

## REELABORATED AMMONITES AS INDICATOR OF CONDENSED DEPOSITS FROM DEEP MARINE ENVIRONMENTS. CASE STUDY FROM LOWER PLIENSBACHIAN LUMPY LIMESTONES OF PORTUGAL \*

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**Abstract:** Lumpy limestones with reelaborated ammonites are a typical facies in the Lower Pliensbachian of the Lusitanian Basin. They were developed in deep marine environments, induced by sedimentary starving. Reelaborated ammonites, with various taphonomic attributes, provide a key to recognition of condensed deposits developed in deep offshore environments during intervals of low sediment input.

**Key words:** applied taphonomy, sequence stratigraphy, carbonate platforms, palaeobathymetry, Jurassic, Portugal.

**Résumé:** Les calcaires grumeleux avec des ammonites réélaborées, correspondent a un facies très typique dans le Pliensbachien inférieur du Bassin Lusitanien. Ils se sont développés en milieu marin profond, sur conditions de bas taux de sédimentation. Ces ammonites réélaborées, avec des différents attributs taphonomiques, sont un moyen important pour la reconnaissance de dépôts condensés en milieu marin profond.

**Mots-clés:** taphonomie appliquée, stratigraphic séquentielle, plate-formes carbonatées, paléobathymétrie, Jurassique, Portugal.

### INTRODUCTION

The lithofacies of lumpy limestones is very common in the Lower Pliensbachian of the Lusitanian Basin, having been located at Peniche, S. Pedro de Moel, Coimbra, Rabaçal and Brenha. Previous studies of this facies have been predominantly of biostratigraphical nature (Mouterde, 1955; Mouterde *et al.*, 1983; Phelps, 1985; Dommergues, 1987; Dommergues *et al.*, 1997). Some sedimentological items have also been discussed (Hallam, 1971; Dommergues *et al.*, 1981; Dromart y Elmi, 1986; Elmi *et al.*, 1988; Soares *et al.*, 1993). In the present work attention has been focused on the taphonomic attributes of the reelaborated ammonites recorded in these lumpy limestones.

### CASE STUDY FROM LOWER PLIENSBACHIAN LUMPY LIMESTONES OF PORTUGAL

The lithofacies analysed consists of limestones and shales of Early Pliensbachian age. Thin limestones, heavily bioturbated, alternate with thicker, weaker bioturbated, marly mudstones and some bituminous, laminated shales. Limestones are mudstone to wackestone with very recrystallized bioclasts (ammonoids, brachiopods, belemnites, thin shelled gastropods, spicules of sponges, bivalves, radiolaria, ostracods, equinoderms and algae). Carbonized wood fragments of centimetric size are also present. *Chondrites* and other bioturbation structures are common.

The lumps included in limestone beds and marly intervals are micritic, calcareous concretions, subspherical and angular in shape, millimetric or centimetric in size (Fig. 1). Sometimes several concretions are clumped together to form larger masses up to 3 cm diameter. Contacts between lumps and matrix are sharp and well defined in the marly intercalations, but gradational in some limestone levels. They may be aligned on certain sedimentary surfaces. Some lumps are covered by micritic envelopes as cryptalgal oncolite structures (Elmi *et al.*, 1988). The concretions are scattered fairly uniformly through limestones. However, they can be sorted in marly intervals. These concretions show distribution grading, also (*i.e.*, gradual variation, in a progressively upward direction within a marly interval, of the upper concretion-size limit). Gradual reduction of the size or normally distribution grading of concretions is more common than gradual increase or inversely distribution grading, in these marly intervals.

Ammonites occur throughout the sections. They show locally little size. The degree of packing of ammonites (estimated by the difference between the number of specimens and the number of fossiliferous levels subdivided by the number of fossiliferous levels) and the stratigraphical persistence (proportion of fossiliferous levels) display high values. Ammonite normally appear dispersed in the sediment, showing no pattern of imbricated or encased regrouping. The aragonitic shells have been dissolved. Moldic porosity is filled by spar cement.

