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Paleontological Studies on the Neogene (Miocene and Quaternary) Carbonate Rocks of Rabigh-Ubhur Areas, Red Sea Coast, Saudi Arabia

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Abstract. The syn-rift Miocene carbonate rocks in Rabigh and Ubhur areas belong to the Jerba carbonate member of Dafin Formation and Ubhur Formation, respectively. The carbonate rocks of Rabigh overlie Wadi Al-Hakkak clastic section and are considered as a lateral facies equivalent to the Jehfa evaporite section. The Ubhur carbonate rocks underlie the Middle Miocene shale and evaporite rocks. Raised Quaternary coral terraces are dominant in Rabigh area.

Field, paleontological and palynofacies studies of the Neogene rocks (carbonate and shale) of Ubhur and Rabigh areas, Red Sea coast of Saudi Arabia indicate the existence of corals, gastropods, bivalves, echinoderms, foraminifers and amorphous organic matter. Taxonomic and paleoecological interpretations of the recorded fossils are the purpose of this work.

Keywords: Neogene, paleontology, Rabigh, Ubhur, Red Sea, Saudi Arabia.

Introduction

Most paleontological, palynological and stratigraphical studies on the eastern shore of the Red Sea coast of Saudi Arabia were done on the Midyan Peninsula, Gulf of Aqaba, where profitable hydrocarbon occurrences are discovered in the sixties of the last century. Based on these studies, various informal lithostratigraphic schemes have been applied to the Saudi Arabian Red Sea succession by numerous authors (*e.g.* Beydoun, 1991; Hughes & Beydoun, 1992; Filatoff & Hughes, 1996; Hughes *et al.,* 1999; and Hughes & Johnson, 2005). Whereas in Makkah and Rabigh Quadrangles, most sedimentological and stratigraphical studies deal with the pre-rift sequences (Shumaysi and Usfan formations); (*e.g.* Brown *et al.,* 1963; Moltzer & Binda, 1984; Spencer & Vincent, 1984; Srivatsava & Binda, 1991; Gheith & Abou Ouf, 1994; Abou Ouf ,1998; and Hughes & Johnson, 2005), and the coastal sediments of the Red Sea region (*e.g.* Basaham, 1998; Basaham *et al.,* 2006; Bantan, 2006; and Al-Sofyani & Niaz, 2007). The clay deposits of the syn-rift Miocene sediments are the interest of Taj *et al.* (2002), and Basyoni *et al.* (2002). However, no paleontological studies are dealt with for the Neogene sediments at the central part of the eastern shore of the Red Sea coast of Saudi Arabia. So, the purpose of this work is to study the taxonomy and paleoecology of the Neogene rocks in Ubhur-Rabigh areas, north of Jeddah city (Fig. 1).

Location and General Geology

Ubhur and Rabigh areas are located north of Jeddah city by ~ 20 km and 175 km respectively (Fig. 1). The two areas are located in Makkah and Rabigh Quadrangles where the Precambrian basement rocks are exposed to the east that are unconformably overlain by Tertiary sedimentary rocks in the west, and by Miocene to Pliocene lavas in the north (Moore & Al- Rehaili, 1989). Extensive areas of Quaternary surficial deposits (sand and gravel) are extended on the coastal plain and in the major wadis. The stratigraphic succession of the Tertiary formations, as well as, the paleogeography and structures of these sediments are studied by Spencer & Vincent (1984).

The Tertiary layered rocks of Makkah Quadrangle are composed of tilted and faulted strata, which are exposed sporadically, and usually poorly, beneath a cover of flat-lying lavas and Quaternary deposits in the western part of the Quadrangle. They were assigned by Brown *et al.* (1963) to the Shumaysi and Usfan formations. Spencer & Vincent (1984) replaced the Shumaysi Formation with several formations; they are Haddat Ash-Sham, Shumaysi, Khulays and Buraykah formations. It is noticed that the Haddat

Ash-Sham, Usfan and Shumaysi formations are facies variants and thus chronostratigraphic near-equivalents (Spencer & Vincent, 1984).

Fig. 1(A). Geologic map and location of the studied sections in Rabigh area, Red Sea, Saudi Arabia. (After Ramsey, 1986).

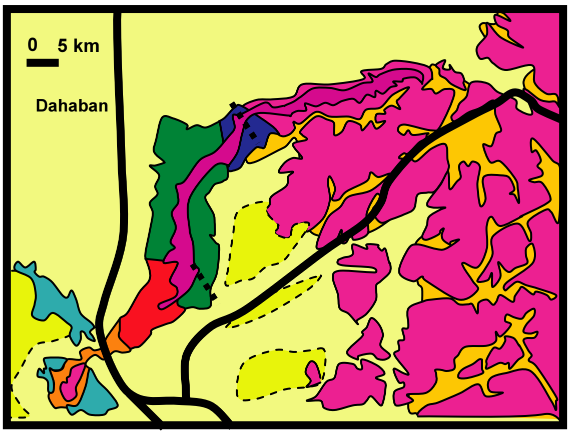

Fig. 1(B). Geologic map and location of the studied sections in Ubhur area, Red Sea, Saudi Arabia (After Moore and Al-Rehaili, 1989).

The Tertiary sedimentary rocks in the western part of Rabigh Quadrangle are best preserved adjacent to where they have been covered by Tertiary basalt flows; elsewhere, they occur in low hills rising above the coastal plain, largely concealed by sand and gravel (Ramsay, 1986). The rocks are generally horizontal but have been faulted and consequently attain flexure dips, in places, as much as 40°. They lie unconformably beneath Tertiary lava flows and unconformably overlie, or are faulted against, the Precambrian rocks. They have been assigned to the Usfan, Shumaysi (?), and Daffin formations (Ramsay, 1986).

Lithologically, the Tertiary formations in Makkah and Rabigh Quadrangles that were studied by Taj *et al.* (2002 & 2004) have a limited extent that consist mainly of siliciclastic material, derived from the surrounding Precambrian basement and pre-existing sedimentary rocks. However, the overwhelming clastic sedimentation is temporarily interrupted by limited but persistent marine and lacustrine carbonate units in Usfan Formation and Dafin Formation (Taj *et al.,* 2002).

Despite the similarity of the lithology, age and the close geographic locations of Ubhur and Rabigh areas, the exposed Miocene rocks in these areas are assigned with different formation names. In Ubhur area, the Ubhur Formation as described by Moore & Al-Rehaili (1989) consists of green sandy clay, siltstone and soft, white bioclastic limestone with gypsum bed interbedded with the clay. Based on the microfossils and bivalves present in the limestone, Andreieff (1983) assigned an Early Miocene age to the Ubhur Formation.

In Rabigh area, Taj & Hegab (2005) studied the lithostratigraphy, sediment characteristics and depositional environments of the Miocene rocks of Dafin Formation. They classified Dafin Formation into three sedimentary facies; they are siliciclastic, carbonate and evaporite rocks. The siliciclastic rocks are deposited in a meandering system, the carbonates are formed in shallow marine to protected lagoon, whereas the evaporites are formed in saline pond and in sabkha (Taj & Hegab, 2005). Mandurah & Aref (2009) interpreted the deposition of the evaporite facies of Dafin Formation in a very shallow salina dominated with microbial activity.

Lithostratigraphy

Two composite lithostratigraphic sections have been measured and sampled in detail for the Miocene carbonate rocks in Rabigh and Ubhur areas, and one section for the Quaternary terraces in Rabigh area (Fig. 2). In addition, samples from the marls, claystone, shale and mudstone beds are checked for their microfaunal and palynological contents. However,

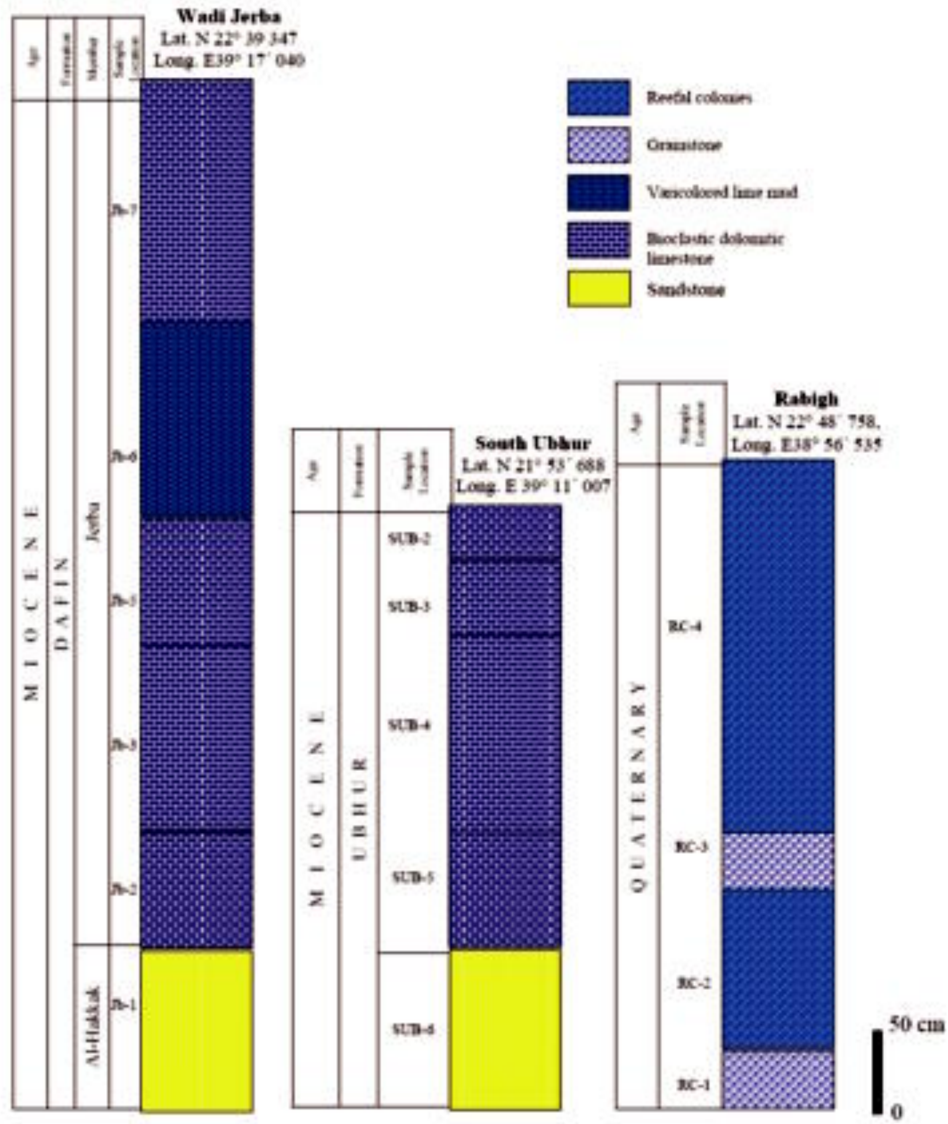

Fig. 2. Lithostratigraphic sections of the Neogene carbonates in Rabigh and Ubhur areas, Red Sea, Saudi Arabia.

sampling and interpretation of the evaporite sections at Rabigh and Ubhur areas (Mandurah & Aref, 2009) and the clastic section at Rabigh area (Taj & Hegab, 2005), and Ubhur area (Taj *et al.,* 2001) are out of the scope of this work. It is important to mention that Taj & Heqab (2005) subdivided the Miocene Dafin Formation of Ramsey (1986) in Rabigh area into three members, these are from the base to the top; Al-Haqqaq clastic member, Wadi Jehfa gypsum member and Wadi Jerba carbonate member. The following is a description of the measured carbonate sections in Rabigh and Ubhur areas.

