

Ostracod biostratigraphy in the Lower Cretaceous of the Iberian chain (eastern Spain)

Bioestratigrafía de ostrácodos en el Cretácico Inferior de la Cordillera Ibérica (este de España)

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Abstract

Lower Cretaceous ostracod associations (marine and nonmarine) have been studied from 34 sections of the Iberian chain or, geologically spoken, the Iberian basin (eastern Spain), in order to contribute to the chronostratigraphic correlation of the various predominantly nonmarine lithostratigraphic units in the Cameros, Maestrazgo, and South Iberian sub-basins (and the Central Iberian high in between). We have combined 87 ostracod species from 22 genera to 11 associations, each typical for certain stratigraphic levels (mostly stages) and ecologies. Nonmarine associations (dominated by the genera *Cypridea* and *Theriosynoecum*) prevailed from the Berriasian to the Barremian interval, whereas marine-brackish associations (much more diverse on the generic level) prevailed during the Aptian and Albian, and to a lesser extent during the Berriasian and Barremian. In most cases, our new ostracod data are consistent with previous correlative charts, as based upon other biostratigraphic data, mainly from charophytes, but also from few marine fossils in marine intercalations, and on depositional sequence stratigraphy. But in a few cases, our results are more or less different from those of established charts, namely in the eastern Cameros sub-basin (the Urbión group considered Late Berriasian in age instead of Valanginian-Barremian, and the Enciso group considered Late Valanginian-Barremian instead of Late Barremian-Aptian), in the northeastern Maestrazgo sub-basin (the Polacos Formation considered Late Berriasian-Early Hauterivian instead of Late Berriasian only), and in the uppermost part of the Lower Cretaceous in the South Iberian sub-basin (the Contreras and El Caroig Formations considered Albian instead of Aptian). Finally, we evaluate the usability of ostracod biostratigraphy in the Lower Cretaceous of eastern Spain and conclude that, if treated with great care especially under consideration of the biogeography and reproduction/dispersal strategies of the various groups, it should be given priority over pure lithostratigraphic correlations in conflicting cases.

Keywords: Ostracoda, biostratigraphy, Lower Cretaceous, eastern Spain.

Resumen

Las asociaciones de ostrácodos del Cretácico Inferior (marino y no marino) han sido estudiadas en 34 secciones de la cadena Ibérica, o en términos geológicos, la cuenca Ibérica (este de España) con el fin de contribuir a la correlación cronoestratigráfica de las variadas unidades, predominantemente no marinas, de las subcuencas de Cameros, Maestrazgo y Suribéricas (así como el alto Centroibérico intermedio). Hemos descrito 87 especies de ostrácodos pertenecientes a 22 géneros e incluidos en 11 asociaciones, cada una de ellas características de un determinado nivel estratigráfico (pisos sobre todo) y con una paleoecología concreta. Las asociaciones no marinas (dominadas por los géneros *Cypridea* y *Theriosynoecum*) prevalecieron desde el Berriasiense hasta el Barremiense, mientras que las asociaciones marinas-estuarinas (mucho más diversificadas a nivel genérico) se desarrollaron durante el Aptiense y Albiense, y en un grado menor, durante el Berriasiense y Barremiense. En la mayoría de los casos, nuestros nuevos datos de los ostrácodos son consistentes con los esquemas de correlación previos, basados en otros datos bioestratigráficos, sobre todo en charofitas, aunque también en los pocos fósiles presentes en las intercalaciones marinas, así como en la estratigrafía secuencial. Sin embargo, en algunos casos nuestros resultados son más o menos diferentes de los esquemas establecidos, sobre todo para la subcuenca oriental de Cameros (el Grupo Urbión es considerado de edad Valanginiense Superior-Barremiense, en lugar de Barremiense Superior-Aptiense), en la subcuenca nordoriental del Maestrazgo (la Formación Polacos es considerada Berriasiense Superior-Hauteriviense Inferior, en lugar de solo Berriasiense Superior) y en la parte superior del Cretácico Inferior en la subcuenca Suribérica (las Formaciones Contreras y El Caroig son consideradas del Albiense en lugar del Aptiense). Finalmente evaluamos la utilidad de la bioestratigrafía basada en los ostrácodos en el Cretácico Inferior del este de España y concluimos en que, si se trata con cuidado y se toma en consideración la biogeografía y las estrategias de reproducción/dispersión de los diferentes grupos, en caso de conflicto se debería dar prioridad a la bioestratigrafía de ostrácodos sobre las correlaciones puramente litoestratigráficas.

Palabras clave: Ostracoda, bioestratigrafía, Cretácico Inferior, este de España..

1. Introduction

In many parts of middle and western Europe, the Lower Cretaceous (at least the more basal parts) is composed of nonmarine deposits, which interfinger with marine sediments to a certain (and various) extent. Such terms as “Wealden” (“Wealdien”, “Wealdico) for these nonmarine lower Cretaceous strata originally derived from the typus area in southern England, but are nowadays replaced by various new and more local formation names, typical for the different areas such as Northern Germany, Spain, and others.

One essential problem remaining is the stratigraphy and correlation within these strata, as significant marine guide fossils are mostly lacking. Therefore, nonmarine ostracods, spores and pollen and members of the charophyte family Clavatoraceae are particularly useful for biostratigraphic correlation.

This paper presents some results of a research project which focuses on the biostratigraphy, biogeography and evolution of nonmarine ostracod faunas on both sides of the Proto-North-Atlantic diverging during the Early Cretaceous. For this purpose (and others demanded from neighbouring disciplines), a well founded biostratigraphy of the various nonmarine formations of the Lower Cretaceous is crucial. The state of knowledge, however, is rather problematic: Ostracod sequences and lineages from these “Wealden” or “Bückeberg” formations in England and NW-Germany are well investigated, but the analysis of faunal associations, for instance, in Spain is

still rather fragmentary. Non-marine formations, to some extent of some thousands of meters in thickness (“Wealden, Purbeck, Utrillas”), are widespread throughout the former rifting basins, now forming the Iberian chain.

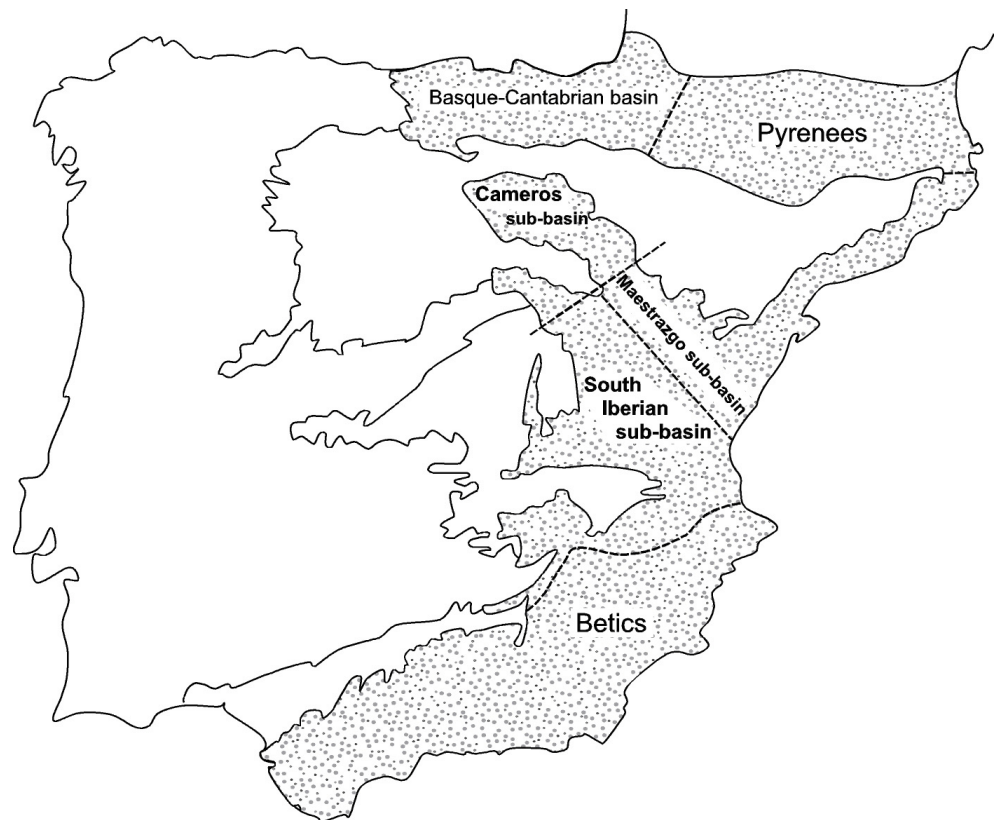
The ostracod faunas from 34 sections in the Iberian chain (or – geologically spoken – the Iberian basin, Figs. 1, 2) were systematically reviewed and described in three accompanying papers (Schudack, U., in review; submitted a; submitted b). This paper focuses on the biostratigraphic conclusions derived from the ostracod occurrences, partly approving, partly enhancing, but also partly contradicting previous age determinations of the various formations in the Lower Cretaceous of Northern and Eastern Spain.

2. Geology

The area of investigation comprises the Iberian chain (incl. Maestrazgo and Serrania de Cuenca). Geologically spoken, these areas form the Iberian basin, a tectonic structure subdivided into the Cameros, Maestrazgo, and South Iberian sub-basins (Fig. 1). Each sub-basin contains a sequence of highly variable Lower Cretaceous formations, of various thicknesses and depositional ecologies, but mostly nonmarine (Salas *et al.*, 2001; Martín-Chivelet *et al.*, 2002). Among the six Early Cretaceous stages (see figures 3-8), the Berriasian, Barremian, Aptian, and Albian are documented most completely, whereas the Valanginian and Hauterivian often (but not always) are represented by a stratigraphic gap within the successions.

Fig. 1. - Main tectogenetic areas with Cretaceous sedimentation in Spain (names according to Salas *et al.*, 2001 and Martín-Chivelet *et al.*, 2002). The material presented in this paper originates from the Cameros, Maestrazgo, and South Iberian sub-basins, the three parts of the Iberian basin (or – geographically spoken – Iberian chain). The nonmarine ostracods from the Basque-Cantabrian basin, the Pyrenees, and the Betic Cordilleras are not sufficiently known to be considered in this paper.

Fig. 1.- Áreas tectogenéticas principales con sedimentación cretácica en España (nombres según Salas *et al.*, 2001 y Martín-Chivelet *et al.*, 2002). El material presentado en este artículo procede de los Cameros, Maestrazgo y subcuencas Suribéricas, las tres partes de la cuenca Ibérica (o, en términos geológicos, la Cadena Ibérica). Los ostrácodos no marinos de la cuenca Vasco-Cantábrica, los Pirineos y las Cordilleras Béticas no son suficientemente bien conocidos para ser considerados en este trabajo.



A fourth investigation area (the “Central Iberian chain” in the borderland between the Cameros and Maestrazgo sub-basins, a term also used by various previous authors, area 2 on Fig. 2) was separated during our investigations, with reduced thicknesses and even more incomplete sedimentary sequences as compared to the three other sub-basins with their mostly more complete and thick sedimentary successions (Fig. 1, and nos.1,3,4 on Fig. 2). On the palaeogeographic maps in Salas *et al.* (2001), this area in fact shows no sedimentation during most of the Valanginian and Hauterivian, but – for instance – a separated non-marine basin during the Late Hauterivian and Early Barremian, and thus an individual (and topographically more high) development as compared to the other three basins (or: sub-basins) at issue (Fig. 2).

The basins examined here are part of the “Mesozoic Iberian Rift System” and contain thick sedimentary sequences of Permian and Mesozoic age, mostly continental and shallow marine clastics and carbonates, and less evaporates (Salas *et al.*, 2001). Extreme lateral variations of their thicknesses (from less than 1000 up to about 6000 meters, partly over distances of only few kilometres) clearly indicate the strong tectonic control on these basins (and their sedimentary development).

The overall evolution of the area was influenced by long-term cycles of rifting and relative tectonic inactivity: 1) the Late Permian-Triassic rifting cycle, 2) the Early-Middle Jurassic post-rift stage, 3) the Late Jurassic-Early Cretaceous rifting cycle, and 4) the Late Cretaceous post-rift stage (Salas *et al.*, 2001).

The Lower Cretaceous sediments of the second rifting cycle (or rather – their ostracod biostratigraphy) are the topic of the present paper. During this interval of time, the three sub-basins evolved within the Iberian basin (Figs. 1 and 2). Their isolated positions, and the large distance of the Cameros sub-basin (and – to a lesser extent – the South Iberian sub-basin) from the open-marine Tethys complicate the correlation and chronostratigraphic classification of the lithostratigraphic units within and between these basins.

3. Materials and methods

34 sections of the four investigation areas (see their names and position in Fig. 2 and its caption) yielded a rich ostracod fauna (87 species from 22 genera, described in Schudack, U., in review, submitted a, submitted b). Nonmarine formations yielding *Cypridea* (and other, but

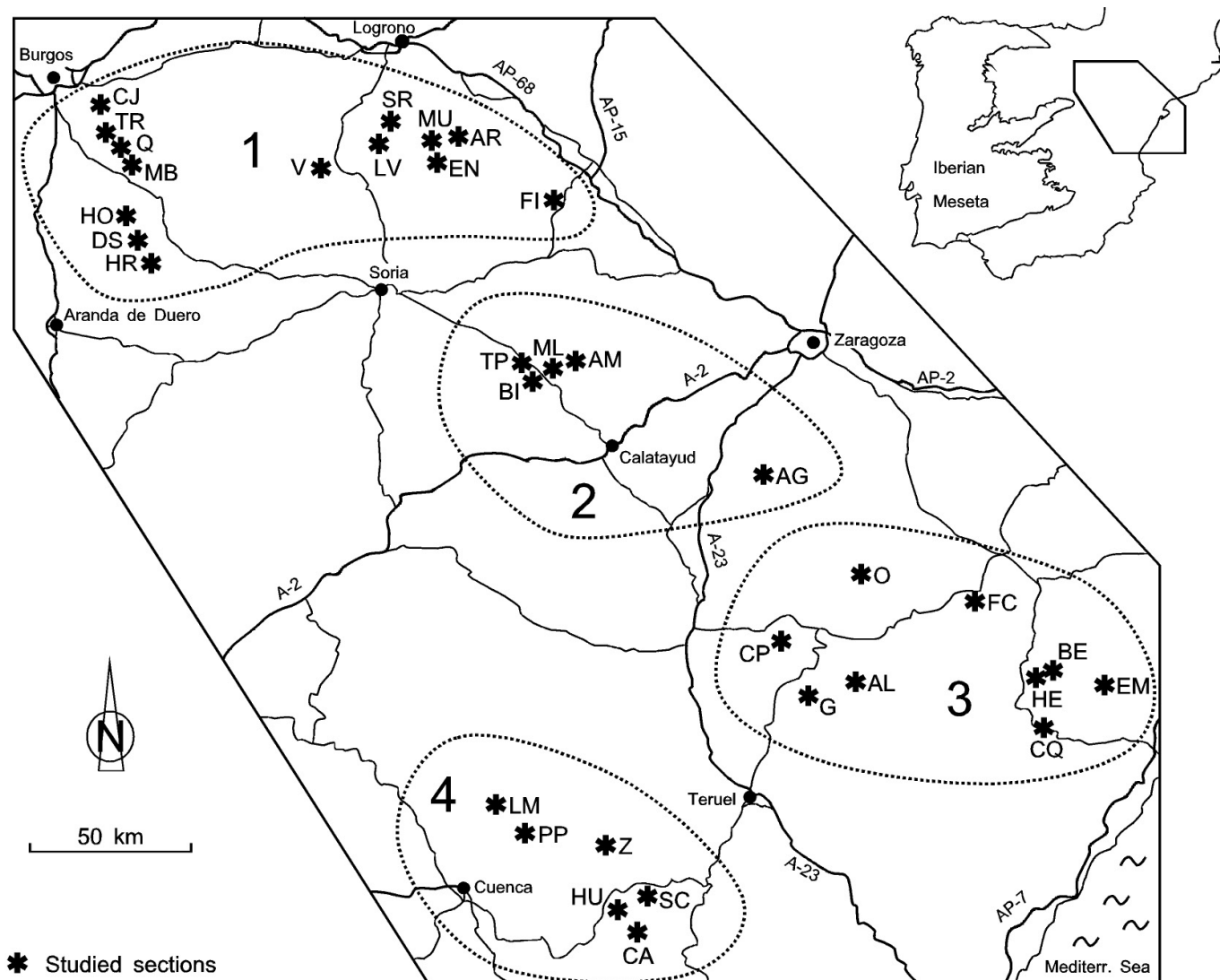


Fig. 2. - Location of the 34 investigated sections, as grouped into 4 individual areas each comprising an individual tectonic and sedimentologic history.

