Rivista Italiana di Paleontologia e Stratigrafia	volume 110	no. 1	pp. 219-230	April 2004

FOSSILIZATION OF AMMONITES AND SEDIMENTARY EVENTS IN DEEP ENVIRONMENTS OF CARBONATE PLATFORM (HIGHEST MIDDLE TO LOWEST UPPER OXFORDIAN, IBERIAN RANGE, SPAIN)

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Received September 19, 2002; accepted September 22, 2003

Keywords: taphonomy, facies analysis, stratigraphic condensation, sedimentary condensation, sediment starvation, sea-level change, Upper Jurassic, Western Tethys.

Abstract. In the Ricla area (Zaragoza, Aragonese Branch of the Iberian Range), at the top of the Yátova Formation, grey-reddish wackestone limestones grade into yellow-green siliciclastic limestones of the Aldealpozo Formation. These changes of facies between the two successive formations are associated with syndepositional palaeoreliefs developed during the Late Oxfordian. The uppermost deposits of the Yátova Formation represent an Oxfordian condensed section, from the upper Bifurcatus Zone (Middle Oxfordian) and Hypselum Zone (Upper Oxfordian). These deposits are interpreted as developed in an open marine, moderately deep carbonate platform, showing uniform low-energy conditions with extremely reduced carbonate and terrigenous background sedimentation, and very low sedimentation rates. The low diversity of the benthic fauna, scarce development of sponge bioherms and ammonite populations inhabiting the platform are palaeobiological criteria which corroborate these palaeoenvironmental conditions.

Ammonite assemblages are composed of Sub-Mediterranean taxa. Over 900 ammonite specimens have been collected from the upper Bifurcatus and Hypselum zones. Oppeliidae (45,2%) and Perisphinctidae (37,9 %) are dominant. Aspidoceratidae (14,3%) are common. Haploceratidae (2,2%) are scarce. Two phylloceratids and a lytoceratid have been found. Ammonoids are commonly preserved as concretionary calcareous internal moulds of reelaborated elements. Resedimented shells are scarce. The degree of packing of ammonite remains and the stratigraphical persistence display high values. Taphonomic features indicative of sedimentary starving in deep carbonate platform environments are: 1) high concentrations of reelaborated ammonites, 2) taphonic population of type two, 3) phragmocones completely filled with sediment, and 4) homogeneous concretionary internal moulds, bearing no signs of abrasion, bioerosion or dense encrusting by organisms (such as serpulids, bryozoans or oysters). In conclusion, the occurrence of these ammonite associations confirms the development of an advanced deepening phase, within a 3rd order deepening/shallowing cycle, in the Aragonese platform, during the late Bifurcatus to Hypselum zones.

Riassunto. Nell'area di Ricla (Saragoza, ramo aragonese della Catena Iberica), alla sommità della Formazione Yátova, gli wackestone grigio-rossastri sfumano nei calcari silicoclastici giallo-verdi della Formazione Aldealpozo. Questi cambiamenti di facies tra le due formazioni successive sono associati a paleorilievi sindeposizionali sviluppatisi durante l'Oxfordiano superiore. I depositi sommitali della Formazione Yátova rappresentano una sezione oxfordiana condensata, dalla Zona a Bifurcatus superiore (Oxfordiano medio) alla Zona ad Hypselum (Oxfordiano superiore). Questi depositi sono interpretati come sviluppati in una piattaforma carbonatica moderatamente profonda di mare aperto, che mostra uniformi condizioni di bassa energia, con sedimentazione carbonatica e terrigena di sottofondo estremamente ridotte, e tassi di sedimentazione molto bassi. La bassa diversità della fauna bentonica, lo scarso sviluppo di bioerme a spugne e le popolazioni di ammoniti che abitavano la piattaforma sono criteri paleobiologici che corroborano queste condizioni paleoambientali.

Le associazioni ad ammoniti sono composte da taxa submediterranei. Sono stati raccolti oltre 900 esemplari di ammoniti dalle zone a Bifurcatus superiore e ad Hypselum. Gli Oppeliidae (45,2%) e i Perisphinctidae (37,9 %) sono dominanti. Gli Aspidoceratidae (14,3%) sono comuni. Gli Haploceratidae (2,2%) sono scarsi. Sono stati trovati due phylloceratidi ed un lytoceratide. Gli ammonoidi sono comunemente conservati come modelli interni calcarei concrezionali di elementi rielaborati. Le conchiglie risedimentate sono scarse. Il grado di impaccamento dei resti di ammoniti e la persistenza stratigrafica mostrano valori alti. Caratteri tafonomici indicativi di starvazione sedimentaria negli ambienti profondi della piattaforma carbonatica sono: 1) alta concentrazione di ammoniti rielaborati, 2) popolazione tafonica di tipo due, 3) fragmoconi completamente riempiti di sedimento, e 4) modelli interni concrezionali omogenei, che non presentano segni di abrasione, bioerosione o dense incrostazioni da organismi (come serpulidi, briozoi od ostriche). In conclusione, il ritrovamento di queste associazioni ad ammoniti conferma lo sviluppo, nella piattaforma aragonese dalla zona a Bifurcatus superiore alla zona ad Hypselum, di una fase avanzata di approfondimento, all'interno di un ciclo di terzo ordine di approfondimento/riduzione di profondità.

