ISSN (print): 1698-6180. ISSN (online): 1886-7995
www.ucm.es/info/estratig/journal.htm

Journal of Iberian Geology 37 (2) 2011: 153-160
doi: 10.5209/rev_JIGE.2011.v37.n2.4

Journal of Iberian Geology
AN INTERNATIONAL PUBLICATION OF EARTH SCIENCES

Discussion about the stratigraphic range of *Pseudofurnishius murcianus* van den Boogaard (Conodonta) in the Iberian Peninsula, from the Calasparra section (Murcia, Spain)

Discusión sobre la distribución estratigráfica de *Pseudofurnishius murcianus* van den Boogaard (Conodonta) en la Península Ibérica, a partir de la sección de Calasparra (Murcia, España)

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Received: 13/06/11 / Accepted: 21/10/11

Abstract

The biostratigraphy of Calasparra Section is well-estabished with an ammonoid biozonation and ranges from Lower to Upper Ladinian. The continuous presence of *Pseudofurnishius murcianus* van den Boogaard, a characteristic conodont species of the Sephardic realm, along the section makes it one of the most important sections in the Iberian Peninsula for the study of the species. The first apparition of *P. murcianus* in the section corresponds with the first of *Eoprotrachyceras curionii* taxon, which is the principal marker for the base of the Ladinian stage in the GSSP of the Anisian-Ladinian boundary, and the age of the youngest conodonts, based on ammonoids (Epigonus Zone) is Lower Ladinian (upper Fassanian). This is similar to the range of *P. murcianus* in the Saharonim Formation in Israel, where its earliest appearance is also Early Fassanian (Curionii zone) age.

Keywords: Conodonts, bivalves, Betic Cordillera, Middle Triassic, Spain

Resumen

La bioestratigrafía de la Sección de Calasparra está bien establecida mediante biozonación de ammonoideos, con una edad que va desde el Ladiniense inferior hasta el Longobardiense. La presencia continua de *Pseudofurnishius murcianus* van den Boogaard, una especie de conodontos característica del Dominio Sephardí, a lo largo de la sección la hace una de las más importantes de la Península Ibérica para el estudio de la especie. La primera aparición de *P. murcianus* en la sección se corresponde con el taxón *Eoprotachyceras curionii,* que es el principal marcador para la base del piso Ladiniense en el GSSP del límite Anisiense-Ladiniense, mientras que la edad de los conodontos más recientes, basada en ammonites (Epigonus Zone) es Ladiniense Inferior (Fassaniense superior) Este rango es similar al de *P. murcianus* en la Formación Saharonim en Israel, de edad Fassaniense inferior (Zona Curionii).

Palabras clave: Conodontos, bivalvos, Cordillera Bética, Triásico Medio, España

1. Introduction

The Betic Cordillera is a mountain system in southern Spain that extends in SW-NE direction from the city of Cadiz on the Atlantic Ocean to the Balearic Islands in the Mediterranean. The Cordillera is part of the Gibraltar Arc that represents the westernmost part of the Alpine system, generated by the convergence of the African and Iberian plates in Tertiary times (Vera, 2001; López-Gómez, 2002; Martín-Algarra and Vera, 2004; Pérez-Lopez and Pérez-Varela, 2007).

Extending S-SE of the Iberian Massif and Guadalquivir Valley, the External Zone of the Betic Cordillera is divided in the large Prebetic and Subbetic tectono-stratigraphic domains (Fig. 1), that comprise thrust-sheets of Triassic to Miocene mainly marine successions (Pérez-Lopez and Pérez-Varela, 2007). The Prebetic is the nearest to the Iberian Masif while the Subbetic is the more distant. The Internal Zone in the southernmost part of the Betic Cordillera is strongly deformed and frequently showing metamorphism.

Our study area, southeast of Calasparra (NE of the province of Murcia) straddles the limit between the Prebetic and Subbetic domains.

