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Depositional sequences and ammonoid assemblages in the upper Cenomanian-lower Santonian of the Iberian Peninsula (Spain and Portugal)

M. SEGURA[1] F. BARROSO-BARCENILLA[1,2] P. CALLAPEZ[3,4] J.F. GARCÍA-HIDALGO[1] J. GIL-GIL[1]

[1]**Grupo de Investigación IBERCRETA, Universidad de Alcalá de Henares**
28871 Alcalá de Henares, España – Spain. Segura E-mail: manuel.segura@uah.es Barroso-Barcenilla E-mail: fbarroso@uah.es
García-Hidalgo E-mail: jose.garciahidalgo@uah.es Gil-Gil E-mail: javier.gil@uah.es

[2]**Departamento de Paleontología, Universidad Complutense de Madrid**
28040 Madrid, España – Spain. E-mail: fbarroso@geo.ucm.es

[3]**Departamento de Ciências da Terra, Universidade de Coimbra**
3000-272 Coimbra, Portugal. E-mail: callapez@dct.uc.pt

[4]**Centro de Geofísica, Universidade de Coimbra**
3000-134 Coimbra, Portugal. E-mail: callapez@dct.uc.pt

ABSTRACT

A clear relationship exists between eustatic sea-level rises and falls recorded as cyclical depositional sequences and ammonite faunas during the Cenomanian-Santonian in the Iberian and West Portuguese basins. Most of the faunal turnovers correlate with stratigraphic intervals related to marine transgressions, maximum flooding of the shelf (locally associated to anoxic events), and marine regressions. Specifically, within each depositional sequence, three distinct and identical events of morphological change occur, involving ammonoids belonging to different groups. Transgressive sediments are characterized by moderately ornamented, inflated and evolute morphologies, which are replaced by smooth, involute and compressed oxycones (the most hydrodynamic shells) during maximum flooding (and to a lesser extent at the early highstand) of the sequences. The latter morphologies in turn are replaced by coarsely ornamented and evolute shells during late highstands. We conclude that ammonoid faunal analysis can be used to trace sea-level changes and provides an additional tool for sequence stratigraphy.

KEYWORDS **Depositional sequences. Ammonoid assemblages. Upper Cenomanian-lower Santonian. Spain. Portugal.**

INTRODUCTION

During the Late Cretaceous, the Iberian Peninsula was a relatively independent tectonic block. Its privileged palaeogeographical location favoured the arrival of boreal faunas from the Protoatlantic and temperate-warm faunas from the Tethys to its epicontinental flooded regions, such as the Iberian and the West Portuguese basins. As the arrangement of these regions enabled the development of rather confined marine environments, endemic species arose in its waters as well. The combined incidence of eustatic changes and local tectonics generated several depositional sequences with characteristic faunal assemblages (particularly well-recorded during major sea-level rises) from the upper Cenomanian to the lower Santonian in the Iberian and the West Portuguese basins.

These sequences and their ammonoid assemblages, after a first approximation limited to the upper Cenomanian to lower Turonian interval (Barroso-Barcenilla *et al.*, 2011a), have been related and interpreted in detail for the first time in this paper, considering the narrow relationship that can be established in the epicontinental platforms between palaeoenvironmental changes (*e.g.* sea-level oscillations, anoxic events) and palaeontological successions (Fernández-López, 1999; Hirano *et al.*, 2000).

GEOGRAPHICAL AND GEOLOGICAL SETTING

The Iberian Peninsula contains Upper Cretaceous sedimentary sequences, mainly composed of marls and limestones with several terrigenous and dolomitic intervals. These sequences yield fossils of the Iberian and West Portuguese basins (Fig. 1A-C). The Iberian Basin was a relatively stable intracratonic platform and comprised certain parts of the northern, central and south-eastern regions the Iberian Peninsula that were temporally or permanently flooded by the Protoatlantic ocean, the Tethys sea or both (Fig. 1B-C). During the late Cenomanian-early Santonian the Iberian basin had high subsidence and sedimentation rates, mainly controlled by eustatic changes (Floquet *et al.*, 1982; Segura *et al.*, 2001, 2002; Barroso-Barcenilla *et al.*, 2011a). The sedimentary and palaeontological successions of the northern part of the basin (southern Cantabrian Range), show a nearly continuous record in marly materials of relatively deep and open inner platform with ammonites, inoceramids and other benthic, non-rudist bivalves. In the southern part of the Iberian Basin (northern Central System and western Iberian Range) nodular carbonates (limestones and dolostones) of relatively shallow and restricted inner platform and siliciclastic rocks corresponding to a narrow coastal belt predominate (Gil *et al.*, 2006; García-Hidalgo *et al.*, 2007) (Fig. 1C). The nodular carbonates contain thinner and less abundant levels with ammonites, rudists (mainly Coniacian) and other molluscs, whereas the siliciclastic rocks have scarce palaeontological content.

The West Portuguese Basin included the western-central regions of the Iberian Peninsula temporally or permanently flooded by the Protoatlantic (Fig. 1B-C). It was part of an active continental margin controlled by reactivated Late Hercynian faults and halokinetic structures with Triassic-Lower Jurassic evaporites. Nevertheless, as in the Iberian Basin, the main depositional episodes and faunal assemblages were related to global sea-level changes, but the sedimentary infill was less continuous and influenced by local tectonics and continental influx episodes (Ferreira Soares, 1980; Callapez, 1998, 2008; Rey *et al.*, 2006; Dinis *et al.*, 2008; Barroso-Barcenilla *et al.*, 2011a). During the Cenomanian a carbonate platform with different domains developed. A nodular carbonate shelf with ammonites, and a related micaceous littoral plain occurred at the northern part of the West Portuguese Basin (Beira Littoral Range). The southern part of the basin (Estremadura Range) was occupied by a rimmed carbonate platform with coral and rudist fringes, and by a lagoonal system with other molluscs and echinoids. After a hiatus related to regional uplift, at the middle lower Turonian, carbonate sedimentation was temporarily re-established on the northern part of the basin. The remaining record was alluvial and littoral, but punctuated by a single and short eustatic episode with middle upper Coniacian ammonites (Fig. 1C).

