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Taphonomy of Middle Jurassic (Bathonian) shell concentrations from Ras El Abd, west Gulf of Suez, Egypt

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ABSTRACT

The Middle Jurassic (Bathonian) rocks of the Ras El Abd area include three main shell concentrations: a molluscan shell bed, the lower rhynchonellid bed, and the upper rhynchonellid bed. Analysis of the taphonomic signatures indicates that; the molluscan shell bed represents a proximal tempestite, the lower rhynchonellid bed corresponds to a primary biogenic concentration sensu [Fürsich, F.T., Oschmann, W., 1993. Shell beds as tools in basin analysis: the Jurassic of Kachchh, western India. Journal of the Geological Society 150, 169–185], and the upper rhynchonellid bed a proximal storm-flow concentration. The shell concentrations formed below fair-weather wave-base in shallow, relatively high energy environments.

1. Introduction

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 and Oschmann, 1993; Fürsich, 1995; Abbott, 1997; Boyer et al., 2004; Tomašových, 2004). In the present study, three shell concentrations from the Middle Jurassic rocks of Ras El Abd, Gulf of Suez are described and interpreted.

2. Stratigraphic setting

The first attempt to study the Jurassic rocks of the Gulf of Suez was carried out by Barthoux and Douvillé (1913). Sadek (1926) described and measured the Jurassic sequence as 220 m thick. According to him, the lower part is unfossiliferous, while the upper two-thirds of the succession are of Bathonian age. Carpenter and Farag (1948) regarded the basal part of the Khashm El Galala section as Triassic (Rhaetian) based on their floral content. Nakkady (1955) assigned the middle part of the Jurassic succession, which is characterized by having two “Rhynchonella” beds, to the Bathonian. Abdallah (1961, 1964), Abdallah et al. (1963) attributed the Jurassic rocks at Wadi Qisieb and Abu Darag sections based on their macrofossil assemblages to the Callovian, Oxfordian (“Lusitanian”), and Kimmeridgian. Abd-Elshafy (1981) described two claystone beds below the lower “Rhynchonella” bed in both Khashm El Galala and Ras El Abd, where the lower one (bed A) is rich with plant remains and Bathonian microfauna. The upper bed (bed B) is crowded with marine macrofauna and contains a foraminiferal association of Bathonian age. Bed B varies in thickness from 0 to 30 cm and represents the top of the Bathonian. It underlies in some parts the Callovian lower “Rhynchonella” bed and vanishes in other parts, where the later rests directly over bed A. Abd-Elshafy and El-Saadawi (1982) recorded a third claystone bed containing plant remains beneath the lower “Rhynchonella” bed of Ras El Abd by 15 m. Darwish et al. (1984) recognised three informal members at Khashm El Galala; a lower sandy member, a middle shale-limestone member, and an upper sand-shale member. Abd-Elshafy (1988), El-Younsy (2001), Abu El-Hassan and Wanas (2003) subdivided the Jurassic rocks exposed at the Gulf of Suez into two formations, the Rieina Formation (Bajocian) and the Ras El Abd Formation (Bathonian-Oxfordian). Hegab and Aly (2004) followed the classification of Darwish et al. (1984) and regarded the two rhynchonellid beds as of Bathonian age based on their brachiopod content.

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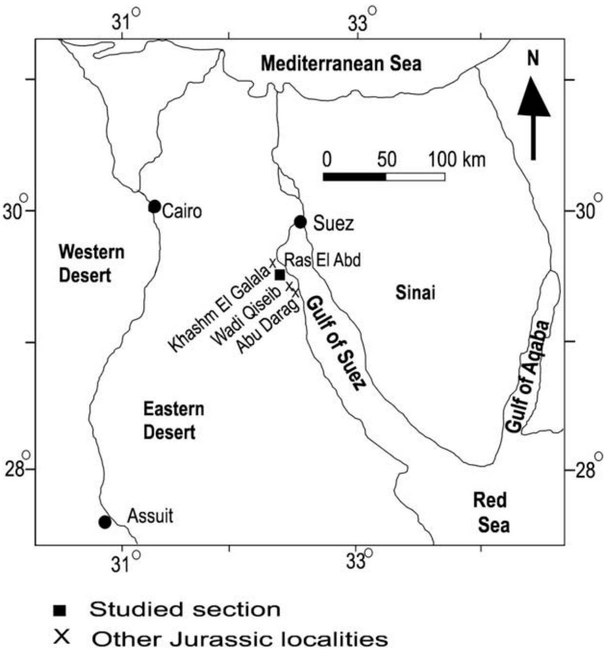

Fig. 1. Location map of the studied section.