1. Wadi Jerba Miocene Carbonate Rocks

The Miocene carbonate rocks are exposed only at Wadi Jerba, which conformably overly the clastic member of Rabigh Formation. At Wadi Jehfa, the evaporite rocks are also conformably overlying the clastic member of Dafin Formation. So, the carbonate and evaporite rocks are considered as lateral facies equivalent. The carbonate rocks are recorded as residual hills and elongated ridges that were covered with black boulders from Al-Harrat basalt.

The following is a description of the carbonate section at Wadi Jerba from base to the top:

Symbol	Bed thickness (cm)	Description
Jb-1	100	Massive, hard, olive to yellow medium sized sandstone.
Jb-2	70	Massive, hard, dirty white dolomitic limestone, with few gastropod and bivalve shells.
Jb-3	120	Very hard, vuggy, pale yellow to white dolomitic limestone that forms prominent, resistant ridge for the whole carbonate exposures. The dolomitic limestone consists of scattered shells of foraminifers, gastropods (small and large), (Fig. 3) and bivalves embedded in fine bioclastic matrix (Fig. 4). The distribution of the fossils is sporadic, where bivalve shell concentrations are observed locally (Fig. 4). Thalassinoids burrows are also recorded, that may enclose the mold or shell of gastropods. Sand sized quartz grains and pebble and cobble-sized volcanic rock fragments are recorded also in the dolomitic limestone layer. Millimetric moldic vugs of bivalve and gastropod shells are common, where the internal and external molds of the shells are filled with bioclasts and fine sand sediments.
Jb-5	40	Medium hard, dolomitic bioclastic limestone with gastropod and bivalve shells and molds. The upper surface of this layer shows high concentration of shells and shell fragments from Clypeaster and *Echinolampas* sp. that are dispersed at the weathered surface of the dolomitic limestone. No pebbles are recorded from this layer. Also, a fewer shell concentration is observed than the underlying carbonate layer.
Jb-6	120	Massive, medium hard, varicolored yellow to pink to white carbonate mud, without any observed macrofossils or ghost of them.
Jb-7	150	Massive, vuggy dolomitic limestone that consists of foraminifers, gastropods and bivalves embeded in a matrix of bioclasts. The gastropod and bivalve shells are mostly dissolved leaving moldic cavity, whereas the internal molds of the shells are composed of fine bioclastic material. Coral debris are recorded overlying this layer.

Fig. 3. Internal mold of large sized gastropod steinkern that is filled with bioclastic materials, Miocene, Jerba Member, Dafin Formation,Wadi Jerba.

Fig. 4(a). Internal molds and moldic cavities of bivalve shells set in bioclastic materials, Miocene, Jerba Member, Dafin Formation, Wadi Jerba.

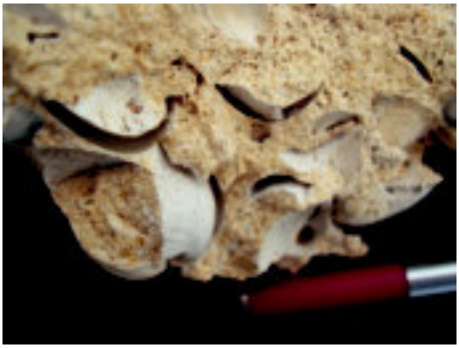

Fig. 4(b). The internal molds of bivalve shells are filled with yellow sandy bioclastic sments, Miocene, Jerba Member, Dafin Formation, Wadi Jerba.

2. Ubhur Miocene Carbonate Rocks

The Miocene carbonate rocks have limited exposure near the piedmont of the hill (~200 m) of Ubhur area, and they are exposed only as a result of excavation by dredger as they are covered with aeolian sand, basalt and other volcanic boulders. The sequence at a newly excavated face is as follows from the base to the top:

Symbol	Bed thickness (cm)	Description
SUB-6	100	Greenish grey, massive, slightly hard, pebbly litharenite with some burrows filled with greenish carbonate mud.
SUB-5	70	Light yellow, sandy bioclastic limestone, with internal and external molds and few shells of bivalves and gastropods.
SUB-4	130	Pale yellow, medium hard bioclastic limestone with few bivalve shells and burrows filled with green mud.
SUB-3	50	Dirty white, hard, vuggy (< 5 cm in size) bioclastic limestone.
SUB-2	~30	White to pink, hard, bioclastic limestone, with moldic voids of bivalves. Highly weathered and partially dissolved *Clypeaster* that recorded at the sediment surface of this layer.

3. Quaternary Coral Reefs

Sandy beach sediment forms the coast of Ubhur area, whereas carbonate rocky beach forms the coast of Rabigh area. This is due to the existence of raised coral terraces facing the shore line in Rabigh area, whereas coral debris are recorded far from the beach (~ 1500 m) below sabkha sediments and aeolian sands in Ubhur area.

At Rabigh city, raised coral reefs form two prominent terraces throughout all the coastal area from the refinery station of Saudi Aramco to the north of the city. Each terrace starts with dissolution notches at the base and a hard ledge or overhang at the top (Fig. 5). The lower notch is encrusted with thin black organic crust. The sequence in the coral reefs from the base to the top is as follows:

Fig. 5. Two reefal terraces start with dissolution notches and capped by a hard ledge or overhang, Quaternary, Rabigh.

Symbol	Bed thickness (cm)	Description
RC-1	> 30	Turbid white, very hard, with solution pits, pebbly to sandy grainstone that forms hard ground.
RC-2	100	Yellowish brown, cavernous, colonial corals that exhibit a variety of morphotypes such as branching and massive types. Between the coral colonies, bivalves, gastropods and echinoid spines are scattered in a carbonate matrix.
RC-3	30	White, very hard, well sorted, graded bedded sandy to pebbly bioclastic and intraclastic grainstone (Fig. 6). Sometimes branching colonial coral from the lower layer grow upward that are mixed with encrusted corals and form hard masses (~ 3 m in size) that intersect the grainstone layer.
RC-4	230	Turbid white, very hard, colonial corals that exhibit a variety of morphotypes such as branching, encrusted and massive types (in order of decreasing abundance). The branched colonial corals form large vase shaped masses, less than 2 m in height (Fig. 7). The encrusted colonial corals form several crusts with sediment fill in-between (Fig. 8 and 9). Most of the encrusted colonies are dissected by the growth of the branching colonial corals. Massive colonial corals are scattered in carbonate sediment. Numerous bivalves, gastropods and echinoid spines are dispersed between the colonial coral masses. Near the lower bedding surface, numerous calcareous rhizocretion are observed (Fig. 10).

Fig. 6. Graded bedded in bioclastic and intraclastic grainstone, Quaternary, Rabigh.

Fig. 7. Close up view of different hermatypic well preserved colonial corals, Quaternary, Rabigh.

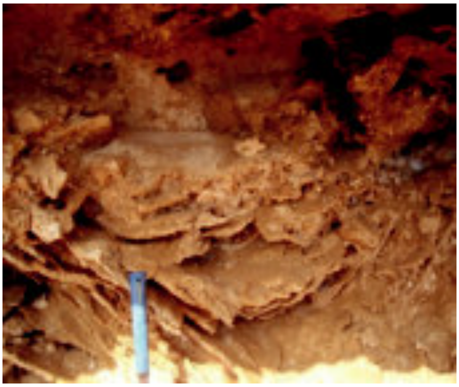

Fig. 8. Encrusted colonial coral crusts with sediments in-between, Quaternary, Rabigh.

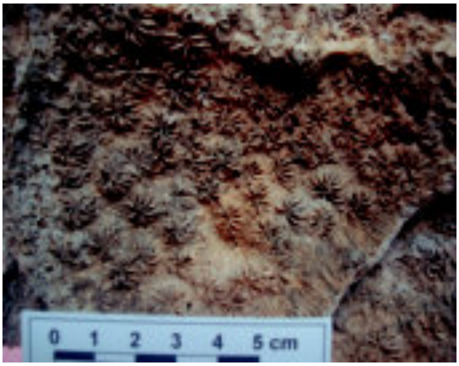

Fig. 9. Surface exposure of the encrusted colonial corals showing distinct corallites and septae, Quaternary, Rabigh.

Fig. 10. Calcareous rhizocretion at the base of the upper terrace, Quaternary, Rabigh.

Systematic Paleontology

The Miocene and Quaternary carbonate rocks of Rabigh and Ubhur areas are highly dominated with faunal content (both macroinvertebrates and microinvertebrates). The following is a systematic description of the recorded fauna:

1. Macroinvertebrates

The studied specimens have been cleaned from the attached rocks and washed in the laboratory, fully described, photographed and generically classified. Specific identification was carried out by comparing the studied fauna with previous works. The studied macrofossils include corals, bivalves, gastropods and sea urchins.

1. A. Corals

Phylum: Cnidaria Hatschek 1888
Class: Anthozoa Ehrenberg, 1834
Subclass: Zoantharia Blainville, 1830
Order: Scleractinia Bourne, 1900
Family Faviidae Gregory 1900
Genus *Favia* Oken 1815
Favia sp.
(PI. 1, Fig. 1a & 1b)

Material

One moderately preserved specimen from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Dimensions (in mm)

Diameter of circular calice	Distance between calice centers	Number of septa
1-4	3-7	16-18

Description

Colony shape massive; attachment of skeleton attached; wall development between buds always; symmetry of bud geometry multi-directional; calice or valley width medium (5-10mm); calice relief low (<2mm); calicular platform shape u-shaped; coenosteum narrow (< valley width); exothecal dissepiments present; number of septal cycles >3; septal spacing (per 5mm) 6-12; relative septa thickness unequal; relative costae thickness equal; continuity of costae continuous; septal lobes absent; paliform lobes absent; columella continuity continuous; columella width 1/2; endothecal dissepiments abundant; wall structure parathecal; double or single wall single.

