Pakistan J. Zool., vol. 47(5), pp. 1287-1296, 2015.

Taphonomic Processes of Some Intertidal Gastropod and Bivalve Shells from Northern Red Sea Coast, Egypt

Abdelbaset S. El-Sorogy*
Geology and Geophysics Department, College of Science, King Saud University, Riyadh, Saudi Arabia
Geology Department, Faculty of Science, Zagazig University, Zagazig, Egypt

Abstract.- Disarticulation, encrustation, bioerosion, fragmentation and abrasion are the recorded taphonomic processes in the intertidal gastropod and bivalve shells from the northern Red Sea coast, Egypt. Balanoids, polychaetes, bivalves and bryozoans are the recorded encrusters. Bioerosion traces were predominately of clionid sponges and gastropods. They are represented by the ichnogenera *Entobia* and *Oichnus*. Fragmentation was mainly resulted from mechanical and biological processes. Many specimens are abraded, lacking-sheen, and showed evidence of corrosion. Most bivalve shells are dominated by disarticulated valves.

Key words: Taphonomy, Gastropoda, Bivalvia, Red Sea coast, Egypt.

INTRODUCTION

Taphonomy of marine skeletal organisms involves biological, chemical and mechanical processes that led to abrasion, bioerosion, disarticulation, dissolution, encrustation, fragmentation, precipitation, orientation, and sorting (Nielsen, 2004; El-Gendy *et al*., 2015). These taphonomic signatures may indicate that the processes happened in a certain time sequence controlled by life habits and environmental conditions (Barkati and Asif, 1984; Meldahl and Flessa, 1990; Viana and Richter, 1998). The taphonomic condition of shells varied with environment. Santos and Mayoral (2008) indicated that in intertidal and shallow sublittoral environments, the hard substrates, including the skeletons of living and dead organisms as well as rock clasts, may be colonised by a diverse array of endobionts (borers) and grazers, in addition to suspension feeding epibionts (encrusters). Shell beds, lags, or concentrations can be a common feature of shelf and coastal areas, and considerable research has been devoted to understanding their formation through taphonomic analysis (Brett, 2003).

* Corresponding author: elsorogyabd@yahoo.com & asmohamed@ksu.edu.sa
0030-9923/2015/0005-1287 $ 8.00/0

Many studies have been dealt with fauna, environmental assessment, and sedimentology of the Red Sea coast (Beltagy, 1984; Anan, 1984; Ziko and El-Sorogy, 1995; Mansour and Anwar, 2000, 2006; Nour *et al*., 2006; El-Sorogy, 1997a,b, 2008; Ostrovsky *et al*., 2011; Ziko *et al*., 2012; Abd El-Wahab and El-Sorogy, 2003; Nour and El-Naggar, 2007; El-Sorogy *et al*., 2012, 2013a, b, 2015). The works have been dealt with the postmortem processes of molluscan shells along the Red Sea coast are very rare, therefore, the aim of the present study is to document the taphonomic processes of the intertidal molluscan shells (bivalves and gastropods) collected from the northern Red Sea coast, Egypt and discuss the factors controlling them.

MATERIALS AND METHODS

More than 404 specimens of gastropods and bivalves have been collected at low tide from the intertidal zone of El Fanader lagoon, Hurghada, Makadi Bay, Al Qweh lagoon, and El-Humrawen harbor, northern Red Sea coast, Egypt (Fig. 1) Shell samples were washed, cleaned, sorted, identified and illustrated (Figs. 2-4). The identification of the present fauna is based on the classification of Moore (1960, 1969) and Bosch *et al*. (1995).

When necessary, the dead shells were carefully washed and brushed to remove sediments. All specimens are deposited in the collections of Department of Geology and Geophysics, College of Science, King Saud University.

Studied areas

Five localities were chosen for study (Fig. 1), namely: 1) El Fanader lagoon, 2) Hurghada, 3) Makadi Bay, 4) Al Qweh lagoon, and 5) El-Humrawen harbor. The following are description of the five studied areas:

El Fanader lagoon

This locality lies 10 km in the sea, facing to Hurghada city, between 27˚01´17´´-27˚38´16´´N and between 33˚40´49´´-33˚49´49´´E (Fig. 1). The site contains small reef patches and a barrier reef arises from the seabed to about 14 m height. This barrier reef includes some mixed species of stony corals and soft ones. Field survey illustrated high percentage of dead corals and faunal accumulation on the beach, indicating high water energy. Also, the study area is situated under human impacts in the form of diving and snorkeling activities.

Hurghada

This site lies at about 20 km to the north of Hurghada City. It is located within the main Hurghada port between 27˚38´12´´-27˚56´13´´N and between 33˚04´01´´-33˚39´50´´E (Fig. 1). Generally, faunal accumulation along the beach is rare in this site, may be due to many types of pollutants, such as reject brain water from desalination plants, light oil resulting from basin repair boats, the sewage output from the harbor Mosque and the port and fishing activities.

Makadi bay

Makadi Bay lies at 30 km to the south of Hurghada city, between 26˚59´46´´-27˚00´58´´N and between 33˚44´54´´-33˚54´17´´E (Fig. 1). It has semi-circular shape and receives all clastic sediments from main tributaries. Makadi Bay is sheltered from the direct currents and waves by barrier reefs off the bay, where it is bounded on the west by Pre-Cambrian metamorphic and igneous rocks and is separated from it by a sandy coastal plain covered with patches of post Miocene and limestone gravel banks (Shehata, 2011). The beach is relatively wide, while the intertidal zone is narrow with maximum depth of 1.5 m during high tide, and extends to a distance about 100 m from the shoreline. Its bottom floor is sandy inhabited with some spots of algae, followed by back reef zone which includes some coral patches.