The Jurassic rocks at Ras El Abd (29° 33′ 30″ N and 32° 21′ 10″ E) (Fig. 1) can be subdivided into the three informal units of Darwish et al. (1984). The lower member is composed mainly of varicoloured sandstones. The middle member (shale–limestone member) is 72 m thick (Fig. 2) and consists of a succession of claystone-shale, with limestone intercalations and minor sandstone interbeds. The sandstones are cross-bedded and laminated and are common in the middle part of this member. Primary sedimentary structures were destroyed by bioturbation in most beds. This shale–limestone member is rich in macrofauna chiefly brachiopods, bivalves, and gastropods. Moreover, it contains flora and benthic foraminifera (Abd-Elshafy, 1981, 1982; Abd-Elshafy and El-Saadawi, 1982). The distribution of the faunal elements is not random. They either form monotaxic or polytaxic shell concentrations. In agreement with Hegab and Aly (2004) a Bathonian age is proposed for the middle member. The upper member consists of a succession of sandstones and shales, and underlies the varicoloured lower cretaceous sandstones of the Malha Formation. The latter is directly overlain by the Cenomanian Galala Formation.

3. Methods and terminology

The Middle Jurassic sediments are highly fossiliferous, especially with respect to brachiopods, and contain two main brachiopod beds in addition to a molluscan shell bed. Shell concentrations were described in the field and labratory using methods of Kidwell et al. (1986), Kidwell (1991), Kidwell and Holland (1991). In the field, the thickness, lateral extent, sedimentary structures, bioturbation and bedding plane features were recorded. For each shell concentration, taxonomic composition, biofabric, matrix, packing density, orientation patterns, disarticulation, and fragmentation were described (Table 1). In the laboratory, representative free specimens of the faunal elements together with some polished slabs of selective samples have been studied using the binocular microscope. For additional information on some taphonomical features and the matrix 21 thin-sections were investigated. The term shell concentration is used herein to denote deposits of any geometry containing a relatively dense accumulation of biogenic hardparts larger than 2 mm (Kidwell, 1991; Fürsich, 1995; Tomašových, 2004).

The two rhynchonellid shell beds can be classified based on their taxonomic composition, following Boyer et al. (2004) into monotaxic and polytaxic. The upper rhynchonellid bed is monotaxic, composed of one taxonomic group (brachiopods) but more than one species. Polytaxic beds refer to fossil concentrations consisting of several taxonomic groups (two or more). This type is represented by the lower rhynchonellid bed, where apart from brachiopods, also bivalves, gastropods, and echinoids occur (arranged according to their decreasing relative). It also applies to the molluscan shell bed, which represents the base of the lower rhynchonellid bed.

4. Results

4.1. The shell beds

4.1.1. Molluscan shell bed

The lower rhynchonellid bed overlies a polytaxic molluscan shell bed, composed mainly of the bivalves *Neocrassina* (*Coelastarte*) *excavatus* (J. Sowerby, 1819), *Nicaniella pisiformis* (J. de C. Sowerby, 1840), *Modiolus* sp., and *Nucula* sp., in addition to small gastropods. The bed varies in thickness from 4 to 7 cm. Most bivalves are disarticulated and most shells are convex-up oriented (Fig. 3). Some of the bivalve and gastropod shells show a low degree of micritization. The matrix consists of biointra-packstone to -grainstone (Fig. 4A). The bioclasts of this shell bed are densely packed, poorly sorted, randomly oriented, fragmented and abraded. Although the degree of disarticulation and fragmentation is high, there are many bivalves of variable sizes that are very well preserved.

