

Bollettino della Società Paleontologica Italiana	34 (2), 1995	ISSN 0375-7633	139-145	–	Modena, Novembre 1995
--	--------------	----------------	---------	---	-----------------------

Biostratinomy of Upper Cenomanian oyster storm shell beds from the Northeastern Desert of Egypt

Ahmed S. KASSAB
Geology Department
Assiut University, Egypt

KEY WORDS – Biostratinomy, Dynamic stratigraphy, Storm events, Upper Cenomanian, Oyster shell beds, Eastern Desert, Egypt.

ABSTRACT – Exogyrene oysters abundantly occur in the Upper Cenomanian Galala Formation exposed at the confluence of Wadi Qena and Wadi Abu Had area, Northeastern Desert, Egypt. They build sharp-based shell beds of thin stratigraphic intervals. Oysters of these shell beds belong to *Ilymatogyra africana* (Lamarck). They show a wide tolerance to face fluctuations in substratum. Two associations of *Ilymatogyra* have been distinguished in the studied shell beds: the cup-shaped reclining, which secondarily adapted to life on soft substratum, and the encrusting *Ilymatogyra*. Bed-by-bed biostratinomic analysis has revealed the nearshore shallow marine origin of such shell beds confirming their accumulation during storm events.

RIASSUNTO – [Biostratinomia dei livelli tempestici ad ostreidi del Cenomaniano superiore del Deserto Egiziano nord-occidentale] – Ostreidi exogiriformi sono presenti in abbondanza nella Formazione Galala del Cenomaniano superiore affiorante nella zona di confluenza del Wadi Qena e Wadi Abu Had, nel Deserto Egiziano nord-occidentale. Essi costituiscono dei livelli conchigliari molto netti riferibili ad intervalli stratigrafici molto limitati. Gli ostreidi, che appartengono alla specie *Ilymatogyra africana* (Lamarck), mostrano un'ampia tolleranza alle variazioni del substrato. Nei livelli conchigliari è stato possibile distinguere due associazioni ad *Ilymatogyra*: quella con individui a forma di coppa reclinata che si adattarono successivamente a vivere su di un substrato molle, e le forme incrostanti. L'analisi biostratinomica effettuata livello per livello ha rivelato l'origine di questi straterelli conchigliari, confermandone il loro accumulo durante eventi di tempesta in vicinanza della riva ed in acque marine basse.

INTRODUCTION

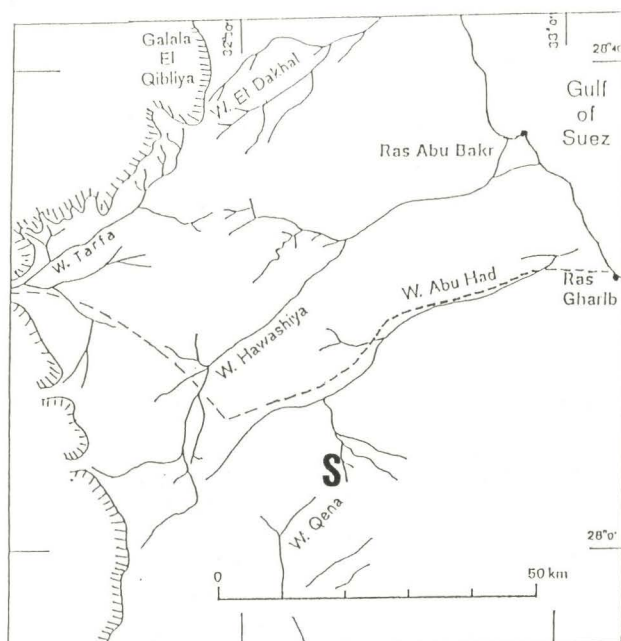
Shallow marine sequences are common throughout the Upper Cretaceous covering large areas of the Egyptian Eastern Desert. Descriptive stratigraphy of the Upper Cenomanian of these sequences has long attracted the attention of many workers (e.g. Hume, 1911; El-Nakkady, 1958; Said, 1962, 1971; Abdallah & El Adindani, 1963; Awad & Abdallah, 1966; Mazhar *et al.*, 1979; Kassab, 1982, 1985, 1991; Mohamed, 1983; Hermina *et al.*, 1989; Luger & Gröschke, 1989; Klitzsch *et al.*, 1990). In contrast, the dynamic processes that controlled deposition of these sequences have received little attention (e.g. Klitzsch, 1986; Luger & Schrank, 1987).

