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Taphonomy of Ammonite Condensed Associations – Jurassic Examples from Carbonate Platforms of Iberia

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Spain
Jurassic
Cephalopods
Ammonoidea
Condensation
Sequence Stratigraphy

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Taphonomie kondensierter Ammoniten-Assoziationen – Beispiele von jurassischen Kalkplattformen Iberias

Zusammenfassung

Kondensierte Assoziationen von Ammoniten auf epikontinentalen Karbonatplattformen zeigen bei Ablagerung unter Seichtwasserbedingungen verglichen mit Ablagerungen unter Tiefwasserbedingungen ein unterschiedliches Erhaltungsbild. Die Erfassung der Typen kondensierter Assoziationen ist bei der Analyse der Beziehung zwischen kondensierten Profilen und stratigraphischen Zyklen von Bedeutung. Assoziationen, die in großer Tiefe kondensiert sind, sind gute Indikatoren für relativen Meeresspiegelanstieg und transgressive Trends. Dagegen sind Seichtwasserassoziationen Anzeiger relativer Meeresspiegelabsenkungen und regressiver Trends.

Abstract

Condensed associations of ammonites developed in carbonate epicontinental platforms show different preservational features in expanded deposits of shallow environments in relation to condensed deposits of deep environments. Recognizing these types of condensed associations is important when analysing the relationship between condensed sections and stratigraphical cycles. Deep condensed associations are a very good indicator of relative sea-level rises and transgressive trends. In contrast, shallow condensed associations provide an indicator of relative sea-level falls and regressive trends.

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1. Introduction

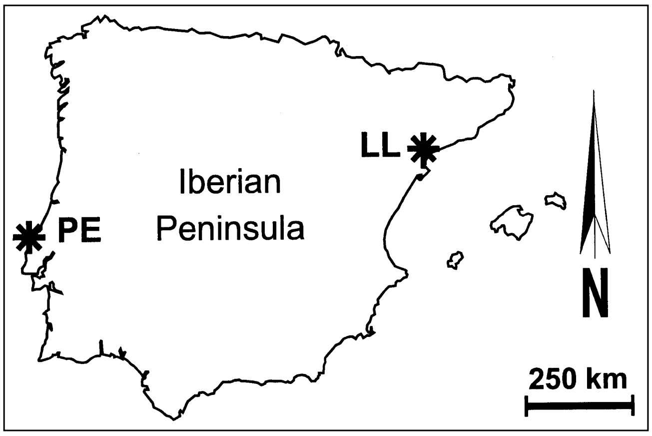
In basinal environments, condensed sections are thin stratigraphic units comprising pelagic to hemipelagic deposits characterized by very low sedimentation rates. These units are geographically most extensive at the time of maximum regional transgression of the shoreline. Consequently, episodes with very low sedimentation rates are generally related to a relative sea-level rise and abrupt transgression of the shoreline. These condensed sections may be identified in the field on the basis of sedimentological evidence. They are associated with marine hiatuses, occurring both as thin but continuous zones of burrowed lithified beds and as marine hard-grounds. They may also be characterized by abundant and diverse planktic and benthic assemblages, authigenic minerals (glauconite, phosphate and siderite) and organic matter (LOUTIT et al., 1988; SARG, 1988; BOMBARDIERE & GORIN, 1998).

In shallow environments of carbonate epicontinental platforms, however, condensed sections are developed at the time of maximum regional regression of the shoreline. Consequently, condensed sections or episodes with very low sedimentation rates are not diagnostic criteria of relative sea-level rise and transgression in shallow carbonate epicontinental platforms. In order to distinguish condensed sections of these two palaeogeographic settings, a clear distinction should be made between rate of sedimentation and rate of sediment accumulation, or between stratigraphic condensation and sedimentary condensation (GÓMEZ & FERNÁNDEZ-LÓPEZ, 1994). The rate of sedimentation, or the degree of stratigraphic condensation, of a stratigraphic interval is calculated by dividing the thickness of sediment by the total time interval including the gaps. In contrast, the rate of sediment accumulation, or the degree of sedimentary condensation, of a stratigraphic interval can be estimated by dividing the thickness of sediment by the time interval of positive net sedimentation. The distinction between these concepts allows one to predict that the degree of sedimentary and stratigraphic condensation will be higher towards the deep portions of the platforms, whereas the stratigraphic condensation processes without sedimentary condensation will show the maximum intensity and frequency in the shallowest portions of the platforms. Episodes of relative sea-level rise produce condensed sections composed by condensed deposits. In contrast, episodes of relative sea-level fall produce condensed sections composed by expanded deposits (e.g., tempestites) in shallow carbonate epicontinental platforms.

From a palaeontological point of view, very little work has been done on the recognition of the preservational features of condensed associations included in condensed sections from deep to shallow environments. Ammonites have been traditionally used in dating and chronocorrelation of Mesozoic deposits. However, they can also be used in interpreting some features of the sedimentary palaeoenvironments. In particular, preservational features of ammonites can be a useful tool to recognize and distinguish condensed associations formed in separate palaeobathymetric conditions. Several cases of condensed associations of Jurassic ammonites formed in shallow environments (FERNÁNDEZ-LÓPEZ, 1997) and in deep environmental conditions (FERNÁNDEZ-LÓPEZ et al., 1999b) have been recognized in the Iberian Peninsula. The results of previous studies have provided information about the palaeogeographical conditions and the features of each one of these particular taphofacies. In the present work, the comparative analysis of several ammonite condensed associations developed in carbonate epicontinental platforms will be shown in order to yield taphonomic criteria to distinguish expanded deposits of shallow environments in relation to condensed deposits of deep environments.