(1) Cameros sub-basin: CJ = Cueva de Juarros, TR = Torrelara, Q = Quintanilla de las Viñas, MB = Mambrillas de Lara, HO = Hortezuolos, DS = Doña Santos, HR = Huerta del Rey, V = Villoslada, SR = San Roman de Cameros, LV = Leza Valley, MU = Munilla, EN = Enciso, AR = Arnedillo, FI = Fitero. (2) Central Iberian chain: TP = Torrelapaja, ML = Malanquilla, BI = Bijuesca, AM = Aranda de Moncayo, AG = Aguilón. (3) Maestrazgo sub-basin: O = Oliete, FC = Foz de Calanda, CP = Cuevas de Portalrubio, G = Galve, AL = Aliaga. HE = Herbers, BE = Barranc de l'Escresola, EM = El Mangraners, CQ = Coll de Querol. (4) South Iberian sub-basin: LM = Las Majadas, Z = Zafrilla, PP = Pié Pajaron, HU = Huérquina, CA = Campillos-Paravientos, SC = Salvacañete.

Fig. 2.- Localización de las 34 secciones investigadas, agrupadas en 4 áreas individualizadas, incluyendo en cada una su historia tectónica y sedimentaria.

(1) subcuenca de Cameros: CJ = Cueva de Juarros, TR = Torrelara, Q = Quintanilla de las Viñas, MB = Mambrillas de Lara, HO = Hortezuolos, DS = Doña Santos, HR = Huerta del Rey, V = Villoslada, SR = San Roman de Cameros, LV = Valle de Leza, MU = Munilla, EN = Enciso, AR = Arnedillo, FI = Fitero. (2) Cadena Ibérica Central: TP = Torrelapaja, ML = Malanquilla, BI = Bijuesca, AM = Aranda de Moncayo, AG = Aguilón. (3) subcuenca del Maestrazgo: O = Oliete, FC = Foz de Calanda, CP = Cuevas de Portalrubio, G = Galve, AL = Aliaga. HE = Herbers, BE = Barranc de l'Escresola, EM = El Mangraners, CQ = Coll de Querol. (4) subcuenca Suribérica: LM = Las Majadas, Z = Zafrilla, PP = Pié Pajaron, HU = Huérquina, CA = Campillos-Paravientos, SC = Salvacañete.

less diverse nonmarine ostracod genera such as *Therionocum*, *Darwinula*, etc.) are most widespread in the more isolated Cameros sub-basin, where these conditions prevailed almost throughout the complete Early Creta-

ceous. In the other areas, more opened to the Tethys, most nonmarine formations are from the Berriasian-Barremian (with more or less brackish or marine intercalations and influences), whereas the Aptian-Albian is often brack-

ish-marine or marine (with *Cytherelloidea*, *Matronella*, *Cythereis*, and other marine genera, but no *Cypridea* findings). For a complete list of the genera and species – see appendage.

We investigated (or re-investigated) a total number of 285 samples, mostly from a field campaign into the Maestrazgo and Southern Iberian sub-basins (3 and 4 on Fig. 2) in October 2005, but also from previous own field works in the course of research projects focussing other questions. In addition, we worked on materials from Spanish and German colleagues: C. Martín-Closas (Barcelona), B. Krebs († Berlin), O.F. Geyer († Stuttgart), J. Kriwet (Stuttgart), F. Kneuper-Haack (Saarbrücken) and C. Peropadre (Madrid).

Most of the correlations presented here are based on species of the freshwater genus *Cypridea* (44 species overall, stratigraphic ranges – as possible - summarized in Fig. 3, names in appendage, descriptions in Schudack, U., submitted a). In addition, species from other genera were used, but these were mostly useful for the stratigraphic correlation of brackish or marine strata (43 species overall, stratigraphic ranges – as possible - summarized in Fig. 4, names in appendage, descriptions in Schudack, U., submitted b). In elaborating the new (or confirmed) stratigraphic data presented here, the following sequence of reasoning was applied:

First priority for chronostratigraphic classification (i.e. one of the six stages of the Lower Cretaceous or parts of them) of one sample and thus the lithostratigraphic formation or member was given to ostracod species which also occur in one of the so far better correlated “Wealden” basins such as Southern England (Anderson, 1967; 1971; 1985; Horne, 1995) and Northwest Germany (Martin, 1940; Wolburg, 1959; Schudack, U., 1994; Elstner and Mutterlose, 1997; and others). For brackish or marine species (mostly in the Aptian or Albian strata), a larger variety of papers (listed in Schudack, U., submitted b) was used. Hoedemaeker and Hengreen (2003) presented a detailed correlation chart, comparing the Tethyan Berriasian to Barremian successions of Spain and France with the boreal strata of England, Germany and the Netherlands, which is a well-funded basis and essential for our analysis. For more details about the most important *Cypridea* index species see Schudack, U. (submitted a).

Second priority was given to non-ostracod biostratigraphic or other stratigraphic information about the age of the formations at issue from other sources, such as charophytes (for instance Schudack, M., 1987; Martín-Closas, 1989; 2000; Martín-Closas and Salas, 1994; 1998), spores and pollen (for instance Peyrot *et al.*, 2007), or sequence stratigraphy (depositional sequences and un-

conformities of Salas *et al.*, 2001). In many cases, these ages agree with our ostracod correlations, in a few other cases there are – more or less - strong discrepancies (see below in detail).

Third (and last) priority was given to the occurrences of ostracod species which were previously only found in other Spanish basins, for instance by Kneuper-Haack (1966), Jordan and Bless (1971), Brenner (1976), Solomon (1982) or Schudack, U. (1984). Provided that – as is the case for many of these species – it was only described from one isolated basin, its true stratigraphic ranges must be considered insufficiently known, and therefore such species should only carefully be used as biostratigraphic markers in other basins.

4. Stratigraphic ranges of the ostracod species

Most of the biostratigraphic correlations in this paper were based on species of the genus *Cypridea* (Fig. 3). 40 species were considered stratigraphically useful, but only very few of them comprise truly short chronostratigraphic ranges (i.e. just one stage or even half of it, mostly in the Berriasian and Lower Valanginian, see Fig. 3). Instead, most *Cypridea* species provide ranges of 2 or even 3 stages, which is in many cases the Hauterivian and Barremian. Therefore, assemblages of different species (also from other genera, see Fig. 4) are crucial for ostracod biostratigraphy in these basins.

Among the non-Cypridean ostracods from the Lower Cretaceous of eastern Spain (Fig. 4), many species and genera were adapted to brackish-marine (*Eocytheropteron*, *Fabanella*, *Mantelliana*, and *Macrodentina*) or truly marine waters (*Asciocythere*, *Centrocythere*, *Cythereis*, *Cytherella*, *Cytherelloidea*, *Haplocytheridea*, *Matronella*, *Paranotocythere*, *Platycythereis*, *Protocythere*, and *Schuleridea*). In consequence, these occur only rarely in most of the basins, but can be used for biostratigraphic correlation of marine intercalations. Nonmarine (i.e. fresh or only slightly brackish water) genera are – besides *Cypridea*, see Fig. 3) – *Cetacella*, *Darwinula*, *Klieana*, *Rhinocypris*, *Scabriculocypris*, and *Theriosynoecum*. Among the latter, species of the genus *Theriosynoecum* (10 overall) are most useful for biostratigraphy in the nonmarine formations.

Figure 4, as compared to Figure 3, clearly indicates that many non-Cypridean species provide much shorter stratigraphic ranges than most of the *Cypridea* species (Fig. 3). However, this fact refers mostly to the brackish-marine taxa, and also mostly to the various Aptian and Albian formations, which are often marine in origin. Moreover, most of these species occur only rarely, whereas many

Species of <i>Cypridea</i>	Berriasian		Valanginian		Hauterivian		Barremian		Aptian		Albian	
	L	U	L	U	L	U	L	U	L	U	L	U
<i>Cypridea granulosa</i>	—	—										
<i>Cypridea dunkeri carinata</i>	—	—										
<i>Cypridea tumescens tumescens</i>	—	—										
<i>Cypridea tumescens praecursor</i>	—	—										
<i>Cypridea sp. A</i>	—	—										
<i>Cypridea pulchra</i>	—	—										
<i>Cypridea sp. 9</i>	—	—										
<i>Cypridea sp. 2</i>	—	—										
<i>Cypridea sp. 3</i>	—	—										
<i>Cypridea vidrana</i>	—	—										
<i>Cypridea aff. parallela</i>	—	—	—	—								
<i>Cypridea dolabrata</i>	—	—	—	—								
<i>Cypridea brevirostrata</i>	—	—	—	—								
<i>Cypridea soriana</i>	—	—	—	—								
<i>Cypridea cf. aculeata</i>	—	—	—	—								
<i>Cypridea laevigata var. laevigata</i>	—	—	—	—								
<i>Cypridea bispinosa</i>	—	—	—	—								
<i>Cypridea tuberculata</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea aff. alta</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea aff. valdensis</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea piedmonti</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea modesta</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea alcaramae</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea isasae</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea aff. alta wicki</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea sp. 1</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea demandae</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea brendae</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea turgida</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea aragonensis</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea cidacosia</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea cornuta</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea clavata</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea procera</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea sp. 10</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea sp. B</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea sp. C</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea sp. 8</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea pseudomarina</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cypridea ventriosa</i>	—	—	—	—	—	—	—	—	—	—	—	—

Fig. 3. - Stratigraphic ranges of 40 *Cypridea* species in eastern Spain. 4 species (*Cypridea* sp. 4-7, see appendage and Schudack, U., submitted a) with doubtful stratigraphic ranges are not listed here.

Fig. 3.- Rangos estratigráficos de 40 especies de *Cypridea* en el este de España. Cuatro especies (*Cypridea* sp. 4-7, ver apéndice y Schudack, U., enviado a) con rangos estratigráficos dudosos, no han sido incluidos en esta lista.

Cypridea species (Fig. 3) are widespread over several basins and abundant in many samples.

5. Lower Cretaceous stratigraphy of the four areas based upon our new biostratigraphic results

Due to their individual evolution and lithostratigraphic units, each of the four areas of investigation (Fig. 2) will be discussed here separately, both concerning their research history / state of knowledge and new stratigraphic results.

For detailed descriptions of the tectonic, sedimentologic and palaeogeographic evolution of these areas (and more references) see Martín-Chivelet *et al.* (2002) and Salas *et al.* (2001).

5.1. Cameros sub-basin (area 1 in Fig. 2)

This is a basin predominantly filled with alluvial and lacustrine deposits, and with only rare marine incursions. Its depocenters (often with very high thicknesses of sev-

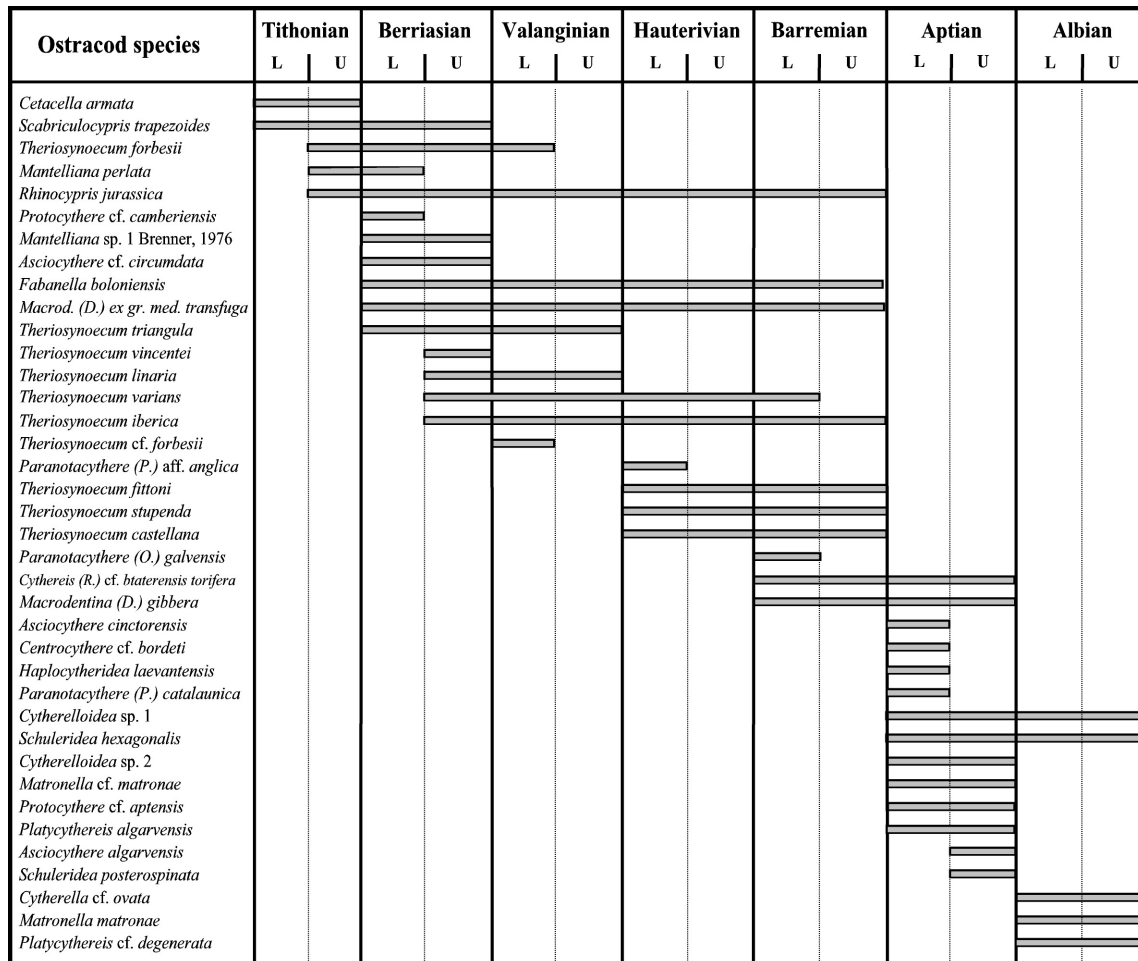


Fig. 4. - Stratigraphic ranges of 38 stratigraphically useful non-Cypridean ostracod species in eastern Spain. 5 long-ranging genera with no specific determinations (see appendage) are not listed here.

Fig. 4.- Rangos estratigráficos de 38 especies de ostrácodos no-Cypridea con utilidad estratigráfica en el este de España. Cinco géneros de amplio rango temporal sin determinaciones específicas (ver apéndice) no han sido incluidos.

eral thousand meters) migrated progressively northwards (Salas *et al.*, 2001), a fact, which already became evident during the studies of Beuther (1966), Tischer (1966) and Salomon (1982) some decades ago. Beuther (1966) subdivided the “Wealden” layers of the western Cameros into the Tera and Urbión groups, whereas Tischer (1996) was able to split the succession into five groups (Tera, Oncala, Urbión, Enciso, and Oliván). These five names for the main lithostratigraphic units are still used today by modern authors (Salas *et al.*, 2001; among others), though in combination with other lithostratigraphic terminologies. Being a member of the same working group as Beuther and Tischer, Kneuper-Haack (1966) carried out a first examination of the Cameros “Wealden” ostracods, leading to too old chronostratigraphic correlations for most of the lithostratigraphic groups (Kimmeridgian and Tithonian for the Tera and Oncala groups, Berriasian for the Urbión group, and Valanginian for the Enciso and Oliván groups). The main reason for these obviously wrong age determinations is that the studies of Kneuper-Haack (op.

cit.) were carried out prior to the publication of the most important papers about the “Wealden” ostracod faunas from England and Germany, and the publication of the manuscript had a delay of more than 5 years. Therefore she compared her findings only with insufficiently known faunas from the “Wealden” (now Bückeberg Fm.) of Germany, which is only Berriasian and Lower Valanginian in age.

More than one decade later, Brenner (1976), using the group names described by Beuther and Tischer (op. cit.), examined a number of ostracod samples from isolated localities. However, on the basis of important papers on the ostracod biostratigraphy of the English “Wealden” (Anderson, 1967; 1971), which were not yet available to Kneuper-Haack (1966), he was able to elaborate some age determinations which were much closer to our actual knowledge (though still including some strong differences). For instance, he dated the Tera group in the western Cameros as Berriasian, and the Enciso group in the eastern Cameros as Hauterivian-Barremian, both geo-

logically much younger times than suggested by Kneuper-Haack (1966).

On the contrary, Salomon (1982) proposed a very different subdivision for the nonmarine Upper Jurassic – Lower Cretaceous of the Cameros sub-basin, based upon the concept of tectonic-sedimentologic sequences (megasequences I, II, III, IV and several sub-sequences). Though his stratigraphic concept appears quite modern, some of the ostracod and charophyte biostratigraphic data he applied (for instance from *Theriosynoecum fittoni*) can not be accepted by the present authors. In summary, he suggested – similar to Kneuper-Haack (1966) – too old ages for most of his sequences.

Schudack, M. (1987) then presented several new biostratigraphic data for the Beuther and Tischer (op. cit.) groups (Tera, etc.), mostly based upon charophytes, but also upon a few new ostracod data. Here, many ages are yet younger than previously supposed, for instance a Barremian age for the Urbión group in the western Cameros. The oldest “Wealden” deposits are thought to be the basal Tera beds in the eastern Cameros (Upper Kimmeridgian). However, these data are only punctual, not spanning complete parts of the series. Many questions remained open.