4.1.2. The lower rhynchonellid bed

The lower rhynchonellid shell bed is about 1 m thick and consists of biointra-wackestone to -floatstone (Fig. 4B, Figs. 5 and 6). Apart from the most common rhynchonellids *Globirhynchia concinna* (J. Sowerby, 1812) and *Echyrosia expansa* Cooper, 1989, the associated macrofossils are the bivalves *Pholadomya orientalis* Douvillé, 1916, *Neocrassina* (*Coelastarte*) *excavatus* (J. Sowerby, 1819), *Nicaniella pisiformis* (J. de C. Sowerby, 1840), *Mactromya* cf. *concentrica* Münster in Goldfuss, 1840, *Modiolus* sp., *Plagiostoma* cf. *rigidum* J. Sowerby, 1815, *Pleuromya alduini* (Brongniart, 1821), *Nucula* sp., the gastropods *Buckmanina laevis* (Buvignier, 1852), *Amphitrochus mogharensis* Douvillé, 1916 and *Procerithium* sp., the cassiduloid echinoid *Nucleolites* sp., and the brachiopod "*Terebratula*" cf. *globata* J. de C. Sowerby, 1825. The shells are loosely packed and dominantly articulated (especially the brachiopods). Some bivalves are fragmented and exhibit signs of abrasion. The difference in the proportion of disarticulation between brachiopods and bivalves can be explained the greater hinge strength of the former. The shells are randomly oriented, relatively poorly sorted, and brachiopods commonly occur in clusters and some even in growth position (Fig. 5A and B).

4.1.3. The upper rhynchonellid bed

This shell bed represents a monotaxic concentration of the rhynchonellids *Globirhynchia triangulata* Cooper, 1989 and *Echyrosia expansa* Cooper, 1989. It is lensoid in shape, ranging in thickness from 8 to 14 cm. This bed can be subdivided into two layers (Fig. 7A and B) separated by an internal erosion surface. The microfacies varies from biointra-floatstone to biointra-wackestone (Fig. 4C). The lower layer is about 6–10 cm thick. Shells are poorly sorted, densely packed, dominantly articulated, and randomly oriented. Articulated shells partly show geopetal fills (Fig. 7B), the infilling either starting with biointra-wackestone and the remaining cavity being filled with calcite spar, or the infilling starting with mudstone followed in the upper part by intra-wackestone. The shells are neither bioeroded nor encrusted.