DEPOSITIONAL SEQUENCES

Stratigraphic studies have allowed us to recognize the main depositional episodes and to reconstruct the architecture of the 2nd- and 3rd-order sequences in the upper Cenomanian-lower Santonian of the Iberian and West Portuguese basins, recognizing and correlating the larger and most extensive sea-level oscillations, and evaluating the depositional hiatuses towards the coastal margins.

Mostly in carbonates with ammonites of the Iberian Basin, six 3rd-order depositional sequences, belonging to the UZA-2 and UZA-3 (*sensu* Haq *et al.*, 1988) 2nd-order megasequences, have been recognized. These are sequences UZA-2.4 (lower upper Cenomanian, although its base seems to be upper middle Cenomanian), UZA-2.5 (uppermost Cenomanian-lower Turonian) and UZA-2.6+2.7 (middle Turonian) and, after a marked sedimentary discontinuity corresponding to the middle/upper Turonian boundary, UZA-3.1 (upper Turonian) and UZA-3.2 (lower Coniacian-lowermost Santonian) (Floquet, 1998; Gräfe, 1999; Segura *et al.*, 2001) (Fig. 2).

In the West Portuguese Basin, UZA-2 megasequence is also recorded by carbonates with ammonites, but the succession is incomplete due to local tectonics. UZA-2.4 is well recognized on the entire carbonate platform bearing a cephalopod assemblage with *Neolobites-Angulithes*. UZA-2.5 starts with an uppermost Cenomanian interval with *Vascoceras-Spathites* (*Jeanrogericeras*), but it was truncated due to regional tectonic uplift. In its upper part a middle lower Turonian ammonite assemblage with *Choffaticeras* (*Leoniceras*) is locally recognized. Finally, UZA-2.6+2.7 has only been recorded in the northern part of the basin with littoral to alluvial micaceous sandstones. Concerning the UZA-3 megasequence, the lack of carbonates with marine faunas hinders an accurate stratigraphic control, except for a middle upper Coniacian event with *Hemitissotia*. Nevertheless, the UZA-3.1/UZA-3.2 boundary can be located into a discontinuity related with the transition to coarser siliciclastic sediments (Callapez, 1998) (Fig. 2).

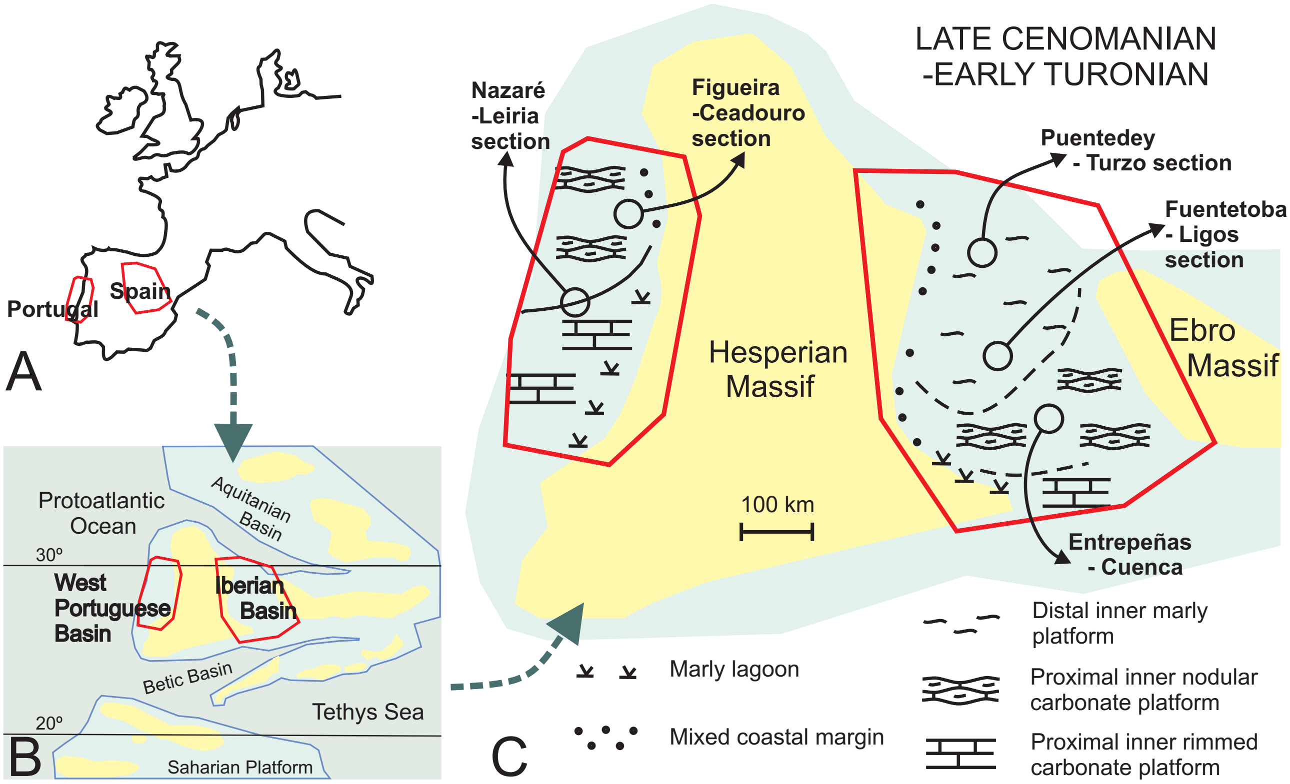

FIGURE 1. A) Geographic location of the Spanish and Portuguese studied areas (red polygons) in South-Western Europe. B-C) Palaeogeographic situation of the Iberian Peninsula during the maximum transgression of the late Cenomanian-early Turonian, with B) the approximate locations of the studied basins, and C) the main composite-sections and facies distribution. Figure 1B-C is modified from Philip and Floquet (2000), Stampfli *et al.* (2001) and Gelabert *et al.* (2002).

