

Correlation between the base of Drumian Stage and the base of middle Caesaraugustan Stage in the Iberian Chains (NE Spain)

RODOLFO GOZALO, JUAN BAUTISTA CHIRIVELLA MARTORELL, JORGE ESTEVE & ELADIO LIÑÁN



Inter-regional Cambrian correlations are difficult amongst different palaeogeographic provinces, because of a lack of shared genera and species between different palaeogeographic provinces. The Drumian Stage shows this difficulty because it was defined by the FAD of the agnostoid *Ptychagnostus atavus*, which species has not yet been found in the Mediterranean subprovince. Thus it is necessary to establish a correlation between the ISCS scale and the local scale using other trilobites. New data from the Iberian Chains and a review of previous works suggest that the bases of *Pardailhania hispida* and *Ptychagnostus atavus* zones are approximately equivalent. Therefore *Pardailhania hispida* FAD could be used to mark the beginning of the Drumian Stage in the Mediterranean region. This level is easily identifiable in several places: Montagne Noire (France), Cantabrian Mountains, Demanda Mountains and Iberian Chains (Spain), Sardinia (Italy), Amanos and Sultan Mountains (Turkey), and, probably, AntiAtlas (Morocco). • Key words: trilobites, biostratigraphy, Cambrian Stage 5 – Drumian boundary, middle Cambrian / Cambrian Series 3, Mediterranean region.

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Rodolfo Gozalo (corresponding author) & Juan Bautista Chirivella Martorell, Departamento de Geología, Universitat de València, C/ Dr. Moliner 50 E-46100 Burjassot, Spain; rodolfo.gozalo@uv.es, jchirive@xtec.cat • Jorge Esteve & Eladio Liñán, Área y Museo de Paleontología, Departamento de Ciencias de la Tierra – Instituto Universitario de Ciencias Ambientales (IUCA), Universidad de Zaragoza, E-50009 Zaragoza, Spain; jorgeves@unizar.es, linan@unizar.es

During recent years the International Subcommission on Cambrian Stratigraphy (ISCS) has been engaged in defining new series and stages for the Cambrian System (see Peng *et al.* 2009). One of the most important problems facing inter-regional correlation in the Cambrian is the lack of genera and species shared between different palaeogeographic provinces. For example, many of the zonal trilobite species for Cambrian Series 3 are representatives of the family Ptychagnostidae, and the Drumian Stage was defined by Babcock *et al.* (2007) at the first occurrence of *Ptychagnostus atavus*, whereas localities in the Mediterranean subprovince (*sensu* Sdzuy *et al.* 1999; Fig. 1) do not yield any ptychagnostids. Nevertheless, a correlation between the official chronostratigraphy ISCS scale and the Mediterranean scale is needed. Therefore this correlation has to be carried out using polymeroid trilobites. Our aim is to recognize the base of Drumian Stage in the Iberian Chains (NE Spain).

Hitherto, the base of *Ptychagnostus atavus* Zone has been correlated with an undetermined level in the upper part of the lower Caesaraugustan (Sdzuy 1971, 1972;

Shergold & Geyer 2003). Caesaraugustan biozonation of the Iberian Peninsula was developed originally by Sdzuy (1968). However each zone in Caesaraugustan was used with different criteria (*e.g.* Acme zones, assemblage zones, range zones or phylozones, see Álvaro & Vizáino 1998). These disagreements as to criteria make any international correlation difficult. We have worked on the revision of the Caesaraugustan zones in various sections of the Iberian Chains (northeast Spain). The new detailed samplings allow us to propose interval phylozones throughout the Caesaraugustan Stage. The sections studied are close to the villages of Murero, Jarque, Villafeliche, and Purujosa, which are located about 100 km west and south-west of Zaragoza, in the Aragonese branch of the Iberian Chains (Fig. 2). From a geological point of view, these localities belong to the Badules Unit (see Gozalo & Liñán 1988).

We have studied the trilobites of the transition from lower to middle Caesaraugustan succession from the basal part of the Murero Formation in five sections: Rambla de Valdemiedes 1 and 2 (RV1 and RV2; Liñán & Gozalo 1986; Gozalo *et al.* 1996, 2003a; Chirivella Martorell

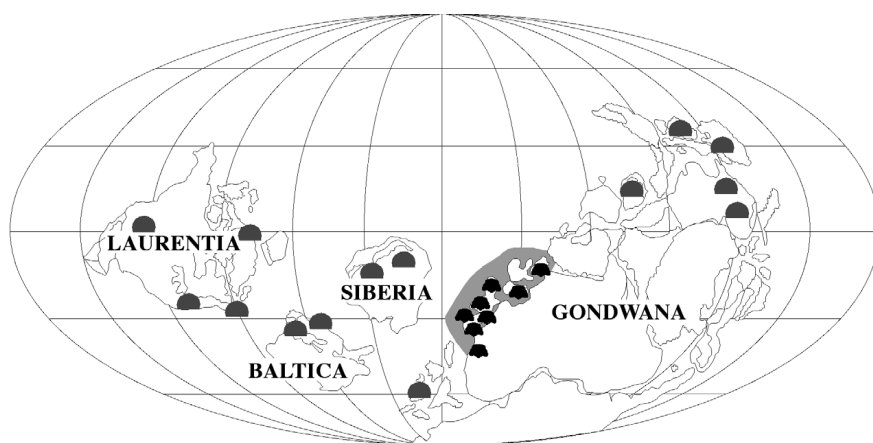


Figure 1. Distribution of *Ptychagnostus atavus* and *Pardailhanian hispidia* [plotted on the McKerrow *et al.* (1992) palaeogeographic map]. These two species have not been recorded in the same areas, *Pardailhanian hispidia* (Thoral, 1935) is restricted to the Mediterranean Subprovince in contrast to *Ptychagnostus atavus* (Tullberg, 1880) with a much more widespread distribution.