Recorded associations of ammonites of this facies are dominated by reworked elements (*i.e.*, reelaborated or resedimented elements *sensu* Fernández-López, 1991). Accumulated elements, showing no evidence of removal, are very scarce or absent. Reelaborated internal moulds, exhumed and displaced before their final burial, may be dominant (Figs. 2-4). Resedimented shells, displaced on the sea-bottom before their burial, are locally common. The degree of removal (*i.e.*, the ratio of reelaborated and resedimented elements to the whole of recorded elements) and the degree of taphonomic heritage (*i.e.*, the ratio of reelaborated elements to the whole of recorded elements) can reach 100%. These associations, however, are not condensed associations formed by

mingling of fossils of distinct zones. Ammonite mixed assemblages composed of specimens representing several biozones or biohorizons in a single bed have not been identified. The degree

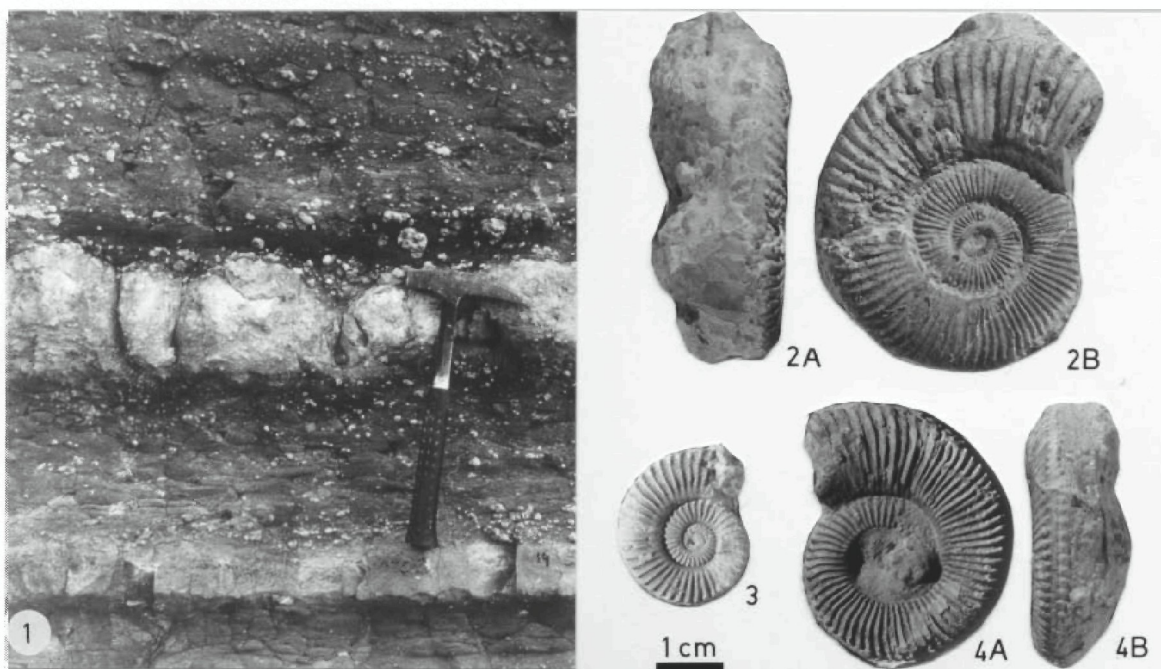


Fig. 1 - Outcrop photo of Lower Pliensbachian deposits, Peniche (Portugal), showing lumpy limestones and marly intervals.

Fig. 2 - 4 - *Dayiceras*, reelaborated, calcareous, concretionary internal moulds, maintaining their original volume and form as a result from rapid early cementation. Specimens represented in figures 2A and 4B are preferentially encrusted by calcareous, stromatolitic laminae on a side. Fig. 2 - specimen BR2, Brenha. Fig. 3 - specimen PE55/1, Peniche. Fig. 4 - specimen BR1, Brenha.

of taphonomic condensation in the ammonite recorded associations reaches very low to zero values in all cases.