AMMONOID ASSEMBLAGES

Detailed ammonite zones and assemblages of both boreal and temperate-warm affinities have been established for the upper Cenomanian-lower Santonian of the Iberian and West Portuguese basins. The ammonite zones and assemblages have been compared and correlated with those identified in South-Western Europe, North Africa and the Western Interior of USA. Systematic and biostratigraphic data provided by the specimens collected by the authors of this paper (>2500) and other researchers in the region (*e.g.* Karrenberg, 1935; Wiedmann, 1960; Mojica and Wiedmann, 1977; Wiedmann and Kauffman, 1978; Santamaría-Zabala, 1992; Callapez, 2003; Callapez and Ferreira Soares, 2001; Gallemí *et al.*, 2007; Barroso-Barcenilla *et al.*, 2009, 2011a, 2013) have been analyzed. The main part of these cephalopods do not present signs of taphonomic resedimentation or reelaboration (*sensu* Fernández-López, 2000), and the few that show any of these signs do not seem to have suffered notable alterations. Therefore, it has been considered that all of them maintain their respective original stratigraphic positions (Callapez, 1998; Barroso-Barcenilla, 2006; Barroso-Barcenilla *et al.*, 2011a).

The stratal architecture and the palaeontological successions of the above mentioned 3rd-order depositional sequences show that their Maximum Flooding Surfaces (mfs) are coincident in the Iberian and West Portuguese basins. Though the stratigraphic record in the latter basin is somewhat incomplete due to local tectonics, both show four especially rich and widespread ammonitiferous intervals. These acme-type intervals are laterally continuous in every sequence all along the main part of both basins, and successively contain numerous specimens of *Neolobites vibrayeanus-Angulithes mermeti* (UZA-2.4 mfs), *Choffaticeras* (*Choffaticeras*) *quaasi-pavillieri* (UZA-2.5 mfs), *Coilopoceras requienianum* (UZA-3.1 mfs), and *Hemitissotia ceadouroensis*/*celtiberica-turzoi* (UZA-3.2 mfs) (Figs. 2; 3).

The first interval (*N. vibrayeanus-A. mermeti*) coincides with the mfs (lower upper Cenomanian) of the UZA-2.4, providing specimens of these cephalopods both in the northern and central parts of the Iberian Basin (IB). It can be also recognized in the West Portuguese Basin (WPB), where the assemblage of *N. vibrayeanus-A. mermeti* is abundant as well. The second interval (*Ch.* (*Ch.*) *quaasi-pavillieri*) corresponds to the mfs (lowermost Turonian) of the UZA-2.5, containing ammonites even in southern areas of the IB (up to the Entrepeñas-Cuenca Section). In the WPB this interval coincides with the local

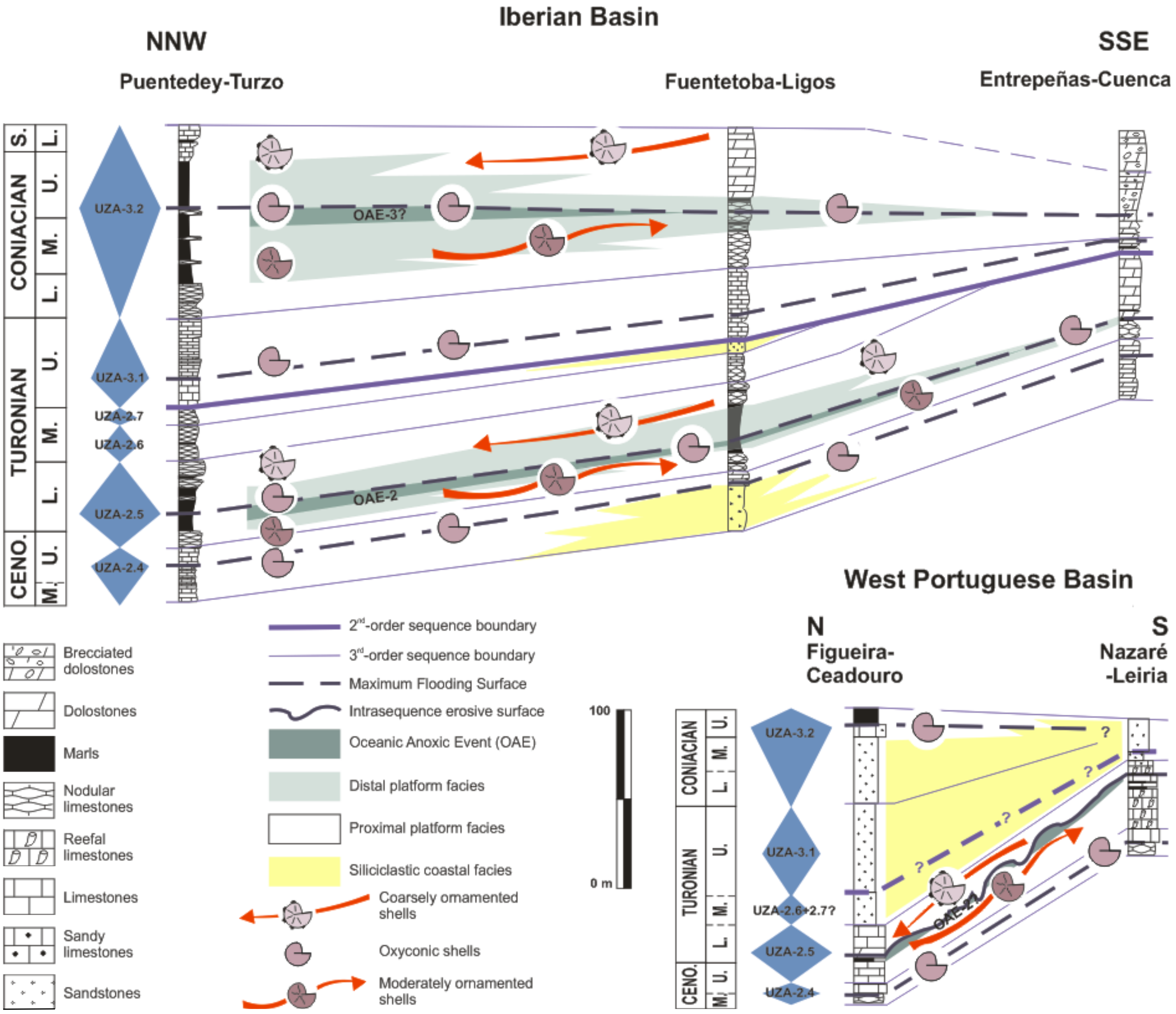

FIGURE 2. Dip cross-section of the upper Cenomanian-lower Santonian 3rd-order depositional sequences (UZA-2.4 to UZA-3.2) in the Iberian and West Portuguese basins, showing the depositional architecture and the main ammonoid assemblages relative to the reference surfaces (Maximum Flooding Surfaces and sequence boundaries) and the systems tracts (Transgressive Systems Tracts and Highstand Systems Tracts). Ceno.: Cenomanian, S.: Santonian, L.: Lower, M.: Middle, U.: Upper. Approximate locations of the represented composite-sections can be observed in Figure 1C.