The section presents traditional "Germanic-type" units (Pérez-Valera and Pérez-López, 2003). The lower one is of Budsandstein facies, formed by detritic red sandstones and clays. Above it, Muschelkalk deposits consist of carbonate successions of dolomites, limestones and marly limestones, increasingly dominated by marls towards the upper part. This unit was defined as Cehegín Formation (Pérez-Valera and Pérez-López, 2008) and can be correlated with the Majanillos Formation (Pérez-López, 1991) that was defined in the central part of the Betic Cordillera. Finally, a detrital-evaporitic unit with shale, sandstone, gypsum, and occasional basic subvolcanic rocks represents a characteristic Keuper facies that belong to the Jaén Keuper Group (Pérez-López 1991). Our study encompasses the Muschelkalk deposits of the Cehegín Formation.

2. Biostratigraphy

The section, located SE of the locality of Calasparra (Murcia) and S of the Sierra de Molino (MAGNA sheet Nº 890 "Calasparra", coordinates 38º 12' 30"N 1º 38' 10 W). The column, 90 m thick, comprises five units based on the ammomoid biozonation of Pérez-Valera *et al.* (2005), Pérez-Valera and Pérez-López (2008) and Pérez-Valera *et al.* (2011) (Fig. 2).

Unit 1: 8m thick, and above the Buntsandstein facies; is mainly composed of thick laminated dolomite packs, with algal structures and evaporate moulds in different degrees of bioturbation. On top, a fossiliferous level of black nodular limestone yielding numerous fragments of bivalves and small gastropods, foraminifers like *Lamelliconus?* sp., crinoids, fish micro-remains and polen, is covered by a hardground.

Unit 2: 25 m thick, in the base presents a ferruginous bioclastic nodular limestone with intensive bioturbation

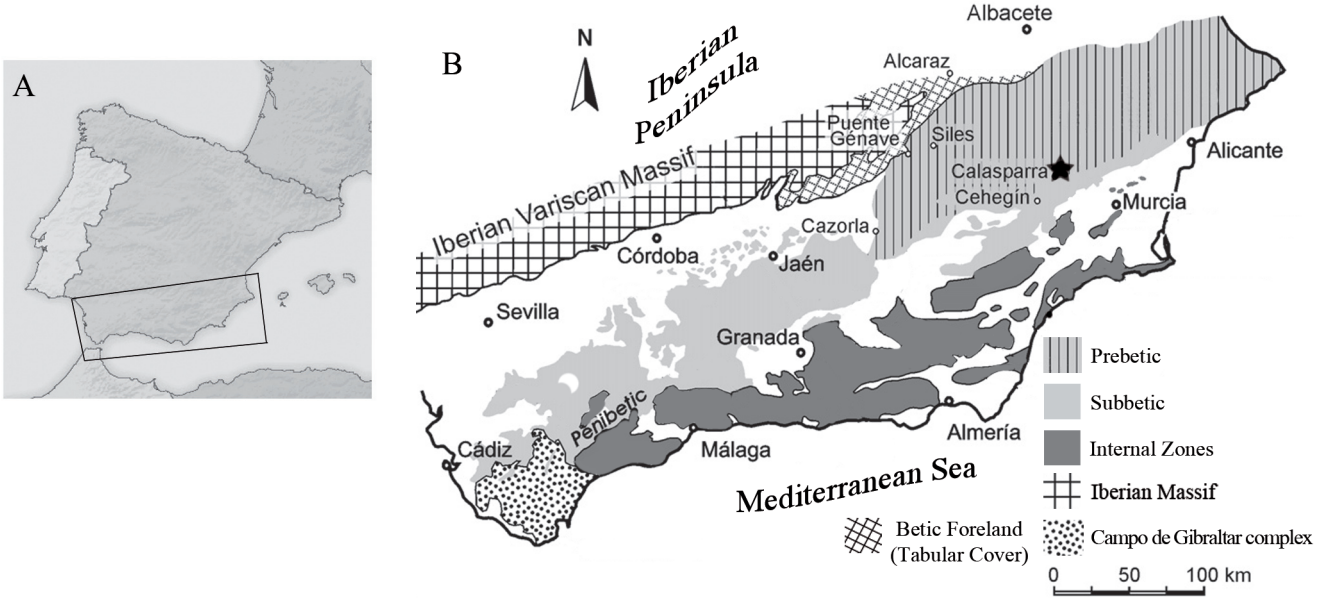


Fig. 1 – Main tectonic units in the Betic Cordillera; star marks location of the section at Calasparra (Modified from Pérez-López and Pérez-Valera (2007).

