Ammonite Taphocycles in Carbonate Epicontinental Platforms

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Abstract: Variations of preservational features of the successive recorded associations of ammonites in carbonate epicontinental platforms enable distinction of taphonomic cycles induced by relative sea-level changes. A taphocycle comprises two or more successive recorded-associations showing cyclical variations in their taphonomic characters, resulting from an environmental cycle. Shallowing-upwards sequences in carbonate outer platforms, and positive taphosequences, were formed during phases of increasing water turbulence and decreasing rate of sedimentation. Positive and negative taphosequences, (or taphosequences of increasing and decreasing turbulence), enable identification of shallowing-upwards sequences and infilling sequences of fifth-order respectively. Condensed sections show different characters in shallow and proximal environments in relation to deep and distal environments of the carbonate epicontinental platforms. The degree of taphonomic condensation in preserved ammonite associations reaches the highest values in shallow and proximal environments of the platform, not in deep and distal environments, though the degree of taphonomic heritage (i.e., the ratio of reelaborated (reworked) elements to total recorded elements) can, in both cases, reach 100%. These taphonomic data are of stratigraphic interest since they provide an independent test of the cycles distinguished in sequence stratigraphy.

Introduction

Preservational characters and the distribution of the ammonites are a function of, and enable the interpretation of, different sedimentary environments on Mesozoic epicontinental platforms (Fig. 1; Fernández-López, 1997a). The ammonite associations preserved in distal and deep environments of the platform show distinctive characters which contrast with those formed in proximal and shallow environments. Some significant features of sedimentary basins, such as variation in the degree of communication between sedimentary environments, as well as water turbulence, rate of sedimentation, and rate of sediment accumulation, can be estimated on the basis of changes in the state of preservation of ammonites. A clear distinction should be made between rate of sedimentation and rate of sediment accumulation (Gómez & Fernández-López, 1994). The rate of sedimentation of a stratigraphic interval is calculated by dividing sediment thickness by the total time interval, including the gaps. In contrast, the rate of accumulation of a stratigraphic interval can be estimated by dividing sediment thickness 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 distal 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. Variations in water turbulence and rate of sedimentation are two major factors in these sedimentary environments. From deep to shallow areas, when increases in the water turbulence are associated with decreases in rate of sedimentation, several processes of taphonomic alteration are intensified (Fig. 1). Consequently, more than forty taphonomic gradients can be used to recognize changes in the palaeoenvironmental conditions.