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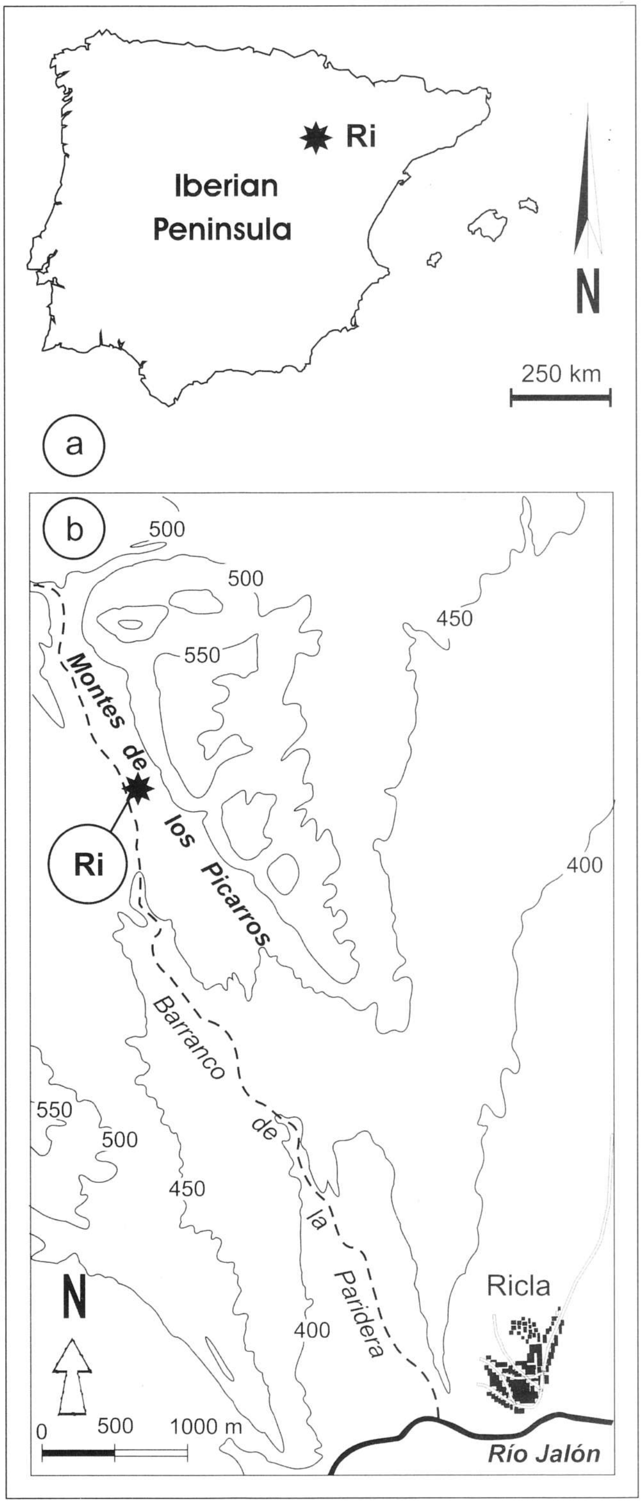


Fig. 1 - Geographical location of the study area, north of the locality of Ricla (Zaragoza province, north-eastern Iberian Peninsula), showing the point of the sampled outcrops (Ri).

Introduction

One of the best outcrops of Upper Oxfordian deposits in the Aragonese Branch of the Iberian Range is in the surroundings of the village of Ricla (Zaragoza province). In these outcrops, Oxfordian marine deposits are superbly exposed with wide lateral continuity up to 4 km (Fig. 1). They show a good development of the characteristic lithostratigraphic units of this branch of the Iberian Range. Moreover, they contain abundant ammonoids, allowing recognition of a detailed biostratigraphic succession. The most relevant point, of particular regional importance, is the occurrence of fossiliferous marly deposits, displaying stratigraphic and sedimentary condensation and indicating development under deep marine environmental conditions. However, these deposits have been previously interpreted as the upper part of a depositional sequence (Bifurcatus to Hypselum zones) or HST, showing a typical thickening, shallowing upward trend (Aurell et al. 2000). Lithologies and sedimentary structures of these deposits are poorly indicative and hence the new palaeoenvironmental interpretation is mostly grounded on the taphonomic features of ammonoids.

Stratigraphic framework

Middle and Upper Oxfordian deposits in the studied area correspond to two successive lithostratigraphical units, the Yátova and Aldealpozo formations (Fig. 2). Both units are well developed and widespread in the north-western part of the Aragonese Branch of the Iberian Range (Gómez & Goy 1979; Aurell 1990; Ramajo et al. 1999; Aurell et al. 2000). In the Ricla area, the Yátova Formation is composed of wackestone to packstone and boundstone beds alternating with thin marly intervals, bearing common sponges and ammonites, and reaching a thickness of ten to fifteen metres. It ranges from lower Transversarium Chronozone (Middle Oxfordian) to Hypselum Chronozone (Upper Oxfordian). The Aldealpozo Formation is composed of siliciclastic limestone beds alternating with argillaceous siltstones, bearing scarce ammonites, and reaching a thickness of five to ten metres. From a biochronostratigraphical point of view (Meléndez 1989; Meléndez et al. 1995; Pérez Urresti 1996), these upper deposits range from Bimammatum to Hauffianum chronozones (Upper Oxfordian). The boundary between these successive formations generally corresponds to a sharp surface and a sudden facies change, in which grey-reddish sponge boundstone beds or marly limestones are on-lapped by yellow-green siliciclastic and argillaceous siltstones. However, a gradual vertical facies change, from micritic sponge limestones to siliciclastic and argillaceous siltstones, may be locally observed. At the top of the Yátova Formation, grey-reddish wackestone limestones locally grade vertically and laterally into yellow-green siliciclastic limestones. These changes of facies between the two successive formations are associated with syndepositional palaeoreliefs developed during the Late Oxfordian, as indicated in Figs. 2 and 3. Sharp changes between these formations