Dynamic stratigraphy is a tool for reconstruction of processes in shallow marine basins (Aigner, 1985) allowing, for example, a better understanding of storm processes and their depositional products. The effects of storms in nearshore environments have been summarized by Aigner (1985) to involve coastal erosion by wave attack, raised water levels (wind set up), and landward sediment transport by on-shore wind drift currents. The importance of storms, as episodic events, in stratigraphy has been emphasized by many authors (e.g. Raif, 1982; Einsele & Seilacher, 1982; Aigner, 1982, 1984, 1985).

The purpose of the present paper is to analyze biostratinomically a number of oyster shell beds accumulated in the Egyptian Northeastern Desert during the Late Cenomanian time and to provide stratigraphic evidence for their storm origin. This study is based on four successional oyster shell beds, composed mainly of *Ilymatogyra africana* (Lamarck), from the basal succession of the Galala Formation, exposed at the confluence of Wadi Qena and Wadi Abu Had area, Northeastern Desert of Egypt (Text-fig. 1).

MATERIAL AND METHODS

Surface sediments and associated fossils have been surveyed throughout face exposures as well as bedding planes. The cord quadrate and stretched line methods (Ager, 1963) were used to study bedding planes and face exposures respectively. The preservational state of the oysters and their side view orientation (convex or concave downward, vertical or oblique) were noted for each horizon. Directions of beak-commissure planes of the oysters have been measured. Histograms and rose diagrams were then constructed for the collected data.



Text-fig. 1 - Location map. (--) = El Sheikh Fadl-Ras Gharib Road; (S) = measured section.

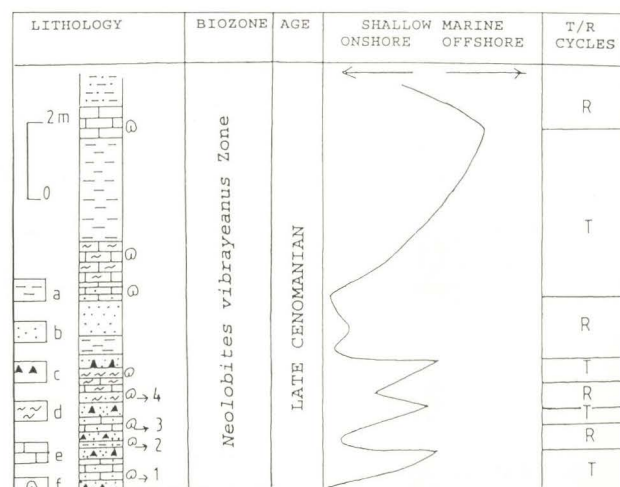
STRATIGRAPHY AND DEPOSITIONAL SETTING

The term Galala Formation has been introduced, in Egyptian stratigraphy, by Abdallah & El Aden-dani (1963) to designate the Upper Cenomanian marl-shale succession with calcareous sandstone and limestone interbeds exposed at the Galala El Bahariya massif, Northeastern Desert.

The Galala Formation of the study area is composed of alternating siliciclastic and carbonate sediments of generally fine-grained nature (Text-fig. 2). It unconformably overlies the non-marine sandstones of the Wadi Qena Formation, pointing to the first Late Cenomanian transgression in the area, and underlies the Umm Omeiyid Formation.

Shell beds with sharp undulating base, bioturbation, fining upward microsequences, flaser and lenticular bedding, graded bedding, desiccation cracks, and discontinuity surfaces (both firm and hardgrounds) are the characteristic features of the studied basal succession of the Galala Formation. Apart from oysters, venerid, trigonid, lithophagid and pectinid bivalves, turritellid gastropods, and ichnofossils are common throughout the sequence. The *Thalassinoides*, *Rhizocorallium* and *Ophiomorpha* are the most abundant traces. Borings on some oyster valves and other benthic faunas are also recognized.

The oysters, together with other faunal elements of the *Neolobites vibrayeanus* ammonite Zone



Text-fig. 2 - Stratigraphy, depositional setting and selective sea-level changes of the measured section.

(R) = Regression; (T) = Transgression; (a) = Shale; (b) = Sandstone; (c) = Glauconite; (d) = Marl; (e) = Limestone; (f) = Oyster beds; (1-4) = the storm shell beds studied.

(Kassab, 1991a), assign the measured succession to early Late Cenomanian age.