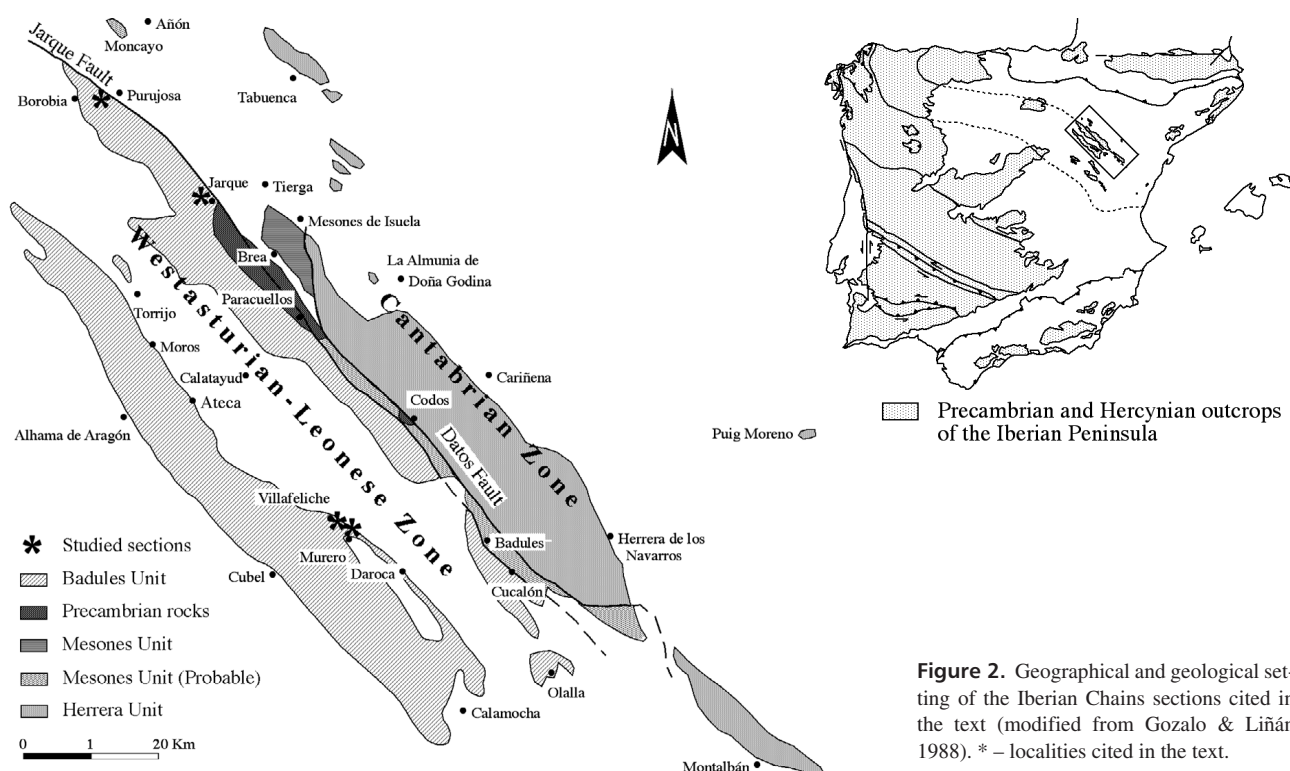


Figure 2. Geographical and geological setting of the Iberian Chains sections cited in the text (modified from Gozalo & Liñán 1988). * – localities cited in the text.

2008; Liñán *et al.* 2008), Jarque 1 (J1: Liñán *et al.* 1996, 2008, Chirivella Martorell 2008), Villafeliche 1 (Vil: Gozalo *et al.* 1993, 1996; Chirivella Martorell 2008) and Purujosa 6 (Pur6, unpublished data).

Biostratigraphic framework

The classical Spanish middle Cambrian biozonation was established by Sdzuy (1968, 1971, 1972) and has been used with minor modifications until now (*i.e.* Liñán & Gozalo 1986; Sdzuy *et al.* 1996; Álvaro & Vizcaíno 1998; Liñán *et al.* 2002, 2004; Gozalo *et al.* 2003b, 2008; Esteve *et al.* 2008; Fig. 3). From a historical point of view the Mediter-

anean zones that are involved in the base of Drumian Stage seem to correspond with the *Badulesia granieri* and *Pardailhanian hispidia* zones (*sensu* Sdzuy 1968, 1971, 1972). According to Liñán *et al.* (1993) the boundary between these zones also marks the lower-middle Caesarugustan boundary.

Sdzuy (1968, 1971, 1972) put the base of *Pardailhanian hispidia* level at the FAD of *Pardailhanian hispidia hispidia*; however the older specimens of *Pardailhanian hispidia* n. spp. were recorded together with *Badulesia granieri* and *Badulesia paschi* in the previous level. Therefore the FAD of *Pardailhanian hispidia* lies lower than the former use of the *P. hispidia* Zone that was used as acme zone by Sdzuy (1968, 1971, 1972) and considered as an interval zone by

Sdzuy 1968			Sdzuy 1971, 1972		Liñán & Gozalo 1986		Sdzuy <i>et al.</i> 1996, 1999; Liñán <i>et al.</i> 2002, 2004; Gozalo <i>et al.</i> 2003b			Álvaro & Vizcaíno 1998, Esteve <i>et al.</i> 2008, Gozalo <i>et al.</i> 2008			New proposal		
PARDAILHANIA (pars)			SOLENOPLERUOPSIDAE (pars)		SOLENOPLERUOPSIDAE (pars)		CAESARAUGUSTAN (pars)			CAESARAUGUSTAN (pars)			CAESARAUGUSTAN (pars)		
<i>Pardailhania hispanica</i>			<i>Pardailhania</i> (pars)		2		<i>Pardailhania</i> (pars)			<i>Pardailhania hispanica</i>			<i>Pardailhania multispinosa</i>		
<i>Pardailhania hispida</i>			<i>Pardailhania</i> (pars)		1		<i>Pardailhania</i> (pars)			<i>Pardailhania hispida</i>			<i>Pardailhania hispida</i>		
<i>Badulesia granieri</i>			<i>Badulesia</i> (pars)		4		<i>Badulesia</i> (pars)			<i>Badulesia granieri</i>			<i>Badulesia granieri</i>		
<i>Badulesia juliverti</i>					3										
<i>Badulesia tenera</i>			<i>Badulesia</i> (pars)		2		<i>Badulesia</i> (pars)			<i>Badulesia granieri + juliverti</i>			<i>Badulesia tenera</i>		
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			<i>Badulesia</i> (pars)				<i>Badulesia</i> (pars								

Figure 3. Sketch showing the main biostratigraphic subdivisions of the level studied in the Middle Cambrian of the Spain and France. *B.p.*: *Badulesia paschi*, *g. + p.*: *granieri + paschi*

Liñán & Gozalo (1986), Álvaro & Vizcaíno (1998) and others. Nevertheless they did not change the position of the lower boundary of the *P. hispida* Zone. The problem has been that all the researchers until now accepted the *facto* Sdzuy's idea about the existence of two subspecies of *Pardailhanian hispida*; although *Pardailhanian hispida* n. spp. never was defined and/or figured (Sdzuy 1971, table 1; 1972, table 2). Currently we accept that *Pardailhanian hispida* has a wide and continuous morphological variation within the features of cranidia (Chirivella Martorell 2008, Esteve et al. 2008) and it is not possible to recognise two subspecies, as Sdzuy had proposed. Thus, the lower boundary of the *Pardailhanian hispida* interval Zone should be placed at the *P. hispida* FAD, slightly below Sdzuy's original definition for the *P. hispida* Zone (Figs 3, 4). This modification of the systematic interpretation of *P. hispida* makes it necessary to redefine the *Badulesia granieri* and *Pardailhanian hispida* zones.

Badulesia granieri interval Zone

Synonymy: "Nivel de *B. granieri*" (part.), sublevel "*B. juliverti*" (Sdzuy 1968). "Nivel de *B. juliverti* y *B. granieri*" (Sdzuy 1971). "Biozona *Badulesia granieri* + *Badulesia juliverti*" (Liñán & Gozalo 1986). "Superbiozone à *B. granieri*" (part.) and "phylozone à *B. juliverti*" (Álvaro & Vizcaíno 1998). See Fig. 3.

Our proposal is to consider this zone as an interval phylozone, the base of which coincides with the *Badulesia granieri* FAD and the top is the level immediately below the *Pardailhanian hispida* FAD.

The trilobites recorded in the Iberian Chains in this time interval (see Chirivella Martorell 2008; Fig. 5) are: *Pernopsis acadica*, *Condylomyge* sp., *Eccaparadoxides asturianus*, *E. sulcatus*, *E. sequeirosi*, *E. acadicus* (Fig. 6K, L), *Badulesia granieri*, *B. tenera*, *Parabailiella schmidtii*, *P. languedocensis*, *Bailiella* cf. *tenuicincta* and *Ctenocephalus* (*Hartella*) cf. *terravovis*.