For a summary of the “older” subdivisions and age determinations of the “Cameros Wealden” (including figures comparing them) prior to 1993, see Schudack, M. (1987) and Martín-Closas and Alonso (1998).

Cameros sub-basin stratigraphy then stepped into a new era. Several authors published subdivisions of these predominantly nonmarine successions based upon unconformity-bounded main depositional sequences. In particular: Mas *et al.* (1993), with their six sequences which are thought to correlate with the J10 to K1.10 sequences of the marine Mediterranean basins. Biostratigraphic data were no longer considered of primary importance, though still providing many important and useful data. Unquestionably, such an interdisciplinary approach is the only solution for a refined stratigraphy within such basins with their problematic biostratigraphy.

Nevertheless, new biostratigraphic studies are still necessary, because pure sequence stratigraphic correlations are not sufficient. The hitherto most important paper on Cameros sub-basin biostratigraphy was the one by Martín-Closas and Alonso (1998) about the charophyte biostratigraphy for its western part. Charophytes are much more abundant in the western Cameros than in its eastern part, a fact which is similar (but not quite the same) for ostracods (at least for stratigraphically important taxa). These authors were able to establish a refined charophyte biostratigraphy for the three older depositional sequences (Tithonian-Barremian) and correlated them with the established western European charophyte biozonation pro-

posed by Martín-Closas and Schudack, M. (1996), thus providing important new data for their chronostratigraphic correlation. However, their depositional sequences IV and V (there are only five sequences in the western Cameros, the second one of the eastern Cameros – K1.1, see below - is missing here) are still undated, due to the lack of stratigraphically important microfossils. Moreover, Martín-Closas and Alonso (1998) also proposed a biostratigraphic model for the eastern Cameros, despite the scarcity of biostratigraphic data there, but based upon their western Cameros biostratigraphy and various lithostratigraphic and sequence stratigraphic correlations.

The totality of all these sequence-, tectono-, litho- and biostratigraphic data were combined to the now well-established stratigraphic chart of the Cameros sub-basin during the Late Jurassic – Early Cretaceous rifting stage, as published by Salas *et al.* (2001), Martín-Chivelet *et al.* (2002), and Mas *et al.* (2004), see Fig. 5. The succession is subdivided into six unconformity-bounded main depositional sequences, which are (data largely from Salas *et al.*, 2001):

(1) The Tithonian-Berriasian initial rift sequence (J10), mostly consisting of alluvial and lacustrine deposits, with a maximum thickness of 3000 meters in the eastern part of the basin, and resting on progressively older Jurassic strata towards the west (Mensink and Schudack, M., 1982).

(2) A Late Berriasian – Early Valanginian sequence (K1.1) which only exists in the easternmost part of the basin.

(3) The Valanginian-Hauterivian sequence (K1.2-K1.4) comprising various carbonate, mixed siliciclastic-carbonate and siliciclastic fluvial and lacustrine sediments, missing in the central part of the sub-basin.

(4) The (Late Hauterivian?)-Barremian sequence (K1.5-K1.6) displays two separated depocenters in the western and in the eastern part of the basin, beginning with fluvio-lacustrine (K1.5) and then characterized by fluvial deposits (K1.6).

(5) The Late Barremian-Early Aptian sequence (K1.7-K1.8), partly with high subsidence rates, high thicknesses of up to 1900 meters, clastic fluvial and lacustrine carbonate deposits, and a slight marine influence.

(6) The final Late Aptian-Middle Albian syn-rift sequence (K1.9-K1.10) with up to 1500 meters of alluvial clastics and rare lacustrine carbonates.

New biostratigraphic contributions from our ostracod studies

We studied new and restudied older ostracod faunas from 7 sections in the western and 7 sections in the east-

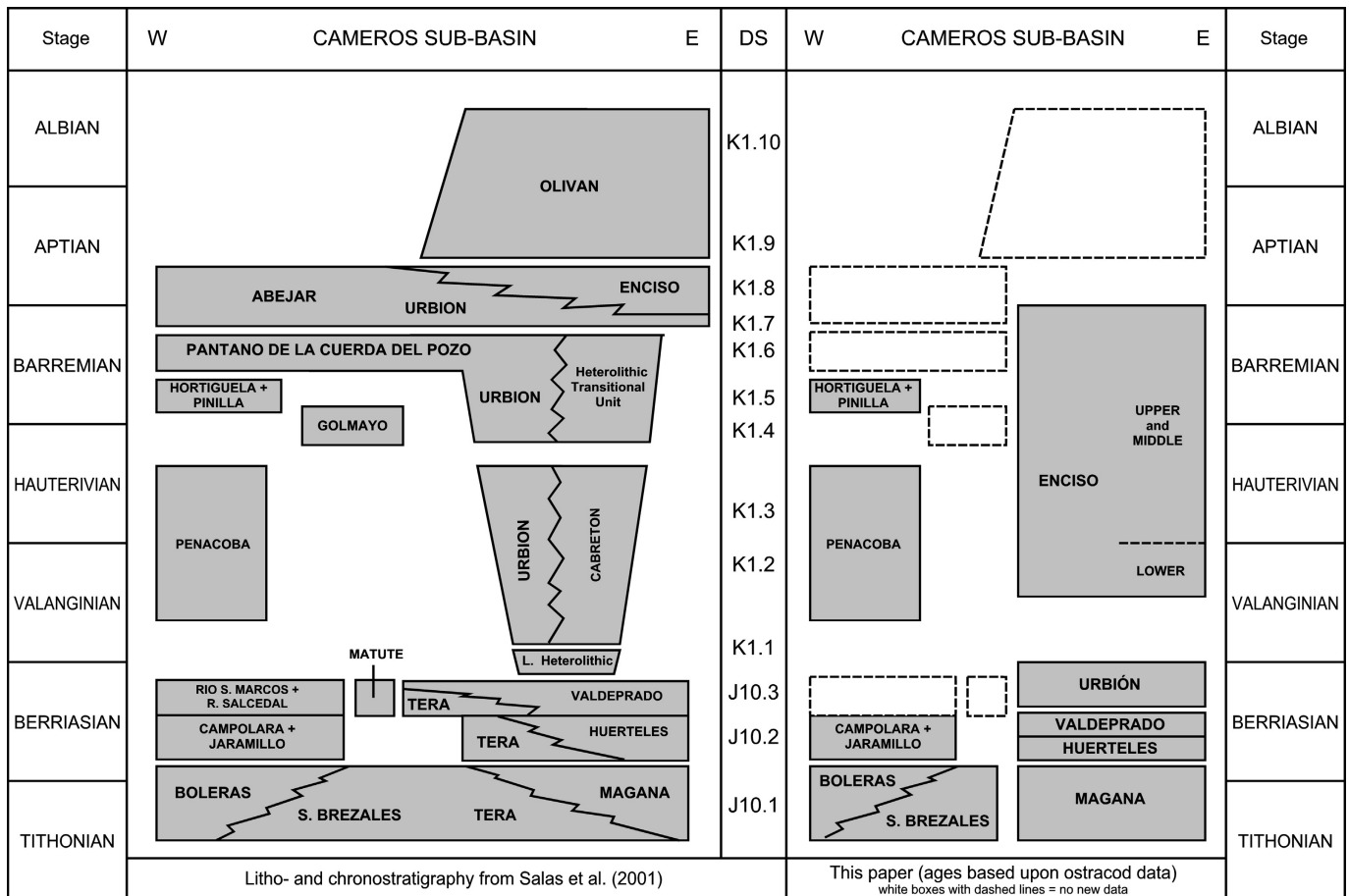


Fig. 5. - Left: Chrono-lithostratigraphic chart of the Cameros sub-basin during the Late Jurassic – Early Cretaceous rifting stage, with depositional sequences and lithostratigraphic units (formations). Simplified and based upon Salas *et al.* (2001). A similar chart was published by Mas *et al.* (2004). Right: Biostratigraphic correlations for several formations (in grey) based upon ostracods. There are no discrepancies for the western Cameros, but strong conflicts with previous chronostratigraphic views (see left part of the figure) for the eastern part of the sub-basin.

Fig. 5.- Izquierda: Cuadro cronoestratigráfico de la cuenca de los Cameros durante el estadio de rifting Jurásico Superior-Cretácico Inferior, con las secuencias deposicionales y las unidades litoestratigráficas (formaciones). Simplificado y basado en Salas *et al.*, (2001). Un cuadro similar fue publicado por Mas *et al.* (2004). Derecha: Correlaciones bioestratigráficas para algunas formaciones (en gris) basadas en los ostrácodos. No hay discrepancias para el oeste de Cameros, aunque si fuertes divergencias con planteamientos cronoestratigráficos previos (ver parte izquierda de la figura) para el sector oriental de la subcuenca.

ern Cameros (for names and position see Fig. 2). Similar to earlier studies (see above), biostratigraphic results were quite positive for the western part, but – at least in parts - rather inconsistent with current views (Salas *et al.*, 2001; Mas *et al.*, 2004) for the eastern part of the sub-basin (see Fig. 5).

The western Cameros sub-basin

The basal sub-sequence (J10.1, Boleras and S. Brezales Formations of the Tera group) yielded rare freshwater ostracods: *Cypridea* sp. A at Huerta del Rey and *Theriosynoecum forbesii* at Quintanilla. Both support a Berriasian (or Late Tithonian) age for this sub-sequence.

In the following sub-sequence (J10.2, Campolara and Jaramillo Formations of the Tera group), ostracods are much more frequent. Except for the Cueva de Juarros

section in the outermost northwest, all sections delivered a rich freshwater fauna with *Cypridea tuberculata*, *C. tumescens tumescens*, *C. tumescens praecursor*, *C. aff. parallela*, *C. aff. valdensis*, *C. dunkeri carinata*, *C. sp. 2*, *Theriosynoecum forbesii*, (?) *Klieana* sp., *Darwinula* sp., *Rhinocypris jurassica*, *Cetacella armata*, *Fabanella boloniensis*, and *Scabriculocypris trapezoides*. This association strongly supports the Berriasian age for the sub-sequence as proposed by previous authors.

The Peñacoba Formation (K1.2-K1.3, traditionally part of the Tera group) yielded ostracods in only one section, Quintanilla. Here, fresh (to brackish) water species *Fabanella boloniensis* and *Cypridea tuberculata* point to a Late Berriasian to Early Barremian age, which is in agreement with the Valanginian-Hauterivian age suggested so far.

In three sections (Cueva de Juarros, Mambrillas, and Huerta del Rey), the Hortiguera Formation of the Urbión group (K1.5) contains *Cypridea demandae*, *C. procera*, and *Theriosynoecum fittoni*, all Hauterivian-Barremian freshwater ostracod species. Both age and ecology are consistent with previous suggestions for this unit. The following sequences (K1.6-K1.10) yielded no ostracods.

Kneuper-Haack (1966) did not provide important data for this part of the Cameros, whereas Brenner (1976) published descriptions of several species from the Berriasian of Talveila, which proved to be erroneous and in fact Bathonian (and thus pre-“Wealden”) in age as given by Schudack, M. and Schudack, U. (1990).

The ostracod findings of Schudack, M. (1987) from the Quintanilla, Mambrillas, Huerta del Rey and Hortezeulos sections were incorporated into this paper (and mentioned above, but modified - mainly *Cypridea* species and subspecies).

To conclude: In the western part of the Cameros sub-basin, all old and new ostracod findings and determinations presented here (for the J10.1, J10.2, and K1.5 sub-sequences) are in consistency with, and a strong support for, the now widely accepted chronostratigraphic classifications (Fig. 5) by Martín-Closas and Alonso (1998) and Salas *et al.* (2001).

The eastern Cameros sub-basin

In this part of the sub-basin, general lithostratigraphy and biostratigraphy are much more complicated than in its western part. Stratigraphically useful microfossils are much less abundant (though ostracods – but biostratigraphically doubtful species – occur in almost rock-forming abundance in some layers), and the geometry of the lithostratigraphic units is really complicated.

Part of this study is a revision of the Kneuper-Haack (1966) ostracod fauna from the eastern Cameros sub-basin. Her material was given to us and is now part of our own collections (including the type material). Some of her new *Cypridea* and *Theriosynoecum* species (hitherto supposed to be endemic to the Cameros sub-basin) were attributed to already existing species, known from other basins of Europe (see Schudack, U., submitted a; submitted b), others are still considered valid species. The Kneuper-Haack (1966) material is therefore part of the conclusions presented here, but only as far as the species described in her paper were really identified in the material given to us – which was not always the case - or her figures and descriptions are sufficient to approve her determinations. Altogether, her old and our new ostracod findings allow the following conclusions:

The basal parts of the succession (J10.1, Tera group p.p. see Fig. 5) yielded only few *Cetacella armata* (Villoslada section), which – in the given lithostratigraphic context - approve a Tithonian age (and freshwater ecology) at least for this part of the section.

From the following unit (J10.2, Huerteles Formation, lower Oncala group), new findings of *Scabriculocypris trapezoides* (Terroba section, which is near San Roman, see Fig. 2) point to a Late Tithonian, Berriasian, or Early Valanginian age. Among the species listed by Kneuper-Haack (1966) from the lower part of the Oncala group (which were, however, not identified in her material and therefore not validated), *Fabanella boloniensis* would restrict the maximum age of the Huerteles Formation to the Berriasian (Fig. 5). In terms of ecology, the association points to a mixed fresh and brackish water environment.

The Valdeprado Formation (J10.3, upper Oncala group) provided considerably more ostracod species. The association of stratigraphically important species such as *Mantelliana perlata*, *Cypridea granulosa*, and *Macrodentina retirugata textilis* (the latter not identified in the Kneuper-Haack material, but sufficiently validated through her descriptions) from the Villoslada, San Roman (Terroba), Leza Valley, and Fitero sections strongly confirms the Berriasian age currently suggested for this depositional sub-sequence (Fig. 5). The range of ostracod genera (*Cypridea*, *Theriosynoecum*, *Klieana*, *Darwinula*, *Mantelliana*, *Macrodentina*, *Fabanella*) indicates mixed fresh and brackish water environments with some marine incursions for this formation.

The Urbión group of Tischer (1966) is subdivided into several units which range in age, according to Salas *et al.* (2001) and Mas *et al.* (2004), from the Valanginian (base) to the Aptian (top), or from K1.1 to K1.8 in terms of depositional sequences (Fig. 5). The lower main lithostratigraphic unit (Cabretón Formation, K1.2-K1.3), yielded a rich ostracod fauna with the stratigraphically important freshwater species *Cypridea laevigata* var. *laevigata*, *C. tuberculata*, and *C. tumescens tumescens* (all from Fitero section). According to this association, the Cabretón Formation should be Late Berriasian in age, which is in strong contrast to the views of Salas *et al.* (2001) and Mas *et al.* (2004): Valanginian-Hauterivian (see Fig. 5). Kneuper-Haack (1966) also mentioned a few *Theriosynoecum* and *Darwinula* species. Along with the many *Cypridea* findings and the total lack of brackish-marine ostracod genera, we assume a mere freshwater environment for the Cabretón Formation.

The upper part of the Urbión group (“clastic facies” of previous authors, Late Hauterivian to Early Aptian

according to Salas *et al.*, 2001, and Mas *et al.*, 2004, K1.4-K1.6), originated only few ostracods. *Cypridea tumescens tumescens* from Fitero as well as *C. laevigata* var. *laevigata* and *Theriosynoecum vincentei* from Leza Valley again point to a Late Berriasian age, which is even more in contrast to the above-mentioned age determinations (but – to underline this fact quite strongly – absolutely consistent for the two sections quite distant to each other, and based upon different species according to their independently pre-identified supraregional stratigraphic range). The ecology was similar – no indications for any brackish or marine influence, mere freshwater (*Cypridea*, *Theriosynoecum*, *Darwinula*).

By far the most ostracods from the Lower Cretaceous of the eastern Cameros sub-basin are from the Enciso group (K1.8). In one of its subunits, ostracods even occur in rock-forming abundance, which was already documented by the name “Fazies der ostrakodenreichen Mergel” (facies of ostracod-rich marls) as used by Tischer (1966) and subsequent authors. Kneuper-Haack (1966) was even able to elaborate a succession of four local *Cypridea* biozones (*encisiensis* – *demandae* – *cornuta* – *aragonensis*). A revision of the many species occurring here (our sections San Roman, Leza Valley, Munilla, Arnedillo, Enciso, and Fitero, see Fig. 2) revealed the following stratigraphically important taxa for the Enciso group:

Cypridea aragonensis, *C. clavata*, *C. cornuta*, *C. cidacosia*, *C. demandae*, *C. procera*, *C. turgida*, *Theriosynoecum castellana*, *Th. fittoni*, and *Th. stupenda* would allow an Hauterivian or Barremian age for the main parts of the unit (mostly the middle or upper part). *Cypridea piedmonti*, *C. modesta*, *C. alcaramae*, *C. isasae*, *C. tuberculata*, and *Theriosynoecum iberica* would allow a Valanginian, Hauterivian or Barremian age for the main parts of the unit (mostly the middle or upper part). Therefore, we suggest that the middle and upper parts of the Enciso group are Hauterivian-Barremian in age, most probably Barremian in its upper part, but not Aptian as suggested by Salas *et al.* (2001) and Mas *et al.* (2004).