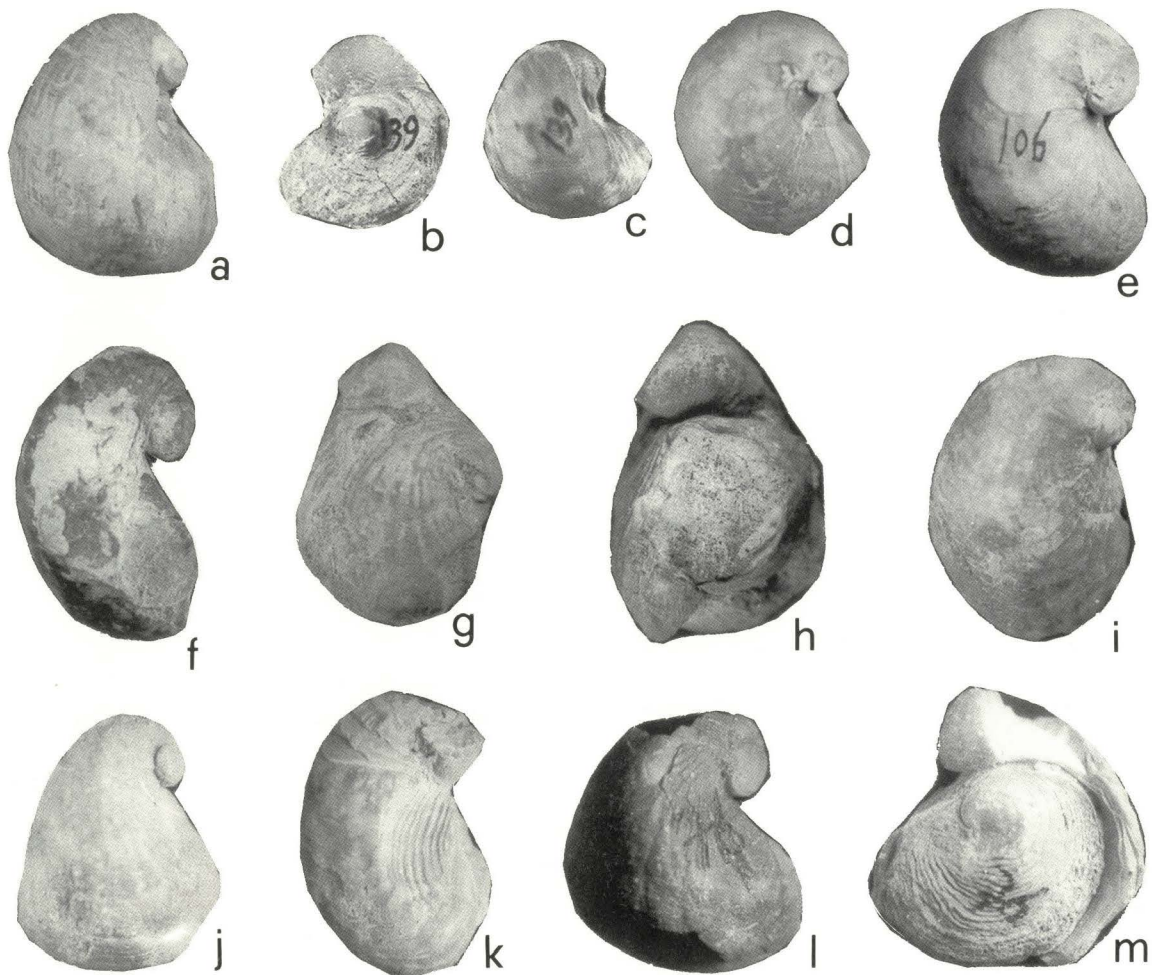
Sedimentologic aspects, trace fossil composition, and macro and microfaunal content point to deposition in shallow, fully marine environments of variable distances from the shore reflecting fluctuations of the relative sea-level (Text-fig. 2) resulting in transgressive/regressive cycles. Cyclicity has been recognized by alternation of shell beds with horizons free from shells.

High energy events appear to have prevailed during deposition of some *Ilymatogyra* shell beds. Tidal influence may be observed by development of flaser, lenticular, and interlayered bedding at certain levels. At others, prevailing of low energy conditions is inferred by a benthic fauna of low diversity.

MODE OF LIFE OF *ILYMATOGYRA*

Ilymatogyra africana (Lamarck) is a common exogyrine oyster which inhabited Tethyan near shore water displaying a wide variation in individual morphology within its populations (Kassab, 1991b). It is probably a dimorphic species. Such dimorphism is reflected as differences in shell convexity, curvature and ornament (Text-fig. 3). Sexual dimorphism is one of several factors controlling the intraspecific variation in oyster populations (Kassab & Zakhira, 1994).

As shown in Text-fig. 3, most shells of the studied *Ilymatogyra africana* (Lamarck), are generally



Text-fig. 3 - The main morphologic features of the *Ilymatogyra africana* (Lamarck) showing highly convex left valves, flat to slightly convex right valves, xenomorphism, attachment area, and variation in shell convexity, curvature and ornament. All specimens are $\times 1.0$ except for b, c, d $\times 0.9$, and k, l, m $\times 1.4$.

characterized by: (1) cup-shaped, highly convex, twisted left valve reflecting a helicospiral growth pattern, (2) small attachment area, (3) flat to slightly convex right valve, and (4) a narrow umbonal area.