Al Qweh lagoon

Al Qweh downstream lies at about 44 Km to the south of Safaga city. It lies along the main Safaga–Quseir asphaltic road, between 26˚/36´/22´´ -26˚/39´/22´´N and between 34˚58´07´´-34˚08´00´´E (Fig. 1). The beach is sandy in the northern part, while the middle and southern parts are of the rocky beaches. Tidal flat is shallow, wide, extends 2km and composed of biogenic sand inhabited with seagrass and algae. This zone is followed by high biodiversity of corals, molluscans and sponges.

El-Humrawen harbor

This site lies at about 20 km to the north of Quseir city. It is located between 26˚01´10´´-26˚08´10´´N and between 34˚02´12´´-34˚05´12´´E (Fig. 1). Beach zone is very narrow. The width of the intertidal zone is 30 m at the edge of coral reefs. Middle part of the marine area is rich with seagrass and algae. Marine fauna and flora are characterized by low diversity in this site. This may be due to spread of phosphate dust, especially during the shipping process.

RESULTS AND DISCUSSION

Disarticulation

Bivalve shells may serve as sensitive indicators of rapid, episodic sediment accumulation (Allen, 1992). The rate at which organisms skeletons disintegrate after the death is a function of their delicacy, environmental energy, temperature, oxygen level and residence time on the seafloor (Brett, 2003). Degree of articulation is a good indicator of relative exposure time, or energy of the depositional environment.

In the studied areas, More than 97% of the examined bivalve shells are disarticulated and the articulated ones are generally rare (Fig. 2A). In rocky shore along Al Qweh lagoon, articulation is present in comparison with sandy coastline of other areas. It is limited to specimens that are physically wedged within interstices of rock blacks (thus making the separation of valves difficult) and to species that have very thick ligaments or dentitions resistant to disarticulation. Most disarticulated valves occurred at El Fanader lagoon, due to the influence of high water energy.

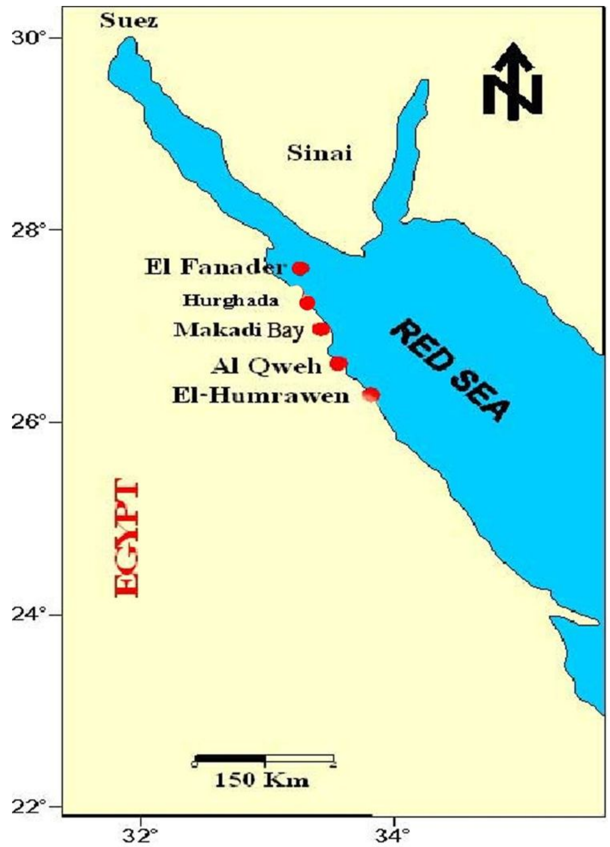

Fig. 1. Location map of the studied areas.

The articulated shells are connected with ligament areas. No size sorting is recognized and shells are more commonly oriented concave-up than concave-down. Shells occur with others that are oriented obliquely and vertically. Boucot *et al*. (1958), Seeling and Bengtson (1999) indicated a transport of short duration in a moderately-energetic setting for such case. Valves are rarely found in their life position and appear as parautochthonous associations (transported slightly in the vicinity of their habitats (Seeling and Bengtson, 1999).

Encrustation

Encrusters on Cenozoic shells are very common, but the published studies of them are surprisingly few (*e.g.*, Taylor and Wilson, 2003; Kidwell, 2013; El-Gendy *et al*., 2015). Taphonomically, important encrusters whose have hard-parts include bryozoans, serpulid worms, foraminifera, corals and barnacles (Parsons and Brett, 1991; Perry, 2000; McKinney, 1996, El-Hedeny, 2005, 2007a, b). In the studied areas, four types of encrusters were recorded, in descending order of abundance they are: balanoid barnacles, polychaetes, bivalves and bryozoa.

The balanoid barnacles *Balanus perforatus* is the most common encrusters in the studied areas. Balanoid barnacles are recorded at nearly similar morphological sizes and same directions. They are usually found in all modern shallow marine environments, occupying shorelines of the continent (El Sorogy *et al*., 2003). They are well developed as aggregates on the external/somewhat the inner and outer surfaces of the bivalve *Acrosterigma lacunosa* and *Marcia flammea* (Fig. 2B-D). Their position of attachment may indicate the direction of flow of food-bearing water. It is supposed that balanoid barnacles are able to orientate to water movement in order to allow for efficient food collection over a wide range of conditions (El-Hedeny, 2007a). In addition, there are some gastropods species encrusted with balanoid barnacle as *Cerithium caeruleum*, *Siphonarìa belcheri* and *Lunella coronata* (Fig. 2E-G).

The second type of encrusters is the calcareous tube-forming worms (serpulid). They may be present judging from tube morphology, are moderately common on some bivalve shells. They sometimes appear as dense clusters (Fig. 2H) and in some cases develop as small aggregates on the inner and somewhat outer surfaces of some bivalve shells (Fig. 2I-L). The following are the recorded bivalves encrusted by serpulid worms: *Pinctada margaritifera*, *Trapezium sublaevigatum*, *Mactra rochebrunei*; *Anadara antiquata*, *Glycymeris pectunculus*, *Barbatia setigera*, *Brachidontes variabilis*, *Madiolus* cf. *barbatus*, *Alectryonella plicatula* (Fig. 2H-K).