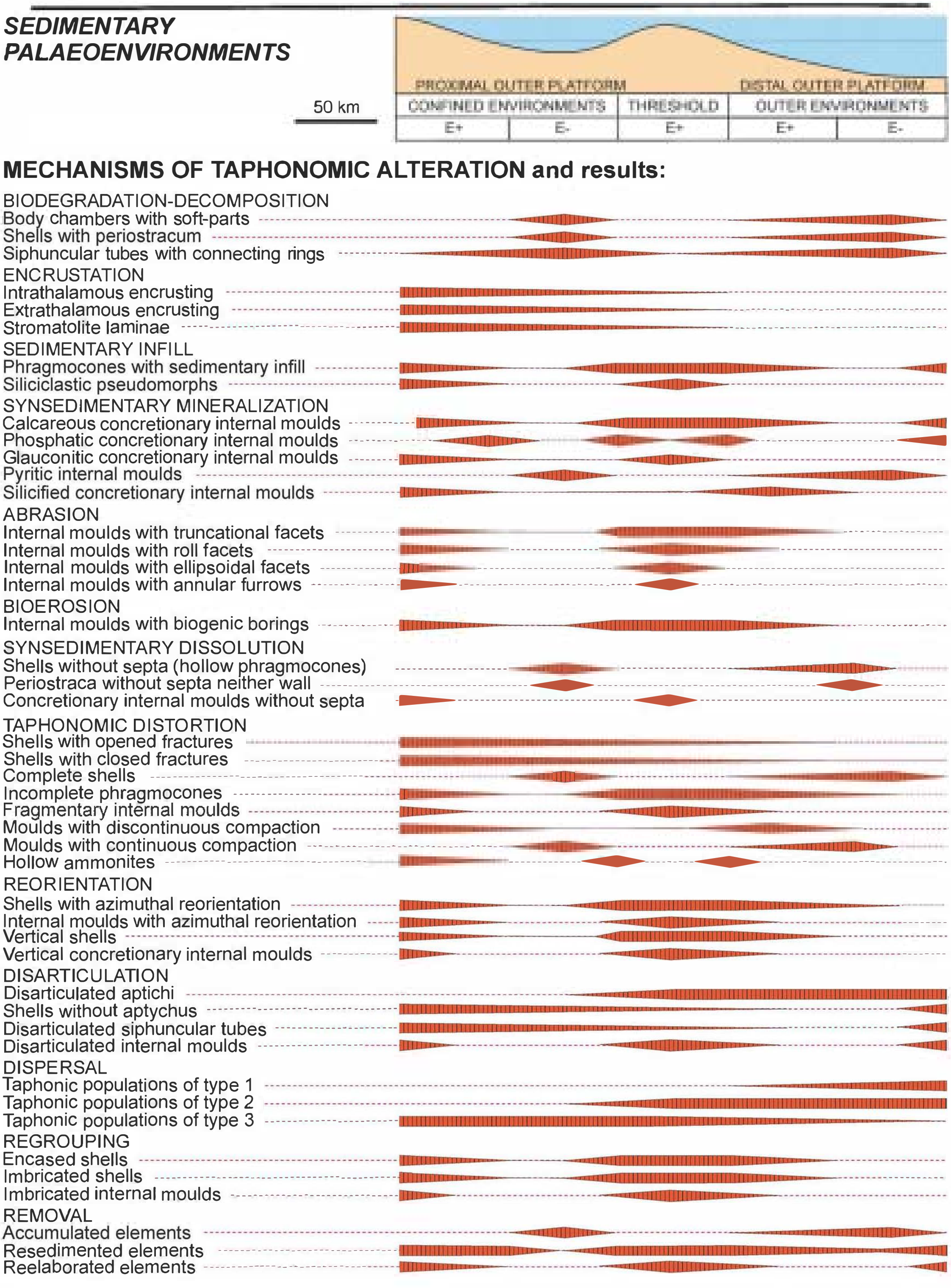

Figure 1. Taphonomic gradients developed in outer platform environments and observed in Jurassic ammonites of the Iberian Range (Fernández-López, 1997a).

Stratigraphic Cycles and Taphonomic Cycles

Stratigraphic cycles result from cyclical environmental modifications (e.g., eustatic, climatic and/or tectonic modifications). In the stratigraphic record it is possible to distinguish stratigraphic cycles and sequences of different order which result from relative sea-level changes. In a similar way, some variations of the preservational features of the successive recorded associations of ammonites in carbonate epicontinental platforms enable distinction of taphonomic cycles and sequences, of different order, induced by relative sea-level changes. A taphonomic cycle or a taphocycle comprises two or more successive recorded-associations showing cyclical variations in their taphonomic characters, as the result of an environmental cycle. Relationships between cyclical processes that have conditioned the continuity/discontinuity of the stratigraphical record or of the fossil record in carbonate epicontinental platforms can be tested on the basis of the relative duration of such processes (Fig. 2). Calibration between stratigraphic cycles and taphocycles was achieved using geochronological and geochronometric data published by Gradstein et al. (1994), Callomon (1995), Odin et al. (1995) and Gradstein and Ogg (1996).

