

Upper Oxfordian to lower Kimmeridgian successions in the NE Iberian Range (E Spain): some new stratigraphical and palaeontological data

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With 4 figures and 1 table

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Abstract: Upper Oxfordian deposits in NE Iberian Range, from Hauffianum to Galar biozones, are mainly developed in terrigenous carbonate facies (the so-called Talamantes Member; Aldealpozo Formation), being markedly thicker in the NW sector of the platform. This terrigenous complex is interpreted as the front part of a pro-delta sedimentary system prograding towards the southeast. From Galar Biozone onwards sedimentation becomes progressively more carbonate. Bivalve associations reveal a progressive replacement of infaunal by epifaunal communities. Similarly, ammonite succession shows the replacement at this point of representatives of Ataxioceratinae genera *Orthosphinctes* and *Subnebrodites* by genus *Planites*. This fact, underlined by the record of *Sutneria galar* (OPPEL) in the Sot de Chera Formation, makes the Planula-Galar biozone boundary an acceptable possibility for the Oxfordian-Kimmeridgian stage boundary, thus giving further support to recent proposals within the Oxfordian-Kimmeridgian boundary Working Group of the ISJS.

Zusammenfassung: Die oberoxfordischen Ablagerungen von der Hauffianum- bis zur Galar-Biozone in den nordöstlichen Iberischen Ketten, sind überwiegend in terrigener Karbonatfazies ausgebildet (so genannter Talamantes-Member der Aldealpozo-Formation), die im NW-Abschnitt der Plattform deutlich mächtiger entwickelt ist. Dieser terrigene Komplex wird als vorderer Abschnitt eines Prodelta-Ablagerungssystems interpretiert, das sich nach Südosten vorbaute. Ab der Galar-Biozone wurde die Sedimentation zunehmend karbonatischer. Muschel-Vergesellschaftungen zeigen einen Ersatz von infaunalen durch epifaunale Gemein-

schaften. Die Ammoniten-Abfolge zeigt zur selben Zeit einen Ersatz der Vertreter der Ataxioceratinae-Gattungen *Orthosphinctes* und *Subnebrodites* durch die Gattung *Planites*, was die Grenze zwischen der Planula- und Galar-Biozone zu einer akzeptablen Oxfordium-Kimmeridgium-Stufengrenze werden lassen könnte, zusätzlich noch unterstrichen durch den Nachweis von *Sutneria galar* (OPPEL) in der Sot de Chera-Formation. Mit diesen Daten werden diesbezügliche Vorschläge innerhalb der Oxfordium-Kimmeridgium-Grenz-Arbeitsgruppe der ISJS unterstützt.

Key words: Upper Jurassic, biostratigraphy, facies analysis, ammonites, Bivalvia, Oxfordian-Kimmeridgium boundary.

1. Introduction

During the Middle Jurassic the eastern Iberian carbonate platform was divided into a northern, or northeastern, and a southern, or southwestern, carbonate platform, called respectively Aragonese and Castillian platforms (GÓMEZ & FERNÁNDEZ-LÓPEZ 2004, 2006). During the Upper Jurassic, from middle Oxfordian onwards, these platforms evolved into a wide, homogeneous carbonate ramp (AURELL 1990; AURELL et al. 1990, 2003; BÁDENAS 1999; BÁDENAS & AURELL 2001), resulting in the development of thick carbonate sequences including:

- A basal sponge limestone unit (the Yátova Formation, middle to early upper Oxfordian).
- A thick terrigenous, marly unit (the Sot de Chera Formation, uppermost Oxfordian to ?lowermost Kimmeridgian).
- A rhythmic interbedding of lithographic limestones and marls (the Loriguilla Formation, Kimmeridgian) and
- A thick, oncolitic to biohermal limestone unit (the Higuieruelas Formation, Tithonian). This last regressive unit is well developed only in the outer part of the ramp.

At the turn of the middle to late Oxfordian (Hypselum Chronozone) the platform reached the maximum values of depth so far detected for the whole Jurassic of this basin as a part of the Oxfordian deepening-shallowing cycle (FERNÁNDEZ-LÓPEZ & MELÉNDEZ 2004). From this point onwards, a progressive restriction of the sedimentary environment during the late Oxfordian produced the slow retreat of open marine sponge limestone facies of the Yátova Formation and the consequent progradation of terrigenous facies from the northwest (from the Veruela area).

During the early Kimmeridgian, Platynota to Acanthicum chronozones, the former homogeneous ramp, underwent a slow differentiation into deeper, subsident and shallower, elevated areas. A progressively elevated paleogeographic threshold area was developed at the middle-outer sector of the platform (the “Ariño-Andorfa High”; AURELL 1990; MELÉNDEZ et al.