Fig. 1 – Principales unidades tectónicas de la Cordillera Bética; la estrella señala la localización de la sección en Calasparra (Modificado de Pérez-López y Pérez-Valera (2007)

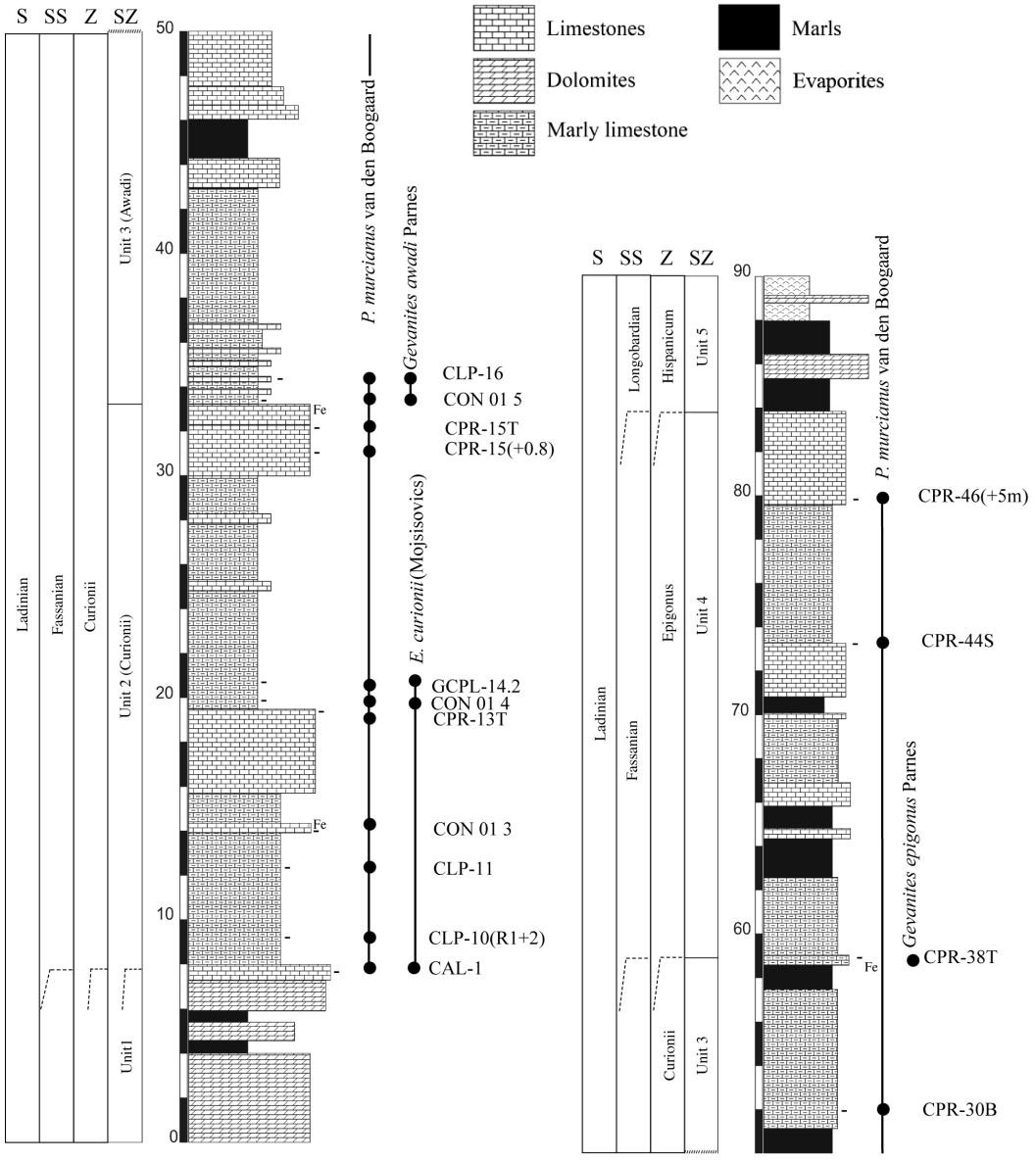


Fig. 2 – Stratigraphic column of the section of Calasparra. S: Stage, SS: Substage, Z: Zone, SZ: Subzone. CAL-1 includes samples CLP-6 CLP-8, CON 01 2, CPR-10.4 and CLP-10(R1+2) (see table 1).

Fig. 2 – Columna estratigráfica de la sección de Calasparra. S: Piso, SS: Subpiso, Z: Zona, SZ: Subzona. CAL-1 incluye las muestras CLP-6 CLP-8, CON 01 2, CPR-10.4 y CLP-10(R1+2) (ver tabla 1)

and very rich in fossils, including the ammonite *Eotrachyceras curionii* (Mojsisovics). At 12m, a massive limestone with parallel and diffuse lamination corresponds with a second fossiliferous hardground. Above, there are alternating marly limestone and marls, followed by stratified wavy marls with bioclastic limestone (tempestite) packs of variable thickness and abundant gutter and pot cast structures with bioturbated marly limestone at top. In the upper part, follows a 3 m thick level of limestone layers, each topped by a ferruginous surface and accumulated hardground type bioclasts. In this unit, many fossiliferous levels are found, including conodonts (samples CAL-1, CAL-2 and CON 01 3 at the base, CPR-13T, Con 01 4, GCPL-14.2 in the middle and CPR-15 (+0.8), CPR-15T, CON 01 5, CLP-16 at the top), fish micro-remains, briozoans, echinoderms, bivalves like C*ostatoria sp., Umbostrea sp. and Unicardium sp.* and foraminifers like *L.* cf. *multispirus* (Overhauser), *L*. aff. *procerus* (Liebus) and *Pilamminella generica* Salaj, *T. eomesozoicus* (Oberhauser) and *Aulotortus praegaschei* (Koehn-Zaninetti) (Márquez-Aliaga *et al.,* 1999; Márquez-Aliaga and Márquez, 2000). The unit corresponds to the Curionii subzone, characterized by *Eotrachyceras curionii* (Mojsisovics) that marks the lower part of the Curionii Zone, the base of the Fassanian (Lower Ladinian). Other ammonoids found in the unit are *Israelites ramonensis* Parnes and *Negebites zaki* Parnes (Pérez-Valera *et al.* 2011).