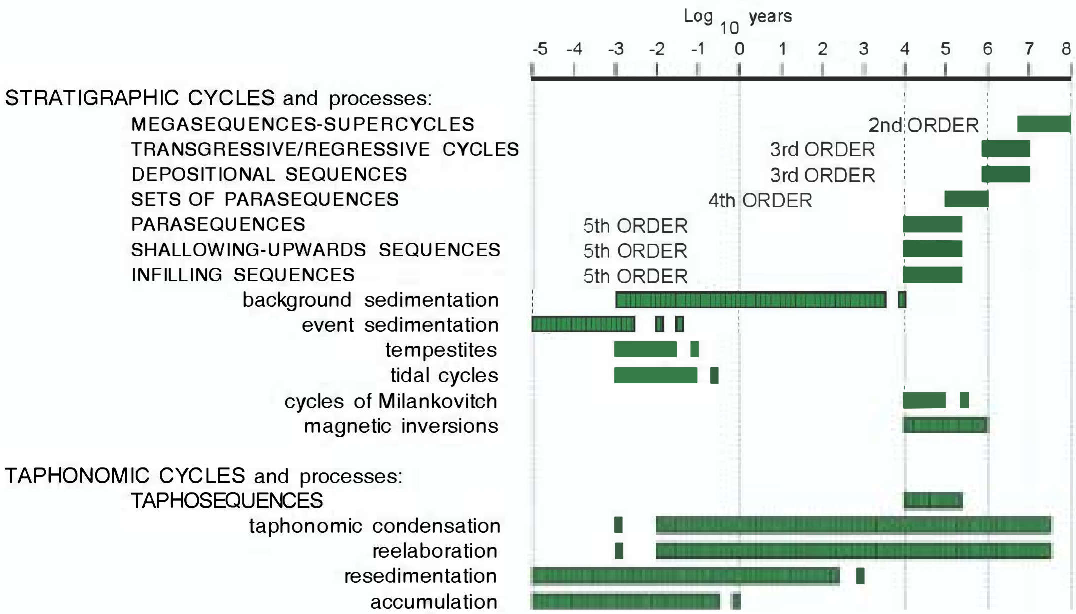

Figure 2. Resolution of stratigraphic and taphonomic cycles of different order, as well as of some processes mentioned in text.

Stratigraphic cycles, stratigraphic sequences, parasequences and taphofacies are genetic terms employed in sequence stratigraphy and applied taphonomy, comprising rock bodies of the stratigraphical record. Taphocycles, taphosequences and taphorecords are genetic terms of taphonomy comprising preserved elements, taphonic populations or preserved associations of the fossil record. The identification of taphonomic sequences and cycles enables testing of genetic differences between the fossil record and the stratigraphical record.

The stratigraphic record and the fossil record are different in nature, and they can be dissociated and studied separately (Fernández-López, 1991). The fossil record may supply relevant data on sedimentary environments and processes which themselves have left no traces in the stratigraphic record. A single stratigraphic level can enclose a set of successive recorded-associations showing distinctive preservational features and composing discrete taphorecords. This set of preserved associations forming a condensed association can even correspond to a time interval without a corresponding stratigraphic record. Interpreting these processes of taphonomic condensation in carbonate epicontinental platforms requires taking into account the relative duration of such taphonomic processes as accumulation, resedimentation and reelaboration (Fig. 2). Accumulation of ammonite shells on the floor of deep sea basins may be practically instantaneous after the death of the organisms. However, in carbonate epicontinental platforms, accumulation of ammonite shells can take place at least several months after death (Fernández-López, 1997a). Resedimented shells may stay on the depositional surface for several tens of years before being buried. Reelaborated internal moulds of ammonites may stay on the depositional surface after being exhumed, and before final burial, for more than ten million years, as indicated by many ammonite moulds subjected to reelaboration processes in the Castilian, Aragonese and Tortosa platforms during the Middle Jurassic (Fernández-López et al., 1996).

Stratigraphic Sequences and Ammonite Taphosequences

Carbonate sediments of shallow epicontinental platforms are organized in shallowing-upwards sequences and infilling sequences, of metre to decimetre thickness, which represent changes in relative depth between subtidal or intertidal and supratidal environments. These sequences represent cyclical variations of fifth-order, for which a time interval of 20,000 to 100,000 years has been estimated, according to Einsele (1992) and Vera Torres (1994); also, 10,000 to 200,000 years according to Miall (1995, 1997).