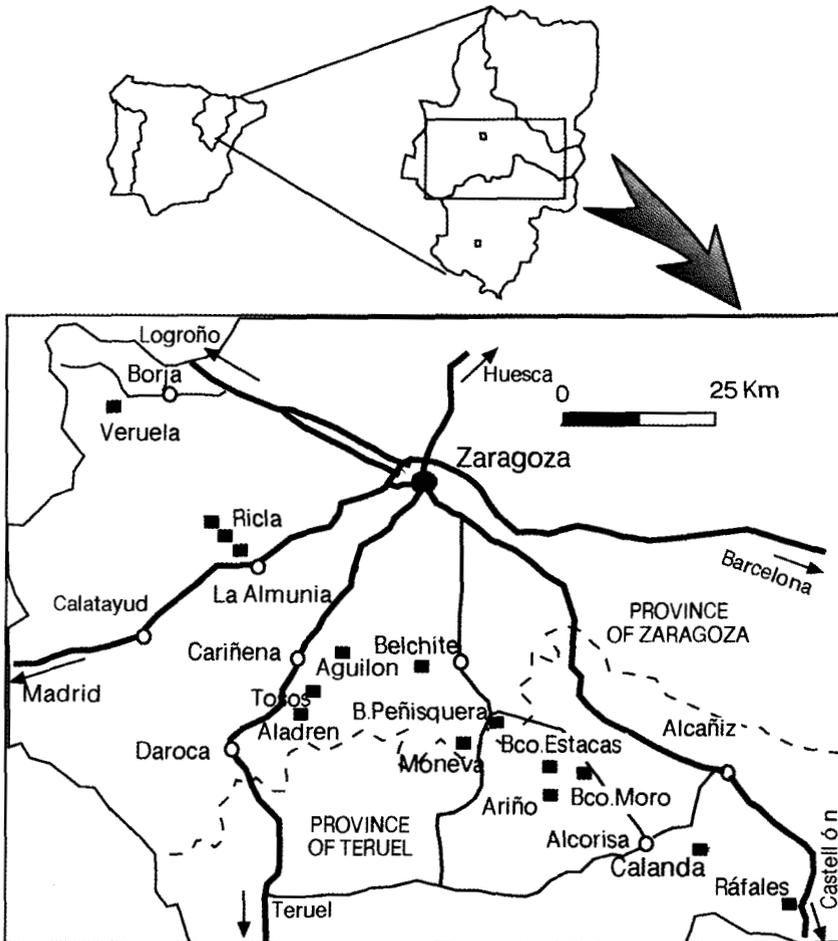


Fig. 1. Geographic location of the studied sections in Spain along the NE Iberian Range, in the so-called "Aragonese Branch".

1990, 1997; BÁNCORA et al. 2005). This produced the progressive restriction of middle and proximal areas and the gradual decrease of pelagic elements, mainly ammonites, from early Kimmeridgian Platynota Chronozone, onwards. The sole exception is the outermost part of the platform (the Calanda-Alcorisa-Ráfales area) where early Kimmeridgian sequences, up to the Acanthicum Chronozone, are widely known by their richness in ammonites, and have been the base for numerous detailed biostratigraphic and palaeon-

tological studies (GEYER & PELLEDUHN 1981; ATROPS & MELÉNDEZ 1985; MOLINER & OLÓRIZ 1985; MELÉNDEZ et al. 1999, BÁNCORA et al. 2005).

The studied profiles have been selected from classical key-sections along the platform following a general NW-SE direction (Fig. 1), from proximal to distal areas, showing the palaeogeographic constraints that controlled the facies variations, the different fossil content and the rate of sedimentation (Fig. 2). In the proximal, more subsident areas, at Northwest, the sections of Vuela and Ricla are the best known and most fossiliferous; in the middle part of the ramp, the sections of Tosos, Aladrén and Aguilón have been the subject of successive studies by the present authors (PÉREZ-URRESTI 1995, 1996; PÉREZ-URRESTI et al. 1998; DELVENE 2001). In the outer threshold

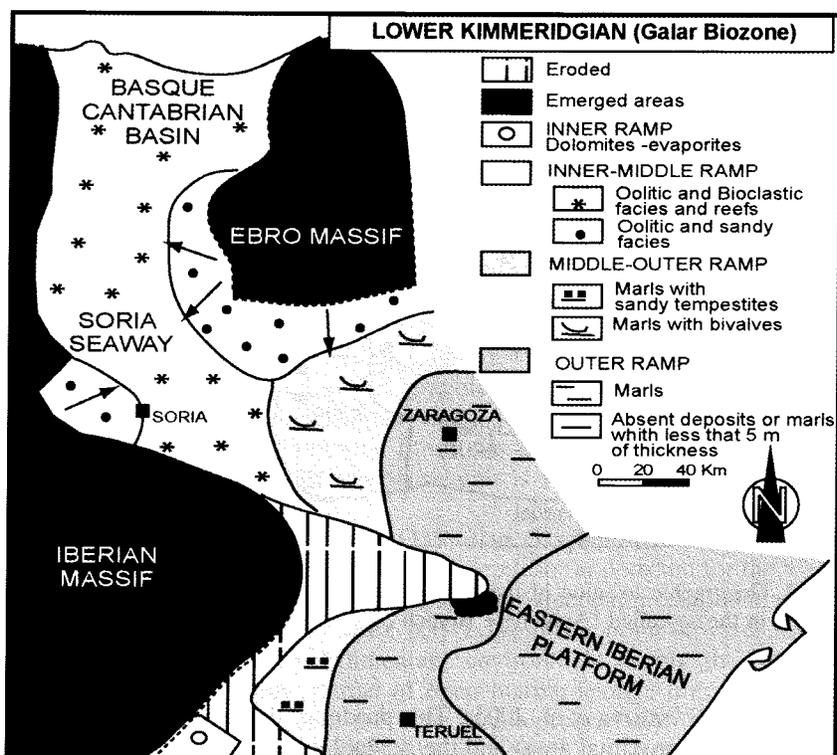


Fig. 2. Palaeogeographic setting of the East-Iberian carbonate platform at the turn of the Oxfordian and Kimmeridgian stages (Galar Biozone). From BÁDENAS (1999) and BÁDENAS & AURELL (2001). During the late Oxfordian-early Kimmeridgian, this sedimentary area is developed as a homogeneous, uniform homoclinal carbonate ramp.

area of Sierra de Arcos, where the studied units reach their minimum values of thickness, the studies of PÉREZ-URRESTI (loc. cit), MELÉNDEZ (1989), ATROPS et al. (1997) and MELÉNDEZ et al. (1997) have provided recent information on ammonite successions and lithofacies. Finally, the outermost part of the platform, the Calanda-Ráfales area, is characterized by the condensed character of Oxfordian sequences and the converse expanded character of Kimmeridgian units, i.e. the Loriguilla Formation. The lower part of this formation forms a well-defined, remarkably fossiliferous lithostratigraphic unit (the Calanda Member; MELÉNDEZ et al. 1990). These sequences have provided relevant biostratigraphic information and have given rise to numerous studies (see above).

