A Přídolí–Lochkovian conodont zonation in Sardinia and the Carnic Alps: implications for a global zonation scheme

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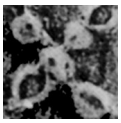

The main conodont zonation schemes for the Přídolí and the Lochkovian presents some problems that make difficult their use in several geographical areas. Data from several sections in Sardinia and the Carnic Alps not only allow to built a regional zonation scheme for these areas, but also suggest possible solutions of global validity. In the Carnic Alps and Sardinia, the Přídolí is subdivided into three zones: *eosteinhornensis* s.l., Lower and Upper *detortus*. The latter results after the subdivision of the former *detortus* Zone on the basis of the Last Appearance Datum of some coniform species (*Dapsilodus obliquicostatus*, *Coryssognathus dubius* and *Panderodus recurvatus*) that became extinct almost simultaneously in the latest Přídolí. *Daps. obliquicostatus* is chosen as the marker, being the most common and easily identifiable species. In the Lochkovian six zones are discriminated: *hesperius*, *carlsi*, *transitans*, *eleanorae*, *trigonicus* and *pandora* β. The *hesperius* Zone, which includes the *postwoschmidti* subzone in its upper part, is expanded to include most of the *eurekaensis* zone of the "global" scheme, because the marker *Oz. eurekaensis* is not present. The *carlsi* Zone corresponds to the upper part of the *eurekaensis* Zone and to the lower part of the former mid-Lochkovian *delta* Zone (= *omoalpha* Zone). The rest of the Middle Lochkovian is subdivided into the three zones (*transitans*, *eleanorae* and *trigonicus*) already proposed in Nevada and Spain, followed by the *pandora* β Zone. All the zones are discussed and checked for their applicability in other palaeogeographical regions. • Key words: biostratigraphy, conodont zonation, Přídolí, Lochkovian, Carnic Alps, Sardinia.

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This paper deals on a Přídolí–Lochkovian conodont zonation, based on sections in Sardinia and in the Carnic Alps, with the intention to make a step towards a standard zonation across the Silurian/Devonian boundary. The biozones defined in this paper are based on described and named taxa, that are easy to recognize unequivocally and have a wide geographic distribution, also outside the regions investigated in this paper. We choose markers in order that the zones should be widely recognized and applicable across geographic regions as broad as possible. Based on these principles, we avoided taxa with a small geographic diffusion, even if locally these forms can increase the biostratigraphic resolution of the scheme.

Data from Sardinia and the Carnic Alps were compared with data available in literature, not only in other North Gondwana regions (Bohemia, Spain, *etc*.) but also in other geographic areas (North America, Australia), in order to check the validity of the proposed scheme as a possible new global "standard" zonation. However, it is difficult to base correlations on literature only, because often the precise distribution of taxa is not given, and some paper are not adjourned with recent taxonomic novelties.

Before focusing on open problems in the main zonation schemes in use, it is necessary briefly summarizing the history of the Přídolí and Lochkovian conodont zonations.

History of Přídolí and Lochkovian zonation schemes

A separate discussion of the biozonation schemes of the Silurian and the Lower Devonian is necessary because almost none covers the complete interval examined in this paper. In fact, almost all the schemes based on the Silurian only indicate the first Devonian Zone, and the Devonian schemes starts just above the system boundary.

EPOCH AGE	Walliser (1964)	Aldridge & Schoenlaub (1989)	Nowlan (1995)	Corradini & Serpagli (1999)	Ogg *et al.* (2008)	Corriga & Corradini (2009)	Cramer *et al.* (2011)
Přídolí	"*Oz. stein. eosteinsis*"	*I. w. woschmidti*	*O. eost.-Ou. e. det.*	*elegans detortus*	*elegans detortus*	*detortus*	*detortus*
		O. rem. eosteinsis	*remscheidensis* i. Z.	*remscheidensis* i. Z.	*remscheidensis* i. Z.	*eostein.* s.l. i. Z.	*eostein.* s.l. i. Z.
L.	"*S. crispus*"	O. crispa	*crispa*	*crispa*	*crispa*	*crispa*	*crispa*

Figure 1. Main conodont zonation schemes of the Přídolí. L. means Ludlow.

Přídolí

The first conodont zonation for the Silurian was proposed by Walliser (1964), who based his scheme primarily on the Cellon Section (Carnic Alps, Austria), taking in account also some data from Bohemia and Spain. The author defined twelve successive appearance zones spanning the Silurian and the lowermost Devonian. The Přídolí was undivided (Fig. 1), being equivalent to the "*Ozarkodina steinhornensis eosteinhornensis* Zone". Several zones of the Walliser's scheme have been widely recognized, but the difficulties of applying the complete scheme in other parts of the world have led to the development of many local zonations. Also, since the seventies the nomenclature of conodonts have been greatly changed, because of recognition of multielement taxa.

Aldridge & Schönlaub (1989), considering all the available data, provided a new scheme, which is a "step on the path to the development of a reference biozonation" (p. 275). The Přídolí is here subdivided into two parts: the great majority belongs to the "*Ozarkodina steinhornensis eosteinhornensis* Zone", whereas the very uppermost part was referred to the lower part of the "*Icriodus woschmidti woschmidti* Zone". It should be noted that the latter zone was identified also by Walliser (1964), but the First Appearence Datum of *Icr. w. woschmidti* was considered marking the base of the Lochkovian and therefore the latter zone to be of Devonian age.

The global zonation by Aldridge & Schönlaub (1989) has been reported also in the Newsletter of the Subcommission on Silurian Stratigraphy (Silurian Times No. 1; 1993). Two years later, a new Conodont Global Zonation chart appeared (Silurian Times No. 3; Nowlan 1995), significantly different from the others, but never fully justified or discussed. The Přídolí zonation is not significantly different than the previous one, being subdivided into a "*remscheidensis* interval Zone" followed by a very thin "*Ozarkodina eosteinhornensis-Oulodus elegans detortus* Zone" in the uppermost part. Recognition of the latter zone is based on paper by Jeppsson (1988, 1989) on Silurian/Devonian boundary GSSP, the Klonk section in Bohemia. The *I. w. woschmidti* Zone was considered to be Devonian.

Corradini & Serpagli (1998, 1999) proposed a new scheme, based on Sardinian data: the authors proved that the Sardinian conodont zonation is widely usable worldwide and claimed that it is "of practical use for Silurian biostratigraphy, and therefore more generally useful than extremely detailed schemes, sometimes based on not yet defined or endemic taxa" (Corradini & Serpagli 1999, p. 270). Following these considerations, the same authors (Corradini & Serpagli 2000) proposed their scheme as a Standard Silurian Conodont Zonation for the Wenlock–Přídolí time span. The Přídolí is subdivided into the same two zones of the Nowlan (1995) scheme, but the base of the *detortus* Zone was moved down within the Přídolí on the basis of new older recoveries of the marker *Oulodus elegans detortus*. This subdivision of the Přídolí was followed also by Ogg *et al*. (2008).

In the meantime, some taxonomical problems arose from the revision of some Ozarkodinids carried on by a few authors in the last few years (Murphy *et al*. 2004; Carls *et al*. 2005, 2007), who restricted the definition of the species *remscheidensis* and moved to genus *Zieglerodina*. In this new definition, *Z. remscheidensis* has its First Appearance Datum at the very top of the Přídolí (Corriga *et al*. 2009, Corradini & Corriga 2010), but not in lower levels. Therefore, because it is not appropriate to name a zone by an absent taxon, Corriga & Corradini (2009) renamed the former *remscheidensis* Zone as "*Oz. eosteinhornensis* s.l. interval Zone", without changing "the biostratigraphic meaning, since definition of the boundaries remains the same" (Corriga & Corradini 2009, p. 160). Also, the base of the *detortus* Zone is moved again into a lower level, because of recoveries of the marker around the middle of the Přídolí in several geographical areas (Bohemia: Carls *et al*. 2007;

EPOCH AGE	Klapper (1977) North America	Ziegler (1979)	Weddige (~ 1985) *in* Weddige (1996)	Murphy & Valenzuela-Ríos (1999)	House & Gradstein (2004)	Ogg *et al.* (2008)
Lochkovian	*pesavis*	*l. pesavis*	*pesavis*	*pandora beta*	*pesavis*	*pesavis*
	Oz. sp. nov. D	*Ancyrodelloides*	*delta*	*trigonicus*	*delta*	*delta*
				eleanorae		
				transitans		
				omoalpha		
	eurekaensis	*postwoschmidti*	*eurekaensis*	*eurekaensis*	*postwoschmidti* *woschmidti*	*eurekaensis*
	hesperius	*woschmidti*	*postwoschmidti* *woschmidti*	*hesperius*		*postwoschmidti* *woschmidti*

Figure 2. Main conodont zonation schemes of the Lochkovian.