tectonic uplift and emersion of the carbonate platform. After a major stratigraphic discontinuity, the third interval (*C. requienianum*) corresponds to the mfs (lower upper Turonian) of the UZA-3.1. This interval is less extensive than the previous ones with abundant cephalopods (UZA-2.4 and UZA-2.5) and it is only recognized in the northern part of the IB. The location and reduced extension of UZA-3.1 interval is related to its sequence stratigraphic context (the transgressive base of a 2nd-order megasequence after the major sea-level fall at the middle/upper Turonian transition, corresponding to the UZA-2/UZA-3 boundary: Gil *et al.*, 2006). The same interval is unknown in the WPB, where correlative series are terrigenous, lacking marine fossils. The fourth interval (*H. ceadouroensis/celtiberica-turzoi*) corresponds to the mfs (middle upper Coniacian) of the UZA-3.2, providing specimens of these ammonites in the northern and central parts of the IB (up to the Fuentetoba-Ligos Section). In the WPB, this transgression is recorded by sandstones with H. ceadouroensis/celtiberica (in the Figueira-Ceadouro Section) and coarse alluvial sediments (Figs. 2; 3).

DISCUSSION

The relationship of these ammonites with mfs of specific sequences can be contrasted through the analysis of their distributions out of the Iberian Peninsula. *N. vibrayeanus* has been identified in the upper Cenomanian (*Calycoceras* (*Calycoceras*) *naviculare* Zone *sensu* Gradstein *et al*., 2004) of South-Western Europe (Callapez and Ferreira Soares, 2001; Barroso-Barcenilla, 2006), North Africa, Middle East (Kennedy and Simmons, 1991; Wiese and Schulze, 2005), Niger and, possibly, Peru. The co-occurrence and abundance of *Neolobites* and *Angulithes* in this interval has been observed by different authors in other basins (*e.g.* Benavides-Cáceres, 1956; Meister and Rhalmi, 2002), and seems to be related to important palaeoenviromental changes (Barroso-Barcenilla *et al*., 2011a). *Ch. (Ch.) quaasi-pavillieri* have been collected in the lower Turonian (*Watinoceras devonense* Zone *sensu* Gradstein *et al*., 2004) of North Africa (Chancellor *et al*., 1994; Amédro *et al*., 1996; Meister and Abdallah, 2005), Middle East, South-Western Europe (Barroso-Barcenilla and Goy, 2007), Madagascar, USA and, probably, Rumania and Nigeria. *C. requienianum* has been identified in the upper Turonian (*Subprionocyclus neptuni* Zone *sensu* Gradstein *et al*., 2004) of South-Western Europe (Kennedy and Wright, 1984), North and West Africa (Kassab and Obaidalla, 2001; El-Hedeny, 2002; Hewaidy *et al*., 2003; Nagm *et al*., 2010), Madagascar, Middle East, Pakistan, North America, Trinidad and Tobago, and South-Western America. *H. ceadouroensis*/*celtiberica-turzoi* have been collected in the upper Coniacian (*Paratexanites serratomarginatus* Zone *sensu* Gradstein *et al*., 2004) of South-Western Europe (Wiedmann and Kauffman, 1978; Wiedmann, 1979; Santamaría-Zabala, 1995; Gallemí *et al*., 2007; Barroso-Barcenilla *et al*., 2013), Madagascar, Saudi Arabia (El-Asa'ad, 1991) and, possibly, Morocco. Most of these ammonites are so abundant in their respective intervals that some of them, such as *N. vibrayeanus*, *Ch.* (*Ch.*) *quaasi*, *C. requienianum* and *H. turzoi*, are considered as biostratigraphic markers in numerous basins of the Western Tethys (*e.g.* Wiese and Schulze, 2005; Meister and Abdallah, 2005; Nagm *et al*., 2010; Barroso-Barcenilla *et al*., 2013).

The morphology of these ammonoids (Fig. 3) corresponds to smooth and compressed oxycones (morphogroup 11 *sensu* Batt, 1989; Westermann, 1996) and, therefore, to nektonic forms, well adapted to active swimming. Then, the relationship of oxycones with mfs seems to be an adaptive response to sea-level changes (maximum depths in the basin). Hydrodynamically, a smooth and compressed form usually has a lower drag coefficient and higher swimming velocity, developing more efficient locomotion than an ornamented and depressed one (Chamberlain, 1980; Westermann, 1996). This morphological relationship can be established both in intracratonic (Iberian Basin) and active marginal (West Portuguese Basin) areas and has been suggested in other basins (*e.g.* Middle Jurassic of Germany: Bayer and McGhee, 1984; Upper Cretaceous of USA: Jacobs *et al*., 1994), relating sea-level changes with ammonoid morphologies (ecophenotypic variations: Diedrich, 2000; Wilmsem and Mosavinia, 2011) and turnovers (O'Dogherty *et al*., 2000; Sandoval *et al*., 2001, 2002; Yacobucci, 2008).