During the development of shallowing-upwards sequences, variations in the degree of removal (i.e., proportion of resedimented elements plus reelaborated elements) and taphonomic heritage (i.e., proportion of reelaborated elements) of the ammonite associations will depend on variations in rates of sedimentation and in rates of sediment accumulation, rather than exclusively on variations of water turbulence. The degree of removal and the degree of taphonomic heritage of the ammonite associations are inversely proportional to both the rate of sedimentation and rate of sediment accumulation. A decrease in either rate will produce an increase in the degree of taphonomic removal and taphonomic heritage, leading to the development of a positive taphosequence. Yet, an increase in either the rate of sedimentation or rate of sediment accumulation will produce a decrease in the degree of removal and taphonomic heritage of the preserved association, leading to the development of a negative taphosequence (Fernández-López, 1997b). These positive and negative taphonomic sequences (or taphosequences of increasing or decreasing turbulence), enable identification of shallowing-upwards sequences and infilling sequences of fifth-order, respectively.

Shallowing-upwards sequences in carbonate outer platform, and positive taphosequences, were formed during phases of increasing water turbulence and decreasing rate of sedimentation. In contrast, infilling sequences of fifth-order and negative taphosequences were formed during phases of decreasing water turbulence and increasing rate of sedimentation (Fig. 3). In outer platform environments, when decreases in rates of sedimentation are associated with strong turbulence, preserved associations of ammonites show gradual increase in concentration and taphonomic heritage. In such conditions, some taphonomic processes such as biodegradation-decomposition, encrustation, sedimentary infill, synsedimentary mineralization, abrasion, bioerosion, synsedimentary dissolution, fragmentation, reorientation, disarticulation, regrouping and removal of ammonite remains, are intensified. In contrast, when increases in the rate of sedimentation are associated with lowering of turbulence, decreased influence of the same taphonomic processes leads to the formation of ammonite associations with low values of concentration and taphonomic heritage.

Preserved associations of ammonites generated in different environmental conditions compose separate taphorecords. Each taphorecord comprises one or more preserved associations showing distinctive preservational features. Taphorecords and taphofacies have different meanings. Taphorecords are units comprising fossils. Taphofacies comprise rock bodies of the stratigraphical record. Preserved associations of ammonites generated in different phases of these environmental cycles show distinctive preservational characters and compose separate taphorecords. As indicated in Figure 3, shallowing-upwards sequences in carbonate outer platforms, preserving a positive taphosequence and different taphorecords, were formed during a phase of increasing turbulence and decreasing rate of sedimentation. Preserved associations found in positive taphosequences can be grouped in three successive taphorecords: a low turbulence taphorecord (LTT), a moderate turbulence taphorecord (MTT) and a high turbulence taphorecord (HTT). High turbulence taphorecords (HTT) are predominant in shallowing-upwards sequences developed in shallow environments of proximal platforms. In contrast, low turbulence taphorecords (LTT) are commonly formed in shallowing-upwards sequences developed in deep environments of distal platforms.

In the lower portion of a complete shallowing-upwards sequence, where accumulated elements and pyritic ammonites may be found, complete shells are most common. Hollow ammonites (i.e., showing no sedimentary infill in the phragmocone) and hollow phragmocones (i.e., without septa) are the dominant fossils, but are usually compressed by diagenetic compaction. The occurrence of taphonic populations of type 1 (i.e., composed of monospecific shells showing unimodal and asymmetric distribution of size-frequencies, with positive skew) is indicative of autochthonous biogenic production, showing no signs of sorting by necroplanktic drift. Resedimented and reelaborated ammonites become more common in the upper portions of these sequences, as shells are completely infilled with sediment and tend to acquire an encased pattern of grouping.