The high convexity of the left valve topped with a flat right one and the twisted helicoidal beak of most shells, as well as the small rounded attachment area, document adaptation to life on soft substratum. Absence of juveniles and very small individuals are probably due either to high initial growth rate and low juvenile mortality or to biogenic destructions and winnowing by currents.

As a rule, living and fossil oysters have a planktic larval stage which becomes cemented to a firm substrate with its convex left valve after the metamorphosis (Stenzel, 1971).

It seems likely that *Ilymatogyra africana* lived with the convex left valve downward. This oyster

belongs to the cup-shaped recliners of Seilacher (1984) which secondarily adapted to life on soft substrates. It is also similar to the cup-shaped reclining *Nanogyra* described by Fürsich & Oschmann (1986a, b). This oyster may have remained as an encruster throughout its life growing into hard substrates (such as pebbles, hardgrounds, shells, etc.) were available. This means that we deal with reclining and encrusting associations of *Ilymatogyra* in the studied shell beds. Such observation points to the wide tolerance of *Ilymatogyra africana* to face fluctuations in substratum.

BIOSTRATINOMY

The analyzed shell beds are mainly composed of calcitic shells of exogyrine oysters. They attain a thickness varying between 15 and 40 cm. Their

lower surfaces are generally bioturbated, but sharp and undulating. The shell beds yield well-preserved articulated and disarticulated oyster valves of which the left valves constitute the main bulk of the samples. Other bivalves, mainly the epifaunal pectinids and the infaunal venerids, as well as trace fossils are also abundant. Bioturbation markedly increases towards the top of the sequence. This points to the rapid deposition of these shell beds and downward extension of bioturbation from a level where rate of sedimentation was suitable for colonization by benthic faunas. Shells are randomly oriented in the studied beds, probably pointing to rapid dumping by storm flows.

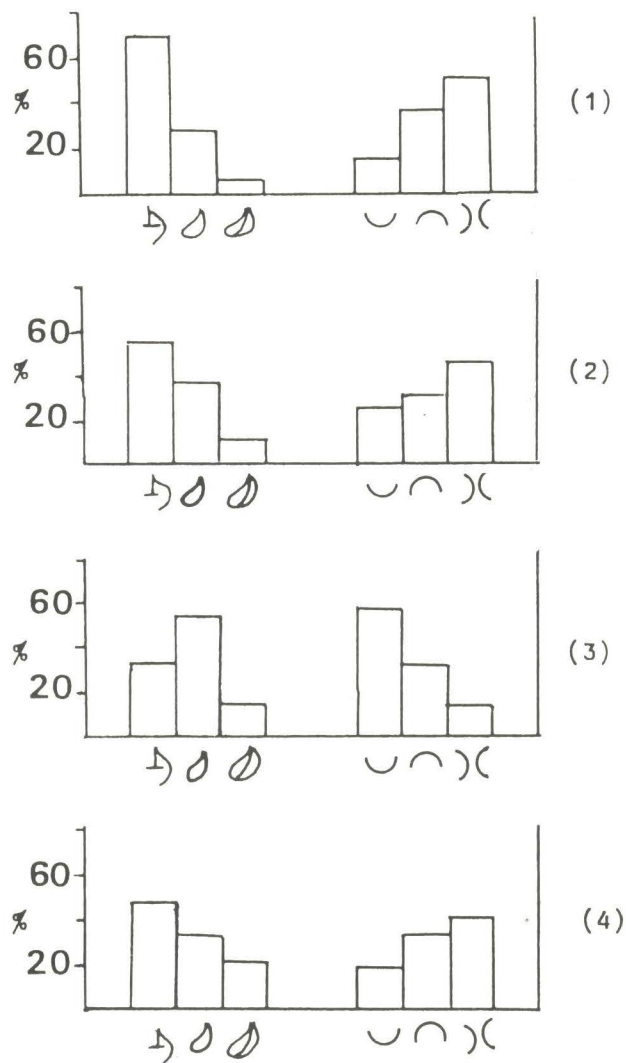
Text-fig. 4 expresses the great similarity in preservational state of shells in horizons 1, 2, and 4 as opposed to horizon 3. It shows also that shells having oblique or vertical side orientation represent the largest fraction (40-50%) in all horizons except horizon 3. Convex-down oriented shells dominate at horizon 3 contributing 56.1% of the total skeletal elements. This may point to decrease in the intensity of storms at this level.

Measurements of the beak-commissure directions (dorsoventral-axis) of the concerned oysters in the four shell beds are plotted as rose diagrams (Text-fig. 5). As shown in this figure, plotting of orientational data is polymodal exhibiting no preferred plan-view orientation. Such random pattern is also documented by the side-view orientation of the valves.

