

Cephalopod assemblages and depositional sequences from the upper Cenomanian and lower Turonian of the Iberian Peninsula (Spain and Portugal)

Asociaciones de cefalópodos y secuencias deposicionales en el Cenomaniense superior y Turoniense inferior de la Península Ibérica (España y Portugal)

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Received: 16/07/10 / Accepted: 15/01/11

Abstract

The comparison and correlation of the biostratigraphic successions identified in the upper Cenomanian and lower Turonian of the Iberian Trough (IT, Spain) and the Western Portuguese Carbonate Platform (WPCP, Portugal) allows differentiating nine cephalopod assemblages (1 to 9), with notably different taxa, and two (3rd order) depositional sequences (A and B). Some of these main intervals can be divided in minor ones, such as assemblage 4 (in 41 and 42) and sequence B (in B1 and B2). Assemblages 1 to 3 are related with sequence A, and assemblage 4 to 9 with sequence B (specifically, 4 to 6 with B1, and 7 to 9 with B2). The analysis and interpretation of these biostratigraphic data allows us to infer certain palaeoecologic turnovers that happened in the studied basins, both with external origin or due to local tectonic and palaeogeographical changes. Though partially altered by hypoxic phenomena (especially the sequence B1, assemblage 4) and local tectonics (mainly in the WPCP), in each of these cycles there were events of extinction of the cephalopods from shallow environments and survival of those from pelagic or deep environments, of settling of new environments, and of adaptation to them caused, successively, by intervals of low, ascending and high sea-level.

Keywords: Cephalopoda, fossil assemblage, depositional sequence, upper Cenomanian, lower Turonian, Iberian Peninsula

Resumen

La comparación y correlación de las sucesiones bioestratigráficas identificadas en el Cenomaniense superior y Turoniense inferior del Surco Ibérico (IT, España) y la Plataforma Carbonatada Occidental Portuguesa (WPCP, Portugal) permiten diferenciar nueve

asociaciones de cefalópodos (1 a 9), con taxones notablemente diferentes, y dos secuencias deposicionales principales (3er orden) (A y B). Algunos de estos intervalos principales pueden dividirse en secundarios, como la Asociación 4 (en 41 and 42) y la Secuencia B (en B1 y B2). Las asociaciones 1 a 3 pueden se pueden relacionar con la secuencia A, y la asociación 4 a 9 con la secuencia la B (concretamente, 4 a 6 con B1, y 7 a 9 con B2). El análisis y la interpretación de estos datos bioestratigráficos permiten deducir ciertos cambios paleoecológicos sucedidos en las cuencas estudiadas, tanto de origen externo como debidos a la tectónica local ó a cambios paleogeográficos. Aunque parcialmente alterados por fenómenos de hipoxia (especialmente la secuencia B1, asociación 4) y de tectónica local (principalmente en el WPCP), en cada uno de estos ciclos se produjeron fenómenos de extinción de los cefalópodos de medios someros y de supervivencia de los de ambientes pelágicos ó profundos, de colonización de nuevos espacios, y de adaptación a los mismos provocados, sucesivamente, por intervalos de nivel de mar bajo, ascendente y y alto.

Palabras clave: Cephalopoda, asociación fósil, secuencia deposicional, Cenomaniense superior, Turoniense inferior, Península Ibérica

1. Introduction

The well-marked relative sea-level changes during the late Cenomanian and early Turonian have been widely recorded in the Iberian Peninsula, especially when carbonate or mixed sequences are concerned. These facies yielded a diverse ensemble of boreal and meridional cephalopod assemblages, which allow the establishment of detailed stratigraphic settings and interregional correlations with Western Europe, North Africa and, even, the Western Interior of the USA.

Both the Spanish and Portuguese domains have a long historical tradition, from the early 19th century, of research on the stratigraphy and palaeontology of the Upper Cretaceous, and are especially known for their meridional ammonite assemblages with vascoceratids and associated temperate and warm faunas, mainly acanthoceratids and pseudotissotiids. Unfortunately, with only few exceptions, such as the Iberian Field Conference on Mid Cretaceous Events of 1979, these investigations have been carried out separately, without significant shared field-works, discussions or conclusions. With the purpose to join common efforts on this matter, next work presents a first concise synthesis and correlation of the Iberian cephalopod biostratigraphy for the upper Cenomanian and lower Turonian, considering the advances of the last decades on the Upper Cretaceous palaeontology and biostratigraphy.

Field work was carried out in outcrops with upper Cenomanian and lower Turonian sequences situated in the localities of Puentede y Soncillo, in the north of the province of Burgos, of Fuentetoba and Villaciervos, in the centre of Soria, and of Cantalojas, Galve de Sorbe, Condemios, Somolinos, Atienza and Tamajón, in the north of Guadalajara, Spain. Within Portugal, the exposures of Salmana-Figueira da Foz, Costa d'Arnes, Tentúgal, Ançã-Trouxemil, in the west of the province of Beira Litoral, and of Olival, Leiria and Nazaré, in the north of Estremadura, were sampled (Text-fig. 1). These Spanish

sections are distributed along the southeastern Cantabrian Ranges, the southwestern Iberian Ranges and the northeastern Central System, whereas the Portuguese ones are located between the Atlantic Coast, the uplifted Jurassic Massifs of Estremadura, and the western border of the Hesperian Massif.

2. Historical background

Both the Iberian Trough and the Western Portuguese Carbonate Platform successions have been exhaustively studied since the late 19th century. During the 60's and 70's of the 20th century, when Wiedmann worked on the Spanish cephalopods, and Ferreira Soares and Berthou on the correlative palaeofaunas of Portugal, there has been a substantial advance in the knowledge about the ammonite assemblages. In the last decades, the ammonite palaeofaunas from the upper Cenomanian and lower Turonian of Western Portugal have been methodically reviewed by Callapez (1998) and Callapez and Ferreira Soares (2001), with recognition of new meridional ammonite assemblages with North African affinities. Identical work has been done by Barroso-Barcenilla (2006) in the Iberian Trough, but with the advantage of a larger field-work area with more expanded successions and deeper water facies. However, there has not been a tradition of comparing the Spanish and Portuguese faunal and stratigraphic settings, in order to set up an integrated biostratigraphic model with obvious implications on further palaeogeographic interpretations.

2.1. Iberian Trough

From the end of the 19th and the beginning of the 20th centuries many systematic and biostratigraphic studies on the cephalopods collected from the upper Cenomanian and lower Turonian of the Iberian Trough were carried out, but only a few of the studied specimens were described and illustrated in an appropriate way. Among



Fig. 1.- Geographic general location (A) and stratigraphic context of the main Spanish (B) and Portuguese (C) studied sections and other mentioned places. Photographic views of the outcrops of Puentevedy (D), Condemios (E), Salmanha (F) and Nazaré (G).

Fig. 1.- Situación geográfica general (A) y contexto estratigráfico de las principales secciones españolas (B) y portuguesas (C) estudiadas y otros lugares citados. Vistas fotográficas de los afloramientos de Puentevedy (D), Condemios (E), Salmanha (F) y Nazaré (G).

these works, those by Mallada (1891, 1892), Karrenberg (1935), Wiedmann (1960, 1964, 1975a, 1975b, 1979), Mojica and Wiedmann (1977), Wiedmann and Kauffman (1978), Segura and Wiedmann (1982), Carretero-Moreno (1982), Meléndez-Hevia (1984), Santamaría-Zabala (1991, 1992, 1995), Gräfe and Wiedmann (1993), Martínez *et al.* (1996), Kuchler (1998), Barroso-Barcenilla (2004, 2006, 2007), Barroso-Barcenilla and Goy (2007, 2009, 2010) and Barroso-Barcenilla *et*

al. (2009) stood out.

The sequence stratigraphy of the Upper Cretaceous of the Iberian Trough was studied in detail by several authors, such as Gräfe and Wiedmann (1993, 1998) and Gräfe (1994, 1996), in the Outer Navarro-Cantabrian Platform and the North-Castilian Sector; and Segura *et al.* (2001), Gil *et al.* (1993), Gil (1994), Gil and García (1996) and García-Hidalgo *et al.* (2003), in the Central Sector. Among them, the works of Floquet (1998) and

Gräfe (1999) in the Outer Navarro-Cantabrian Platform and the North-Castilian Sector, and of Alonso *et al.* (1993) and Segura *et al.* (1999) in the Central Sector, stood out by their exhaustivity and acceptance.

2.2. Western Portuguese Carbonate Platform

In Portugal, early research on palaeontology and stratigraphy is dated from the middle 19th century (Sharpe, 1849) and had continuity with subsequent contributions (among them those by Choffat, 1886, 1898, 1900, 1901-02) that described the Cretaceous of West Central Portugal, including the regions of Beira Litoral (Figueira da Foz to Coimbra and Aveiro) and Estremadura (Lisbon to Nazaré and Leiria), with emphasis on the Cenomanian and Turonian stages and main palaeontological groups. After these first decades of fruitful research, more than half a century elapsed till the stratigraphy and palaeontology of the Baixo Mondego was reviewed by Ferreira Soares (1966, 1972, 1980). These works were followed by biostratigraphic studies undertaken by Lauerjatz (1982) and Berthou (1984), among others.

Since 1992, the Cenomanian and lower Turonian cephalopod faunas of West Central Portugal have been extensively reviewed, with emphasis on systematics and biostratigraphy (Callapez, 1992, 1998, 2003, 2004, 2008; Callapez and Ferreira Soares, 2001; Callapez *in* Hart *et al.*, 2005). These studies have been based on a new reference collection assembled at the University of Coimbra (with species *in*edit to the Lusitanian area), and the Choffat Collection of the Geological Survey, making it possible for the first time, to establish an integrated biostratigraphy with other areas of the Tethyan Realm.

3. Geological setting

The studied Spanish outcrops form part of a large north-west-to-southeast orientated band constituted by a thick carbonate sedimentary sequence (limestones and marlstones), with some interbedded terrigenous and dolostone intervals. Their cephalopods have been mainly collected from the Margas de Puentedey (Floquet *et al.*, 1982) and Margas de Picofrentes (Floquet *et al.*, 1982) formations, deposited in the inner and the marginal environments of the platform, respectively. The studied Portuguese exposures are part of a band of Upper Cretaceous carbonate platform that outcrops across the northern margin of the Baixo Mondego, from Coimbra to Figueira da Foz. To the south there is a related set of outcrops orientated along the southern block of the northeast-southwest tectonic and diapiric axis of Nazaré-Leiria-Pombal.

During the Late Cretaceous, the current Iberian Peninsula was a relatively independent tectonic unit, called Iberian Subplate. The combined incidence of the eustatic worldwide changes and the local tectonic readjustments generated several faunal turnovers and depositional sequences in the epicontinental flooded regions of the Iberian Subplate, among those the Iberian Trough and the Western Portuguese Platform (Text-fig. 2).

Specifically, the Iberian Trough (IT) was a long, narrow and relatively stable intracratonic ramp, and comprised the northern, central and south-eastern regions of the Iberian Subplate that were temporally or permanently flooded by the Protoatlantic Ocean, the Tethys Sea or both. It was bordered on the west by the Hesperian Massif and on the east by the Ebro Massif, and was broadly related to the North Cantabrian, Basque, Pyrenean and Levantine basins. The IT was divided into different domains. These were, from the north to the southeast, the Outer Navarro-Cantabrian Platform, the Inner Castilian Platform and the Levantine Platform. The Inner Castilian Platform was divided into the North-Castilian Sector and the Central Sector. The North-Castilian Sector included the North-Ebro Area and the South-Ebro Area, and the Central Sector comprised the La Demanda Area and the Guadarrama Area. Further readings about the main subjects related with the geological evolution of the IT were given by Amiot (1982), Floquet *et al.* (1982), Rosales *et al.* (2002), Mas *et al.* (2002), Floquet (2004) and García *et al.* (2004).