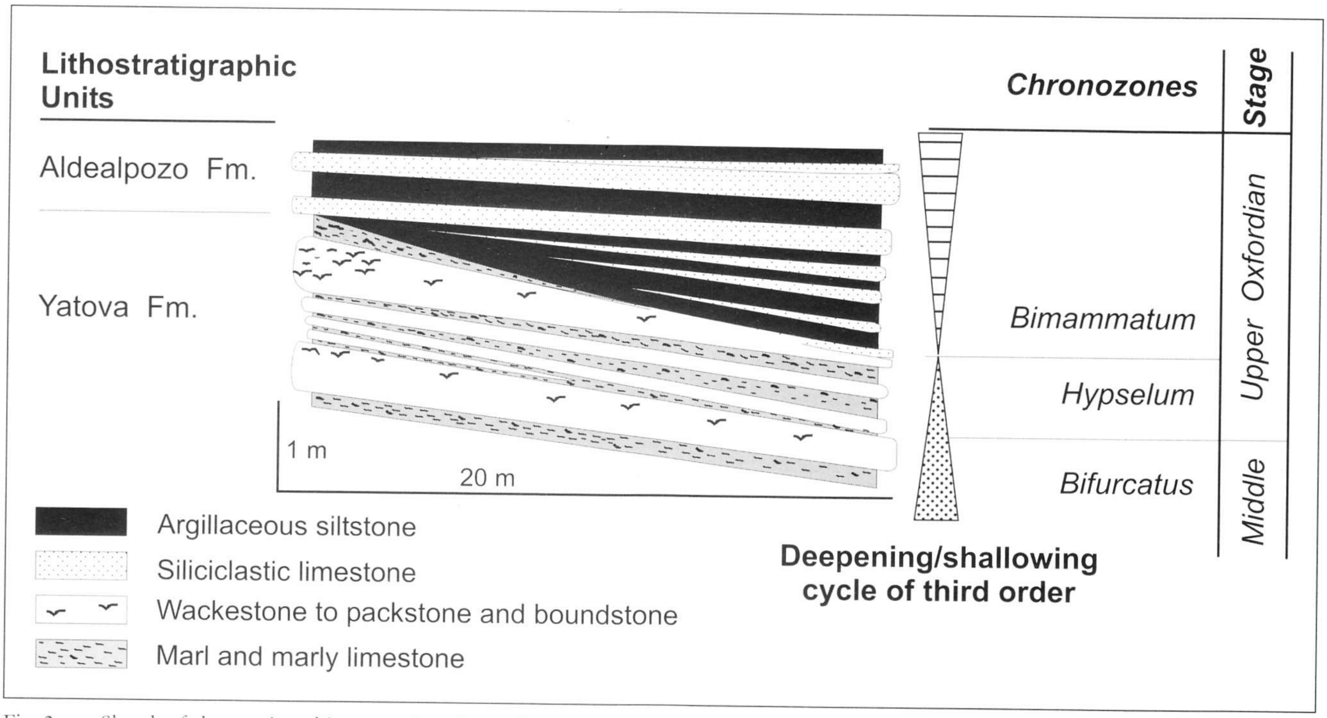


Fig. 2 - Sketch of the stratigraphic succession along a lateral extension of 20 m, as observed in one of the studied outcrops and shown in Fig. 3. This stratigraphic succession comprises a 3 m thick interval, from which the first 2 m correspond to the upper part of Yátova Formation and the uppermost metre belongs to the lower part of Aldealpozo Formation. This succession corresponds to the Bifurcatus (upper part of Middle Oxfordian), Hypselum and Bimammatum (Upper Oxfordian) chronozones. The boundary between these successive formations represents a gradual or a sudden facies change, associated with syndepositional palaeoreliefs developed during the Late Oxfordian. The highest stratigraphic interval of the Yátova Formation developed during the Hypselum Chronozone is composed of marly condensed deposits and represents a condensed section, according to the results of the present work. Upper Oxfordian deposits in this area belong to a single third order deepening/ shallowing environmental cycle. Deposits of the Yátova Formation represent the last phase, of advanced deepening conditions, within a deepening half-cycle. In contrast, deposits of the Aldealpozo Formation represent the first phase, of incipient shallowing conditions, within a shallowing half-cycle.

were normally associated with positive reliefs and build-ups, whilst gradual changes occurred in adjacent topographic depressions.

The uppermost deposits of the Yátova Formation represent an Oxfordian condensed section, according to the results of the present work. This highest stratigraphic interval, developed during the Hypselum Chronozone, is composed of marls and marly limestones, ranging from mudstone to packstone and boundstone. This condensed marly stratigraphic interval, generally 1 to 1.5 m thick,

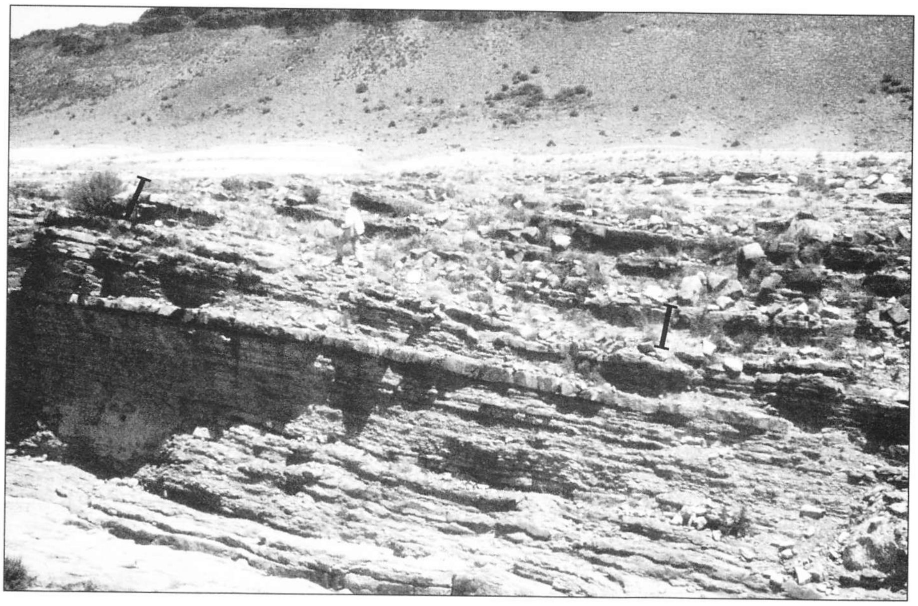


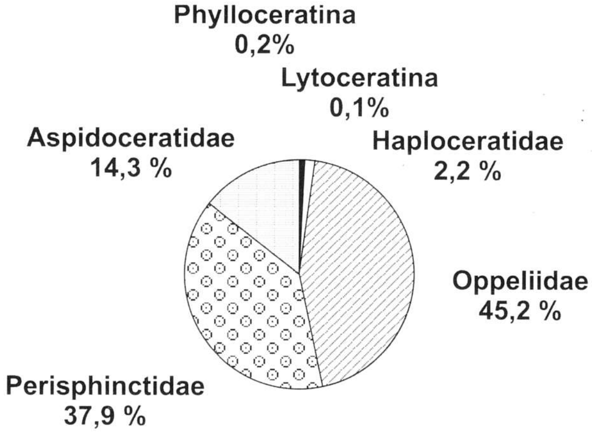
Fig. 3 - Outcrop view of the boundary between the Yátova and Aldealpozo formations, in one of the studied sections in the Ricla area. The two vertical bars on the picture, 1 to 1.5 m long, indicate the thickness of the Hypselum condensed section. The transition between these formations may be a gradual or a sudden facies change, associated with syndepositional palaeoreliefs developed during the Late Oxfordian. Height of section c. 10 m. Chronozones as in Fig. 2.