The third types of encrusters are the bivalves. Some bivalves encrusted by other bivalves to form aggregates or banks. Examples from the study areas are *Alectryonella plicatula*, *Chama asperella*, *Ch. reflexa* and *Spondylus hystrix* (Fig. 2M-O). The fourth types of encrusters are the bryozoans. Bryozoans are small benthic aquatic invertebrates

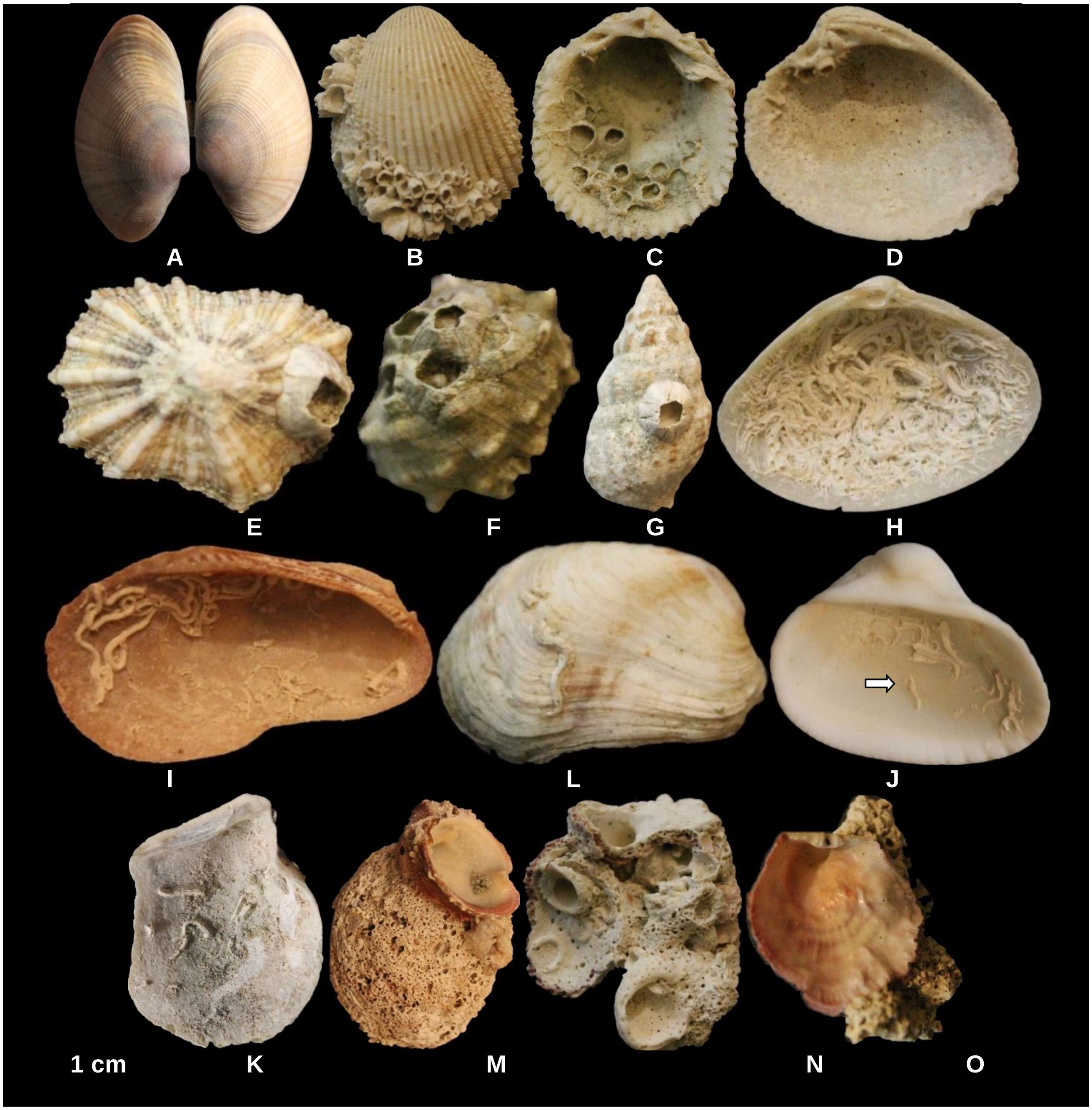

Fig. 2. A, Double valved *Callista florida* jointed only by ligamental area, Hurghada; B, C, Balanoid barnacles encrusted on the internal and external surfaces of *Acrosterigma lacunosa* with similar sizes and directions, Al Qweh lagoon; D, Balanoid barnacles encrusted the internal surface of *Marcia flammea*, Hurghada; E-G, Balanoid barnacles encrusted the external surfaces of *Siphonarìa belcheri*, *Lunella coronata* and *Cerithium caeruleum* respectively, Makadi bay; H-K, Sepulid worms aggregates on the internal surfaces of *Mactra rochebrunei*, *Barbatia setigera*, *Anadara antiquata* and *Pinctada margaritifera* respectively, El-Humrawen harbor. Note, bryozoan colonies encrusted the internal surface of *Anadara antiquata* (arrow). L, Sepulid worms aggregates on the external surface of *Trapezium sublaevigatum*, Makadi bay; M, N, Aggregate of *Chama asperella* and *Ch. reflexa*, El Fanader lagoon; O, Cemented *Spondylus hystrix* on coralline fragment, El-Humrawen harbor.