The lower part of the unit is biostratigraphically more complicated and controversial. It comprises the hitherto Berriasian species *Cypridea vidrana* and *C. pulchra*, and the Berriasian-Valanginian species *Cypridea brevirostrata*, *C. bispinosa*, *C. soriana*, *Theriosynoecum triangula*, and *Th. linaria*. *C. vidrana* is problematic, because it is not endemic to Spain and also occurs in NW Germany, but in the Upper Berriasian exclusively. Assuming that the stratigraphic range of this species is more expanded in Spain than in NW Germany, and giving priority to the larger number of (non-endemic!) lower Enciso species

which would also allow a Valanginian age (*C. brevirostrata* and *C. bispinosa*), we prefer to propose a Valanginian age for the lower part of the Enciso group.

To summarize: The ostracod-based ages for the Enciso group presented here are substantially different from the established current views (Aptian age according to Salas *et al.*, 2001, and Mas *et al.*, 2004). We propose a Valanginian age for its lower part and an Hauterivian-Barremian age for its middle and upper part (Fig. 5). The ecology of the group is freshwater (*Cypridea* and *Theriosynoecum* in overwhelming abundance, and several *Darwinula*, but no brackish water or marine genera).

The uppermost group of the Cameros Lower Cretaceous sequence (Oliván group, K1.9-K1.10) yielded no ostracods (and also no charophytes), and thus no biostratigraphic data.

The chronostratigraphic correlation of the Enciso group (or at least its main parts) into the Hauterivian-Barremian (in contrast to its “original” age determination of Kneuper-Haack, 1966, as Valanginian) was first presented by Brenner (1976) on the basis of ostracod association comparisons with the Basco-Cantabrian basin and the Maestrazgo sub-basin (see Fig. 1) as well as some palaeographic considerations. These ages were supported by the investigations of Schudack, U. (1984) in a neighbouring area.

Schudack, M. (1987) presented a few more data, mainly based upon charophytes, but also on a few ostracods. In the northernmost part of the eastern Cameros, near Torrecilla en Cameros, he described *Cetacella striata* (and Kimmeridgian charophytes) in the basal Tera group, which points to a Late Kimmeridgian age (and Kimmeridgian charophytes) of its basal layers. The Oncala group of the same area (Terroba section, near San Roman, Fig. 2) yielded several Berriasian ostracods and charophytes. Its uppermost part (Valdeprado Formation of modern terminology, Fig. 5) is definitely Berriasian in age (*Globator maillardii nurrensis* charophyte zone of Martín-Closas and Schudack, M., 1996). New charophyte findings within the Enciso group again supported its Hauterivian-Barremian age supposed by Brenner (1976), more likely the Barremian (*Atopochara trivolvus triquetra* charophyte zone of Martín-Closas and Schudack, M., 1996). Moreover, Schudack, M. (1987) supported the Berriasian age for large parts of the Urbión group (in contrast to the views of Salas *et al.*, 2001, and Mas *et al.*, 2004), based upon his charophyte findings.

Some essential new data from charophytes were then presented by Martín-Closas (1989) in his thesis, published eleven years later (Martín-Closas, 2000). The Tera and Matute Formations (J10.1-J10.3) of the larger Soria

area (southernmost part of the eastern Cameros sub-basin) provided Tithonian-Berriasian charophyte floras. From the Golmayo Formation (K1.4) of the central Cameros sub-basin, he described Late Hauterivian to Early Barremian charophytes, and from Cervera del Rio Alhama (near Fitero), Late Berriasian charophytes from the lower part and Valanginian-Hauterivian charophytes from the upper part of the Cabretón Formation (lower Urbión group, K1.2-K1.3). His data are essential biostratigraphic bases for the chrono-lithostratigraphic charts of Salas *et al.* (2001) and Mas *et al.* (2004).

In summary: Our biostratigraphic results were summarized on Figure 5. For the three basal depositional sequences (J10.1-J10.3), the Tithonian-Berriasian ages, as generally accepted today, were confirmed. However, the rest of the sequence is much more critical. From the ostracod point of view (and also from the charophyte one, see Schudack, M., 1987), all parts of the Urbión group (depositional sequences K1.1-K1.6) were deposited during the Late Berriasian, which is in strong contrast to the concepts given by Salas *et al.* (2001) and others. Also for the Enciso group (K1.8), our chronostratigraphic correlations differ substantially from the accepted concepts: According to our data, the basal parts of this group were deposited during the (Late?) Valanginian, and the middle and upper parts during the Hauterivian-Barremian stages.

5.2. Central Iberian chain (area 2 in Fig. 2)

This is an area intermediate between the larger Cameros and Maestrazgo sub-basins of the Iberian chain (Figs. 1 and 2). As compared to these basins, thicknesses are often much lower, and the stratigraphic gaps larger (compare figures 5-7). Therefore, it constitutes an orographic high, though there are also some smaller local basins such as the Aguilón basin on it, and it also includes the southeastern prolongations of the Cameros sub-basin (areas around Bijuesca, Aranda de Moncayo, etc.). On the palaeogeographic maps for the latest Oxfordian up to the Middle Albian of Spain presented by Salas *et al.* (2001), and refigured by Martín-Chivelet *et al.* (2002), the area presents no sedimentation for large parts of the Early Cretaceous.

We investigated 5 sections from this area (see Fig. 2), one from the Aguilón basin (very southeast of the area), and 4 from the larger surroundings of Bijuesca (Aranda de Moncayo, Bijuesca, Malanquilla, and Torrelapaja). The Aguilón area was treated quite sufficiently in the literature (for instance Soria *et al.*, 1995), whereas the lower Cretaceous of the vicinity of Bijuesca was not

often studied so far. In the summarizing papers most relevant here, the area is not mentioned nor considered on the stratigraphic charts. Therefore, we still use the old lithostratigraphic names from Schudack, M. (1987), though these were not formally described.

In the Aguilón area (see left part of the chart on Fig. 6), there is a large stratigraphic gap between the marine Tithonian Higuereles Formation (lower J.10 depositional sequence) and the clastic continental Valanginian - Lower Hauterivian Villanueva de Huerva Formation (K1.2-K1.3 depositional sequences). The succession here is terminated by the Aguilón Formation (K1.4 depositional sequence), late Hauterivian - early Barremian in age and consisting of lacustrine limestones and marls. Chronostratigraphic correlations of these units are mostly from biostratigraphic data (charophytes, Soria *et al.*, 1995; Martín-Closas, 1989; 2000) and sequence stratigraphy (Salas *et al.*, 2001).

From the surroundings of Bijuesca, Torrelapaja, Malanquilla, and Aranda de Moncayo (see Fig. 2), Schudack, U. (1984), Schudack, M. (1987), and Martín-Closas (1989; 2000) studied microfossil assemblages (ostracods and charophytes) and carried out biostratigraphic correlations. The informal lithostratigraphic units introduced by Schudack, M. (1987) are: Bijuesca Formation (Upper Kimmeridgian - Tithonian), Ciria Formation (Berriasian - Lower Valanginian), and Torrelapaja Formation (Barremian), all based on ostracod and charophyte biostratigraphy. Martín-Closas (1989; 2000) then modified the ages of the Bijuesca (only Tithonian, no Kimmeridgian) and Torrelapaja Formations (latest Hauterivian - earliest Barremian) due to his evaluation of the Iberian charophyte biozonation. According to our knowledge, biostratigraphic correlations using other fossils or any sequence stratigraphic attempts (such as those figured in Salas *et al.*, 2001) were not yet carried out here.

New biostratigraphic contributions from our ostracod studies

From the Aguilón area, only the Aguilón Formation (K1.4 depositional sequence) yielded rich new ostracod faunas from several samples. With the exception of a few *Fabanella boloniensis* findings in its middle part (allowing more saline brackish water environments), all species are fresh- to only slightly brackish water ones: *Cypridea modesta*, *C. clavata*, *C. isasae*, *C. aff. valdensis*, *C. sp. 7*, and *Darwinula* sp. This association points to an Hauterivian to Early Barremian age for the formation and is therefore consistent with previous age determinations (Fig. 6).

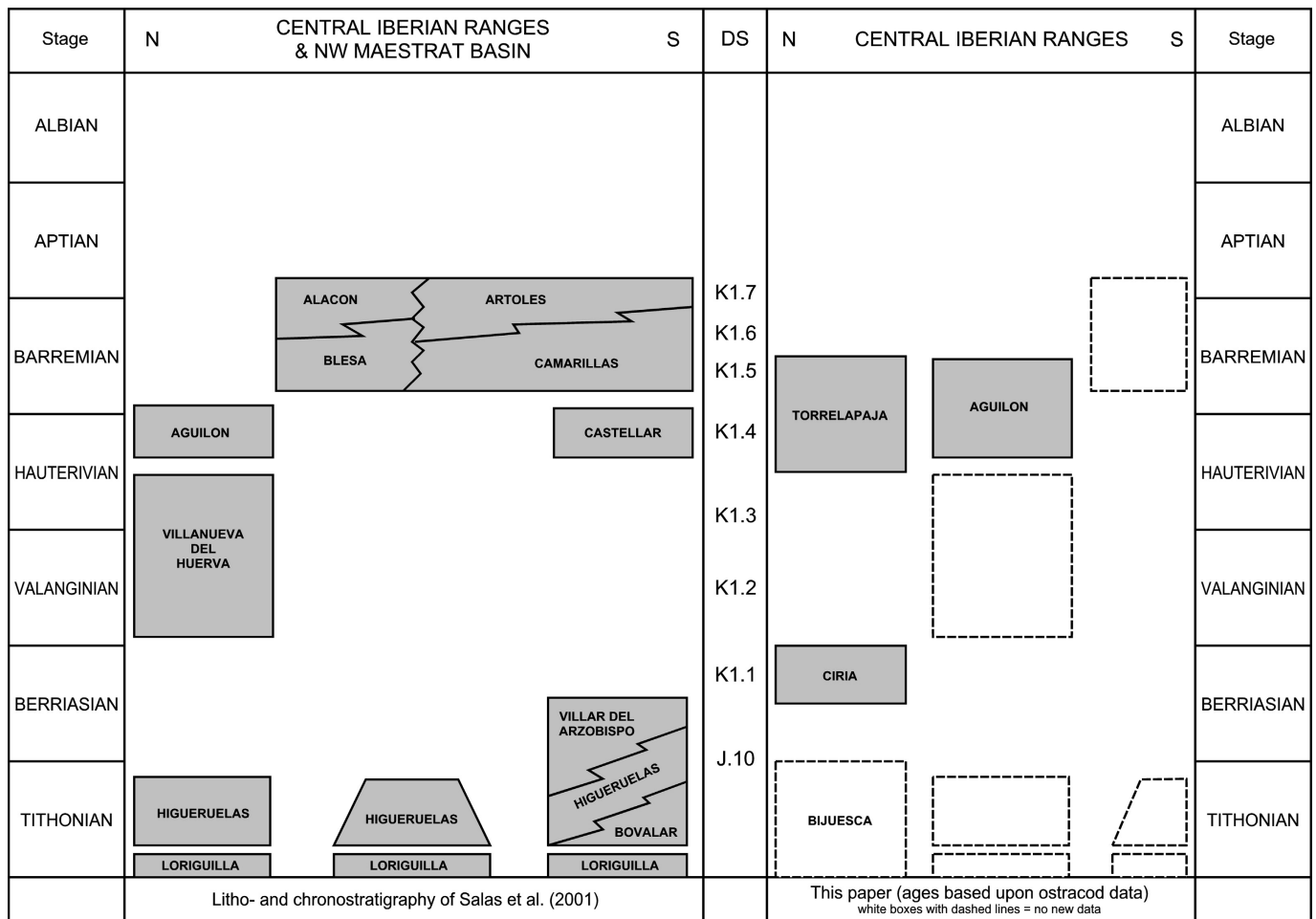


Fig. 6. - Left: Chrono-lithostratigraphic chart of the Central Iberian chain during the Late Jurassic – Early Cretaceous rifting stage, with depositional sequences and lithostratigraphic units (formations). Simplified and based upon Salas *et al.* (2001). Right: Biostratigraphic correlations for several formations (in grey) based upon ostracods. The left columns are new (Bijuesca area not considered in Salas *et al.*, 2001).

Fig. 6.- Izquierda: Cuadro cronoestratigráfico de la Cadena Ibérica Central durante el estadio de rifting del Jurásico Superior-Cretácico Inferior, con las secuencias deposicionales y las unidades litoestratigráficas (formaciones). Simplificado y basado en Salas *et al.*, (2001). Derecha: Correlaciones bioestratigráficas para algunas formaciones (en gris) basadas en los ostrácodos. Las columnas de la izquierda son nuevas (el área de Bijuesca no es considerada por Salas *et al.*, 2001).

In the Aranda-Bijuesca-Malanquilla-Torrelapaja area (4 sections, see Fig. 2), the palaeoecologic results are similar to Aguilón: the wealth of species (genera *Cypridea*, *Theriosynoecum*, and *Darwinula*) strongly point to freshwater (at the most slightly brackish water) environments, with only very few *Mantelliana* and *Fabanella* findings (brackish to marine waters).

The predominantly clastic Bijuesca Formation (J3.7 depositional sequence and Tithonian in age, as currently suggested) yielded no ostracods, but from the Ciria Formation (K1.1 depositional sequence and Berriasian in age according to previous age determinations) of Bijuesca and Malanquilla sections, we have a rich fauna containing *Cypridea tuberculata*, *C. tumescens tumescens*, *C. tumescens praecursor*, *C. bispinosa*, *C. aff. parallela*, *C. sp. 2*, *C. sp. 3*, *C. sp. 5*, *C. sp. 6*, *C. sp. 9*, *Theriosynoecum fittoni*, *Th. forbesii*, *Th. vincentei*, *Th. varians*, *Th. iberi-*

ca, *Mantelliana* sp. 1, and *Darwinula* sp. This association points to almost exclusively freshwater environments and a Late Berriasian age for the formation (at Malanquilla also allowing – but not verifying – a Valanginian age). Therefore, the Ciria Formation was deposited during Late Berriasian times.

In all four sections of the area, the Torrelapaja Formation (K1.4-K1.5 depositional sequences and Late Hauterivian – Early Barremian in age, as currently suggested, Fig. 6) yielded rich, again almost exclusively freshwater ostracod faunas: *Cypridea cidacosia*, *C. aragonensis*, *C. piedmonti*, *C. cornuata*, *C. tuberculata*, *C. isasae*, *C. demandae*, *C. turgida*, *C. aff. valdensis*, *C. aff. brevisrostrata*, *C. aff. alta wicki*, *C. sp. C*, *C. sp. 1 – sp. 5*, *Theriosynoecum iberica*, *Th. fittoni*, *Th. castellana*, *Th. linaria*, *Fabanella boloniensis*, *Mantelliana* sp., and *Darwinula* sp. This association indicates an Hauterivian to Early Bar-

remian age for the formation, thus corresponding with the currently suggested Late Hauterivian – Early Barremian age. The lowermost layers of Torrelapaja Formation near Aranda de Duero would also allow a Late Valanginian, but also an Hauterivian or Early Barremian age (*Theriosynoecum iberica*, *Cypridea tuberculata*, and *C. isasae*).

In summary: Our biostratigraphic results were summarized on Fig. 6. For the basal depositional sequence (J.10), we have no new stratigraphic results. However, the previously suggested ages for the Ciria (K1.1, Late Berriasian), Torrelapaja (K1.4-K1.5, Late Hauterivian – Early Barremian) and Aguilón (K1.4, Late Hauterivian) Formations are largely confirmed by our new ostracod data. Depositional environments for the three formations were almost exclusively freshwater. There are no new data for the Valanginian (K1.2-K1.3), Late Barremian (K1.6-K1.7) and Aptian-Albian (K1.8-K1.10) intervals.

5.3. Maestrazgo sub-basin (area 3 in Fig. 2)

In this sub-basin, syn-rift subsidence commenced already during the latest Oxfordian (Salas *et al.*, 2001). The depositional system here was – very different from the Cameros and other sub-basins – dominated by shallow marine carbonates, with deltaic clastics mainly in the Aptian and Albian (Salas *et al.*, 1995). The Jurassic depositional sequences (J.8-J.9) are exclusively marine, but during the Early Cretaceous, various nonmarine sediments were repeatedly intercalated.