So far *Badulesia granieri* has been recorded in France (Montagne Noire: Courtessole 1973, Álvaro & Vizcaíno 1998); in Spain (Sdzuy 1961, 1968, 1969; Liñán & Gozalo 1986; Gámez et al. 1991; Gozalo et al. 1993; Liñán et al. 1995) and Morocco (Geyer et al. 1995, Geyer & Landing 2006). Furthermore, it may be possible to recognise equivalent levels of this zone in Turkey and Italy, where the index taxa for the previous and/or subsequent zones have been recognized.

Pardailhanian hispida interval Zone

Synonymy: "Nivel de *B. granieri*" (part), sublevel "*B. paschi*" and "Nivel de *P. hispida*" (Sdzuy 1968). "Nivel de *B. paschi* y *B. granieri*" and "Nivel de *P. hispida*" (Sdzuy 1971). "Biozona de *Badulesia granieri* + *Badulesia juliverti*" and biozona "*Pardailhanian hispida*" (Liñán & Gozalo 1986). "Superbiozone *B. granieri*", "phylozone à *B. paschi*" and "phylozone à *P. hispida*" (Álvaro & Vizcaíno 1998). See Fig. 3.

We consider the *Pardailhanian hispida* Zone as an interval phylozone, the base of which lies at the FAD of *Pardailhanian hispida* and the top immediately below the FAD of *Pardailhanian multispinosa* (see Esteve et al. 2008).

System Tracts	Seq.	Stratigraphic Events	Series	Iberian Stages		Trilobites zones	Cambrian Stages and series proposed by the ISCS	
LST	S8	Intra Languedocian regressive pulses	MIDDLE CAMBRIAN	LANGUEDOCIAN		Unnamed	GUZHANGIAN	SERIE 3
HST	S7							
TST								
LST		Base-Languedocian Regres		S. thoralis+S.marginata				
HST	CAESAR-AUGUSTAN				Upper	S. simula	DRUMIAN	
TST						S6		
		S.ribeiroi+S.verdiagana						
		S. ribeiroi						
		Middle		P. sdzuyi				
P. multispinosa								
P. hispida								
HST	S5	Mid Leonian Regression		LEONIAN	Lower	Badulesia granieri	STAGE 5	
						Badulesia tenera		
TST	S5					Upper		
				Middle		Eccaparadoxides sdzuyi		
			Lower	Acadoparadoxides mureoensis				

Figure 4. Middle Cambrian chronostratigraphic units for the Mediterranean Subprovince (modified from Liñán *et al.* 2002) and the correlation with the Cambrian Stages and Series proposed by ISCS, with a subdivision into sequences and systems tracts (from Gámez *et al.* 2009). Abbreviations: HST – highstand system tract; LST – lowstand system tract; TST – transgressive system tract.

Our proposal to define the *P. hispida* Zone as an interval phylozone implies that the levels with *Badulesia paschi* (former *B. granieri* + *B. paschi* Subzone) that occur in the top of *B. granieri* Zone (lower Caesaraugustan) currently are the base of *P. hispida* Zone (middle Caesaraugustan). The *P. hispida* Zone seems to bear the highest diversity and relative abundance of trilobites in the Iberian Chains (see Chirivella Martorell 2008; Fig. 5). At least eighteen species have been collected in the lower part: *Peronopsis acadica*, *P. segmenta* (Figs 6A–C, 7), *Peronopsella westergardi*, *Diplagnostus planicauda* (Figs 6G–I, 8), *Condylomyge rex* (Fig. 6D–F), *Pardailhania hispida* (Fig. 6M), *Badulesia granieri*, *B. paschi*, *Eccaparadoxides asturianus*, *E. sequeirosi*, *E. acadicus* (Fig. 6K, L), *E. rouvillei* (Fig. 6J), *Parabailiella schmidtii*, *P. languedocensis*, *Ctenocephalus (Hartella) antiquus*, *Agraulos longicephalus*, *A. arenosus* and *Skreiaspis miqueli*. The diversity of agnostids, five species, may indicate a transgressive pulse.

So far *Pardailhania hispida* has been recorded in France (Montagne Noire: Thoral 1935, Courtessole 1973, Álvaro & Vizcaíno 1997), in Spain (Sdzuy 1961, 1968; Palacios 1982; Liñán & Gozalo 1986), in Italy (Sardinia: Rasetti 1972, Loi *et al.* 1995) and in Turkey (Shergold & Sdzuy 1984; Dean 2005, 2006). In addition, Geyer *et al.* (1995) and Geyer & Landing (2006) cited the presence of the genus *Pardailhania* in Morocco.

Correlation between the base of the Drumian Stage and the base of the middle Caesaraugustan

The classical correlation between Spain and Baltica (Sdzuy 1971, 1972) placed the base of *Pardailhania* within the *Tomagnostus fissus* and *Ptychagnostus atavus* Zone without further qualification, and slightly above of the *Paradoxides hicksii* Zone in Eastern Newfoundland. These correlations have been followed by later workers (*e.g.* Shergold & Geyer 2003, Liñán *et al.* 2002, Gozalo *et al.* 2008). Recently, Fletcher (2006, p. 68, 2007) and Elicki & Geyer (2010) moved this boundary below the previous proposal. They have considered that the correlation of the base of *Ptychagnostus atavus* Zone would be with a level just below the base of the *Badulesia granieri* (see Fletcher 2006, fig. 18) or with the base of Caesaraugustan (base of *Badulesia tenera* Zone) (see Elicki & Geyer 2010, fig. 1). On the other hand, the redefinition of the *Pardailhania hispida* Zone, the lower boundary of which lies below the old *Pardailhania hispida* Zone (*sensu* Sdzuy 1971, 1972). Therefore, it is likely that the correlation of the base of *Pardailhania hispida* would be roughly equivalent to the base of *Tomagnostus fissus* and *Ptychagnostus atavus* Zone. This roughly corresponds to the base of Drumian Stage.

The available data reinforce this correlation. Although many of trilobite species are endemic to the Mediterranean

Spanish Stages	Zones	Agnostids	Polymeroids	I.S.C.S. Stages
middle CAESAR- AUGUSTAN (part.)	<i>Pardailhania multispinosa</i>	↑	↑	DRUMIAN
	<i>Pardailhania hispida</i>	↑	↑	
lower CAESAR- AUGUSTAN	<i>Badulesia granieri</i>	↑	↑	STAGE 5
	<i>Badulesia tenera</i>	↑	↑	

Figure 5. Stratigraphic distribution of trilobite species in the lower and middle Caesaraugustan of the Iberian Chains showing the proposed correlation with ISCS subdivision. Names of species comment in the correlation section are highlighted.

region (e.g. *Badulesia granieri*, *Badulesia paschi*, *Pardailhania hispida*, *Eccaparadoxides sequeiroi*, *Parabailiella languedocensis*, etc.), there are some species that have been recorded also in other palaeogeographic regions: *Eccaparadoxides acadicus*, *Agraulos longicephalus*, *Diplagnostus planicauda*, *Peronopsis segmenta* and *Condylomyge rex*. We discuss the biostratigraphical information of these species below.

a) *Eccaparadoxides acadicus* (Avalonian species) (Fig. 6K, L) whose stratigraphic range is in the *Eccaparadoxides eteminiensis* and *Hartella* zones in New Brunswick and Newfoundland (Kim et al. 2002) and which was recorded from the top of the *Ptychagnostus gibbus* or base of the *Tomagnostus fissus* Zone in England (Rushton et al. 2007); thus its presence in the *Pardailhania hispida* Zone indicates that the youngest age for this zone would be the base of *Ptychagnostus atavus* Zone, which is the base of Drumian Stage.