The Western Portuguese Carbonate Platform (WPCP) included the central-western regions of the Iberian Subplate, and was broadly related with the Atlantic Lusitanian Basin (Ferreira Soares and Rocha, 1985). It experienced a complex tectonic control with reactivated late Hercynian faults and halokinetic structures, and at least three main rifting phases intercalated with intervals of post-rift thermal subsidence (Wilson *et al.*, 1989; Hiscott, 1990). The tectono-sedimentary evolution of this basin enabled the formation of a relatively homogeneous and stable basal upper Cenomanian carbonate platform with cephalopods. Subsequently, a clear differentiation on the palaeogeographic setting of this carbonate platform was established, with ammonites restrained to the Baixo Mondego, and a large domain of shoals with coral and rudist fringes developed southwards in Leiria and Nazaré. Further readings about the main subjects related with the stratigraphy of the WPCP can be consulted in Ferreira Soares (1980), Lauerjatz (1982), Berthou (1984), Callapez (1998, 2004, 2008), Hart *et al.*, (2005) and Rey *et al.* (2006).

In the present paper, the palaeogeographical division and the ammonite zonation for the upper Cenomanian and

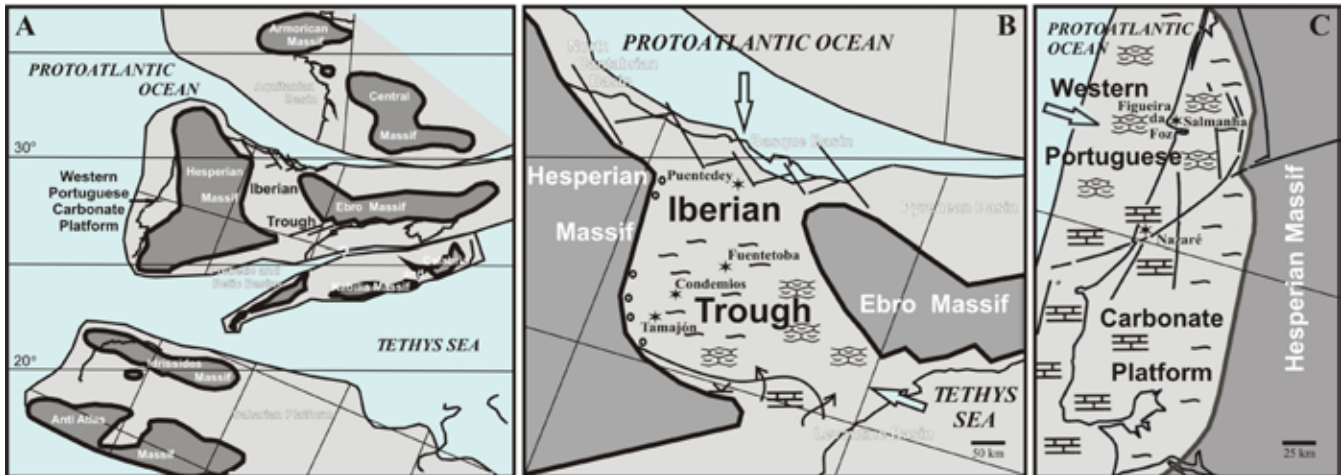


Fig. 2.- Palaeogeographic general situation of the Iberian Peninsula during the maximum transgression of the late Cenomanian-Early Turonian (A), with the approximate locations of the main Spanish (B) and Portuguese (C) studied outcrops and the facies distribution. Modified from Philip and Floquet (2000), Stampfli *et al.* (2001) and Gelabert *et al.* (2002). The circles symbolize coastal terrigenous, the horizontal rectangles indicate the position of relatively shallow water carbonate platform sediments, the curved lines stand for the marls deposited in deeper regions of the platform, and the hexagons represent bioclastic limestones located in intermediate bathymetries.

Fig. 2.- Situación paleogeográfica general de la Península Ibérica durante el máximo transgresivo del Cenomaniense superior-Turonense inferior (A), con la localización de las principales secciones españolas (B) y portuguesas (C) estudiadas y la distribución de facies. Modificado de Philip y Floquet (2000), Stampfli *et al.* (2001) y Gelabert *et al.* (2002). Los círculos simbolizan depósitos terrígenos costeros, los rectángulos horizontales carbonatos someros, las líneas onduladas margas más profundas y los hexágonos calizas bioclásticas de batimetrías intermedias.

lower Turonian of the IT proposed by Barroso-Barcenilla *et al.* (2009) and of the WPCP developed by Callapez and Ferreira Soares (2001) and Callapez (2003, 2008) have been followed. These zonal schemes, on the basis of the occurrence of the index species, have been correlated between them and with that of the type-section of Pueblo, USA, and with those zonations that can be considered as representative of the Boreal (Western Europe) and Tethyan (North Africa) domains (Text-fig. 3). The interregional correlations presented herein have been made according to the conclusions of Graciansky *et al.* (1998).

4. Cephalopod assemblages

The main part of the cephalopods collected in the upper Cenomanian and the lower Turonian of the IT (Barroso-Barcenilla, 2006, 2007; Barroso-Barcenilla and Goy, 2007, 2009, 2010; Barroso-Barcenilla *et al.*, 2009) and the WPCP (Callapez, 1998, 2003; Callapez and Ferreira Soares, 2001) do not present signs of taphonomic re-sedimentation 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 can be considered that all of them maintain their respective original stratigraphic positions (Callapez, 1998; Barroso-Barcenilla, 2006). The comparison and integration of the successions and co-occurrences of these cephalopods

has allowed us to differentiate nine cephalopod assemblages within the materials of this interval, which have been numbered in stratigraphic ascending order (Text-fig. 4).

These assemblages (1 to 9) own notably different taxa and can be related to certain palaeoecologic turnovers that happened in the studied basins, both with external origin or due to local tectonic and palaeogeographical changes. Each of them has been interpreted considering the narrow relation that was established in the epicontinental platforms between the palaeoecologic changes and the general palaeontological record, emphasized by Fernández-López (1999, 2000), or the specific succession of cephalopods, studied by Hirano *et al.* (2000) and Toshimitsu and Hirano (2000), among others. These authors maintain that the ammonoid diversity was primarily controlled by changes in the marine environments. On this basis, several eustatic, tectonic or geochemical alterations have been inferred, which concerned the habitability of the region during the considered interval, providing interesting information about the evolution of the Iberian Subplate.

4.1. Assemblage 1

This assemblage can be recognized overlaying the stratigraphic discontinuity of the middle-upper Cenomanian

boundary, in the *Eucalycoceras rowei* zone of the IT, and includes the co-occurrence of *Eucalycoceras* with *Calycoceras*. In it, the taxa *Eucalycoceras rowei*, *Calycoceras* (*Proeucalycoceras*) sp., *Calycoceras* (*Calycoceras*) sp. and, seemingly, *Calycoceras* (*Calycoceras*) *naviculare*, have been identified, all of them belonging to the Acanthoceratidae. In the WPCP its lower part corresponds to a stratigraphic interval with the bivalve *Gyrostrea ouremensis*, but without known ammonites. The materials in which this assemblage has been recorded reach a restricted geographic distribution (exclusively the IT) and only own cephalopods moderately adapted to shallow marine environments (*Eucalycoceras* and *Calycoceras*: Batt, 1989; Westermann, 1996). In the same way, it can be added that both the number and the diversity of the collected specimens are relatively scarce (3 or 4 species).

4.2 Assemblage 2

It is recorded in the upper Cenomanian *Neolobites vibrayanus* subzone of the IT and the *Calycoceras* (*Eucalycoceras*) *guerangeri* zone of the WPCP, and includes the co-occurrence of *Angulithes* with *Neolobites*, in the Nautilidae and Engonoceratidae in both basins, and of *Euomphaloceras* with *Calycoceras*, in the Acanthoceratidae in the former, and of *Calycoceras*, in the same family, in the latter. In it, the following taxa have been recognized: *Angulithes mermeti*, *Neolobites vibrayanus* and *Calycoceras* (*Calycoceras*) *naviculare*, in both basins; *Lotzeites* sp. and *Euomphaloceras euomphalum*, in the IT; and *Neolobites bussoni*, *Calycoceras* (*Proeucalycoceras*) *guerangeri*, *Eucalycoceras pentagonum*, *Thomelites hancocki* and *Puzosia* (*Parapuzosia*) sp., in the WPCP. In this interval, it can be observed a notable increase in the number of localities that yielded fossil cephalopods, as well as in the diversity of these invertebrates (10 species). Among them, the abundance of *Angulithes* and *Neolobites* stand out, initially typical of relatively deep or open waters, and there is a near absence of taxa characteristic of epicontinental environments. The co-occurrence of *Angulithes* and *Neolobites* in this interval has been observed by different authors in other basins (Peru: Benavides-Cáceres, 1956; Morocco: Meister and Rhalmi, 2002, Cavin et al., 2010).

4.3 Assemblage 3

It can be recognized in the upper Cenomanian *Metoicoceras mosbyense* and *Metoicoceras geslinianum* subzones of the IT, where includes the co-occurrence of *Metoicoceras*, and only owns the species *Metoicoceras*

mosbyense and *Metoicoceras geslinianum*, of the Acanthoceratidae. Although it can be identified across a relatively high number of localities of the IT, its taxonomic diversity is very low (2 species). Nevertheless, it is within this assemblage that the first phylogenetic line between two species of cephalopods (*M. mosbyense* and *M. geslinianum*) can be established in the upper Cenomanian of the Iberian Subplate. Also, it seems to be especially significant the fact that, as revealed by geochemical analyses realized in collaboration with the Prof. Dr. W.J. Kennedy in the Puentedey Section, the materials corresponding to the *M. geslinianum* subzone registered the first and punctual of the two positive excursions of the δC^{13} signal (the second and main in the *S. (J.) subconciiliatus* zone), seemingly related with the Ocean Anoxic Event of the Cenomanian-Turonian Transition (OAE2) of Schlanger and Jenkyns (1976) (Barroso-Barcenilla et al., 2011). Similar isotopic variations were observed by other authors, such as Kennedy et al. (2000) and Caron et al. (2006) in correlative levels of other regions and, thus, they were possibly produced by worldwide oceanographic and climatic changes.