The Tithonian-Berriasian depositional sequence J.10 (Talaies, Bovalar, and Pleta Formations, Fig. 7) shows a shallow platform with tidal flat deposits and oolitic/bioclastic shoal banks, passing seaward into open marine *Calpionella* carbonates (Martín-Closas and Salas, 1994). During the Berriasian-Valanginian sequences (K1.1-K1.2, Mora, En Siroll, El Mangraners, Polacos, and Bastida Formations), the marine influence is restricted to the center of the sub-basin, whereas there is considerable freshwater influence in other areas (op.cit.). The Hauterivian sequence (K1.3, Castellar, Gaita, Llacova, Avella and Herbers Formations) again shows a great variety of sediments, including marine and freshwater carbonates. Similar to the Valanginian (K1.2), deposition is mostly restricted to the center of the sub-basin, and large stratigraphic gaps between the Berriasian and the Barremian occur near the margins (Fig. 7). During the Late Hauterivian-Barremian (K1.4-K1.7, Artoles, Camarillas, and Cantaperdius Formations), sedimentation again occupied larger areas of the sub-basin, including shallow marine carbonate platforms with large fresh water discharges at their margins (Martín-Closas and Salas, 1994). Above

an important basinwide infra-Aptian unconformity, the earliest Aptian (lower part of K1.8, Cervera and Morella Formations) consists of deltaic sediments, partly rich in dinosaur remains (Salas *et al.*, 2001), whereas the main part of the Aptian (K1.8-K1.9) shows very extensive shallow marine carbonate platforms (Xert, Forcall, and Villaroya Formations, Fig. 7). Finally, the Early to Middle Albian sequence (K1.10) consists of a delta system with thick coal layers (Escucha Formation).

Chronostratigraphic correlations of these various units (as presented in Fig. 7) was mainly based upon (i) various biostratigraphic data from marine fossils (such as ammonites and foraminifera) from the many marine formations and intercalations within the succession (Fig. 7), as summarized for instance by Brenner (1976) and Martín-Closas and Salas (1998), (ii) biostratigraphic data from charophytes (clavatoracean lineages, see Martín-Closas, 1989; 2000; Martín-Closas and Salas, 1994; 1998; Martín-Closas and Schudack, M., 1996), and (iii) – last but not least – sequence stratigraphic correlations (for instance Salas *et al.*, 2001, and several other papers not to be listed here). In general, biostratigraphic correlations of the lithostratigraphic units from the Maestrazgo area are easier than – for instance – of those from the Cameros sub-basin due to their much more frequent marine units and intercalations, containing marine guide fossils. Among the nonmarine guide fossils, charophytes (clavatoracean taxa) are by far the most important for the Lower Cretaceous of the sub-basin.

On the contrary, spores and pollen were only rarely used so far. A few examples are the papers by Mohr (1987; 1989, indicating an Early Barremian age for the vertebrate-bearing layers near Galve, see also Schudack, M., 1989) or Peyrot *et al.* (2007, proposing a slightly older age – Late Aptian to Early Albian – for the Escucha Formation near Oliete; see also reference list for papers on the palynology for the Lower Cretaceous of Spain herein). Altogether, palynologists do not yet provide many important contributions to the chronostratigraphy of the Lower Cretaceous in the Maestrazgo sub-basin.

The same applies to the ostracodologists. Though several authors published ostracod data during the last decades, most of them are rather fragmentary or isolated, or their origin from parts of the measured sections (if given at all) is very dubious. For instance, Jordan and Bless (1971) published *Cypridea* (and other genera) from the Berriasian of Aliaga, Helmdach (1974) some *Theriosynoecum*, *Cypridea*, and *Paranotocythere* species from the Lower Barremian of Galve, and Cugny and Grosdidier (1987) several genera and species from the Barremian, Aptian, and Albian of Oliete.

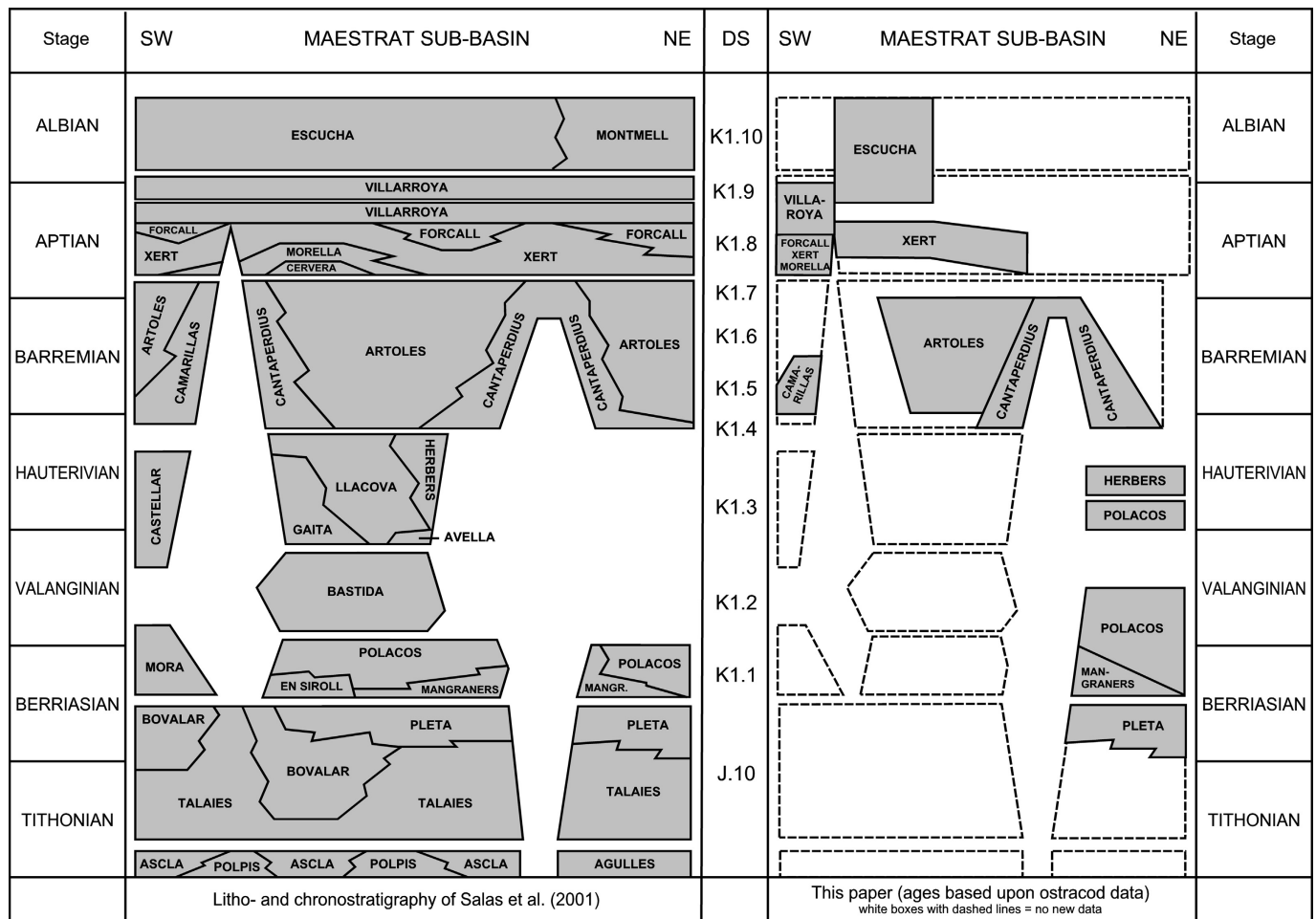


Fig. 7. - Left: Chrono-lithostratigraphic chart of the Maestrazgo ("Maestrat") sub-basin during the Late Jurassic – Early Cretaceous rifting stage, with depositional sequences and lithostratigraphic units (formations). Simplified and based upon Salas *et al.* (2001). Right: Biostratigraphic correlations for several formations (in grey) based upon ostracods.

Fig. 7.- Izquierda: Cuadro cronoestratigráfico de la subcuenca del Maestrazgo ("Maestrat") durante el estadio de rifting del Jurásico Superior-Cretácico Inferior, con las secuencias deposicionales y las unidades litoestratigráficas (formaciones). Simplificado y basado en Salas *et al.* (2001). Derecha: Correlaciones bioestratigráficas para algunas formaciones (en gris) basadas en los ostrácodos.

Brenner (1976) described several species of the genera *Fabanella*, *Macrodentina*, *Pontocyprilla*, *Schuleridea*, *Cythereis*, *Paracypris*, *Asciocythere*, *Haplocytheridea*, *Eocytheropteron*, *Paranotocythere*, *Cytherella*, *Metacytheropteron*, *Dolocytheridea*, *Clithrocytheridea* (all brackish-marine), *Darwinula*, *Theriosynoecum* and *Cypridea* (all predominantly freshwater) from the Barremian and Aptian of the larger area around Morella (from several localities), but did not give any sections or lithostratigraphic schemes enabling us to identify his sample points and thus help with chronostratigraphic correlation of the actual lithologic units (Fig. 7).

Swain (1993) and Swain *et al.* (1991) published ostracod faunas from eight Lower Cretaceous localities in northern and eastern Spain, three out of them from the Maestrazgo sub-basin (the others from areas not treated in the present paper). At Mas de Barberans (about 15 km NE of El Man-

graners section of the present paper, see Fig. 2), they listed several marine Barremian-Aptian species of the genera *Cytherelloidea*, *Bythocypris*, *Clithrocytheridea*, *Paracyprideis*, *Paraschuleridea*, *Asciocythere*, *Schuleridea*, *Eocytheropteron*, *Cytherura*, *Neocythere*, *Hechticythere*, *Rehacythereis*, *Veeniacythereis*?, and *Cythereis*, from El Mangraners (also a section of the present paper) marine-brackish and nonmarine Barremian? species of the genera *Cypridea*, *Asciocythere*, *Mantelliana*, *Fabanella*, *Timiria-sevia*?, and *Macrodentina*, and from Perello (about 45 km NE of El Mangraners section) marine-brackish and nonmarine Aptian? species of the genera *Dolocytheridea*?, *Asciocythere*?, *Haplocytheridea*?, and *Cypridea*. Similar to Brenner (1976), the authors did not give any measured sections or lithostratigraphic names, thus it is not possible to attribute their ostracod findings to the established stratigraphic units of Fig. 7.

New biostratigraphic contributions from our ostracod studies

We studied new (and in a few cases restudied older) ostracod faunas from 9 sections or localities in the Maestrazgo sub-basin. Most new biostratigraphic data are very consistent with previous chronostratigraphic correlations for the lithologic units, as presented by Salas *et al.* (2001).

The upper part of the lowermost depositional sequence considered in this paper (J.10 – here: Pleta Formation, see Fig. 7) yielded a mostly brackish-marine ostracod fauna with *Macrodentina (Dictyocythere)* sp. ex gr. *mediostricta transfuga*, *Protocythere* cf. *camberiensis*, *Fabanella boloniensis*, and *Asciocythere* cf. *circumdata* as well as a few *Cypridea tumescens preaecursor* and *C. aff. tumescens* (both freshwater) in El Mangraners section. This association points to an Early Berriasian age, at least for the upper part of the formation, which is in consistency with previous age determinations (Fig. 7).

From the lower part of following depositional sequence (K1.1 – here: El Mangraners Formation) of El Mangraners section, we identified the brackish-marine species *Macrodentina (Dictyocythere)* sp. ex gr. *mediostricta transfuga*, *Protocythere* cf. *camberiensis*, *Fabanella boloniensis*, *Schuleridea* sp., and *Asciocythere* cf. *circumdata* as well as the freshwater species *Cypridea tumescens preaecursor* and *Theriosynoecum* sp. Altogether, this association indicates a Berriasian age and mixed freshwater, brackish water and marine environments (and thus more freshwater influence than for the underlying Pleta Formation). This is also consistent with previous correlations (Fig. 7).

The upper part of the K1.1 depositional sequence (here: Polacos Formation) at El Mangraners section yielded mostly freshwater ostracod species such as *Cypridea tumescens tumescens*, *C. cf. aculeata*, *C. aff. valdensis*, *C. dolabrata*, *Theriosynoecum* ex gr. *forbesii*, and *Th. cf. forbesii* as well as a few marine *Protocythere* sp. This association points to a Late Berriasian or Early Valanginian age and almost exclusively freshwater conditions. Only in its uppermost beds, *Cypridea clavata* and *C. piedmonti* (both also freshwater species) indicate an Early Hauterivian age. The latter is a little in contradiction to previous age determinations, but there is strong consistency between our new age data and previous age determinations for the main part of the formation (Fig. 7).

A mixed brackish-marine (*Fabanella* sp., *Paranotacythere (P.) aff. anglica*) / freshwater (*Cypridea demandae*, *C. sp. 10*) ostracod fauna was extracted from the uppermost layers of Herbers Formation (K1.2-K1.3) in El Mangraners section. This association indicates an Early

Hauterivian age, consistent with previous age determinations (Fig. 7).

The following depositional sequence (K1.4 – here: Cantaperdius Formation) yielded a rich ostracod fauna from El Mangraners and Barranc de l'Escresola sections, mostly with freshwater ostracods (*Cypridea clavata*, *C. demandae*, *C. isasae*, *C. aff. valdensis*, and *C. sp. 10*), but also a few brackish-marine species (*Cytherella* sp., *Macrodentina (Dictyocythere)* sp. ex gr. *mediostricta transfuga*, and *Fabanella boloniensis*). This association indicates an Hauterivian or Barremian (Early Barremian at El Barranc de l'Escresola) age, as previously suggested (Fig. 7).

We have no new data from K1.5 depositional sequence, but the following sequence (K1.6 – here: middle part of Artoles Formation at Coll de Querol section) provided exclusively brackish-marine ostracod species: *Macrodentina (D.) gibbera*, *Fabanella boloniensis*, *Paracypris* sp., and *Paranotacythere (U.)* sp. These indicate a Barremian or Aptian age for this part of the section (Barremian according to previous age determinations, Fig. 7).

A mixed marine-nonmarine (but mostly nonmarine) ostracod association derives from the upper part of the Artoles Formation (K1.7 depositional sequence) of Oliete-Alcaine section, indicating a Barremian age: *Cypridea demandae*, *C. piedmonti*, *C. cidacosia*, *C. pseudomarina*, *Theriosynoecum fittoni*, *Platycythereis* cf. *degenerata*, *Paracypris* sp., and *Haplocytheridea laevantensis* (also consistent with previous age determinations, Fig. 7). In the uppermost part of the formation, the marine influence increases.

The lower part of the overlying depositional sequence K1.8 (Morella Formation at Cuevas de Portalrubio section and lowermost Xert Formation at Cuevas de Portalrubio and Oliete-Alcaine sections) delivered exclusively brackish-marine species: *Haplocytheridea laevantensis*, *Asciocythere cinctorensis*, *A. alvarvensis*, *Macrodentina (D.) gibbera*, *Cythereis (R.)* cf. *btaterensis torifera*, *Eocytheropteron* sp., *Platycythereis algarvensis*, and *Schuleridea hexagonalis*. The association allows an age assignment to the Early Aptian (and thus identical to current knowledge, Fig. 7). The upper part of the Xert Formation yielded only *Cythereis (R.)* cf. *btaterensis torifera* at Cuevas de Portalrubio section (Barremian-Aptian, marine).

The overlying Forcall Formation (K1.8, middle part) was only examined at Cuevas de Portalrubio section and provided the ostracod species *Schuleridea* sp., *Platycythereis algarvensis*, *Paranotacythere (P.) catalaunica*, *Protocythere* cf. *aptensis* (all marine, which is the predominant ecology here), *Cypridea ventriosa*, and *C. gr. tuberculata*

(both freshwater, only slight brackish influence). This association again points to an Early Aptian age.

According to the stratigraphic chart of Salas *et al.* (2001), the Villaroya de los Pinares Formation corresponds to the upper part of the K1.8 and the complete K1.9 depositional sequences. From Cuevas de Portalrubio section, we identified exclusively marine ostracod species: *Cythereis (R.) cf. btaterensis torifera*, *Platycythereis algarvensis*, *Cytheropteron sp.*, *Cytherelloidea sp. 1*, *C. sp. 2*, *Schuleridea posterospinata*, and *Matronella matronae* from the lower part of the formation (K1.8), as well as *Asciocythere algarvensis*, *Schuleridea sp.*, *Platycythereis algarvensis*, and *Protocythere cf. aptensis* from its upper part (K1.9). These associations indicate a Late Aptian age for the bulk of the formation, but allow a late Early Aptian age for its lowermost part.

All our new data for Cuevas de Portalrubio section (depositional sequences K1.8-K1.9) are in good correlation with the recently published data given by Peropadre *et al.* (2007), except for the slight freshwater influence within Forcall Formation detected by the *Cypridea* findings, and with the established stratigraphic chart (Fig. 7).

Ostracods of the Escucha Formation (K1.10) were studied from Foz de Calanda and Aliaga sections (see Fig. 2). The species found in the upper part of the formation at Aliaga section point to a mixed marine-nonmarine environment: *Cytherella cf. ovata*, *Cytherelloidea sp. 1*, *Matronella matronae*, *Centrocythere cf. bordeti*, *Platycythereis cf. degenerata* (all marine), *Cypridea ventriosa* and *C. modesta* (both freshwater). The association as a whole would allow an Aptian or Albian age, but with rather conflicting stratigraphic ranges of the various species in this case: most of the marine species point to an Albian age, whereas the *Cypridea* and *Centrocythere* species would indicate an Aptian (or even Barremian) age. However: the two *Cypridea* species are endemic to the Iberian peninsula, and therefore not given first priority for age determination. In consequence, an Albian age of the Escucha Formation, as previously suggested (Fig. 7), is most probable also from ostracod biostratigraphy. However, the above-mentioned possibly slightly older ages (Late Aptian?) for at least parts of the Escucha Formation are in agreement with the latest palynologic ages published by Peyrot *et al.* (2007).