Carnic Alps: Corriga & Corradini 2009; Frankenwald: Carls *et al*. 2007; Sardinia: Corriga *et al*. 2009).

Finally, Cramer *et al*. (2011) accept the Corriga & Corradini (2009) proposal as the conodont zonation of the Přídolí into the more recent biostratigraphic and chronostratigraphic subdivision of the Silurian.

Lochkovian

If the history of conodont zonation of the Přídolí shows a linear evolution, with biozones usable world-wide, this is not the case for the Lochkovian (Fig. 2). In the seventies regional zonation schemes or successions of faunal units were proposed for various regions (*i.e*.: North America – Klapper & Murphy 1975, Klapper 1977; Podolia – Mashkova 1978), whereas conodont faunal sequences were described in other areas (*i.e*: Spain – Carls 1969, 1975; Carls & Gandl 1969). Difficulties in correlating these areas were well evident (Klapper & Ziegler 1979). Nevertheless, a compilation of conodont zones was done by Ziegler (1979, fig. 5), mainly based on Spanish and central European data.

In the eighties an attempt towards a global zonation was done (*cf*. Weddige ~1985 *in* Weddige 1996), mainly following the North American scheme. The lower and middle Lochkovian was subdivided into three zones: a *woschmidti* Zone, with the possible recognition of a *postwoschmidti* interval in its upper part, followed by the *eurekaensis* Zone and the *delta* Zone. This proposal, even if not widely accepted because of problems in recognizing the *woschmidti* and the *eurekaensis* zones in several regions (*cf*. Valenzuela-Ríos 1994a, Valenzuela-Ríos & Murphy 1997, Murphy & Valenzuela-Ríos 1999) was extensively used by conodont workers and in the more recent schemes (House & Gradstein 2004, Ogg *et al*. 2008) there are no further variations for the lower Lochkovian.

Valenzuela-Ríos (1994a) working in the Spanish Central Pyrenees, recognized some intervals in the Lochkovian: his subdivision of the middle Lochkovian was the basis for further assessments by Valenzuela-Ríos & Murphy (1997) and Murphy & Valenzuela-Ríos (1999). These authors, on the basis of data from western United States and Spain, subdivided the *delta* Zone into four zones based on first appearances of species of genera *Lanea* and *Ancyrodelloides*: from the base *L. omoalpha*, *Ad. transitans*, *L. eleanorae* and *Ad. trigonicus*; the base of the upper Lochkovian would have been recognized by the First Appearance of *Ozarkodina pandora* morph β (now *Masaraella pandora* morph β).

This proposal was not considered in the more recent zonations of the Lochkovian (House & Gradstein 2004, Ogg *et al*. 2008), who repeat the previous schemes, without any comment. These schemes have been reported as "standard zonations", even if it is well known that they does not work in most of the world. This is even more surprising if we consider that these papers have been published under the auspices of the International Commission on Stratigraphy, and therefore many authors not aware of the Lower Devonian stratigraphy could consider valid.

Table 1. Age of the sections studied in Sardinia and in the Carnic Alps.

Sections	Age
SARDINIA	
Galemmu II	Lochkovian
Genna Arrela	Ludlow–Přídolí
Genna Ciuerciu	Ludlow–Přídolí
Mason Porcus	Přídolí–Lochkovian
Monte Fruccas	Ludlow–Přídolí
Perda S'Altari	Lochkovian
Ponte Monte Lora	Přídolí
Punta Carroga	Přídolí
San Basilio Fenugu	Ludlow–Lochkovian
Silius	Ludlow–Přídolí
CARNIC ALPS	
Casera La Valute	Ludlow–Přídolí
Casera Pal Piccolo	Ludlow–Lochkovian
Cima Pizzul	Přídolí–Lochkovian
Costone Lambertenghi	Přídolí–Lochkovian
Cuestalta	Ludlow–Lochkovian
La Valute	Lochkovian
Monte Cocco II	Ludlow–Lochkovian
Monte Cocco III	Ludlow–Přídolí
Rifugio Lambertenghi Fontana	Ludlow–Přídolí
Rifugio Lambertenghi Fontana III	Přídolí–Lochkovian
Rio Malinfier	Lochkovian
Rio Malinfier West	Ludlow–Lochkovian

Open problems and goal of the paper

In the conodont zonation schemes for the Přídolí and the Lochkovian there are still some open problems that should be solved before reaching a true global zonation. They can be summarized as follows:

– in the Přídolí, recoveries of *Oul. el. detortus* in older levels expanded the *detortus* Zone, that now occupy more than half of the series. A subdivision of this interval into two zones is desirable.

– the *eurekaensis* Zone, widely used in Lochkovian schemes, is based on a taxon with a limited geographical distribution in the western North America. Its applicability in Europe and elsewhere is not possible.

– the subdivision of the *delta* zone into four zones, proposed by Murphy & Valenzuela-Ríos (1999) for Spain and Nevada, should be checked in other palaeogeographic regions.

The main goal of this paper is to provide a regional zonation for the investigated areas. In addition we try to propose possible solutions to the problems highlighted above in order to make a step towards a global conodont zonation for the Přídolí and the Lochkovian.

Notes on taxonomy

In the last few years a taxonomical revision of several late Silurian-Early Devonian conodont taxa was started by several authors. This work, mainly based on several genera of Ozarkodinids, has not been completed up to date, and probably a more detailed zonation shall be achieved when several *Zieglerodina* species, previously named *Ozarkodina remscheidensis*, will be described.

Discussion on taxonomy is not the goal of this paper, even more if it is based on the generic attribution of valid species. As example, the species "*carlsi*", was described by Boersma (1973) as *Ozarkodina carlsi*, and referred to the genus *Ancyrodelloides* by Klapper (1991). Recently, the species was attributed to genus *Lanea* by Slavík (2011) on the basis of the reconstruction of the apparatus. Basically we agree on this approach, but also the diagnoses of genera *Lanea* and *Ancyrodelloides* should be changed on the basis of a multielement apparatus, in order that the revision will be completed. However, independently from its generic attribution the species is valid and has the characteristics of a good index taxon, and therefore can be chosen as zonal marker.

Material and geological settings

The Přídolí–Lochkovian zonation proposed in this paper is based on several sections in the Carnic Alps and in Sardinia (Fig. 3, Table 1). During the middle Palaeozoic time these regions represented two terranes in the Northern Gondwana margin (Schönlaub 1997, Ferretti *et al.* 2009). Silurian and Lower Devonian sequences of these areas are among the better exposed in the whole North Gondwana and deposed in various depositional environments, from shallow platform to basinal.

Carnic Alps

Silurian and Lower Devonian deposits are irregularly distributed within the Carnic Alps, and range from shallow water bioclastic limestones to nautiloid-bearing limestones, interbedded shales and limestones to black graptolitic shales and cherts. The overall thickness does not exceed 60 meters. It is subdivided into four lithofacies associations representing different depths of deposition and hydrodynamic conditions (Wenzel 1997). The Wolayer-facies is characterised by proximal shelf sediments and the Bischofalm-facies by deep water deposits; the Plöcken-facies and the Findenig-facies represent intermediate facies associations. For a more detailed description refer to Histon & Schönlaub (1999) and Schönlaub & Histon (2000).