Distribution

Red Sea coast, Arabian Gulf, Atlantic and Pacific Oceans.

Range

Pleistocene-Recent.

Family Fungiidae Dana, 1846
Genus *Fungia* Lamarck, 1801
Fungia sp.
(PI. 1, Fig. 2 & 3)

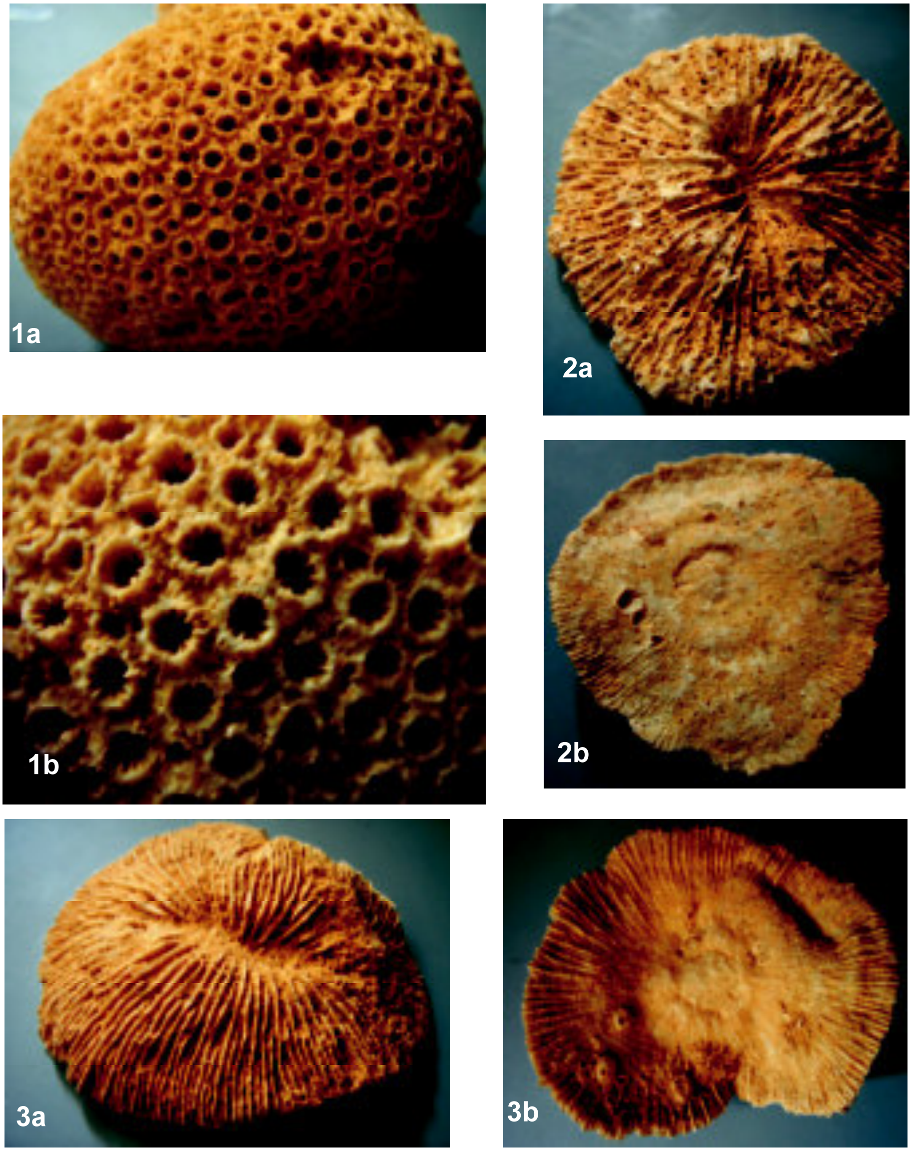

Plate 1

1. ***Favia*** **sp.; a) original specimen, b) close up view (X2); Je-1, Miocene, Rabigh, Saudi Arabia.**

2-3. ***Fungia*** **sp.; a) top view, b) lower surface showing encrustations of small** ***Barnacles*****; Quaternary coral reef of Rabigh, Saudi Arabia.**

All specimens are figured in their natural size.

Material

Two complete well preserved specimens from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Dimensions (in mm):

Height of corallite	Diameter of the calice	Depth of the calice
10	49	3
16	63	4

Description

The corallite is discoid, solitary with rounded sharp margins and convex and elevated upper surface and without a calicular depression. The lower surface is flat to slightly concave and without epitheca. The septa are thick, compact and long. The lateral faces of septa are strongly pennulat. Septa are arranged in five cycles and 6 systems. The first two cycles extend to the center of the corallite and joined by their inner margins to form a trabecular columella.

Distribution

Red Sea coast, and Arabian Gulf.

Range

Pleistocene-Recent.

1. B. Bivalves

Abbreviations used (All linear measurements are given in millimeter)

H - Shell height. RV - Right valve

L - Shell length. LV- Left valve

T - Shell thickness. EL- Estimated length.

Class Bivalvia Linnè, 1758

Subclass Palaeohertrodonta Newell, 1965

Order Unionoidea Stoliczka, 1871

Superfamily Unionacaea Fleming, 1828

Family Unionidae, Fleming, 1828

Genus *Caelatura* Conrad, 1853

Type species: *Unio aegyptiaca* Cailliaud, 1926

Subgenus *Grandidieria* Bourguigrant, 1885

Type species: *Unio burtoni* Woodward, 1895

Caelatura (Grandidieria) burtoni (Woodward, 1895)

(PI. 2, Fig. 1-2)

1969. *Caelatura burtoni* (Woodward); Moore: 418, Fig. D19: 1.

Material

Three well preserved original valves from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Dimensions (in mm)

H	L	T
34	38	-
35	42	-
39	45	-

Description

Small, oval, rounded shell, heavy, much inflated. Beaks high with zigzag wrinkles which become finely nodulose and sulcate on disc. Hinge line curved, cardinals short, deeply cleft, lamellar teeth short somewhat curved. Sculpture consists of zigzag generally postulate ridges.

Age and distribution

Worldwide Pleistocene-Recent species.

Suborder Ostreina Ferussac, 1822
Superfamily Ostreacea Rafinesque, 1815
Family Ostreidae Rafinesque, 1815
Genus *Laevigyra* MALCHUS, 1990
Type species: *Ostrea luynesi* LARTET, 1872.
Laevigyra sp.
(PI. 2, Fig. 3a & 3b)

Material

One well preserved original valve from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Dimensions (in mm):

H	L	T
50	41	-

Description

The studied specimens are of moderate size, exogyriform with the height much exceeds length. The shell is relatively coiled, opithogyral and strongly convex. It is characterized by the presence of precentral to central keel. The shell surface is smooth, only covered with undulated growth laminae.

Subclass Heterodonta Neumayr, 1884
Order Veneroida H. Adams and A. Adams, 1856
Superfamily Cardiacea
Family Cardiidae Lamarck, 1809
Genus *Cerastoderma*
Cerastoderma edule (Linné, 1758)
(PI. 2, Fig. 4 & 5)

1870 *Cardium edule* Hörnes: 185, pl. 25, Fig. 2,4.

2001 *Cerastoderma edule* (Linné); El-Shazly & Abdel Hamid: 283, pl. 5, Fig. 11.

Material

Four internal molds from the Miocene, Jb-1, Wadi Jerba, Rabigh, Saudi Arabia.

Dimensions (in mm)

H	L	T
20	21	15
19	17	10
18	19	11
13	13	9

Description

Subtrigonal shell with more or less blunt posterior carina. The beaks are strongly prosogyrate with a remarkable lunule. The two valves are inflated and wider near the umbo.

Age and Distribution

Miocene of Saudi Arabia, Egypt, Libya and Algeria.

Superfamily Veneracea Rafinesque, 1815
Family Veneridae Rafinesque, 1815
Genus *Callista* Poli, 1791
? *Callista* sp.
(Pl. 2, Fig. 6)

Material

One badly preserved internal mold from the Miocene, Jb-1, Wadi Jerba, Rabigh, Saudi Arabia.

Dimensions (in mm):

H	L	T
33	42	23

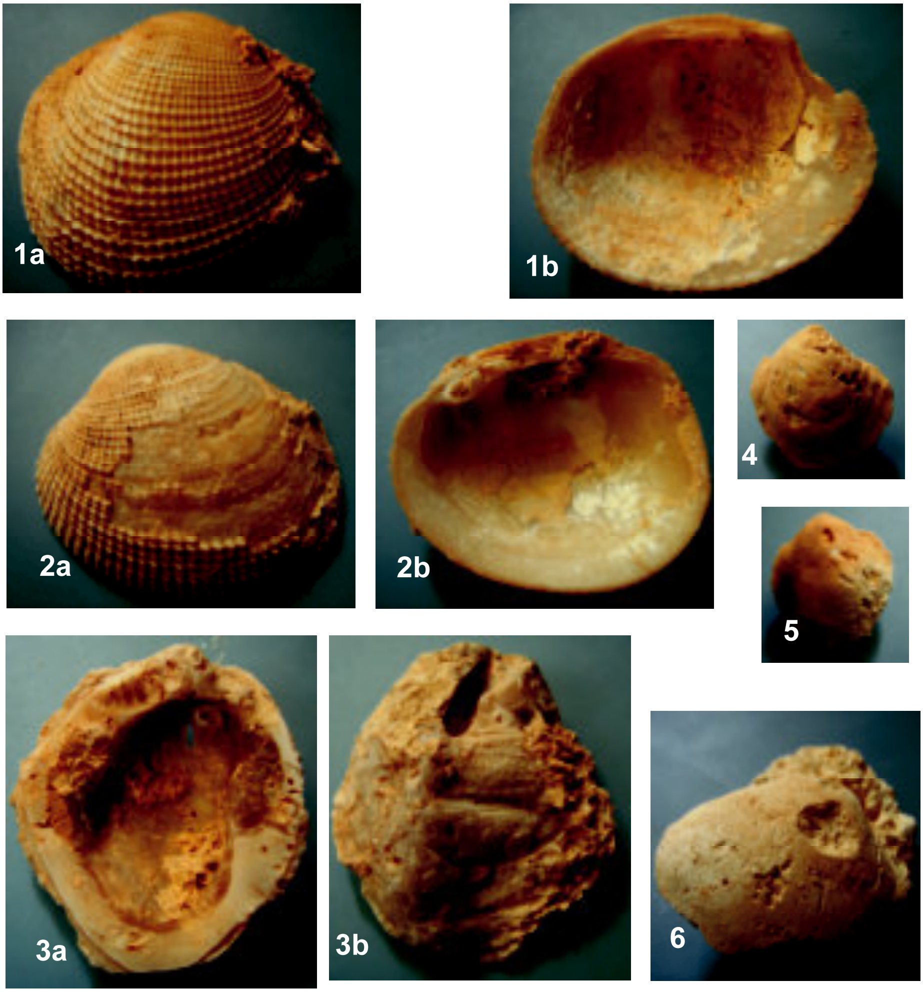

Plate 2

1-2. *Caelatura (Grandidieria) burtoni*, 2a) RV external surface, 2b) RV internal surface, 3a) LV external surface, 2b) LV internal surface; Quaternary coral reef of Rabigh, Saudi Arabia.
3. *Laevigyra* sp., 4a) LV external surface, 4b) LV internal surface; Quaternary coral reef of Rabigh, Saudi Arabia.
4-5. *Cerastoderma edule*, LV external surfaces, Je-1, Miocene, Rabigh, Saudi Arabia.
6. *Callista* sp., RV external surfaces, Je-1, Miocene, Rabigh, Saudi Arabia.
All specimens are figured in their natural size.