In addition to the measured sections reported above, we examined a number of samples from the Galve area, famous for its vertebrate findings. The chronostratigraphy of the various formations cropping out in the "synclinal de Galve" was summarized by Diaz and Yébenes (1987), the Lower Barremian then by Mohr (1987; 1989: spores and pollen), Martín-Closas (1989: charophytes)

and Schudack, M. (1989: charophytes), see also Sánchez-Hernández *et al.* (2007) for a large list of more recent references. Galve is situated in the very southwest of the Maestrazgo sub-basin (see Fig. 2), the lithostratigraphic units of Cretaceous age containing ostracods (and charophytes as well as vertebrates) are the Bovalar, El Castellar, Camarillas, and Artoles Formations (see Fig. 7). The ostracod material considered here is from the "vertebrate working group" of Prof. Krebs (Berlin), the members of which carried out intensive excavations during the 1960s and 1970s in this area. Unfortunately, they failed to elaborate a useful measured section (or – at least – a compound) to work with, and therefore our four samples are isolated, not to be tied into the sections published – for instance – by Sánchez-Hernández *et al.* (2007). Nevertheless, based upon the ostracod and other faunas and floras therein, it is clear that they mostly come from the Lower Barremian part of the section (depositional sequences K1.4-K1.5, Camarillas Formation, see Fig. 7). The species are *Cypridea tuberculata*, *C. sp. 1*, *C. sp. 2*, *C. sp. C*, *Timiriasevia sp.* (all freshwater), *Paranotacythere (O.) galvensis*, *Fabanella boloniensis*, *Macrodentina (D.) aff. mediostriata*, and *M. (D.) gibbera* (all brackish-marine). This association indicates an Early Barremian age and mixed freshwater - brackish water - marine environments.

In summary: Our biostratigraphic results were summarized on Fig. 7. We have new data for the Berriasian to Barremian of the northeastern and central parts and for the Barremian to Albian of the central and southeastern parts of Maestrazgo sub-basin. For the Pleta and El Mangraners Formations (J.10 and K1.1 depositional sequences), the Berriasian ages, as generally accepted today, were confirmed. However, the Polacos Formation may be younger in parts (Upper Berriasian, Lower Valanginian, and Lower Hauterivian, K1.1 to K1.3 depositional sequences) than previously suggested, at least at El Mangraners section. On the other hand, the ages of the latest Hauterivian - Barremian Cantaperdius, Artoles, and Camarillas Formations (K1.4-K1.7) were confirmed by our new ostracod data, but with the exclusion of some earliest Aptian ages as demonstrated by Salas *et al.* (2001). And it is the same for the hitherto Early Aptian Morella, Xert, and Forcall Formations (K1.8) and the Late Aptian Villaroya Formation (K1.9), whose ages were also supported (but not an earliest Albian age for the latter formation's uppermost part, as demonstrated by Salas *et al.*, 2001). Finally, the Escucha Formation mostly yielded ostracods of Albian age (K1.10), but – also in contradiction to the established charts – allows a Late Aptian age for its lowermost part.

5.4. South Iberian sub-basin (area 4 in Fig. 2)

This NW-SE trending, 300 km long sub-basin is separated from the northernmore Maestrazgo sub-basin by the so-called Valencia high, an also NW-SE striking positive structure. It contains more than 2000 meters of syn-rift sediments of Berriasian to Middle Albian age (Salas *et al.*, 2001). The older parts of the succession are mostly continental and lacustrine, whilst the upper parts consist essentially of shallow marine carbonates.

Marine Jurassic carbonates (Oxfordian-Kimmeridgian Sot de Xera and Loriguilla Formations, J.9 depositional sequence, see Fig. 8, based upon Salas *et al.*, 2001) are overlain by shallow subtidal carbonate bars and tidal-flats, as well as siliciclastic sediments (J.10 depositional sequence, Middle Tithonian to Early Berriasian, Higuere-las and Villar del Arzobispo Formations, Fig. 8).

The first depositional sequences of the Cretaceous (K1.1-K1.4, Late Berriasian to basal Barremian) were not deposited in most parts of the sub-basin, except for a small trough (variegated sediments, Valanginian-Hauterivian Aldea de Cortes Formation). The Barremian K1.5 - K1.7 depositional sequences then overlapped over most parts of the sub-basin (siliciclastic alluvial El Collado and shallow lacustrine carbonate La Huérguina Formations), except for the very southwest.

After this predominantly nonmarine period, marine conditions prevailed during most of the Aptian (K1.8 - K1.9 depositional sequences, El Caroig Formation), interfingering with continental siliciclastics (Contreras Formation). Finally, the Early to Middle Albian (K1.10) Escucha and Sácaras Formations consist of siliciclastic alluvial and deltaic as well as mixed siliciclastic-carbonate deposits.

Similar to the Maestrazgo sub-basin, chronostratigraphic correlations of these various units (as presented in Fig. 8) were based upon various biostratigraphic data (but generally less than in that sub-basin) from a few marine fossils and nonmarine groups such as spores and pollen, ostracods, and charophytes. Especially spores/pollen and ostracods were only rarely described from this area. Mohr (1987; 1989) indicated an Early Barremian age for the dinosaur-bearing La Huérguina Formation at Uña from spores and pollen. Ostracods were mentioned from Uña near Pié Pajaron, see Figure 2 (a few *Mantelliana* and *Cypridea* species which should indicate a Barremian or Aptian age according to Brenner, 1976) or from the Buenache de la Sierra (Buscalioni *et al.*, 2008) / Las Hoyas (Rodríguez Lázaro, 1995) area, the latter indicating a Late Barremian age for the upper part of the La Huérguina Formation. A few ostracods from various localities were also mentioned by Geyer and Krautter

(1998), determined by the authors of the present paper.

Charophytes from the clavatoracean family were stratigraphically much more important, used by Schudack, M. (1989) for an age determination of the La Huérguina Formation at Uña (Late Barremian and thus younger than indicated by Mohr, 1987; 1989) and mainly in the various papers of Martín-Closas (Martín-Closas in Buscalioni *et al.*, 2008; Martín-Closas; 2000, Martín-Closas and Dieguez, 1998). Moreover, one of the present authors (M. Schudack) determined several charophyte species mentioned by Geyer and Krautter (1998) from several sections.

In addition to these biostratigraphic data, sequence stratigraphic correlations (for instance Salas *et al.*, 2001) play a major role for the elaboration of the actual stratigraphic chart (Fig. 8), as in the other areas considered in this paper.

A detailed summary of the Lower Cretaceous sedimentology and formations was published by Geyer and Krautter (1998). These authors mentioned the richness of ostracods and charophytes in some of the formations (as shown on Fig. 8, mainly La Huérguina Formation). Location and stratigraphy of the sections within the South Iberian sub-basin sampled during this study are all from that paper.

New biostratigraphic contributions from our ostracod studies

We studied new ostracod faunas from 5 sections or localities (for position see Fig. 2) in the South Iberian sub-basin (all samples from one additional section, Campillos-Paravientos, were barren of ostracods). Most new biostratigraphic data are very consistent with previous chronostratigraphic correlations of the lithologic units, as presented by Salas *et al.* (2001), except for the uppermost part of the sequence.

We have no new data from the J.10 (Higuere-las and Villar del Arzobispo Formations, Tithonian-Berriasian), K1.1 (Late Berriasian), K1.2-K1.3 (Aldea de Cortes Formation, Valanginian-Hauterivian), and K1.4 (Late Hauterivian) depositional sequences. However, the Barremian La Huérguina Formation (K1.5-K1.7) yielded a wealth of ostracods from Huérguina, Las Majadas, Pié Pajarón, and Zafrilla. These are exclusively species of the freshwater genera *Cypridea* and *Theriosynoecum*: *Cypridea clavata*, *C. pseudomarina*, *C. brendae*, *C. aff. alta*, *C. aff. valdensis*, *C. sp. B*, *C. sp. 5*, *C. sp. 7*, *C. sp. 8*, and *Theriosynoecum fittoni*. This association points to a Barremian age of the formation (for all parts from bottom to top), which is largely consistent with previous suggestions (see Fig. 8), but with no hints on the presumed stratigraphic gap for the earliest part of the Barremian and the basalmost

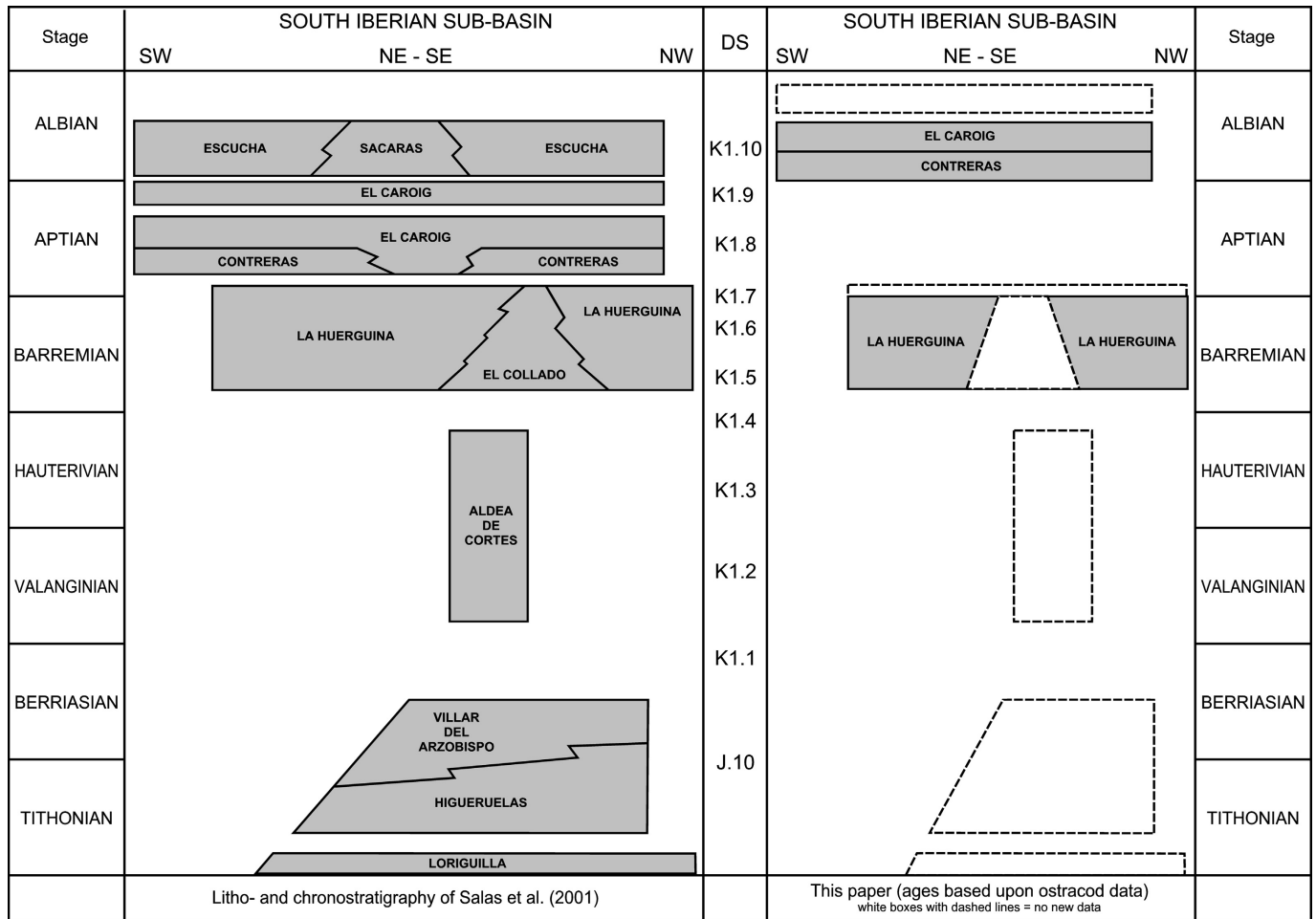


Fig. 8. - Left: Chrono-lithostratigraphic chart of the South Iberian sub-basin during the Late Jurassic – Early Cretaceous rifting stage, with depositional sequences and lithostratigraphic units (formations). Simplified and based upon Salas *et al.* (2001). Right: Biostratigraphic correlations for several formations (in grey) based upon ostracods.

Fig. 8.- Izquierda: Cuadro cronoestratigráfico de la subcuenca Suribérica durante el estadio de rifting del Jurásico Superior-Cretácico Inferior, con las secuencias deposicionales y las unidades litoestratigráficas (formaciones). Simplificado y basado en Salas *et al.*, (2001). Derecha: Correlaciones bioestratigráficas para algunas formaciones (en gris) basadas en los ostrácodos.

Aptian age of its uppermost part (see Salas *et al.*, 2001 and Fig. 8).

All samples from the contemporaneous, but more classic Collado Formation (also K1.5-K1.7 depositional sequences and Barremian) were barren of ostracods and therefore delivered no new data.

The overlying K1.8 and K1.9 depositional cycles (Contreras and El Caroig Formations), yielded three exclusively marine ostracod species from Salvacañete section: *Matronella matronae* and *Platycythereis cf. degenerata* from the Malacara member of the Contreras Formation and the same two species plus *Cytherella cf. ovata* from the Burgal member of El Caroig Formation. The species point to an Albian age for both members, which is in strong contradiction to their now widely accepted Aptian age (see Salas *et al.*, 2001 and Fig. 8).

In summary: Our biostratigraphic results are summarized on Figure 8. We have new biostratigraphic data for La Huérguina (K1.5-K1.7), Contreras (K1.8), and El Caroig (K1.8-K1.9) Formations. Data for the La Huérguina Formation are in agreement with its previously suggested, largely Barremian age, whereas data for the Contreras and El Caroig Formations are in contradiction (Albian instead of the previously suggested Aptian age).

6. Summary and discussion

6.1. Lower Cretaceous ostracod associations of eastern Spain

The study of so many ostracod samples and populations used in this paper resulted in the establishment of several ostracod associations typical for the different stages

or substages (and also different ecologies) in the Lower Cretaceous of eastern Spain. In the following paragraphs, they will be specified, each with its main characterizing and most abundant species. Species in open nomenclature (sp. 7 etc.) are not considered here. On figures 9

(freshwater) and 10 (marine), the most abundant species are summarized.

Berriasian freshwater association (in order of abundance): *Theriosynoecum forbesii*, *Cypridea tumescens praecursor*, *Fabanella boloniensis*, *Rhinocypris jurassica*

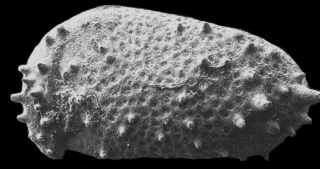
Fig. 9. - The most abundant and stratigraphically important freshwater ostracod species for the four stages Berriasian, Valanginian, Hauterivian, and Barremian. Each association starting with the most frequent species (lowest number).