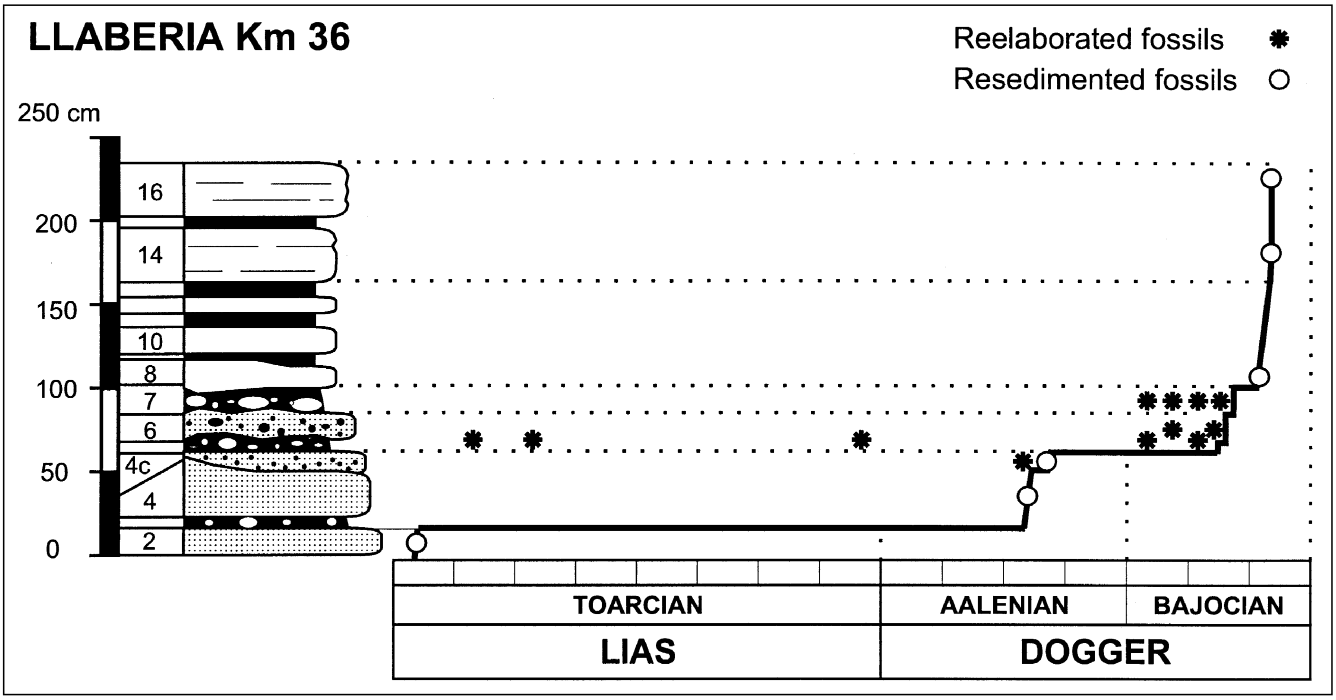
2. Jurassic Examples of Condensed Associations from Iberia

The Jurassic examples presented in this paper provide a data set that highlights the differential preservational features of the ammonite condensed associations developed in shallow environments in relation to deep environments of carbonate platform: from the Lower/Middle Jurassic transition in the Catalan Basin and from the Lower Pliensbachian lumpy limestones in the Lusitanian Basin (Text-Fig. 1).



Text-Fig. 1.
Location map of mentioned outcrops in the Iberian Peninsula – Llaberia (LL) in the Catalan Basin and Peniche (PE) in the Lusitanian Basin.

The Lower/Middle Jurassic transition in the Catalan Basin contains many examples of ammonite condensed associations developed in shallow environments of carbonate epicontinental platform (FERNÁNDEZ-LÓPEZ et al., 1998, 1999a). The stratigraphic successions of the Lower/Middle Jurassic transition observed in two outcrops (Llaberia km 36 and Barranco de Romullá) provide the best examples of this basin of condensed sections developed in very shallow environmental conditions. These condensed sections span the uppermost portion of the Barahona Formation and the lower portion of the San Blai Formation (Text-Fig. 2). The Toarcian, Aalenian and Lower Bajocian are represented by a thickness lower than 50 cm. Deposits of this interval consist of fossiliferous, glauconitic, thin limestones (5–30 cm) interbedded with thinner bioclastic marls, containing ferruginous and phosphatic ooids. Limestone beds comprise wackestone to packstone with recrystallized bioclasts (ammonoids, bivalves, equinoderms, brachiopods, belemnites, gastropods, sponges, serpulids, bryozoans, foraminifers, ostracods and algae). *Thalassinoides, Rhizocorallium* and *Zoophycos* are common. Deposits of this facies exhibit high gamma ray counts and a high concentration of ammonites. Stratification surfaces are highly bored and represent time of nondeposition. Common hard-grounds and scarce lateral continuity of the beds in this stratigraphic interval provide indications of both a low stratigraphic completeness and