Taphonic populations of type 1 and 2 are dominant. Taphonic populations of type 1 are composed of monospecific shells, showing unimodal and asymmetric distribution of size-frequencies, with positive skew. These populations have a high proportion of microconchs and the shells of juvenile individuals are predominant, whilst shells of adult individuals are scarce. Taphonic populations of type 2 are composed of mono- or polyspecific shells, showing unimodal and normal distribution of size-frequencies, with high kurtosis. Populations of this second type have a low proportion of microconchs and the shells of juvenile individuals are scarce, whilst the shells of adult individuals are common. The occurrence of taphonic populations of type 1, showing no signs of sorting by necroplanktic drift, is indicative of autochthonous biogenic production of shells (Fernández-López, 1991, 1997).

Biostratinomic processes of biodegradation-decomposition are generally intense. Ammonite shells commonly lack the soft-parts and aptychus in the body chamber, as well as periostracum and connecting rings, before their final burial. Uncompressed, complete sedimentary internal moulds of the body chamber and phragmocone, indicative of low rate of sedimentation and low degree of accommodation of sediments, are abundant. In contrast, compressed, partial internal moulds of the body chamber (*i.e.*, hollow ammonites), indicative of very rapid sedimentary infill and high rate of sedimentation, are scarce. Processes of early mineralization are intense. Concretionary internal moulds are calcareous. In the most lumpy intervals, pyritic internal moulds may locally be common, as reelaborated elements.

Concretionary internal moulds with septa are the dominant fossils. Hollow phragmocones (*i.e.*, shells without septa) are scarce, and they are compressed by gravitational compaction during early diagenesis. The septa can disappear by early dissolution, while the wall of the shell may still remain, giving rise to compressed elements showing discontinuous deformation by gravitational diagenetic compaction.

Reworked concretions, shell fragments and concretionary internal moulds can be encrusted, developing oncolitic cryptalgal structures. Shells and internal moulds can present microbial laminae, developed during the removal processes. Reelaborated, internal moulds show commonly calcareous microbial or stromatolitic laminae, developed preferentially on the exposed upper side during the exhumation and displacement processes (Figs. 2A, 4B and 5). However, skeletal remains of encrusting organisms (such as serpulids, bryozoans or oysters) and biogenic borings are very scarce. Remains of intrathalamous or extrathalamous serpulids are only developed on some resedimented shells.

Shells and concretionary internal moulds are usually reorientated. Ammonites oriented with their long axes parallel to the bedding are dominant. Fragmentary shells are common. Shells can show closed and open fractures on the wall. Signs of abrasion and bioerosion on shells and internal moulds are very scarce. Reelaborated internal moulds can show disarticulation surfaces and fractures with sharp margins; more seldom, associated with erosional sedimentary surfaces, they may show truncational abrasion facets. Fragmentary internal moulds can also occur, but bearing no signs of rounding or bioerosion.

## PALAEOENVIRONMENTAL IMPLICATIONS

Sediments of this facies are interpreted as having been deposited in an open sea, below wave base, taking into account the absence of sedimentary structures indicating either shallow water (such as wave reworking) or storm deposition (such as hummocky bedding). However, the presence of reelaborated ammonites implies that some form of current flow or winnowing affected the burial of the concretionary internal moulds. Currents were slight, but concretionary internal moulds of ammonites were disarticulated and azimuthally reorientated on softgrounds by reelaboration (*i.e.*, exhumation and displacement on the sea-bottom, before their final burial). The concretions must have formed either contemporaneously with the sedimentation or within the sediment in early diagenesis. In this hemipelagic environment, episodes of lower rate of sedimentation and lower degree of accommodation of sediments favour a higher degree of bioturbation and reworking of ammonite shells.

The reelaboration processes and the activity of burrowing organisms are the main factors that induced the development of ammonite associations showing a high degree of taphonomic heritage, but the degree of stratigraphic and taphonomic condensation is negligible over geochronological time-scales. Increasing porosity was induced by draught filling in the ammonite shells (intra-cameral draught stream created by external turbulence through constricted siphuncular openings; Seilacher, 1971) and bioturbation of the sedimentary matrix, favouring a

**TAPHONOMIC PROCESSES and results:**

**ACCUMULATION**

Ammonite shell on the sea floor

**BIODEGRADATION-DECOMPOSITION**

Body chamber without soft-parts  
Shell without periostracum

**DISARTICULATION**

Shell without aptychus  
Disarticulated siphuncular tube

**RESEDIMENTATION**

Moved shell or fragmented wall

**SEDIMENTARY INFILLING (by intra-cameral draught streams)**

Complete sedimentary infill of the shell,  
more size-grained in the lower-anterior portions  
and more clayey in the upper-apical portions  
than the sedimentary matrix