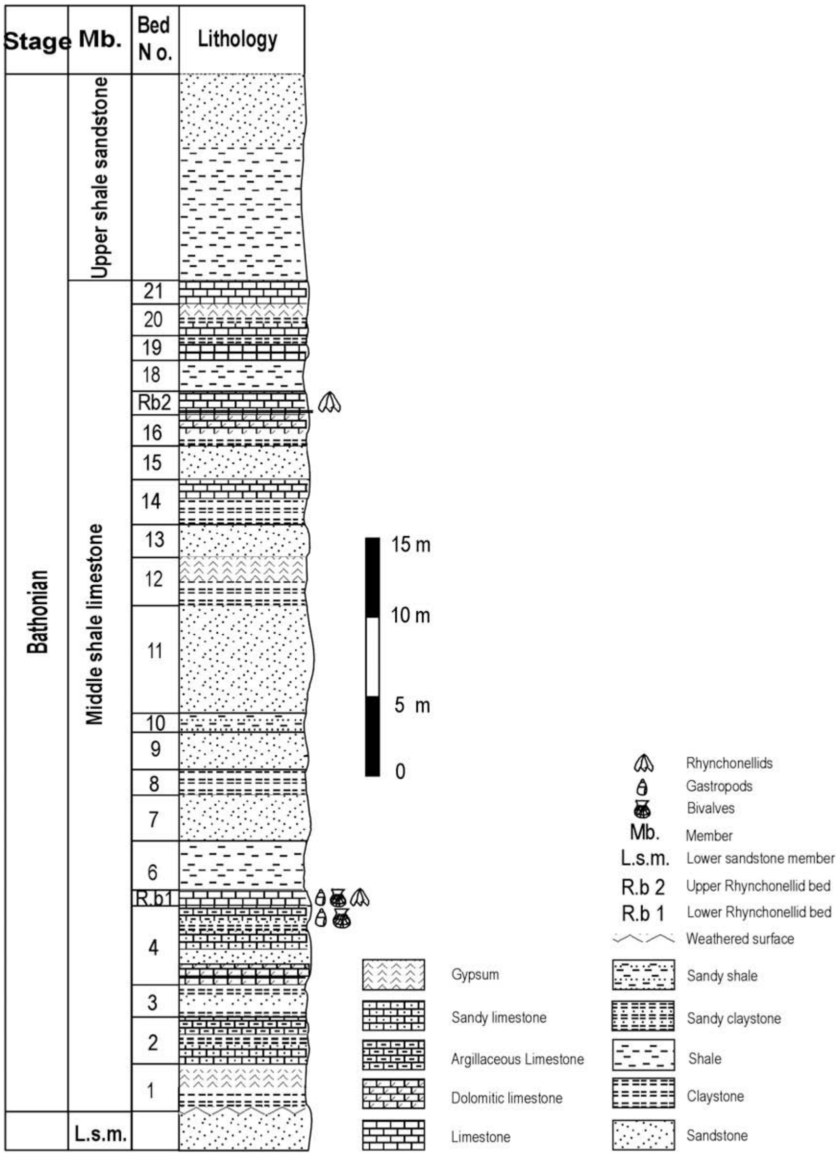

Fig. 2. Stratigraphic columnar section of the Middle Jurassic (Bathonian) rocks at Ras El Abd.

Table 1
Comparison of the taphonomic properties and taphonomic signatures of the three shell concentrations (FWWB = fair-weather wave-base).

Concentration	Molluscan Shell bed	Lower rhynchonellid bed	Upper rhynchonellid bed	
			Lower layer	Upper layer
Assemblage	Polytaxic	Polytaxic	Monotaxic	Monotaxic
Fragmentation	High	Low	Low	High
Disarticulation	High	Low	Low	High
Microfacies	Biointra-packstone to biointra-rudstone	Biointra-wackestone to biointra-floatstone	Biointra-floatstone	Biointra-rudstone to biointra-grainstone
Packing	Dense	Dispersed – loose	Dense	Dense – loose
Sorting	Poor	Poor	Poor – moderate	Poor
Orientation	Random	Random	Random	Random
Geometry	Bed	Bed	Lens	Lens
Internal structure	Simple	Simple	Simple	Simple
Setting	Below FWWB	Below FWWB	Below FWWB	Below FWWB

The upper layer varies in thickness from 2 to 4 cm. It contains the same rhynchonellids (*Globirhynchia triangulata* and *Echyrosia expansa*) as the lower layer. Shells are poorly sorted, highly disarticulated, moderately to highly fragmented, randomly oriented, and loosely to densely packed (Fig. 7C). The microfacies varies from biointra-rudstone to -grainstone (Fig. 4D).

5. Discussion

Based on their taphonomic signatures, the genesis of the three shell concentrations from the Middle Jurassic rocks of the Ras El Abd area can be interpreted in the following way.

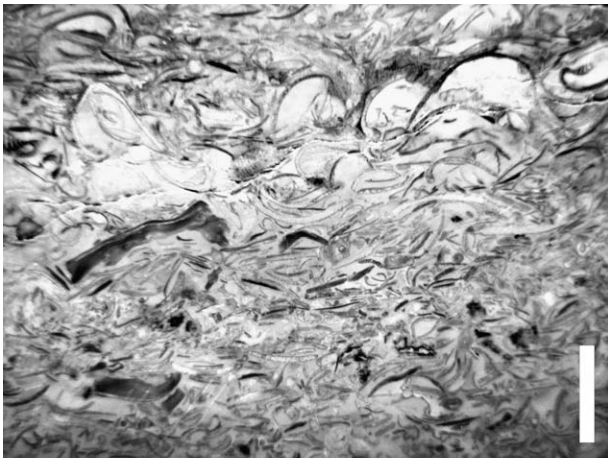

Fig. 3. Polished cross-section of the polytaxic molluscan shell bed, scale bar 6.5 mm.