Size of the attachment area forms less than 15% of the individual shell height (Text-fig. 3). The small, rounded attachment area of some shells reflects cementation of mature individuals to small rounded objects to facilitate fixation on a soft substratum at certain level.

Interesting is that some individuals are attached to pieces of shell material suggesting that the oysters colonized a substratum rich in shell fragments. Such substratum is probably formed by subsequent exhumation, *in situ* reworking, disarticulation, and fragmentation of shells of pre-existing oyster populations during high energy conditions. This is evidenced by erosional base of shell beds, occurrence of borings on some shells, and attachment of some individuals to left valves of other shells, i.e. the oyster shells became exhumed and overturned. Other individuals are attached directly to bedding surface. In this case oysters are planispirally grown showing less convexity.

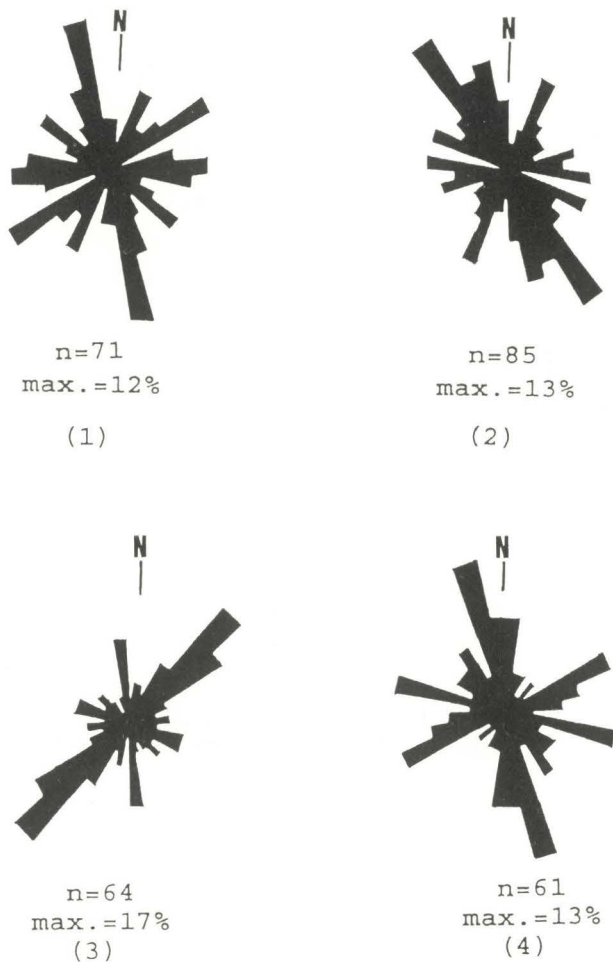
No correlation is recognized between size of the attachment area and shell size. However, a positive relationship between size of the attachment area and degree of convexity of a shell can be observed.



Text-fig. 4 - Histograms of the preservational state and side-view orientation of *Ilymatogyra* in the four beds studied. (↵) = broken left valves; (♂) = complete left valves; (∪) = convex-down; (∩) = concave-down; (⌋⌋) = oblique; (⌢) = articulated shells.

STORM ORIGIN OF THE *ILYMATOGYRA* SHELL BEDS

As already described in the text, flaser and lenticular bedding, graded bedding, erosive base, amalgamation and random orientation of oyster shells, and boring on some benthic faunas are the most characteristic features of the present shell beds. Such biostratinomic and sedimentological features are similar to those reported in the literature to be common in modern (e.g. Reineck & Singh, 1972; Kumar & Sanders, 1976; Nelson, 1982; Aigner, 1985) and ancient (Goldring & Bridges, 1973; Aigner, 1979, 1982, 1985; Kelling & Mullin, 1975; Kreisa & Bambach, 1982; Fürsich & Oschmann, 1986b) storm deposits.