2. Stratigraphy and lithofacies

The Oxfordian sequence in the NE Iberian Range, the so-called “Aragonese Branch” comprises several main lithostratigraphic units (Fig. 3), recognized as follows:

- (1) The Yátova Formation, ranging in age from middle to early late Oxfordian and formed by sponge biostrome highly fossiliferous micritic to somewhat bioclastic limestones. Occasionally, sponge developments may form small bioherms decimetric to metric in size (e.g. in Ricla). Its thickness usually ranges from less than 2 m in the Calanda-Alcorisa area (southeast) to 12-14 m in the Ricla-Tosos area (centre-northwest). A lower term, more massive and an upper term, more regularly bedded with intercalations of marls, can be generally distinguished.
- (2) The Aldealpozo Formation, defined in the northwest areas of the Aragonese Platform, from the internal to proximal external platform (between the Iberian and Ebro Massifs and the area of Ricla-Veruela) is a clastic to dolomitic limestone unit, being the lateral equivalent of the external platform Yátova Formation. In the area of Ricla it overlies the upper terms of Yátova Formation and has yielded a rich ammonite association from *Hypselum* to *Hauffianum* biozones. Due to its predominantly terrigenous character, silty limestones and marls, some authors have regarded it as a lower term of the overlying sot de Chera Fm (BÁDENAS et al. 1998; BÁDENAS 1999), even as a separate member of this unit (the “Talamantes Member”, RAMAJO 2006). As a whole, this terrigenous interval represents the progradation of a deltaic sedimentary system from the emerged areas in the north towards the open platform in the Southeast.
- (3) In the farthest Northwest sector (Veruela-Talamantes area) a siliciclastic interval is developed: the Veruela Member (Aldealpozo Formation). This interval is formed by a 40 m thick sandstone sequence wedging out to the Southeast and passing laterally (in Ricla) to the levels of silty

- limestones and marls of the Talamantes Member. It is formed by sandy limestones grading upwards into cross-bedded sandstone and conglomerates. The age of this unit is difficult to assess due to the absence of determinative fossils. The record of *Subnebrodites proteron* (NITZOPOULOS) at the base of the overlying unit suggests a late Oxfordian age, (Bimammatum to Hauffianum chronozones) for this interval.
- (4) The Sot de Chera (s.str.) Formation, ranging in age from late Oxfordian Planula Chronozone to the early Kimmeridgian Galar Chronozone. It is formed by a variably thick terrigenous interval, mostly including marls, silty marls and, occasionally, siliciclastic limestones. It shows important thickness variations across the external platform: from over 100 m in the NW proximal sector, to 2-4 m in the SE distal outer areas. Facies also show a progressive variation from NW to SE, the siliciclastic input being more important to the Northwest (in the Veruela-Ricla area) at the vicinities of the near emerged Iberian and Ebro massifs (BÁDENAS 1999; BÁDENAS & AURELL 2001) and gradually fading out towards the Southeast, in the surroundings of Calanda. This facies distribution results in a series of lithological intervals, which have been recognized as lithostratigraphic units (Fig. 3).

3. Bivalve associations

The bulk of studied bivalve assemblages (Table 1) have been collected in the Sot de Chera Formation, in the NW sector of Iberian Range, most precisely at the sections of Ricla, Tosos and Aguilón (province of Zaragoza: DELVENE 1997, 2001a, b, 2003; DELVENE et al. 1998; PÉREZ-URRESTI et al. 1998). The stratigraphic interval showing the highest abundance and diversity of bivalves corresponds to Planula, Galar and Platynota biozones. The most common species are: *Gervillia aviculoides* (J. SOWERBY), *Nanogyra nana* (J. SOWERBY), *Cingetolium (C.) cingulatum* (GOLDFUSS), *Cingetolium (C.) partitum* (J. DE C. SOWERBY), and *Nicaniella (Trautscholdia) carinata* (PHILLIPS). This bivalve association often includes a certain amount of gastropods and scaphopods. Among the bivalves, a large majority are suspension-feeders, although some species were deposit-feeders. Deposit-feeder species are limited to this northwest sector (Ricla, Tosos and Aguilón areas). They belong to the order Nuculoida, the most common species being:

Fig. 3. Litho- and biostratigraphic correlation across the Aragonese Platform for the upper Oxfordian-lower Kimmeridgian units. The selected sections are classical outcrops from the different sectors of NE Iberian Range (see Fig. 1) and correspond to different palaeogeographic and sedimentary areas (see Fig. 2).