4.4 Assemblage 4

This important set has been registered in the upper Cenomanian *Vascoceras gamai* subzone and the *Spathites* (*Jeanrogericeras*) *subconciiliatus* zone of the IT, and the *Euomphaloceras septemseriatus* and the *Pseudaspidoce- ras pseudonodosoides* zones of the WPCP. It includes, in the IT, the co-occurrence of *Vascoceras* 1 (*sensu* Barroso-Barcenilla, 2006), in the Vascoceratidae, and of *Spathites* (*Jeanrogericeras*) 1 (*sensu* Barroso-Barcenilla, 2006), in the Acanthoceratidae, and, in the WPCP, the co-occurrence of *Vascoceras* 1 with *Rubroceras*, in the Vascoceratidae, and of *Euomphaloceras* with *Pseudocalyoceras* and of *Spathites* (*Jeanrogericeras*) 1 with *Pseudaspidoce- ras*, in the Acanthoceratidae. In this assemblage, the following taxa have been recognized: *Vascoceras gamai*, *Vascoceras barcoicense*, *Fagesia catinus* and *Spathites* (*Jeanrogericeras*) *subconciiliatus*, in both basins; *Vascoceras charoni*, *Vascoceras durandi*, *Vascoceras cauvinii*, *Spathites* (*Jeanrogericeras*) *robustus* and *Parapuzosia* (*Austiniceras*) sp., in the IT; and *Pseudocalyoceras* sp., *Euomphaloceras septemseriatus*, *Vascoceras adonense*, *Vascoceras silvanense*, *Vascoceras* sp., *Vascoceras douvillei*, *Vascoceras kossmati*, *Rubroceras* cf. *alatum*, *Rubroceras* sp., *Pseudaspidoce- ras pseudonodosoides*, *Puzosia* (*Puzosia*) sp. and *Pachydesmoceras denisonianum*, in the WPCP. It records the early arrival of vascoceratid ammonites to the Iberian Subplate, and reveals a domi-

Substages	Cephalopod Assemblages								
	Iberian Trough, Spain				Western Portuguese Platform, Portugal				This work
	Barroso-Barcenilla (2006, 2007) and Barroso-Barcenilla and Goy (2007, 2009, 2010)								
Acanthoceratidae	Vascoceratidae	Pseudotissotiididae	Other families	Acanthoceratidae	Vascoceratidae	Pseudotissotiididae	Other families		
Lower Turonian	Spathites with Mammites	Fagesia with Neoptychites	Hrightoceras with Donenriquoceras	Hoplitoidea					9
	Mammites		Donenriquoceras						8
	Spathites (Jeanrogericeras) 3		Choffaticeras (Leoniceras)	Nostoceras (Eubostrychoceras)	Kamerimoceras	Fagesia with Neoptychites	Choffaticeras (Leoniceras) with Thomasites	Pachydesmoceras	7
	Spathites (Ingridella)					Vascoceras 2			6
	Spathites (Jeanrogericeras) 2	Vascoceras 2	Choffaticeras (Choffaticeras)						5
Upper Cenomanian	Spathites (Jeanrogericeras) 1	Vascoceras 1			Spathites (Jeanrogericeras) 1 with Pseudaspidoceras	Vascoceras 1 with Rubroceras		Pachydesmoceras	4
					Euomphaloceras with Pseudocalycoceras				
	Metoicoceras								3
	Euomphaloceras with Calycoceras			Angulites with Neolobites	Calycoceras			Angulites with Neolobites	2
	Eucalycoceras with Calycoceras								1

Fig. 4.- Cephalopod assemblages identified in the Iberian Trough and the Western Portuguese Carbonate Platform. The oblique lines indicate interval without record, and the arrows represent that the assemblage continues.

Fig. 4.- Asociaciones de cefalópodos identificadas en el Surco Ibérico y la Plataforma Carbonatada Occidental Portuguesa. Las líneas oblicuas indican intervalo sin registro, y las flechas representan que la asociación continúa.

levels of the second and main phase of the OAE2 in the North-Ebro Area (Puentedy, Barroso-Barcenilla et al., 2011), together with numerous and almost monospecific levels with *S. (J.) subconciatus* in the whole IT, as well as a widespread marly-dolomitic sequence with spatangoids and cephalopods in the WPCP stand out. In them, the cephalopod diversity is much lower (2 species), and besides *S. (J.) subconciatus*, only *V. durandi* has been identified, specifically in the Guadarrama Area (Tamañón: Barroso-Barcenilla et al., 2009). The deposition of hypoxic sediments in deep environments of the IT was studied by several authors, such as Paul et al. (1994) and Rodríguez-Lázaro et al. (1998), and recently confirmed by the geochemical analyses developed in the Puentedy Section by Barroso-Barcenilla et al. (2011). The practically exclusive presence of a species of cephalopod that shows a wide morphologic variability in a biostratigraphic interval, like in case of *S. (J.) subconciatus* in a part of the homonymous zone, was observed by different researchers, such as Meister et al. (1992). Finally (3rd), the cephalopod diversity increases notably (11 species), having registered representatives of *S. (Jeanrogericeras)*, *Fagesia*, *P. (Austiniceras)*, *P. (Puzosia)* and *Pachydesmoceras* and, mainly of *Vascoceras*, some of them belonging to exotic species.

4.5. Assemblage 5

It is recorded in the lower Turonian *Choffaticeras (Choffaticeras) quaasi* zone of the IT, and includes the co-occurrence of *Spathites (Jeanrogericeras) 2* (*sensu* Barroso-Barcenilla, 2006), in the Acanthoceratidae, and the first interval of the co-occurrence of *Vascoceras 2* (*sensu* Barroso-Barcenilla, 2006), in the Vascoceratidae, and of *Choffaticeras (Choffaticeras)*, in the Pseudotissotiidae, with the species *Spathites (Jeanrogericeras) subconciatus*, *Spathites (Jeanrogericeras) tavense*, *Spathites (Jeanrogericeras) saenzi*, *Spathites (Jeanrogericeras) postsaenzi*, *Vascoceras durandi*, *Vascoceras amieirensis*, *Vascoceras hartii*, *Choffaticeras (Choffaticeras) quaasi*, *Choffaticeras (Choffaticeras) pavillieri* and, possibly, *Pseudotissotia* sp. This assemblage has not been recognised in the sedimentary record of WPCP. Its taxonomic diversity is very high (9 or 10 species) and, in it, phylogenetic relationships can be established between almost all the represented species (Acanthoceratidae: Barroso-Barcenilla, 2007; Vascoceratidae: Barroso-Barcenilla and Goy, 2009, 2010; Pseudotissotiidae: Barroso-Barcenilla and Goy, 2007). Although the two endemics *S. (J.) saenzi* and *S. (J.) postsaenzi* exist in the same, the groups from the Tethys, such as the vascoceratids and the pseudotisso-

tiids (Meister et al., 1994; Courville et al., 1998), clearly predominate.

4.6. Assemblage 6

It is typical of the lower Turonian *Spathites* (*Ingridella*) *malladae* subzone of the IT, and includes the co-occurrence of *Spathites* (*Ingridella*), in the Acanthoceratidae, and the second interval of the co-occurrence of *Vascoceras* 2 and of *Choffaticeras* (*Choffaticeras*). In it, the following species have been identified: *Spathites* (*Ingridella*) *malladae*, *Spathites* (*Jeanrogericeras*) *obliquus*, *Spathites* (*Jeanrogericeras*) *reveliereanus*, *Kamerunoceras ganuzai*, *Vascoceras amieirensis*, *Vascoceras harttii*, *Vascoceras kossmati*, *Choffaticeras* (*Choffaticeras*) *pavillieri*, *Choffaticeras* (*Choffaticeras*) *sinaiticum*, *Wrightoceras llarenai*, *Angulithes vascogoticus* and, possibly, *Choffaticeras* (*Choffaticeras*) *segne*. It could also be partly correlative to the K level of the WPCP, which includes the co-occurrence of *Vascoceras* 2 and of *Choffaticeras* (*Choffaticeras*) just below a diverse fauna from the *Thomasites rollandi* zone. In this dolomitic unit of the WPCP, which yielded a very scarce fauna of bivalves (*Mytiloides*) and ammonites, the species *Vascoceras kossmati*, *Vascoceras durandi* and, possibly, *Pachydesmoceras denisonianum* have been identified. In assemblage 6, although the ammonite diversity become extraordinarily high (11 or 12 species), the increase on the proportion of taxa almost exclusively from the Iberian Subplate (Wright, 1996; Barroso-Barcenilla and Goy, 2007) is very relevant. Among these, the subgenus *Spathites* (*Ingridella*) stands out for its higher relative abundance.

4.7. Assemblage 7

It can be recognized in the lower Turonian *Choffaticeras* (*Leoniceras*) *luciae* subzone of the IT, and the L level of the *Thomasites rollandi* zone of the WPCP, and includes the co-occurrence of *Spathites* (*Jeanrogericeras*) 3 (*sensu* Barroso-Barcenilla, 2006), in the Acanthoceratidae, of *Choffaticeras* (*Leoniceras*), in the Pseudotissotiidae, and of *Nostoceras* (*Eubostriochoceras*), in the Nostoceratidae, in the former region, and of *Kamerunoceras*, in the Acanthoceratidae, of *Fagesia* with *Neoptychites*, in the Vascoceratidae, of *Choffaticeras* (*Leoniceras*) with *Thomasites*, in the Pseudotissotiidae, and of *Pachydesmoceras*, in the Desmoceratidae, in the latter region. In it, the following taxa have been identified: *Spathites* (*Jeanrogericeras*) *reveliereanus*, *Choffaticeras* (*Leoniceras*) *luciae*, *Choffaticeras* (*Leoniceras*) *barjonai* and *Nostoceras* (*Eubostriochoceras*) sp., in the IT, and *Kamerunoceras douvillei*, *Vascoceras kossmati*, *Vascoceras*

durandi, *Fagesia tevesthensis*, *Fagesia superstes*, *Neoptychites cephalotus*, *Thomasites rollandi*, *Choffaticeras* (*Leoniceras*) *barjonai*, *Pachydesmoceras denisonianum* and *Parapuzosia* (*Austiniceras*) *intermedia orientalis*, in the WPCP. In this assemblage, fully recognised in both Spanish and Portuguese lower Turonian successions, the diversity is relatively higher (14 species). Nevertheless, each of the identified families is represented by a single species, with the only exception of Pseudotissotiidae. Within this family, a progressive replacement of *Ch. (L.) luciae* by *Ch. (L.) barjonai* seems to be observed, since the latter species presents, at least in the IT, a slightly higher range than the former. Likewise, the near absence of taxa from shallow environments stands out, since the majority of the identified forms were from open or relatively deep waters, such as the oxycone *Choffaticeras* (*Leoniceras*) and the torticone *Nostoceras* (*Eubostriochoceras*) (Batt, 1989; Westermann, 1996).

Within the highest interval recorded from the levels where this assemblage has been identified, *Fagesia tevesthensis* has been recognized. For this reason, although it can be a mere effect of the sampling detail, the lower part of the assemblage of *Fagesia* with *Neoptychites*, in the Vascoceratidae, has been placed inside the same one.

4.8. Assemblage 8

It is recorded in the lower Turonian *Mammites nodosoides* subzone of the IT, and includes the co-occurrence of *Mammites*, in the Acanthoceratidae, of *Donenriquoceras*, in the Pseudotissotiidae, and the middle part of *Fagesia* with *Neoptychites*, with the species *Mammites nodosoides*, *Spathites* (*Jeanrogericeras*) *reveliereanus*, *Fagesia tevesthensis*, *Fagesia rudra*, *Fagesia mortzestus*, *Fagesia superstes*, *Neoptychites cephalotus*, *Donenriquoceras forbesiceratiforme* and *Pachydesmoceras linderi*. In the WPCP it corresponds to a stratigraphic interval with gastropods of the species *Actaeonella caucasica* and of the group of the nerineids, but without ammonites. Inside its notable diversity (9 species), the groups proceeding from the Protoatlantic stand out, such as *Mammites* and *Fagesia* (Wiedmann, 1975b; Kennedy and Cobban, 1976), but those from relatively open and deep environments, such as *Neoptychites* (Batt, 1989; Westermann, 1996), and the endemics, such as *Donenriquoceras* (Wright, 1996; Barroso-Barcenilla and Goy, 2007), are also represented.