bears common sponges and ammonites. Also noteworthy is the local development of small sponge mud mounds, some few metres wide and less than 50 cm high. Limestone beds are generally 10 to 40 cm thick. Thickening and coarsening upwards sequences of metric thickness are common. Thinning and fining upwards sequences are scarce, generally developed between the sponge mounds. Hardground surfaces on the limestone beds, ferruginous crusts and glauconite grains are common. In contrast, hardground surfaces are not developed within marly intervals, but remobilization surfaces and reworked concretions are common, often capping the underlying argillaceous sediments. Macrofossils are abundant. Dish- or plate-shaped hexactinosan sponges are dominant, ranging in size from few millimetres to twenty centimetres. Thin tube-shaped sponges are scarce, and smaller in size. Macrofossils of other benthic groups, including terebratulid and rhynchonellid brachiopods, bivalves, gastropods, serpulids, bryozoans, crinoids and echinoids are, however, very scarce. Microbial crusts are scarcely developed. In comparison with Middle Oxfordian intervals, the studied deposits show lower diversity of the benthic fauna, and scarcer development of sponge bioherms and microbial crusts. Bioturbation textures are common within the marly intervals and in the upper part of the limestone beds.

Among the diverse deposits composing this Hypselum condensed section, limestone beds and marly intercalations present some opposite features. The lower surface of the limestone beds is sharp, erosional or nongradational. Gradual size-increase or inverse grading of bioclasts is more common than gradual size-reduction or normal grading, in these beds. Limestones generally do not contain bioclasts displaying imbricated grouping, long axes parallel to bedding surface or preferential azimuthal-orientation. The upper boundary of limestone beds is sharp or burrowed, and they grade into the overlying marly intervals. In contrast, gradual size-reduction or normal grading of bioclasts is more common than gradual size-increase or inverse grading, in the marly intervals (Fig. 4). Marls and marly limestones contain common reelaborated ammonites and sponges, displaying imbricated grouping, long axes parallel to bedding surface and preferential azimuthal-orientation. However, burrowing is not evenly distributed throughout the limestone beds, as it is in marly intervals, but concentrated in the last few centimetres of each bed.

According to the stratigraphical and palaeontological data mentioned, Oxfordian deposits of the Ricla area are interpreted as developed in an open marine, moderately deep carbonate platform, showing uniform low-energy conditions with extremely reduced carbonate and terrigenous background sedimentation, during the late Bifurcatus to Hypselum zones (latest Middle to earliest Late Oxfordian). Limestone beds show several features indicative of rapid deposition. Fining-upwards or normal grading and erosive or sharp base are interpreted as a result of sediment gravity flows, most probably storm deposits, during event sedimentation episodes. In contrast, marly intervals are the result of background sedimentation time intervals, which may be due to winnowing action or bypassing of sediments on the sea bottom as well as to sedimentary starving. Marls and marly limestones, showing inverse grading, and limestone beds showing gradational upper boundary and gradual-size increase represent environments of lowest rates of sedimentation in moderately deep areas. In comparison with Middle Oxfordian intervals, the lower diversity of the benthic fauna, and scarcer development of sponge bioherms and microbial crusts, are palaeobiological criteria suggesting deeper palaeoenvironmental conditions during the Hypselum Chrono-

Fig. 4 - Close-up view of the sharp boundary between Yátova and Aldealpozo formations (indicated by the arrow). The highest Hypselum marl interval contains common reelaborated ammonites and sponges, displaying gradual size-reduction or normal grading, imbricated grouping, long axes parallel to bedding surface and preferential azimuthal-orientation. These marly intervals represent condensed deposits developed in marine environments of lowest rates of sedimentation in moderately deep areas. Bar for scale is 22 cm long.



	Specimens:
Order Ammonoidea Zittell, 1884	894
Suborder Phylloceratina Zittell, 1884	
Phylloceras	1
Holcophylloceras	1
Suborder Lytoceratina Hyatt, 1889	
Lytoceras	1
Suborder Ammonitina Hyatt, 1889	
Superfamily Haplocerataceae Zittel, 1884	
Family Haploceratidae Zittel, 1884	
Lissoceratoides [M]	3
Taramelliceras [M]	14
Proscaphites [M]	3
Family Oppelliidae Douvillé, 1890	
Trimarginites [M+m]	17
Ochetoceras [M+m]	203
Glochiceras [m]	184
Superfamily Perisphinctaceae Steinmann, 1890	
Family Perisphinctidae Steinmann, 1890	
Ampthillia [m]	3
Perisphinctes [M+m]	43
Passendorferia [M+m]	89
Orthosphinctes [M+m]	203
Geyssantia [M+m]	1
Family Aspidoceratidae Zittel, 1895	
Euaspidoceras [M]	71
Paraspidoceras [M]	4
Neaspidoceras [M]	1
Epipeltoceras [m]	50
Mirosphinctes [m]	2

Fig. 5 - Relative abundance of different ammonoid groups from the Hypselum condensed section in Ricla area.

zone. However, among other palaeontological criteria, taphonomic analysis of ammonoids supply more relevant criteria to recognize condensed deposits of an advanced stage of deepening, within a 3rd order deepening/shallowing cycle, in the Aragonese platform, during the late Bifurcatus to Hypselum zones.

Taphonomic analysis of ammonoids

Oxfordian ammonite assemblages are composed of Sub-Mediterranean taxa. Over 900 ammonite specimens have been collected from the upper Bifurcatus and Hypselum chronozones. Two phylloceratids and one lytoceratid have been found, which respectively represent 0.2 and 0.1% of the whole ammonoids. Haploceratidae (2.2%) are also scarce. Aspidoceratidae (14.3%) are common. Perisphinctidae (37.9 %) and Oppeliidae (45.2%) are dominant (Fig. 5).