b) *Agraulos longicephalus* has been recorded in Great Britain, eastern Newfoundland, Spain and France. The range in Wales is *Tomagnostus fissus* and *Hypagnostus parvifrons* zones (Thomas et al. 1984); eastern Newfoundland, *Paradoxides hicksii* Zone (Martin & Dean 1988;

Fletcher 2006, 2007); Spain, *Pardailhania hispida* to *Solenopleuropsis ribeiroi* zones (Liñán & Gozalo 1986); France, levels A1, A2 and B? (Courtesole 1973), which is equivalent to middle Caesaraugustan and upper Caesaraugustan (Álvaro & Vizcaíno 1998). The biostratigraphical range is equivalent to *Ptychagnostus atavus* Zone in the sense of Peng & Robison (2000).

c) *Diplagnostus planicauda* (Figs 6G–I, 8) has a wide geographic and stratigraphic distribution. Its FAD is recorded in the base of *Ptychagnostus atavus* Zone (Peng & Robison 2000), thus its presence in the base of *Pardailhania hispida* Zone indicates that the oldest age for this zone would be Drumian.

d) *Peronopsis segmenta* (Figs 6A–C, 7) has been recorded only in the eastern Great Basin (Robison 1964, 1982, 1984) and the observed range is from middle *Ptychagnostus gibbus* to *Ptychagnostus punctuosus* Zone or upper part of the Cambrian Stage 5 and Drumian Stage.

e) *Condylomyge rex* (see Appendix 1; Fig. 6D–F) has been recorded beyond the Mediterranean region in Bohemia, Baltica, England and eastern Newfoundland where shows a wide stratigraphic range. The range in Bohemia is *Eccaparadoxides pusillus* to *Onymagnostus hybridus*

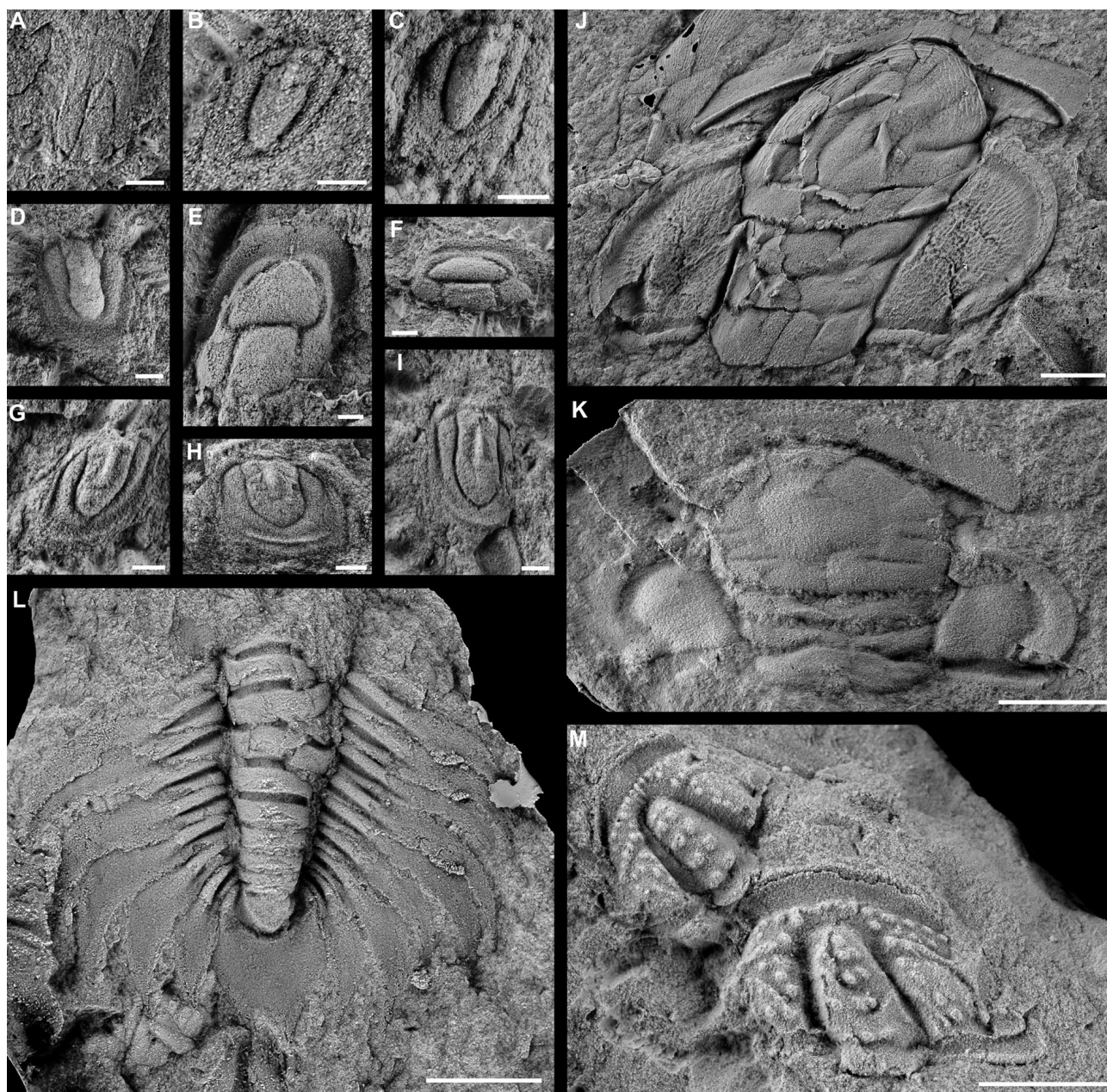


Figure 6. Trilobites of the *Pardailhania hispida* Zone. • A–C – *Peronopsis segmenta* Robison, 1964; A – cephalon, internal mould, MPZ 2007/350; B, C – pygidium, internal mould (B) and latex cast (C) of the same specimen, MPZ 2007/348. • D–F – *Condylpyge rex* (Barrande, 1846); D – pygidium, internal mould, MPZ 2007/456; E – cephalon, latex cast, MPZ 2007/447; F – cephalon, internal mould, MPZ 2007/461. • G–I – pygidia of *Diplagnostus planicauda* (Angelin, 1851); G – internal mould, MPZ 2007/422; H – latex cast, MPZ 2007/428; I – internal mould, MPZ 2007/423. • J – *Eccaparadoxides rouvillei* (Miquel, 1905), cranidium, latex cast MPZ 2011/78. • K, L – *Eccaparadoxides acadicus* (Matthew, 1883); K – cranidium, latex cast, MPZ 2007/501; L – thoracic segments and pygidium, latex cast, MPZ 2007/516. • M – cranidia of *Pardailhania hispida* (Thoral, 1935), latex cast, MPZ 3078 and 3079 (specimens figured by Liñán & Gozalo 1986, pl. 24, figs 9, 10). All the specimens are housed in Museo de Paleontología de la Universidad de Zaragoza (MPZ). Scale bars: figures A–I 1 mm, figures J–M 5 mm.

zones (Fatka *et al.* 2004); in Sweden and Norway, *Hypagnostus parvifrons* Zone (Westergård 1946) or top of *Ptychagnostus atavus* Zone *sensu* Høyberget & Bruton (2008); in Warwickshire, England, it occurs in the *hicksii* Zone (Illing 1916; Fletcher 2007, fig. 2) in beds equivalent to the *Ptychagnostus gibbus* and *Tomagnostus fissus* zones

(Rushton 1979, Thomas *et al.* 1984); in Spain, *Pardailhania hispida* to *Solenopleuropsis thoralis* zones (Sdzuy 1961, Liñán & Gozalo 1986, Chirivella Martorell 2008); in France, level B (Courtessole 1973) equivalent to *Solenopleuropsis ribeiroi* Zone (Álvaro & Vizcaíno 1998); in Eastern Newfoundland, *Paradoxides hicksii* and

P. davidis zones (Howell 1925; Hutchinson 1962; Fletcher 2006, 2007, fig. 3), and in Germany, upper part of Caesaraugustan (Sdzuy 2000). In summary the total range of this species would be from the upper part of the *Ptychagnostus gibbus* to the *Ptychagnostus atavus* zones or the upper part of the Cambrian Stage 5 and Drumian Stage.