We have sections from the Wolayer, Plöcken and Findenig facies. From the Wolayer facies the Rifugio

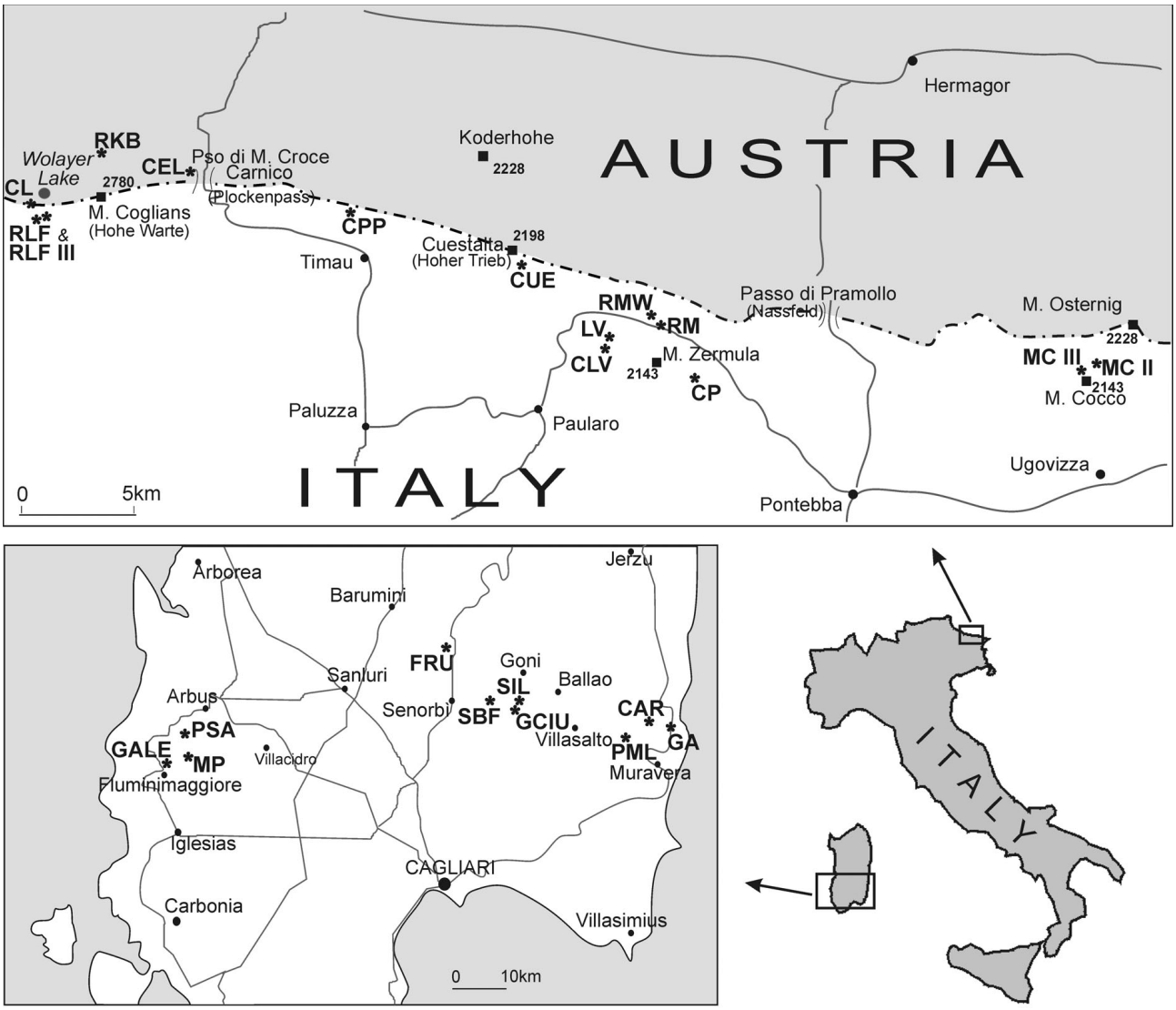


Figure 3. Location map of the studied sections. Locality abbreviations: *Carnic Alps*: CEL – Cellon; CL – Costone Lambertenghi; CLV – Casera La Valute; CP – Cima Pizzul; CPP – Casera Pal Piccolo; CUE – Cuestalta; LV – La Valute Cave; MC II – Monte Cocco II; MC III – Monte Cocco III; RKB – Rauchkofel Boden; RLF – Rifugio Lambertenghi Fontana; RLF III – Rifugio Lambertenghi Fontana III; RM – Rio Malinfier; RMW – Rio Malinfier West. *Sardinia*: CAR – Punta Carroga; FRU – Monte Fruccas; GA – Genna Arrela; GALE – Galemmu II; GCIU – Genna Ciuerciu; MP – Mason Porcus; PML – Ponte Monte Lora; PSA – Perda S'Altari; SBF – San Basilio Fenugu; SIL – Silius.

Lambertenghi Fontana and Rifugio Lambertenghi Fontana III sections (Corradini & Corriga 2010) and the Costone Lambertenghi section (partly equivalent to the Seekopf Sockel section by Schönlaub 1980). From a facies similar to the Plöcken we studied the Monte Cocco II section (Corriga & Corradini 2009), in the easten part of the Carnic Alps. From the Findenig facies the Rio Malinfier, Rio Malinfier West (Corriga 2011) and the La Valute section (Corriga *et al*. 2011). Furthermore, the first author had the chance to study the collections from the Silurian part of the Cellon Section (Walliser 1964) and from the Rauchkofel Boden (Schönlaub 1980) and other sections deposited at Göttingen University and in the Geologisches Bundesandstalt in Wien. We included data from the Seewarte section (Suttner 2007) and several other sections still in study and/or unpublished in the Freikofel, Cuestalta/Hoher Trieb, Monte Zermula and Monte Cocco areas.

Sardinia

In Sardinia different sequences are exposed in the southeastern and in the southwestern part of the island: they remind to coeval sequences of Thuringia and Bohemia, respectively. For a complete description of the Silurian and

Lower Devonian of Sardinia refer to Corradini *et al.* (2009c, and reference herein).

In SE Sardinia Přídolí rocks belong to the upper part of the Ockerkalk limestone, an argillaceous limestone with a blue-grey color weathering into ochre and a typical irregular flaser texture. The Lochkovian is represented by the "Upper graptolitic Shales", exclusively composed by alum slates. In this area conodonts are abundant only in the Ockerkalk, where several sections are known. For this paper we mainly considered the fauna from the sections where the Přídolí is better exposed: Silius (Barca *et al.* 1995, Corradini *et al.* 2009a), Genna Ciuerciu (Barca *et al.* 1995, Corradini *et al.* 2009b), Genna Arrela (Corradini & Olivieri 1997, Corriga 2011); we also included data from the Ponte Monte Lora and the Monte Fruccas sections (Corradini & Olivieri 1997), and San Basilio Fenugu (Corradini *et al.* 2001). We revised the conodont collections from these sections, stored in the Museum of Palaeontology of the University of Modena and Reggio Emilia.

In SW Sardinia the upper Silurian and Lower Devonian belong to the Fluminimaggiore and the Mason Porcus formations. The first is mainly represented by metric blocks and lenses of "*Orthoceras*" and graptolitic limestone interbedded with non calcareous pelites and shales; the latter consists of nodular and massive limestones alternating with compact dark siltstone and shales (Gnoli *et al.* 1990). Continuous sections with well preserved, abundant conodonts have been measured only from the latest Přídolí to the Lower Lochkovian: collections of the Mason Porcus (Gnoli *et al.* 1988, Olivieri & Serpagli 1990) and Galemmu II (Mastandrea 1985, Corradini *et al.* 1998) sections have been restudied and updated on the basis of recent taxonomic revisions (Corriga 2011); data from Perda S'Altari section (Corriga 2007) have been considered, too.

The Přídolí–Lochkovian conodont zonation in Sardinia and the Carnic Alps

The conodont range of more than sixty taxa recovered from the investigated section is the base of the Přídolí–Lochkovian conodont zonation here presented. Nine conodont zones have been discriminated (Fig. 4). The stratigraphical distribution of taxa is shown in Fig. 5; index fossils and other taxa useful for stratigraphy are illustrated in Fig. 6.

All the biozone are here defined and discussed; lists of associated conodonts includes only taxa occurring in Sardinia and/or in the Carnic Alps. For further discussions see below.

Eosteinhornensis s.l. interval Zone

Lower limit. – Last occurrence of *Ozarkodina crispa*.

Upper limit. – First occurrence of *Oulodus elegans detortus*.

Associated conodonts. – *Belodella anomalis* Cooper, *Belodella resima* (Philip), *Coryssognathus dubius* (Rhodes), *Dapsilodus obliquicostatus* (Branson & Mehl), *Dvorakia amsdeni* Barrick & Klapper, *Oulodus elegans elegans* (Walliser), *Oulodus siluricus* (Branson & Mehl), *Ozarkodina confluens* (Branson & Mehl), *Ozarkodina eosteinhornensis* s.l. (Walliser), *Ozarkodina snajdri* (Walliser), *Panderodus recurvatus* (Rhodes), *Panderodus unicostatus* (Branson & Mehl), *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Pseudooneotodus bicornis bicornis* Drygant, *Pseudooneotodus bicornis contiguus* Corradini, *Wurmiella excavata* (Branson & Mehl), *Wurmiella alternata* Corradini & Corriga, *Zieglerodina zellmeri* Carls *et al*.