- Berriasian association: **1.** *Cypridea tumescens tumescens* (Anderson, 1939), Fitero section, sample 281-KH, right valve, length 1395 μ . MT 2008-14-2.18. **2.** *Cypridea tuberculata* (Sowerby, 1836), Hortezielos section, sample 83/66, left valve, length 999 μ . MT 2008-14-1.14. **3.** *Theriosynoecum forbesii* (Jones, 1882), Huerta del Rey section, sample 83/13, left valve, length 799 μ . MT 2008-15-2.1. **4.** *Cypridea tumescens praecursor* (Oertli, 1963), Hortezielos section, sample 83/69, right valve, length 1330 μ . MT 2008-14-2.20. **5.** *Cypridea* aff. *parallela*, Wolburg, 1959, bold variety, Hortezielos section, sample 87/31, right valve, length 1471 μ . MT 2008-14-2.9. **6.** *Theriosynoecum vincentei* (Kneuper-Haack, 1966), Bijuesca section, sample W 125, left valve, length 971 μ . MT 2008-15-2.14. **7.** *Cypridea laevigata* var. *laevigata* (Dunker, 1846), Leza Valley section, sample 87/178, left valve, length 986 μ . MT 2008-14-2.6. **8.** *Rhinocypris jurassica* Martin, 1940, juvenile specimen, Huerta del Rey section, sample 83/14, right valve, length 479 μ . MT 2008-15-3.16.
- Valanginian association: **9.** *Theriosynoecum triangula* (Kneuper-Haack, 1966), Fitero section, sample 281-KH, right valve, length 1049 μ . MT 2008-15-2.8. **10.** *Cypridea brevirostrata* Martin, 1940, Enciso section, sample 280-KH, left valve, length 1265 μ . MT 2008-14-3.21. **11.** *Theriosynoecum linaria* (Kneuper-Haack, 1966), Foz de Calanda section, sample FC-3, left valve, length 752 μ . MT 2008-15-2.4. **12.** *Cypridea bispinosa* (Jones, 1878), Fitero section, sample 281-KH, left valve, length 949 μ . MT 2008-14-3.3.
- Hauterivian-Barremian association (in general): **13.** *Theriosynoecum iberica* (Kneuper-Haack, 1966), Bijuesca section, sample 83/51, left valve, length 1066 μ . MT 2008-15-2.3. **14.** *Theriosynoecum fittoni* (Mantell, 1844), Hortezielos section, sample 83/67, left valve, length 1015 μ . MT 2008-15-1.17. **15.** *Cypridea clavata* (Anderson, 1939), El barranc de l'Escresola section, sample Es-2-C, right valve, length 847 μ . MT 2008-14-3.9. **16.** *Cypridea isasae* (Kneuper-Haack, 1966), Fitero section, sample 281-KH, left valve, length 1129 μ . MT 2008-14-3.24. **17.** *Cypridea demandae* (Kneuper-Haack, 1966), Cueva de Juarros section, sample CJ-2, right valve, length 945 μ . MT 2008-14-2.1. **18.** *Cypridea* aff. *valdensis* (Sowerby in Fitton, 1836), Aranda de Moncayo section, sample 86/31, right valve, length 1205 μ . MT 2008-14-2.14. **19.** *Cypridea piedmonti* (Roth, 1933), Arnedillo section, sample 242-KH, right valve, length 1108 μ . MT 2008-14-2.5. **20.** *Cypridea modesta* (Kneuper-Haack, 1966), Enciso section, sample 280-KH, Hauterivian to Barremian, right valve, length 1019 μ . MT 2008-14-3.26.
- Barremian only (index species for more refined correlation): **21.** *Cypridea pseudomarina* Anderson, 1967, Las Majadas section, sample Las Majadas-G, left valve, length 789 μ . MT 2008-14-1.19. **22.** *Cypridea ventriosa* Brenner, 1976, Aliaga section, sample 6J., left valve, length 1037 μ . MT 2008-14-2.16.

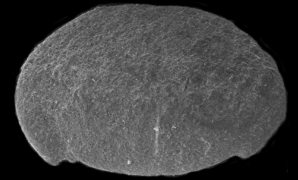
Fig. 9.- Especies más abundantes y de interés estratigráfico de ostrácodos no marinos para los cuatro pisos Berriasiense, Valanginiense, Hauteriviense y Barremiense. Cada asociación comienza con la especie más frecuente (número más bajo).

- Asociación Berriasiense: **1.** *Cypridea tumescens tumescens* (Anderson, 1939), sección de Fitero, muestra 281-KH, valva derecha, longitud 1395 μ . MT 2008-14-2.18. **2.** *Cypridea tuberculata* (Sowerby, 1836), sección de Hortezielos, muestra 83/66, valva izquierda, longitud 999 μ . MT 2008-14-1.14. **3.** *Theriosynoecum forbesii* (Jones, 1882), sección de Huerta del Rey, muestra 83/13, valva izquierda, longitud 799 μ . MT 2008-15-2.1. **4.** *Cypridea tumescens praecursor* (Oertli, 1963), sección de Hortezielos, muestra 83/69, valva derecha, longitud 1330 μ . MT 2008-14-2.20. **5.** *Cypridea* aff. *parallela*, Wolburg, 1959, variedad negrita, sección de Hortezielos, muestra 87/31, valva derecha, longitud 1471 μ . MT 2008-14-2.9. **6.** *Theriosynoecum vincentei* (Kneuper-Haack, 1966), sección de Bijuesca, muestra W 125, valva izquierda, longitud 971 μ . MT 2008-15-2.14. **7.** *Cypridea laevigata* var. *laevigata* (Dunker, 1846), sección del Valle de Leza, muestra 87/178, valva izquierda, longitud 986 μ . MT 2008-14-2.6. **8.** *Rhinocypris jurassica* Martin, 1940, espécimen juvenil, sección de Huerta del Rey, muestra 83/14, valva derecha, longitud 479 μ . MT 2008-15-3.16.
- Asociación Valanginiense: **9.** *Theriosynoecum triangula* (Kneuper-Haack, 1966), sección de Fitero, muestra 281-KH, valva derecha, longitud 1049 μ . MT 2008-15-2.8. **10.** *Cypridea brevirostrata* Martin, 1940, sección de Enciso, muestra 280-KH, valva izquierda, longitud 1265 μ . MT 2008-14-3.21. **11.** *Theriosynoecum linaria* (Kneuper-Haack, 1966), sección de Foz de Calanda, muestra FC-3, valva izquierda, longitud 752 μ . MT 2008-15-2.4. **12.** *Cypridea bispinosa* (Jones, 1878), sección de Fitero, muestra 281-KH, valva izquierda, longitud 949 μ . MT 2008-14-3.3.
- Asociación Hauteriviense-Barremiense (en general): **13.** *Theriosynoecum iberica* (Kneuper-Haack, 1966), sección de Bijuesca, muestra 83/51, valva izquierda, longitud 1066 μ . MT 2008-15-2.3. **14.** *Theriosynoecum fittoni* (Mantell, 1844), sección de Hortezielos, muestra 83/67, valva izquierda, longitud 1015 μ . MT 2008-15-1.17. **15.** *Cypridea clavata* (Anderson, 1939), sección El barranc de l'Escresola, muestra Es-2-C, valva derecha, longitud 847 μ . MT 2008-14-3.9. **16.** *Cypridea isasae* (Kneuper-Haack, 1966), sección de Fitero, muestra 281-KH, valva izquierda, longitud 1129 μ . MT 2008-14-3.24. **17.** *Cypridea demandae* (Kneuper-Haack, 1966), sección de Cueva de Juarros, muestra CJ-2, valva derecha, longitud 945 μ . MT 2008-14-2.1. **18.** *Cypridea* aff. *valdensis* (Sowerby in Fitton, 1836), sección de Aranda de Moncayo, muestra 86/31, valva derecha, longitud 1205 μ . MT 2008-14-2.14. **19.** *Cypridea piedmonti* (Roth, 1933), sección de Arnedillo, muestra 242-KH, valva derecha, longitud 1108 μ . MT 2008-14-2.5. **20.** *Cypridea modesta* (Kneuper-Haack, 1966), sección de Enciso, muestra 280-KH, Hauteriviense a Barremiense, valva derecha, longitud 1019 μ . MT 2008-14-3.26.
- Barremiense (especies índice para una correlación más fina): **21.** *Cypridea pseudomarina* Anderson, 1967, sección de Las Majadas, muestra Las Majadas-G, valva izquierda, longitud 789 μ . MT 2008-14-1.19. **22.** *Cypridea ventriosa* Brenner, 1976, sección de Aliaga, muestra 6J., valva izquierda, longitud 1037 μ . MT 2008-14-2.16.

Barremian only

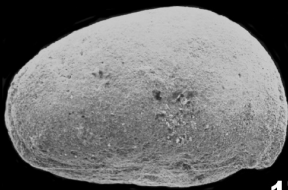


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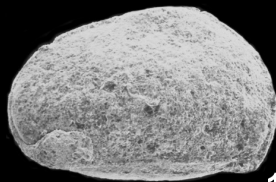


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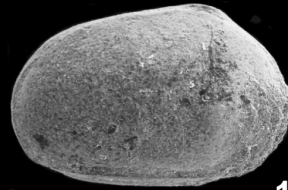
Hauterivian-Barremian (in general)



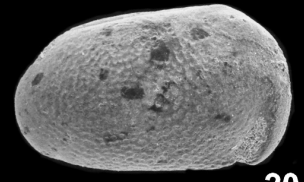
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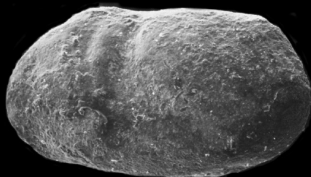
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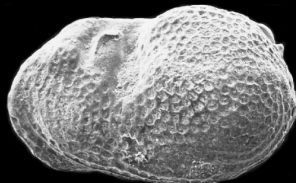
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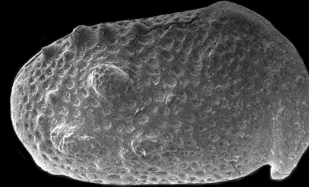
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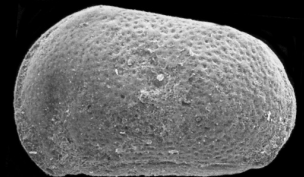
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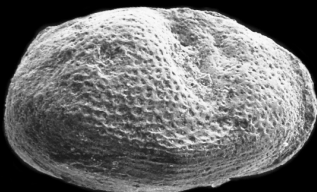


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Valanginian



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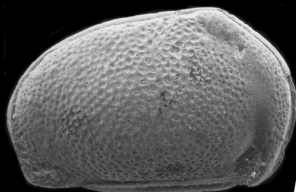


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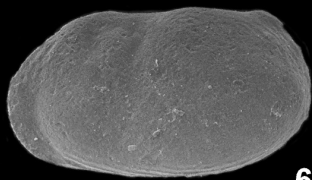


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Berriasian



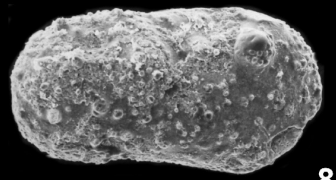
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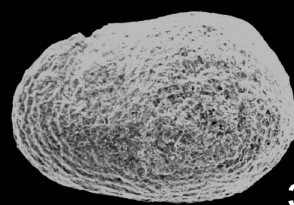
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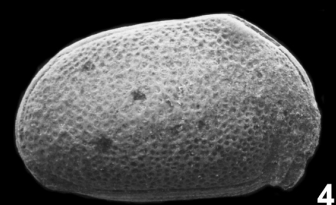
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ca, *Scabriculocypris trapezoides*, *Mantelliana perlata*, *C. tumescens tumescens*, *C. tuberculata*, *C. granulosa*, *C. dunkeri carinata*, *C. aff. valdensis*.

Berriasian mixed brackish-marine association (in order of abundance): *Asciocythere* cf. *circumdata*, *Macroden-*

tina (*Dictyocythere*) ex gr. *mediostriata transfuga*, *Proto-*
cythere cf. *camberiensis*, *Fabanella boloniensis*.

Late Berriasian freshwater association (chronostratigraphically more refined, in order of abundance): *Cypri-*
dea tumescens tumescens, *C. tuberculata*, *Theriosyno-*

Fig. 10. - The most abundant and stratigraphically important marine-brackish ostracod species for the five stages Berriasian, Hauterivian, Barremian, Aptian, and Albian. Each association starting with the most frequent species (lowest number).

Berriasian association: **1.** *Asciocythere* cf. *circumdata* (Donze, 1964), El Mangraners section, sample MG-4, (Pleta-Fm.), right valve, length 714 μ . MT 2008-15-2.17. **2.** *Macrodentina* (*Dictyocythere*) ex gr. *mediostriata transfuga* Malz, 1958, El Mangraners section, sample MG-1, right valve, length 996 μ . MT 2008-15-3.5. **3.** *Proto-*
cythere cf. *camberiensis* Donze, 1964, El Mangraners section, sample MG-2, left valve, length 1004 μ . MT 2008-15-3.13. **4.** *Fabanella boloniensis* (Jones, 1882), El Mangraners section, sample MG-47, left valve, length 809 μ . MT 2008-15-1.9.

Hauterivian association: **5.** *Paranotacythere* (*P.*) aff. *anglica* Neale, 1960, El Mangraners section, sample MG-40, left valve, length 852 μ . MT 2008-15-1.13.

Barremian association: **6.** *Macrodentina* (*Dictyocythere*) *gibbera* Brenner, 1976, Coll de Querol section, sample CQ-9, right valve, 971 μ . MT 2008-15-3.3.

Aptian association: **7.** *Cythereis* (*Rehacythereis*) cf. *btaterensis torifera* Bischoff, 1963, Cuevas de Portalrubio/la Rambla de Martin section, sample CPRM 2 20,1, left valve, length 825 μ . MT 2008-15-2.19. **8.** *Platycythereis algarvensis* Damotte, Grosdidier and Rey, 1988, Cuevas de Portalrubio section, sample CPRM 3B 0,3, left valve, length 875 μ . MT 2008-15-3.17. **9.** *Proto-*
cythere cf. *aptensis* Oertli (1958) sensu Brenner (1976), Cuevas de Portalrubio section, sample CPRM 2 33,1, right valve, length 982 μ . MT 2008-15-3.14. **10.** *Asciocythere algarvensis* Damotte, Cabral and Berthou, 1990, Cuevas de Portalrubio section, sample CPRM 3B 0,3 (Morella Fm), left valve, length 920 μ . MT 2008-15-2.15. **11.** *Schuleridea posterospinata* Damotte, Cabral and Berthou, 1990, Cuevas de Portalrubio section, sample CPRM 3B 6,13, right valve, length 627 μ . MT 2008-15-1.11. **12.** *Schuleridea hexagonalis* Brenner, 1976, Oliete section, sample 16, right valve, length 592 μ . MT 2008-15-1.10. **13.** *Paranotacythere* (*Paranotacythere*) *catalaunica* (Damotte and Grosdidier, 1963), Cuevas de Portalrubio section, sample CPRM 3B 5,5, right valve, length 491 μ . MT 2008-15-3.12. **14.** *Asciocythere cinctorensis* (Brenner, 1976), Oliete section, sample 15, right valve, length 693 μ . MT 2008-15-2.16.

Albian association: **15.** *Cytherella* cf. *ovata* (Roemer, 1841), Salvacanete section, sample Salv 4, Burgal Fm., right valve, length 668 μ . MT 2008-15-1.1. **16.** *Platycythereis* cf. *degenerata* Triebel, 1940, Salvacanete section, sample Salv-2, left valve, length 695 μ . MT 2008-15-3.18. **17.** *Matronella matronae* (Damotte and Grosdidier, 1963), Salvacanete section, sample Salv-2, right valve, length 966 μ . MT 2008-15-3.8. **18.** *Centrocythere* cf. *bordeti* Damotte and Grosdidier, 1963, Aliaga section, sample 6 (Escucha Fm.), right(?) valve damaged, length 584 μ . MT 2008-15-2.18.

Fig. 10. – Especies más abundantes y de interés estratigráfico de ostrácodos marinos-estuarinos para los cinco pisos Berriasense, Hauteriviense, Barremiense, Aptiense y Albiense. Cada asociación comienza con la especie más frecuente (número más bajo).

Asociación Berriasense: **1.** *Asciocythere* cf. *circumdata* (Donze, 1964), sección El Mangraners, muestra MG-4, (Pleta-Fm.), valva derecha, longitud 714 μ . MT 2008-15-2.17. **2.** *Macrodentina* (*Dictyocythere*) ex gr. *mediostriata transfuga* Malz, 1958, sección El Mangraners, muestra MG-1, valva derecha, longitud 996 μ . MT 2008-15-3.5. **3.** *Proto-*
cythere cf. *camberiensis* Donze, 1964, sección El Mangraners, muestra MG-2, valva izquierda, longitud 1004 μ . MT 2008-15-3.13. **4.** *Fabanella boloniensis* (Jones, 1882), sección El Mangraners, muestra MG-47, valva izquierda, longitud 809 μ . MT 2008-15-1.9.

Asociación Hauteriviense: **5.** *Paranotacythere* (*P.*) aff. *anglica* Neale, 1960, sección El Mangraners, muestra MG-40, valva izquierda, longitud 852 μ . MT 2008-15-1.13.

Asociación Barremiense: **6.** *Macrodentina* (*Dictyocythere*) *gibbera* Brenner, 1976, sección del Coll de Querol, muestra CQ-9, valva derecha, 971 μ . MT 2008-15-3.3.

Asociación Aptiense: **7.** *Cythereis* (*Rehacythereis*) cf. *btaterensis torifera* Bischoff, 1963, sección de Cuevas de Portalrubio/la Rambla de Martin, muestra CPRM 2 20,1, valva izquierda, longitud 825 μ . MT 2008-15-2.19. **8.** *Platycythereis algarvensis* Damotte, Grosdidier and Rey, 1988, sección de Cuevas de Portalrubio, muestra CPRM 3B 0,3, valva izquierda, longitud 875 μ . MT 2008-15-3.17. **9.** *Proto-*
cythere cf. *aptensis* Oertli (1958) sensu Brenner (1976), sección de Cuevas de Portalrubio, muestra CPRM 2 33,1, valva derecha, longitud 982 μ . MT 2008-15-3.14. **10.** *Asciocythere algarvensis* Damotte, Cabral and Berthou, 1990, sección de Cuevas de Portalrubio, muestra CPRM 3B 0,3 (Fm. Morella), valva izquierda, longitud 920 μ . MT 2008-15-2.15. **11.** *Schuleridea posterospinata* Damotte, Cabral and Berthou, 1990, sección de Cuevas de Portalrubio, muestra CPRM 3B 6,13, valva derecha, longitud 627 μ . MT 2008-15-1.11. **12.** *Schuleridea hexagonalis* Brenner, 1976, sección de Oliete, muestra 16, valva derecha, longitud 592 μ . MT 2008-15-1.10. **13.** *Paranotacythere* (*Paranotacythere*) *catalaunica* (Damotte and Grosdidier, 1963), sección de Cuevas de Portalrubio, muestra CPRM 3B 5,5, valva derecha, longitud 491 μ . MT 2008-15-3.12. **14.** *Asciocythere cinctorensis* (Brenner, 1976), sección de Oliete, muestra 15, valva derecha, longitud 693 μ . MT 2008-15-2.16.