We do not know currently whether the base of Drumian lies at a lower level. However, a comparison of the biostratigraphic ranges of these species seems to show that the best correlation of the basal level of *Pardailhanian hispidus* is likely with the basal part of the *Ptychagnostus atavus* Zone. Thus, the FAD of *Pardailhanian hispidus* in the Mediterranean subprovince can be used as the local index trilobite for the Drumian Stage in this region.

Other data

The biofacies analysis and the sequence stratigraphy established for the Iberian Chains (see Gámez Vintaned *et al.* 2009; Fig. 4) show that the basal beds of *Pardailhanian hispidus* Zone was deposited during the Transgressive System Tract of the Sequence 6. The relative abundance of agnostids and diversity of polymeroids trilobites could be indicative of a relative maximum transgressive for these levels. Likewise the basal levels of the *Ptychagnostus atavus* Zone in Drum Mountains [(USA Babcock *et al.* 2007)] are associated with a relative maximum transgressive pulse (Babcock *et al.* 2004, 2007). This transgressive event also supports our proposal of correlation between the bases of *Pardailhanian hispidus* and *Ptychagnostus atavus* zones.

Recently, Álvaro *et al.* (2008) on the basis of the carbon isotopic studies suggested a different correlation for the Mediterranean subprovince. They considered that a negative $\delta^{13}\text{C}_{\text{org}}$ shift from a background of -22‰ to a negative peak of -24.5‰ in the Campelou section Montagne Noire, France) belong to the Drumian Carbon Isotope Excursion (DICE), more or less equivalent to the base of Drumian (see Ahlberg *et al.* 2009, Howley & Jiang 2010). The DICE falls in the base of middle Languedocian (of the Mediterranean scale) in the Campelou section Álvaro *et al.* (2008). Because the Montagne Noire and Iberian Chains share trilobite faunas, this correlation suggested that all the species listed above in the Iberian Chains have an age of Cambrian Stage 5. However the middle Languedocian in the Campelou section does not share any trilobites with areas where the DICE excursion has been detected. This disagreement between the biostratigraphic data and isotopic data could be due to various issues. Firstly, this disagreement is likely the result of low resolution, 27 samples in a section of 200 m thick with different intervals between samples and meter scale close to chemostratigraphic anomalies. Despite of fine sampling close to the chemostratigraphic anomalies, many negative anomalies

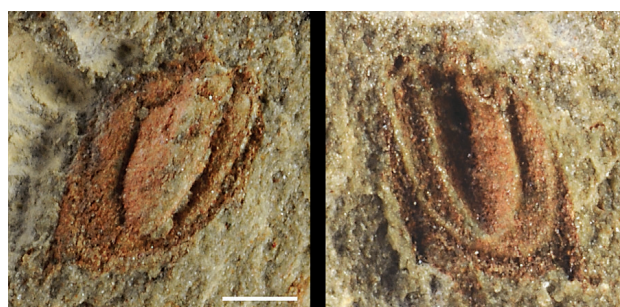


Figure 7. Pygidium of *Peronopsis segmenta* Robison, 1964. • A – internal mould, B – external mould of the same specimen, also figured in Fig. 6B, C, MPZ 2007/348. Scale bar 1 mm.

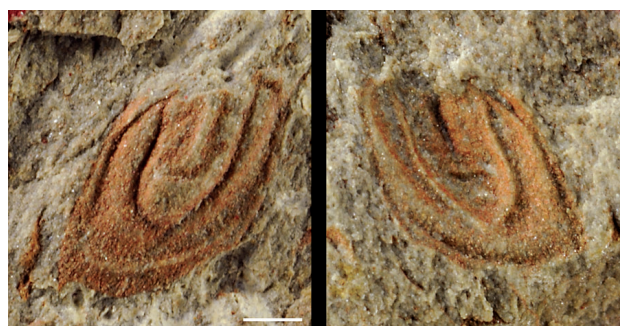


Figure 8. Pygidium of *Diplagnostus planicauda* (Angelin, 1851). • A – internal mould, B – external mould of the same specimen, also figured in Fig. 6G, MPZ 2007/422. Scale bar 1 mm.

are detected in other researches close to SPICE (Montañez *et al.* 2000; Zhu *et al.* 2004, 2006). Therefore a lack of a biostratigraphical control with trilobites in the Campelou section prevents us from knowing whether this negative anomaly belongs to DICE or to a negative excursion closer to the SPICE peak. For the moment, the biostratigraphic data of Montagne Noire and Iberian Chains and their trilobitic correlation with other regions show that the negative isotope excursion considered as DICE by Álvaro *et al.* (2008) in the Montagne Noire really correspond with a high stratigraphic level within Drumian, not below.

Conclusion

The new data and the previous work on biostratigraphy and sequence stratigraphy demonstrate that the bases of the *Pardailhanian hispidus* and *Ptychagnostus atavus* zones are roughly equivalent. The FAD of *Pardailhanian hispidus* could be used in the Mediterranean region as a marker for the beginning of the Drumian Stage. This level is easily identifiable in several places: the Montagne Noire (France), Cantabrian Mountains, Demanda Mountains and Iberian Chains (Spain), Sardinia (Italy), Amanos and Sultan Mountains (Turkey), and, probably, the AntiAtlas (Morocco).

Systematic appendix

Condylopyge rex (Barrande, 1846)

Figure 6D–F

- v 1986 *Condylopyge* aff. *regia* (Sjögren, 1872). – Liñán & Gozalo, pp. 39, 40, pl. 1, fig. 9.
- v 1986 *Condylopyge rex rex* (Barrande, 1846). – Liñán & Gozalo, p. 40 (with previous synonym).
- v 1986 *Condylopyge rex hispanica* n. ssp. – Liñán & Gozalo, pp. 40, 41, pl. 1, figs 10–20 (with previous synonym).
- 2002 *Condylopyge rex* (Barrande, 1846). – Valíček & Szabad, pp. 75, 76, pl. 1, fig. 1 (with previous synonym).
- 2004 *Condylopyge rex* (Barrande, 1846). – Buchholz, p. 516, pl. 3, figs 10, 11.
- 2005 *Condylopyge rex* (Barrande). – Cotton & Fortey, fig. 1A.
- 2006 *Condylopyge rex* (Barrande, 1846). – Valíček, pl. 1, figs 7–9, fig. 2.
- v 2008 *Condylopyge rex* (Barrande, 1846). – Chirivella Martorell, pp. 69–72, pl. 3, fig. 12, pl. 4, figs 1–11 (with previous synonym).
- 2008 *Condylopyge rex* (Barrande, 1846). – Høyberget & Bruton, pp. 71, 72, pl. 12, figs K, M (with previous synonym).
- 2009 *Condylopyge rex*. – Ahlberg, Axheimer, Babcock, Eriksson, Schmitz & Terfelt, fig. 3G.
- 2009 *Condylopyge rex*. – Fatka & Mergl, fig. 9e.

