studied species indicate environments ranging from the upper reef slope to back-reef. The bathymetric ranges of the recent species suggest a depth between 1-50 m.

Conclusions

Thirty species belonging to twenty seven genera and eighteen families have been identified from the Pleistocene coral reefs at Gebel Zeit and Ras Gemsha (western side of the Gulf of Suez). The identified taxa include bryozoans, scleractinian corals, bivalves and gastropods. They are exclusively of Indo-Pacific affinity. *Crisia elongata* MILNE-EDWARDS, *Scrupocellaria elliptica* (REUSS) and *Spondylus* (*S.*) *gaederopus* (LINNAEUS) have Mediterranean-Atlantic as well as Indo-Pacific affinity. Three microfacies types were recorded, they are: sandy bioclastic wackestone, scleractinian framestone and/or bafflestone and sandy algal bindstone. Many coral specimens show no alterations of their primary microstructures while few show early meteoric diagenesis, in the form of dissolved aragonite needles of sclerodermites. The difference in Sr^{++}, Ca^{++} and Mg^{++} contents among Acroporidae, Poritidae and Faviidae is related to the degree of intercrystalline porosity within the sclerodermites and their relation to the rate of diagenetic alteration. The habits and habitats of the studied species indicate a deposition on the upper reef slope to back-reef environment, in 1-50 m water depth.

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References

ABD EL-FATTAH, Z. A. (1998): Stratigraphy and paleontology of some Neogene-Quaternary successions on the Red Sea coast, Egypt. – M. Sc. Thesis, Geology Depart. Fac. Sci. Mansoura Univ., 227 p.

Abed, M. M. (1982): Quaternary fauna from Gebel Tanka, Sinai Peninsula, Egypt. – Bull. Fac. Sci. Mansoura Univ., **9**: 227-307.

Abou Khadrah, A. M. & Darwish, M. (1986): On the occurrence of raised beach sediments in the Hammam Faraun area, Sinai, Egypt. – Arab Gulf J. Sci. Res., **4**/1: 159-175.

Al-Awadi, Z. A. (1980): Tertiary and Recent molluscs of Kuwait. – M. Sc. Thesis, Fac. Sci. Kuwait Univ., 485 p.

Al-Rifaiy, I. A. & Cherif, O. H. (1988): The fossil coral reefs of Al-Aqaba, Jordan. – Facies, **18**: 219-230.

– (1989): Paleogeographic significance of Pliocene and Pleistocene mega-invertebrates of the Red Sea and the Gulf of Aqaba. – J. Univ. Kuwait, **16**: 367-399.

Andres, W. & Radtke, U. (1988): Quartäre Strandterrassen an der Küste des Gebel Zeit (Golf von Suez/Ägypten). – Erdkunde, **42**: 7-16.

Bosch, D. T., Dance, S. P., Moolenbeek, R. G. & Oliver, P. G. (1995): Seashells of Eastern Arabia. – Montivate Publ., 296 p.

Bosworth, W. & Taviani, M. (1996): Late Quaternary reorientation of stress field and extension direction in the southern Gulf of Suez, Egypt: Evidence from uplifted coral terraces, mesoscopic fault arrays and borehole break outs. – Tectonics, **15**/4: 791-801.

Chevalier, J. P. (1975): Les scléractiniaires de la Mélanesie Française (Nouvelle-Calédonie. Iles Chesterfield. Ils Loyauté, Nouvelle Hébrides). 2ième part. – Exped. Franç. Récifs corall. Nouvelle-Cáledonie, **7**, 407 p.

Constantz, B. R. (1984): Functional comparison of the microarchitecture of *Acropora palmata* and *Acropora cervicornis*. – Paleont. Amer., **54**: 548-551.

– (1986): The primary surface area of corals and variations in their susceptibility to diagenesis. – In: Schroeder, J. H. & Purser, B. H. Eds.: Reef diagenesis: 53-76, Springer-Verlag.

Cox, L. R. (1927): Neogene and Quaternary Mollusca from Zanzibar Protectorate. – Rep. Paleont. Zanzibar Protect., **13**-102.

Cuffey, R. J. (1977): Bryzoan contribution to reefs and bioherms through geologic time. – A. A. P, G., Stud. Geol. **4**: 181-194.

David, L. & S. Pouyet (1974): Révision des bryozoaires cheilostome miocènes du Bassin de Vienne-Autriche. – Docum. Lab. Géol. Fac. Sci. Lyon, **60**: 83-257.

Dullo, W.-C (1984): Progressive diagenetic sequence of aragonite structures: Pleistocene coral reefs and their modern counterparts on the eastern Red Sea coast, Saudia Arabia. – Palaeont. Amer., **54**: 254-260.