4.9. Assemblage 9

It can be recognized in the lower Turonian *Wrightoceras munieri* subzone of the IT, and includes the co-occurrence of *Spathites* with *Mammites*, in the Acanthoceratidae,

of *Wrightoceras* with *Donenriquoceras*, in the Pseudotissotiidae, of *Hoplitoidea*, in the Colopoceratidae, and the upper part of *Fagesia* with *Neoptychites*, with the species *Spathites* (*Jeanrogericeras*) *obliquus*, *Spathites* (*Jeanrogericeras*) *reveliereanus*, *Spathites* (*Jeanrogericeras*) *combesi*, *Spathites* (*Ingridella*) *depressus*, *Spathites* (*Spathites*) *laevis*, *Spathites* (*Spathites*) *sulcatus*, *Mammites* *nodosoides*, *Fagesia* *superstes*, *Neoptychites* *cephalotus*, *Wrightoceras* *munieri*, *Donenriquoceras* *forbesiceratiforme* and *Hoplitoidea* *ingens*. In it, the taxonomic diversity is comparatively high (12 species), and among the represented forms the endemic ones stand out, such as *S. (J.) obliquus*, *S. (I.) depressus* and *S. (S.) sulcatus* (Santamaría-Zabala, 1995; Barroso-Barcenilla 2007), together with those which seem to have arisen by means of processes more or less marked of adaptation to the platform palaeoenvironments, such as *S. (J.) combesi* and *F. superstes* (Batt, 1989; Westermann, 1996).

5. Depositional sequences

Both the IT and WPCP sedimentary successions of the studied interval were deposited during the course of two 3rd order depositional sequences, known by Haq *et al.* (1988) as UZA-2.4 and UZA-2.5, respectively.

In the IT, the first one of them, named DC-5 by Floquet (1998), UC-4/5 by Gräfe (1999), DS-5 by Alonso *et al.* (1993) and S-3 by Segura *et al.* (1999), includes the basal and middle upper Cenomanian. The second sequence extends from the higher upper Cenomanian to the middle Turonian. In detail, in the north of the IT (Outer Navarro-Cantabrian Platform and North-Castilian Sector), within this second sequence, two other lower order sequences can be differentiated, called DC-6a and DC-6b by Floquet (1998), and UC-5/6 and UC-6/7 by Gräfe (1999), respectively. However, these two intervals can not be individualized in the centre of the IT (Central Sector), but are coincident with the lower and middle part of the sequence DS-6 of Alonso *et al.* (1993) and with the sequence S-4 of Segura *et al.* (1999), and present a more diffuse upper boundary. These differences between the sequences of the north and the centre of the IT can be caused, in part, by the inequality of records of both areas.

In the WPCT, and despite a perceptible influence of local tectonics over the eustatic signature, the same sequences of the IT can be correlated with the 3rd order depositional sequences and subsequent sequences defined by Callapez (1998). In particular, the Portuguese sequence CD records part of the depositional sequence A proposed on this work; sequences E/I and J match with the lower half of B₁, and K/L and M/O with B₂ (Text-fig. 5).

There is an obvious relationship between these two major depositional sequences and the nine cephalopod assemblages described above in the Iberian Subplate. The first of these sequences, which have been named A, can be related to the assemblages 1 to 3, and the second one, called B, to 4 to 9. Each of these depositional sequences includes different genera of cephalopods and coincides with specific worldwide 3rd order eustatic cycles observed by Haq *et al.* (1988), and certain depositional sequences recognized in the IT by numerous authors, as Floquet (1998), Gräfe (1999), Alonso *et al.* (1993) and Segura *et al.* (1999). In the same way, inside the second major sequence, two minor depositional sequences have been differentiated, named B₁ and B₂, which group, respectively, 4 to 6 and 7 to 9 assemblages, and which agree with some specific sequences of Floquet (1998) and Gräfe (1999), among others. All these sequences, both major and minor, can be assimilated to the palaeontological cycles defined by Fernandez-Lopez (2000).

5.1. Sequence A

It is seemingly related to the 3rd order depositional sequence UZA-2.4 of Haq *et al.* (1988) and the sequences DC-5 of Floquet (1998), UC-4/5 of Gräfe (1999), DS-5 of Alonso *et al.* (1993) and S-3 of Segura *et al.* (1999). It shows an extensive record that ranges from the base of the upper Cenomanian to the top of the *Metoicoce- ras geslinianum* subzone, and includes the cephalopod assemblages 1 to 3. Lithologically, this sequence is composed, in the north of the IT by bioclastic limestones with abundant burrows and algae laminations that upwards change to nodular biomicritic limestones. In the centre of the IT this sequence is constituted by flaggy to massive dolostones or limestones with less intense burrowing and algae lamination. As a whole, this first sequence corresponds to shallow marine platform deposits that experienced a slow and complex deepening (Carenas *et al.*, 1989).

The boundary with the following sequence is marked by an interruption on the record of the Acanthoceratidae, till then continuous, together with the complete replacement of the identified genera and the appearance of the Vascooceratidae. Lithologically, this boundary corresponds to a net surface with a marked lithological change caused by a fast eustatic fall (Carenas *et al.*, 1989).

5.2. Sequence B

It seems to coincide with the 3rd order depositional sequence UZA-2.5 of Haq *et al.* (1988) and with the sequences DC-6a and DC-6b of Floquet (1998), UC-

Substages	Depositional Sequences								
	Global	Iberian Trough, Spain				Western Portuguese Platform, Portugal		This work	
		Haq et al. (1988)	North-Castilian Sector Floquet (1998)	North-Castilian Sector Gräfe (1999)	Central Sector Alonso et al. (1993)	Central Sector Segura et al. (1999)	Callapez (1998)		Major
Lower Turonian	UZA-2.5	DC-6b	UC-6/7	DS-6	S-4	L(O)		B	B 2
						(M/O)	L		
Upper Cenomanian	UZA-2.4	DC-6a	UC-5/6	DS-5	S-3	K		A	
							K		
						J			
						B/J	E/I		
						C/D			
						B/J	B		

Fig. 5.- Depositional sequences identified in the Iberian Trough and the Western Portuguese Carbonate Platform. The oblique lines indicate interval without record, and the arrows represent that the sequence continues.

Fig. 5.- Secuencias deposicionales identificadas en el Surco Ibérico y la Plataforma Carbonatada Occidental Portuguesa. Las líneas oblicuas indican intervalo sin registro, y las flechas representan que la secuencia continúa.

5/6 and UC-6/7 of Gräfe (1999), DS-6 of Alonso *et al.* (1993), in its lower and middle interval, and of S-4 of Segura *et al.* (1999). Its record, notably more expanded and rich than that of sequence A, ranges from the base of the *Vasoceras gamai* subzone to the top of the lower Turonian, and includes the cephalopod assemblages 4 to 9. Lithologically, this sequence is composed by biomicritic limestones that upwards change quickly to marls and, near the top, to chalky sandstones (notably dolomitized in the centre of the IT). It corresponds to an extraordinarily extensive sequence of open marine ramp, finally affected by a fast eustatic fall that generates a very prograding shallow marine platform (Segura *et al.*, 1993).

This sequence can be divided in two others of lower order that can be related to the sequences DC-6a of Floquet (1998) and UC-5/6 of Gräfe (1999), and DC-6b of Floquet (1998) and UC-6/7 of Gräfe (1999), respectively. The first one, B₁, ranges from the base of the *Vasoceras gamai* subzone to the top of the *Spathites (Ingridella) malladae* subzone and includes the assemblages 4 to 6. In its upper limit another marked faunal change takes place, though of minor magnitude. The second one, B₂, ranges from the base of the *Choffaticeras (Leoniceras) luciae* subzone to the top of the lower Turonian, and includes the assemblages 7 to 9. In detail, lithologically, these two

lower order sequences correspond to two prograding lithosomes separated by nodular limestones or marls (Floquet, 1991).

6. Discussion and conclusions

The above indicated facts suggest that assemblage 1 began after the disappearance of the cephalopods that dominated the IT during the latest middle Cenomanian, mainly *Acanthoceras*, caused by a marked worldwide marine regression. Seemingly, it coincided with a period in which, as consequence of a widespread and moderate eustatic ascent, the first ammonites typical of the earliest late Cenomanian, belonging to *Eucalycoceras* and *Calycoceras* and proceeding from the Protoatlantic, arrived to the Iberian Subplate and occupied some of the vacant ecologic niches.

Assemblage 2 seems to correspond to a faunal response to a marked and fast rise of the relative sea-level. This transgression both in the IT and WPCP made possible the permanency of *Calycoceras*, the appearance of new groups, such as *Lotzeites* and *Euomphaloceras*, and the record of several taxa of relatively deep waters in shallow platform sediments. Seemingly, the relative sea-level rise was kept the necessary time so that *Neolobites* could be

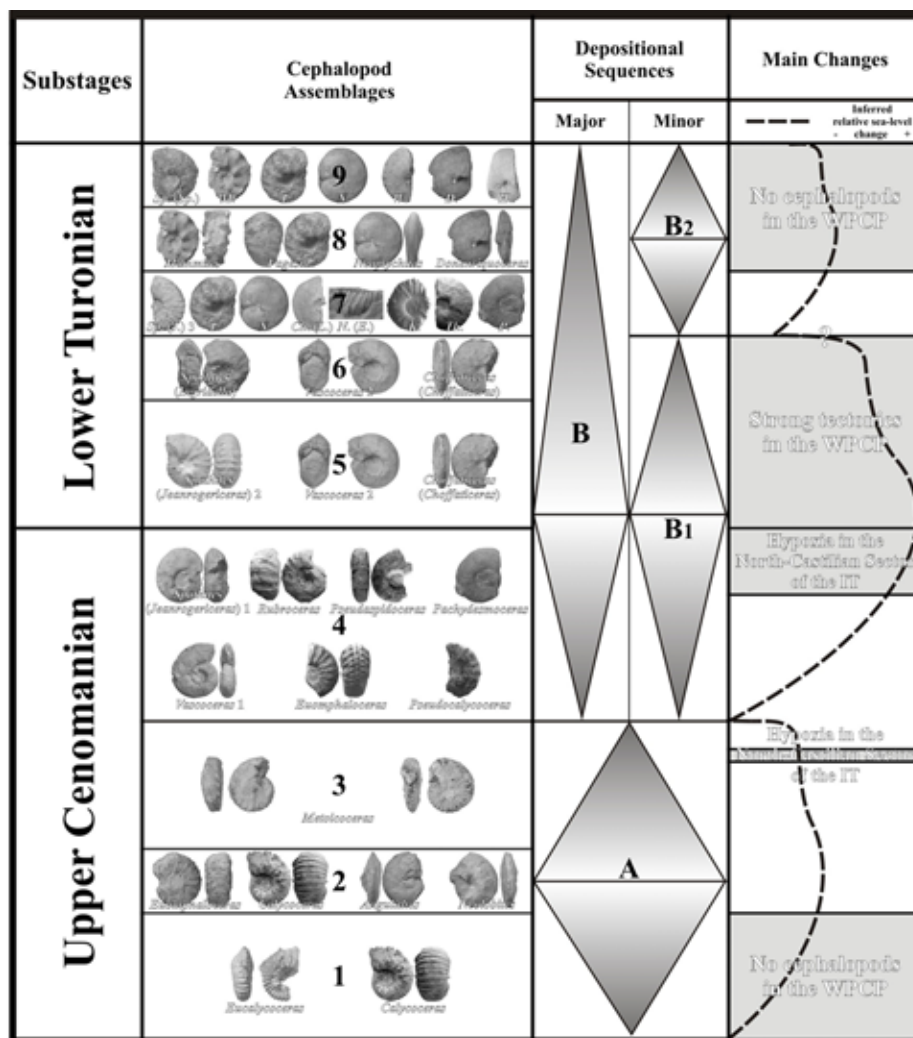


Fig. 6.- Main changes in the Iberian Trough and the Western Portuguese Carbonate Platform, inferred from the cephalopod assemblages and the depositional sequences (with graphic representations of the most important cephalopod groups and depositional cycles). *Sp. (J.) 3* is *Spathites (Jeanrogericeras) 3*, *F.* is *Fagesia*, *N.* is *Neptychites*, *Ch. (L.)* is *Choffaticeras (Leoniceras)*, *N. (E.)* is *Nostoceras (Eubostrihoceras)*, *K.* is *Kamerunoceras*, *Th.* is *Thomasites*, *P.* is *Pachydesmoceras*, *Sp. (Sp.)* is *Spathites (Spathites)*, *M.* is *Mammites*, *W.* is *Wrightoceras*, *D.* is *Donenriquoceras*, and *H.* is *Hoplitoides*.