Towards the top of the sequence, processes of early mineralization are more intense and taphonic populations of type 3 (i.e., composed of polyspecific shells showing uni- or polymodal and asymmetric distribution of size-frequencies, with negative skew) are dominant. Reelaborated concretionary internal moulds become dominant. They may display several distinctive features such as abrasion, fragmentation, disarticulation, reorientation and regrouping. Such reelaborated elements show no traces of deformation by gravitational diagenetic compaction during early burial. However, they may develop abrasion facets formed before final burial. Ammonite shells and concretionary internal moulds tend to produce imbricate patterns of grouping and show azimuthal reorientation. They may be covered by encrusting organisms and biogenic borings. Siphuncular tubes are usually disarticulated as a consequence of intense and lasting biostratinomic processes of biodegradation-decomposition and dissolution. Reelaborated concretionary internal moulds are also preferentially disarticulated along septal surfaces. In the later stage, concretionary internal moulds with ellipsoidal abrasion facets and annular abrasion furrows are formed. Long episodes of emersion and erosion favour the formation of concretionary internal moulds without septa, resulting from dissolution of the septa and filling of interior cavities with sediments (Fig. 4).

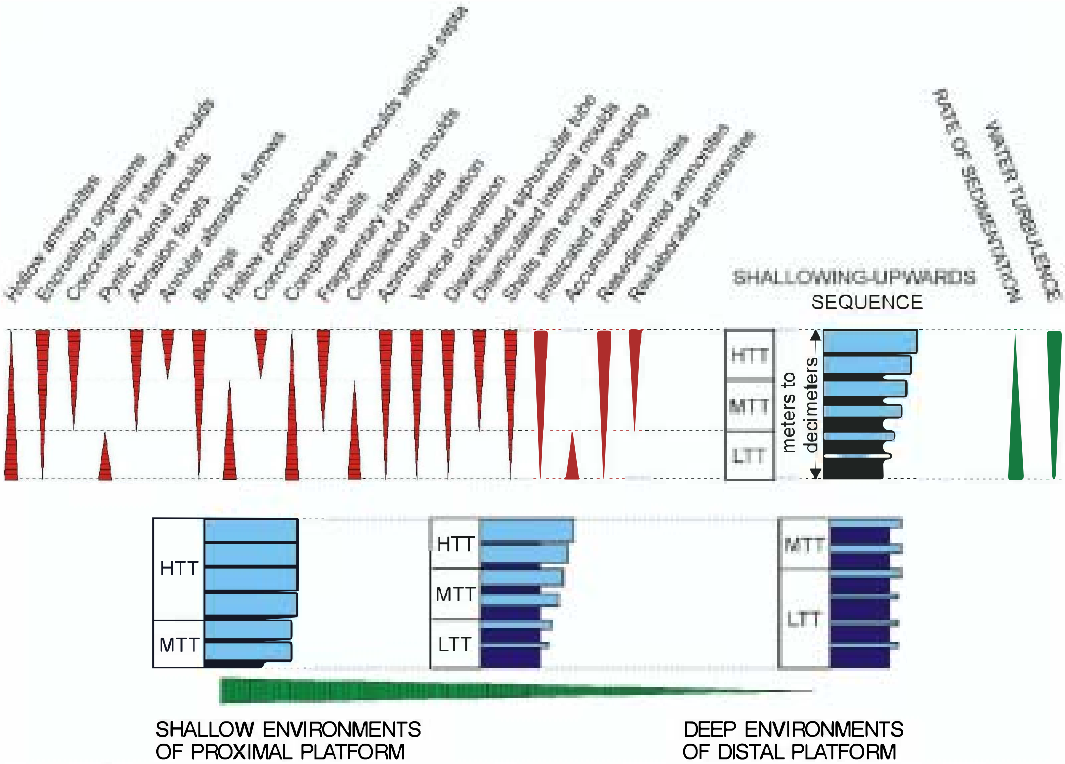

Figure 3. Frequency of different taphonomic characters displayed by ammonites in shallowing-upwards sequences in carbonate outer platform, forming a positive taphosequence and different taphorecords (Fernández-López, 1997b). LTT = low turbulence taphorecord. MTT = moderate turbulence taphorecord. HTT = high turbulence taphorecord.