Comments. – Liñán & Gozalo (1986) subdivided the species *C. rex* in two subspecies. They defined *C. rex hispanica* from Spain and France and suggested the possibility of another Scandinavian subspecies. Their main criteria were geographic and the different morphological combinations of the pygidium and cephalon borders. The Bohemian specimens have both convex borders (see Šnajdr 1958). The Mediterranean specimens have the plane cephalic border and convex pygidial border (Sdzuy 1961, Liñán & Gozalo 1986), and the Scandinavian forms have a plane cephalic border and convex pygidial border (Westergård 1946). Also the age of the three subspecies seemed different.

The material classified as *C. rex hispanica* by Liñán & Gozalo (1986) have been recorded of the upper Caesar-augustan levels. They found a similar cephalon from the base of *Pardailhania hispida* Zone that classified as *Condylopyge* aff. *regia* (Sjögren, 1872) because the cephalon morphology is close to this species, but the lack of pygium prevent to classify in open nomenclature. The new samplings on the level where had been found *Condylopyge* aff. *regia* by Liñán & Gozalo (1986) allow us to find several cephalia and pygidia of *Condylopyge*. The pygidium morphology is *C. rex* type, thus we assign this material to this species.

New specimens of *C. rex* have been published from Bohemian region (Valíček & Szabad 2002, Valíček 2006) that

show an important morphological variability in the cephalic and pygidial borders and increase the stratigraphic range for this species (see Fatka *et al.* 2004). Now the age range of Spanish specimens is similar to the Bohemian and Scandinavian specimens, and the morphological variability does not permit to recognise the different subspecies proposed by Liñán & Gozalo (1986).

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References

- AHLBERG, P., AXHEIMER, N., BABCOCK, L.E., ERIKSSON, M.E., SCHMITZ, B. & TERFELT, F. 2009. Cambrian high-resolution biostratigraphy and carbon isotope chemostratigraphy in Scania, Sweden: first record of SPICE and DICE excursions in Scandinavia. *Lethaia* 42, 2–16.
DOI 10.1111/j.1502-3931.2008.00127.x
- ÁLVARO, J.J., BAULUZ, B., SUBÍAS, I., PIERRE, C. & VIZCAÍNO, D. 2008. Carbon chemostratigraphy of the Cambrian-Ordovician transition in a midlatitude mixed platform, Montagne Noire, France. *Geological Society of America Bulletin* 120, 962–975. DOI 10.1130/B26243.1
- ÁLVARO, J.J. & VIZCAÍNO, D. 1997. Révision des Trilobites Sole-nopleuropsinae du Cambrien moyen de la Montagne Noire (France). *Geobios* 30, 541–561.
DOI 10.1016/S0016-6995(97)80121-0
- ÁLVARO, J.J. & VIZCAÍNO, D. 1998. Révision biostratigraphique du Cambrien moyen du versant méridional de la Montagne Noire (Languedoc, France). *Bulletin de la Société Géologique de France* 169, 233–242.
- ANGELIN, N.P. 1851. *Palaeontologica Svecica. Pars I; Iconographia crustaceorum formationis transitionis*. 24 pp. Academie Regiae Scientiarum Suecanae, Holmiae (Stockholm).
- BABCOCK, L.E., REES, M.N., ROBISON, R.A., LANGENBURG, E.S. & PENG, S.C. 2004. Potential Global Stratotype-section and Point (GSSP) for a Cambrian stage boundary defined by the first appearance of the trilobite *Ptychagnostus atavus*, Drum Mountains, Utah, USA. *Geobios* 37, 149–158.
DOI 10.1016/j.geobios.2003.03.007
- BABCOCK, L.E., ROBISON, R.A., REES, M.N., PENG, S. & SALTZMAN, M.R. 2007. The Global boundary Stratotype Section and Point (GSSP) of the Drumian stage (Cambrian) in the Drum Mountains, Utah, USA. *Episodes* 30, 84–94.
- BARRANDE, J. 1846. *Notice préliminaire sur le système silurien et les trilobites de Bohême*. vi + 96 pp. Hirschfeld, Leipzig.
- BUCHHOLZ, A. 2004. Ein Geschiebe der *Hypagnostus parvifrons*-Zone (Mittelkambrium B3) mit feinstratigraphischer Schichtun und seltenen sowie neuen Trilobiten. *Archiv für Geschiebekunde* 3 (8/12), 501–524.