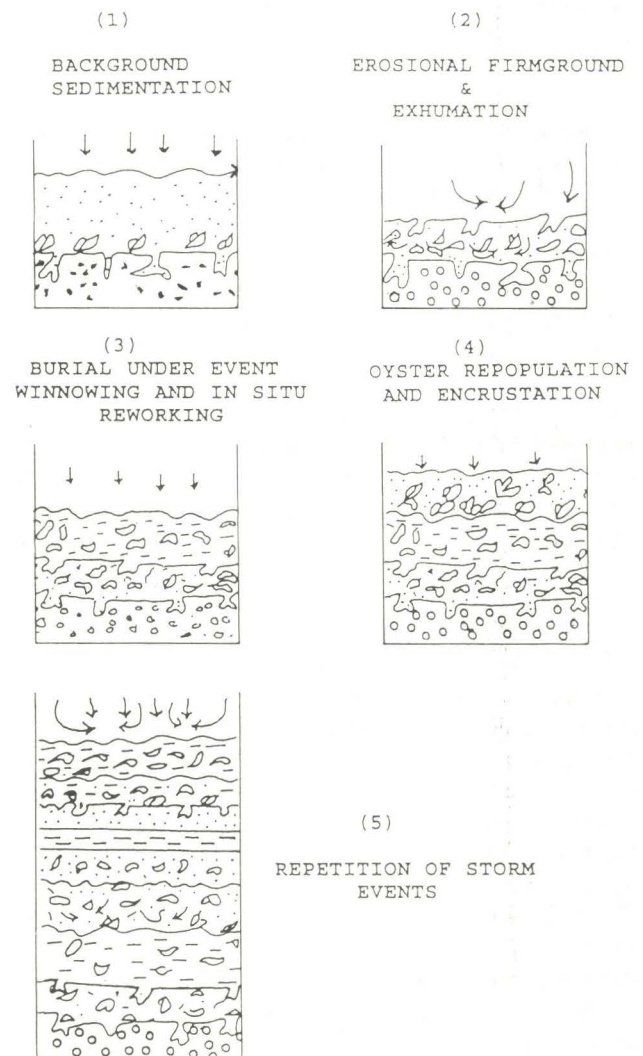
Text-fig. 5 - Rose diagrams of plain-view orientation of *Ilymatogyra* in the four shell beds (1-4) studied.

The Upper Cenomanian *Ilymatogyra* shell beds are very similar to the storm shell beds of *Nanogyra virgula* described by Fürsich & Oschmann (1986b) from the Jurassic of France. Regardless of the age, it seems likely that the two types of oyster shell beds were controlled by similar dynamic processes.

The high percentage of complete shells, absence of highly fragmented shells, and low percentage of articulated ones strongly support the parautochthonous origin of the shell beds. Such beds were probably concentrated by *in situ* reworking and winnowing effects of episodic storms. Differences in preservation and orientation pattern in horizon 3 point probably to changes in intensity of storms, for example high percentage of convex-down oriented shells in this horizon indicates decrease in intensity of storms at this level.

The idealized sequence of events (Text-fig. 6) suggested here to have led to development of the *Ilymatogyra* storm shell beds can be summarized as

follows: Background sedimentation of the basal part of the Galala Formation took place in a near shore environment covering a pre-existing firm-ground, characterized by crustacean burrows (e.g. *Thalassinoides* and *Ophiomorpha*), on the top of the non-marine Nubia Sandstone during the first Late Cenomanian transgression in the study area. It seems likely that the soft substratum formed on the sea floor, during the background sedimentation, was colonized by the epibenthic oysters and populated with infaunal bivalves (the venerids and trigonids). After formation and before lithification, the unconsolidated sediments has been exhumed and eroded during a storm. During this event, the loose sediments were removed and winnowed away, while oyster shells were concentrated as packstones or grainstones and exposed on the sea floor to form a



Text-fig. 6 - Idealized sequence of events represented by *Ilymatogyra* storm shell beds.

hard substrate. The resulted hard-ground has been encrusted by oysters and pectinid bivalves and bored by lithophagid bivalves and serpulids. In some cases, oyster shells have been winnowed free of sediments, overturned and attacked by borers.

Erosion and exhumation by episodic storm events have also led to winnowing, disarticulation, *in situ* reworking, and redeposition of oyster shells. This process may also led to formation of a substratum rich in shell pieces.

Burial under episodic storm events has also led to concentration of the oysters, at certain levels, into shell banks. Post-event colonization of these oysters seems also likely. Such colonization is evidenced by bioturbation and sharp-base of most shell beds and the occurrence of shells having their left valves attached to the left valves of other oyster individuals or to other epibenthic bivalves.

Repopulation of the sea floor by oysters and other bivalves and repetition of such storm events have led to cyclicity in the succession, reflected by alternation of oyster shell horizons with layers free of oysters.

DISCUSSION AND CONCLUSIONS

Ilymatogyra africana (Lamarck) is one of the stratigraphically important Late Cenomanian oysters, forming conspicuous shell beds distributed widely in Egypt.

As documented by various observations and measurements carried out in four successional horizons in a single outcrop. The species shows a wide tolerance to face fluctuations in substratum. This species can be interpreted as a cup-shaped reclining oyster which secondarily adapted to life on soft substratum. This species may remain an encruster throughout life as evidenced by its encrustation of hardgrounds and/or other shells as recorded at certain horizons.