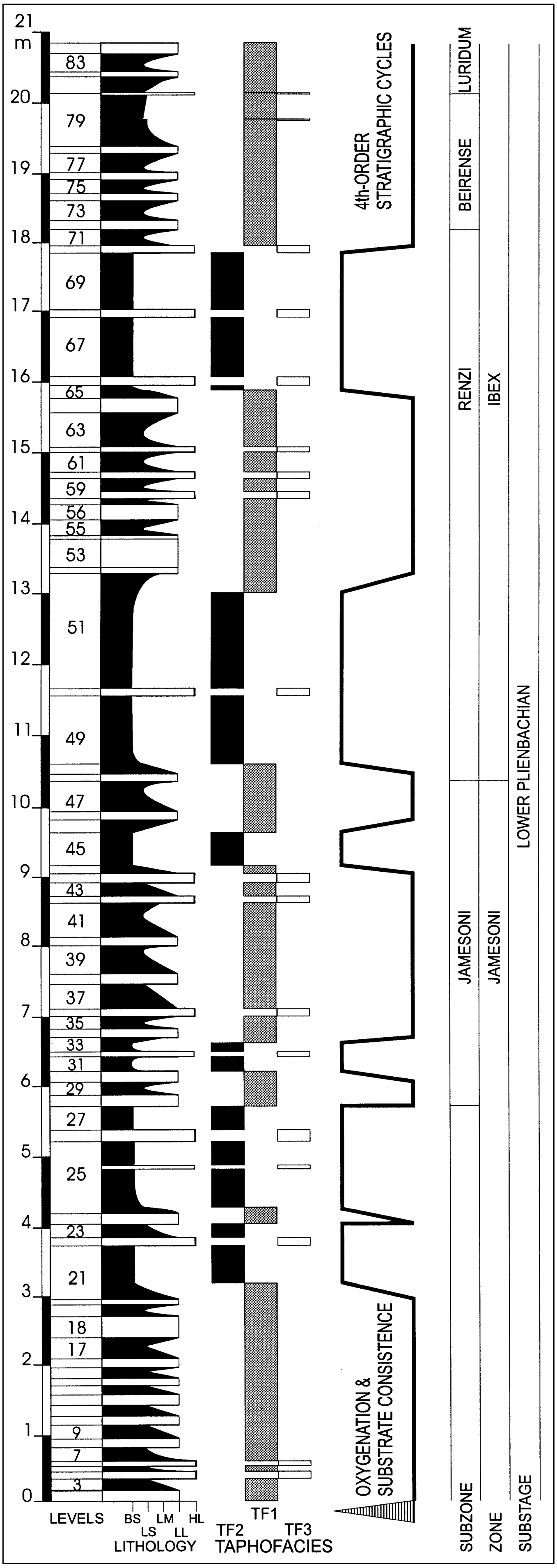
Text-Fig. 2.
Stratigraphic section of the Lower/Middle Jurassic transition observed in the outcrop of Barranco de Romullá (Llaberia, Catalan Basin).
Based on data from FERNÁNDEZ-LÓPEZ et al. (1996).

a low microstratigraphic acuity (sensu SCHINDEL, 1982). Chronostratigraphical completeness (i.e., proportion of recorded chronostratigraphical units; cf. SADLER, 1981) is lower to 40 % at zonal scale, although it can reach values of 100 % at stage scale. Stratigraphic successions in shallow epicontinental platforms are usually more incomplete than those formed in deep basins (cf. SCHINDEL, 1982; MCKINNEY, 1985; KOWALEWSKI, 1996). In shallow environments of carbonate epicontinental platforms, however, the fossil record may reach higher continuity than the stratigraphic record. Registratic gaps (i.e., gaps of the fossil record) identified by means of ammonites have generally smaller geochronological amplitude than the contemporary biostratigraphic gaps in shallow epicontinental platforms (FERNÁNDEZ-LÓPEZ, 1997). Deposits of these condensed sections are interpreted as having been deposited in very shallow environments of open marine platform, as a result of winnowing processes and bypass of fine-grained sediments.

The Lower Pliensbachian in the Lusitanian Basin is represented by a thickness of over several tens of metres. The Lower Pliensbachian lumpy limestones is a typical facies in the Lusitanian Basin (Text-Fig. 3). Deposits of this lithology have been included with the term “Vale das Fontes marls and marly limestones” in the lower portion of the Quiaios Formation (SOARES et al., 1993; SOARES & DUARTE, 1997). The lithofacies comprises thin limestones (5–40 cm), heavily bioturbated, alternating with thicker, less bioturbated, marly mudstones and bituminous, laminated shales. Limestone beds comprise mudstone to wackestone with 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. These facies exhibit high gamma ray counts (PARKINSON, 1996) and a high concentration of ammonites (ELMI et al., 1988). Since there are no indications of hard-grounds or large variations in sedimentation, these lumpy limestones provide both a high stratigraphic completeness and a high microstratigraphic acuity. Chronostratigraphical completeness reaches values of 100 % at zonal scale. The taphofacies of lumpy limestones and marly intervals with reelaborated ammonites (taphofacies of type 1 in Text-Fig. 3) represents the intervals of deposition when the rates of sedimentation and sediment accumulation reached the lowest values, and starvation reached a maximum (FERNÁNDEZ-LÓPEZ et al., 1999b). Sediments of this facies are interpreted as having been deposited in deep marine environments, below wave base, induced by sedimentary starving. However, the presence of reelaborated ammonites implies that some form of current flow or winnowing affected the burial of the concretionary internal moulds.