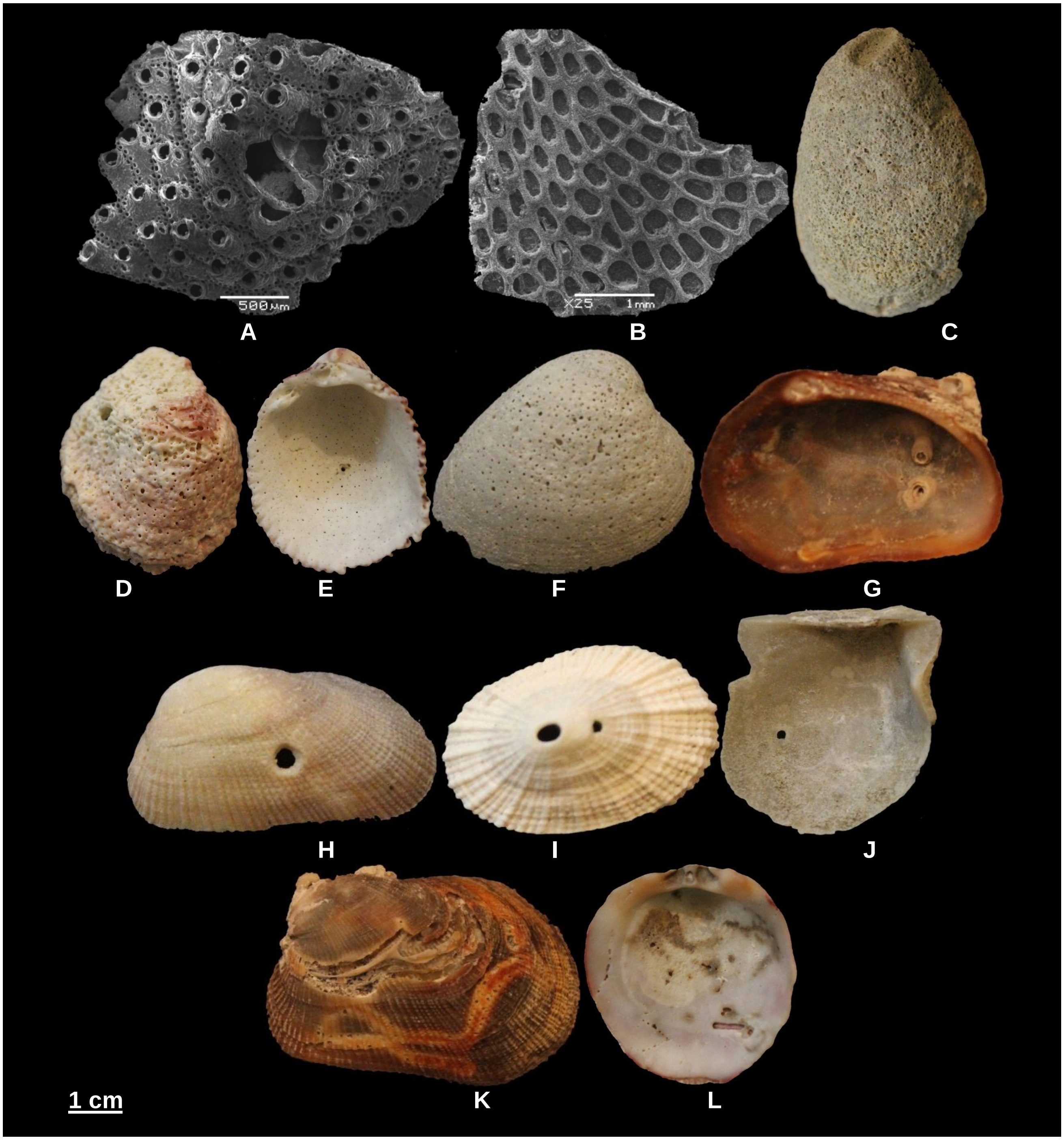

Fig. 3. A, B, Enlagment of bryozoan encrustations *Parasmitina* sp and *Biflustra* sp. on the inner surfaces of *Anadara antiquate* and *Mactra rochebrunei*, Al Qweh lagoon; C-F, Dense rounded and closely spaced ichnogenus *Entobia* on external surface of *Spondylus hystrix, Chama reflexa, Acrosterigma assimile* and *Marcia flammea,* El Fanader lagoon*;* G-J, Internal surface of bivalve shells *Barbatia parva, B. setigera, Diodora funiculate* and *Pinctada margaritifera* showing a complete penetration of *Oichnus paraboloides*, Al Qweh lagoon; K, L, Bioerosion on the outer and inner surfaces of *Barbatia parva* and *Spondylus marisrubri,* El-Humrawen harbor.