5.1. Molluscan shell bed

The comparatively high degree of disarticulation and fragmentation is evidence that the shells were repeatedly reworked. In contrast, the presence of articulated, well preserved bivalve shells and the poor sorting indicate that the reworking events were of short duration and that little transport was involved. The articulated bivalves most likely were alive when they were reworked (Fürsich and Oschmann, 1993) and died by suffocation during the immediately following burial. Lack of encrustation and bioerosion indicate that residence time of shells on the sea floor must have been very short. Thus, the shells most likely were uprooted by storm wave action (Fürsich and Pandey, 1999) and correspondingly, represent a proximal tempestite.

5.2. Lower rhynchonellid bed

The low degree of disarticulation and fragmentation, lack of encrustation and bioerosion and the poor sorting indicate no or only very limited transport and a short residence time on the sea floor. In particular the clustering of articulated rhynchonellids suggests that they are preserved in-situ. This concentration can be interpreted as having formed largely by biological processes; a high rate of production of biogenic hardparts and gregarious settling behaviour combined with a relatively low rate of sedimentation. According to Fürsich and Pandey (1999) polyspecific concentrations often develop gradually up-section from scattered shells into a matrix-supported shell bed, suggestive of a gradual decrease in the rate of sedimentation. Consequently, the lower rhynchonellid bed (polytaxic and polyspecific) corresponds to a primary biogenic concentrations *sensu* Fürsich and Oschmann (1993). The lack of an encrusting and boring biota and the occurrence of brachiopods in clusters, however, indicate that the brachiopods on the sea floor were quickly covered with sediment, possibly while some of them were still alive.

5.3. Upper rhynchonellid bed

The good preservation of skeletal elements (*Globirhynchia triangulata* and *Echyrosia expansa*), low degree of disarticulation, and poor sorting as well as absence of bioerosion and encrustation in the lower layer suggest that the shells underwent a similar history as the lower rhynchonellid bed and represent a biogenic concentration. In contrast, the upper layer characterized by an erosional base, high percentage of disarticulated shells, moderate to high de-