Remarks. – Naming this zone as "*eosteinhornensis* s.l. Zone" have been proposed by Corriga & Corradini (2009) to substitute the "*remscheidensis* Zone" by Corradini & Serpagli (1999). It was necessary after the taxonomical revision of late Silurian and Early Devonian Ozarkodinids (Murphy *et al.* 2004), that introduced a more restricted definition of *Zieglerodina remscheidensis* and shortened its range to younger levels. *Ozarkodina eosteinhornensis* s.l. is the more common taxon in this interval. The name variation did "not change the biostratigraphic meaning of the zone, since the definition of the boundaries remains the same" (Corriga & Corradini 2009, p. 160). *Oulodus elegans elegans* could have been a good marker, too, but is less abundant than *Oz. eostenhornensis* s.l. After a revision at species level of lower Přídolí ozarkodinids, it is possible that this interval can be further subdivided.

The base of this zone (LAD of *Oz. crispa*) is the best conodont datum point to recognize the Ludlow/Přídolí boundary. *Zieglerodina zellmeri* is limited to this zone; *Wurmiella alternata* enters near the base of the zone and *Dvorakia amsdeni* in the upper part; *Pseudooneotodus bic. bicornis* became extinct in the lower part.

Lower *detortus* Zone

Lower limit. – First occurrence of *Oulodus elegans detortus*.

Upper limit. – Last occurrence of *Dapsilodus obliquicostatus.*

Associated conodonts. – *Amydrotaxis* sp., *Belodella anomalis* Cooper, *Belodella coarctata* Barrick & Klapper, *Belodella resima* (Philip), *Coryssognathus dubius* (Rhodes),

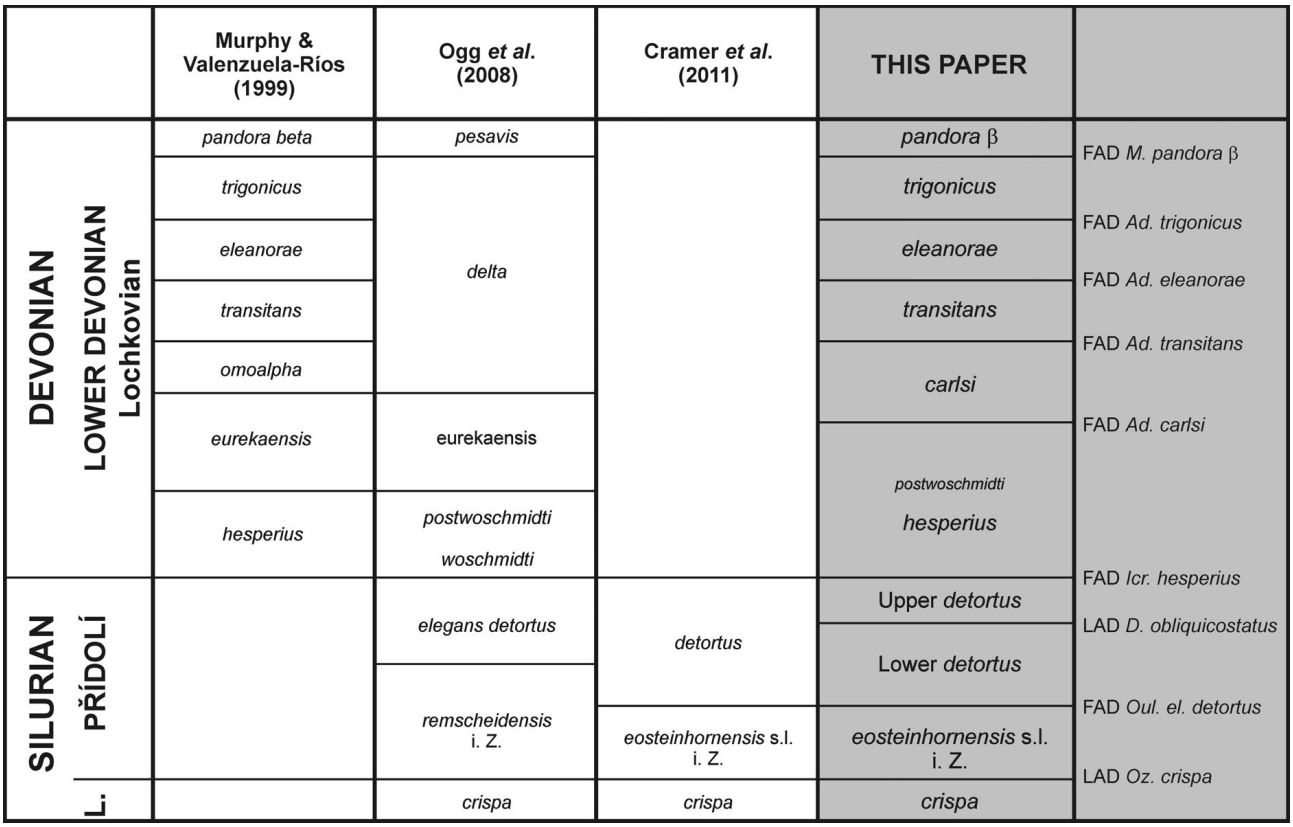


Figure 4. The Přídolí–Lochkovian zonation scheme in Sardinia and the Carnic Alps with definition of the conodont zones. Selected previous schemes are reported for comparison. The column by Ogg *et al.* (2008), even if is based on old data and not usable in most of the world, is reported because is the more recent scheme and has been published as "standard" by the International Commission on Stratigraphy.

Dapsilodus obliquicostatus (Branson & Mehl), *Dvorakia amsdeni* Barrick & Klapper, *Oulodus elegans elegans* (Walliser), *Oulodus elegans detortus* (Walliser), *Oulodus siluricus* (Branson & Mehl), *Ozarkodina confluens* (Branson & Mehl), *Ozarkodina eosteinhornensis* s.l. (Walliser), *Ozarkodina eosteinhornensis* s.s. (Walliser), *Ozarkodina planilingua* Murphy & Valenzuela-Ríos, *Ozarkodina snajdri* (Walliser), *Panderodus recurvatus* (Rhodes), *Panderodus unicostatus* (Branson & Mehl), *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Pseudooneotodus bicornis contiguus* Corradini, *Wurmiella excavata* (Branson & Mehl), *Wurmiella alternata* Corradini & Corriga, *Zieglerodina ivoclupaci* Carls *et al*., *Zieglerodina klonkensis* Carls *et al*.

Remarks. – This biozone is introduced herein. It corresponds to the lower part of the *detortus* Zone of previous schemes. In Sardinia and in the Carnic Alps a simultaneous last occurrence of some taxa (*Dapsilodus obliquicostatus*, *Coryssognathus dubius* and *Panderodus recurvatus*) in the upper Přídolí is documented: we chose to subdivide the *detortus* Zone on the basis of this extinction. As marker for the upper boundary we chose the Last Appearance Datum of *Dapsilodus obliquicostatus*, because is the more abundant and better documented species also in other part of the world. An extinction of several coniform species in the late Přídolí, including *D. obliquicostatus*, is documented also in North America (Jacobi *et al.* 2009). In the studied regions also *Coryssognathus dubius* could be a good marker, but choosing this species as marker would make more difficult long distance correlations, since the species is documented in the Přídolí only in Sardinia and the Carnic Alps (Corriga & Corradini 2009), and in the Frankenwald (Carls *et al.* 2007).

In the upper part of the zone is present an horizon (grey shade in Fig. 5) characterized by *Ozarkodina eosteinhornensis* s.s.: the morphotype with a denticle or a small ridge above the basal cavity, similar to the specimen designed as holotype by Walliser (1964). These forms are useful in biostratigraphy, being present in the same narrow interval also in Bohemia and in the Frankenwald (Carls *et al.* 2007).

Zieglerodina ivochlupaci is exclusive of the central part of the zone, below the *Oz. eosteinhornensis* s.s. horizon. *Ozarkodina snajdri* and *Oulodus siluricus* became extinct within this zone; *Z. klonkensis*, *Oz. planilingua* and *Belodella coarctata* have their first occurrences in the upper part.

Upper *detortus* Zone

Lower limit. – Last occurrence of *Dapsilodus obliquicostatus*.