The UZA-2.5 and UZA-3.2 are the most extensive sequences, representing the transgressive/regressive transition of two consecutive megasequences (2nd-order). They contain, by coincidence with their respective mfs, the megasequence mfs, and show three other important particularities. Firstly, they have well-developed Transgressive Systems Tracts (TST) with abundant ammonites, containing numerous specimens of *Vascoceras gamai-Spathites* (*Jeanrogericeras*) *subconciliatus* (uppermost Cenomanian) in the UZA-2.5, and of *Tissotiodes hispanicus-Prionocycloceras iberiense-Protexanites bourgeoisi* (lower upper Coniacian) in the UZA-3.2 (Fig. 3). The presence of abundant morphologically less hydrodynamic ammonites with moderately ornamented and evolute discocones and platycones (close to morphogroups 6, 9 *sensu* Batt, 1989; Westermann, 1996) in the TST is interpreted here as related to sea-levels markedly lower than those of the maximum flooding stages, even during the superimposition of the highstand portions of the high-frequency cycles (4th-order). Secondly, they present, close to the mfs of these two sequences, the dark levels corresponding to the Oceanic Anoxic Event 2 (OAE-2) of the Cenomanian/Turonian transition and to the less known and more controversial Oceanic Anoxic Event 3 (OAE-3) of the Coniacian/Santonian transition (Schlanger and Jenkyns, 1976; Jenkyns, 1980; Schlanger *et al*., 1987; Arthur *et al*., 1988, 1990; Jenkyns *et al*., 1994) (Fig. 2). Both events are characterized by the hypoxic character of the oceanic waters and the reduced abundance and diversity of their macrofaunas (Sepkoski, 1986; Barroso-Barcenilla *et al*., 2011b). Thirdly, they also have well-developed and complex Highstand Systems Tracts (HST) with abundant ammonites, which can be divided in two intervals: early and late. The early HST contains numerous specimens of *Choffaticeras* (*Leoniceras*) *luciae-barjonai* (middle lower Turonian) in the UZA-2.5, and of *Hemitissotia dullai-lenticeratiformis* (uppermost Coniacian) in the UZA-3.2 (Fig. 3), coinciding to oxyconic, involute and moderately compressed species with hydrodynamically efficient shells (morphogroup 11 *sensu* Batt, 1989; Westermann, 1996), and making the characterization/differentiation of mfs and early HST difficult on the exclusive basis of the cephalopod morphologies. The late HST has less abundant ammonites, mostly representative of *Mammites nodosoides* (upper lower Turonian) in the UZA-2.5, and of *Texanites hispanicus* (lowermost Santonian) in the UZA-3.2 (Fig. 3).These ammonites correspond to coarsely ornamented planorbicones and similar (close to morphogroup 1 *sensu* Batt, 1989; Westermann, 1996) with

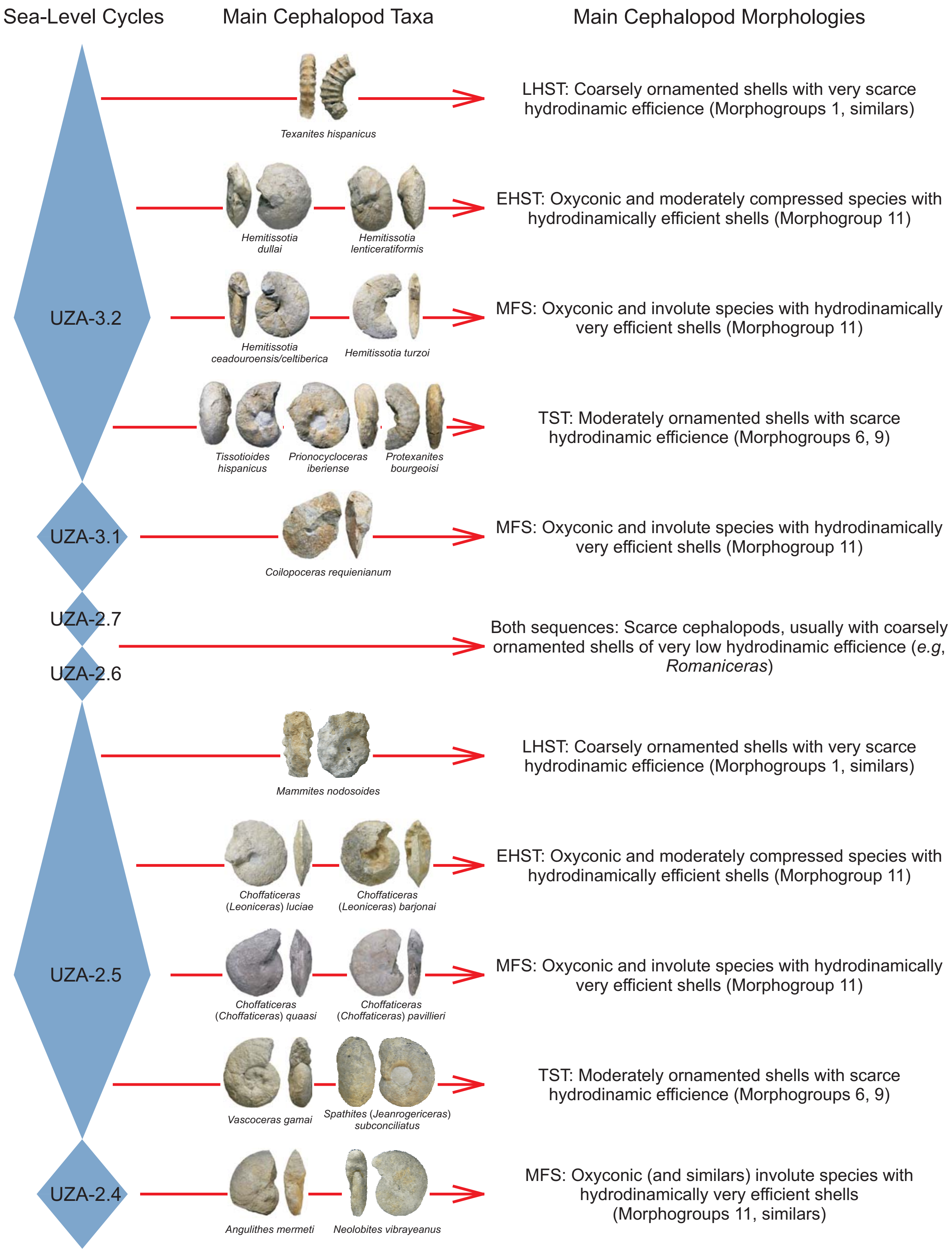

FIGURE 3. Sea-level cycles and characteristics of their main cephalopods, with lateral and ventral or dorsal views of some representative taxa and remarks on their characteristics. The width of the blue rhombuses represents the relative sea-level changes. TST: Transgressive Systems Tracts, mfs: Maximum Flooding Surfaces, EHST: Early Highstand Systems Tracts, LHST: Late Highstand Systems Tracts. Morphogroups sensu Batt, 1989; Westermann, 1996. All the figured specimens are held in the Departamento de Paleontología of the Universidad Complutense de Madrid, and taxonomical discussions on most of them were given by Barroso-Barcenilla (2006) and García-Hidalgo *et al.* (2012).

very low hydrodynamism. The presence of progressively less hydrodynamic ammonites in the HST is also interpreted here as related to sea-levels lower than those of the maximum flooding stages, as a result of the loss of accommodation, even during the superimposition of the highstand portions of the high-frequency cycles (4th-order).