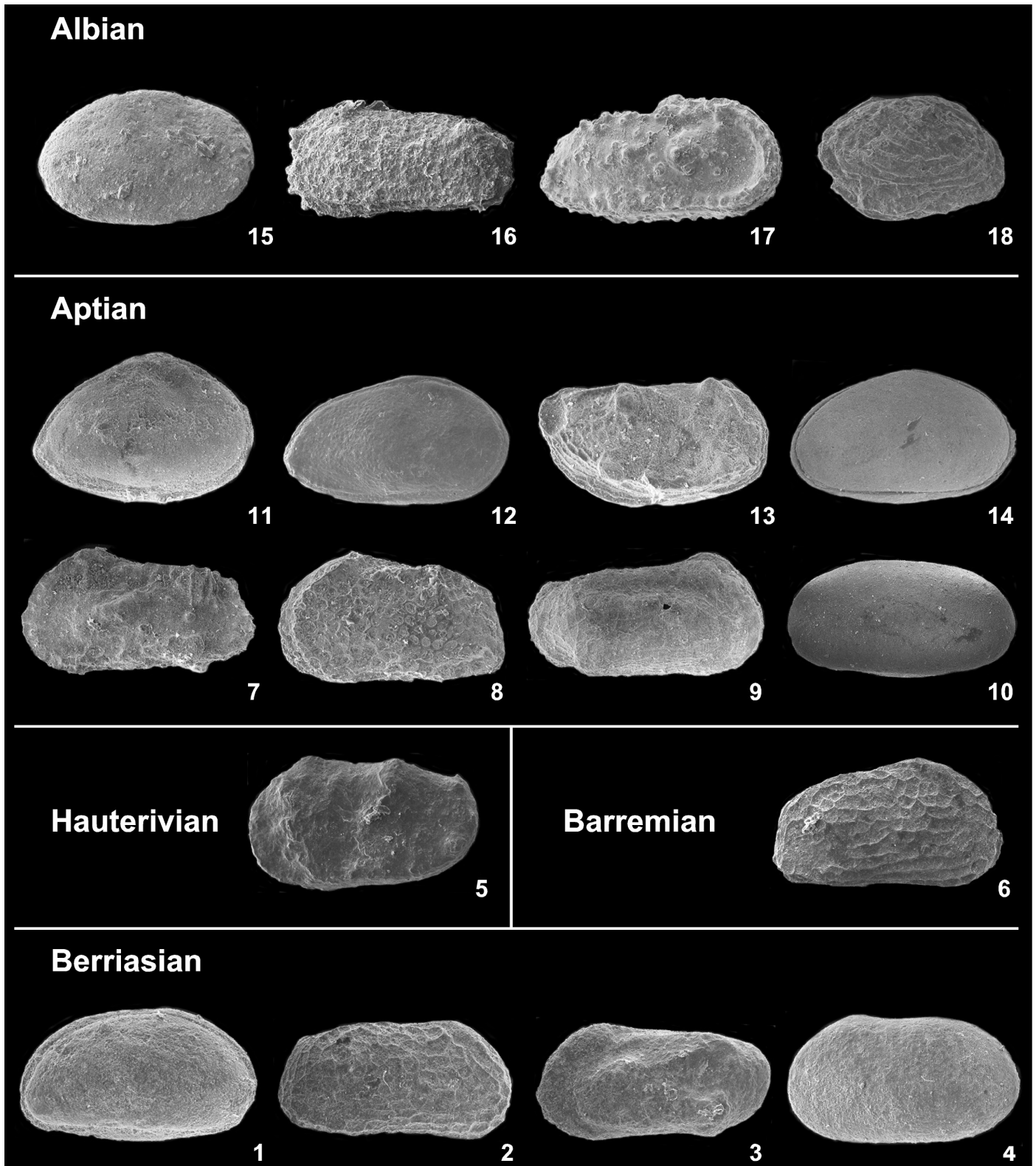
Asociación Albiense: **15.** *Cytherella* cf. *ovata* (Roemer, 1841), sección de Salvacañete, muestra Salv 4, Fm. Burgal, valva derecha, longitud 668 μ . MT 2008-15-1.1. **16.** *Platycythereis* cf. *degenerata* Triebel, 1940, sección de Salvacañete, muestra Salv-2, valva izquierda, longitud 695 μ . MT 2008-15-3.18. **17.** *Matronella matronae* (Damotte and Grosdidier, 1963), sección de Salvacañete, muestra Salv-2, valva derecha, longitud 966 μ . MT 2008-15-3.8. **18.** *Centrocythere* cf. *bordeti* Damotte and Grosdidier, 1963, sección de Aliaga, muestra 6 (Fm. Escucha), valva derecha(?) deformada, longitud 584 μ . MT 2008-15-2.18.

cum forbesii, *C. aff. parallela*, *Th. vincentei*, *C. tumescens praecursor*, *C. laevigata* var. *laevigata*, *Th. varians*, *Th. iberica*, *C. dolabrata*, *C. bispinosa*, *C. aff. valdensis*.

Valanginian freshwater association (in order of abundance): *Theriosynoecum triangula*, *Fabanella bolonien-*

sis, *Cypridea brevirostrata*, *Th. linaria*, *C. tuberculata*, *C. soriana*, *C. bispinosa*.

Hauterivian mixed brackish-marine association (in order of abundance): *Macrodentina (Dictyocythere) ex gr. mediostricta transfuga*, *Fabanella boloniensis*, *Parano-*



tacythere (*P.*) aff. *anglica*.

Hauterivian-Barremian freshwater association (in order of abundance): *Cypridea demandae*, *Theriosynoecum iberica*, *C. piedmonti*, *Th. fittoni*, *Th. castellana*, *Fabanella boloniensis*, *C. procera*, *C. isasae*, *C. clavata*, *C. cidacosia*, *C. turgida*, *C. modesta*, *C. cornuta*, *C. aragonensis*, *Th. stupenda*, *C. pseudomarina*.

Late Hauterivian – Early Barremian freshwater association (chronostratigraphically more refined, in order of abundance): *Theriosynoecum iberica*, *Cypridea isasae*, *C. clavata*, *C. modesta*, *Fabanella boloniensis*, *C. cornuta*, *C. aff. valdensis*, *Th. castellana*, *C. demandae*, *C. cidacosia*, *Th. fittoni*, *C. turgida*, *C. tuberculata*, *C. piedmonti*, *C. aragonensis*.

Barremian freshwater association (chronostratigraphically more refined, in order of abundance): *Theriosynoecum fittoni*, *Cypridea* aff. *valdensis*, *C. pseudomarina*, *C. brendae*, *C. aff. alta*, *C. clavata*.

Barremian mixed brackish-marine association (in order of abundance): *Macrodentina* (*Dictyocythere*) ex gr. *mediostriata transfuga*, *Fabanella boloniensis*, *M. (D.) gibbera*.

Aptian marine association (in order of abundance): *Cythereis* (*Rehacythereis*) cf. *btaterensis torifera*, *Platythereis algarvensis*, *Protocythere* cf. *aptensis*, *Asciocythere algarvensis*, *Schuleridea posterospinata*, *S. hexagonalis*, *Paranotacythere* (*P.*) *catalaunica*, *Macrodentina* (*Dictyocythere*) *gibbera*, *A. cinctorensis*.

Albian marine association (in order of abundance): *Cytherella* cf. *ovata*, *Matronella matronae*, *Platythereis* cf. *degenerata*.

6.2. Evaluation of the biostratigraphic usability of ostracods in the Lower Cretaceous of eastern Spain

As demonstrated in chapter 5, results of our chronostratigraphic correlations for various formations in the Lower Cretaceous of eastern Spain are in most cases rather consistent with previous stratigraphic charts (here: mostly from Salas *et al.*, 2001), as based upon other fossil groups and depositional sequence stratigraphy. However, in a few cases (namely some cases in the eastern Cameros sub-basin, chapter 5.1, Fig. 5, the northeastern Maestrazgo sub-basin, chapter 5.3, Fig. 7, or the uppermost part of the Lower Cretaceous in the Southern Iberian sub-basin, chapter 5.4, Fig. 8), our results are more or less different from those established charts.

The wealth of agreement between our ostracod chronostratigraphic correlations and the established charts (Figs. 5-8) demonstrate the principally solid base of ostracod biostratigraphy in the Lower Cretaceous. Nevertheless, its possible accuracy is not too strong, as com-

pared for instance with ammonite biostratigraphy in the Jurassic or conodont biostratigraphy in the Devonian. In most cases, supraregional (or regional, if the species is endemic to the Iberian peninsula) stratigraphic ranges of the various species at issue here comprise one, two or even more of the six Early Cretaceous stages (see figures 3-4). Only few species are restricted to very short intervals, such as the Upper Berriasian (*Cypridea vidrana*, Fig. 3) or the Lower Hauterivian (*Paranotacythere* aff. *anglica*, Fig. 4).

Therefore, the use of associations (instead of single species only) and the intersection of the individual stratigraphic ranges of their species is crucial for ostracod biostratigraphy in the Lower Cretaceous of eastern Spain (see chapter 6.1 and figures 9-10). Only in very few cases, single species (and then mainly marine ones) are significant enough to base the chronostratigraphic correlation of a sample onto one species alone. In such cases, we have almost only used species which are not endemic to the Iberian peninsula and are also known from one of the basins with better correlation to the marine biozonations (such as Northern Germany or Southern England). Or – even better – the species are marine ones, previously described from well correlated marine sequences in Southern France, Morocco or elsewhere in the Mediterranean.

Furthermore, it has – once again - become evident that marine ostracods are generally (but not strictly) better guide fossils than nonmarine ones. In our case, a simple comparison of figures 3 (stratigraphic ranges of *Cypridea* species) and 4 (stratigraphic ranges of non-*Cypridea* species, mostly marine-brackish) allows an impression about the fact that many nonmarine species have longer stratigraphic ranges than brackish or marine ones. Moreover, many marine species are biogeographically more widespread, and can therefore be compared with more basins (with possibly better and well-established chronostratigraphic correlations), which simply makes a better correlation. In consequence, the best (at least in most, but not all cases) chronostratigraphic correlations within the Lower Cretaceous of eastern Spain (as carried out by means of ostracods) are those using marine (or brackish) species occurring in marine formations or intercalations. Second best are nonmarine species of the genus *Cypridea* with their advantageous reproduction and dispersal strategies as compared to the other nonmarine genera occurring here (for instance *Theriosynoecum*, see discussions in Whatley, 1990; 1992; Schudack, M., 1999; partly challenged by Horne and Martens, 1998; Horne, 2003).

To conclude: Ostracod biostratigraphy, if treated with care and – very important! - differentiation between the various groups with respect to their ecology, biogeogra-

phy, systematics and biology, is a valuable tool for chronostratigraphic correlations within the mixed marine and (mostly) nonmarine Lower Cretaceous of eastern Spain. In cases where ostracod data are in conflict with biostratigraphic data from other fossil groups (such as charophytes or marine groups like foraminifera, dasyclads or molluscs), their validity should be weighted with great care. However, in cases where ostracod data are in conflict with simple lithostratigraphic correlations (and even the more refined approach of “depositional sequence stratigraphy” is nothing else, in principal), we are prone to favour the ostracod age determinations for the establishment or correction of stratigraphic charts.

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APPENDAGE 1

Ostracod species from the Lower Cretaceous of the Iberian chain

- Asciocythere algarvensis* Damotte, Cabral and Berthou, 1990
Asciocythere cf. *circumdata* Donze, 1964
Asciocythere cinctorensis (Brenner, 1976)
Centrocythere cf. *bordeti* Damotte and Grosdidier, 1963
Cetacella armata (Martin, 1940)
Cypridea cf. *aculeata* Jones, 1885
Cypridea alcaramae (Kneuper-Haack, 1966)
Cypridea aff. *alta* (Wolburg, 1959)
Cypridea aff. *alta wicki* Wolburg, 1959
Cypridea aragonensis (Kneuper-Haack, 1966)
Cypridea bispinosa (Jones, 1878)
Cypridea brendae Anderson, 1985
Cypridea brevirostrata Martin, 1940
Cypridea cidacosia (Kneuper-Haack, 1966)
Cypridea clavata (Anderson, 1939)
Cypridea cornuta (Kneuper-Haack, 1966)
Cypridea demandae (Kneuper-Haack, 1966)
Cypridea dolabrata (Anderson, 1939)
Cypridea dunkeri carinata (Martin, 1940)
Cypridea granulosa (Sowerby, 1836)
Cypridea isasae (Kneuper-Haack, 1966)
Cypridea laevigata var. *laevigata* (Dunker, 1846)
Cypridea modesta (Kneuper-Haack, 1966)
Cypridea aff. *parallela* (Martin, 1940)
Cypridea piedmonti (Roth, 1933)
Cypridea procera (Kneuper-Haack, 1966)
Cypridea pseudomarina Anderson, 1967
Cypridea pulchra (Kneuper-Haack, 1966)
Cypridea soriana (Kneuper-Haack, 1966)
Cypridea sp. 1 Schudack, submitted a
Cypridea sp. 2 Schudack, submitted a
Cypridea sp. 3 Schudack, submitted a
Cypridea sp. 4 Schudack, submitted a
Cypridea sp. 5 Schudack, submitted a
Cypridea sp. 6 Schudack, submitted a
Cypridea sp. 7 Schudack, submitted a
Cypridea sp. 8 Schudack, submitted a
Cypridea sp. 9 Schudack, submitted a
Cypridea sp. 10 Schudack, submitted a
Cypridea sp. A Schudack, submitted a
Cypridea sp. B Schudack, submitted a
Cypridea sp. C Schudack, submitted a
Cypridea tuberculata (Sowerby, 1836)
Cypridea tumescens praecursor (Oertli, 1963)
Cypridea tumescens tumescens (Anderson, 1939)
Cypridea turgida (Kneuper-Haack, 1966)
Cypridea aff. *valdensis* (Sowerby in Fitton, 1836)
Cypridea ventriosa Brenner, 1976
Cypridea vidrana Wolburg, 1959
Cythereis (*Rehacythereis*) cf. *btaterensis torifera* Bischoff, 1963- sensu Damotte et al., 1990
Cytherella cf. *ovata* (Roemer, 1841)
Cytherella sp.
Cytherelloidea sp. 1 Schudack, submitted b
Cytherelloidea sp. 2 Schudack, submitted b
Darwinula sp.
Eocytheropteron sp.
Fabanella boloniensis (Jones, 1882)
Haplocytheridea laevantensis Brenner, 1976
Klieana sp.
Macrodentina (*Dictyocythere*) *gibbera* Brenner, 1976
Macrodentina (*Dictyocythere*) ex gr. *mediostricta transfuga* Malz, 1958
Mantelliana perlata Wienholz, 1968
Mantelliana sp. 1 Brenner, 1976
Mantelliana sp.

- Matronella matronae* (Damotte and Grosdidier, 1963)
Matronella cf. *matronae* (Damotte and Grosdidier, 1963)
Paranotacythere (*Orthonotacythere*) *galvensis* Helmdach, 1974
Paranotacythere (*Paranotacythere*) aff. *anglica* Neale, 1960
Paranotacythere (*Paranotacythere*) *catalaunica* (Damotte and Grosdidier, 1963)
Platycythereis algarvensis Damotte, Grosdidier and Rey, 1988
Platycythereis cf. *degenerata* Triebel, 1940
Protocythere cf. *aptensis* Oertli, 1958 sensu Brenner, 1976
Protocythere cf. *camberiensis* Donze, 1964
Rhinocypris jurassica Martin, 1940
Scabriculocypris trapezoides Anderson, 1941
- Schuleridea hexagonalis* Brenner, 1976
Schuleridea posterospinata Damotte, Cabral and Berthou, 1990
Theriosynoecum castellana (Kneuper-Haack, 1966)
Theriosynoecum forbesii (Jones, 1882)
Theriosynoecum cf. *forbesii* (Jones, 1882)
Theriosynoecum fittoni (Mantell, 1844)
Theriosynoecum iberica (Kneuper-Haack, 1966)
Theriosynoecum linaria (Kneuper-Haack, 1966)
Theriosynoecum stupenda (Kneuper-Haack, 1966)
Theriosynoecum triangula (Kneuper-Haack, 1966)
Theriosynoecum varians Helmdach, 1974
Theriosynoecum vincentei (Kneuper-Haack, 1965)