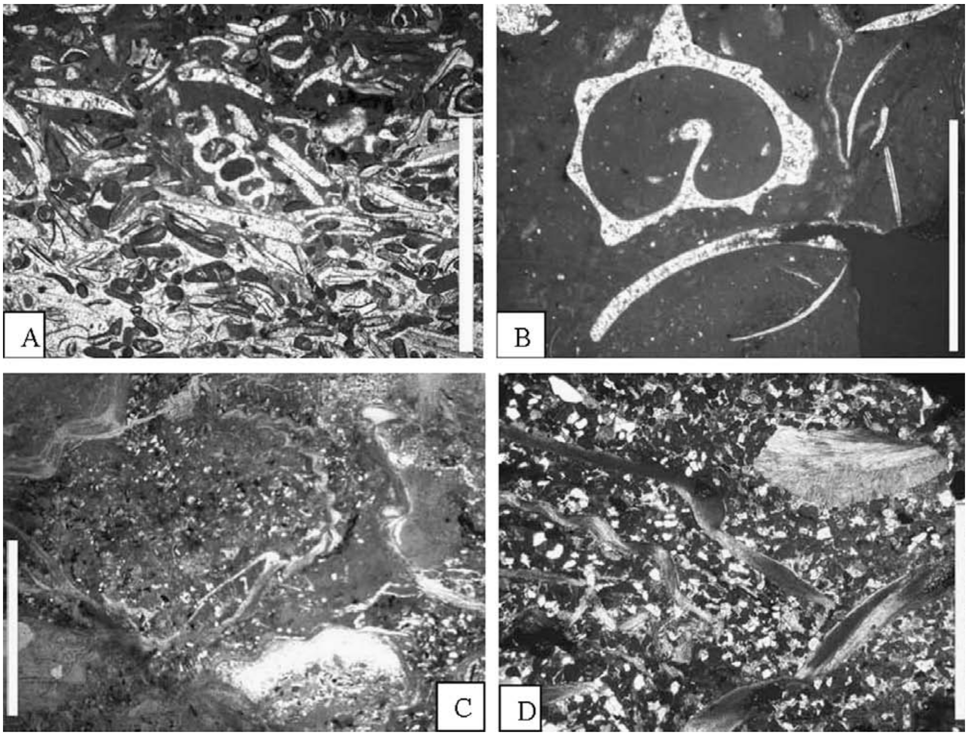

Fig. 4. Thin-sections of (A) biointra-packstone to -rudstone, the molluscan shell bed; (B) bio-floatstone, matrix of the lower rhynchonellid bed; (C) biointra-floatstone, with articulated rhynchonellid shells, lower layer of the upper rhynchonellid bed; (D) biointra-rudstone to -grainstone upper layer of the upper rhynchonellid bed, scale bars A: 5 mm, B–D: 6 mm.

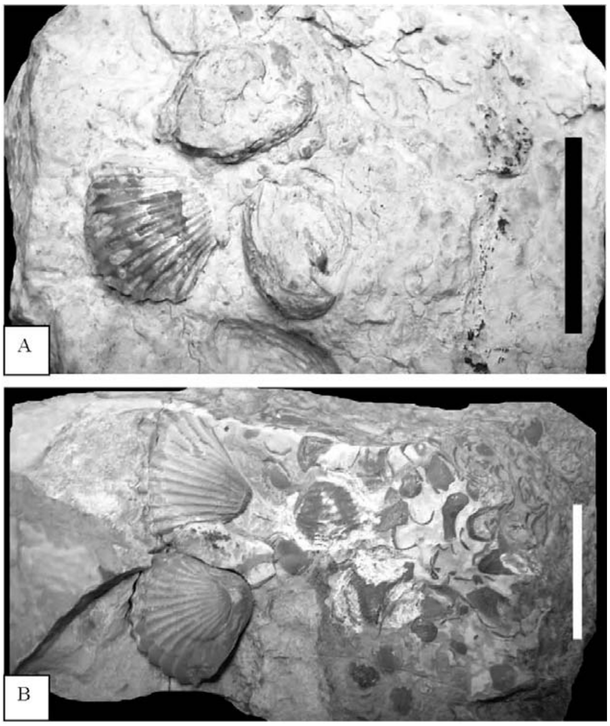

Fig. 5. (A–B) Upper surface views of the polytaxic lower rhynchonellid bed (in B it overlies the molluscan shell bed), scale bar 20 mm.

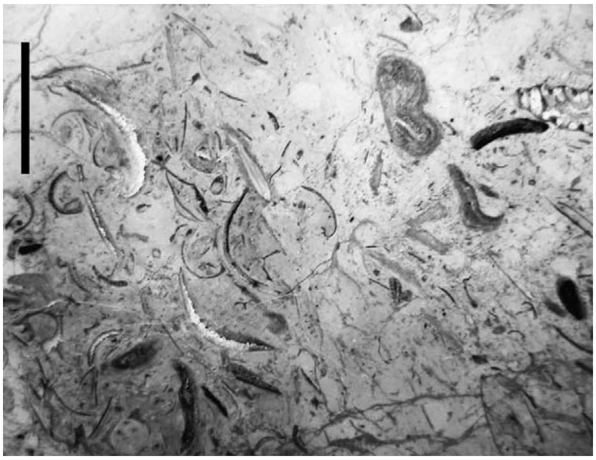

Fig. 6. Polished cross-section of the polytaxic lower rhynchonellid bed, biointra-wackestone to -floatstone, scale bar 10 mm.