Upper limit. – First occurrence of *Icriodus hesperius.*

Associated conodonts. – *Belodella anomalis* Cooper, *Belodella coarctata* Barrick & Klapper, *Belodella resima* (Philip), *Dvorakia amsdeni* Barrick & Klapper, *Oulodus elegans detortus* (Walliser), *Oulodus elegans elegans* (Walliser), *Ozarkodina confluens* (Branson & Mehl), *Ozarkodina eosteinhornensis* s.l. (Walliser), *Ozarkodina planilingua* Murphy & Valenzuela-Ríos, *Panderodus unicostatus* (Branson & Mehl), *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Pseudooneotodus bicornis contiguus* Corradini, *Wurmiella excavata* (Branson & Mehl), *Zieglerodina eladioi* (Valenzuela-Ríos), *Zieglerodina klonkensis* Carls *et al*., *Zieglerodina remscheidensis* (Ziegler).

Remarks. – This biozone is introduced herein. It corresponds to the upper part of the former *detortus* Zone. For discussion of the lower boundary see above (Remarks to the Lower *detortus* Zone). The upper boundary approximate the Silurian/Devonian boundary.

Even if the Upper *detortus* Zone probably represents a short time interval, some important datum points can be recognized: the LAD of *Ozarkodina confluens* occur in the upper part, immediately followed by the FAD of *Zieglerodina remscheidensis* and *Z. eladioi*.

Hesperius Zone

Lower limit. – First occurrence of *Icriodus hesperius*.

Upper limit. – First occurrence of *Ancyrodelloides carlsi.*

Associated conodonts. – *Belodella anomalis* Cooper, *Belodella coarctata* Barrick & Klapper, *Belodella resima* (Philip), *Dvorakia amsdeni* Barrick & Klapper, *Icriodus hesperius* Klapper & Murphy, *Icriodus postwoschmidti* Mashkova, *Icriodus woschmidti* Ziegler, *Lanea omoalpha* Murphy & Valenzuela-Ríos, *Oulodus aclys* Mawson, *Oulodus elegans elegans* (Walliser), *Oulodus elegans detortus* (Walliser), *Oulodus greilingi hirpex* Mawson, *Ozarkodina eosteinhornensis* s.l. (Walliser), *Ozarkodina planilingua* Murphy & Valenzuela-Ríos, *Panderodus unicostatus* (Branson & Mehl), *Pandorinellina repetitor* Carls & Gandl, *Pedavis biexoramus* Murphy & Matti, *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Sannemannia ichnusae* Olivieri & Serpagli, *Wurmiella excavata* (Branson & Mehl), *Zieglerodina eladioi* (Valenzuela-Ríos), *Zieglerodina klonkensis* Carls *et al*., *Zieglerodina remscheidensis* (Ziegler).

Remarks. – A basal Devonian zone defined by the first occurrence of species of *Icriodus* of the "*woschmidti* Group" was established from the beginning of Silurian/Devonian zonations (Walliser 1964), when all these species were named as *Icr. woschmidti*. Later on it appeared evident that other species, like *Icr. hesperius*, were more common and widespread than *Icr. woschmidti*, but in different schemes either one or the other species were used to name the first Devonian zone. Carls *et al.* (2007, pp. 158, 159) state that "the named taxon with wide distribution that appear closest to the lower Devonian system boundary is *Icr. hesperius* Klapper & Murphy, 1975" and that *Icr. woschmidti* enters somewhere above within the lower Lochkovian. We agree that the best marker for this zone is *Icr. hesperius* (so the name), that is much more abundant than *Icr. woschmidti*; furthermore *Icr. woschmidti* occur only in the lower part of the zone.

We included in this zone also the *postwoschmidti* Zone of other schemes: the index taxon *Icr. postwoschmidti* is very rare in our sections, and therefore it looks not appropriate discriminate a zone after a taxon that in many sections has not been documented. However, since, when present, the species helps in the identification of the upper part of the zone and in other regions it is abundant, we indicate a "*postwoschmidti* subzone" in the upper part of the *hesperius* Zone.

The *hesperius* Zone, as we define here, includes the *woschmidti-postwoschmidti* and most of the *eurekaensis* Zone of the more recent scheme (Ogg *et al.* 2008). The *eurekaensis* zone cannot be discriminated outside a few North American regions, because the marker has a limited geographical distribution. Carls *et al.* (2007, p. 158) agree that "a succession of *hesperius* Zone and revised *postwoschmidti* Zone for the interval before *Ancyrodelloides carlsi* would be more appropriate".

Icr. woschmidi is limited to the lower part of the zone, and *Sannemannia ichnusae* to a short interval at the base of the *postwoschmidti* subzone. *Pedavis biexoramus* enters in the central part of the zone; *Ozarkodina eosteinhornensis* s.l. and *Oulodus el. elegans* have their last occurrence within the zone, just below the first occurrence of *Pandorinellina repetitor* and *Icr. postwoschmidti*.

Carlsi Zone

Lower limit. – First occurrence of *Ancyrodelloides carlsi*.

Upper limit. – First occurrence of *Ancyrodelloides transitans.*

Associated conodonts. – *Ancyrodelloides carlsi* (Boersma), *Belodella anomalis* Cooper, *Belodella resima* (Philip), *Icriodus angustoides alcoleae* Carls, *Lanea eoeleanorae* Murphy & Valenzuela-Ríos, *Lanea omoalpha* Murphy &

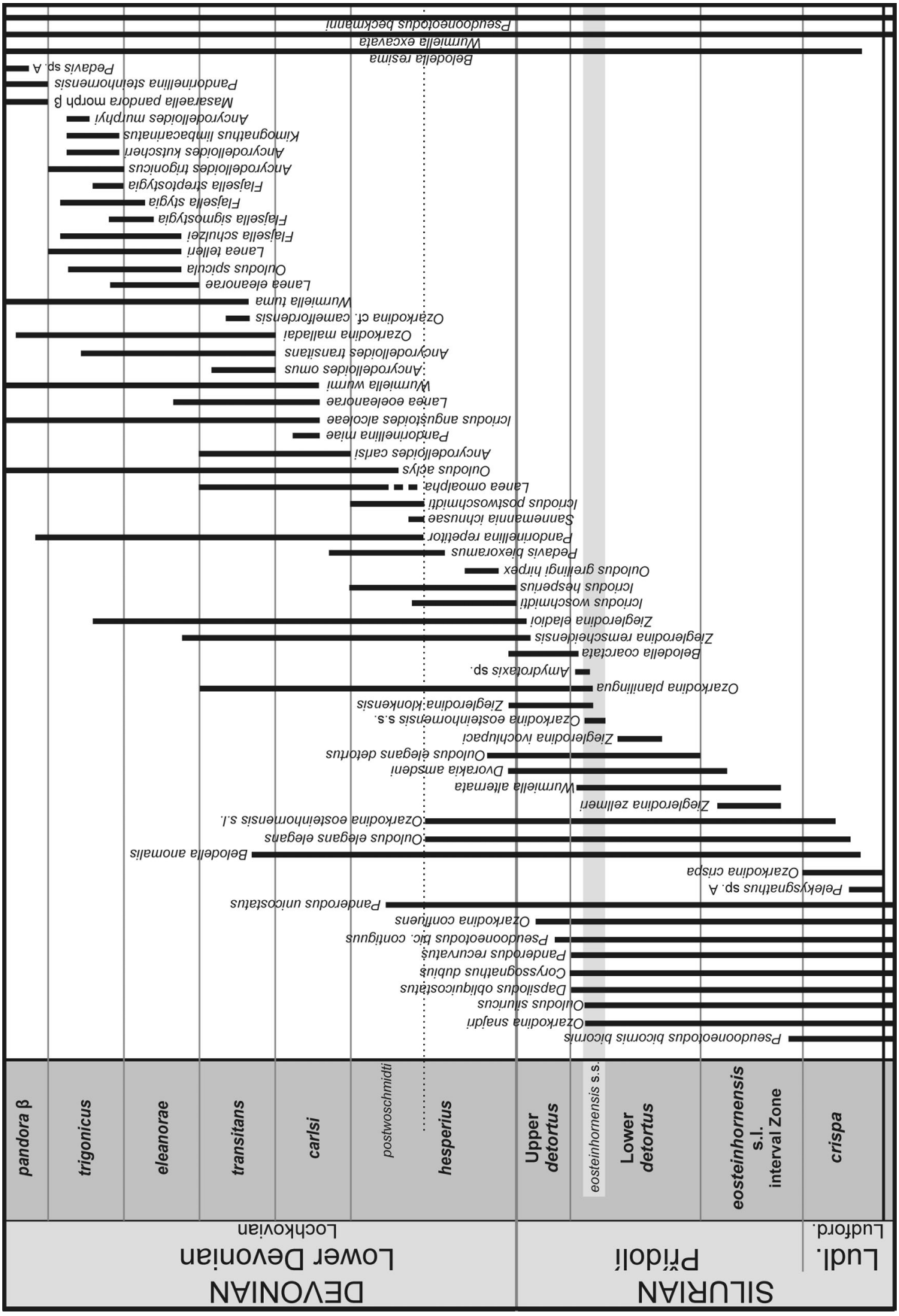


Figure 5. Distribution of conodont taxa in the Přídolí and Lochkovian of Sardinia and the Carnic Alps, based on data from the sections indicated in Fig. 4 and Table 1, and a few other unpublished localities. Note that long ranging taxa are reported at the right side of the figure.