Fig. 6.- Principales cambios en el Surco Ibérico y la Plataforma Carbonatada Occidental Portuguesa deducidos de las asociaciones de cefalópodos y las secuencias deposicionales (con representaciones gráficas de los grupos de cefalópodos y ciclos deposicionales más importantes). *Sp. (J.) 3* es *Spathites (Jeanrogericeras) 3*, *F.* es *Fagesia*, *N.* es *Neptychites*, *Ch. (L.)* es *Choffaticeras (Leoniceras)*, *N. (E.)* es *Nostoceras (Eubostrihoceras)*, *K.* es *Kamerunoceras*, *Th.* es *Thomasites*, *P.* es *Pachydesmoceras*, *Sp. (Sp.)* es *Spathites (Spathites)*, *M.* es *Mammites*, *W.* es *Wrightoceras*, *D.* es *Donenriquoceras*, y *H.* es *Hoplitoides*.

adapted to shallower environments, but not so that the representatives of other genera evolved to specialized forms of inner platform. The important taxonomic replacement observed among assemblages 2 and 3 could be related to the beginning of a drop on relative sea-level that favoured the disappearance of many of the cephalopods of the Iberian Subplate.

The interpretation of the assemblage 3 is extremely difficult, as it has numerous and complex indicators. In general, it could correspond to a fall on the relative sea-level (no known record in the WPCP and disappearance

of *Angulithes* and *Neolobites*). Nevertheless, this change should be very moderate (establishment of *Metoicoceras* in the IT) and, even, could experience punctual ascending pulses, possibly related to the first and punctual phase of the OAE2 (*sensu* Barroso-Barcenilla et al., 2011). According to Meister et al. (1992), the practically exclusive presence of a species of cephalopod that shows a wide morphologic variability in a biostratigraphic interval is usually caused by the existence of a highly unstable environment in which the occupation of several ecological niches by a unique taxon was produced. Therefore, this

seemingly unstable environment could be the cause of the presence in this assemblage of a single group (one genus: *Metoicoceras*) with certain morphologic variability (two species: *M. mosbyense* and *M. geslinianum*). Among assemblages 3 and 4, a whole replacement of the genera can be inferred. This change could be caused by a significant fall of the relative sea-level that deeply affected the sedimentary processes and the marine palaeobiotas of the Iberian Subplate. However, it does not seem rejectable that the same change was also influenced by the above indicated hypoxic event.

Assemblage 4 took place during the initial and intermediate stages of the great eustatic rise associated with the second and main phase of the OAE2 (*sensu* Barroso-Barcenilla et al., in press.) of the Cenomanian-Turonian Transition. Firstly and coinciding with the beginning of the relative sea-level rise, the fast widespread of the Vascoceratidae, specifically of *V. gamai* (one of its earliest members), happened. Secondly, these earliest *Vascoceras* diversified, giving place to some species almost exclusive of the Iberian Subplate, such as *V. barcoicense*, and even seemingly endemic, such as *V. charoni*, and the Acanthoceratidae returned to the region, by means of the earliest *S. (J.) subconciliatus*. Simultaneously, the WPCP experienced a notable arrival of American taxa, such as *Rubroceras*.

Nevertheless, this expansive process was interrupted by the effect of the second and main phase of the OAE2 that, with diverse intensity, concerned all the oceans of the planet. These new and unfavourable conditions of the epicontinental waters of the Iberian Subplate, although they should not have been very marked, since they did not cause the disappearance of the inoceramids in the Outer Navarro-Cantabrian Platform and the North-Castilian Sector, were responsible for the disappearance of all previous cephalopod taxa present up to this moment in the Iberian Subplate, except for *S. (J.) subconciliatus*. In fact, the practically exclusive presence of a species of cephalopod with a wide morphologic variability in a biostratigraphic interval (*S. (J.) subconciliatus* in this part of the homonymous zone) can be observed again and, as indicated by Meister et al. (1992), also seems to be caused by the existence of a highly unstable environment. This species, after overcoming the most intense phase of this palaeoceanographic crisis, occupied several of the vacant ecological niches, diversifying notably its morphology, especially in the IT. Likewise, the fact that the hypoxia affected more moderately the shallow than the deep marine environments allowed the subsistence of the Vascoceratidae in the IT and WPCP by means of *V. durandi* and *V. gamai*, among others.

Later, when the second and main phase of the OAE2 reduced its intensity, the adaptative process of *S. (J.) subconciliatus* continued, giving place to the varieties described by Wiedmann (1960, 1964) and to the endemic *S. (J.) robustus* in the IT. Finally, when the normal marine conditions came again and the high relative sea-level was reached, an important recovery of the Vascoceratidae began, being especially abundant *V. durandi*, and a significant arrival or return to the Iberian Subplate of exotic ammonoids of diverse origins, such as *V. cauvinii*, *F. catinus* and *P. (A.) sp. P. (P.) sp.* and *P. denisonianum*, took place.

The transition between assemblages 4 and 5 is gradual and, seemingly, caused by progressive processes of adaptation to the favourable palaeoceanographic conditions and the arrival to the region of new taxa. This is valid for all the IT, but not for the WPCP where this was an interval of increased tectonic and diapiric activity, with uplift of the present onshore sectors of the Western Iberian Margin and subaerial exposure of the upper Cenomanian levels. These structural readjustments have been interpreted as the result of rotational movements within the subplate, but they could also be related to the tilting of the overall Iberian Ranges to the east or southeastwards. As a consequence of that and despite the contemporaneous sea-level highstand, there is no known record of marine carbonates on the WPCP below the middle part of lower Turonian.

Assemblage 5 corresponds to the beginning of the early Turonian, with a maximum relative sea-level and very favourable marine conditions that allowed the occupation of a great variety of ecological niches, the faunal exchange and the appearance of new taxa. Among others, the first Pseudotissotiidae arrived to the IT, who seemingly acceded to this region directly from the Tethys. Likewise, the arising of specialized morphologies proper of restricted ecologic niches, such as *S. (J.) saenzi* and *S. (J.) postsaenzi*, continued in the Acanthoceratidae, whereas the appearance of forms progressively more adapted to the epicontinental shallow environments persisted in the Vascoceratidae. In the development of the latter family the wide morphologic variability of *V. durandi* stood out. This seems to be an adaptative process to gradually more diverse ecological niches, similar to that followed by *S. (J.) subconciliatus* during the latest Cenomanian, with the subsequent appearance of successively more specialized forms, such as *V. amieirensis* and *V. harttii*. As in the previous case, there are not strong differences between the taxonomic composition of assemblages 5 and 6, for what the transition between both was possibly produced as consequence of gradual evolu-

tionary changes of adaptation to small modifications in the environmental conditions.

Assemblage 6 could be caused by a small fall of the relative sea-level. The same change would be influenced not only by a eustatic change but also by sedimentary accommodation and infill of the basin, which produced certain confinement of some areas of the IT, allowing the appearance of several nearly endemic taxa, among them *S. (I.) malladae* and *S. (J.) obliquus*. As consequence of the development of the long term evolutionary process followed by *Vascoceras* to give place to forms that are increasingly adapted to the shallow platform environments, specialized cadicones arose, such as *V. kossmati*. Likewise, *Wrightoceras* arrived to the IT by the first time. Except for *S. (J.) reveliereanus* (a widespread acanthoceratid with relatively long range), none of the species of the assemblage 6 have been identified in the assemblage 7. This fact seems to indicate that the ending of the assemblage 6 was probably produced by a sudden environmental change in the region. Possibly, a rapid and marked fall of the relative sea-level took place, which motivated the disappearance (in some cases temporary but in others definitive) of all shallow water taxa, such as *S. (Ingridella)* and *Vascoceras*.

Assemblage 7 seems to correspond to the faunal recovery that took place after the strong fall of the relative sea-level that led to the disappearance of nearly all marine environments of the Iberian Subplate for a time. In fact, a moderate rise of the relative sea-level made possible the arrival of some ammonites of pelagic spaces or higher bathymetries to this region. Among the species identified, seemingly *S. (J.) reveliereanus* could survive in relatively deep waters and, thus, overcome the absence of shallow environments. Supposedly, *Ch. (L.) luciae* and *Ch. (L.) barjonai* could not adapt to the IT, although they acceded often to the region (numerous records with no or minimum signs of taphonomic resedimentation or reelaboration in the Central Sector). In fact, the incursions of big predator oxycones, such as those of *Choffaticeras (Leniceras)*, to very shallow and coastal waters already have been reported by Hewitt and Westermann (1989) and Kauffman (1990). *N. (E.)* sp. could install in the Outer Navarro-Cantabrian Platform and the North-Castilian Sector. In the WPCP this is the single lowest Turonian assemblage recorded with diverse and abundant faunas, clearly associated with a transgressive event related to the eustatic relative sea-level rising, but limited to certain parts of the basin.

Assemblage 8 seemingly took place during the advance of the relative sea-level rising that controlled the previous assemblage. The progress of the rising of the relative sea-level favoured the arrival of new taxa

to the IT, principally from the Protoatlantic (*Mammittes*: Wiedmann, 1975b; *Fagesia*: Kennedy and Cobban, 1976). Some of them could adapt to this region (again with vacant shallow epicontinental environments), and even gave place to ammonites practically exclusive of the IT (*Donenriquoceras*: Wright, 1996; Barroso-Barcenilla and Goy, 2007). Nevertheless, the relative sea-level must be lower than that reached during the span of assemblage 5, since it does not seem that the region had a direct connection with the Tethys (scarce number of cephalopods from this sea). Nearly all the groups identified in assemblage 8 can be recognized in assemblage 9. This fact suggests that any significant palaeoecological changes should have been produced during the transition between them.

Assemblage 9 seemingly was related to the stabilization of the favourable conditions on the IT. During its development, possibly a slight fall of the relative sea-level was produced, by eustatism or even by sedimentary fill of the basin, causing certain isolation in some areas of the region and the consequent appearance or recovering of several nearly endemic species. Nevertheless, the fall of the relative sea-level should be very moderated, since the marine epicontinental environments did not disappear, allowing the permanency, the appearance and the development of some cephalopods of these spaces. The Acanthoceratidae experienced a new diversification, which it made possible for *Spathites* to be represented by three subgenera, whereas *Fagesia* continued the adaptive process initiated time before. *Wrightoceras*, after coming from other basins of the Tethys, returned to the IT (in the absence of evidence of a direct connection with the Tethys, possibly around the Iberian Subplate), region that also was reached by the earliest Coilopoceratidae. Many of the species from the assemblage 9 disappear on the top of the lower Turonian where they are replaced by middle Turonian taxa, such as *Collignoniaceras*, *Romaniceras* and *Coilopoceras*. This notable and global taxonomic replacement (very useful to establish the lower-middle Turonian boundary: Bengtson, 1996) could be caused by a marked fall on the relative sea-level that forced the extinction of numerous cephalopods in the IT.