3. Taphonomy of Ammonite Condensed Associations

The examples from the Lower/Middle Jurassic transition in the Catalan Basin and from the Lower Pliensbachian lumpy limestones in the Lusitanian Basin show that low sedimentation rates, high concentrations of ammonites and high gamma ray counts may be associated with the development of condensed sections and ammonite condensed associations. These features, however, developed both in shallow carbonate epicontinental platforms during regressions or episodes of relative sea-level fall and in deep carbonate environments during transgressions or episodes of relative sea-level rise. Ammonite condensed associations from shallow environments can show similar preservational features in relation to those developed in deep environments, as a result of the low rate of sedimen-



Text-Fig. 3.
Lower Pliensbachian section at Peniche (Lusitanian Basin).
Biostratigraphical data are based on ammonites (MOUTERDE, 1955; PHELPS, 1985; DOMMERGUES, 1987; ELMI et al., 1988; DOMMERGUES et al., 1997).
BS = Bituminous shales; HL = Homogeneous limestones; LL = Lumpy limestones; LM = Lumpy, marly intervals; LS = Laminated mudstones; TF1 = Taphofacies of type 1: Lumpy limestones and marly intervals with reelaborated ammonites; TF2 = Taphofacies of type 2: Laminated marls and bituminous shales with resedimented ammonites; TF3 = Taphofacies of type 3: Homogeneous limestones with resedimented ammonites.

tation and associated processes such as: high degree of biodegradation-decomposition, synsedimentary mineralization and reelaboration (i.e., exhumation and displacement of the preserved elements, before the final burial; FERNÁNDEZ-LÓPEZ, 1991). During the development of condensed associations both in shallow and in deep environments, biostratinomic processes of biodegradation-decomposition are generally intense. Ammonite shells commonly lose the soft-parts and the aptychus, as well as the periostracum and connecting rings, before the final burial. Uncompressed, cemented, sedimentary internal moulds of the shell, indicative of low rate of sedimentation and early mineralization processes, are abundant. 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 in the whole assemblage) can reach 100 %.

However, ammonite condensed associations of shallow environments may show some distinctive preservational features with respect to those developed in deep environmental conditions, resulting from taphonomic processes such as: sedimentary infilling, encrustation, abrasion and bioerosion, reorientation, dispersal, regrouping and removal.

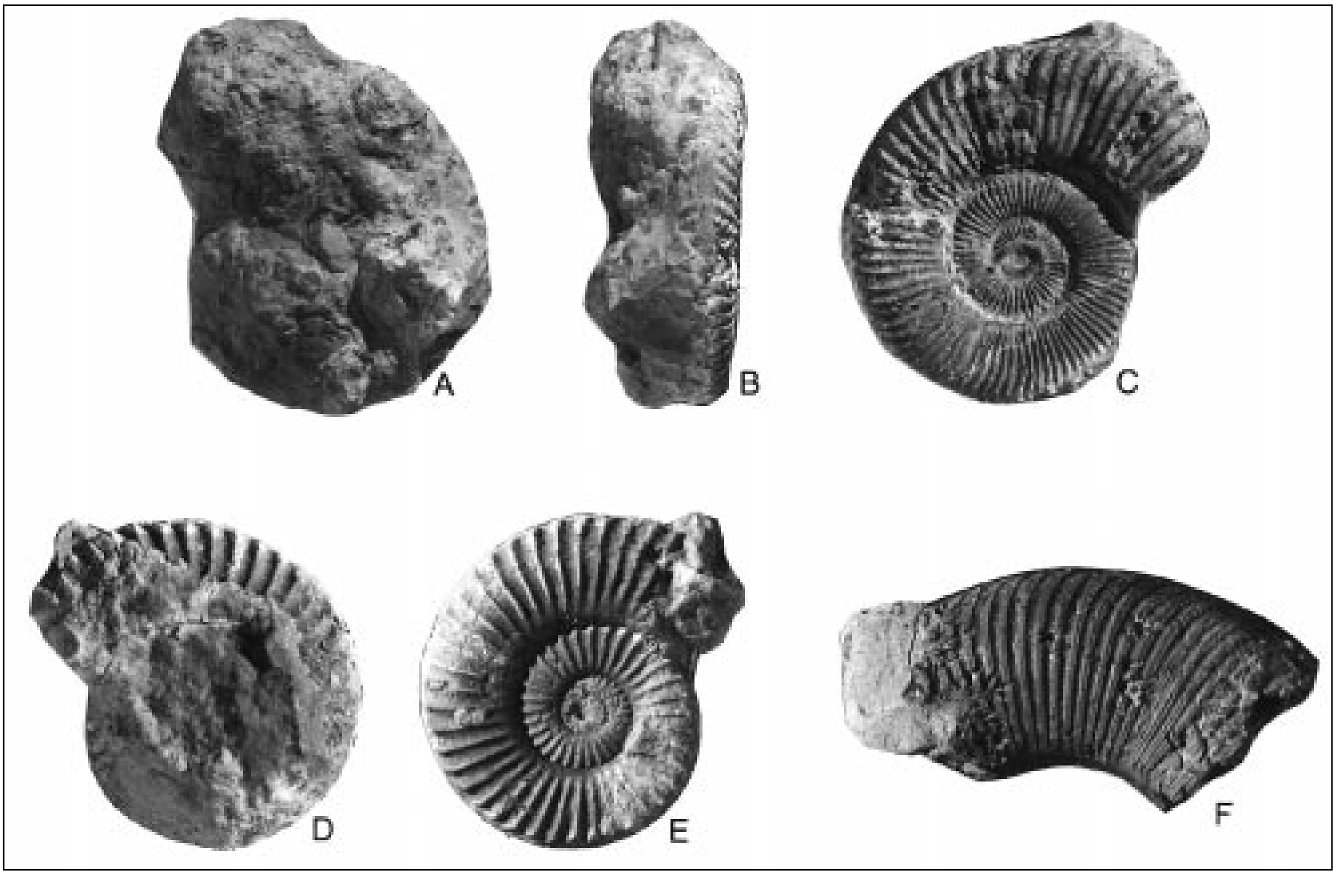
3.1. Sedimentary Infilling

In shallow environments, hollow ammonites (i.e., shells showing no sedimentary infill in the phragmocone) are abundant. These hollow ammonites are indicative of very rapid sedimentary infill and high rate of accumulation of sediment, although associated with episodes of low rate of sedimentation. Calcareous, phosphatic and glauconitic, concretionary internal moulds are common, showing evidence of iterative and heterogeneous sedimentary infill (FERNÁNDEZ-LÓPEZ, 2000, Fig. 4). Pyritic ammonites are scarce.