Unit 3: 25 m thick, is formed by lightly bioturbed layers of grey marls alternating with marly limestone (mudstone to wackestone), with few bioclasts and variable bioturbation. Higher up in the unit, marly limestone and marls with lutite and thin-bedded bioclastic limestone levels

alternate. At top, the unit ends with a hardground of ferruginous limestone, with many bioclasts, especially bivalves. Fossil record is more abundant in the lower part of the unit, which starts with the appearance of *Gevanites awadi* Parnes at its base. Among ammonoids further occur *Gevanites virgiliae* Goy and *Gevanites altecarinatus* Parnes (Pérez-Valera, 2005; Pérez-Valera *et al.*, 2011). The fossil record include also bivalves as *Plagiostoma striata* (Schlotheim), *Chlamys schroeteri* (Giebel), *Chlamys* sp., *Gervilleia joleaudi* Schmidt, *Leptochondria alberti* (Goldfuss), *Modiolus myoconchaeformis* (Philippi), *Pseudocorbula gregaria* (Münster), *Pleuromya elongata* (Schlotheim), *Costatoria kiliani* (Schmidt), *Neoschyzodus laevigatus* (Goldfuss), *Bakevellia costata* (Schlotheim),"*Enatiostreon*"cf. *flabellum* Schmidt and *Unionites* sp., foraminifers as *Lamelliconus* cf. *procerus* (Liebus), *Nodosaria ordinata* Trifonova, the annelid *Spirorbis phlyctaena* Bronnimann and Zaninetti and gastropods. (Márquez-Aliaga *et al.,* 1999; Márquez-Aliaga and Márquez, 2000) Microfossils include conodonts (*P. murcianus*, in samples CON 01 5, CLP-16 at base and CPR-30B at top) and fish micro-remains. *Gevanites awadi* allows the attribution of the unit to the Awadi- subzone of the Fassanian Curionii-Zone (lower Ladinian).