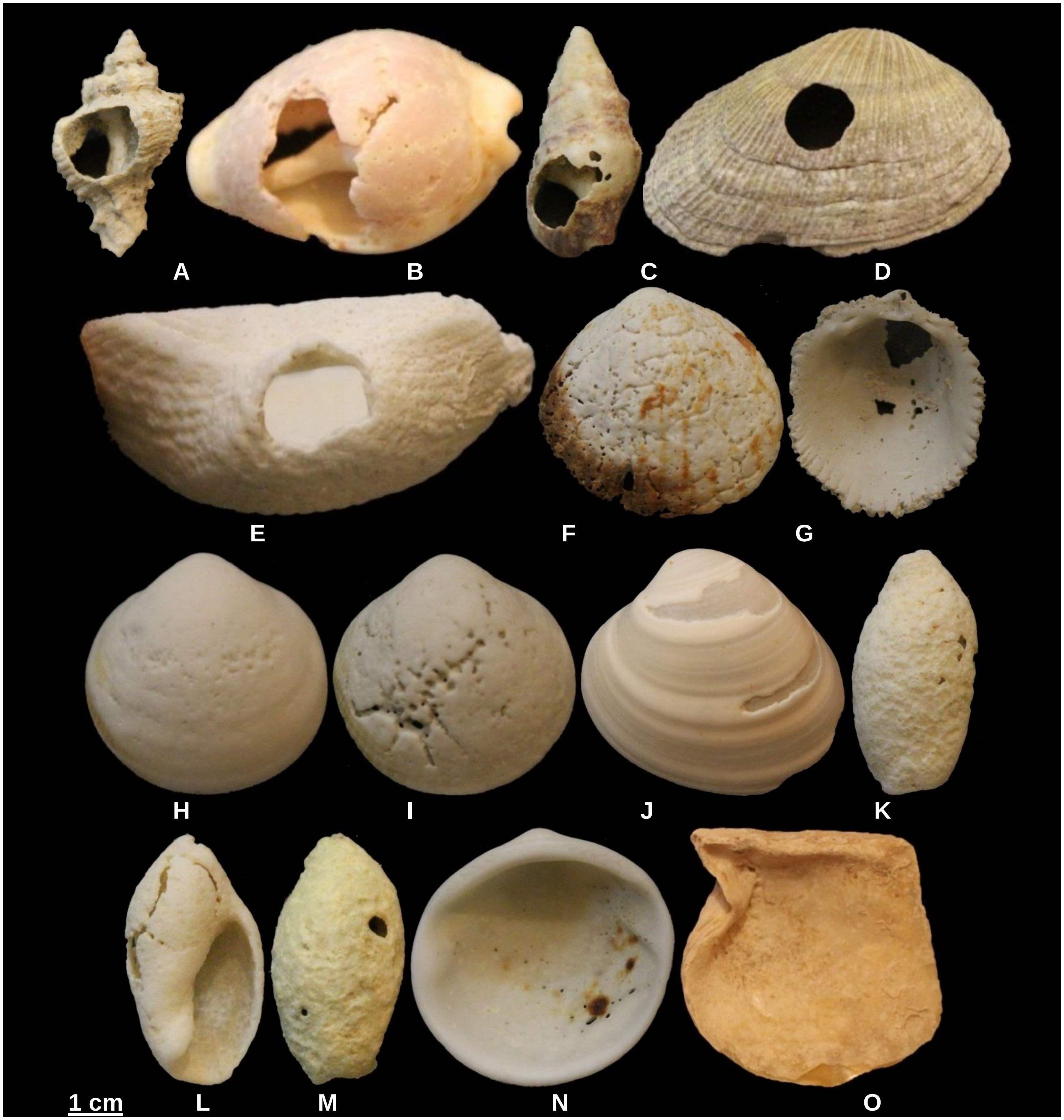

Fig. 4. A-C Fragmentation caused by bird pickings of the gastropods *Hexaplex kuesterianus, Cypraea annulus* and *Cerithium caeruleum* respectively, Al Qweh lagoon; D-F, Fragmentation of the bivalves *Asaphis violascens, Anadara antiquata* and *Acrosterigma lacunosa* respectively, Hurghada. Note, bryozoan colonies encrusted the internal surface of *Acrosterigma lacunosa* (arrows); G-J, loss of surfaces features (radial ribs and growth lines) caused by abrasion of the bivalves *Glycymeris pectunculus, G. livida* and *Marcia flammea,* Makadi bay; K-M, Lack of luster and loss of surfaces features due to abrasion of the outer surface of *Ancilla (Sparella) castanea,* Makadi bay; N, O, Lack of luster appearance due to abrasion from the inner surface of *Glycymeris livida* and *Pinctada margaritifera,* Al Qweh lagoon.

growing as colonies of connected zooids on submerged substrates (Massard and Geimer, 2008; El-Sorogy, 2015). In the studied shells, *Parasmittina* sp and *biflustra* sp encrusted parts of the inner smooth surfaces of dead disarticulated bivalves and gastropods drifted with the upper tide (Fig. 3A and B, Fig. 4F). Rare ones encrusted the outer surfaces. Surfaces of seashells act as hard substrate needed for larval settlement and then ostogenic development. The diameter of the examined bryozoan colonies ranges from a few millimeters to a few centimeters and somewhat covering the complete shell surface.

Bioerosion

Bioerosion is an important process in both modern and ancient marine environments (*e.g.*, Gibert *et al*., 2007; Fang *et al*., 2013). In the present study, borings are present in many specimens ascribed to either predators or endobionts (sponges and gastropods). Shells with galleries of the boring sponge *Cliona* were most common in the hardground samples. Clionid sponges are the most frequent borers in all environments, and environments with hard substrata have the highest diversities of borers (Best and Kidwell, 2000).

The majority of borings were small, rounded and closely spaced to connect chambers. Depth of penetration did not exceed three millimeters and apertures were always less than one millimeter in diameter. These bioerosion traces were identified as *Entobia* Bronn, 1837. It is a product of borings by the siliceous clionid sponges (Bromley and D'Alessandro, 1984). They are strongly developed on external and somewhat internal surfaces of *Spondylus hystrix, Chama reflexa, Acrosterigma assimile* and *Marcia flammea* (Fig. 3C-F).

The second type of bioerosion is represented by small borings, perpendicular to the shell surface, produced by carnivorous gastropods. Predatory gastropods have the ability to drill through the shells of other molluscans and feed on the animal inside. These predators (*e.g.*, muricids and naticids) leave a distinctive beveled hole on their prey (Parsons, 2004).

These bioerosion traces were identified as *Oichnus*, Bromley, 1981 and they were known from the Palaeozoic to Recent. For whole specimens it is recorded the presence of predatory drill holes and identified them as either *Oichnus paraboloides* or *O. simplex*. The hole is circular, with paraboloid shape, 1.5-2.3 mm in diameter on the shells of *Barbatia parva, B. setigera, Diodora funiculate* and *Pinctada margaritifera* (Figs. 3G-J). It was most probably produced by a naticid gastropod. On the other hand, *Oichnus simplex* (Fig.4A, C) consist of smooth, vertical, circular to subcircular holes with axes oriented perpendicular to the host, piercing throughout the shell, diameters range from 2.5-3.1 mm.