Biostratigraphic analysis of the studied oyster shell beds has revealed that: 1) All oyster individuals are mature, well preserved and having calcitic shells. Most of these shells are disarticulated including complete and broken left valves. Highly fragmented shells are generally lacking. Separated right valves as well as articulated valves are also present. 2) There is no preferred orientation of oysters. Plotting of orientation-data shows a close similarity between three of four horizons, whereas the fourth one exhibits quite different conditions. This is thought to reflect changes in intensity of storms. 3) Left valves are highly convex and cup-shaped having a helicospirally twisted beak and narrow umbonal region. They are topped with nearly flat right valves

having a low planispiral beak. This feature is probably an adaptation to life on soft substratum. 4) Most individuals possess a small, rounded attachment area, whereas others have a relatively large elongated one, which shows that these oysters were cemented to shell pieces. No relation has been observed between size of attachment area and shell height. However, a reverse relationship has been noted between the attachment area and the degree of convexity of a shell.

Occurrence of bivalve shells resting with their concave side downward is a familiar example of the mechanical arrangement of such fossils (Ager, 1963). The random orientation of the studied oysters with a considerable number of complete left valves and few articulated shells, and mixed convex and concave side orientation and uneven distribution in bedding plane-view may be explained by *in situ* reworking, and rapid winnowing by storm currents and immediate burial.

Sharp-based shell beds, fining-up microsequences and grading in some layers, bioturbation, and colonization of burrowed (crustacea and venerid and trigonid bivalves) and bored (lithophagid bivalves and serpulids) discontinuity surfaces by oysters and pectinid bivalves, strongly support the storm origin of the studied succession. The sharp undulating base of the shell beds points to erosion prior to sedimentation of overlying layers.

A combination of wave and wind effects on the basin floor is probably the physical process responsible for this example of storm shell beds.

The transgressive/regressive episodes recognized within the studied sequence are probably the result of a combined effect of changes in sea-level and syndimentary tectonism.

In conclusion, the present study provides the evidence for an ancient storm deposition during the Late Cenomanian time in the study area, and underlines the role of episodic storm events in formation of shell beds.

ACKNOWLEDGEMENTS

The author is greatly indebted to Prof. Dr. E. Philobos (Assiut University) for critically reading the manuscript, and to the Editorial Committee of the *Bollettino della Società Paleontologica Italiana* for providing many helpful comments.

REFERENCES

- ABDALLAH, A. & EL-ADENDANI, A., 1963, Stratigraphy of Upper Paleozoic rocks, Western side of the Gulf of Suez: *Geol. Surv. Egypt*, 25: 1-18.
- AGER, D.V., 1963, Principles of palaeoecology. McGraw-Hill Book Comp. Inc., New York, 347 pp.