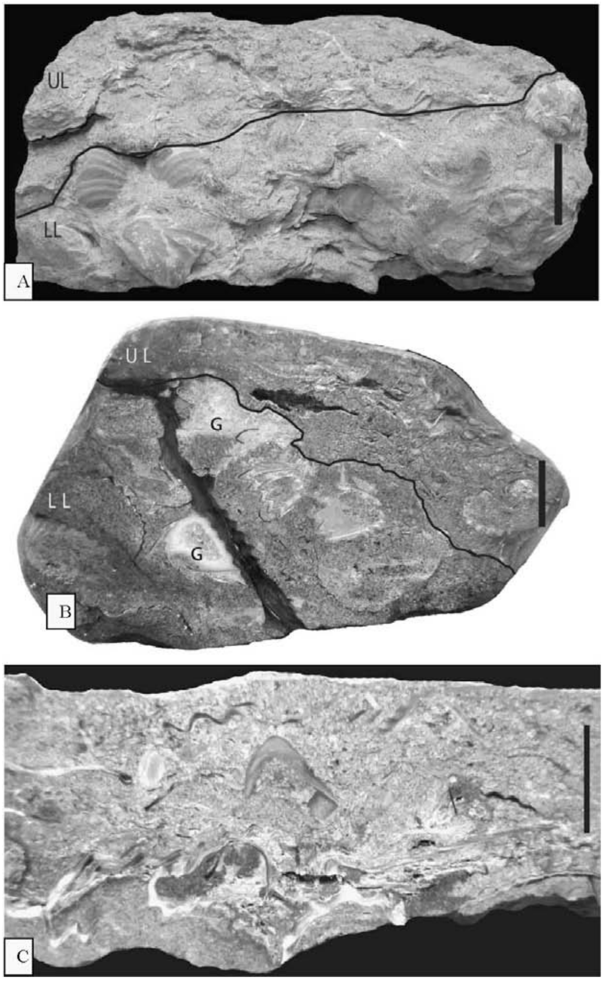

Fig. 7. Upper rhynchonellid bed: (A) side view, clearly seen is the change from the lower layer (dominantly articulated) to the upper layer with dominantly disarticulated and fragmented shells. (B) Polished cross-section, in the lower layer (LL) rhynchonellids largely articulated and with geopetal fills (G); upper layer (UL) with mainly disarticulated brachiopods. (C) Polished cross-section, note the upward change from biointra-rudstone to biointra-grainstone, scale bars A, B 10 mm; C 7.5 mm.

gree of fragmentation, preferred convex-up orientation, and dense packing of bioclasts, suggests that the skeletal elements underwent transport, most likely by storm-induced currents. The brachiopod bed is therefore interpreted as a proximal storm flow concentration.

6. Environmental conclusions

The shell concentrations occurring in the Middle Jurassic rocks of the Ras El Abd area are interpreted as proximal tempestite in the case of the molluscan shell bed, as primary biogenic concentrations in the case of the lower rhynchonellid bed, and as a proximal storm flow concentration in the case of the upper rhynchonellid bed. The shell concentrations correspond to three of the nine types of concentrations proposed by Fürsich and Oschmann (1993) in an attempt to genetically classify shell concentrations in the Middle Jurassic of Kachchh, western India. The main agents responsible for the formation of the shell concentrations from Egypt were storm-induced waves and currents, reduced sediment input, settling behaviour of benthic macroinvertebrates and productivity. The sea floor was below fair-weather wave-base, but within the reach of storms. Based on the various taphonomic features of the three shell concentrations, it is possible to differentiate them to some degree with respect to their position along an onshore–offshore gradient. The upper layer of the upper rhynchonellid bed represents the upper range of the bathymetric scale, close to the fair-weather wave-base, where the high degree of fragmentation points to repeated reworking under the influence of high-energy storm-induced waves and currents. The molluscan shell bed represents an intermediate position along the bathymetric gradient, the shells having been uprooted by storm waves of short duration. The lower rhynchonellid bed, as well as the lower layer of the upper rhynchonellid bed, indicate relatively quiet conditions compared to the other two concentrations, and the dominance of biological over physical concentration mechanisms.

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