SE

Sandstone and siltstone
Conglomerates
Silty limestone
Glauconitic-pelloidal limestone
Sponge limestone
Marls and silty marls

Sot de Chera Fin (Upper form) **SCh**
Aldaiçozo Fin (Veruela Mb) **Ve**
"Aldaiçozo" Fin (Tatamantes Mb) **Ta**
Yátova Fin **Ya**
Level number 176

Biozone Key
Hyp: *Hypselum* Bz
Bim: *Bimammatum* Bz
Hauf: *Hauffianum* Bz
Pl: *Planula* Bz
Gl: *Galar* Bz

NW

VERUELA
SCh
176
90
80
70
60
50
40
30
20
10
0
Pl
Hauf
Ve
Bim
Hyp
Ta
Ya

TOSOS
SCh
112
98
90
88
72
60
50
41
30
20
10
0
Pl
Hauf
Hyp
Bim
Ya

BARRANCO DE LAS ESTACAS
60
50
41
30
20
10
0
Gl
Pl
Bim
Ya

CALANDA RÁFALES
SCh
40
38
36
30
20
10
0
Pl
Hauf
Bim
Hyp
Ya

Stage	lower Kim.	Galar
	Upper Oxfordian	Planula Tomerense Hauffianum Bimammatum Berense Sammammatum Iypselum
Biozone	lower Kim.	Galar
	Upper Oxfordian	Planula Tomerense Hauffianum Bimammatum Berense Sammammatum Iypselum
Subzone	lower Kim.	Galar
	Upper Oxfordian	Planula Tomerense Hauffianum Bimammatum Berense Sammammatum Iypselum
Stage	middle Oxfordian	Grossavret Stensy- dödes Rotules Schilli Luciaelombs Parandieri Antecedens Paturatensis
	lower Kim.	Picatlis

Table 1. Geographic-stratigraphic distribution of main bivalve species in the analysed sections of the upper Oxfordian-lower Kimmeridgian of the NE Iberian Range.

Geographic area/ Age Species	NW (Ricla, Tosos Valmadrid)		"Sierra de Arcos"		"Bajo Aragón" (Calanda-Ráfales)	
	U Oxf.	L Kimm.	U Oxf.	L Kimm.	U Oxf.	L Kimm.
<i>Palaeonucula calliope</i>	•	•				
<i>Palaeonucula menkii</i>	•	•				
<i>Palaeonucula monnandi</i>	•	•				
<i>Nuculana (Praesacella)</i> <i>venusta</i>	•	•				
<i>Dacryomya roederi</i>		○				
<i>Barbatia tenuitexta</i>		○				
<i>Grammatodon (G.) concinnum</i>	•	•		•		
<i>G (Cosmetodon) elongatum</i>		○				
<i>Gervillia aviculoides</i>	•	•				
<i>Isognomon promytiloides</i>		•				
<i>Pinna (P.) cf. socialis</i>	•					
<i>Plagiostoma laeviusculum</i>		○				
<i>Plagiostoma buckmani</i>	•					
<i>Plagiostoma oepybolum</i>		○				○
<i>Plagiostoma prazi</i>	•					
<i>Pseudolimea duplicata</i>		○				
<i>Liostrrea dubiensis</i>	•					
<i>Nanogyra nana</i>	•	•				
<i>Camptonectes auritus</i>	•	•				
<i>Chlamys textoria</i>	•					
<i>Radulopecten fibrosus</i>		○				
<i>Radulopecten scarburgensis</i>		○				
<i>Spondylopecten (S.)</i> <i>subpunctatus</i>		○				
<i>Spondylopecten (Plesiopecten)</i> <i>subspinosus</i>	•	•				•
<i>Cingentolium (C.) cingulatum</i>	•	•				
<i>Cingentolium (C.) partitum</i>	•	•	•	•		•
<i>Entolium (E.) corneolum</i>	•	•				
<i>Inoperna perlicata</i>		○				
<i>Trigonia (T.) cf. reticulata</i>		○				
<i>Corbulomima suprajurensis</i>	•	•				
<i>Anisocardia (A.) cf. choffati</i>		○				
<i>Rollierella laubei</i>	•					
<i>Rollierella tenuidentata</i>	•	•				
<i>Nicaniella (N.) cf. phillis</i>		○				
<i>Nicaniella (T.) carinata</i>	•	•				
<i>Prorokia aff. moriceana</i>		○				
<i>Mactromya aequalis</i>		○				
<i>Mactromya globosa</i>	•	•				
<i>Mactromya ovalis</i>	•	•				
<i>Unicardium angulatum</i>	•	•				
<i>Unicardium bernardinum</i>	-	○				

Table 1 (continued).

Geographic area/ Age Species	NW (Riela, Tosos Valmadrid)		"Sierra de Arcos"		"Bajo Aragón" (Calanda-Ráfales)	
	U Oxf.	L Kimm.	U Oxf.	L Kimm.	U Oxf.	L Kimm.
<i>Unicardium exiguum</i>		○				
<i>Unicardium josephense</i>	●					
<i>Unicardium</i> aff. <i>tombecki</i>		○				
<i>Pholadomya</i> (Ph.) <i>acuminata</i>	●					●
<i>Pholadomya</i> (<i>Bucardiomya</i>) <i>protei</i>			●			
<i>Pleuromya alduini</i>				○		
<i>Pleuromya uniformis</i>			●			
<i>Ceratomya excentrica</i>		○				

- Species recorded in upper Oxfordian and lower Kimmeridgian levels from this area
- Species recorded only in lower Kimmeridgian levels from this area

Palaeonucula calliope (D'ORBIGNY), *Palaeonucula menkii* (ROEMER), and *Dacryomya roederi* (DE LORIO). These benthic organisms are shallow infaunal, excavating soft substrates and are able to dig into the sediment.

Suspension-feeder bivalves excavate soft substrates, 30.5% are shallow infaunal (trigoniids and heterodonts) and 1% are deep infaunal (pholadomyids). Byssate semi-infaunal bivalves are 5.7%, represented by *Grammatodon* (*Cosmetodon*), *Gervillella*, and *Pinna*. The rest of bivalves comprise epifaunal elements: 3% are byssate (*Plagiostoma*, *Pseudolimea* and some pectinids), 37.8% are encrusting elements (order Ostreoida) and 18% are free, able to swim in some particular moments (*Cingetolium*, *Entolium*).