Considering the changes produced during the development of the depositional sequences and their assemblages, some differences and several similarities between them can be established, which allow us to infer certain guidelines on the dynamics of the sequences. Among the differences, it stands out that the taxonomic diversity, and the abundance and variety of endemics are much lower in sequence A than in sequence B. This circumstance can be explained by the minor duration of the former

sequence and the lower sea-level reached. Analyzing the palaeogeographic distribution of the exotics, it can be verified that the majority of those integrated in the sequences A and B₂ are mainly characteristic of the relatively cold and deep Protoatlantic, whereas the majority of those included in the sequence B₁ are fundamentally typical of the comparatively warmer and shallower Tethys. This fact can reflect a change in the influence received, which begins being principally Protoatlantic (from the base of the upper Cenomanian to the top of the *Metoicoceras geslinianum* subzone), changes being mainly Tethyan (between the *Vascoceras gamai* and *Spathites (Ingridella) malladae* subzones), and finishes being eminently boreal (from the top of the *Choffaticeras (Leoniceras) luciae* subzone to, at least, the base of the middle Turonian).

Among the similarities, it is remarkable that, without considering the possible changes caused by the geochemical oceanic variations and the evolutionary dynamics of the implied taxa, in each of the three differentiated sequences, a recurrence of the same succession of biotic events followed by their respective cephalopods can be inferred. Initially, the arrival of cosmopolitan forms of pelagic or deep environments, later, the appearance of derivative species from the previous ones relatively adapted to the shallow environments and, finally, the increase of the proportion of endemic forms can be observed (Text-fig. 6).

Though this succession of events is more difficultly observed in the major sequence A than in the minor ones B₁ and B₂ (possibly as consequence of the record being notably worse in the first one), each one of these intervals seems to correspond to successive periods of low, rising, and high relative sea-level, in which phenomena occurred respectively, of extinction of cephalopods from shallow environments, survival of taxa from pelagic or deep waters, settling of new spaces, and adaptation to them. Several studies have been developed recently relating sea-level changes and cephalopod faunal turnovers in the Mesozoic (O'Dogherty *et al.*, 2000; Sandoval *et al.*, 2002; Yacobucci, 2008). Specifically, when the sea-level goes down and the epicontinental environments disappeared, most of the cephalopods of shallow waters become extinct and only those that possessed certain aptitude to survive in open or deep oceanic environments overcame the crisis. During the sea-level rising, the cosmopolitan, pelagic or deep-water forms were the first ones to occupy the spaces available again as a consequence of the marine transgression in process, but soon they were replaced by others, derived from these cephalopods and better adapted to the shallow environments. Finally, specialized or nearly endemic taxa arose and

dominated the region until, with the following fall of the sea-level, a new sequence began and a repetition of the described events occurred.

Acknowledgements

The authors recognise the constructive work of Prof. Dr. K.U. Gräfe, from the Universität Bremen, Germany, and of an anonymous reviewer of the original manuscript of the present paper. They also thank the Centro de Geofísica da Universidade de Coimbra (FCT - Foundation of Science and Technology), Portugal, for its support. This study has been carried out within the projects CGL2008-03112/BTE and CGL2009-12008 of the Ministerio de Ciencia e Innovación, and PAI08-0204-1312 and PEIII1-0237-7926 of the Junta de Castilla-La Mancha, Spain.

References

- Alonso, A., Floquet, M., Mas, R., Meléndez, A. (1993): Late Cretaceous carbonate platforms: origin and evolution, Iberian Range, Spain. *AAPG Special Memoir*, 56: 297-313.
- Amédro, F., Accarie, H., Robaszynski, F. (2005): Position de la limite Cénomanién-Turonien dans la Formation Bahloul de Tunisie centrale. *Eclogae Geologicae Helvetiae*, 98: 151-167. doi: 10.1007/s00015-005-1158-5
- Amiot, M. (1982): El Cretácico Superior de la Región Navarro-Cántabra. In: García, A. (ed.), *El Cretácico de España*. Universidad Complutense de Madrid, Madrid: 88-111.
- Amiot, M., Floquet, M., Mathey, B., Pascal, A., Rat, P., Salomon, J. (1982): Évolution de la marge cantabrique et de son arrière-pays ibérique au Crétacé. *Cuadernos de Geología Ibérica*, 8: 37-63.
- Barroso-Barcenilla, F. (2004): Acanthoceratidae y zonación de ammonites del Cenomaniense superior y del Turoniense inferior en el Área de Puentedeley, Cuenca Vasco-Cantábrica, España. *Coloquios de Paleontología*, 54: 83-114.
- Barroso-Barcenilla, F. (2006): Cefalópodos del Cenomaniense superior y del Turoniense inferior en el Surco Ibérico, España. Unpublished PhD Thesis, Universidad Complutense de Madrid: 626 p.
- Barroso-Barcenilla, F. (2007): Revision and new data of the ammonite family Acanthoceratidae de Grossouvre, 1894, from the lower Turonian of the Iberian Trough, Spain. *Palaeontographica, Abteilung A*, 280: 123-163. doi: 0375-0442/07/0280/0123
- Barroso-Barcenilla, F., Goy, A. (2007): Revision and new data of the ammonite family Pseudotissotiidae in the Iberian Trough, Spain. *Geobios*, 40: 455-487. doi: 10.1016/j.geobios.2006.05.006
- Barroso-Barcenilla, F., Goy, A. (2009): The ammonite genera *Fagesia* and *Neoptychites* (family Vascoceratidae) in the Iberian Trough, Spain. *Geobios*, 42: 17-42. doi: 10.1016/j.geobios.2006.05.006
- Barroso-Barcenilla, F., Goy, A. (2010): The ammonite genus

- Vascoceras* Choffat, 1898 (family Vascoceratidae Douvillé, 1912) in the Iberian Trough, Spain. *Palaeontographica, Abteilung A*, 290: 199-235. doi: 0375-0442/10/0290/0004
- 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. doi: 10.1127/0078-0421/2009/0043-0139
- Barroso-Barcenilla, F., Pascual, A., Peyrot, D., Rodríguez-Lázaro, J. (2011): Integrated biostratigraphy and chemostratigraphy of upper Cenomanian and lower Turonian in Puentevedy, Iberian Trough, Spain. *Proceedings of the Geologists' Association*, 122: 67-81. doi: 10.1016/j.pgeola.2010.11.002
- Batt, R.J. (1989): Ammonite shell morphotype distribution in the Western Interior Greenhorn Sea and some paleoecological implications. *Palaios*, 4: 32-42.
- Bengtson, P. (Comp.) (1996): The Turonian stage and substage boundaries. In: Rawson, P.F., Dhont, A.V., Hancock, J.M., Kennedy, W.J. (eds.), Proceedings of the Second International Symposium on Cretaceous Stage Boundaries. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, 66 Supplément: 69-79.
- Berthou, P.Y. (1984): Albian-Turonian stage boundaries and subdivisions in the Western Portuguese Basin. *Bulletin of the Geological Society of Denmark*, 33: 41-45.
- Callapez, P.M. (1992): Estudo paleoecológico dos "Calcários de Trouxemil" (Cenomaniano-Turoniano) na região entre a Mealhada e Condeixa-a-Nova (Portugal Central). Unpublished MsC Thesis, Universidade de Coimbra: 272 p.
- Callapez, P.M. (1998): Estratigrafia e Paleobiologia do Cenomaniano-Turoniano. O significado do eixo da Nazaré-Leiria-Pombal. Unpublished PhD Thesis, Universidade de Coimbra: 491 p.
- Callapez, P.M. (1999): The Cenomanian-Turonian of the Western Portuguese Basin: Stratigraphy and Palaeobiology of the Central and Northern sectors. *European Paleontological Association Workshop, Field Trip B*, Lisbon: 65 p.
- Callapez, P.M. (2003): The Cenomanian-Turonian transition in West Central Portugal: ammonites and biostratigraphy. *Ciências da Terra*, 15: 53-70.
- Callapez, P.M. (2004): The Cenomanian-Turonian central West Portuguese Carbonate Platform. In: Dinis, J., Proença Cunha, P. (eds.), Cretaceous and Cenozoic events in West Iberia margins. Field Trip Guidebook 2, 23rd IAS Meeting of Sedimentology, Coimbra, 2004: 39-51.
- Callapez, P.M. (2008): Palaeobiogeographic evolution and marine faunas of the Mid-Cretaceous Western Portuguese Carbonate Platform. *Thalassas*, 24: 29-52.
- Callapez, P.M., Ferreira Soares, A. (2001): Fósseis de Portugal: Amonóides do Cretácico Superior (Cenomaniano-Turoniano). Museu Mineralógico e Geológico da Universidade de Coimbra, Coimbra: 106 p.
- Carenas, B., García, A., Calonge, A., Pérez, P., Segura, M. (1989): Middle Cretaceous (Upper Albian-Turonian) in the Central Sector of the Iberian Ranges (Spain). In: Wiedemann, J. (ed.), Proceedings of the 3rd International Cretaceous Symposium. Cretaceous of the Western Tethys. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart: 265-279.
- Caron, M., Agnolo, S., Dall', Accarie, H., Barrera, E., Kauffman, E.G., Amédro, F., Robaszynski, F. (2006): High-resolution stratigraphy of the Cenomanian-Turonian boundary interval at Pueblo (U.S.A.) and Wadi Bahloul (Tunisia). *Geobios*, 39: 171-200. doi: 10.1016/j.geobios.2004.11.004
- Carretero-Moreno, M.E. (1982): Estudios paleontológicos del Cretácico de la Serranía de Cuenca y de la Cordillera Central. PhD Thesis, Universidad Complutense de Madrid: 392 p.
- Cavin, L., Tong, H., Boudad, L., Meister, C., Piuz, A., Tabouelle, J., Aarab, M., Amiot, R., Buffetaut, E., Dyke, G., Hua, S., Le Loeuff, J. (2010): Vertebrate assemblages from the early Late Cretaceous of southeastern Morocco. *Journal of African Earth Sciences*, 57: 391-412. doi: 10.1016/j.jafrearsci.2009.12.007
- Chancellor, G.R., Kennedy, W.J., Hancock, J. (1994): Turonian ammonite faunas from Central Tunisia. *Special Papers in Palaeontology*, 50: 118 p.
- Choffat, P.L. (1886): Recueil d'études paléontologiques sur la Faune Crétacique du Portugal, I. Section des Travaux Géologiques du Portugal, Lisbonne: 40 p.
- Choffat, P.L. (1898): Recueil d'études paléontologiques sur la Faune Crétacique du Portugal, II. Section des Travaux Géologiques du Portugal, Lisbonne: 45 p.
- Choffat, P.L. (1900): Recueil de monographies stratigraphiques sur le Système Crétacique du Portugal, II. Direction des Services Géologiques du Portugal, Lisbonne: 287 p.
- Choffat, P.L. (1901-02): Recueil d'études paléontologiques sur la Faune Crétacique du Portugal, III. Direction des Services Géologiques du Portugal, Lisbonne: 84 p.
- Cobban, W.A. (1984): Mid-Cretaceous ammonite zones, Western Interior, United States. *Bulletin of the Geological Society of Denmark*, 33: 71-89.
- Cobban, W.A., Hook, S.C., Kennedy, W.J. (1989): Upper Cretaceous rocks and ammonite faunas of southeastern New Mexico. *New Mexico Bureau of Mines and Mineral Resources Memoir*, 45: 137 p.
- Courville, P., Lang, J., Thierry, J. (1998): Ammonite faunal exchanges between South Tethyan platforms and South Atlantic during the Uppermost Cenomanian-Lower most/Middle Turonian in the Benue Trough (Nigeria). *Geobios*, 31: 187-214. doi: 10.1016/S0016-6995(98)80038-7
- 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*. Workshop of the European Palaeontological Association, Lisboa: 9-13.
- Fernández-López, S.R. (2000): Temas de Tafonomía. Universidad Complutense de Madrid, Madrid: 167 p.
- Ferreira Soares, A. (1966): Estudo das formações pós-jurássicas da região entre Sargento-Mor e Montemor-o-Velho. *Memórias e Notícias*, 62: 343 p.
- Ferreira Soares, A. (1972): Contribuição para o estudo do Cretácico em Portugal. *Memórias e Notícias*, 74: 56 p.