- CHIRIVELLA MARTORELL, J.B. 2008. *Sistematica de los Trilobites, bioestratigrafia y paleoecologia del limite Leoniense-Caesaraugustense (Cámbrico medio) en las Cadenas Ibéricas (NE de España)*. 226 pp. Doctoral thesis, Universitat de València, Spain (unpublished).
- COURTESOLE, R. 1973. *Le Cambrien Moyen de la Montagne Noire. Biostratigraphie*. 248 pp. Imprim. d'Oc, Toulouse.
- COTTON, T.J. & FORTEY, R.A. 2005. Comparative morphology and relationships of the Agnostida, 95–136. In KOENEMANN, S. & JENNER, R. (eds) *Crustacea and arthropod relationships. Crustacean Issues* 16.
- DEAN, W.T. 2005. Trilobites from the Çal Tepe Formation (Cambrian), Near Seydischir, Central Taurides, Southwestern Turkey. *Turkish Journal of Earth Sciences* 14, 1–71.
- DEAN, W.T. 2006. Cambrian Stratigraphy and Trilobites of the Samur Dag Area, South of Hakkâri, Southeastern Turkey. *Turkish Journal of Earth Sciences* 15, 225–257.
- ELICKI, O. & GEYER, G. 2010. Cambrian biostratigraphy, 103–114. In LINNEMANN, U. & ROMER, R.L. (eds) *Pre-Mesozoic Geology of Saxo-Thuringia – From the Cadomian Active Margin to the Variscan Orogen*. Schweizerbart, Stuttgart.
- ESTEVE, J., GOZALO, R., LIÑÁN, E. & CHIRIVELLA MARTORELL, J.B. 2008. *Pardailhania* Thoral, 1947 (Solenopleuropsinae, Trilobita) from Caesaraugustan (Middle Cambrian) of the Iberian Chains (NE Spain), 99–103. In RÁBANO, I., GOZALO, R. & GARCIA-BELLIDO, D. (eds) *Advances in Trilobite Research. Cuadernos del Museo Geominero* 9. Instituto Geológico y Minero de España, Madrid.
- FATKA, O., KORDULE, V. & SZABAD, M. 2004. Stratigraphical distribution of Cambrian fossils in the Příbram-Jince Basin (Barrandian area, Czech Republic). *Senckenbergiana lethaea* 84, 367–381.
- FATKA, O. & MERGL, M. 2009. The ‘microcontinent’ Perunica: status and story 15 years after conception. *Geological Society of London, Special Publications* 325, 65–101.
- FLETCHER, T.P. 2006. *Bedrock geology of the Cape St. Mary's Peninsula, southwest Avalon Peninsula, Newfoundland (includes parts of NTS maps sheets 1M/1, 1N/4, 1L/6 and 1K/13), Newfoundland*. 117 pp. Report 06-02, Government of Newfoundland and Labrador, Geological Survey, Department of Natural Resources, St. John's.
- FLETCHER, T.P. 2007. Correlating the zones of ‘*Paradoxides hicksii*’ and ‘*Paradoxides davidis*’ in Cambrian Series 3. *Memoirs of the Association of Australasian Palaeontologists* 33, 35–56.
- GÁMEZ, J.A., FERNÁNDEZ-NIETO, C., GOZALO, R., LIÑÁN, E., MANDADO, J. & PALACIOS, T. 1991. Bioestratigrafía y evolución ambiental del Cámbrico de Borobia (Provincia de Soria, Cadena Ibérica Oriental). *Cuadernos do Laboratorio Xeolóxico de Laxe* 16, 251–271.
- GÁMEZ VINTANED, J.A., SCHMITZ, U. & LIÑÁN, E. 2009. Upper Vendian-lowest Ordovician sequences of the western Gondwana margin, NE Spain, 231–244. In CRAIG, J., THUROW, J., THUSU, B., WHITHAM, A. & ABUTARRUMA, Y. (eds) *Global Neoproterozoic Petroleum Systems: The Emerging Potential in North Africa*. Geological Society of London, Special Publications 326.
- GEYER, G. & LANDING, E. 2006. Edicaran-Cambrian depositional environments and stratigraphy of the western Atlas regions. *Beringeria, Special Issue* 6, 47–112.
- GEYER, G., LANDING, E. & HELDMAIER, W. 1995. Faunas and depositional environments of the Cambrian of the Moroccan Atlas regions. *Beringeria, Special Issue* 2, 47–119.
- GOZALO, R. & LIÑÁN, E. 1988. Los materiales hercínicos de la Cordillera Ibérica en el contexto del Macizo Ibérico. *Estudios geológicos* 44, 399–404.
- GOZALO, R., LIÑÁN, E. & ÁLVARO, J. 1993. Bioestratigrafía del Cámbrico Medio de Villafeliche (Prov. Zaragoza, España). *Revista Española de Paleontología* n.º. extr., 49–57.
- GOZALO, R., LIÑÁN, E. & DIES, M.E. 2003a. Intraspecific dimorphism in an evolutionary series of paradoxidids from the Middle Cambrian of Murero, Spain. *Special Papers in Palaeontology* 70, 141–156.
- GOZALO, R., LIÑÁN, E., GÁMEZ VINTANED, J.A., DIES ÁLVAREZ, M.E., CHIRIVELLA MARTORELL, J.B., ZAMORA, S., ESTEVE, J. & MAYORAL, E. 2008. The Cambrian of the Cadenas Ibéricas (NE Spain) and its trilobites, 137–151. In RÁBANO, I., GOZALO, R. & GARCIA-BELLIDO, D. (eds) *Advances in Trilobite Research. Cuadernos del Museo Geominero* 9. Instituto Geológico y Minero de España, Madrid.
- GOZALO, R., LIÑÁN, E., PALACIOS, T., GÁMEZ VINTANED, J.A. & MAYORAL, E. 2003b. The Cambrian of the Iberian Peninsula: an overview. *Geologica Acta* 1, 103–112. DOI 10.1344/105.000001596
- GOZALO, R., LIÑÁN, E. & SDZUY, K. 1996. September 20. The Lower and Middle Cambrian of Murero and Villafeliche (West Asturian-Leonese Zone. Western Iberian Chain), 73–80. In LIÑÁN, E., GÁMEZ VINTANED, J.A. & GOZALO, R. (eds) *II Field Conference of the Cambrian Stage Subdivision Working Groups. International Subcommission on Cambrian Stratigraphy. Spain, 13–21 September 1996. Field Trip Guide and Abstracts*. Universidad de Zaragoza, Zaragoza.
- HOWELL, B.F. 1925. Faunas of the Cambrian *Paradoxides* Beds at Manuels, Newfoundland. *Bulletins of American Paleontology* 11(43), 1–140.
- HOWLEY, R.A. & JIANG, G. 2010. The Cambrian Drumian carbon isotope excursion (DICE) in the Great Basin, western United States. *Palaeogeography, Palaeoclimatology, Palaeoecology* 296, 138–150. DOI 10.1016/j.palaeo.2010.07.001
- HØYBERGET, M. & BRUTON, D. L. 2008. Middle Cambrian trilobites of the suborders Agnostina and Eodiscina from the Oslo Region, Norway. *Palaeontographica, Abteilung A* 286, 1–87.
- HUTCHINSON, R.D. 1962. Cambrian stratigraphy and Trilobite faunas of southeastern Newfoundland. *Geological Survey of Canada, Bulletin* 88, 1–165.
- ILLING, V.C. 1916. The paradoxidian fauna of a part of the Stockford Shales. *Quarterly Journal of the Geological Society of London* 71 (for 1915), 386–450.
- KIM, D.H., WESTROP, S.R. & LANDING, E. 2002. Middle Cambrian (Acadian series) conocoryphid and paradoxid trilobites from the Upper Chamberlain's Brook Formation, Newfoundland and New Brunswick. *Journal of Paleontology* 76, 822–842. DOI 10.1666/0022-3360(2002)076<0822:MCASCA>2.0.CO;2
- LIÑÁN, E., ÁLVARO, J.J., GOZALO, R., GÁMEZ-VINTANED, J.A. & PALACIOS, T. 1995. El Cámbrico Medio de la Sierra de Córdoba (Ossa-Morena, S de España): trilobites y paleoicnología. Implicaciones bioestratigráficas y paleoambientales. *Revista Española de Paleontología* 10, 219–238.
- LIÑÁN, E. & GOZALO, R. 1986. Trilobites del Cámbrico inferior y medio de Murero (Cordillera Ibérica). *Memorias del Museo Paleontológico de la Universidad de Zaragoza* 2, 1–104.
- LIÑÁN, E., GOZALO, R., DIES ÁLVAREZ, M.E., GÁMEZ VINTANED, J.A., MAYORAL, E., CHIRIVELLA MARTORELL, J.B., ESTEVE, J., ZAMORA, S., ZHURAVLEV, A.Y. & ANDRÉS, J.A. 2008. *Fourth International Trilobite Conference Trilo 08 Toledo, Spain, 2008. Post-Conference Field Trip. Lower and Middle Cambrian trilobites of selected localities in Cadenas Ibéricas (NE Spain)*. 52 pp. Universidad de Zaragoza, Zaragoza.
- LIÑÁN, E., GOZALO, R., PALACIOS, T., GÁMEZ VINANED, J.A., UGIDOS, J.M. & MAYORAL, E. 2002. Cambrian, 17–29. In GIB-