The fossiliferous uppermost deposits of the Yátova Formation, representing an Oxfordian condensed section and developed during the Hypselum Chronozone, allow a detailed analysis of their preservational features. However, the overlying deposits of the Aldealpozo Formation contain very scarce ammonites, which precludes a comparative study of these successive taphofacies. As shown in Fig. 6, taking into account the model proposed by Fernández-López (1997 a and b), the taphonomic analysis of these ammonite assemblages includes over 47 preservational features mainly related to biostratinomic and synsedimentary modifications. Ammonite remains are dominated by shells in the Hypselum condensed interval with aptychi very scarce and less than 1%. Ammonite fossils are commonly recorded throughout the studied sections, but they rarely exceed 45 mm diameter (less than 10%). The degree of ammonite packing (estimated by the difference between the number of specimens and the number of fossiliferous levels divided by the number of fossiliferous levels) and the ammonite stratigraphical persistence (proportion of fossiliferous levels) display high values.

Biostratinomic processes of biodegradation-decomposition are generally intense in this marly facies, as ammonite shells usually lose the soft-parts, aptychus and periostracum before burial. Siphuncular tubes are generally disarticulated due to intense and long-lasting biostratinomic processes of biodegradation and dissolution.

Mechanisms of taphonomic alteration by encrustation show low incidence. Pisolitic, oncolitic or half-lump ammonites have not been observed. However, some reworked concretions and concretionary internal moulds (less than 25% of the whole) are partially encrusted by a few remains of epilithic organisms as well as local micritic crusts or microbial stromatolitic laminae. Among encrusting organisms, serpulids are the most common, followed by bryozoans, foraminifera, bivalves, brachiopods, sponges and crinoids (Figs. 7 and 8). Encrustation by organisms generally affects the surface of concretionary internal moulds, being probably associated with reelaboration processes. Intrathalamous encrusting of shells, i. e. encrustation of the inner surface of the body chamber, is very unusual and preferentially developed on the largest resedimented shells.

Sedimentary infill of the ammonite shells is complete up to the innermost whorls (Fig. 9). Internal moulds

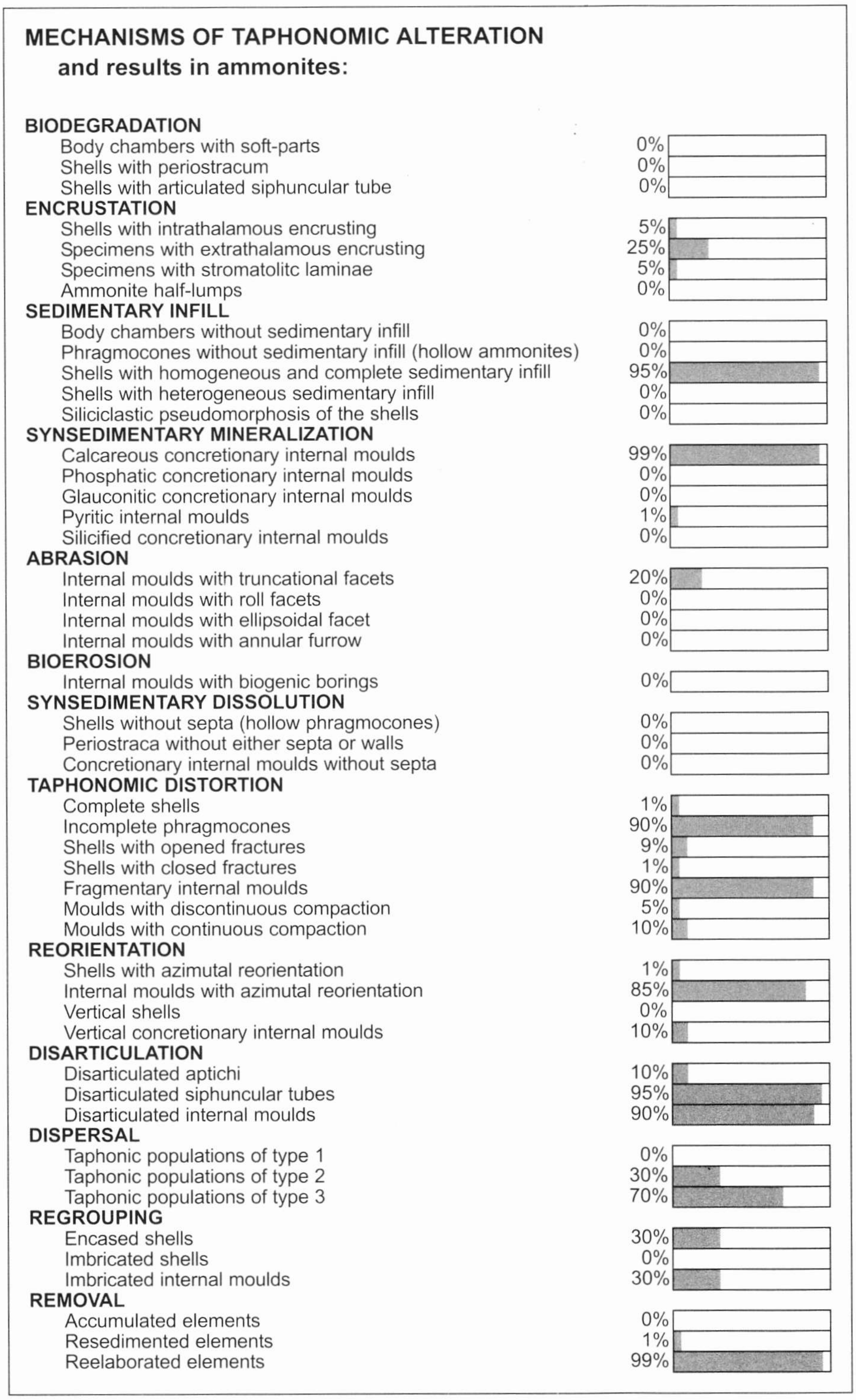


Fig. 6 - Mechanisms of taphonomic alteration and results leading to the development of the ammonites included in condensed deposits from the Hypselum Chronozone in Ricla area.

of shells completely filled with homogeneous sediments are predominant. The sedimentary infill is similar in petrological composition and texture to the sedimentary matrix, but it is separated from the matrix by a sharp and erosive structural discontinuity. Phragmocones without sedimentary infill (i.e., hollow ammonites) or shells with heterogeneous sedimentary infill are very scarce. Body chambers without sedimentary infill and siliciclastic pseudomorphosis of the shells are virtually absent. This abundance of complete sedimentary internal moulds of ammonite shells is indicative of both low rate of sedimentation and low rate of accumulation of sediment during biostratinomic processes.