Figure 3K, L indicates biological erosion on the outer and inner surfaces of *Barbatia parva* and *Spondylus marisrubri.* These bioerosions may be of muricid gastropods, which typically hunt and drill prey epifaunally (Ziegelmeier, 1954; Carriker, 1981).

Fragmentation

Shell fragments are important components of many modern and fossil marine benthic ecosystems (Zuschin *et al*., 2003). They are very common in modern death assemblages (Tauber, 1942; Hollmann, 1968; Pilkey *et al*., 1969; Zuschin and Hohenegger, 1998; El-Gendy *et al*. 2015). In general, fragmentation is associated with high-energy environments such as beaches and tidal channels (Parsons and Brett, 1991), although Best and Kidwell (2000) observed high levels of fragmentation in all environments, even those with low energy. Fragmentation is potentially derived from a range of both physical and biological processes (Zuschin *et al*., 2003).

Physical agents consider the primary agent determining fragmentation in the study area, where Red Sea waters have high currents and tidal range. Also, fragmentation process may come next to other preceding operations such as abrasion and bioerosion that may reduce the density and thickness of the shells and consequently facilitate breaking. Predators and other organisms are other likely agents of fragmentation in such environment.

Shell holes, caused by bird pickings (Fig. 4A-F) were observed in many specimens (n=35) of the studied shells. Previously, MacArthur and Wilson

(1967) have noted the importance of bird attack in fragmentation processes. Predators (biological factor) are enhanced fragmentation and should take into account in taphonomic studies and depend mainly on shell strength (Zuschin *et al*., 2003).

The recorded gastropods showing fragmentation by bird pickings are *Hexaplex kuesterianus*, *Cypraea annulus* and *Cerithium caeruleum* (Fig. 4A-C) and the bivalve ones are *Asaphis violascens*, *Anadara antiquata* and *Acrosterigma lacunose* (Fig. 4D-F).

Abrasion

Abrasion is another important taphonomic process, being probably associated with shell damages (Kotzian and Simões, 2006). Shell abrasion is often associated with physical transport, but it also can occur when the predator uses its radula and/or shell to abrade the shelled prey (Glaub *et al*., 2007). In the present study, abrasion is seen in the loss of surfaces ornamentation such as growth lines and radial ribs of the following bivalves and gastropods: *Glycymeris pectunculus*, *G. livida*, *Marcia flammea* and *Ancilla (Sparella) castanea* (Fig. 4G-M); by a mottling of the shell surface and a lack of luster on the inner surface (Fig. 4G and O). The processes of abrasion often leave shells with a glassy appearance (Driscoll and Weltin, 1973).

The hard rocky shore area of Al Qweh lagoon exhibits considerably higher levels of abrasion than the other studied sandy shores. Mechanical abrasion results from the movement of the shells on the substrate and due to imbricate over each other's by wave actions. Shells on hard grounds are exposed to current and wave activity for longer periods of time, and therefore, hard ground samples tend to display greater mechanical abrasion.

The loss of color occurs when the outer layers of the shell are either abraded off, or the colors simply fade with time. Color loss is higher on average on the hardground substrates than at sand-bottom sites.

CONCLUSIONS

The coastline of the northern Red Sea coast is rich with intertidal molluscan shells that are affected by several taphonomic processes, such as disarticulation, encrustation, bioerosion, abrasion and fragmentation. The bivalve accumulation is totally dominated by disarticulated valves, except very few which are articulated. Fragmentation is mainly caused mechanically and the biological one is somewhat effectible due to increase energy gradient in the study area. Encrustation was common in molluscan shells by balanoids, polychaete tubes, some ontogenically bivalve shells and bryozoa. Balanoid barnacles represent the most common encrusters, and are probably the most abundant ones in the terms of area occupied and skeletal biomass. Bioerosion traces are predominately of clionid sponges and gastropods. Abrasion is observed in the loss of surfaces ornamentation and loss of shells color. Abrasion increased in rocky shore of Al Qweh lagoon.

ACKNOWLEDGEMENTS

This work was funded by the Deanship of Scientific Research, College of Science Research Center, King Saud University, to whom the authors are greatly thankful.

REFERENCES

ABD EL-WAHAB, M. AND EL-SOROGY, A.S., 2003. Scleractinian corals as pollution indicators, Red Sea coast, Egypt. *N. Jb. Geol. Paläont. Abh*., **11**: 641-655.

ALLEN, J.R.I., 1992. Transport hydrodynamics. In: *Palaeobiology: A synthesis* (eds. D.E.G. Briggs and P.R. Crowther), Blackwell Sci. Publ., pp. 237-230.

ANAN, H.S., 1984. Littoral recent foraminifera from the Quseir–Mars Alam stretch of the Red Sea coast, Egypt. *Rev. Paleobiol*., **3**: 235-242.

BARKATI, S. AND ASIF, M., 1984. Reproductive cycle and sex ratio of the date mussel *Lithophaga nigra* (d'Orbigny). *Pakistan J. Zool*., **16**: 1-7.

BELTAGY, A.I., 1984. Elemental geochemistry of some recent marine sediment from north Red Sea. *Bull. Inst. Ocean. Fish., Egypt*, **10**: 12.

BEST, M.M.R. AND KIDWELL, S.M., 2000. Bivalve taphonomy in tropical mixed siliciclastic-carbonate settings: I. Environmental variation in shell condition. *Paleobiol*ogy, **26**: 80-102.

BOSCH, D.T., DANCE, S.P., MOOLENBEEK, R.G. AND OLIVER, P.G., 1995. *Seashells of Eastern Arabia*. Motivate Publ., pp. 296.

BOUCOT, A.J., BRACE, W. AND DEMAR, R., 1958. Distribution of brachiopod and pelecypod shells by currents. *J. Sediment. Petrol*., **28**: 321-332.

BRETT, C.E., 2003. Taphonomy: Sedimentological implications of fossil preservation. In: *Encyclopedia of sediments and sedimentary rocks* (ed. G.V. Middleton), Springer, Dordrecht, p. 723–729.