In deep environments, non-hollow ammonites (i.e., shells showing sedimentary infill in the phragmocone) are abundant. Non-hollow ammonites are indicative of very slow sedimentary infill, and low values in sedimentation and accumulation rates. Concretionary internal moulds are calcareous, showing no evidence of iterative and heterogeneous sedimentary infill. Pyritic internal moulds may locally be common, even as reelaborated elements (Text-Fig. 4F).

3.2. Encrustation

In shallow environments, reworked concretions, ammonite shells an d concretionary internal moulds of ammonites can be encrusted, developing oncolitic or pisolitic structures. Shells and concretionary internal moulds



Text-Fig. 4.
Ammonites (*Dayiceras* sp.) from Lower Pliensbachian lumpy limestones of the Lusitanian Basin.
A–E) Examples of ammonite half-lumps.
Specimens are preferentially encrusted by calcareous, stromatolitic laminae on a side. They are reelaborated, calcareous, concretionary internal moulds, maintaining their original volume and form as a result of rapid early cementation.
A–C) Specimen BR2; ×1, Brenha.
D–E) Specimen PE55/1; ×2, Peniche.
F) Reelaborated, pyritic internal mould, showing desarticulation surfaces.
Specimen PE67/1; ×2, Peniche.
Coll. SRFL (after FERNÁNDEZ-LÓPEZ et al., 1999b).

can present ferruginous and/or phosphatic, stromatolitic laminae, developed during the removal processes. Skeletal remains of calcareous, encrusting organisms (such as serpulids, bryozoans or oysters) are very common. Remains of extrathalamous encrusters are developed both on resedimented shells and concretionary internal moulds.

In deep environments, reworked concretions, shell fragments and concretionary internal moulds of ammonites can be encrusted, developing oncolitic cryptalgal structures. Shells and internal moulds can present calcareous, microbial laminae, developed during the removal processes. Concretionary, internal moulds show commonly calcareous microbial or stromatolitic laminae, developed preferentially on the exposed upper side during the exhumation and displacement processes. Ammonite half-lumps (a particular case of reelaborated ammonites) is a common preservational type (Text-Fig. 4A–E). However, skeletal remains of calcareous, encrusting organisms (such as serpulids, bryozoans or oysters) are very scarce. Remains of intrathalamous or extrathalamous serpulids are only developed on some resedimented shells of ammonites.