**INITIAL BURIAL**

Umbilical cavities of the shell with sedimentary infill

**SYNSEDIMENTARY MINERALIZATION**

Calcareous cementation of the sedimentary infill  
(preferentially in the lower-anterior portions)

**REELABORATION**

Exhumed and moved concretionary internal mould and shell  
Formation of abrasion surfaces on the internal mould  
Preferential development of microbial laminae,  
on the exposed upper side  
Reorientation of the internal mould and shell,  
with the long axis parallel to the bedding

**FINAL BURIAL AND COMPACTION**

Compacted concretionary internal mould and shell  
(preferentially in the upper-apical portions)  
Dissolution of the aragonite shell  
Calcareous cementation of moldic porosity

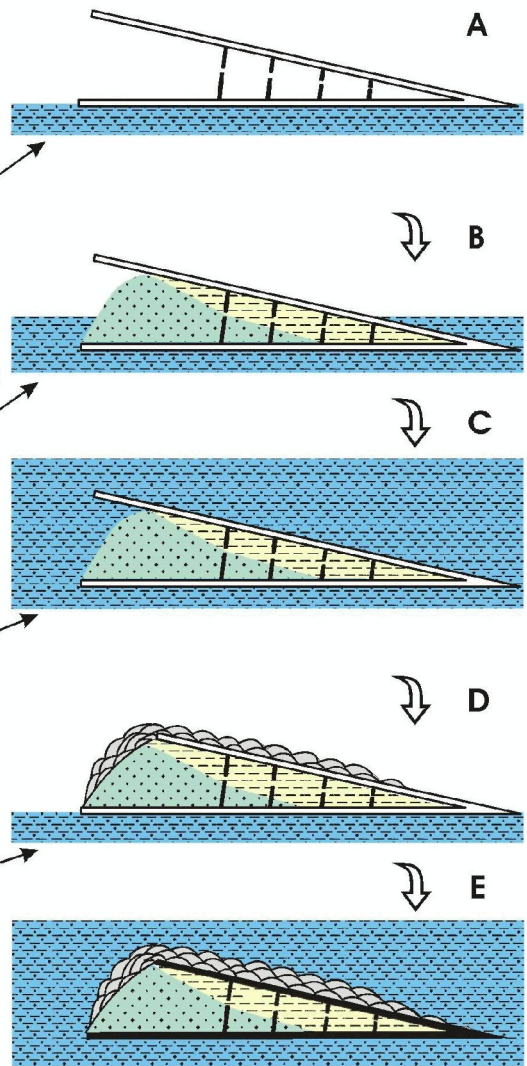


Fig. 5 - Processes leading to the formation of "ammonite half-lumps" (a particular case of reelaborated ammonites) in condensed sediments from Early Pliensbachian of Portugal.

relatively faster lithification. Lumpy limestones with reelaborated ammonites, showing gradational boundaries and inversely distribution grading, represent environments of starving and lowest rate of sedimentation as well as lowest degree of accommodation of sediments in deep, marine areas.

**CONCLUSIONS**

Preservational features of the ammonites can be an useful tool to identify condensed deposits developed in deep, marine environments of Mesozoic carbonate platforms. Ammonites in condensed deposits from the Lower Pliensbachian lumpy limestones of Portugal show the

following taphonomic attributes as indicator of deep environments: 1) high values of stratigraphic persistence and degree of packing, but showing no pattern of imbricated or encased regrouping; 2) the degree of removal and the degree of taphonomic heritage can reach 100% in some stratigraphic levels, but the degree of taphonomic condensation reaches very low to zero values in all cases; 3) taphonic populations of type 1 and 2 are dominant; 4) complete concretionary internal moulds are abundant and hollow ammonites are scarce; 5) ammonite preservation of type "half-lumps" is a common preservation type, but skeletal remains of encrusting organisms (such as serpulids, bryozoans or oyster) and biogenic borings are very scarce; 6) reelaborated internal moulds can show disarticulation surfaces and fractures with sharp margins, bearing no signs of rounding or bioerosion.

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