Among the numerous forms listed in Table 1, some of them are particularly relevant since they are found only in the lower Kimmeridgian levels, hence supplying valuable information to further characterising the Oxfordian-Kimmeridgian transition in the Iberian platform. This is mainly the case of such forms as *Dacryomya roederi* (DE LORIO), *Barbatia tenuitexta* (MORRIS & LYCETT), *Grammatodon* (*Cosmetodon*) *elongatum* (J. DE C. SOWERBY), *Plagiostoma laeviusculum* J. SOWERBY, *Plagiostoma oepybolum* (WHIDBORNE), *Pseudolimea duplicata* (J. DE C. SOWERBY), *Radulopecten fibrosus* (J. SOWERBY), *Radulopecten scarburgensis* (YOUNG & BIRD), *Spondylopecten* (*S.*) *subpunctatus* (MÜNSTER), *Inoperna perlicata* (ÉTALLON), *Trigonia* (*T.*) cf. *reticulata* AGASSIZ, *Anisocardia* (*A.*) cf. *choffati* DE LORIO, *Nicaniella* (*N.*) cf. *phillis* (D'ORBIGNY), *Prorokia* aff. *moriceana* (DOLLFUS), *Mactromya aequalis* AGASSIZ, *Unicardium bernardinum* D'ORBIGNY, *Unicardium exiguum* DE LORIO, *Unicardium* aff. *tombecki* DE LORIO, *Pleuromya alduini* (BRONGNIART), and *Ceratomya excentrica* (ROEMER). This interesting fact, which might be probably linked to ecological variations

in the basin, will supply crucial information to the current debates on the definition of GSSP for the Oxfordian-Kimmeridgian stage boundary.

4. Biostratigraphy

Late Oxfordian Tethyan biostratigraphy has undergone a certain progress in the last ten years since the "Standard" zonal scheme put forward by the Jurassic French Group (CARIOU et al. 1971, 1997). Different proposals by MELÉNDEZ (1989), ATROPS and MELÉNDEZ (1993, 1994), PÉREZ-URRESTI (1996), ATROPS et al. (1997) and RAMAJO et al. (1999) have contributed to summarize the knowledge reached on the succession of main ammonite groups at this interval (Fig. 4) and to incorporate the recent trends on what concerns the proposed position of the Oxfordian-Kimmeridgian boundary as regards wide, universal correlation with other provinces. The "classical" upper Oxfordian zonation based on species of genera *Epipeltoceras*, *Taramelliceras* and *Subnebrodites*, is here supplemented with a parallel biozonation based on *Orthosphinctes* species. This still tentative succession will allow a bigger biostratigraphic precision and wider correlation potential.

The classical Hypselum Subbiozone, widely used so far as the lower standard subbiozone for the upper Oxfordian Bimammatum Biozone, is here accepted with the rank of full biozone, as it has been recognized in almost all sedimentary basins across the Submediterranean Province, from Portugal (Montejunto) to Polish Jura. The wide expansion of the index-species *Euaspidoceras hypselum* (OPPEL) and easy characterization of this stratigraphic interval makes it advisable to keep it as a standard chronozone index. This lower biozone is subdivided into two clear intervals; the former Semimammatum and Berrense biohorizons, which are assumed with subzonal rank (CARIOU et al. 1997). The base is clearly marked by the sharp occurrence of first representatives of *Epipeltoceras semimammatum* (QUENSTEDT), which characterizes the lower Semimammatum Subbiozone. The parallel *Orthosphinctes* succession includes the lower Ariniensis interval; index-species: *Orthosphinctes ariniensis* (MELÉNDEZ), a very early *Orthosphinctes* still keeping many features of its presumed Passendorferiinae ancestors and first included in the genus *Passendorferia* (MELÉNDEZ, 1989), and the upper, "Kirkdalensis" interval, index species: *Orthosphinctes kirkdalensis* ENAY (non ARKELL).

The Bimammatum (s.str.) Biozone is generally characterized by the common occurrence of *Epipeltoceras bimammatum* (QUENSTEDT), a form commonly found across the East-Iberian platform and widely expanded throughout the Submediterranean (S Europe) and true Mediterranean provinces, as far as the Subbetic Zone in the Betic Range, S Spain (SEQUEIROS 1974). Two *Orthosphinctes* intervals, which might, in the near future be proposed as subbiozones, are recognized (PÉREZ-URRESTI 1996; ATROPS et

Stage	Chronozone	Subchronozone	Tentative horizons
LOWER KIMMERIDGIAN	Divisum	Uhlandi	
		Tenuicostatum	
	Hypselocyclum	Lothari	
		Hippolytense	
	Platynota	Guilherandense	
		Desmoides	Desmoides
			Enayi
		Polygyratus	Pseudopolypliocoides
	(?)Polygyratus		
	Galar	Aff. Polygyratus	
(?Freybergi)			
UPPER OXFORDIAN	Planula	Planula	
		Proteron	Gidoni
	Hauffianum	Hauffianum	Tiziani/Bauhini
			aff. Tiziani
	Bimammatum	Bimammatum	?Laufenensis Alternans - Gredingensis
	Hypselum	Berrense	"Kirkdalensis"
		Semimammatum	Ariniensis

Fig. 4. Late Oxfordian to early Kimmeridgian ammonite zonal scheme for the Submediterranean Province, Tethyan Realm, mainly based on the succession of Ataxioceratinae species (genera *Orthosphinctes* and *Planites*) as shown by RAMAJO (2006).

al. 1997): a lower, Alternans interval, characterized by the common occurrence of *Orthosphinctes alternans* ENAY, and the Laufenensis interval, characterized by the presence of *Orthosphinctes (Praeaataxioceras) laufenensis* (SIEMIRADZKI) – *virgulatus* (QUENSTEDT) (see ATROPS 1982). Representatives of “*Perisphinctes*” *gredingensis* WEGELE are also common in the lower interval (PÉREZ-URRESTI 1996; AURELL et al. 1997). This late Oxfordian form, formerly regarded as a late representative of genus *Larcheria* by TINTANT (1961) has been recently transferred to the new monotypic genus *Wegelea* GYGI (2000: 92).