Processes of early mineralization are intense. Ammonoids are generally preserved as homogenous concretionary calcareous internal moulds of reelaborated elements. Complete concretionary internal moulds of the body chamber and phragmocone, indicative of a low rate

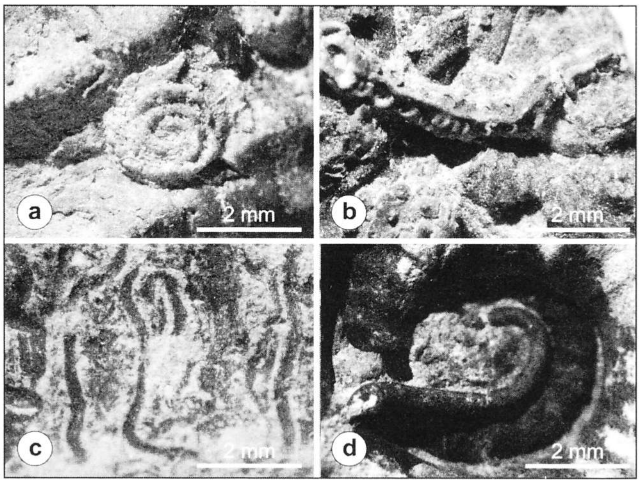


Fig. 7 - Encrusting serpulids growing on the surface of ammonite reelaborated internal moulds. a - Ri876. b - Ri626. c - Ri611. d - Ri696.

of sediment accumulation, are abundant. Pyritic internal moulds are formed only locally (less than 1%). Phosphatic, glauconitic or silicified concretionary internal moulds are also very scarce or absent.

Traces of abrasion and bioerosion on shells and internal moulds are very scarce or absent. Internal moulds with roll facets, ellipsoidal facets, annular furrow or biogenic borings are virtually absent. However, truncational facets apparently occur in some ammonites (less than 20%, Figs. 10 and 11). An abraded side seems to occur preferentially among the smallest-size ammonites. This worn surface is at least partly due to the grater friability of the more argillaceous upper portion of the concretionary internal moulds during the processes of taphonomic reelaboration.

Concretionary internal moulds showing calcitic septa of the phragmocone are the dominant fossils. Hollow phragmocones (i.e. shells without septa; cf.

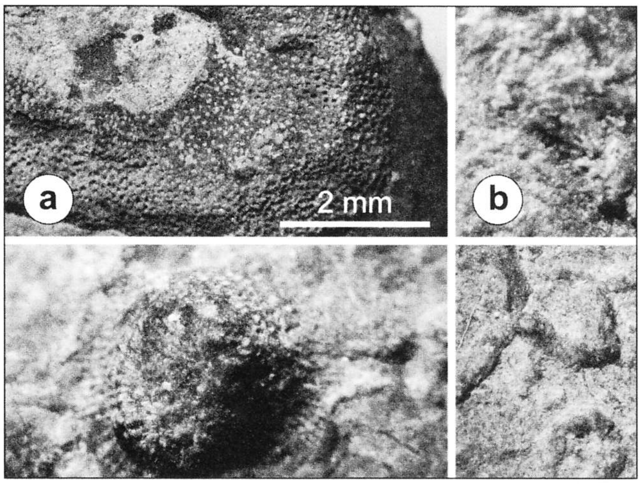


Fig. 8 - Encrusting bryozoans on the surface of ammonite reelaborated internal moulds. a - Ri298. b - Ri274. c - Ri674. d - Ri169.

Seilacher et al. 1976; Maeda & Seilacher 1996) are very scarce, and they are usually compressed by increasing sedimentary loading during diagenesis. Septa of hollow phragmocones may have disappeared by early dissolution, whilst the walls of the shells still persist, giving rise to compressed elements showing discontinuous deformation by gravitational diagenetic compaction. Concretionary internal moulds without septa, indicative of synsedimentary dissolution of septa (Fernández-López 1997a, 2000), are absent. No signs of synsedimentary dissolution of the aragonitic remains have been recognized. Aragonitic septa and shells have been dissolved during later diagenetic processes. Moldic porosity resulting from dissolution processes has been partially filled by spar cement in these deposits. In turn, recent geopetal cements of white caliche are also common, filling the lower voids in the stratification sense of the moldic porosity (Fig. 9).

The composition of ammonite assemblages shows a high proportion of incomplete phragmocones (up to 90%) and scarce complete shells. Fragmented specimens of resedimented shells or reelaborated internal moulds are abundant, but generally bearing no signs of rounding, encrustation or bioerosion, due to low turbulence near the water/sediment surface. Reelaborated internal moulds are predominant, often showing disarticulation surfaces along septa with sharp margins (Fig. 12), and they usually display no traces of gravitational deformation by diagenetic compaction.

Taphonic populations of type 3 and 2 are dominant (Fig. 13). Taphonic populations of type 1 are composed of monospecific shells showing unimodal and asymmetric distribution of size-frequencies, with positive skew (Fernández-López 1997a, b). These populations have predominant juveniles and high proportion of microconchs, whilst adults 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. Taphonic populations of type 3 are composed of polyspecific shells showing uni- or polymodal and asymmetric distribution of size-frequencies, with negative skew. Shells of juveniles are absent, adults are predominant, and microconchs are very scarce in taphonic populations of this last type. Although the concentration of ammonite shells tends to be higher than in the underlying Middle Oxfordian deposits, taphonic populations of type 1, indicative of eudemic taxa and autochthonous biogenic production, showing no signs of sorting by necroplanktic drift, have not been recognized (cf. Callomon 1985; Morton 1988; Fernández-López & Meléndez 1996). Specimens with body chamber which represent taphonic populations of type 2, located in the second or third interval of the distribution diagram of size-frequencies portrayed in Fig.