- AIGNER, T., 1979, Schill-Tempestite im Oberen Muschelkalk (Trias, SW-Deutschland): N. Jb. Geol. Palaont., Abh., 157: 326-343.
- , 1982, Event-stratification in Nummulite accumulations and in shell beds from the Eocene of Egypt. In Einsele, G. & Seilacher, A. (eds.), Cyclic and event stratification: 248-262, Springer Verlag.
- , 1984, Dynamic stratigraphy of epicontinental carbonates, Upper Muschelkalk (M. Triassic), South-German Basin: N. Jb. Geol. Palaont., Abh. 169: 127-159.
- , 1985, Storm Depositional Systems: Dynamic stratigraphy in Modern and Ancient shallow marine sequences. Lecture notes in Earth Sciences, vol. 3: 1-174.
- AWAD, G. & ABDALLAH, A., 1966, Upper Cretaceous in Southern Galala, Eastern Desert with emphasis on neighbouring areas: Egypt. J. Geol., 10: 125-144.
- EINSELE, G. & SEILACHER, A., 1982 (eds.), Cyclic and event stratification, Springer Verlag, 536 pp.
- EL NAKKADY, S., 1958, Stratigraphical and petroleum geology of Egypt: Assiut Univ. Press, Assiut, ser. 1, 215 pp.
- FÜRSICH, F. & OSCHMANN, W., 1986a, Autecology of the Upper Jurassic *Nanogyra virgula*: Palaontologische Zeitschrift, 60: 65-74.
- , & —, 1986b, Storm shells beds of *Nanogyra virgula* in the Upper Jurassic of France: N. Jb. Geol. Palaont., Abh. 172: 141-161.
- GOLDRING, R. & BRIDGES, P., 1973, Sublittoral sheet sandstones: J. Sediment. Petrol., 43: 736-747.
- HERMINA, M., KLITZSCH, E. & LOST, F., 1989 (eds.), Stratigraphic lexicon and explanatory notes to the geological map of Egypt. Conoco Inc. & E.G. P.C. Cairo, 236 pp.
- HUME, W., 1911, The effects of secular oscillation in Egypt during the Cretaceous and Eocene periods: Quart. J. Geol. Soc. London, 67: 118-148.
- KASSAB, A.S., 1982, Stratigraphical and paleontological studies on the Upper Cretaceous rocks of northern Wadi Wena, Eastern Desert. M. Sc. Thesis, Fac. Sci., Assiut Univ., 243 pp.
- , 1985, Palaeontological and stratigraphical studies of Cretaceous sections in Wadi Tarfa and Wadi Qena, Eastern Desert, Egypt. Ph.D. Thesis, Fac. Sci., Assiut Univ., 221 pp.
- , 1991a, Cenomanian-Coniacian Biostratigraphy of the northern Eastern Desert of Egypt, based on ammonites: Newsl. Stratigr., 25: 25-35.
- , 1991b, Statistical analysis of a Cretaceous oyster from Egypt: N. Jb. Geol. Paläont. Abh., 182 (2): 239-254.
- , & ZAKHERA, M.S., 1994, Sexual dimorphism in the Late Cretaceous oyster *Exogyra overwegi* Von Buch of the Egyptian Western Desert: N. Jb. Geol. Paläont., Abh. 193 (3): 383-399.
- KELLING, G. & MULLIN, P., 1975, Graded limestones and limestone-quartzite couplets: possible ancient storm deposits from the Moroccan Carboniferous: Sediment. Geol., 13: 161-190.
- KLITZSCH, E., 1986, Plate tectonics and cratonal geology in Northeast Africa (Egypt; Sudan): Geol. Rundsch., 75: 755-768.
- , GROSCHKE, M. & HERMAN-DEGEN, W., 1990, Paleozoic and Pre-Campanian Cretaceous strata in Wadi Qena. In Said, R. (ed.), The Geology of Egypt: 321-327, Balkema, Rotterdam.
- KREISA, R.D. & BAMBACH, R.K., 1982, The role of storm processes in generating shell beds in Paleozoic shelf environments. In Einsele, G. & Seilacher, A. (eds.), Cyclic and event stratification: 200-207, Springer Verlag.
- KUMAR, N. & SANDERS, J. E., 1976, Characteristics of shoreface storm deposits: modern and ancient examples: J. Sediment. Petrol., 46: 145-162.
- LUGER, P. & GROSCHKE, M., 1989, Late Cretaceous ammonites from the Wadi Qena area in the Egyptian Eastern Desert: Palaeontology, 32: 355-407.
- , & SCHRANK, E., 1987, Mesozoic and Paleogene transgressions in middle and southern Egypt: summary of palaeontological evidence. In Matheis, G. & Schandelmeyer, H. (eds.), Current research in African Earth Sciences: 199-202, Balkema, Rotterdam.
- MAZHAR, A., ENNAY, N. & ABDEL KADER, Y., 1979, Contributions to the Cretaceous-Early Tertiary stratigraphy of El Galala El Qibliya plateau: Ann. Geol. Surv. Egypt, 9: 377-787.
- MOHAMED, G.E., 1983, Stratigraphical and sedimentological studies on El Sheikh Fadl-Ras Gharib road, Eastern Desert, Egypt. M.Sc. Thesis, Fac. Sci., Assiut Univ., 176 pp.
- NELSON, C.H., 1982, Modern Shallow Water graded sand layers from storm surges, Bering Shelf: a mimic of Bouma sequences and turbidite systems: J. Sediment. Petrol., 52: 537-545.
- RAIF, W., 1982, Muschelkalk/Keuper bone-beds (Middle Triassic, SW-Germany): storm condensation in a regressive cycle. In Einsele, G. & Seilacher, A. (eds.), Cyclic and event stratification: 299-325, Springer Verlag.
- REINECK, H. & SINGH, I., 1972, Genesis of laminated sand and graded rhythmites in storm-sand layers of shelf muds: Sedimentology, 18: 123-128.
- SAID, R., 1962, The geology of Egypt. Elsevier, Amsterdam, New York, 377 pp.
- , 1971, Explanatory notes to accompany the geological map of Egypt: Geol. Surv. Egypt, Pap. 56, 123 pp.
- SEILACHER, A., 1984, Constructional morphology of bivalves: evolutionary pathways in primary versus secondary soft-bottom dwellers: Palaeontology, 27: 207-237.
- STENZEL, H.B., 1971, Oysters. In Moore, R.C. & Teichert, C. (eds.), Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia 3: N953-N1224, Geol. Soc. America, Boulder and Univ. Kansas, Lawrence.

(manuscript received April 18, 1994
accepted July 31, 1995)

Ahmed S. KASSAB

Geology Department, Faculty of Sciences
Assiut University, Assiut, 71516, Egypt