BROMLEY, R.G., 1981. Concepts in ichnotaxonomy illustrated by small round holes in shells. *Acta Geol. Hisp*., **16**: 55-64.

BROMLEY, R.G. AND D'ALESSANDRO, A., 1984. The ichnogenus *Entobia* from the Miocene, Pliocene and Pleistocene of southern Italy. *Rev. Ita. Paleontol. Stratig*., **90**: 227-296.

BRONN, H.G., 1837. Lethaea geognostica *oder Abbildungen und Beschreibungen der für die Gebirgs-Formationen bezeichnendsten Versteinerungen*, vol. 1: 481-768. Schweizerbart, Stuttgart.

CARRIKER, M.R., 1981. Shell penetration and feeding by naticacean and muricacean predatory gastropods: a synthesis. *Malacology*, **20**: 403-422.

DRISCOLL, E.G. AND WELTIN, T.P., 1973. Sedimentary parameters as factors in abrasive shell reduction. *Palaeogeogr. Palaeoclimat. Palaeoecol*., **13**: 275-288.

EL-GENDY, A., AL-FARRAJ, S. AND EL-HEDENY, M., 2015. Taphonomic Signatures on Some Intertidal Molluscan Shells from Tarut Bay (Arabian Gulf, Saudi Arabia). *Pakistan J. Zool*., **47**: 125-132.

EL-HEDENY, M., 2005. Taphonomy and paleoecology of the Middle Miocene oysters from Wadi Sudr, Gulf of Suez, Egypt. *Rev. Paléobiol*., **24**: 719-733.

EL-HEDENY, M., 2007a. Encrustation and bioerosion on Middle Miocene bivalve shells and echinoid skeletons: Paleoenvironmental implications. *Rev. Paléobiol*., **26**: 381-389.

EL-HEDENY, M., 2007b. Ichnology of the Upper Cretaceous (Cenomanian - Campanian) sequence of western Sinai, Egypt. *Egypt. J. Paleontol*., **7**: 121-132.

EL-SOROGY, A.S., 1997a. Progressive diagenetic sequence of Pleistocene coral reefs in the area between Quseir and Marsa Alam, Red Sea coast, Egypt. *Egypt. J. Geol*., **41**: 519-540.

EL-SOROGY, A.S., 1997b. Pleistocene coral reefs of southern Sinai, Egypt: Fossil record, facies analysis and diagenetic alterations. *M.E.R.C., Earth Sci. Ser*., **11**: 17-36.

EL-SOROGY A.S., 2008. Contributions to the Pleistocene coral reefs of the Red Sea coast, Egypt. *Arab. Gulf J. Sci. Res*., **26**: 63-85.

EL-SOROGY, A.S., 2015. Bryozoan nodules as a frame-builder of bryzoan microreef, Middle Miocene sediments, *Egypt. J. Earth Sci*., **26**: 251-258.

EL-SOROGY, A.S., EL KAMMAR, A., ZIKO, A., ALY, M. AND NOUR, H., 2013a. Gastropod shells as pollution indicators, Red Sea coast, Egypt. *J. Afr. Earth Sci*., **87**: 93–99.

EL-SOROGY, A.S., NOUR, H., ESSA, E. AND TAWFIK, M., 2013b. Quaternary coral reefs of the Red Sea coast, Egypt: diagenetic sequence, isotopes and trace metals contamination. *Arab. J. Geosci*., **6**: 4981-4991.

EL-SOROGY, A.S., ABDELWAHAB, M. AND NOUR, H.E., 2012. Heavy metals contamination of the Quaternary coral reefs, Red Sea coast, Egypt. *Environ. Earth Sci*., **67**: 777-785.

EL-SOROGY, A.S., ABDEL-WAHAB, M., ZIKO, A. AND SHEHATA, W., 2015. Impact of some trace metals on bryozoan occurrences, Red Sea coast, Egypt. *Indian J. Geomar. Sci*. (Accepted).

EL-SOROGY, A. S., ZIKO, A., SABER, N. AND NOUR, H.E., 2003. The most common rocky shore invertebrate dwellers of the Red Sea coast. *Egypt. J. Paleontol*., **3**: 271-284.

FANG, J.K.H., MELLO-ATHAYDE, M.A., SCHÖNBERG, C.H.L., HOEGH-GULDBERG, O. AND DOVE, S., 2013. Sponge biomass and bioerosion rates increase under ocean warming and acidification. *Global Change Biol*., **19**: 3581-3591.

GIBERT, D.E., DOMÈNECH, R. AND MARTINELL, J., 2007. Bioerosion in shell beds from the Pliocene Roussillon Basin, France: implications for the (macro) bioerosion Ichnofacies model. *Acta Palaeontol. Pol*., **52**: 783-798.

GLAUB, I., GOLUBIC, S., GEKTIDIS, M., RADTKE, G. AND VOGEL, K., 2007. Microborings and microbial endoliths: geological implications. In: *Trace fossils: concepts, problems, prospects* (ed. W. Miller). Elsevier, Amsterdam, p. 368-381.

HOLLMANN, R., 1968. Zur Morphologie rezenter Molluskenbruchschille. *Paläontol. Z.*, **42**: 217-235.

KIDWELL, S.M., 2013. Time-averaging and fidelity of modern death assemblages: building a taphonomic foundation for conservation palaeobiology. *Palaeontology*, **56**: 487-522.

KOTZIAN, C. B. AND SIMÕES, M. G., 2006. Taphonomy of recent freshwater molluscan death assemblages, Touro Passo Stream, Southern Brazil. *Rev. Bras. Paleontol*., **9**: 243-260

MACARTHUR, R.H. AND WILSON, E.O., 1967. *The theory of island biogeography*. Princeton University Press. Princeton, New Jersey, USA, pp. 224.