The Hauffianum Subzone, assumed with full biozone status, is generally characterized by the common occurrence of such forms as *Taramelliceras hauffianum* (OPPEL) and *Orthosphinctes tiziani* (OPPEL), generally at the upper part of the Oxfordian lithologic unit Yátova Formation or the equivalent more clastic Aldealpozo Formation. Generally, the OPPEL species is recorded in the uppermost part whilst the lower levels of this biozone are covered by an earlier, more coarsely ribbed form, initially recognised as *O. tizianiformis* (CHOFFAT) (SCHWEIGERT & CALLOMON 1997). However, this name would be difficult to maintain, since the type-specimen of CHOFFAT’s species would come from the bed 5 of “Couches de Cabaço” in Montejunto, Portugal; which, according to the recent revision of the section would correspond to the middle Oxfordian, most probably, Plicatilis to early Transversarium biozones (ATROPS & MARQUES 1988).

The remarkable record at the upper part of this interval of *Amoeboceras bauhini* (OPPEL) in the type area of the species (Plettenberg, SW Germany; see SCHWEIGERT & CALLOMON 1997; SCHWEIGERT 2000), a form which characterizes the base of the Kimmeridgian stage by his record in the type area, (Ringstead Bay in Dorset, S England, Great Britain) together with the basal zone index-species: *Pictonia densicostata* SALFELD, led open the possibility to delineate the Oxfordian-Kimmeridgian boundary at this level: the Hauffianum-Planula Zone boundary (SCHWEIGERT & CALLOMON 1997, fig. 10). This possibility has been for some time regarded as more or less “obvious” since in the type area the species *Amoeboceras bauhini* (OPPEL) is associated both with *Orthosphinctes tiziani* (OPPEL) and *Taramelliceras hauffianum* (OPPEL) thus enabling a wide correlation over large areas (SCHWEIGERT & CALLOMON 1997). However, some objections have also been recently put forward by specialists from different countries in Submediterranean areas, in the sense that the species *Amoeboceras bauhini* (OPPEL) is not common at all in S Europe areas, and also by the fact that it would involve a profound alteration of the current biostratigraphic scale for the Oxfordian stage in the Tethyan Realm. So the debate is still open.

The Planula Zone is well recognized in the studied area by the widespread record of representatives of genus *Subnebrodites*. The homogeneity of the faunas across the Submediterranean Province, the clear differences with the

upper Galar Subbiozone (see below) and the possibility that the Oxfordian-Kimmeridgian stage boundary be eventually placed at the precise Planula-Galar boundary (at the base of the Galar Subchronozone) are criteria for both subzones making it more advisable to be considered as full chronozones.

A lower *S. proteron* (NITZOPOULOS) interval (the Proteron Subbiozone) is clearly characterized in all recorded sections, generally in the top levels of the Oxfordian Yátova Formation (as, e.g. in the Sierra de Arcos and the Calanda area) or its clastic equivalent, Aldealpozo Formation (e.g. in the Ricla area). The form *S. tonerrense* (LORIO), sometimes regarded as an older synonym of *S. proteron* (NITZOPOULOS) (and hence, holding the priority of the name) has not been clearly found or characterized so far in the studied area and, in our opinion, could be rather regarded as a separate form. The upper, Planula interval (the Planula Subbiozone s.str) is also recognized in some of the studied sections although not so clearly characterized as the lower subbiozone. This may be due to two possible reasons: (a) this interval (the Planula Subbiozone s. str.) may be absent by a small stratigraphic gap at the boundary between the Yátova Formation and the overlying unit, the Sot de Chera Formation, as could be the case of the sections of distal areas in Sierra de Arcos (Ariño-Andorra area). Or else, (b) The Planula Subbiozone is, at least partly developed in the Sot de Chera Marl Formation. In such case, it is generally difficult to collect good specimens of *S. planula* (HEHL in ZIETEN) within this marl unit. However, the species *S. planula* (HEHL in ZIETEN) is commonly recorded in wide areas across the Iberian Range. Representatives of genus *Planites*, i.e. forms around the “*Orthosphinctes*” *polygyratus* (REINECKE) group, are recorded in some localities, most particularly the forms closer to the species *Planites gidoni* (ATROPS).

The Galar Biozone, recognized with full biozone status, is generally well developed throughout the studied area, although its characterisation by ammonites may involve some difficulties. In the middle and external part of the platform (= Moneva, Sierra de Arcos and Calanda areas) it fully corresponds to the Sot de Chera marl Formation. The ammonite content is sometimes partly blurred by the marly character of this unit. Ammonite specimens are often crushed and badly preserved in the scarce marly limestone intercalations. The species *Sutneria galar* (OPPEL) has been collected in few sections, near the localities of Moneva and Moyuela (AURELL et al. 1997), Ariño (section of Barranco de las Estacas) and in the Calanda-Alcorisa area. Ataxioceratinae are also represented by scarce microconch specimens of such still poorly known forms as those figured by ATROPS (1982) as “*Orthosphinctes*” *polygyratus* (REINECKE) group from this interval at SE France (e.g. pl. 11, fig. 2; pl. 12, fig. 3) slightly evolute and coarsely ribbed, and also some involute densicostate forms which clearly match the features of *Pl. freybergi* (GEYER), as figured by ATROPS (1982, pl. 15, fig. 1,

non fig. 2). In the area of Ricla, some scarce macroconchs collected at this interval, above level 176 (see Fig. 3) show some similarities with the forms described by HANTZPERGUE (1987) as "*Subdiscosphinctes*" *grandiplex* (QUENSTEDT) and "*Lithacosphinctes*" *gigantoplex* (QUENSTEDT) (BÁDENAS et al. 1998). However, the precise stratigraphic position of both QUENSTEDT species is still under debate and the available material from Ricla is still insufficient to add more precision. As a conclusion, a lower Freybergi interval and, perhaps, a second aff.-*Polygyratus* interval (upper) could be considered within the Galar Subbiozone, but the situation so far is still not clear.