- BONS, W. & MORENO, T. (eds) *The Geology of Spain*. Geological Society, London.
- LIÑÁN, E., PEREJÓN, A., GOZALO, R., MORENO-EIRIS, E. & OLIVEIRA, J.T. de 2004. The Cambrian System in Iberia. *Cuadernos del Museo Geominero* 3, 1–63.
- LIÑÁN, E., PEREJÓN, A. & SDZUY, K. 1993. The Lower-Middle Cambrian stages and stratotypes from the Iberian Peninsula: a revision. *Geological Magazine* 130, 817–833. DOI 10.1017/S0016756800023189
- LIÑÁN, E., SDZUY, K., ALVARO, J.J., GÁMEZ VINTANED, J.A. & GOZALO, R. 1996. September 19. The Jarque section: Lower and Middle Cambrian (West Asturian-Leonese Zone. Eastern Iberian Chain), 57–72. In LIÑÁN, E., GÁMEZ VINTANED, J.A. & GOZALO, R. (eds) *II Field Conference of the Cambrian Stage Subdivision Working Groups. International Subcommission on Cambrian Stratigraphy. Spain, 13–21 September 1996. Field Trip Guide and Abstracts*. Universidad de Zaragoza, Zaragoza.
- LOI, A., PILLOLA, G.L. & LEONE, F. 1995. The Cambrian and Early Ordovician of south-western Sardinia. *Rediconti del Seminario della Facoltà di Scienze dell'Univeristà di Cagliari, Suppl.* 65, 61–81.
- MARTIN, F. & DEAN, W.T. 1988. Middle and Upper Cambrian acritarch and trilobite zonation at Manuels River and Random island, Eastern Newfoundland. *Geological Survey of Canada, Bulletin* 381, 1–91.
- MATTHEW, G.F. 1883. Illustrations of the fauna of the St. John Group. No. 1 – The *Paradoxides*. *Transactions of the Royal Society of Canada* 1(4), 271–279.
- McKERRROW, W.S., SCOTSE, C.R. & BRASIER, M.D. 1992. Early Cambrian continental reconstructions. *Journal of the Geological Society of London* 149, 599–606. DOI 10.1144/gsjgs.149.4.0599
- MIQUEL, J. 1905. Essai sur le Cambrien de la Montagne Noire. Coulouma – l'Acadien. *Bulletin de la Société Géologique de France*, 4^{ème} série 5, 465–483.
- MONTAÑEZ, I.P., OSLEGER, D.A., BANNER, J.L., MACK, L.E. & MUSGROVE, M. 2000. Evolution of the Sr and C Isotope Composition of Cambrian Oceans. *GSA Today* 10(5), 1–7.
- PALACIOS, T. 1982. *El Cámbrico entre Viniegra de Abajo y Mansilla (Sierra de la Demanda, Logroño). Trilobites e icnofósiles*. 85 pp. Biblioteca de Estudios Riojanos, Logroño.
- PENG, S., BABCOCK, L.E., ZUO, J., LIN, H., ZHU, X., YANG, X., ROBISON, R.A., QI, Y., BAGNOLI, G. & CHEN, Y. 2009. The Global Boundary Stratotype Section and Point (GSSP) of the Guzhangian Stage (Cambrian) in the Wuling Mountains, North-western Hunan, China. *Episodes* 32, 41–55.
- PENG, S. & ROBISON, R.A. 2000. Agnostid biostratigraphy across the Middle-Upper Cambrian boundary in Hunan, China. *Journal of Paleontology, The Paleontological Society Memoir* 53, 1–104.
- RASETTI, F. 1972. Cambrian trilobite faunas of Sardinia. *Atti della Accademia Nazionale dei Lincei, Memoire* 8(11), 1–98.
- ROBISON, R.A. 1964. Late Middle Cambrian faunas from western Utah. *Journal of Paleontology* 38, 510–566.
- ROBISON, R.A. 1982. Some Middle Cambrian Agnostoid Trilobites from western North America. *Journal of Paleontology* 56, 132–160.
- ROBISON, R.A. 1984. Cambrian Agnostida of North America and Greenland. Part I, Ptychagnostidae. *The University of Kansas Paleontological Contributions* 109, 1–59.
- RUSHTON, A.W.A. 1979. A review of the Middle Cambrian Agnostida from the Abbey Shales, England. *Alcheringa* 3, 43–61. DOI 10.1080/03115517908565439
- RUSHTON, A.W.A., WILLIAMS, M., SIVETER, D.J. & BERG-MADSEN, V. 2007. A new mid-Cambrian trilobite fauna from Shropshire. *Proceedings of the Geologists' Association* 118, 129–142.
- SDZUY, K. 1961. Das Kambrium Spaniens. Teil II: Trilobiten. *Akademie der Wissenschaften und der Literatur, Abhandlungen der mathematisch-naturwissenschaftlichen Klasse* 1961(7–8), 217–408.
- SDZUY, K. 1968. Trilobites del Cámbrico Medio de Asturias. *Trabajos de Geología, Universidad de Oviedo* 1 (for 1967), 77–133.
- SDZUY, K. 1969. Biostratigrafía de la Griotte Cámbrica de los Barrios de Luna (León) y de otros sucesiones comparables. *Trabajos de Geología, Universidad de Oviedo* 2 (for 1968), 45–68.
- SDZUY, K. 1971. La subdivisión bioestratigráfica y la correlación del Cámbrico Medio de España. *I Congreso Hispano-Luso-Americano de Geología Económica, Sección 1, Geología* 2, 769–782.
- SDZUY, K. 1972. Das Kambrium der acadobaltischen Faunenprovinz. *Zentralblatt für Geologie und Paläontologie, Teil II*(1972), 1–91.
- SDZUY, K. 2000. Das Kambrium des Fankenwaldes. 3. Die Lippertsgrüner Schichten und ihre Fauna. *Senckenbergiana lethaea* 79, 301–328.
- SDZUY, K., LIÑÁN, E. & GOZALO, R. 1996. The Middle Cambrian Series, 16–18. In LIÑÁN, E., GÁMEZ VINTANED, J.A. & GOZALO, R. (eds) *II Field Conference of the Cambrian Stage Subdivision Working Groups. International Subcommission on Cambrian Stratigraphy. Spain, 13–21 September 1996. Field Trip Guide and Abstracts*. Universidad de Zaragoza, Zaragoza.
- SDZUY, K., LIÑÁN, E. & GOZALO, R. 1999. The Leonian Stage (early Middle Cambrian): a unit for Cambrian correlation in the Mediterranean subprovince. *Geological Magazine* 136, 39–48. DOI 10.1017/S0016756899002241
- SHERGOLD, J.H. & GEYER, G. 2003. The Subcommission on Cambrian Stratigraphy: the status quo. *Geologica Acta* 1, 5–9. DOI 10.1344/105.000001588
- SHERGOLD, J.H. & SDZUY, K. 1984. Cambrian and Early Tremadocian trilobites from Sultan Dag, Central Turkey. *Senckenbergiana lethaea* 65, 51–135.
- SJÖGREN, A. 1872. Om några försteningar i Ölands kambriska lager. *Geologiska Föreningens i Stockholm Forhandlingar* 1, 67–85.
- ŠNAJDR, M. 1958. Trilobiti českého středního kambria. *Rozpravy Ústředního ústavu geologického* 24, 1–280.
- THOMAS, A.T., OWENS, R.M. & RUSHTON, A.W.A. 1984. *Trilobites in British stratigraphy*. 78 pp. Geological Society of London, Special Report 16.
- THORAL, M. 1935. *Contribution à l'étude paléontologique de l'Ordovicien inférieur de la Montagne Noire et révision sommaire de la faune cambrienne de la Montagne Noire*. 362 pp. Imprimerie de la Charité, Montpellier.
- VALÍČEK, J. 2006. A new agnostid trilobite from the Skryje-Týřovice area (Middle Cambrian, Jince Formation, Barrandian area, Czech Republic). *Palaeontologia Bohemica* 10, 43–46.
- VALÍČEK, J. & SZABAD, M. 2002. Revision early Middle Cambrian trilobite fauna from Bohemia. *Palaeontologia Bohemica* 8, 75–98.
- WESTERGÅRD, A.H. 1946. Agnostidea of the Middle Cambrian of Sweden. *Sveriges Geologiska Undersökning, ser. C* 477, 1–110.
- ZHU, M.-Y., BABCOCK, L.E. & PENG, S.-C. 2006. Advances in Cambrian stratigraphy and paleontology: Integrating correlation techniques, paleobiology, taphonomy and paleoenvironmental reconstruction. *Palaeoworld* 15, 217–222. DOI 10.1016/j.palwor.2006.10.016
- ZHU, M.-Y., ZHANG, J.-M., LI, G.-X. & YANG, A.-H. 2004. Evolution of C isotopes in the Cambrian of China: implications for Cambrian subdivision and trilobite mass extinctions. *Geobios* 37, 287–301. DOI 10.1016/j.geobios.2003.06.001