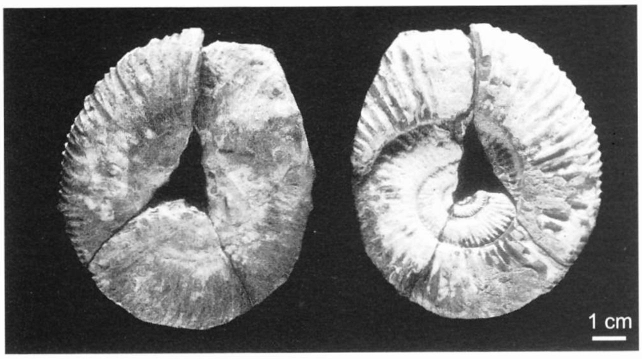


Fig. 9 - Reelaborated phragmocone, maintaining the original costulation on both sides. Recent cement of white caliche occurs on the right side. *Perisphinctes* sp., Middle Oxfordian, specimen Ri578.

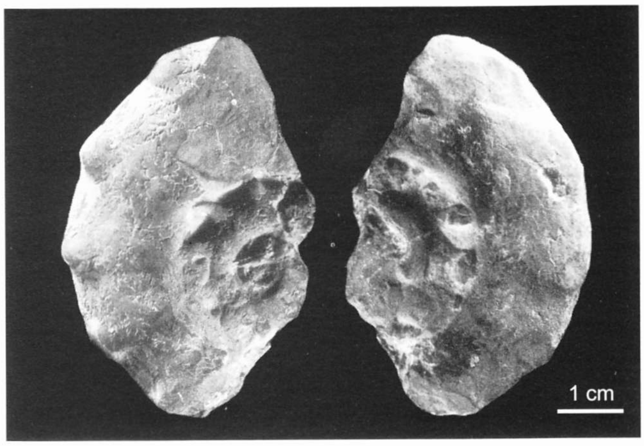


Fig. 11 - Reelaborated phragmocone, showing a surficial truncational facet on the right side. *Paraspidoceras* sp., Upper Oxfordian, specimen Ri004.

13, belong to genera *Trimarginites*, *Glochiceras*, *Euaspidoceras*, and *Epipeltoceras*. Ammonoid taxa represented by predominant adult shells, and by taphonic populations of type 3, correspond to genera: *Lissoceras*, *Taramelliceras*, *Ochetoceras*, *Perisphinctes*, *Passendorferia*, *Orthosphinctes*, and *Paraspidoceras*, as well as *Proscaphites*, *Ampthillia*, *Mirosphinctes*, *Geyssantia*, *Neaspidoceras*, *Lytoceras*, *Holcophylloceras*, and *Phylloceras*.

Ammonites normally appear scattered in the marly deposits, showing no pattern of imbricated or encased regrouping. However, concretionary internal moulds and shells can locally be regrouped and imbricated or azimuthally reoriented. Ammonites with their long axes parallel to bedding surface are dominant in marly intervals. Time intervals with predominance of background sedimentation may give rise to fining or coarsening-upwards recorded associations included in fine grained sediments, showing no evidence of basal stratigraphic discontinuity. In contrast, events of turbulence lead to fining-upwards recorded associations included in limestone beds, with an erosive base, which do not display imbricated grouping, long axes parallel to bedding surface or preferential azimuthal-orientation. After turbulence events and probably storm processes, regrouping of ammonites, by winnowing and bioturbation processes, may be particularly strong at the upper portion of bioclastic deposits.

In the Hypselum condensed interval, ammonite associations are dominated by reworked elements (i.e., reelaborated and resedimented elements sensu Fernández-López 1991). Accumulated elements, showing no evidence of removal after laying on the sea-bottom, are absent. Reelaborated internal moulds (i.e., exhumed and displaced before their final burial) are dominant (up to 98%, Fig. 6). Resedimented shells, displaced on the sea-bottom before their initial burial, are locally present. 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%. However, the degree of taphonomic condensation (i.e., mixture of fossils of different age or different chronostratigraphic units) reaches very low to zero values in all cases. In the Hypselum condensed interval,

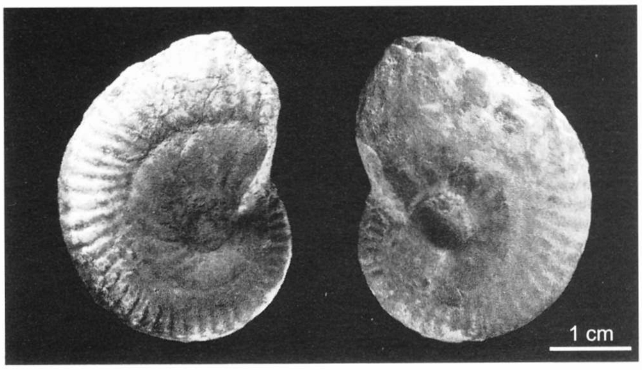


Fig. 10 - Reelaborated phragmocone, showing a surficial truncational facet on the right side. *Ochetoceras* sp., Upper Oxfordian, specimen Ri142.

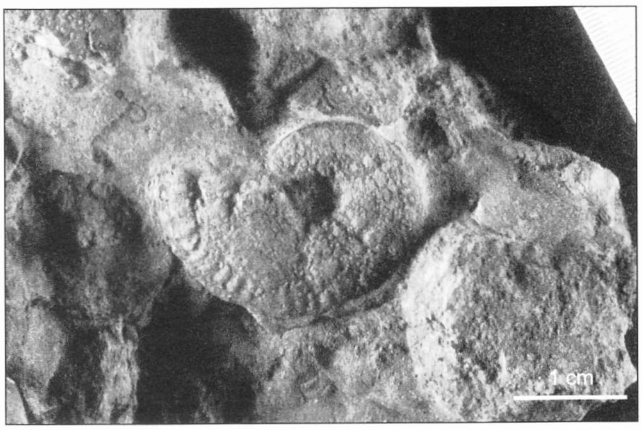


Fig. 12 - Reelaborated phragmocone, showing a disarticulation surface of the phragmocone along septa with sharp margins. *Ochetoceras* sp., Upper Oxfordian. Scale in cm.