5. Note on *Planites* DE HAAN (*Ataxioceratinae*, BUCKMAN, 1921)

A parallel scale based on the *Orthosphinctes-Planites* sequence would be desirable to establish, as an attempt to help fulfilling the phylogeny of early Ataxioceratinae. The name *Planites* DE HAAN, 1825, emend. BUCKMAN, 1913; type-species *Am. planulatus*, SCHLOTHEIM, and subsequently designated as genoelectotype for *Ammonites polygyratus* (REINECKE) by BUCKMAN (1913, Yorkshire Type Ammonites, II: iv), was generally overlooked and eventually considered as invalid in favor of *Orthosphinctes*. However, after the detailed monograph by ATROPS (1982) it became evident that there was a sharp morphological gap between true representatives of upper Oxfordian (Hypselum to Hauffianum zones) *Orthosphinctes*, of the *O. tiziani* (OPPEL) group and latest Oxfordian to earliest Kimmeridgian representatives of this line, set around the group of "*Orthosphinctes*" *polygyratus* (REINECKE). This change would mainly affect the coiling and growth of whorl section: slightly more involute coiling, and more slender, oval whorl section in the *polygyratus* (REINECKE) group. The style of ribbing shows also clear differences, being coarser with thick secondaries, and a trend to develop loose trifurcations and intercalaries in *Orthosphinctes* of the *tiziani* (OPPEL) group. Representatives of the *Planites* group from Planula and Galar biozones, in turn, show a trend to develop wiry ribs, and simpler, mainly single, biplicate, or polygyrate ribbing, as shown by ATROPS (1982, see references above).

It seems therefore that the recovery of the generic name *Planites* could be fully justified. The origin of the genus *Planites* would take place at the turn of the Hauffianum-Planula Biozone, when evolute serpenticones, thickly ribbed late representatives of *Orthosphinctes* of the *tiziani* (OPPEL) group are replaced by the early representatives of *Planites*, of the *fontannesi* (CHOFFAT) – *gidoni* (ATROPS) groups, and characterized by the simpler, and sharper ribbing with acute, very low angle of furcation, and involute, serpenticone coiling with compressed oval whorl section. The genus would therefore range through the Planula and Galar, and lower Platynota biozones, including the groups traditionally described as "*Orthosphinctes*" *gidoni*

ATROPS; *gigantoplex* (QUENSTEDT), *evolutus* (QUENSTEDT), *freybergi* (GEYER) and “*polygyratus*” (REINECKE). Although some of these forms are still poorly known, their precise stratigraphic position remaining doubtful, and the name *polygyratus* has been often overused by some authors who assigned to this species different forms ranging in age from Hauffianum to Platynota biozones (e.g. SCHAIRER 1974) the genus *Planites* forms in fact a distinct and homogeneous line, and an evolutionary link of the subfamily Ataxioceratinae, between late Oxfordian genus *Orthosphinctes* and early Kimmeridgian *ArDESCIA*.

A further relevant point comes from the examination of the type specimen of the species “*Orthosphinctes polygyratus* (REINECKE). The specimen from the original collection of REINECKE believed as being definitively lost, led to the designation by GEYER (1961) of a neotype of this species from the DE LORIOLE collection (DE LORIOLE 1876: 61, pl. 7, fig. 1). However, the recent recovery of REINECKE’S collection in the Natural History Museum of Coburg (E. MÖNNIG, pers. comm. 1995; confirmed by G. SCHWEIGERT) would clearly invalidate that neotype designation. The type specimen, as illustrated by REINECKE (1818) and subsequently re-figured by ZEISS & HELLER (1972) seems to be an incomplete phragmocone showing morphological features very close either to late representatives of *Planites*, as accepted here, or to first representatives of *ArDESCIA*, i.e. the group of *ArDESCIA* (m & M) *enayi* (ATROPS), but still lacking the typical multidivided bundles of secondaries and the slightly more compressed, involute coiling of typical representatives of this genus. According to the current knowledge, the species *Planites polygyratus* (REINECKE), as usually understood, had been assumed to come from the lower Platynota Biozone (the “*Orthosphinctes* Subzone” (ATROPS 1982), or the “*Polygyratus* Subzone” (ATROPS & MELÉNDEZ 1993; 1994). However, the incomplete state and the still scarce knowledge of the original type specimen has cast some doubts on its taxonomic and stratigraphic affinity, as it might also be a nucleus of an early representative of true *ArDESCIA*, of the *enayi* (ATROPS) – *desmoides* (WEGELE) group (G. SCHWEIGERT, personal comm.), hence occupying a similarly well-defined biohorizon within the *Desmoides* Subbiozone. On the other hand, the species *Planites pseudopolypliocoides* (GEYER) would occupy a well-defined interval within the basal *Polygyratus* Subbiozone of the Platynota Biozone (= the *Pseudopolypliocoides* Biohorizon, see Fig. 4). The debate is still open until a detailed revision of the type can be made, and the taxonomic changes, and consequences on the systematics of the subfamily Ataxioceratinae and biostratigraphy of late Oxfordian-early Kimmeridgian are still under discussion.