Valenzuela-Ríos, *Oulodus aclys* Mawson, *Ozarkodina planilingua* Murphy & Valenzuela-Ríos, *Pandorinellina miae* (Bultynck), *Pandorinellina repetitor* Carls & Gandl, *Pedavis biexoramus* Murphy & Matti, *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Wurmiella excavata* (Branson & Mehl), *Wurmiella wurmi* (Bischoff & Sannemann), *Zieglerodina eladioi* (Valenzuela-Ríos), *Zieglerodina remscheidensis* (Ziegler).

Remarks. – This zone is introduced herein. It corresponds to the upper part of the North American *eurekaensis* Zone and to the lower part of the *delta* Zone. In this respect it includes the *omoalpha* Zone by Murphy & Valenzuela-Ríos (1999) because *Lanea omoalpha* occur in definitely lower stratigraphic levels in the Carnic Alps (*i.e*. Monte Cocco II and Costone Lambertenghi sections) and in Bohemia (M. Murphy, pers. comm., August 2011) and therefore its use as a marker should be re-evaluated after its stratigraphical distribution will be clarified.

The enter of *Ancyrodelloides carlsi* Zone can be used to define the base of the middle Lochkovian, as already suggested by Slavík (2011).

Valenzuela-Ríos (1994a) documented an "Intervalo *carlsi* + *transiens*" in the Lochkovian of the central Pyrenees, but this proposal was never considered in other regions and in more recent schemes. This is probably due to taxonomical problems between the species *Ozarkodina carlsi* Boersma and *Oz. masara* Schönlaub: Schönlaub (1980) described the species *Oz. masara* from the Carnic Alps and Bohemia, and several occurrences were referred to this taxon (*i.e*. Chlupáč 2000, Boncheva *et al.* 2007). However, as stated by Corriga (2011) and Slavík (2011), *Oz. masara* Schönlaub is a junior synonym of *Ad. carlsi* (Boersma). Recently, the species was attributed to the genus *Lanea* by Slavík (2011).

Beside the Carnic Alps and Northeastern Spain, the biozone can be recognized in several regions, where *Ad. carlsi* is documented in the uppermost part of the former *eurekaensis* Zone and/or in the lower part of the *delta* Zone: Frankenwald (Bischoff & Sannemann, 1958), Central Spain (Carls & Gandl 1969), Spanish Pyrenees (Boersma 1973; Valenzuela-Ríos, 1990, 1994a), Bohemia (Chlupáč *et al*. 1980, Chlupáč 2000, Slavík 2011), Morocco (Lazreq & Ouanaimi 1998), Bulgaria (Boncheva *et al.* 2007), Australia (Farrell 2003), and possibly Nevada (Murphy & Matti 1983).

In Sardinia the *carlsi* Zone is not documented and the index taxon is missing: probably corresponds to the covered interval above the occurrence of *Icriodus postwoschmidti* in the Mason Porcus section.

Lanea eoeleanorae, *Icr. angustoides alcoleae* and *Wurmiella wurmi* enters within this zone, whereas *Pedavis biexoramus* became extinct it its lower part.

Transitans Zone

Lower limit. – First occurrence of *Ancyrodelloides transitans*.

Upper limit. – First occurrence of *Lanea eleanorae.*

Associated conodonts. – *Ancyrodelloides carlsi* (Boersma), *Ancyrodelloides omus* Murphy & Matti, *Ancyrodelloides transitans* (Bischoff & Sannemann), *Belodella anomalis* Cooper, *Belodella resima* (Philip), *Icriodus angustoides alcoleae* Carls, *Lanea eoeleanorae* Murphy & Valenzuela-Ríos, *Lanea omoalpha* Murphy & Valenzuela-Ríos, *Oulodus aclys* Mawson, *Ozarkodina* cf. *camelfordensis* Farrell, *Ozarkodina malladai* Valenzuela-Ríos, *Ozarkodina planilingua* Murphy & Valenzuela-Ríos, *Pandorinellina repetitor* Carls & Gandl, *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Wurmiella excavata* (Branson & Mehl), *Wurmiella tuma* (Murphy & Matti), *Wurmiella wurmi* (Bischoff & Sannemann), *Zieglerodina eladioi* (Valenzuela-Ríos), *Zieglerodina remscheidensis* (Ziegler).

Remarks. – This zone was introduced by Valenzuela-Ríos (1994a) in the Spanish Central Pyrenees, and later accepted by Murphy & Valenzuela-Ríos (1999) in Nevada and the Spanish Pyrenees. It can be easily recognized in Sardinia and the Carnic Alps. It corresponds to an interval in the lower-central part of the *delta* Zone.

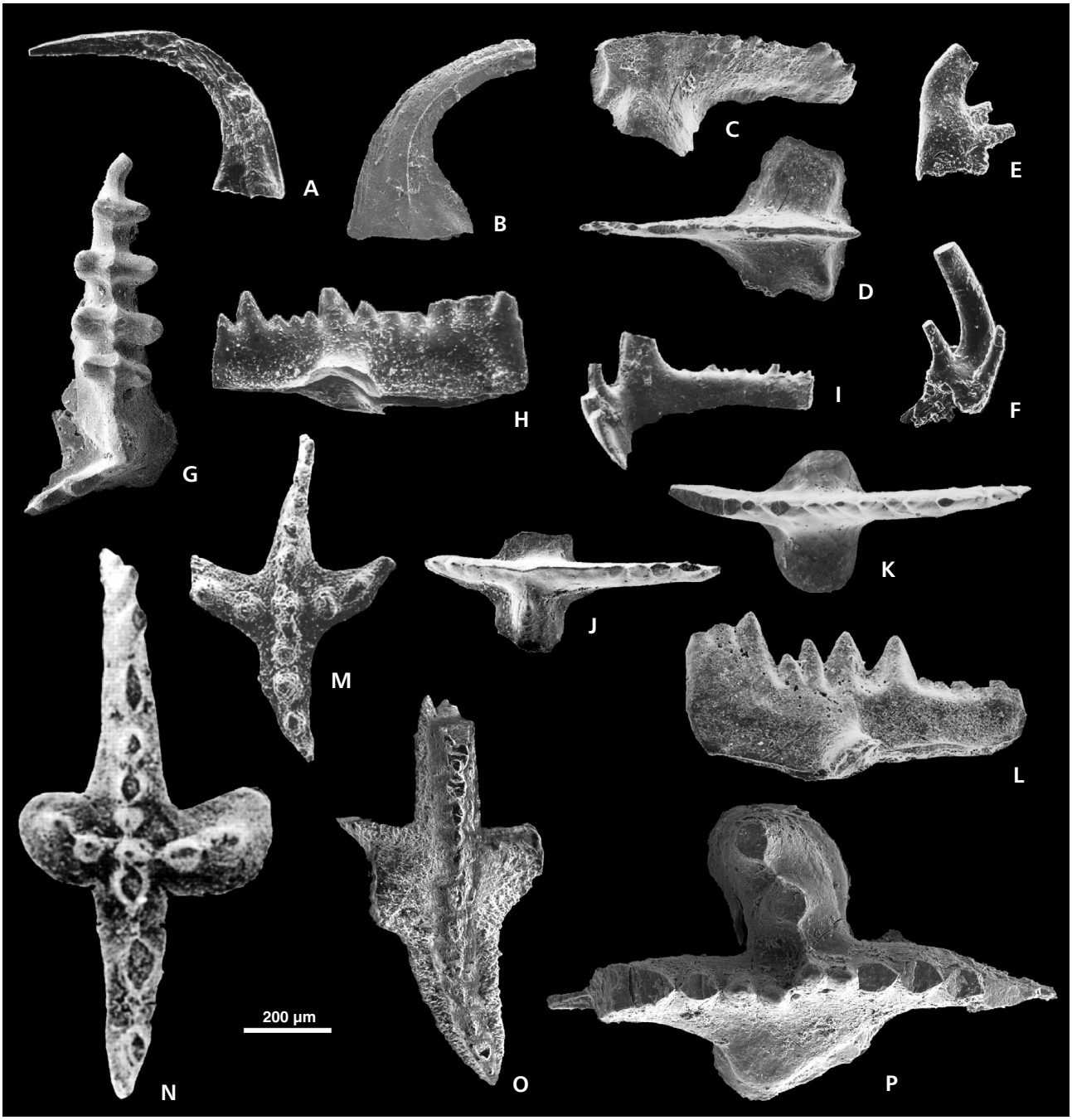
Ancyrodelloides omus, *Ozarkodina malladai* and *Oz.* cf. *camelfordensis* are exclusive of this zone; *Wurmiella tuma* enters within the zone, and *Lanea omoalpha* became extinct in the upper part, and *Ancyrodelloides carlsi* and *Ozarkodina planilingua* at the top of the zone.