Among those ammonoids characterizing even lower sea-level intervals, coarsely ornamented ammonites with very low hydrodynamic efficiency predominate. A good example of this can be observed in the reduced sea-level interval of the middle Turonian (UZA-2.6+2.7). This interval is characterized by the progradation of shallower inner platform and coastal margin facies with thin levels containing bivalves and scarce heavily ornamented ammonites (*e.g. Romaniceras*, Fig. 3) in the northern part of the Iberian Basin (Wiedmann, 1960, 1979; Wiedmann and Kauffman, 1978; Santamaría-Zabala, 1995; Küchler, 1998).

CONCLUSIONS

In the upper Cenomanian-lower Santonian of the Iberian and West Portuguese basins (although with incomplete record in the latter), four mfs corresponding to 3rd-order sequences with abundant cephalopods (UZA-2.4 with *N. vibrayeanus-A. mermeti* in the lower upper Cenomanian; UZA-2.5 with *Ch.* (*Ch.*) *quaasi-pavillieri* in the lowermost Turonian; UZA-3.1 with *C. requienianum* in the lower upper Turonian; UZA-3.2 with *H. ceadouroensis/celtiberica-turzoi* in the middle upper Coniacian) can be identified. The morphology of these ammonites (well adapted active swimmers with smooth and compressed oxycones) is explained in this paper by their close relationship with the deeper facies of every studied sequence, corresponding to their maximum flooding surfaces. This trend is observable in the early HST as well (UZA-2.5 with *Ch.* (*L.*) *luciae-barjonai*, and UZA-3.2 with *H. dullai-lenticeratiformis*), since they also have deep facies. This relationship between morphologies and facies can additionally be observed in other basins of Western Tethys. Other system tracts representing different portions of the sea-level curve of the sequence (particularly the TST and late HST) contain abundant ammonites with less hydrodynamic morphologies. They are the TST of UZA-2.5 with *V. gamai-S.* (*J.*) *subconciliatus*, and of UZA-3.2 with *T. hispanicus-P. iberiense-P. bourgeoisi*; and the late HST of UZA-2.5 with *M. nodosoides* and of UZA-3.2 with *T. hispanicus*. These results clearly suggest that the presence or absence of ammonoids in these basins, their morphologies and, therefore, their evolutionary trends are mainly influenced by eustatic variations, and demonstrate the interest and utility of integrated studies on depositional sequences and faunal assemblages for basinal analyses and correlations.

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REFERENCES

Amédro, F., Busson, G., Cornée, A., 1996. Révision des ammonites du Cénomanien supérieur et du Turonien inférieur du Tinrhert (Sahara algérien). Bulletin du Muséum National d'Histoire Naturelle, Série 4, 18, 179-232.

Arthur, M.A., Dean, W.E., Pratt, L.M., 1988. Geochemical and climatic effects of increased marine organic carbon burial at the Cenomanian/Turonian boundary. Nature, 335, 714-717.

Arthur, M.A., Brumsack, H.J., Jenkyns, H.C., Schlanger, S.O., 1990. Stratigraphy, geochemistry, and paleoceanography of organic carbon-rich Cretaceous sequences. In: Ginsburg, R.N., Beaudoin, B. (eds.). Cretaceous Resources, Events and Rhythms. Dordrecht, Kluwer, 75-119.

Barroso-Barcenilla, F., 2006. Cefalópodos del Cenomaniense superior y del Turoniense inferior en el Surco Ibérico, España. PhD thesis. Madrid, Universidad Complutense de Madrid, unpublished, 626pp.

Barroso-Barcenilla, F., Goy, A., 2007. Revision and new data of the ammonite family Pseudotissotiidae in the Iberian Trough, Spain. Geobios, 40, 455-487.

Barroso-Barcenilla, F., Goy, A., Segura, M., 2009. Ammonite zonation of the upper Cenomanian and lower Turonian in the Iberian Trough, Spain. Newsletters on Stratigraphy, 43, 139-164.

Barroso-Barcenilla, F., Callapez, P.M., Ferreira Soares, A., Segura, M., 2011a. Cephalopod assemblages and depositional sequences in the Upper Cenomanian and Lower Turonian of the Iberian Peninsula (Spain and Portugal). Journal of Iberian Geology, 37, 9-28.

Barroso-Barcenilla, F., Pascual, A., Peyrot, D., Rodríguez-Lázaro, J., 2011b. Integrated biostratigraphy and chemostratigraphy of the upper Cenomanian and lower Turonian succession in Puentedey, Iberian Trough, Spain. Proceedings of the Geologists' Association, 122, 67-81.

Barroso-Barcenilla, F., Callapez, P., Segura, M., 2013. Revision and new data of the Coniacian ammonite genus *Hemitissotia* in the Iberian Peninsula (Spain and Portugal). Paläontologische Zeitschrift, 87, 201-217.

Batt, R.J., 1989. Ammonite shell morphotype distribution in the Western Interior Greenhorn Sea and some paleoecological implications. Palaios, 4, 32-42.

Bayer, U., McGhee, G.R., 1984. Iterative evolution of Middle Jurassic ammonite faunas. Lethaia, 17, 1-16.

Benavides-Cáceres, V.E., 1956. Cretaceous system of northern Peru. Bulletin of the American Museum of Natural History, 108, 353-494.

Callapez, P.M., 1998. Estratigrafia e Paleobiologia do Cenomaniano-Turoniano. O significado do eixo da Nazaré-Leiria-Pombal. PhD Thesis. Coimbra, Universidade de Coimbra, unpublished, 491pp.

Callapez, P.M., Ferreira Soares, A., 2001. Fósseis de Portugal: Amonóides do Cretácico Superior (Cenomaniano-Turoniano). Coimbra, Museu Mineralógico e Geológico da Universidade de Coimbra, 106pp.

Callapez, P.M., 2003. The Cenomanian-Turonian transition in West Central Portugal. Ciências da Terra, 15, 53-70.

Callapez, P.M., 2008. Palaeobiogeographic evolution and marine faunas of the Mid-Cretaceous Western Portuguese Carbonate Plataform. Thalassas, 24, 29-52.

Chamberlain, J.A., 1980. Hydromechanical design of fossil cephalopods. In: House, M.R., Senior, J.R. (eds.). The Ammonoidea. Systematic Association, 18 (Special Volume), 289-336.