6. Discussion

As shown in Fig. 3, late Oxfordian to early Kimmeridgian sequences in the NE Iberian Range, the Aragonese Branch, show a good stratigraphic development and ammonite record completeness through the Planula and Galar biozones. The Calanda area displays an exceptional record of lower Kimmeridgian Platynota Biozone. These points make some of these sections particularly favourable to be proposed as reference sections for the Oxfordian-Kimmeridgian stage boundary of the Submediterranean Province in SW Europe, as a complement to those of Crussol, in SE France (ATROPS & MELÉNDEZ 1985).

In the frame of the current debates on the precise position of the Oxfordian-Kimmeridgian stage boundary, the recent proposal of placing it at the base of Galar Chronozone, would find good acceptance: across the East-Iberian platform this chronostratigraphic boundary roughly coincides with a lithostratigraphic change, between the Yátova Formation, or its equivalent clastic units in proximal areas, and the Sot de Chera Marl Formation. This would make the boundary clearly recognisable throughout the Iberian platforms. In addition to that, this stratigraphic boundary would coincide with a well-recognized sequence boundary (between the Oxfordian and Kimmeridgian depositional sequences), as it has been repeatedly proposed (AURELL 1990; BÁDENAS 1999; BÁDENAS & AURELL 2001; AURELL et al. 2003).

Ammonite associations characterising the Galar Subbiozone in the Iberian platforms are conspicuous and relatively homogeneous, mainly integrated by scarce representatives of *Planites*, still poorly known or described although the few macroconchs available show clear affinities with the groups of *Planites freybergi* (GEYER), and *Planites* aff. *polygyratus* (REINECKE) which are forms similar to *Orth. polygyratus*, in ATROPS (1982, pl. 11, fig. 2; pl. 12, fig. 3) being noteworthy the sharp absence of *Subnebrodites*. The occurrence of *Sutneria galar* (OPPEL) recorded so far in most of the studied localities is also a characteristic feature of this assemblage. They are clearly distinguishable from the underlying Planula Biozone assemblages, which are dominated by *Subnebrodites*, few *Planites*, mainly of the *gidoni* (ATROPS) group, plus scarce *Physodoceras* gr. *circumspinosum* (QUENSTEDT) and *Sutneria* gr. *praecursor* DIETERICH. They are also distinct from those of Platynota Biozone, which are dominated by representatives of true *Planites polygyratus* (REINECKE) at the base and the sudden expansion of *Ardescia* at the middle, Desmoides Subbiozone).

The refinement of the biostratigraphic scale for the late Oxfordian (Hypselum to Planula biozones) and basal Kimmeridgian (Galar Biozone) by means of representatives of Ataxioceratinae (*Orthosphinctes-Planites* line) is still in progress. In fact, it is true that, in the absence of other external

evidence (e.g. *Sutneria*) the Galar-Platynota boundary might be difficult to delineate on the sole evidence of successive links of the *Planites* line. However, the increasing knowledge of this group opens a promising door to enhance their biochronological and correlation potential throughout the Submediterranean Province, up to Western Europe, Atlantic subprovince. At this point, such classical areas as SE France (Crussol and other sections in the Vocontian Basin), the NE Iberian Platform, the Lusitanian Basin (Montejunto), S Germany, Switzerland and Polish Jura Chain appear crucial as to provide further evidence to reconstruct the evolution of this ammonite group. On the other hand, at the present moment, the area showing the most expanded sequences, as well as most complete, rich and detailed ammonite successions is the Crussol area near Valence, as shown by ATROPS (1982) and ATROPS & MELÉNDEZ (1994).

7. Conclusions

Upper Oxfordian to lower Kimmeridgian sequences in the NE Iberian range are well developed in external platform carbonate lithofacies. Their ammonite successions may be regarded as typically Submediterranean and show their best correlation potential with such areas of southern Europe as Portugal; Provence (SE France), southern Germany and Switzerland and Italy; and partly, the Polish Jura Chain. The scarcity or total absence of representatives of both boreal Cardioceratids and typically mediterranean forms (*Phylloceratina* and *Lytoceratina*) is an evidence of the restricted character of this basin with respect both to boreal and properly Mediterranean, i.e. South Tethyan, areas.

The precise position of the Oxfordian-Kimmeridgian stage boundary is still the subject of intense debate. Despite the good correlation potential of the Hauffianum-Planula boundary or the base of the *Tiziani-Bauhini* Biohorizon at the upper part of Hauffianum Biozone, this proposal would involve a profound alteration of the biostratigraphic scale for the Oxfordian stage. Placing the boundary at the base of Galar Biozone would be a less "alterative" choice allowing a similarly good correlation with boreal areas. Correlation with true Mediterranean areas would be possible by the record of *Sutneria galar* (OPPEL) in both provinces. In the East-Iberian platform the boundary would be easy to recognize also on lithostratigraphic criteria as, in a general way, the Galar Subzone roughly corresponds (in the distal part) to the Sot de Chera marl Formation. Furthermore, ammonite successions at this point are underlined by the changes recorded in the bivalve recorded assemblages.

The evolutionary succession of Ataxioceratinae during the late Oxfordian-earliest Kimmeridgian is being slowly completed by the recognition of successive forms of the *Orthosphinctes-Planites* lineage. At this point the

successions recorded in SE France and Iberian range, appear of utmost importance to reconstruct this evolutionary lineage. Although Iberian successions are quite not as complete or diversified as to be proposed as GSSP for this stage boundary, some sections as Ricla, Tosos, Moneva or Ariño (Sierra de Arcos) could form excellent reference sections for Southwest Europe, and the sections of the Calanda-Alcorisa area would be excellent reference sections for the early Kimmeridgian (Platynota to Acanthicum biozones) in this part of western Tethys.

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