Description

Large sized *Callista*, the length exceeds height, prosogyrous beaks with partly truncated posterior margin and moderately convex anterior one. The bad nature of preservation makes complete specific identification difficult.

1. C. Gastropods

Phylum Mollusca Cuvier 1795
Class Gastropoda Cuvier 1797
Subclass Prosobranchia Milne-Edwards 1848
Order Archaeogastropodathiele 1925
Family Turbinidae Rafinesque 1815
Genus *Turbo* Linnaeus 1758
Turbo radiatus (Gmelin 1791)
(PI. 3, Fig. 1a-1c)

1900 *Turbo radiatus* (GMELIN); Newton: 545, pi. xx, Fig. 1.

1982 *Turbo (Batillus) radiatus* (GMELIN); El-Shazly: 117, pi. 12, Fig 5- *Batillus* 6.

1990 *Turbo (Batillus) radiatus* (GMELIN); El-Sorogy: 148, pi. 14, Fig. 5, 6.

1995 *Turbo (Batillus) radiatus* (GMELIN); Bosch *et al.*: 41, Fig. 93.

1997 *Turbo (Batillus) radiatus* (GMELIN); El-Sorogy: 32, pi. 12, Fig.1.

1998 *Turbo (Marmarostoma) radiatus* (GMELIN); Abdel-Fattah: 107, pi. 22, Fig.3.

2001 *Turbo (Batillus) radiatus* (GMELIN); Ziko *et al.*: 99, pl. 1, Fig. 3, 4.

Material

One complete shell from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Description

Shell small to medium, thick and turbinate-shaped. Spire high with 3 whorls. Sutures depressed. Aperture rounded, outer lip smooth and inner lip flat, body whorl large. Sculptured by wavy growth lines and tubercles covered the shoulders.

Dimensions (in mm):

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
41	26	34	37 °

Distribution

Red Sea coast, and Arabian Gulf.

Range

Pleistocene-Recent.

Family Neritidae Rafinesque 1815
Genus *Nerita* Linnaeus 1758
Nerita (Theliostyla) albicilla (Linnaeus 1758)
(PI. 3, Fig. 2a & 2b)

1982 *Nerita (Theliostyla) albicilla* (LINNAEUS); El-Shazly: 123, pi. 13, Fig. 5-7,11.
1986 *Nerita albicilla* (LINNAEUS); Abu Khadrah & Darwish: 174, pi. x, Fig. 12.
1990 *Nerita (Theliostyla) albicilla* (LINNAEUS); El-Sorogy: 150, pi. 14, Fig. 3, 4.
1995 *Nerita albicilla* (LINNAEUS); Bosch *et al.*: 43, Fig. 102.
2001 *Nerita (Theliostyla) albicilla* (LINNAEUS); Ziko *et al.*: 101, pl. 1, Fig. 5, 6.

Material

One complete shell from the Quaternary coral reefs, Rabigh, Saudi Arabia.

Description

Shell small. Spire low. Aperture D-shaped, outer lip and inner lip with fine four teeth. Body whorl large. Sculptured by fine growth lines and black and white bands and others red color.

Distribution

Red Sea coast, Arabian Gulf, South Africa and Madagascar

Range

Pleistocene-Recent.

Order Mesogastropoda Thiele 1925
Family Cypraeidae Fleming 1828
Genus *Cypraea* Linnaeus 1758
Cypraea staphylaea Linnaeus 1758
(PI. 3, Fig. 3a & 3b)

1995 *Cypraea staphylaea* LINNAEUS; Bosch *et al.*: 79, Fig. 275.
2001 *Cypraea staphylaea* LINNAEUS; Ziko *et al.*: 101, pl. 1, Fig. 7, 8.

Material

One complete shell from the Quaternary coral reefs, Ubhur, Rabigh, Saudi Arabia.

Description

Shell solid, rounded to ovate. Spire low. Body whorl large, lipped margins poorly developed. Sulcus deeply incised. Teeth form flat-topped ridges, crossing entire base. Sculptured by small pimples.

Dimensions (in mm):

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
20	-	15	-

Distribution

Red Sea coast, Arabian Gulf, South Africa and Madagascar

Range

Pleistocene-Recent.

Cypraea sp.
(PI. 3, Fig. 4a & 4b)

Material

One badly preserved internal mold from Je-1, Miocene, Wadi Jerba, Rabigh, Saudi Arabia.

Dimensions (in mm):

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
39	--	28	--

Family Conidae Adams 1849
Genus *Conus* Linnaeus 1758
Conus virgo Linnaeus 1758
(PI. 3, Fig. 5a & 5b)

1900 *Conus virgo* LINNAEUS; Newton: 545.
1982 *Conus virgo* LINNAEUS; El-Shazly: 151, pi. 16, Fig. 12, 13.
1990 *Conus virgo* LINNAEUS; El-Sorogy: 164, pi. 15, Fig. 8, 9.
1995 *Conus virgo* LINNAEUS; Bosch *et al.*: 165, Fig. 730.
1998 *Conus virgo* LINNAEUS; Abdel-Fattah: 117, pi. 23, Fig. 8.
2001 *Conus virgo* LINNAEUS; Ziko *et al.*: 102, pl. 1, Fig. 9, 10.

Material

Single internal mold from Je-1, Miocene, Wadi Jerba, Rabigh, Saudi Arabia.

Remarks

Conus virgo LINNAEUS differs from the other *Conus* spp. in that the spire low, relatively flatted and sculptured by weak growth lines.

Dimensions (in mm):

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
22	20	16	148 °

Distribution

Red Sea coast, Aden, East Africa, Ceylon and Philippine.

Range

Miocene-Recent.

Conus sp.
(PI. 3, Fig. 6a & 6b)

Material

One complete steinkern from the Quaternary coral reefs of Rabigh, Saudi Arabia.

Dimensions (in mm):

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
44	41	24	138 °

Description

Moderate-sized shell, and low spired. The suture slightly impressed. The last whorl inflated, measured more than four fifths of the total height. The bad preservation nature makes specific identification difficult.

Genus *Chicoreus* Arakawa 1964
Chicoreus virgineus (Roding, 1798)
(PI. 3, Fig. 7a & 7b)

Material

One complete shell from the Quaternary coral reef, Ubhur, Saudi Arabia.

Dimensions (in mm)

Shell Height	Body Whorl Height	Body whorl width	Spiral angle
113	82	87	37

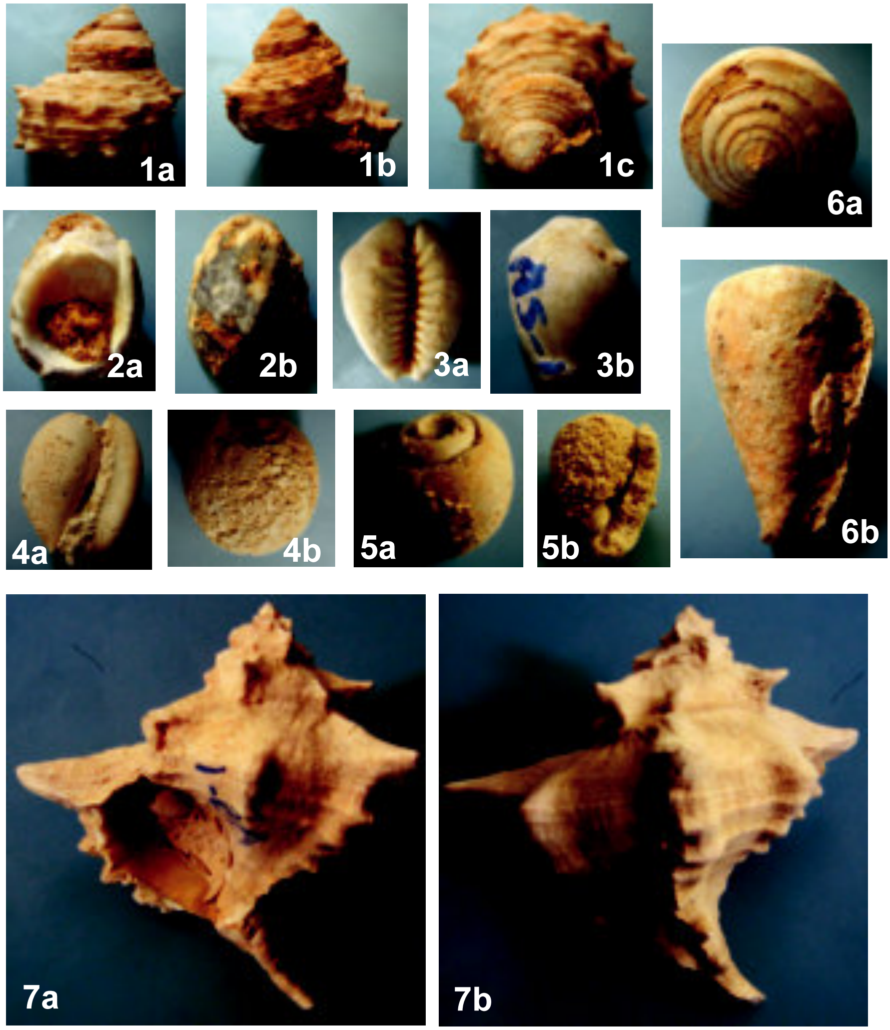

Plate 3

1. ***Turbo (Batillus) radiatus,*** **Quaternary coral reef of Rabigh, Saudi Arabia.**
2. ***Nerita (Theliostyla) albicilla,*** **Quaternary coral reef of Rabigh, Saudi Arabia.**
3. ***Cypraea staphylaea,*** **Quaternary coral reef of Rabigh, Saudi Arabia.**
4. ***Cypraea sp.*****, Je-1, Miocene, Rabigh, Saudi Arabia.**
5. ***Conus virgo,*** **Je-1, Miocene, Rabigh, Saudi Arabia.**
6. ***Conus sp.,*** **Quaternary coral reef of Rabigh, Saudi Arabia.**
7. Chicoreus virgineus., **Quaternary coral reef of Rabigh, Saudi Arabia.**
All specimens are figured in their natural size.