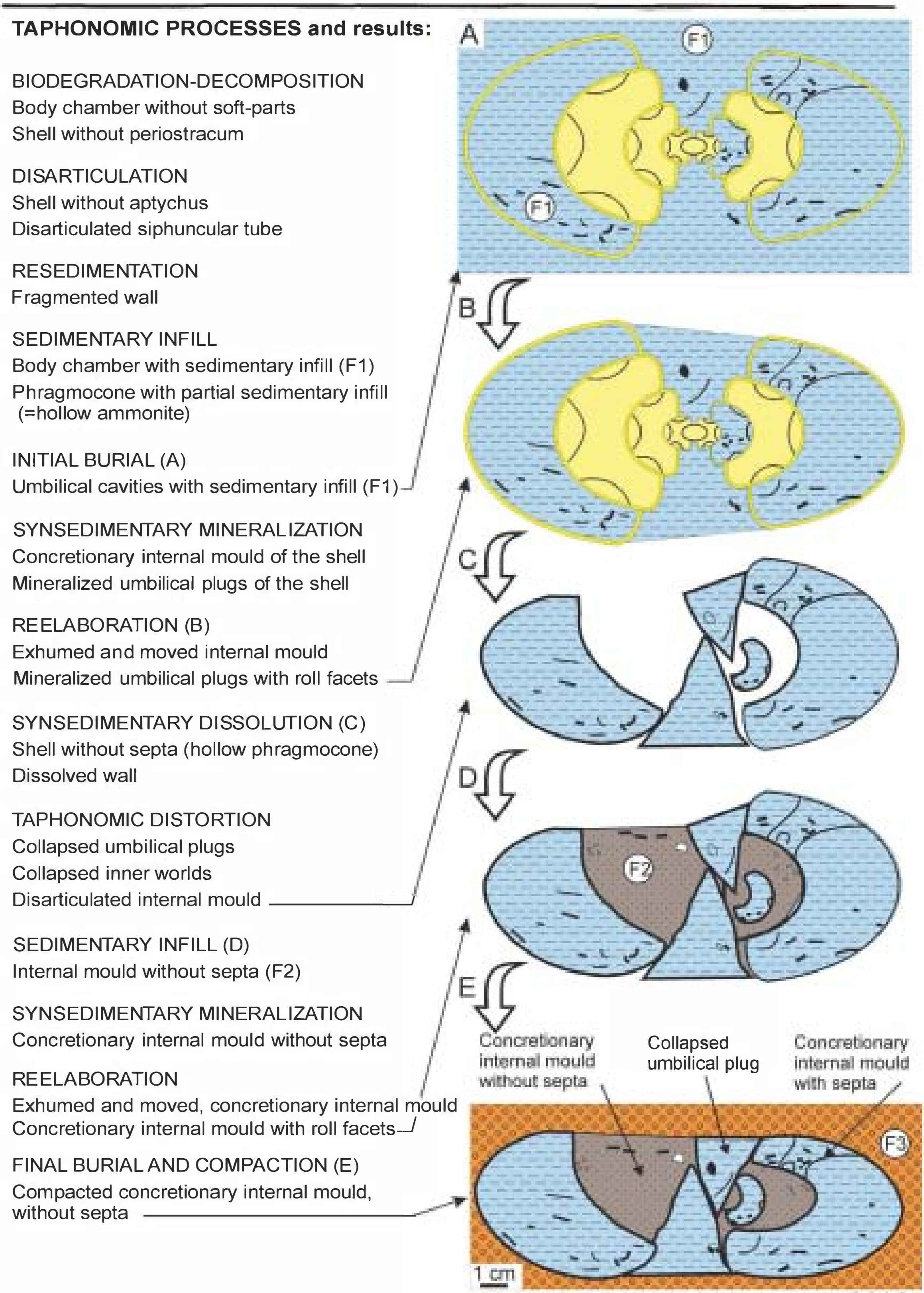

Figure 4.- Model for the formation of concretionary internal moulds without septa, results of dissolution of the septa and ulterior infilling of the cavities with sediments.