Eleanorae Zone

Lower limit. – First occurrence of *Lanea eleanorae*.

Upper limit. – First occurrence of *Ancyrodelloides trigonicus.*

Figure 6. Index fossils and other useful conodonts for the Přídolí and Lochkovian biostratigraphy. • A – *Panderodus recurvatus* (Rhodes, 1953); MDLCA 30043, lateral view, Rifugio Lambertenghi Fontana section, sample RLF 2B. • B – *Dapsilodus obliquicostatus* (Branson & Mehl, 1933); MDLCA 30034, lateral view, Rifugio Lambertenghi Fontana section, sample RLF 1. • C, D – *Ozarkodina crispa* (Walliser, 1964); IPUM 27677, lateral (C) and upper (D) views of P1 element, Monte Cocco II section, sample MC II 1. • E – *Coryssognathus dubius* (Rhodes, 1953);



MDLCA 30035, lateral view of S2 element, Rifugio Lambertenghi Fontana III section, sample RLF III 2B. • F – *Coryssognathus dubius* (Rhodes, 1953); MDLCA 30038, lateral view of S0/S1 element, Rifugio Lambertenghi Fontana III section, sample RLF III 2B. • G – *Icriodus hesperius* Klapper & Murphy, 1975; IPUM 28195, upper view of P1 element, Monte Cocco II section, sample MC II 5F. • H – *Zieglerodina remscheidensis* (Ziegler, 1960); MDLCA 30063, lateral view of P1 element, Rifugio Lambertenghi Fontana III section, RLF III 1X. • I – *Oulodus elegans detortus* (Walliser, 1964); IPUM 23457, lateral view of S2 element, Mason Porcus section, sample MP 11. • J – *Ozarkodina eosteinhornensis* s.s. (Walliser, 1964); IPUM 27673, upper view of P1 element, Monte Cocco II section, sample MC II 3D. • K – *Ozarkodina eosteinhornensis* s.l. (Walliser, 1964); IPUM 27672, upper view of P1 element, Monte Cocco II section, sample MC II 3D. • L – *Ozarkodina confluens* (Branson & Mehl, 1933); IPUM 27681, lateral view of P1 element, Monte Cocco II section, sample MC II 4A. • M – *Ancyrodelloides trigonicus* Bischoff & Sannemann, 1958; IPUM 20953 upper view of P1 element, Galemmu II section, sample GALE II G. • N – *Ancyrodelloides transitans* Bischoff & Sannemann, 1958; upper view of P1 element, Galemmu II section, sample GALE II D. • O – *Lanea eleanorae* (Lane & Ormiston, 1979); MDLCA 30128, upper view of P1 element, La Valute section, sample LV 2. • P – *Ancyrodelloides carlsi* (Boersma, 1973); MDLCA 30186, upper view of P1 element, Rio Malinfier section, sample RM 1. Repository of figured specimens: IPUM = Museo di Paleontologia, Università di Modena e Reggio Emilia; MDLCA = Museo Domenico Lovisato, Università di Cagliari.

Associated conodonts. – *Ancyrodelloides transitans* (Bischoff & Sannemann), *Belodella resima* (Philip), *Flajsella schulzei* (Bardashev), *Flajsella sigmostygia* Valenzuela-Ríos & Murphy, *Flajsella stygia* (Flajs), *Icriodus angustoides alcolae* Carls, *Lanea eleanorae* Murphy & Valenzuela-Ríos, *Lanea eoeleanorae* Murphy & Valenzuela-Ríos, *Lanea telleri* (Schulze), *Oulodus aclys* Mawson, *Oulodus spicula* Mawson, *Ozarkodina malladai* Valenzuela-Ríos, *Pandorinellina repetitor* Carls & Gandl, *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Wurmiella excavata* (Branson & Mehl), *Wurmiella tuma* (Murphy & Matti), *Wurmiella wurmi* (Bischoff & Sannemann), *Zieglerodina eladioi* (Valenzuela-Ríos), *Zieglerodina remscheidensis* (Ziegler).

Remarks. – This zone was introduced by Murphy & Valenzuela-Ríos (1999) in Nevada and in the Spanish Central Pyrenees and can be recognized in Sardinia and the Carnic Alps. It corresponds to an interval in the central-upper part of the *delta* Zone.

Lanea telleri and *Flajsella schulzei* enters in the lower part of the zone, whereas other species of *Flajsella* (*Fl. stygia* and *Fl. sigmostygia*) have their first occurrence one following the others.

Zieglerodina remscheidensis and *Lanea eoeleanorae* have their last occurrence within the zone.

Trigonicus Zone

Lower limit. – First occurrence of *Ancyrodelloides trigonicus*.

Upper limit. – First occurrence of *Masaraella pandora* morph β.

Associated conodonts. – *Ancyrodelloides kutscheri* (Bischoff & Sannemann), *Ancyrodelloides murphyi* Valenzuela-Ríos, *Ancyrodelloides transitans* (Bischoff & Sannemann), *Ancyrodelloides trigonicus* (Bischoff & Sannemann), *Belodella resima* (Philip), *Flajsella schulzei* (Bardashev), *Flajsella sigmostygia* Valenzuela-Ríos & Murphy, *Flajsella streptostygia* Valenzuela-Ríos & Murphy, *Flajsella stygia* (Flajs), *Icriodus angustoides alcoleae* Carls, *Kimognathus limbacarinatus* (Murphy & Matti), *Lanea eleanorae* Murphy & Valenzuela-Ríos, *Oulodus aclys* Mawson, *Oulodus spicula* Mawson, *Ozarkodina malladai* Valenzuela-Ríos, *Pandorinellina repetitor* Carls & Gandl, *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Wurmiella excavata* (Branson & Mehl), *Wurmiella tuma* (Murphy & Matti), *Wurmiella wurmi* (Bischoff & Sannemann), *Zieglerodina eladioi* (Valenzuela-Ríos).

Remarks. – This zone was introduced by Valenzuela-Ríos (1994a) in the Spanish Central Pyrenees, and later accepted by Murphy & Valenzuela-Ríos (1999) in Nevada and the Spanish Pyrenees. It can be easily recognized in Sardinia and the Carnic Alps. It corresponds to the upper part of the *delta* Zone and is the last middle Lochkovian zone.

The marker *Ancyrodelloides trigonicus* is exclusive of this zone, *Flajsella streptostygia* is present only in the lower part, and *Ancyrodelloides kutscheri* and *Ad. murphyi* occur in the central part of the zone. All the species of genus *Flajsella* became extinct within this zone, and *Lanea telleri* has its last occurrence in its uppermost part.

Pandora β Zone

Lower limit. – First occurrence of *Masaraella pandora* morph β.

Associated conodonts. – *Belodella resima* (Philip), *Icriodus angustoides alcoleae* Carls, *Masaraella pandora* morph β Murphy *et al*., *Oulodus aclys* Mawson, *Ozarkodina malladai* Valenzuela-Ríos, *Pandorinellina repetitor* (Carls & Gandl), *Pandorinellina steinhornensis* Ziegler, *Pedavis* sp. A Corriga *et al*., *Pseudooneotodus beckmanni* (Bischoff & Sannemann), *Wurmiella excavata* (Branson & Mehl), *Wurmiella tuma* (Murphy & Matti), *Wurmiella wurmi* (Bischoff & Sannemann).