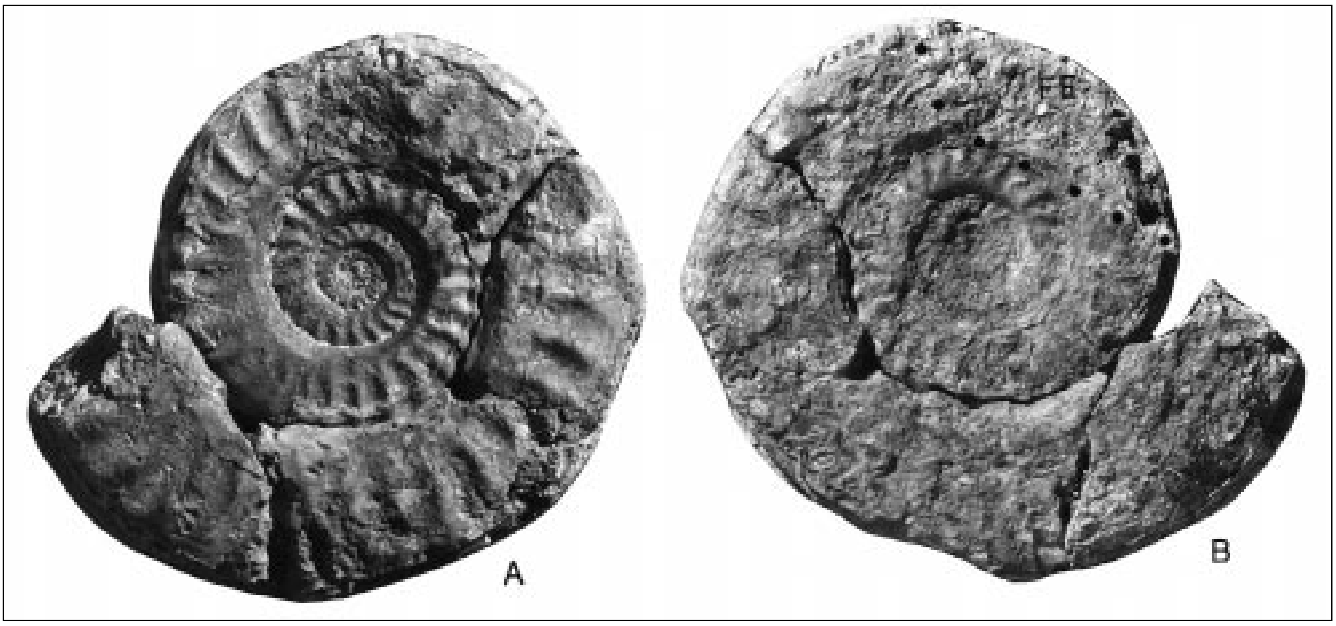
3.3. Abrasion and Bioerosion

In shallow environments, signs of abrasion and bioerosion on shells and internal moulds of ammonites are very common. Concretionary internal moulds show rounded and bioeroded disarticulation surfaces and fractures. Truncational abrasion facets and roll abrasion facets are common. More seldom, associated with hard and homogeneous substrates, concretionary internal moulds display ellipsoidal abrasion facets (Text-Fig. 5) and annular abrasion furrows. Fragmentary internal moulds show high values of roundness and sphericity as well as common biogenic borings. Centimetric borings are common.

In deep environments, signs of abrasion and bioerosion on shells and internal moulds are very scarce. Concretionary internal moulds can show disarticulation surfaces and fractures, but displaying sharp and acute margins. Associated with denudation sedimentary surfaces, internal moulds may show truncational abrasion facets. Fragmentary internal moulds can also occur, but bearing nosigns of rounding or bioerosion. Even millimetric biogenic borings are very scarce.

3.4. Reorientation

In shallow environments, ammonite shells and concretionary internal moulds are usually reorientated, with their long axes parallel to the bedding, at firm- and hardgrounds. Ammonite elements are usually reoriented, even when they are initially included in expanded sediments of channelled facies or deposited by events of turbulence. Ammonites included in tempestites show fining-upwards



Text-Fig. 5.
Hildoceras sublevisoni FUCINI.
Reelaborated, incomplete phragmocone.
The left side has been cleaned (A), carrying off a thin ferruginous crust composed by abundant serpulids. The original ferruginous crust, covering the concretionary internal mould and the ellipsoidal abrasion facet (FE) preferentially developed during reelaboration on the last third of the last preserved whorl, can be observed in the right side (B). This specimen was reelaborated from the Serpentinus Chronozone (Toarcian) and abraded in intertidal environmental conditions before their final burial in subtidal sediments corresponding to the Sauzei Chronozone (Bajocian; after FERNÁNDEZ-LÓPEZ et al., 1996).
Specimen 36L5/1, coll. SRFL; Llaberia km 36 (Catalan Basin); ×1.

grading associated with decreasing values of inclination but tempestites do not contain ammonites displaying preferential azimuthal orientation.

In deep environments, ammonite shells and concretionary internal moulds were reoriented at soft- and firmgrounds. In contrast, the occurrence of verticalized shells of ammonites may imply very soft- or soupy-grounds (WIGNALL, 1994). Currents were slight at condensed sediments, but some concretionary internal moulds of ammonites were disarticulated, moved and azimuthally reorientated on softgrounds by reelaboration (i.e., exhumation and displacement on the sea-bottom, before the final burial; FERNÁNDEZ-LÓPEZ, 1991; FERNÁNDEZ-LÓPEZ et al., 1999b).

3.5. Dispersal

In shallow environments, taphonic populations of ammonites are usually of type 3 or 2, those of type 1 being not represented (FERNÁNDEZ-LÓPEZ, 1995, Fig. 9). 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 juvenile individuals are absent, microconchs are very scarce and shells of adult individuals are predominant in taphonic populations of this type. 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.

In deep environments, condensed associations of ammonites usually contain taphonic population of type 1, 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. The occurrence of taphonic populations of type 1, showing no signs of sorting by necroplanktic drift or transport, is indicative of autochthonous biogenic production of shells (FERNÁNDEZ-LÓPEZ, 1991, 1997).

3.6. Regrouping

In shallow environments, ammonites show significant concentration changes throughout the successive stratigraphic intervals. The degree of packing of ammonite (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 of ammonites (proportion of fossiliferous levels) display low values. In these environments, ammonites show relevant changes in concentration throughout each bed or stratigraphic level. Ammonites are usually clustered, forming encased or imbricated patterns, even when they are included in sediments of channelled facies or deposited by events of turbulence. During the development of elementary sequences in outer environments, when decreases in the rate of sedimentation are associated with increases in the degree of turbulence, the skeletal remains show gradual increase in the concentration and in the degree of taphonomic heritage (i.e., proportion of reelaborated elements), and some taphonomic processes such as biodegradation-decomposition, encrustation, sedimentary infill, concretion, abrasion, bioerosion, fragmentation, reorientation, disarticulation, regrouping and removal of skeletal remains are intensified (FERNÁNDEZ-LÓPEZ, 1997, Fig. 2). Events of turbulence, such as storms, lead to the development of deposits formed under conditions of decreasing values of rate of sedimentation, rate of sediment accumulation and degree of water turbulence. Consequently, ammonites included in tempestites as bioclasts show fining-upwards grading associated with decreasing values of inclination and taphonomic heritage. Tempestites showing fining-upwards grading and erosive or sharp base do not contain ammonites displaying imbricated clustering or preferential azimuthal orientation (FERNÁNDEZ-LÓPEZ, 1997, Fig. 3).

In deep environments, ammonites commonly occur throughout the successive stratigraphic intervals. The degree of packing of ammonites and the stratigraphical persistence show high values. However, ammonite normally appear dispersed in the sediment, showing no pattern of imbricated or encased clustering.