- Ferreira Soares, A. (1980): A "Formação Carbonatada" Cenomano-Turoniana na região do Baixo-Mondego. *Comunicações dos Serviços Geológicos de Portugal*, 66: 99-109.
- Ferreira Soares, A., Rocha, R.B. (1985): Profil d'un géologue. Motif pour une réflexion sur la sédimentation jurassique dans la bordure occidentale du Portugal. *Cahiers de l'Institut Catholique de Lyon*, 14: 225-264.
- Floquet, M. (1991): La plate-forme nord-castillane au Crétacé Supérieur (Espagne). Arrière-pays ibérique de la marge passive basco-cantabrique. Sédimentation et vie. *Mémoires Géologiques de l'Université de Dijon*, 14: 925 p.
- 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. *SEPM Special Publication*, 60: 343-361.
- Floquet, M. (2004): El Cretácico Superior de la Cuenca Vasco-Cantábrica y áreas adyacentes. In: Vera, J.A. (ed.), El Cretácico de España. Sociedad Geológica de España e Instituto Geológico y Minero de España, Madrid: 299-306.
- Floquet, M., Alonso, A., Meléndez, A. (1982): El Cretácico Superior de Cameros-Castilla. In: García, A. (ed.), El Cretácico de España. Universidad Complutense de Madrid, Madrid: 387-456.
- García, A., Mas, R., Segura, M., Carenas, B., García-Hidalgo, J.F., Gil, J., Alonso, A., Aurell, M., Bádenas, B., Benito, M.I., Meléndez, A., Salas, R. (2004): Segunda fase de post-rifting: Cretácico Superior. In: Vera, J.A. (ed.), El Cretácico de España. Sociedad Geológica de España e Instituto Geológico y Minero de España, Madrid: 510-522.
- García-Hidalgo, J.F., Gil, J., Segura, M. (2003): Sedimentología de los términos basales de la sucesión cretácica en el borde sur del Sistema Central. *Cuadernos de Geología Ibérica / Journal of Iberian Geology*, 29: 57-72.
- Gelabert, B., Sàbat, F., Rodríguez-Perea, A. (2002): A new proposal for the late Cenozoic geodynamic evolution of the western Mediterranean. *Terranova*, 14: 93-100.
- Gil, J. (1994): Estratigrafía secuencial del Cretácico del borde meridional del Sistema Central en el sector de San Agustín de Guadalix-Pálmaces de Jadraque (Provincias de Madrid y Guadalajara). Unpublished MsC Thesis, Universidad Complutense de Madrid: 241 p.
- Gil, J., García, A. (1996): El Cretácico del borde meridional del Sistema Central. *Estudios Geológicos*, 52: 37-49.
- Gil, J., García, A., Segura, M. (1993): Secuencias deposicionales del Cretácico en el flanco sur del Sistema Central. *Geogaceta*, 13: 43-45.
- Graciansky, P.C. de, Hardenbol, J., Jacquin, T., Vail, P.R. (1998): Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. *SEPM Special Publication*, 60: 786 p.
- Gradstein, F.M., Ogg, J.G., Smith, A.G. (Eds.) (2004): A Geologic Time Scale 2004. Cambridge University Press, Cambridge: 589 p.
- Gräfe, K.U. (1994): Sequence stratigraphy in the Cretaceous and Paleogene (Aptian to Eocene) of the Basco-Cantabrian Basin (N. Spain). *Tübinger Geowissenschaftliche Arbeiten (A)*, 18: 418 p.
- Gräfe, K.U. (1996): Sedimentary cycles in the Upper Cretaceous of the Basco-Cantabrian Basin (N. Spain). *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg*, 77: 243-270.
- 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.
- Gräfe, K.U., Wiedmann, J. (1993): Sequence stratigraphy in the Upper Cretaceous of the Basco-Cantabrian Basin (Northern Spain). *Geologische Rundschau*, 82: 327-361.
- Gräfe, K.U., Wiedmann, J. (1998): Sequence stratigraphy on a carbonate ramp: the late Cretaceous Basco-Cantabrian Basin (Northern Spain). In: Graciansky, P.C. de, Hardenbol, J., Jacquin, T., Vail, P.R. (eds.), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. *SEPM Special Publication*, 60: 333-341.
- 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., van Wagoner, J.C. (eds.), Sea-Level changes: An integrated approach. *SEPM Special Publication*, 42: 71-108. doi: 10.2110/pec.88.01.0071
- Hart, M.B., Callapez, P.M., Fisher, J.K., Hannant, K., Monteiro, J.F., Price, G.D., Watkinson, M.P. (2005): Micropalaeontology and stratigraphy of the Cenomanian/Turonian boundary in the Lusitanian Basin, Portugal. *Journal of Iberian Geology*, 31: 311-326.
- Hewitt, R.A., Westermann, G.E.G. (1989): Mosasaur tooth marks on the ammonite *Placenticerus* from the Upper Cretaceous of Alberta, Canada. *Canadian Journal of Earth Sciences*, 27: 469-472. doi: 10.1139/e90-042
- 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.
- Hiscott, R.N., Wilson, R., Gradstein, F.M., Pujalte, V., García-Mondéjar, J., Boudreau, R.R., Wishart, H.A. (1990): Comparative stratigraphy and subsidence history of Mesozoic rift basins of North Atlantic. *AAPG Bulletin*, 74: 60-76.
- Karrenberg, M. (1935): Ammoniten aus der Nordspanischen Oberkreide. *Palaeontographica, Abteilung A*, 82: 125-161.
- Kauffman, E.G. (1990): Mosasaur predation on ammonites during the Cretaceous. In: Boucot, A.J. (ed.), Evolutionary Behavior and Coevolution. Elsevier, Amsterdam: 184-189.
- Kennedy, W.J. (1984): Ammonite faunas and the "standard zones" of the Cenomanian to Maastrichtian Stages in their Type areas. *Bulletin of the Geological Society of Denmark*, 33: 147-161.
- Kennedy, W.J., Cobban, W.A. (1976): Aspects of ammonite biology, biogeography and biostratigraphy. *Special Papers in Palaeontology*, 17: 93 p.
- Kennedy, W.J., Walaszczyk, I., Cobban, W.A. (2000): Pueblo, Colorado, U.S.A., candidate Global Boundary Stratotype

- Section and Point for the base of the Turonian Stage of the Cretaceous, and for the base of the Middle Turonian Substage, with a revision of Inoceramidae (Bivalvia). *Acta Geologica Polonica*, 50: 295-334.
- Kirkland, J.I. (1996): Paleontology of the Greenhorn Cyclothem (Cretaceous, Late Cenomanian to Middle Turonian) at Black Mesa, Northeastern Arizona. *New Mexico Museum of Natural History and Science Bulletin*, 9: 131 p.
- Küchler, T. (1998): Upper Cretaceous of the Barranca (Navarra, northern Spain), I. *Acta Geologica Polonica*, 48: 157-236.
- Lauverjat, J. (1982): Le Crétacé Supérieur dans le Nord du Bassin Occidental Portugais. PhD Thesis, Université Pierre et Marie Curie: 716 p.
- Mallada, L. (1891): Sinopsis Paleontológica de España. Sistema Cretáceo (Cretáceo Superior). *Boletín de la Comisión del Mapa Geológico de España*, 17: pls. 7-12.
- Mallada, L. (1892): Catálogo General de las especies fósiles encontradas en España. *Boletín de la Comisión del Mapa Geológico de España*, 18: 253 p.
- Martínez, R., Lamolda, M.A., Gorostidi, A., López, G., Santamaría-Zabala, R. (1996): Bioestratigrafía integrada del Cretácico Superior (Cenomaniense Superior-Santoniense) de la región Vasco-cantábrica. *Revista Española de Paleontología, Número Extraordinario*: 160-171.
- Mas, R., Segura, M., Robles, S., Fregenal-Martínez, M.A., Sanz, J.L., García, A., Meléndez, M.N., Chacón, B., García-Hidalgo, J.F., Ortega, F., Gil, J., Martín-Chivelet, J. (2002): The Iberian Basin. In: Gibbons, W., Moreno, T. (eds.), *The Geology of Spain*. The Geological Society, London: 284-292.
- Meister, C., Rhalmi, M. (2002): Quelques ammonites du Cénomaniense-Turonien de la région d'Errachidia-Boudnid-Erfoud (partie méridionale du Haut Atlas Central, Maroc). *Revue de Paléobiologie*, 21: 759-779.
- Meister, Ch., Alzouma, K., Lang, J., Mathey, B. (1992): Les ammonites du Niger (Afrique occidentale) et la transgression transsaharienne au cours du Cénomaniense-Turonien. *Geobios*, 25: 55-100. doi: 10.1016/S0016-6995(09)90038-9
- Meister, Ch., Alzouma, K., Lang, J., Mathey, B., Pascal, A. (1994): Nouvelles données sur les ammonites du Niger oriental (Ténéré, Afrique occidentale) dans le cadre de la transgression du Cénomaniense-Turonien. *Geobios*, 27: 189-219. doi: 10.1016/S0016-6995(94)80006-5
- Meléndez-Hevia, I. (1984): Ammonoidea del Cenomaniense superior y Turoniense en el borde sur del Sistema Central, entre Tamajón y Somolinos (Guadalajara). Unpublished MSc Thesis, Universidad Complutense de Madrid: 175 p.
- Mojica, J., Wiedmann, J. (1977): Kreide-Entwicklung und Cenomanien/ Turonien Grenze der mittleren Keltiberischen Ketten bei Nuevalos (Prov. Zaragoza, Spanien). *Eclogae Geologicae Helveticae*, 70: 739-759.
- O'Dogherty, L., Sandoval, J., Vera, J.A. (2000): Ammonite faunal turnover tracing sea-level changes during the Jurassic (Betic Cordillera, southern Spain). *Journal of the Geological Society (London)*, 157: 723-736. doi: 10.1144/jgs.157.4.723
- Paul, C.R.C., Mitchell, S., Lamolda, M., Gorostidi, A. (1994): The Cenomanian-Turonian Boundary Event in northern Spain. *Geological Magazine*, 131: 801-817. doi: 10.1017/S0016756800012875
- Philip, J., Floquet, M. (2000): Late Cenomanian. In: Dercourt, J., Gaetani, M. et al. (eds.), *Atlas Peri-Tethys*. CVGM/CGMV, Map 14, Paris.
- 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. INETI, Lisboa: 75 p.
- Robaszynski, F., Caron, F., Amédro, F., Dupuis, Ch., Hardenbol, J., González Donoso, J.M., Linares, D., Gartner, S. (1994): Le Cénomaniense de la région de Kalaat Senan (Tunisie centrale). *Revue de Paléobiologie*, 12: 351-505.
- Robaszynski, F., Caron, F., Dupuis, Ch., Amédro, F., González Donoso, J.M., Linares, D., Hardenbol, J., Gartner, S., Calandra, F., Deloffre, R. (1990): A tentative integrated stratigraphy in the Turonian of Central Tunisia. *Bulletin des Centres de Recherches ELF-Aquitaine*, 14: 213-384.
- Rodríguez-Lázaro, J., Pascual, A., Elorza, J. (1998): Cenomanian events in the deep western Basque Basin: the Leioa section. *Cretaceous Research*, 19: 673-700. doi: 10.1006/cres.1998.0125
- Rosales, I., Gräfe, K.U., Robles, S., Quesada, S., Floquet, M. (2002): The Basque-Cantabrian Basin. In: Gibbons, W., Moreno, T. (eds.), *The Geology of Spain*. The Geological Society, London: 272-284.
- 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. doi: 10.2113/173.1.57
- Santamaría-Zabala, R. (1991): Ammonoideos del Cretácico Superior de la Plataforma Nord-Castellana y parte de la Cuenca Navarro-Cántabra. Unpublished PhD Thesis, Universidad Autónoma de Barcelona: 375 p.
- 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.
- Segura, M., Wiedmann, J. (1982): La transgresión del Cretácico Superior en el sector de Atienza-Sigüenza (Guadalajara, Cordillera Ibérica) y el significado de la fauna ammonitífera. *Cuadernos de Geología Ibérica*, 8: 293-307.
- Segura, M., García-Hidalgo, J.F., Carenas, B., García, A. (1993): Late Cenomanian-early Turonian platform from central eastern Iberia, Spain. *AAPG Special Memoir*, 56: 283-296.
- 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 maximum transgressive in the 2nd order cycles of the Upper Cretaceous from the Iberian Range. *Géologie Méditerranéenne*, 28: 163-166.
- Segura, M., García-Hidalgo, J.F., García, A., Ruiz, G., Carenas, B. (1999): El Cretácico de la zona de intersección del Sistema