MANSOUR, A.M. AND NAWAR, A.H., 2000. Geochemistry of coastal marine sediments and their contaminant metals, Red Sea coast, Egypt: A legacy for the future and a tracer to modern sediment dynamics. *Sedimentol. Egypt*, **8**: 19-34.

MANSOUR, A.M., MOHAMED, A.W., OSMAN, M.R., NASER EL DIEN, A. AND TAHOEN, M.A., 2006. Sedimentological and geochemical studies on some island sediments of the Red Sea coast, Egypt. *Egypt. J. aquat. Res*., **32**: 105-130.

MASSARD, J. A. AND GEIMER, G., 2008. Global diversity of bryozoans (Bryozoa or Ectoprocta) in freshwater: An update. *Bull. Soc. Nat. Luxemb*., **109**: 139-148.

MCKINNEY, F.K., 1996. Encrusting organisms on co-occurring disarticulated valves of two marine bivalves: comparison of living assemblages and skeletal residues. *Paleobiology*, **22**: 543-567.

MELDAHL, K.H. AND FLESSA, K.W., 1990. Taphonomic pathways and comparative biofacies and taphofacies in a recent and intertidal/ shallow shelf environment. *Lethaia*, **23**: 43-60.

MOORE, R.C., 1960. *Treatise on invertebrate paleontology*. Part J. (Gastropoda). Geological Society of America, University of Kansas, Press, pp. 350.

MOORE, R.C., 1969. *Treatise on invertebrate paleontology*. Part N. (Bivalvia). Geological Society of America, University of Kansas Press, pp. 480.

NIELSEN, J.K., 2004. Taphonomy in the light of intrinsic shell properties and life habits: marine bivalves from the Eemian of northern Russia. *Paläontol. Z.*, **78**: 53-72.

NOUR, H., ABDELWAHAB, M. AND EL-SOROGY, A.S., 2006. *Heavy metals distribution in some mangrove sediments of the southern Red Sea coast*, Egypt. 8th Intern. Conf., Geo. Arab world. Cairo Univ., 25-32.

NOUR, H.E. AND EL-NAGGAR, W., 2007. Heavy metals distribution in moluscan shells in northern Safagy Bay and Red Sea coast, Egypt: Atoll for environ. monitor. *M.E.R.C., Ain Shams Univ., Earth Sci. Ser*., **21**: 99-114.

OSTROVSKY, A.N., CÁCERES-CHAMIZO, J.P., VÁVRA N. AND BERNING, B., 2011. Bryozoa of the Red Sea: history and current state of research. *Annls. Bryozool.*, **3**: 67-98.

PARSONS, K.M., 2004. *Taphonomy as an Indicator of Environment: Smuggler 's Cove*, St. Croix, U.S.V.I. NOAA Miami Regional Library, pp. 135-143.

PARSONS, K.M. AND BRETT, C.E., 1991. Taphonomic processes and biases in modern marine environments: An actualistic perspective fossil assemblage preservation. In: *The process of fossilization* (ed. S.K. Donovan), Belhaven Press, London, pp. 22-65.

PERRY, C.T., 2000. Factors controlling sediment preservation on a North Jamaican fringing reef: A process-based approach to microfacies analysis. *J. Sediment. Res.*, **70**: 633-648.

PILKEY, O.H., BLACKWELDER, B.W., DOYLE, L.J., ESTES, E. AND TERLECKY, P.M., 1969. Aspects of carbonate sedimentation on the Atlantic continental shelf off the Southern United States. *J. Sediment. Petrol*., **39**: 744-768.

SANTOS, A. AND MAYORAL, E., 2008. Bioerosion versus colonisation on Bivalvia: A case study from the Upper Miocene of Cacela (southeast Portugal). *Geobios*, **4**: 43-59.

SEELING, J. AND BENGTSON, P., 1999. Cenomanian oysters from the Sergipe Basin, north-eastern Brazil. *Creta. Res*., **20**: 747-765.

SHEHATA, W.M., 2011. *Recent bryozoa of the Red Sea coast, Egypt*. Ph.D. thesis, Geology Department, Faculty of Science, Zagazig University, Egypt, pp. 245.

TAUBER, A.F., 1942. Postmortale Veränderungen an Molluskenschalen und ihre Auswertbarkeit fűr die Erforschung vorzeitlicher Lebensräume. *Palaeobiology*, **7**: 448-495.

TAYLOR, P.D. AND WILSON, M.A., 2003. Palaeoecology and evolution of marine hard substrate communities. *Earth Sci. Rev*., **62**: 1-103.

VIANA, M.S.S. AND RICHTER, M., 1998. Preservation of biomineralized tissues of fishes from the Santana Formation (Lower Cretaceous of the Araripe Basin, NE-Brazil). Estudos tecnológicos. Acta *Geol. Lillo., UNISINOS, São Leopoldo*, **21**: 91-100.

ZIEGELMEIER, E., 1954. Beobachtungen über den Nahrungserwerb bei der Naticide *Lunatia nitida* Donovan (Gastropoda Prosobranchia). *Helgol. Wiss. Meeres*, **5**: 1-33.

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

ZIKO, A., EL-SAFORI, Y., EL-SOROGY, A.S., ABDELWAHAB, M., EL-DERA, N. AND SHEHATA, W., 2012. Bryozoa from northern Red Sea, Egypt: 1 Crisia (Cyclostomata). *Hist. Biol.*, **24**: 113-119.

ZUSCHIN, M. AND HOHENEGGER, J., 1998. Subtropical coral-reef associated sedimentary facies characterized by molluscs (Northern Bay of Safaga, Red Sea, Egypt). *Facies*, **38**: 229-254.

ZUSCHIN, M., STACHOWITSCH, M. AND STANTON, R.J., 2003. Patterns and processes of shell fragmentation in modern and ancient marine environments. *Earth Sci. Rev*., **63**: 33-82

(Received 9 April 2015, revised 11 May 2015)