Unit 4: 24 m thick, consists of alternating marls and marly limestones. Further up, most of the unit consists of alternations of platy bioclastic limestone, marls and lutite levels. The fossil record starts at its base with the first apparition of *Gevanites epigonus* Parnes. This rather scarce unit yields bivalves (*P. gregaria, Bakevellia* sp.) and gastropods; microfossils include *P. murcianus* (samples CPR-44S and CPR-46(+5m) and fish micro-remains. *Gevanites epigonus* Parnes attributes this unit to the Epigonus zone, equivalent to the "Eoprotrachyceras" gredleri zone in Balini *et al.* (2010), of upper part of the Fassanian, (Lower Ladinian).

Unit 5: 6 m thick, is formed by brown dolomites, evaportites, few green lutites and finally a grey and white chalk level that represent the transition to a regressive episode of Keuper facies. It is possible that this unit corresponds to the Hispanicum zone, characterized by *Protrachyceras hispanicum*, and of Longobardian (upper Ladinan) age. Perez-Valera *et al.* (2011) cited a record of *P. hispanicum* in the equivalent levels of a close outcrop.

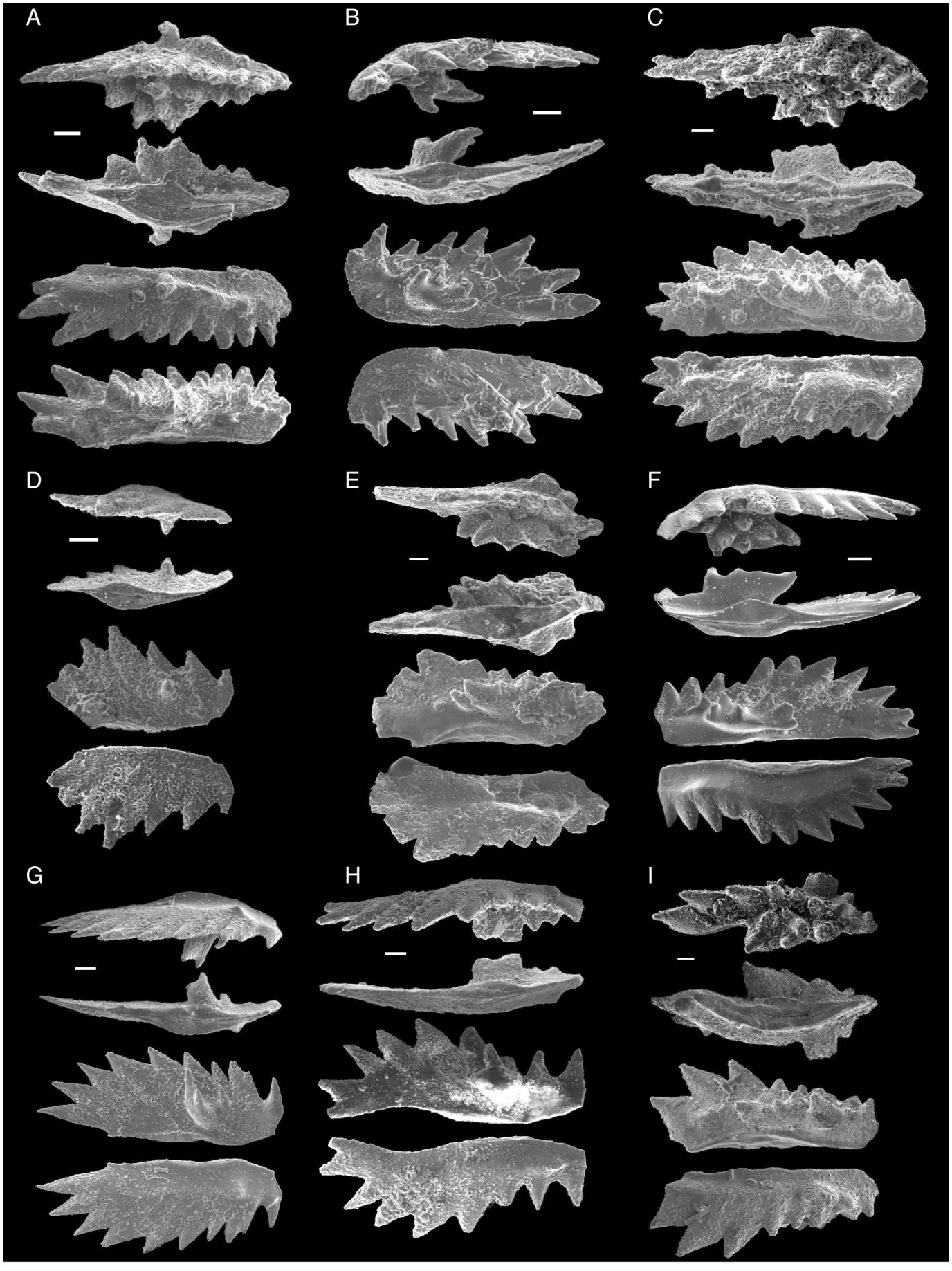
In agreement with the acceptance by the ISTS of the proposition of the Ladinian GPSS at the base of Curionii Zone (as proposed by Bracks *et al.* 2003), the first occurrence of *E. curionii* var. *ramonensis* in the section of Calasparra would correspond with the base of the lower Fassanian (Lower Ladinian) Curionii Zone. The Awadi -Subzone would correspond to the middle Fassanian, the Epigonus Zone to the upper Fassanian and the top of the section could be Hispanicum zone (lower Longobardian).