– (1986): Variation in diagenetic sequence: An example from Pleistocene coral reefs, Red Sea, Saudia Arabia. – In: Schroeder, J. H. & Purser, B. H. (Eds.): Reef diagenesis: 77-90, Heidelberg (Springer).

– (1987): The role of microarchitecture and microstructure in the preservation of taxonomic closely related scleractinians. – Facies, **16**: 11-22.

– (1990): Facies, fossil record and age of Pleistocene reefs from the Red Sea (Saudia Arabia). – Facies, **22**: 1-40.

Dunham, R. J.. (1962) Classification of carbonate rocks according to depositional textures. – A. A.P. G. Mem., **1**: 108-121.

El-Dera, N. (1996): Miocene Bryozoans of Mersa Matruh area. – Ph. D. Thesis, Zagazig Univ.: 220 p.

El-Shazly, S. H. (1982): Stratigraphic and paleontologic studies on Post-Miocene outcrops from Quseir area, Red Sea, Egypt. – M. Sc. Thesis, Fac. Sci., Ain Shams Univ.: 188 p.

El-Sorogy, A. S. (1990): Paleontologic and paleoecologic study on the Pliocene-Quaternary deposits in Quseir area, Red Sea. – M. Sc. Thesis, Fac. Sci., Zagazig Univ.: 225 p.

– (1997): Progressive diagenetic sequence from Pleistocene coral reefs in the area between Quseir and Mersa Alam, Red Sea coast, Egypt. – J. Geol. **41** (1): 519-540.

– (1997): Pleistocene coral reefs of southern Sinai, Egypt: fossil record, facies analysis and diagenetic alterations. – M.E.R.C. Ain Shams Univ., Earth Sci., **11**: 17- 36.

Embry, A. F. & Klovan, J. E. (1972): Absolute water depths limits of the Late Devonian paleoecological zones. – Geol. Rdsch., **61**/2: 672-686.

Faure, G. & Pichon, M. (1978): Description de *Favites peresi*, nouvelle éspèce de Scleractinaire hermatypique de l'Océan Indien (Cnidaria, Anthozoa, Scleractinia). – Bull. Mus. Histoire Natur. Paris, Zoologie, **3**/325: 407-427.

Flügel, E. (1972): Mikroproblematika in Dünnschliffen von Trias-Kalken. – Mitt. Ges. Bergbaustud., **21**: 957-988.

Friedman, G. & Brenner, I. B. (1977): Progressive diagenetic elimination of strontium in Quaternary to Late Tertiary coral reefs of the Red Sea. Sequence and time scale. – A.A.P.G. Stud. in Geology, **4**: 353-355.

Hamza, F. H. (1972): A study on some Pliocene fauna from Egypt. – M. Sc. Thesis, Fac. Sci., Ain Shams Univ.: 228 p.

Heiss, G. A. & Dullo, W.-C. (1997): Stable isotope record from recent and fossil *Porites* sp. In the Northern Red Sea. – Coral Res. Bull. **5**:161-169.

Gameil, M. (1998): Pleistocene reef-associating Mollusca from Wadi Tanka, eastern side of the Gulf of Suez, Sinai. – Egypt J. Geol., **42**/2: 531-546.

– (1998): Pleistocene corals from Wadi Tanka, Sinai, Egypt. – M.E.R.C. Ain Shams Univ., Earth Sci. ser., **12**: 173-187.

Gvirtzman, G. & Friedman. G. M. (1977): Sequence of progressive diagenesis in coral reefs. – A.A.P.G. Stud. Geol. **4**: 357-380.

James, N. P. (1974): Diagenesis of scleractinian corals in the subaerial vadose environment. – J. Paleont., **48**: 785-799.

Klein, R., Loya, Y., Gvirtzman, G., Isdale, P. J. & Susic, M. (1990): Seasonal rainfall in the Sinai Desert during the Late Quaternary inferred from fluorescent bands in fossil corals. – Nature, **345** (6271): 145-147.

Klunzinger, C. B. (1879): Die Korallenthiere des Rothen Meeres. 2: Die Steinkorallen, 1. Abschn.: Madreporaceen and Oculinaceen. Berlin, 88 p.

– (1879): Die Korallenthiere des Rothen Meeres. 3: Die Steinkorallen, 2. Abschn.: Astraeaceen und Fungiaceen. Berlin, 100 p.

Moissette, P. (1988): Faunes de bryozoaires du Méssinien d'Algérie occidentale. – Docum. Lab. Géol. Fac. Sci. Lyon, **102**: 315 p.

Montaggioni, L. F. (1982): Pleistocene marine depositional environments from Mauritius Island, Indian Ocean. – Géobios, **15**/2: 161-179.