Chancellor, G.R., Kennedy, W.J., Hancock, J., 1994. Turonian ammonite faunas from Central Tunisia. Palaeontology, 50 (Special Papers), 1-118.

Diedrich, C., 2000. Faziesabhängige Schalenmorphologie des Großammoniten Puzosia dibleyi (Spath 1922) aus dem Puzosia-Event I (Ober-Cenoman) von Europa. Senckenbergiana Lethaea, 80, 463-483.

Dinis, J., Rey, J., Cunha, P.P., Callapez, P.M., Reis, R.P., 2008. Stratigraphy and allogenic controls on the western Portugal Cretaceous: an updated synthesis. Cretaceous Research, 29, 772-780.

El-Asa'ad, G.M.A., 1991. Late Cretaceous ammonites from Central Saudi Arabia. Journal of the King Saud University, 3, 135-158.

El-Hedeny, M.M., 2002. Cenomanian-Coniacian ammonites from the west-central Sinai, Egypt, and their significance in biostratigraphy. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 397-425.

Fernández-López, S.R., 1999. Applied palaeontology and sequence stratigraphy in carbonate epicontinental platforms. In: Rocha, R.B., Silva, C.M., Caetano, P.S., Kullberg, J.C. (eds.). Links between fossils assemblages and sedimentary cycles and sequences. Lisboa, Workshop of the European Palaeontological Association, 9-13.

Fernández-López, S.R., 2000. Temas de Tafonomía. Madrid, Universidad Complutense de Madrid, 167pp.

Ferreira Soares, A., 1980. A "Formação Carbonatada" Cenomano-Turoniana na região do Baixo-Mondego. Comunicações dos Serviços Geológicos de Portugal, 66, 99-109.

Floquet, M., Alonso, A., Meléndez, A., 1982. El Cretácico Superior de Cameros-Castilla. In: García, A. (ed.). El Cretácico de España. Madrid, Universidad Complutense de Madrid, 387-456.

Floquet, M., 1998. Outcrop cycle stratigraphy of shallow ramp deposits: the late Cretaceous series on the Castilian Ramp (Northern Spain). In: Graciansky, P.C.de, Hardenbol, J., Jacquin, T., Vail, P.R. (eds.). Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. Society for sedimentary Geology (SEPM), 60 (Special Publication), 343-361.

Gallemí, J., López, G., Martínez, R., Pons, J.M., 2007. Macrofauna of the Villamartín Section: Coniacian/Santonian boundary, North Castilian Platform, Burgos, Spain. Cretaceous Research, 28, 93-107.

García-Hidalgo, J.F., Gil, J., Segura, M., Domínguez, C., 2007. Internal anatomy of a mixed siliciclastic-carbonate platform: the Late Cenomanian-Mid Turonian at the southern margin of the Spanish Central System. Sedimentology, 54, 1245-1271.

García-Hidalgo, J.F., Barroso-Barcenilla, F., Gil, J., Martínez, R., Pons, J.M., Segura, M., 2012. Stratal, sedimentary and faunal relationships in the Coniacian 3rd order sequence of the Iberian Basin (Spain). Cretaceous Research, 34, 268-283.

Gelabert, B., Sàbat, F., Rodríguez-Perea, A., 2002. A new proposal for the Late Cenozoic geodynamic evolution of the western Mediterranean. Terra Nova, 14, 93-100.

Gil, J., García-Hidalgo, J.F., Segura, M., García, A., Carenas, B., 2006. Stratigraphic architecture, palaeogeography and sea-level changes of a third order depositional sequence: The late Turonian-early Coniacian in the northern Iberian Ranges and Central System (Spain). Sedimentary Geology, 191, 191-225.

Gradstein, F.M., Ogg, J.G., Smith, A.G, eds, 2004. A Geologic Time Scale 2004. Cambridge, Cambridge University Press, 589pp.

Gräfe, K.U., 1999. Sedimentary cycles, burial history and foraminiferal indicators for systems tracts and sequence boundaries in the Cretaceous of the Basco-Cantabrian Basin (northern Spain). Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 212, 85-130.

Haq, B.U., Hardenbol, J., Vail, P.R., 1988. Mesozoic and Cenozoic Chronostratigraphy and Eustatic Cycles. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.S.C., Posamentier, H., Ross, C.A., Wagoner, J.C.Van (eds.). Sea-Level changes: An integrated approach. Society for sedimentary Geology (SEPM), 42 (Special Publication), 71-108.

Hewaidy, A.A., Azab, M.M., Farouk, S., 2003. Ammonite biostratigraphy of the upper Cretaceous succession in the area West of Wadi Araba, North Eastern Desert, Egypt. Egyptian Journal of Paleontology, 3, 331-359.

Hirano, H., Toshimitsu, S., Matsumoto, T., Takahashi, K., 2000. Changes in Cretaceous ammonoid diversity and marine environments of the Japanese Islands. In: Okada, H., Mateer, H.J. (eds.). Cretaceous environments in Asia. Developments in Paleontology and Stratigraphy, 17, 145-154.

Jacobs, D.K., Landman N.H., Chamberlain, J.A., 1994. Ammmonite shell shape varies with facies and hydrodynamics. Geology, 22, 905-908.

Jenkyns, H.C., 1980. Cretaceous anoxic events: from continents to oceans. London, Journal of the Geological Society, 137,171-188.

Jenkyns, H.C., Gale, A.S., Corfield, R.M., 1994. Carbon- and oxygen-isotope stratigraphy of the English Chalk and Italian Scaglia and its palaeoclimatic significance. Geological Magazine, 131, 1-34.

Karrenberg, M., 1935. Ammoniten aus der Nordspanischen Oberkreide. Palaeontographica, Abteilung A, 82, 125-161.

Kassab, A.S., Obaidalla, N.A., 2001. Integrated biostratigraphy and inter-regional correlation of the Cenomanian-Turonian deposits of Wadi Feiran, Sinai, Egypt. Cretaceous Research, 22, 105-114.

Kennedy, W.J., Wright, C.W., 1984. The Cretaceous ammonite Ammonites requienianus d'Orbigny, 1841. Palaeontology, 27, 281-293.

Kennedy, W.J., Simmons, M.D., 1991. Mid-Cretaceous ammonites and associated microfossils from the central Oman Mountains. Newsletters on Stratigraphy, 25, 127-154.