Condensed sections show different characters in shallow and proximal environments as compared to deep and distal environments (Table 1). The highest values of taphonomic condensation in ammonite associations are displayed in shallow epicontinental platforms rather than in deep sea envíronments. However, the degree of taphonomic heritage (estimated by the ratio of reelaborated elements in the whole assemblage) can reach 100% in both cases. 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 smaller values in proximal than in distal areas. Condensed sections in deep and distal areas usually contain taphonic population of type 1 (Fernández-López, 1997a). In such areas. phragmocones are normally filled by sediment, and concretionary internal moulds display disarticulation surfaces and fractures with acute margins. Pyritic ammonites are common in certain distal areas. On the other hand, in proximal areas, taphonic populations are usually of type 2 or 3, those of type 1 not being represented. Hollow ammonites (i.e., shells showing no sedimentary infill in the phragmocone) are abundant, reelaborated internal moulds show high values of roundness and sphericity as well as frequent biogenic borings, and pyritic ammonites are scarce (Fernández-López. 1997b). Stratigraphic successions in shallow epicontinental platforms are usually more incomplete than those formed in deep basins (cf. Schindel. 1982; McKinney, 1985; Kowalewski, 1996). However, despite the abundance and wide range of biostratigraphic gaps in such sequences, registratic gaps are usually not so important in condensed sections of shallow platforms, the registratic succession being usually more complete than the corresponding biostratigraphic succession.

Condensed sections in shallow and proximal areas:	Condensed sections in deep and distal areas:
Expanded sediments (e.g., tempestites)	Condensed sediments
High taphonomic condensation	Low taphonomic condensation
High taphonomic heritage	Moderate taphonomic heritage
Low degree of packing	High degree of packing
Low stratigraphic persistence	High stratigraphic persistence
Taphonic populations of type 1 are absent	Taphonic populations of type 1 are present
Abundant hollow ammonites	Scarce hollow ammonites
Rounded reelaborate ammonites	Angular reelaborate ammonites
Abundant biogenic borings	Scarce biogenic borings
Scarce pyritic internal moulds	Common pyritic internal moulds
Common stratigraphic gaps	Scarce stratigraphic gaps

Table 1. Differential characters of the condensed sections formed in shallow and proximal areas in relation to deep and distal areas of carbonate epicontinental platforms (Fernández-López, 1997b).

Conclusions

On the basis of changes in the preservational state of successive recorded associations of ammonites, it is possible to distinguish taphocycles and taphorecords resulting from relative changes of sea level in carbonate epicontinental platforms. Preserved associations of ammonites formed in these platforms can be grouped on the basis of taphonomic criteria in taphorecords of different categories: low turbulence taphorecords (LTT), moderate turbulence taphorecords (MTT) and high turbulence taphorecords (HTT). Positive and negative taphosequences, resulting (MTT)from increasing or decreasing turbulence respectively, enable identification of shallowing-upwards sequences and infilling sequences of fifth-order, respectively.

Condensed sections show different characters in shallow and proximal areas as compared to deep and distal areas. The degree of taphonomic condensation in ammonite preserved associations reaches the highest values in shallow epicontinental platforms, not in deep basins, though the degree of taphonomic heritage (i.e., the ratio of reelaborated elements to the total recorded elements) can, in both cases, reach 100%.

Using palaeontological data in sequence stratigraphy analysis of shallow marine platforms requires the prior identification of taphonomic sequences and cycles. These taphonomic data are of stratigraphic interest since they provide an independent test of the cycles distinguished in sequence stratigraphy and genetic stratigraphy. The identification of such taphonomic cycles is of utmost importance in interpreting the stratigraphic cycles of Mesozoic epicontinental platforms when no evidence of coastal onlap is preserved but fossiliferous sediments of the outer platform are widely developed.

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