Description

Large sized *Chicoreus*, fusiform shaped. Spire with about 5 convex whorls. The suture slightly impressed. The last whorl carinate, large, inflated, and approximately three fourth of the total shell height. Sculpture of well developed and pronounced sharp, thick spines.

1. D. Echinoids

Class Echinoidea
Subclass Euechinoidea
Order Clypeasteroida
Suborder Clypeasterina
Family Clypeasteridae
Clypeaster acclivis Pomel, 1887
(PI. 4, Fig. 1)

1887 *Clypeaster acclivis* Pomel: 210, pi. 11, Fig. 1-9.

1899 *Clypeaster Acclivis,* Fourtau: 709, pi. 4, Fig. 1-4.

1913 *Clypeaster acclivis,* Cottreau: 56.

2003 *Clypeaster acclivis* Pomel; Elattar: 216, pl. 1, Fig. 4-6, text-Fig. 5A.

Material & Dimensions

Three incomplete specimens from Je-3 and SUB-2, Miocene, Rabigh, Ubhur, Saudi Arabia.

Description

Test large, high, with pentagonal outline and sharp angles, generally thick margin (thicker at amb areas than interamb ones); maximum width lies at ambs II & IV. Posterior end sinuate. Aboral surface inflated, raised as a cone and strongly inclined toward sides of test, petals very raised as five-fingers, long and wide; 8 tubercles on the ridge between the pair of pores. Oral surface nearly flat with depressed cone and shallow food grooves. Apical system is slightly depressed between petals.

Order Cassiduloida
Suborder Atelostomata
Family Schizasteridae
Schizaster (Paraster) legraini Gau Xhier, 1900

(PI. 4, Fig. 2a & 2b)

1900 *Schizaster Legraini,* Gauthier in Fourtau, p.60, pi. 3, Fig. 9,10.
1913 *Schizaster Legraini,* Cottraeu: 68.
1920 *Schizaster Legraini,* Fourtau: 79, pi. 5, Fig. 2.
1929 *Schizaster Legraini,* Desio: 335, pi. 40, Fig. 4a, b.
2003 *Schizaster Legraini*; Elattar: 234, pl. 10, Fig. 1-6, text-Fig. 7A.

Material & Dimensions

One complete, moderately preserved specimen from the Quatrnary coral reef of Rabigh, Saudi Arabia

Description

Test medium in size, subglobular in shape; maximum width lies slightly anterior, climax point lies posteriorly on interamb 5, with feeble anterior sinus, and narrow, vertically truncated, slightly curved and rostrate posterior end. Apical system lies posteriorly, at about 55 % of L, with 4 genital pores. Amb III is wide, deep, being shallower and narrower at ambitus and extending to peristome.

Brissopsis fraasi Fuchs, 1883
(PI. 4, Fig. 3a & 3b)

1883 *Brissopsis Fraasi* Fuchs: 61, pi. 22, Fig. 4, 5.
1899 *Brissopsis Fraasi,* Fourtau: 714.
1901 *Brissopsis Fraasi,* Fourtau: 106, pi. 3, Fig. 5,6.
2003. *Brissopsis Fraasi,* Elattar: 237, pl. 11, Fig. 1-2, text-Fig. 7B.

Material & Dimensions

One complete, moderately preserved specimen from the Quaternary coral reef of Ubhur, Saudi Arabia

Description

Maximum width located slightly anteriorly. Amb III wide, crossing ambitus in a shallow and narrow furrow extending to peristome. Other ambs petaloid, depressed and slightly flexuous; ambs II & IV longer and more divergent than I & V. Pore pairs unequal and elongated; inner pores longer than outer ones. Apical system is ethmolytic, slightly depressed between interamb areas, centrally located, with large 4 genital pores, arranged in trapezoid.

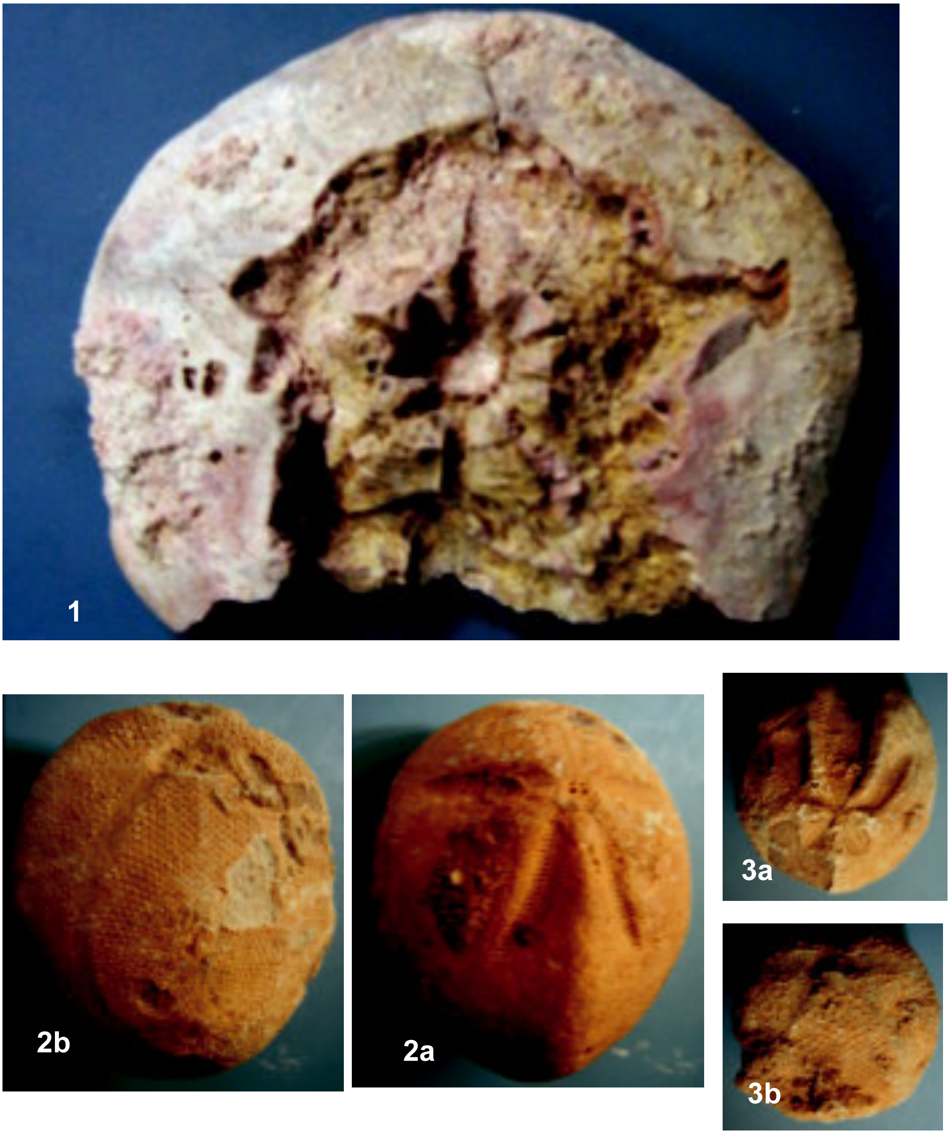

Plate 4

1. ***Clypeaster acclivis*** **Pomel, adapical view, Je-3, Miocene, Rabigh, Saudi Arabia.**
2. ***Schizaster (Paraster) legraini*****, a) adapical, b) apical views, Quaternary coral reef of Rabigh, Saudi Arabia.**
3. ***Brissopsis fraasi*** **Fuchs, *legraini*, a) adapical views, b) apical, Quaternary coral reef of Rabigh, Saudi Arabia.**

All specimens are figured in their natural size.

Family Echinolampadidae
Echinolampas sp. 1
(PI. 5, Fig. 1-2)

Material

One incomplete specimen from Jb-3, Miocene, Rabigh, Saudi Arabia.

Description

Test is large, high with conical shape, acute margin. Oral surface is slightly concave. Peristome with well developed phyllodes and bourrelets, and wider than long. Ambs II & IV are with unequal poriferous zones, unequal pore pairs (inner pores are oval, and outer ones pyriform to slit like. Periproct is large and transversely elongate

2. Microinvertebrates

The studied microfossils include two groups, which are foraminifers and palynofacies.

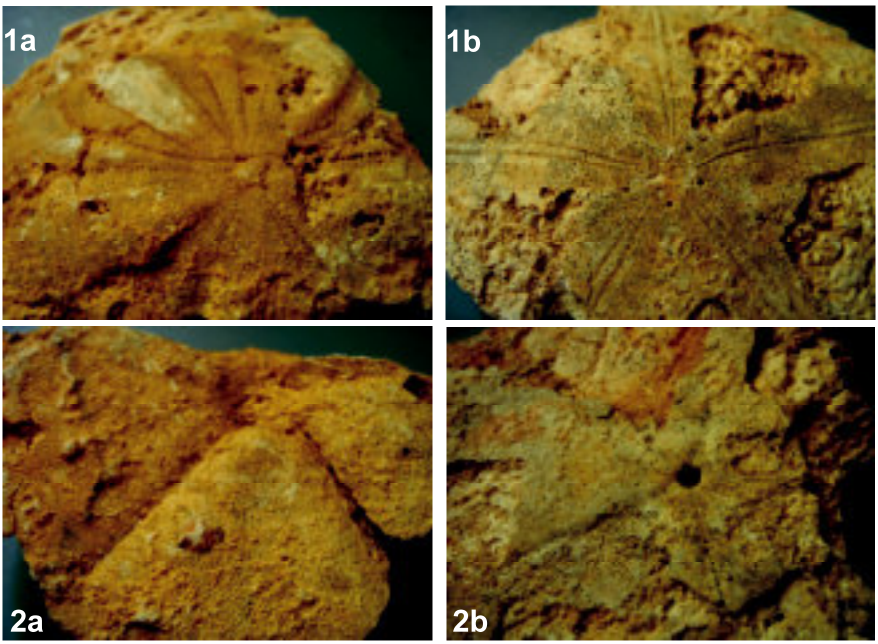

Plate 5

1-2. *Echinolampas* sp., a) adapical view, b) apical view, Je-3, Miocene, Rabigh, Saudi Arabia.