Küchler, T., 1998. Upper Cretaceous of the Barranca (Navarra, northern Spain); integrated litho-, bio-, and event stratigraphy: Cenomanian through Santonian. Acta Geologica Polonica, 48, 157-236.

Meister, C., Rhalmi, M., 2002. Quelques ammonites du Cénomanien-Turonien de la région d'Errachidia-Boudnid-Erfoud (partie méridionale du Haut Atlas Central, Maroc). Revue de Paléobiologie, 21, 759-779.

Meister, Ch., Abdallah, H., 2005. Précision sur les successions d'ammonites du Cénomanien-Turonien dans la région de Gafsa, Tunisie du centre-sud. Revue de Paléobiologie, 24, 111-199.

Mojica, J., Wiedmann, J., 1977. Kreide-Entwicklung und Cenomanien/Turonien Grenze der mittleren Keltiberischen Ketten bei Nuevalos (Prov. Zaragoza, Spanien). Eclogae Geologicae Helvetiae, 70, 739-759.

Nagm, E., Wilmsen, M., Aly, M., Hewaidy, A.G., 2010. Biostratigraphy of the Upper Cenomanian-Turonian (lower Upper Cretaceous) successions of the western Wadi Araba, Eastern Desert, Egypt. Newsletters on Stratigraphy, 44, 17-35.

O'Dogherty, L., Sandoval, J., Vera, J.A., 2000. Ammonite faunal turnover tracing sea-level changes during the Jurassic (Betic Cordillera, southern Spain). London, Journal of the Geological Society, 157, 723-736.

Philip, J., Floquet, M., 2000. Late Cenomanian. In: Dercourt, J., Gaetani, M. Vrielynck, B., Barrier, E., Biju-Duval, B., Brunet, M.F., Cadet, J.P., Crasquin, S., Sandulescu, M. (eds.). Atlas Peri-Tethys. Paris, CVGM/CGMV, Map 14.

Rey, J., Dinis, J.L., Callapez, P.M., Cunha, P.P., 2006. Da rotura continental à margem passiva. Composição e evolução do Cretácico de Portugal. Lisboa, Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI), 75pp.

Sandoval, J., O'Dogherty, L., Guex, J., 2001. Evolutionary rates of Jurassic ammonites in relation to sea-level fluctuations. Palaios, 16, 311-335.

Sandoval, J., O'Dogherty, L., Vera, J.A., Guex, J., 2002. Sea-level changes and ammonite faunal turnover during the Lias-Dogger transition in Western Tethys. Bulletin de la Société Géologique de France, 173, 57-66.

Santamaría-Zabala, R., 1992. Los ammonoideos del Cenomaniense superior al Santoniense de la Plataforma Nord-Castellana y la Cuenca Navarro-Cántabra, I. Treballs del Museu de Geologia de Barcelona, 2, 171-268.

Santamaría-Zabala, R., 1995. Los ammonoideos del Cenomaniense superior al Santoniense de la Plataforma Nord-Castellana y la Cuenca Navarro-Cántabra, II. Treballs del Museu de Geologia de Barcelona, 4, 15-131.

Schlanger, S.O., Jenkyns, H.C., 1976. Cretaceous oceanic anoxic events: causes and consequences. Geologie en Mijnbouw, 55, 179-184.

Schlanger, S.O., Arthur, M.A., Jenkyns, H.C., Scholle, P.A., 1987. The Cenomanian/Turonian anoxic event deposits. In: Einsele, G., Seilacher, A. (eds.). Cyclic and Event Stratification. New York, Springer-Verlag, 161-173.

Segura, M., Carenas, B., Gil, J., García-Hidalgo, J.F., García, A., 2001. Anatomy of the carbonate bodies in relation to their position with respect to the maximun transgressive in the 2nd-order Cycles of the Upper Cretaceous from the Iberian Range. Géologie Méditerranée, 28, 163-168.

Segura, M., García, A., Carenas, B., García-Hidalgo, J.F., Gil, J., 2002. Upper Cretaceous of the Iberian Basin. In: Gibbons, W., Moreno, T. (eds.). The Geology of Spain. London, Geological Society, 288-292.

Sepkoski, J.J., 1986. Phanerozoic overview of mass extinctions. In: Raup, D.M., Jablonski, D. (eds.). Patterns and processes in the history of life. Berlin, Springer-Verlag, 277-295.

Stampfli, G., Borel, G., Cavazza, W., Mosar, J., Ziegler, P.A., 2001. The Paleotectonic Atlas of the Peritethyan Domain. European Geophysical Society, CD ROM ISBN 3-9804862-6-5.

Westermann, G.*E.g*., 1996. Ammonoid life and habitat. In: Landman, N.H., Tanabe, K., Davis, R.A. (eds.). Ammonoid Paleobiology. Topics in Geobiology, 13, 607-707.

Wiedmann, J., 1979. Itineraire géologique à travers le Crétacé moyen des Chaînes Vascogotiques et Celtibériques (Espagne du Nord). Cuadernos de Geología Ibérica, 5, 127-214.

Wiedmann, J., 1960. Le Crétacé Supérieur de l'Espagne et du Portugal et ses Céphalopodes. In: Roger, J. (ed.). Colloque sur le Crétacé Supérieur Français. Paris, Gauthier-Villars, 709-764.

Wiedmann, J., Kauffman, G., 1978. Mid-Cretaceous biostratigraphy of northern Spain. Annales du Muséum d'Histoire Naturelle de Nice, 4, 3.1-3.34.

Wiese, F., Schulze, F., 2005. The upper Cenomanian (Cretaceous) ammonite *Neolobites* vibrayeanus (d'Orbigny, 1841) in the Middle East. Cretaceous Research, 26, 930-946.

Wilmsem, M., Mosavinia, A., 2011. Phenotypic plasticity and taxonomy of Schloenbachia varians (J. Sowerby, 1817) (Cretaceous Ammonoidea). Paläontologische Zeitschrift, 85, 169-184.

Yacobucci, M.M., 2008. Controls on Shell Shape in Acanthoceratid Ammonites from the Cenomanian-Turonian Western Interior Seaway. In: Harries, P.J. (ed.). High-Resolution Approaches in Stratigraphic Paleontology. Topics in Geobiology, 21, 195-226.

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