- Central con la Cordillera Ibérica. In: Libro homenaje a José Ramírez del Pozo. Asociación de Geólogos y Geofísicos Españoles del Petróleo, Madrid: 129-139.
- Sharpe, D. (1849): On the Secondary District of Portugal which lies on the North of the Tagus. *Quarterly Journal of the Geological Society of London*, 6: 135-201.
- Stampfli, G., Borel, G., Cavazza, W., Mosar, J., Ziegler, P.A. (2001): The paleotectonic atlas of the peritethyan domain. In: CD ROM ISBN 3-9804862-6-5, European Geophysical Society.
- Toshimitsu, S., Hirano, H. (2000): Database of the Cretaceous ammonoids in Japan. *Bulletin of the Geological Survey of Japan*, 51: 559-613.
- Tröger, K.A., Kennedy, W.J. (Comp.) (1996): The Cenomanian stage. In: Rawson, P.F., Dhont, A.V., Hancock, J.M., Kennedy, W.J. (eds.), Proceedings of the Second International Symposium on Cretaceous Stage Boundaries. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, 66 Supplément: 57-68.
- 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. (1960): Le Crétacé Supérieur de l'Espagne et du Portugal et ses Céphalopodes. In: Roger, J. (ed.), *Colloque sur le Crétacé Supérieur Français*. Gauthier-Villars, Paris: 709-764.
- Wiedmann, J. (1964): Le Crétacé Supérieur de l'Espagne et du Portugal et ses Céphalopodes. *Estudios Geológicos*, 20: 107-148.
- Wiedmann, J. (1975a): El Cretácico Superior del Picofrentes (Soria), Cadenas Celtibéricas (España). *Boletín Geológico y Minero*, 86: 252-261.
- Wiedmann, J. (1975b): Subdivisiones y precisiones bio-estratigráficas en el Cretácico Superior de las Cadenas Celtibéricas. In: Meléndez, B., Meléndez, F. (eds.), Reunión de campo sobre el Cretácico de la Provincia de Cuenca. Caja Provincial de Ahorros, Cuenca: 135-153.
- 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., Kauffman, G. (1978): Mid-Cretaceous biostratigraphy of northern Spain. *Annales du Muséum d'Histoire Naturelle de Nice*, 4: 3.1-3.34.
- Wilson, R., Hiscott, R., Willis, M., Gradstein, F. (1989): The Lusitanian Basin of west central Portugal. *AAPG Special Memoir*, 46: 341-361.
- Wright, C.W. (1996): Cretaceous Ammonoidea. In: Kaesler, R.L. (ed.), Treatise on Invertebrate Paleontology. Mollusca L (4). Geological Society of America & University of Kansas Press, Lawrence: 362 p.
- 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.

APENDIX

Taxonomical list (generic, subgeneric, specific and subspecific ranks; E: Spain, P: Portugal)

Nautiloidea

- Angulithes* de Montfort, 1808
A. mermeti (Coquand, 1862) [E]
A. vascogoticus Wiedmann, 1960 [E]

Ammonoidea

Acanthoceratidae

- Acanthoceras* Neumayr, 1875
A. rhotomagense (Brongniart, 1822) [E]
Calycoceras Hyatt, 1900
C. (Calycoceras) Hyatt, 1900
C. (C.) naviculare (Mantell, 1822) [E, P]
C. (C.) sp. [E]
C. (Proeucalycoceras) Thomel, 1972
C. (P.) guerangeri (Spath, 1926a) [P]
C. (P.) sp. [E]
Eucalycoceras Spath, 1923a
E. pentagonum (Jukes-Browne, 1896) [P]
E. rowei (Spath, 1926a) [E]
Euomphaloceras Spath, 1923a
E. euomphalum (Sharpe, 1855) [E]
E. septemseriatus (Cragin, 1893) [P]
Kamerunoceras Reymont, 1954
K. douvillei (Pervinquière, 1907) [P]
K. ganuzai (Wiedmann, 1960) [E]
K. turoniense (d'Orbigny, 1850) [E]
Lotzeitites Wiedmann, 1960
L. sp. [E]
Mammites Laube and Bruder, 1887
M. nodosoides (Schlüter, 1871) [E]

- Metoicoceras* Hyatt, 1903
M. geslinianum (d'Orbigny, 1850) [E]
M. mosbyense Cobban, 1953 [E]
Pseudaspidoceras Hyatt, 1903
P. pseudonodosoides Choffat, 1898 [P]
Pseudocalyccoceras Thomel, 1969
P. sp. [P]
Romaniceras Spath, 1923a
R. (Yubariceras) Matsumoto et al., 1957
R. (Y.) ornatissimum (Stoliczka, 1864) [E]
Spathites Kummel and Decker, 1954
S. (Ingridella) Wiedmann, 1960
S. (I.) depressus (Wiedmann, 1960) [E]
S. (I.) malladae (Fallot, 1931) [E]
S. (Jeanrogericeras) Wiedmann, 1960
S. (J.) combesi (Sornay, 1951) [E]
S. (J.) obliquus (Karrenberg, 1935) [E]
S. (J.) postsaenzi (Wiedmann, 1960) [E]
S. (J.) reveliereanus (Courty, 1860) [E]
S. (J.) robustus (Wiedmann, 1960) [E]
S. (J.) saenzi (Wiedmann, 1960) [E]
S. (J.) subconciliatus (Choffat, 1898) [E, P]
S. (J.) tavense (Faraud, 1940) [E]
S. (Spathites) Kummel and Decker, 1954
S. (S.) laevis (Karrenberg, 1935) [E]
S. (S.) sulcatus (Wiedmann, 1960) [E]
Thomelites Wright and Kennedy in Juignet et al., 1973
T. hancocki Juignet and Kennedy, 1976 [P]

Vascoceratidae

- Fagesia* Pervinquièrre, 1907
F. catinus (Mantell, 1822) [E, P]
F. mortzestus (Barroso-Barcenilla and Goy, 2009) [E]
F. pachydiscoides Spath, 1925 [E]
F. rudra (Stoliczka, 1865) [E]
F. superstes (Kossmat, 1897) [E, P]
F. tevesthensis (Peron, 1896) [E, P]
Neoptychites Kossmat, 1895
N. cephalotus (Courtyllier, 1860) [E, P]
Rubroceras Cobban et al., 1989
R.cf. alatum Cobban et al., 1989 [P]
R. sp. [P]
Vascoceras Choffat, 1898
V. adonense Choffat, 1898 [P]
V. amieirensense Choffat, 1898 [E]
V. barcoicensense Choffat, 1898 [E, P]
V. cauvini Chudeau, 1909 [E]
V. charoni (Barroso-Barcenilla and Goy, 2010) [E]
V. douvillei Choffat, 1898 [P]
V. durandi (Thomas and Peron, 1889) [E, P]
V. gamai Choffat, 1898 [E, P]
V. harttii (Hyatt, 1870) [E]
V. kossmati Choffat, 1898 [E, P]
V. silvanense Choffat, 1898 [P]
V. sp. [P]

Pseudotissotiidae

- Choffaticeras* (*Choffaticeras*) *pavillieri* (Pervinquièrre, 1907) [E]
Ch. (Ch.) quaasi (Peron, 1904) [E]
Ch. (Ch.) segne (Solger, 1903) [E]
Ch. (Ch.) sinaiticum (Douville, 1928) [E]
Choffaticeras (*Leoniceras*) Douville, 1912a
Ch. (L.) barjonai (Choffat, 1898) [E, P]
Ch. (L.) luciae (Pervinquièrre, 1907) [E]
Donenriquoceras Wiedmann, 1960

- D. forbesiceratiforme* Wiedmann, 1960 [E]
Pseudotissotia Peron, 1897
P. sp. [E]
Thomasites Pervinquièrre, 1907
T. rollandi (Thomas and Peron, 1889) [P]
Wrightoceras Reymont, 1954a
W. llarenai (Karrenberg, 1935) [E]
W. munieri (Pervinquièrre, 1907) [E]
W. submunieri Wiedmann, 1975b [E]

Other families

- Coilopoceras* Hyatt, 1903
C. sp. [E]
Hoplitoides von Koenen, 1898
H. ingens (von Koenen, 1897) [E]
Hypophylloceras Salfeld, 1924
H. (Neophylloceras) Shimizu, 1934
H. (N.) sp. [E]
Parapuzosia Nowak, 1913
P. (Austiniceras) Spath, 1922a
P. (A.) sp. [E]
P. (A.) intermedia orientalis Matsumoto, 1954 [P]
Puzosia Bayle, 1878
Puzosia (*Puzosia*) sp. [P]
Pachydesmoceras Spath, 1922a
P. denisonianum (Stoliczka, 1865) [P]
P. linderi (de Grossouvre, 1894) [E]
Neolobites Fischer, 1882
N. bussoni Collignon, 1965b [P]
N. vibrayanus (d'Orbigny, 1841) [E, P]
Nostoceras Hyatt, 1894
N. (Eubostrychoceras) Matsumoto, 1967
N. (E.) sp. [E]

Gastropoda

- Actaeonella caucasica* Zekelli, 1847 [P]

Bivalvia

- Gyrostrea ouremensis* Choffat, 1898 [P]