All specimens are figured in their natural size.

2. A. Foraminifers:

Nine rock samples are taken from the nearest marl, mudstone and claystone below or within the Miocene carbonate and evaporite rocks of Rabigh and Ubhur areas. The rock samples are washed for the preparation and extraction of foraminifers. Unfortunately, all samples are barren, except the marl sample overlying the carbonate rocks of Ubhur area.

Five species are identified from the Miocene marl sample; *Sorites, Spirolina, Peneroplis, Quinqueloculina* and *Spiroloculina*. The following is a systematic description of the identified foraminifera:

Kingdom Protista
Phylum Sarcodina
Class Rhizopoda
Order Foraminiferida
Family Soritidae
Genus Sorites
Sorites orbiculus (Forskäl, 1775)
(Pl. 6, Fig. 1)

1775 *Nautilus orbiculus* Forskäl: 125.
1988 *Sorites orbiculus* (Forskä1)-Loeblich & Tappan: 382, pl. 419, Fig. 4-10.

Material

8 specimens, Ubhur, Saudi Arabia.

Description

Test discoid, planispiral in the early stages at least of the microspheric form, later annular, completely divided into chamberlets, typically in a single layer, wall calcareous, imperforate, porcelaneous, smooth, aperture a single row of openings along the periphery.

Range

Miocene-Holocene

Distribution

Atlantic, Caribbean, Pacific and Indian Oceans, Red Sea.

Family Peneroplidae

Genus *Spirolina*

Spirolina cf. *cylindracea* Lamarck, 1804

(PI. 6, Fig. 2) .

1804 *Spirolina cylindracea* Lamarck: 125.

1988 *Spirolina cylindracea* Lamarck- Loeblich & Tappan: 371, pl. 393, Fig. 3-4.

Material

38 specimens, Ubhur, Saudi Arabia.

Description

Test large, early chambers planispirally enrolled and biumbilicate, later uncoiling and rectilinear, wall calcareous, imperforate, porcelaneous, surface ornamented with numerous longitudinal costae, aperture terminal, rounded.

Range

Eocene to Holocene

Distribution

Atlantic, Caribbean, Pacific and Indian Oceans, Red Sea.

Genus Peneroplis

Peneroplis planatus (Fichtel & Moll, 1798)

(PI. 6, Fig. 3a-c)

1798 *Nautilus planatus* Fichtel & Moll: 91.

1988 *Peneroplisplanatus* (Fichtel & Moll)- Loeblicb & Tappan, p.371, pl. 391, Fig. 7, 8, 11-12.

Material

42 specimens, Ubhur, Saudi Arabia.

Description

Test planispiral, involute, suture slightly depressed, wall calcareous, imperforate, porcelaneous, aperture consisting of a series of large, circular to oval pores.

Range

Miocene to Holocene

Distribution

Atlantic, Caribbean, Pacific and Indian Oceans, Red Sea.

Family: Miliolidae
Genus *Quinqueloculina*
(Pl. 6, Fig. 4a & 4b)

Material

55 specimens, Ubhur, Saudi Arabia.

Description

Test ovate in outline, chambers one-half coil in length, added in planes of coiling that are 72 a part, successive chambers added 144 a part, commonly with five chambers visible at the exterior, four of which are visible from one side and three from that opposite, wall calcareous, imperforate, porcelaneous, aperture terminal, ovate provided with a bifid tooth.

Range

Cretaceous to Holocene

Distribution

Atlantic, Caribbean, Pacific and Indian Oceans, Red Sea.

Genus Spiroloculina
Spiroloculina depressa d'orbigny, 1826
(PI. 6, Fig. 5).

1826 *Spiroloculina depressa* d'orbigny: 29.
1988 *Spiroloculina depressa* d'orbigny-Loeblich & Tappan: 33 1, pl. 340, Fig. 2-5.

Material

3 specimens, Ubhur, Saudi Arabia.

Description

Test ovate in outline, slightly flattened fusiform, early chambers quinqueloculine, later added in a single plane on alternate side, periphery rounded, wall calcareous imperforate, porcelaneous, aperture terminal, ovate, provided with elongate and slightly protruding tooth.

Range

Cretaceous to Holocene

Distribution

Atlantic, Caribbean, Pacific and Indian Oceans, Red Sea.

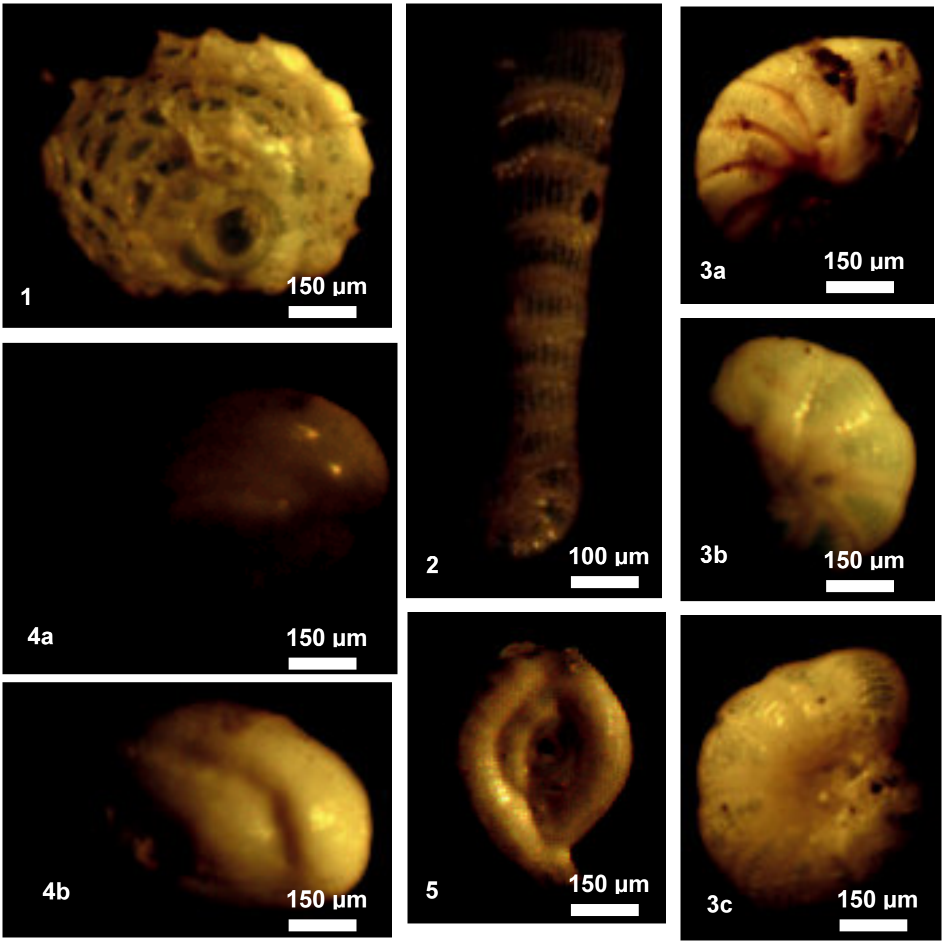

Plate 6

1: *Sorites orbiculus* (Forskäl, 1775), Ubhur Formation, Lower Miocene, Ubhur area.
2: *Spirolina* cf. *cylindracea (*Lamarck, 1804), Ubhur Formation, Lower Miocene, Ubhur area.
3a-3c: *Peneroplis planatus* (Fichtel & Moll, 1798), Ubhur Formation, Lower Miocene, Ubhur area.
4a-4b: *Quinqueloculina,* Ubhur Formation, Lower Miocene, Ubhur area.
5: *Spiroloculina depressa (D*'orbigny, 1826), Ubhur Formation, Lower Miocene, Ubhur area.

2. B- Palynofacies

The procedure for sample preparation for palynological study is that adopted at the Atlantic Geoscience Center with some modifications. Only one sample from the shale of Dafin Formation contains plant remains. The rock sample is calcareous, pale grey, soft to moderately hard shale. The recorded plant remains includes rootlets and very well preserved complete leaves in the shale (Fig. 11 & 12). This implies proximal depositional conditions that may be in vicinity to active fluvio-deltaic sources (proximity of the source area and vegetation cover). The main controlling factor is the short transport of the particles.

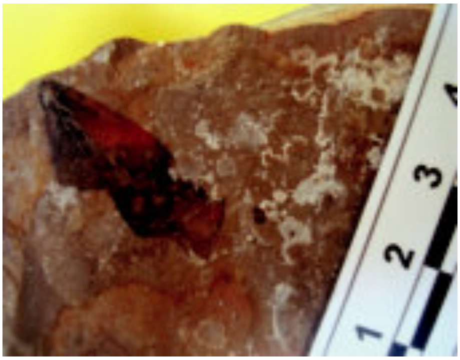

Fig. 11. Complete leaf at the bedding surface of the shale, Al-Hakkak Member, Dafin Formation, Wadi Al-Hakkak.

Fig. 12. Rootlets fragments scattered on the surface of the shale bed, Al-Hakkak Member, Dafin Formation, Wadi Al-Hakkak.

The optical palynofacial analysis of the studied sample indicates the presence of Unstructured Organic Matter (USTOM) and Structured Terrestrial Organic Matter (STOM). The following is a description of these types:

1) Unstructured Organic Matter (USTOM)

Definition

Most unstructured (structureless) organic substances are of amorphous aspect and may be referred to as amorphous organic matter (commonly abbreviated AOM), (Fig. 13). It is generally regarded as bacterially, chemically and/or otherwise altered organic debris with little or non preserved cellular structure. It has no clearly defined shape, and may occur in masses (aggregates, coagulations) or sheets, or be finely dispersed. Other terms that have been used to refer to AOM include amorphogen, bituminous matter, colloidal organic matter, floccules and groundmass, primary shapeless /structureless (organic) matter, sapropel, sapropelic amorphous organic matter, sapropelic groundmass, thermal transformation products and xenomorphic organic matter.

Source

The AOM is derived from a variety of sources ranging from the largest trees to the microscopic organism (*e.g.* plankton), and most of them is attributable to a combination of the various grazing, bacterial, fungal and other degradation processes.

Description

Diffuse edged 'AOM' particle seen in transmitted white light (Fig. 13). The form of the edge and the presence of the inclusions indicate that the particle is structureless and not therefore a phytoclast. Some particles have heterogeneous, "clotted" appearance, while others have much more uniform and have a less distinct margin. At the left part of Fig. 13, some granular variety of 'AOM' which consists of irregular brown granules is recorded in an amorphous matrix. The origin of the granules is uncertain, but they do not appear to be conventional phytoclasts.