Moore, R. C. (Ed.) (1953-1969): Treatise on Invertebrate Paleontology. Geol. Soc. Amer. and Kansas Univ. Press, Lawrence, Kansas.

Newoten, R. B. (1900): Pleistocene shells from the raised beach deposits of the Red Sea. – Geol. Mag., **4**: 544-560.

Pillai, C. S. G. & Scheer, G. (1976): Report on the stony corals from the Maldive Archipelago. – Zoologica, **129**: 1-83.

Plumely, W. J., Risley, G. A., Graves, R. W. & Kaley, M. E. (1962): Energy index for limestone interpretation and classification. – A. A. P. G. Mem., **1**: 85-107.

Sandberg, P. A. & Hudson, J. D. (1983): Aragonite relic preservation in Jurassic calcite-replaced bivalves. – Sedimentology, **30**: 879-892.

Scheer, G. & Pillai, C. S. G. (1983): Report on the stony corals from the Red Sea. – Zoologica, **45**/3: 133 p.

Sheppard, C. R. C. & Sheppard, A. L. S. (1991): Coral and coral communities of Arabia. – Fauna of Saudia Arabia, **125**: 170 p.

Schroeder, J. H., Miller, D. S. & Friedman, G. M. (1970): Uranium distribution in Recent skeletal carbonates. – J. Sed. Petrology, **40**: 672-681; Tulsa.

Schumacher, H. (1979): Experimentelle Untersuchungen zur Anpassung von Fungiiden (Scleractinia, Fungiidae) an unterschiedliche Sedimentations- und Bodenverhältnisse. – Int. Rev. Ges. Hydrobiol. **64**: 207-243.

Souaya, F. (1965): On the bryozoan of Gebel Gharra (Cairo-Suez road) and some other Miocene sections in Egypt. – J. Paleont., **39**/6: 1129-1144.

Strasser, A., Strohmenger, Chr., Davaud, E. & Bach, A. (1992): Sequential evolution and diagenesis of Pleistocene coral reefs, South Sinai, Egypt. – Sed. Geol., **78**: 59-79.

Vávra, N. (1977): Bryozoa, Tertiär. – In: Zapfe, H. (Ed.): Catalogus Fossilium Austriae, Vb, **3**: 210 p.

Veron, J. E. N. & Pichon, M. (1980): Scleractinian of Eastern Australia, Part II. Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae. – Austral. Inst. Marine Sci., Monogr. Ser., **4**: 422.

Veron, J. E. N., Pichon, M. & Wijsman-Best, M. (1977): Scleractinia of Eastern Australia, Part II. Family Faviidae, Trachyphyllidae. – Austral. Inst. Marine Sci., Monogr. Ser., **3**: 233 p.

Veron, J. E. N. & Wallace, C. (1984): Scleractinia of Eastern Australia, Part V. Family Acroporidae. – Austral. Inst. Marine Sci., Monogr. Ser., **6**: 458 p.

Wilson, J. L. (1975): Carbonate facies in geologic history, Berlin, Heidelberg, New York (Springer) 471 p.

Zalat, A. A., Hamza, F., Ziko, A. & El-Sorogy, A. (2000): Scleractinian corals (suborder Faviina) of the Pleistocene coral reefs in the area between Hurghada and Quseir, Red Sea Coast, Egypt. – Egypt, J. Geol. **44**/1: 237-255.

Ziko, A. (1996): Middle Miocene Bryozoa of west-central Sinai, Egypt. – M. E. R. C. Ain Shams Univ., Earth Sci. Ser., **10**: 124-146.

Ziko, A. & Hamza, F. (1987): Bryozoan fauna from a Post-Pliocene outcrop north of the Giza Pyramids Plateau, Egypt. – In: J. R. P. Ross (Ed.): Bryozoa: Present and Past. Western Washington Univ. Press, 301-308.

ZIKO, A., HAMZA, F. & EL-DERA, N. (1992): Miocene Bryozoa from Wadi Hagul, Cairo-Suez District, Egypt. – In: SADEK, A. (Ed.): Geology of the Arab World, Cairo: 295-319.

ZIKO, A., HAMZA, F., ZALAT, A. & EL SOROGY, A. (1993): Scleractinian corals (Suborder Fungiina) of the Pleistocene raised reefs in the area between Hurghada and Quseir, Red Sea coast, Egypt. – Ain Shams Bull. Sci,. **31**: 325-341.

ZIKO, A. & EL-SOROGY, A. S. (1995): New bryozoan records from the Pleistocene coral reefs, Red Sea coast, Egypt. – M. E. R. C. Ain. Shams Univ., Earth Sci. Ser., **9**: 80-92.

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