3.7. Taphonomic Removal

In shallow environments, condensed associations of ammonites are dominated by reworked elements (i.e., reelaborated or resedimented elements sensu FERNÁNDEZ-LÓPEZ, 1991). Accumulated elements, showing no evidence of removal, are absent. Reelaborated internal moulds, exhumed and displaced before their final burial, may be dominant. Resedimented shells, displaced on the sea-bottom before their burial, are locally common. The degree of taphonomic condensation (i.e., mixture of fossils of different age or different chronostratigraphic units) reaches very high values in some cases. These condensed associations are formed by mixing of fossils of distinct zones or stages. Ammonite condensed associations composed of specimens representing several biozones or stages even older than the below bed or stratigraphic level have been identified (FERNÁNDEZ-LÓPEZ et al., 1996).

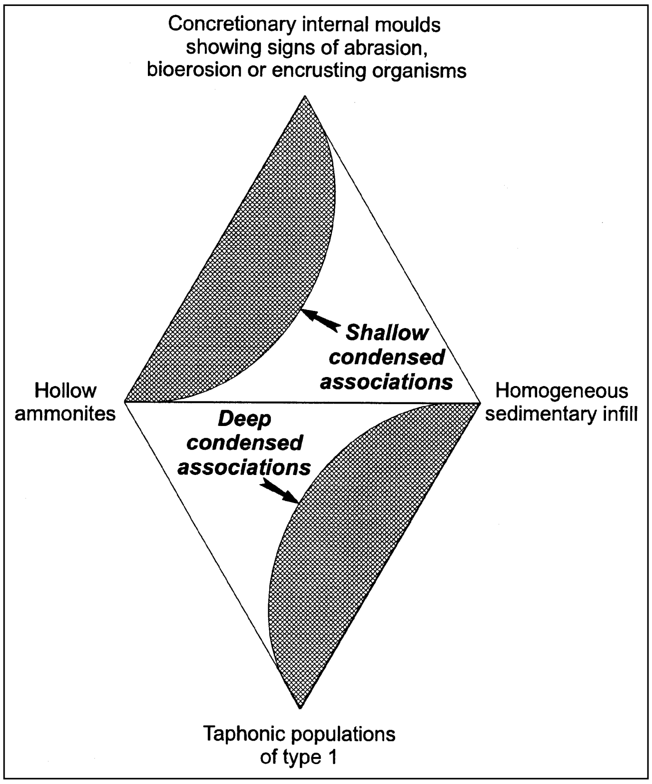
In deep environments, condensed associations of ammonites are also dominated by reworked elements. Accumulated elements are scarce. Reelaborated internal moulds may even be dominant. These condensed associations, however, are not formed by mixing of fossils of distinct zones. Ammonite condensed associations composed of specimens representing several biozones or biohorizons in a single bed have not been identified. The degree of taphonomic condensation in the ammonite recorded associations reaches very low to zero values in all cases.

4. Conclusions

The Jurassic examples from Iberia presented in this paper provide a data set that highlights the differential preservational features of the ammonite condensed associations of shallow environments in relation to those developed in deep environments of carbonate platform.

The occurrence of high concentrations of reelaborated ammonites, high gamma ray counts and low sedimentation rates may be associated with the development of condensed sections both in shallow carbonate epicontinental platforms during regressions or episodes of relative sea-level fall and in deep carbonate environments during transgressions or episodes of relative sea-level rise.

Deep condensed associations (Text-Fig. 6, lower portion) included in condensed deposits are characterized by the occurrence of taphonic population of type 1, composed by reelaborated, non-hollow ammonites and homogeneous concretionary internal moulds, bearing no signs of abrasion, bioerosion or encrusting organisms (such as serpulids, bryozoans or oysters). However, ammonite half-lumps may be a common preservational type. Deep condensed associations are a very good indicator of relative sea-level rises and transgressive trends. In contrast, shallow condensed associations (Text-Fig. 6, upper portion) included in expanded deposits are characterized by the dominance of taphonic population of type 3, composed by reelaborated, hollow ammonites and heterogeneous concretionary internal moulds, bearing signs of abrasion, bioerosion or encrusting organisms (such as serpulids, bryozoans or oysters). Shallow condensed associations provide an indicator of relative sea-level falls and regressive trends in carbonate epicontinental platforms.



Text-Fig. 6.
Reelaborated ammonites may be dominant components of the condensed associations developed in carbonate epicontinental platforms, both in deep and in shallow environments.
However, some preservational features (such as proportion of taphonic populations of type 1, hollow-ammonites, elements showing homogeneous sedimentary infill, and signs of abrasion, bioerosion and encrusting organisms) allow to distinguish condensed associations of deep environments in relation to those formed in shallow environments.

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References

BOMBARDIERE, L. & GORIN, G.E., 1998: Sedimentary organic matter in condensed sections from distal oxic environments: examples from the Mesozoic of SE France. – Sedimentology, **45**, 771–788.

DOMMERGUES, J.L., 1987: L'évolution chez les Ammonitina du Lias Moyen (Carixien, Domerien basal) en Europe occidentale. – Docum. Lab. Géol. Lyon, **98**, 1–297.

DOMMERGUES, J.L., MEISTER, Ch. & MOUTERDE, R., 1997: Pliensbachien. – Bull. Centre Rech. Elf Explor. Prod., Mém. **17**, 15–23.

ELMI, S., ROCHA, R.B. & MOUTERDE, R., 1988: Sédimentation pelagique et encroûtements cryptalgaires: les calcaires grumeleux du Carixien portugais. – Ciências da Terra (UNL), **9**, 69–90.