Conclusions

Slightly preserved AOM dominates the present kerogen assemblage indicating deposition under sufficiently reducing dysoxic-anoxic conditions (oxygen deficient basin). The site of deposition may suffer from the upwelling where the characteristic deposits are upwelling-influenced dysoxic sediment facies in closed or semi-closed lake, swamp, lagoon or estuary.

The degraded state of AOM indicates that the examined surface for the exposed sample is suffered from prolonged oxidation in dry arid climatic conditions.

2) Structured Terrestrial Organic Matter (STOM)

Definition

All kinds of "woody" debris, cuticles and other particulate detritus excluding palynomorphs and amorphous organic matter are considered to fall within the circumscription of structured organic matter, or STOM.

They have cellular organization or display other evidence of botanical features. All are regarded as discrete particles that have shapes and forms that may vary considerably from blocky lumps to thin sheets and splinters. The structure may be clearly displayed, only faintly discernible or suggested, sometimes merely by the fact that it is a membrane or filament (tube) that has a clearly defined, non-amorphous outline.

Source

The majority is derived from plants and is, therefore, considered to be phytoclasts.

Description

In the middle part of Fig. 14, some granular variety of 'AOM' which consists of irregular brown granules in an amorphous matrix. The diffuse edged 'AOM' particles are also common.

Conclusions

The highly reduced inputs of phytoclasts and palynomorphs (structured terrestrial organic matter) indicate arid onshore areas lacking the rainfall precipitation (rivers) at the time of deposition. So the wind may be the principal transporting agent for the plant leaves.

The extensively degraded state of the already few palynomorphs and phytoclasts indicate also that the investigated sample suffered from prolonged oxidation in dry arid climatic conditions.

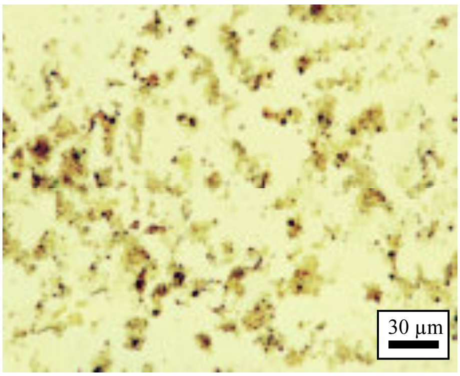

Fig. 13. Aggregates of finely dispers amorphous organic matter (AOM), Al-Hakkak Member, Dafin Formation, Wadi Al-Hakkak.

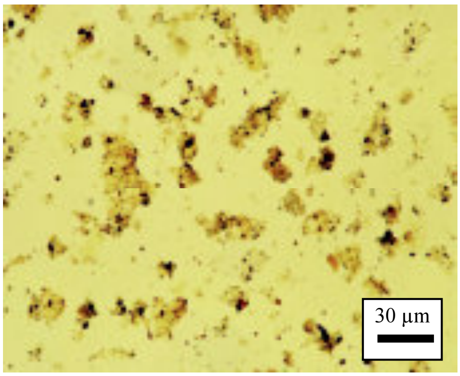

Fig. 14. AOM consists of irregular brown granules in an amorphous matrix, Al-Hakkak Member, Dafin Formation, Wadi Al-Hakkak.

Palynomorphs

Definition

The term palynomorph as used here refers to all discrete acid-resistant, organic-walled microfossils that may be encountered in a palynological preparation. The following are considered to be the main content of palynomorphs: Small spores (isospores, microspores), megaspores, pre-pollen and pollen grains and dinoflagellatecysts (dinocysts).

Description and Conclusions

Although the sample contains some plant remains like rootlets and leaves, but the palynomorph content is very poor and the sample is regarded as barren with respect to palynomorphs. The absence of the terrestrial palynomorphs (spores and pollen grains) could be attributed to two reasons:

1- Hydrodynamic equivalence

The presence of terrestrial palynomorphs is influenced by the hydrodynamic equivalence effects. The rootlets and leaves, being relatively large and are composed of dense organic particles and woody debris comparable to pollen grains and spores. So, the rootlets and leaves are often concentrated in depositional sites far from those where spores and pollen are concentrated. This differentiation process according to the size is well done by the transporting medium. In the present work, most probably the wind has the main effect due to the highly reduced inputs of phytoclasts which imply arid onshore areas lacking the precipitation of rainfall.

2- The extensive oxidation effect

Despite that the shale is sampled from a depth of about 70 cm, the depth of weathering and the prolonged oxidation of the sediment surface of the studied sample argued for the main reasons for the complete degrading and absence of such type of organic walled microfossils.

Paleoecological Implications

The studied shell dominated beds in Rabigh and Ubhur areas are considered as shell concentrations of Early-Middle Miocene and

Pleistocene age. The shell concentrations or dense accumulations of fossils are formed through the combination of three groups of factors: biological processes, physico-chemical processes, and time (Fürsich, 1995) or by combination of mechanical and biological processes (Boyer *et al.,* 2004). Analyses of shell concentrations provide a tool for palaeoenvironmental reconstructions (*e.g.* Kidwell *et al.,* 1986; Kidwell, 1991; Fürsich & Oschmann, 1993; Fürsich, 1995; Abbott, 1997; Boyer *et al.,* 2004; and Tomašových, 2004). The term shell concentration is used herein to denote deposits of any geometry containing a relatively dense accumulation of biogenic hard parts larger than 2 mm (Kidwell, 1991; Fürsich, 1995; Tomašových, 2004).

Two types of shell concentrations are recorded in the present study:

1. Early-Middle Miocene Shell Concentrations

Biofacies and taphonomic analysis has allowed for the reconstruction of the paleoenvironmental history of accumulation of a series of spectacular mollusk-dominated shell-concentrations and the benthic assemblages that inhabited the Miocene sea of the study areas. Mollusk-dominated fossil assemblages were defined from the study areas including the presence of *Favia* sp., *Cerastoderma edule*,? *Callista* sp., *Chicoreus virgineus*, *Clypeaster acclivis* and *Echinolampas* sp.

Transgressive and Maximum Highstand phases preserve the Miocene shell beds of Rabigh and Ubhur areas. They were deposited in tidal current-dominated upper intertidal environments. Based on these fossil assemblages, several benthic life associations can be identified. These faunal assemblages inhabited intertidal and foreshore settings and were represented by soft-bottom infaunal suspension feeders, as well as by firm bottom, vagile carnivorous and suspension-feeding epifauna.

The main agents responsible for the formation of the shell concentrations from the Early-Middle Miocene of the study areas were storm-induced waves and currents, reduced sediment input, settling behavior of benthic macroinvertebrates and productivity. The sea floor was below fair-weather wave-base, but within the reach of storms.

On the other hand, the majority of foraminifera are adapted to normal marine salinities (about 35‰) and it is in such conditions that the highest diversity assemblages are found. The collected and described foraminifers from the Miocene rocks of Ubhur area are porcelaneous forams belonging to Miliolina which represent high $CaCO_3$ concentrations of relatively hypersaline waters.

2. Quaternary Shell Concentrations

A raised beach or a marine terrace is an emergent coastal landfor. Raised beaches and marine terraces are beaches or wave cut platforms raised above the shore line by a relative fall in the sea level.

Around the world, the combination of tectonic coastal uplift and Quaternary sea-level fluctuations has resulted in the formation of marine terrace sequences, most of which were formed during separate interglacial highstands that can be correlated to Marine Oxygen Isotopic Stages (MIS).

A marine terrace commonly retains a shoreline angle or inner edge, the slope inflection between the marine abrasion platform and the associated paleo sea-cliff. The shoreline angle represents the maximum shoreline of a transgression and therefore a paleo sea level.

The Pleistocene raised beaches of Rabigh area are reef dominated shell concentrations formed as a result of biological processes. They are dominated by reef corals (hermartypic), mollusks, barnacles, crustaceans, and sea urchins.

The Pleistocene raised beaches of Rabigh area are composed predominantly of scleractinian corals (Phylum Cnidaria; Class Anthozoa; Order Scleractinia). Most scleractinians, and particularly those that build reefs, are colonial, anemone-like animals that house microscopic algae and secrete skeletal structures composed of calcium carbonate. The coral animal apparently derives energy and nutrients through photosynthesis by the algal symbionts, which enhances its growth and allows it to thrive in nutrient-poor conditions. Corals are usually the main contributors to reef accumulation and provide the main structural network, or "framework", of the reef. However, algae that secrete calcium carbonate, such as coralline red algae and an abundant calcifying green alga known as *Halimeda*, are almost always significant contributors as well. While many calcifying algae contribute particles that rapidly become reef sediments, coralline red algae often have an encrusting growth form that tends to act as a "glue" that holds the reef fragments and sediments together. Another significant component to reef sediments are benthic foraminifera, protozoans that secrete calcium carbonate tests that range from microscopic to millimeters in length. These organisms produce the bulk of the reef structure and the basis for the entire coral reef community, which includes representatives from nearly every marine phylum, from unicellular organisms to fish and mammals.

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References

Abbott, S.T. (1997) Mid-cycle condensed shell beds from mid-Pleistocene cyclothems**,** New Zealand: implications for sequence architecture. *Sedimentology*, **44**: 805-824.

Abdel-Fattah, Z.A.H. (1998) Stratigraphy and paleontology of some Neogene-Quaternary successions on the Red Sea coast, Egypt. *M.Sc. Thesis,* Mansoura Univ., 227 p.

Abou Ouf, M.A. (1998) Paleoenvironmental interpretation of the pre-rift sediments (Usfan Formation in Haddat ash-Sham) in the central Red Sea margin, Jeddah region, Saudi Arabia. *J KAU: Mar. Sci,.* **9**: 63-73.

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

Al-Sofyani, A.A. and **Niaz, G.R.** (2007) A comparative study of the components of the hard coral *Seriatopora hystrix* and the soft coral *Xenia umbellate* along the Jeddah coast, Saudi Arabia. *Revista de Biologia Marina y Oceanografia,* **42/3**: 207-219.

Andreieff (1983) *Etudé micropaleontologique de deux larves-minces,* Arabie Saodite. Bureau de Res. Geol. et Min., Internal Report 83-GEO EM-55.

Bantan, R.A. (2006) Morphological features and sedimentological aspects of Wadi Al-Kura, north of Jeddah, western coast of Saudi Arabia*. JKAU: Mar. Sci.*, **17**: 153-165.

Basaham, A.S. (1998) The composition and diagenetic features of the inland Quaternary coralline limestone, south Sharm Ubhur, Red Sea coastal plain of Saudi Arabia. *JKAU, Mar. Sci.,* **9**: 75-87.