3. The conodont fauna at Calasparra

Conodonts from Calasparra belong to *Pseudofurnishius murcianus* van den Boogaard, the most common Middle Triassic species in the Iberian Peninsula. The denticulated platform that appears on, at least, the inner side of the P_1 element, makes *P. murcianus* a very characteristic species, easily distinguishable from other coetaneous conodont species. A very wide morphological variability of this structure develops during ontogeny, especially

Fig. 3 – Conodonts of the section of Calasparra. *Pseudofurnishius murcianus* van den Boogaard. Specimens deposited in the Museum of Geology of the University of Valencia. Upper, lower, inner and outer views. All scales 50 μm.
Right P_1 element. CLP-6. MGUV-10251. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Left P_1 element. CLP-6. MGUV-10255. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Right P_1 element. CLP-8. MGUV-10258. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Right P_1 element. CON 01 2. MGUV-10307. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Right P_1 element. CLP-11. MGUV-10325. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Left P_1 element. GCLP-14.2. MGUV-10334. Unit 2, lower Ladinian (Subzone Curionii, early Fassanian).
Right P_1 element. CON 01 5. MGUV-10336. Unit 3, lower Ladinian (Subzone Awadi, early-late Fassanian).
Right P_1 element. CPR-44. MGUV-10347. Unit 4, lower Ladinian (Zone Epigonus, late Fassanian).
Right P_1 element. CPR-46. MGUV-10358. Unit 4, lower Ladinian (Zone Epigonus, late Fassanian).