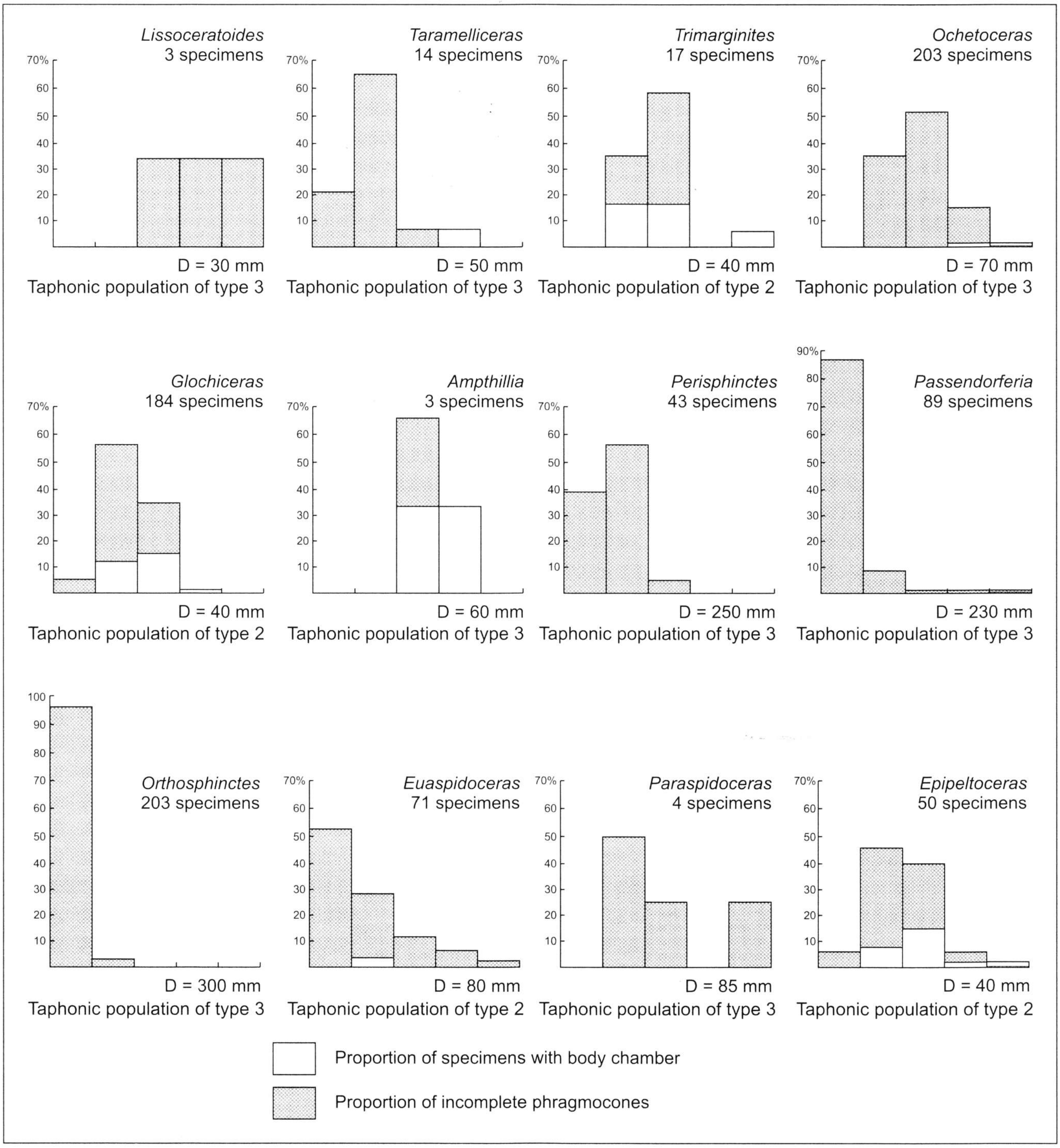


Fig. 13 - Size-frequency distributions of the ammonite genera, from the Hypselum condensed interval, indicating the type of taphonic population.

ammonite mixed assemblages composed of specimens representing several biozones or biohorizons in a single bed or marly intercalation have not been identified.

Taphonomic interpretation of ammonoids

Sediments of these two facies, marls and limestones, are interpreted as having been deposited in an open sea, below or near wave base, taking into account the occurrence of storm deposition events. The presence of reelaborated ammonites implies that some form of current flow or winnowing affected the burial of concretionary internal moulds. Currents were slight, but concretionary internal moulds of ammonites were disarticulated and azimuthally reoriented on softgrounds through reelaboration (i.e., exhumation and displacement on the sea-bottom, before their final burial). The formation of such calcareous concretions must have taken place either on the sea-floor contemporaneously with the sedimentary process or else within the sediment during the early diagenesis. In this hemipelagic environment, time intervals of lower rates of sedimentation and accumulation favoured a higher degree of bioturbation and reworking of ammonite shells. 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-scale. However, reelaborated ammonites and reworked concretions included in some beds, showing the base sharper than the top, could be mobilised by storm processes.

Among the numerous taphonomic features of the described associations, the following are indicative criteria of deep marine environments, associated with sedimentary starving: the occurrence of high concentrations of reelaborated ammonites, including taphonic populations of type 2, phragmocones completely filled with sediment, and homogeneous concretionary internal moulds, bearing no signs of abrasion, bioerosion or dense encrusting by organisms (such as serpulids, bryozoans or oysters). The occurrence of these ammonite recorded associations confirms the development of an advanced deepening phase, within a 3rd order deepening/shallowing cycle, in the Aragonese platform, during the late Bifurcatus to Hypselum zones.

Conclusions

In the Ricla area, at the top of the Yátova Formation, grey-reddish wackestone limestones locally grade into yellow-green siliciclastic limestones of the Aldealpozo Formation. These changes of facies between the two successive formations are associated with syndepositional palaeoreliefs developed during the Late Oxfordian. Sharp changes between these formations were normally developed associated with positive reliefs and build-ups, whilst gradual changes occurred in adjacent topographic depressions.

The uppermost deposits of the Yátova Formation represent an Oxfordian condensed section. Marls and marly limestones, showing inverse grading, and limestone beds showing gradational upper boundary and gradual size-increase represent environments of lowest rates of sedimentation in moderately deep areas. Upper Oxfordian deposits in this area belong to a single third order deepening/shallowing environmental cycle. Deposits of the Yátova Formation represent the last phase, of advanced deepening conditions, within a deepening half-cycle. In contrast, deposits of the Aldealpozo Formation represent the first phase, of incipient shallowing conditions, within a shallowing half-cycle.

Acknowledgements. The authors wish to express their acknowledgement to doctors L. Martire and N. Morton for the critical reading of the manuscript and suggestions made. This work has been funded by the BTE2000-1148 (CICYT-CSIC) Project.

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