Basaham, A.S., Rifaat, A.E., El-Sayed, M.A. and **Rasul, N.** (2006) Sharm Ubhur-environmental consequences of 20 years of uncontrolled coastal urbanization*. JKAU, Mar. Sci.,* **17**: 129-152.

Basyoni, M.H., El Askary, M.A., Saad, N.A. and **Taj, R.J.** (2002) Mineralogy of the clay deposits in Makkah and Rabigh Quadrangles, west central Arabian Shield, Saudi Arabia. *Science and Technology Jour. Sultan Qaboos Univ.,* **7**: 259-277.

Beydoun, Z.R. (1991) Arabian Plate Hydrocarbon Geology and Potential – A Plate Tectonic Approach. *American Association of Petroleum Geologists, Studies in Geology*, no. 334, 77 pp.

Bosch , D.T., Dance, S.P. and **Moolenbeek, R.G.** (1995) Sea shells of Eastern Arabia Gulf. *Montivate*, 296 p.

Boyer, L.D., Bottjer, J.D. and **Droser, L.M.** (2004) Ecological signature of Lower Triassic shell beds of the western United States. *Palaios,* **19**: 372–380.

Brown, G.F., Jackson, R.O., Bogue, R.G. and **McLean, W.H.** (1963) Geology of the southern Hijaz Quadrangle, Kingdom of Saudi Arabia. *Miscellaneous Geologic Investigations Map 1-210A,* Saudi Arabian Directorate General of Mineral Resources, Jeddah.

Cottreau, J. (1913) Les Echinides neogenes du bassin Mediterraneen: *Inst. Oceanogr., Ann.,* **6**(3): 1-192, 1-15, text-Fig.: 1-41.

Desio, A. (1929) Resultati Scientifici della Missione alia Oasi Di Giarabub. Ill: *La Paleontologia. R. Soc. Geogr. Italiana, Rome,* **4**.

EI-Shazly, S.H. (1982) Stratigraphic and paleontologic studies on post-Miocene outcrops from Quseir area, Red Sea, Egypt*. M. Sc. Thesis,* Ain Shams Univ., 188pp.

EI-Sorogy, A.S. (1990) Paleontologic and paleoecologic study on the Pliocene-Quaternary deposits in Quseir area, Red Sea. *M. Sc. Thesis,* Zagazig Univ., 225pp.

EI-Sorogy, A.S. (1997) Progressive diagenetic sequence.of Pleistocene coral reefs in the area between Quseir and Marsa Alam, Red Sea coast, Egypt. *Egypt. Jour. Geol.,* **41/1**: 519-540.

Elattar, A.A. (2003) Early-Middle Miocene echinoids from the Sadaat Formation, Sadat Area, South Gebel Ataqa, NW Gulf of Suez, Egypt. *Egypt. Jour. Paleontol.,* **3**: 209-241.

Filatoff, J. and **Hughes, G.W.** (1996) Late Cretaceous to Recent Paleoenvironments of the Saudi Arabian Red Sea. *Journal of African Earth Sciences*, **22/ 4**: 535–548.

Fourtau, R. (1899) Revision des echinides fossiles de l'Egypte. *Memoires de l'Institut Egyptien*, fasc. 8, serie **3**: 681, pl. 2, Fig 5, 6.

Fourtau, R. (1900) Notes Sur les Echinides fossiles de I, Egypte, 1. *Bull. Inst. Egypt.,* **4/1**: 165-167.

Fourtau, R. (1901) Notes Sur les Echinides fossiles de I, Egypte,2 *.Bull. Inst. Egypt.,* **4/2**: 31-117.

Fourtau, R. (1920) Catalogue des Invertibres fossils de I'Egypte representes dans les collections du Musee geologique du Caire, ser, 4, Terrains, 2eme partie, Echinodermes neogenes, *Egypte Surv. Dept., Cairo.*

Fuchs, Th. (1883) Beitrage zur kenntnis der Miocanfauna Aegyptens und der Lybischen WCiste. *Paleontographica,* **XXX**, Cassel.

Fürsich, F.T. (1995) Shell concentrations. *Eclogae Geologicae Helveticae*, **88**: 643-655.

Fürsich, F.T. and Oschmann, W. (1993) Shell beds as tools in basin analysis: the Jurassic of Kachchh, western India. *Jour. Geol. Soc.*, **150**: 169-85.

Gheith, A.M. and **Abou Ouf, M.** (1994) Sedimentological features of the Bathan Formation (Miocene?) north of Sharm Ubhur, Jeddah region, Saudi Arabia. *Arab Gulf J. Scient. Research,* **15/3**: 563-582.

Hörnes, M. (1870) Die fossilen Mollusken des Tertiaerbeckens von Wien. *Jahrbuch der geologischen Reichssanstalt*, **14**: 509-514.

Hughes, G.W. and **Beydoun, Z.R.** (1992) The Red Sea-Gulf of Aden: biostratigraphy, lithostratigraphy and paleoenvironments. *Journal of Petroleum Geology,* **15/2**: 135–156.

Hughes, G.W. and **Johnson, R.S.** (2005) Lithostratigraphy of the Red Sea Region. *GeoArabia*, **10/3**: 49-126.

Hughes, G.W., Perincek, D., Grainger, D.J., Abu-Bshait, A. and **Jarad, A.M.** (1999) Lithostratigraphy and depositional history of part of the Midyan region, northwestern Saudi Arabia. *GeoArabia*, **4**: 503 - 542.

Kidwell, S.M. (1991) The stratigraphy of shell concentrations: *in* Allison: A., Briggs, D. E. G., (Eds.), *Taphonomy: Releasing the Data Locked in the Fossil Record.* Plenum Press: 211-290.

Kidwell, S.M., Fürsich, F.T. and **Aigner, T.** (1986) Conceptual framework for the analysis and classification of fossil concentrations. *Palaios*, **1**: 228-238.

Mandurah, M.H. and **Aref, M.A.M.** (2009) Origin and diagenesis of the Miocene secondary gypsum rocks at Rabigh area, eastern Red Sea coast, Saudi Arabia. *8th Saudi Meeting of Geosciences*, Jeddah (Abstract).

Moltzer, J.G. and **Binda, L.** (1984) Age and depositional environment of the Middle and Upper Members of the Shumaysi Formation, Saudi Arabia. *Geological Survey of Egypt Annals*, **14**: 269–278.

Moore, R.C. (Ed.) (1969) Treatise on Invertebrate Paleontology. Part J. (Gastropoda), *Geol. Soc. Amer.*, Univ. Kansas Press.

Moore, T.A. and **Al-Rehaili, M.H.A.** (1989) *Geologic Map of the Makkah Quadrangle,* Sheet 21D, Kingdom of Saudi Arabia. Ministry of Petroleum and Mineral Resources, Jeddah.

Newton, R.B. (1900) Pleistocene shells from the raised beach deposits of the Red Sea. *Geol. Mag.*: 544-56.

Pomel, A. (1887) Pal´eontologie ou description des animaux fossiles de l'Alg´erie. Zoophytes. 2e fascicule – E´chinodermes. 2e livraison. *Adolphe Jourdan*, Alger, 344 p.

Ramsey, C.R. (1986) Geological Map of the Rabigh Quadrangle, sheet 22D, Kingdom of Saudi Arabia. *Directorate General of Mineral Resources*, Jeddah.

Spencer, C.H. and **Vincent, L.** (1984) *Bentonite Resources Potential and Geology of Cenozoic Sediments, Jeddah Region.* Saudi Arabia Deputy Ministry for Mineral Resources, Open File Report BRGM-OF-04-31, 60p.

Srivastava, S.K. and **Binda, L.** (1991) Depositional history of the Early Eocene Shumaysi Formation, Saudi Arabia. *Palynology*, **15**: 47-61.

Taj, R.J. and **Hegab, O.A.R.** (2005) *Dafin Formation-Lithostratigraphy, Sedimentology, Depositional Environments, Rabigh Area, Saudi Arabia.* Internal Report, KAU. Project No. 202/423, 172pp.

Taj, R.J., El Askary, M.A., Saad, N.A. and **Basyoni, M.H.** (2001) Economic Potentiality of the Tertiary clay deposits in Makkah and Rabigh Quadrangles, West Central Arabian Shield, Saudi Arabia. *5th Inter. Conf. On Geochemistry, Alex. Univ. Egypt*. **2**: 169-183.

Taj, R.J., El Askary, M.A., Saad, N.A. and **Basyoni, M.H.** (2002) Mineralogical investigation and some sedimentological phenomena of Ubhur Formation, North Jeddah, Saudi Arabia. *Jour. King Abdulaziz Univ. Mar. Sci*., **13**: 93-110.

Taj, R.J., El Askary, M.A., Saad, N.A. and **Basyoni, M.H.** (2004) Geochemistry and depositional environments of the Tertiary Clays in Makkah and Rabigh Quadrangles, West Central Arabian Shield, Saudi Arabia. *Jour. King Abdulaziz Univ. Earth Sci*., **15**: 97-138.

Tomašových, A. (2004) Effect of extrinsic factors on biofabric and brachiopod alteration in a shallow intraplatform carbonate setting (Upper Triassic, West Carpathians). *Palaios* **19**, 349-371.

Ziko, A., El-Sorogy, A.S., Aly, M.M. and **Nour, H.E.** (2001) Sea shells as pollution indicators, Red Sea Coast, Egypt. *Egypt. Jour. Paleontol*., **1**: 97-113.

دراسة الأحافير لصخور كربونات النيوجين في مناطق أبحر – رابغ ، ساحل البحر الأحمر، المملكة العربية السعودية

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المستخلص. تنتمي صخور الكربونات في مناطق أبحر ورابغ أثناء انفلاق البحر الأحمر في عصر الميوسين إلى عضو كربونات جربة لمتكون دافن وإلى متكون أبحر، على التتابع. تقع صخور الكربونات في منطقة رابغ أعلى فتاتيات وادي الحكاك، كما إنها تعتبر سحنة جانبية متماثلة مع قطاع متبخرات الجحفة. وتقع صخور كربونات منطقة أبحر أسفل صخور المتبخرات والطفلة لعصر الميوسين الأوسط. وتوجد المصاطب المرجانية المرفوعة في منطقة رابغ فقط.

تشير الدراسات الحقلية، ودراسة الأحافير، وسحنات حبوب اللقاح القديمة لصخور الكربونات والطفلة لعصر النيوجين لمناطق أبحر ورابغ في ساحل البحر الأحمر بالمملكة العربية السعودية، إلى وجود المرجان، والبطنقدميات، وذوات المصراعيات، والجلد شوكيات، والمنخربات، ومواد عضوية لا شكلية. ولذلك فإن الغرض الرئيسي لهذه الدراسة يهتم بتفسير التقسيم والبيئات القديمة للأحافير التي تم تعريفها.