Fig. 3 – Conodontos de la sección de Calaparra. *Pseudofurnishius murcianus* van den Boogaard. Especímenes depositados en el Museo de Geología de la Universidad de Valencia Vistas superior, inferior, interna y externa. Todas las escalas 50 μm.
Elemento P_1 derecho. CLP-6. MGUV-10251. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 izquierdo. CLP-6. MGUV-10255. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 derecho. CLP-8. MGUV-10258. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 derecho. CON 01 2. MGUV-10307. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 derecho. CLP-11. MGUV-10325. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 izquierdo. GCLP-14.2. MGUV-10334. Unidad 2, Ladiniense inferior (Subzona Curionii, Fassaniense inferior).
Elemento P_1 derecho. CON 01 5. MGUV-10336. Unidad 3, Ladiniense inferior (Subzona Awadi, Fassaniense superior-inferior).
Elemento P_1 derecho. CPR-44. MGUV-10347. Unidad 4, Ladiniense inferior (Subzona Curionii, Fassaniense superior).
Elemento P_1 derecho. CPR-44. MGUV-10358. Unidad 4, Ladiniense inferior (Subzona Curionii, Fassaniense superior).


A
B
C
D
E
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I

		P. murcianus	M elements	S elements
Unit 4	CPR-46(+5m)	1		
	CPR-44S	9	2	2
Unit 3	CPR-30B			2
	CLP-16	1		
	CON 01 5	4		
Unit 2	CPR-15T			1
	CPR-15(+0.8)			1
	GCLP-14.2	1		
	CON 01 4	4		
	CPR-13T	2	2	
	CON 01 3	3		
	CLP-11	3		
	CLP-10(R1+2)	1		
	CPR-10.4	2	5	1
	CON 01 2	45	11	15
	CLP-8	18	2	
	CLP-6	6		

Table 1 – Samples with conodont fossil record in the section of Calasparra.

Tabla 1 – Muestras con registro fósil de conodontos en la sección de Calasparra.

in the more developed stages of the species (Bandel and Waksmundzki, 1985; Plasencia, 2009; Plasencia *et al.*, 2010), and not uncommon is the presence of one or more denticles on the outer side that in some specimens forms a platform that can overgrow the inner one, generating biplatform specimens.

The preservation of the material is in general good, with the most common alterations being broken elements, and, in some specimens, a heavy surface alteration. The collected specimens represent different ontogenetic stages of the species, from the less developed, with one denticle on the inner platform (Fig. C, D and G) to well developed ones with denticles on an outer platform (Fig. 3, A, C, E and I) or naked (Fig. 3, B, F and H). A synthesis of the conodont bearing samples can be found in Table 1.

4. Discussing the age of *Pseudofurnishius murcianus*

Pseudofurnishius murcianus is an important Ladinian biostratigraphic marker of the Sephardic province as it is often the only species found in many localities. Its stratigraphic range has been the object of discussion for a long time. Since Simon (1966) ascribed a Middle to Upper Triassic age to the rocks from which van den Boogaard (1966) described the species, several opinions have been published. One advocates an Early Ladinian origin while others prefer an Upper Ladinian (Longobardian) age.

In the first group, Hirsch (1972) proposed a Lower to Upper Ladinian age based on the ammonoids in the Saharonim Formation (Israel) found together with *P. murcianus*, and suggested a possible Upper Anisian origin. In Hirsch and Gerry (1974), a Lower Ladinian to Early Upper Ladinian age was suggested for the *Pseudofurnishius* assemblage zone, and an Upper Ladinian age for the *Pseudofurnishius murcianus – Epigondolella mungoensis* zone. Recently, Plasencia *et al.* (2007) pointed out an Early Fassanian age for *P. murcianus*.