FERNÁNDEZ-LÓPEZ, S., 1991: Taphonomic concepts for a theoretical biochronology. – Revista Española de Paleontología, **6**, 37–49.

FERNÁNDEZ-LÓPEZ, S., 1995: Taphonomie et interprétation des paléoenvironnements. – In: M. GAYET & B. COURTINAT (ed.): First European Palaeontological Congress, Lyon 1993. Geobios, M.S., **18**, 137–154.

FERNÁNDEZ-LÓPEZ, S., 1997: Ammonites, taphonomic cycles and stratigraphic cycles in carbonate epicontinental platforms. – Cuadernos de Geología Ibérica, **23**, 95–136.

FERNÁNDEZ-LÓPEZ, S., 2000: Ammonite taphocycles in carbonate epicontinental platforms. – In: Jurassic V, Vancouver, Canada, TransTech Publ., Zurich, in litt.

FERNÁNDEZ-LÓPEZ, S., AURELL, M., GARCÍA JORAL, F., GÓMEZ, J.J., HENRIQUES, M.H.P., MARTINEZ, G., MELÉNDEZ, G. & SUÁREZ VEGA, L.C., 1996: El Jurásico Medio de la Cuenca Catalana: unidades litoestratigráficas y elementos paleogeográficos. – Revista Española de Paleontología, extraordinario, 122–139.

FERNÁNDEZ-LÓPEZ, S., GARCÍA JORAL, F., GÓMEZ, J.J., HENRIQUES, M.H.P. & MARTÍNEZ, G., 1998: La diferenciación paleogeográfica de la Cuenca Catalana al principio del Juréasico Medio. – Revista de la Sociedad Geológica de España, **11**, 3–22.

FERNÁNDEZ-LÓPEZ, S., AURELL, M., GARCÍA JORAL, F., GÓMEZ, J.J., HENRIQUES, M.H.P., MARTÍNEZ, G., MELÉNDEZ, G. & SUÁREZ VEGA, L.C., 1999a: La Plataforma de Tortosa (Cuenca Catalana) durante el Jurásico Medio: unidades litoestratigráficas, paleogeografía y ciclos ambientales. – Cuadernos de Geología Ibérica, **24** (1998), 185–221.

FERNÁNDEZ-LÓPEZ, S., DUARTE, L.V. & HENRIQUES, M.H.P., 1999b: Reelaborated ammonites as indicator of condensed deposits from deep marine environments. Case study from Lower Pliensbachian limestones of Portugal. – In: R.B. ROCHA, C.M. SILVA, P.S. CAETANO & J.C. KULLBERG (ed.): Links between fossils assemblages and sedimentary cycles and sequences, Workshop European Palaeontological Association, Lisboa, 42–46.

GÓMEZ, J.J. & FERNÁNDEZ-LÓPEZ, S., 1994: Condensation processes in shallow platforms. – Sedimentary Geology, **92**, 147–159.

KOWALEWSKI, M., 1996: Time-averaging, overcompleteness, and the geological record. – The Journal of Geology, **104**, 317–326.

LOUTIT, T.S., HARDENBOL, J., VAIL, P.R. & BAUM, G.R., 1988: Condensed sections: the key to age determination and correlation of continental margin sequences. – SEPM Special Publications, **42**, 183–213.

MCKINNEY, M.L., 1985: Distinguishing patterns of evolution from patterns of deposition. – Journal of Paleontology, 59, 561–567.

MOUTERDE, R., 1955: Le Lias de Peniche. – Comun. Serv. Geol. Portugal, **36**, 87–115.

PARKINSON, D.N., 1996: Gamma-ray spectrometry as a tool for stratigraphical interpretation: examples from the western European Lower Jurassic. – In: S.P. HESSELBO & D.N. PARKINSON (ed.): Sequence Stratigraphy in British Geology, Geological Soc. Spec. Publ., **103**, 231–255.

PHELPS, R., 1985: A refined ammonite biostratigraphy for the Middle and Upper Carixian (Ibex and Davoei zones, Lower Jurassic) in North-West Europe and stratigraphical details of the Carixian-Domerian boundary. – Geobios, **18**, 321–362.

SADLER, P.M., 1981: Sediment accumulation rates and the completeness of stratigraphic sections. – The Journal of Geology, **89**, 569–584.

SARG, J.F., 1988: Carbonate sequence stratigraphy. – SEPM Special Publications, **42**, 155–181.

SCHINDEL, D.L., 1982: Resolution analysis: a new approach to the gaps in the fossil record. – Paleobiology, **8**, 340–353.

SOARES, A.F. & DUARTE, L.V., 1997: Tectonic and eustatic signatures in the Lower and Middle Jurassic of the Lusitanian Basin. – In: G. MELÉNDEZ & I. PÉREZ-URRESTI (ed.): Abstracts IV Congreso Jurásico de España, Alcañiz, 111–114.

SOARES, A.F., ROCHA, R.B., ELMI, S., HENRIQUES, M.H.P., MOUTERDE, R., ALMERAS, Y., RUGET, C., MARQUES, J.F., DUARTE, L.V., CARAPITO, M.C. & KULLBERG, J.C., 1993: Le sous-bassin nord lusitanien: histoire d'un rift avorté (Trias–Jurassique moyen, Portugal). – C.R. Acad. Sci. Paris, **317**, 1659–1666.

WIGNALL, P.W., 1994: Black shales, Oxford Monographs on Geology and Geophysics. – Oxford, **30**, 127 pp.

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