The second group, that includes, among others, Nicora (1981), Gullo and Kozur (1991) and Kozur (1993), pointed to a Late Ladinian (upper Longobardian) origin of *P. murcianus* and a range up into the Early Carnian. The second authors proposed a phylomorphogenetic lineage that included *Pseudofurnishius priscus, P. huddlei* and several subspecies of *P. murcianus* (*P. murcianus praecursor, P. murcianus murcianus* and *P. murcianus* n. subsp. B), based mainly on the progressive reduction and final disappearance of the outer platform and stage of development of the inner platform. Using this scheme, they proposed a lower middle Longobardian age for *P. huddlei* and a middle Longobardian to Cordevolian age for *P. murcianus*, while successive subspecies of *P. murcianus,* overlapping each other, comprised associations, successively dominated by *P. murcianus praecursor* (early – middle Longobardian), *P. murcianus murcianus* (upper Longobardian) and *P. murcianus* n. sp. B (Cordevolian).

It must be emphasized here that while an Early Ladinian to Upper Ladinian range for *P. murcianus* applies well within the Sephardic realm, the shift of slightly hypersaline environments to South Alpine Tethys periphery towards the end of the Ladinian, which persevered during the Early Carnian, brought typical Sephardic biota outside the Sephardic Realm.

As Calasparra has a well-established biostratigraphy with materials that range from Fassanian (Curionii and Awadi Subzones, Epigonus Zone) to lower Longobardian (Hispanicum Zone), the presence of *P. murcianus* in different samples along the Fassanian materials makes the section one of the most complete Middle Triassic sections, not only in the Betic Cordillera, but also in the whole Iberian Peninsula, to study the early evolution of the species.

The conodonts found in Calasparra are of special importance, especially the specimens from unit 1 and the lower part of the Unit 2 (Fig. 3, A-C). This is the first time that such an early age for *Pseudofurnishius murcianus* has been evidenced in the Iberian Peninsula. Moreover, they are of similar age than *P. murcianus* in the Saharonim Formation at Ramon in Israel, found in the same interval as a rich cephalopod assemblage comprising among others *E. curionii ramonensis*, of early Ladinian (lowermost Fassanian) age (Huddle, 1970; Hirsch and Gerry, 1974; Benjamini *et al.*, 2005). Thus, the stratigraphical range

of *P. murcianus* should be lowered in the Iberian Peninsula thanks to the findings in Calasparra close and below *Israelites ramonensis* Parnes fossils (Pérez-Valera *et al.*, 2011).

For the upper limit of *P. murcianus,* a Lower Carnian (Lower Cordevolian) age in the northern Apuseni Mountains was proposed by Kozur (1980), where the species appears together with *Sephardiella diebeli*, *S. mostleri*, *Metapolygnathus polygnathiformis* and *M. tadpole*. Since then, several authors (Nicora, 1981, Gullo and Kozur, 1991, Kozur, 1993 or Rigo *et al.,* 2006) found *P. murcianus* in Upper Ladinian or Early Carnian levels. In Calasparra, the age of the youngest conodonts in the section (Unit 4, Fig. 3, 8-9), based on ammonoids (*G. epigonus*) is Lower Ladinian (upper Fassanian).

5. Conclusions

The Calasparra section has a well-established biostratigraphy thanks to an ammonoid biozonation that ranges from Upper Anisian (Illyrian) to Upper Ladinian (Longobardian) The continuous occurrence of *P. murcianus* within the Fassanian materials of the section makes it one of the most important localities in the Iberian Peninsula for the study of the evolution of the species.

It is of special significance that, mainly as a consequence of the establishment of the Ladinian GSSP at the base of the Curionii Zone in the Southern Alps, the first occurrence of *P. murcianus,* in the two lower units of the Calasparra section, is Fassanian (Lower Ladinian). That confirms the age given by Hirsch (1972), Hirsch and Gerry (1974) and Plasencia (2007) for the species.

Acknowledgements

We want to thank to Drs. Francis Hirsch (Naruto University of Education, Japan) Alberto Pérez-López (University of Granada, Spain) and Juan Alberto Pérez-Valera (Complutense University of Madrid, Spain) for his comments, which helped us to improve the results.

This work has been supported by the Chinese Academy of Sciences (Young International Scientist Grant "2010Y2ZA02") and by the "Agencia Española de Cooperación Internacional para el Desarrollo" of the "Ministerio de Asuntos Exteriores y Cooperación (MAEC-AECID)".

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