Remarks. – This zone was introduced by Valenzuela-Ríos (1994a) in the Spanish Central Pyrenees, and later accepted by Murphy & Valenzuela-Ríos (1999) also in Nevada. It corresponds to part of the *pesavis* Zone of several zonation schemes. We prefer use *Masaraella pandora* morph β as index, because this taxon is more abundant and easy recognizable than species of *Pedavis*. Furthermore, doubt on the opportunity of naming a zone after *Pe. pesavis* were discussed by other authors (*i.e*. Valenzuela-Ríos 1994b). This zone marks the base of the upper Lochkovian according to Valenzuela-Ríos & Murphy (1997), even if in this subdivision the upper Lochkovian is definitely much shorter that the lower and middle part of the stage.

In our sections the *pandora* β Zone is documented only in the Mason Porcus and La Valute section, where its upper boundary is not exposed. Therefore it is not possible to stress more comments.

Discussion and comparison with other areas

It is difficult comparing a regional zonation scheme with data from other geographic areas for several reasons. The main problem is related to taxonomical attributions of fauna by different authors: in the case of well established species (*i.e. Polygnathoides siluricus*) there are no problems; but it is almost impossible to know the range of recent

species, even more if not all the scientific community accept these new proposal. As example we can consider the recent revision of late Silurian and earliest Devonian Ozarkodinids: Murphy *et al.* (2004) splitted the genus *Ozarkodina* Branson & Mehl, 1933 into several new genera (*Wurmiella*, *Zieglerodina* and another one not established according to the ICZN code), restricting the diagnosis of *Ozarkodina* on the basis of *Oz. confluens* Branson & Mehl, 1933 (= *Oz. typica sensu* Murphy *et al.*, 2004); later on, the same group of authors (Carls *et al.* 2005) introduced genus *Parazieglerodina*, that in our opinion is questionable because it is to much similar to *Zieglerodina*. However, not all the species that previously belong to *Ozarkodina* have a home in this scenario. Moreover, Murphy *et al.* (2004) restricted the diagnosis of *Z. remscheidensis* to morphs similar to the holotype of Ziegler (1960, pl. 13, fig. 4) and Carls *et al.* (2007) introduced three new species, but several other possible species of *Zieglerodina* (before named as *Oz. remscheidensis*) are still to be described; to make things even more difficult, these authors provided only very limited synonymy lists. As a result, this partial revision generate several problems: some scientists do not accept this approach and still refer all these species to *Oz. remscheidensis* (*i.e*. Suttner 2007) or more generally to a "*remscheidensis* Group" (*i.e*. Kleffner *et al.* 2009). This different approaches create a lot of confusion, that will be solved when the taxonomic revision will be completed. As for now it is impossible knowing the precise range of various taxa from literature and refer to a well established zonation scheme.

Our newly introduced zones (Lower and Upper *detortus*, and *carlsi* zones) can be recognized also in other regions:

– the lower boundary of the Upper *detortus* Zone can be recognized in the central-south United States, where Barrick *et al.* (2005) and Jacobi *et al.* (2009) documented a simultaneous extinction of several coniform species in the late Přídolí, including *Dapsilodus obliquicostatus*. The range of *Coryssognathus* in the Frankenwald (Carls *et al*. 2007) allows recognition of this zone. Lack of information on distribution of coniform conodonts in other regions prevents any further comment.

– an interval characterized by *Ancyrodelloides carlsi* between the *hesperius* and the *transitans* zones may be recognized in several european regions (Germany, Central Spain, Spanish Central Pyrenees, Bohemia, Bulgaria), in North Africa (Morocco), Australia, and possibly North America.

The eosteinhornensis *s.s. horizon*

Another important correlation point is the *Ozarkodina eosteinhornensis* s.s. horizon, occurring in the upper part of the Lower *detortus* Zone. The name *Ozarkodina eosteinhornensis* s.s. is widely used in literature to indicate the morphotype similar to the holotype designed by Walliser (1964), characterized by a denticle or a small ridge above one side of the basal cavity. These forms have also been referred to morph β by Olivieri & Serpagli (1990) and to morph α by Murphy *et al.* (2004). Murphy *et al.* (2004) proposed a new genus ("Genus W") to represent the "*eosteinhornensis* group", but their proposal in not valid according to the ICZN code, and therefore it cannot be accepted.

Beside problems of nomenclature, *Ozarkodina eosteinhornensis* s.s. is well known in several North Gondwana regions (Bohemia, the Carnic Alps, Frankenwald, Sardinia) and characterizes a very short interval in the upper Přídolí. However, even if the *eosteinhornensis* s.s. horizon is very useful for correlations, it looks not appropriate naming a zone after it, because the conodont association immediately below and above this horizon is very similar: in case it have not been sampled, being somewhere reduced to a few centimeters of rock, it is not possible to distinguish the correct biostratigraphic position of a sample, if just below or just above the *eosteinhornensis* s.s. horizon, in the upper part of the Lower *detortus* Zone.

The subdivision of the delta *Zone*

In the more recent mid-Lochkovian zonation Murphy & Valenzuela-Ríos (1999) subdivided the *delta* Zone into four zones (*omoalpha*, *transitans*, *eleanorae* and *trigonicus*), on the basis of the conodont distribution in Nevada and Spain. This subdivision works well also in the Carnic Alps and in Sardinia, and the last three zones are accepted. Some problems arose with the *omoalpha* Zone, that we included in the *carlsi* Zone. In fact *L. omoalpha* is present in older levels in some localities: in the Monte Cocco II section (Corriga & Corradini 2009) it occurs together with *Icr. hesperius* and *Ped. biexoramus*, that is in the upper part of the *hesperius* Zone, and in the Costone Lambertenghi section have been found in the lower Lochkovian, well below the entry of *Ad. carlsi*. Similar early occurrence is documented in Bohemia (M. Murphy, pers. comm., August 2011); also in Bohemia, Slavík (2011, fig. 2) reports a "pre-*Lanea*" with incipient terraces and a *Lanea* cf. *omoalpha* from the lower Lochkovian. Therefore, it is better not to use *L. omoalpha* as a zonal marker until its taxonomic characterization will be done, and its stratigraphic range will be clear. On the other hand, *Ad. carlsi* is a good marker, widespread and relatively abundant and its range starts only slightly below the base of the former *delta* Zone, and, therefore, the *carlsi* Zone is a better biostratigraphic unit than the *omoalpha* Zone *sensu* Murphy & Valenzuela-Ríos (1999). Furthermore, as suggested by Slavík (2011), the FAD of *Ad. carlsi* can be a good marker for the base of the middle Lochkovian.

Comments on recognizing the Silurian/Devonian boundary by conodonts

A precise recognition of the Silurian/Devonian boundary on the basis of conodonts has always been a problem. In fact, the boundary is defined by the First Appearance Datum of the graptolite *Monograptus uniformis*, and it is not clear if any conodont species has a simultaneous first occurrence. The *hesperius* Zone is considered the first Devonian conodont zone. For long time this zone have been named *woschmidti* Zone because all the earliest Lochkovian representatives of genus *Icriodus* were attributed to *Icr. woschmidti* (Carls *et al.* 2007). As pointed out above, taxonomic revisions suggest that it is better naming this zone after *Icr. hesperius*, because it is "the named taxon with wide distribution that appears closest to the lower Devonian boundary" (Carls *et al.* 2007, pp. 157, 158).

The occurrence of *Icriodus* can be considered a proof of Devonian age. However, according to Jeppsson (1988), in many sections, *I. woschmidti* occurs slightly before *M. uniformis*, but this fact may be due to facies control: in fact graptolites are normally collected from shales and conodonts from limestones. Furthermore, icriodids are typical of inshore shallow water deposits (Bultynck 2003), whereas are rare in other marine environments. As a result, *Icriodus* is very rare, if not absent, in many sections.

In our sections in the Carnic Alps and Sardinia some datum points have been observed just below or above the first occurrence of *Icriodus* and can help to approximate the Silurian/Devonian boundary position:

1. *Ozarkodina confluens* has its last occurrence in the latest Přídolí (upper part of the Upper *detortus* Zone), immediately followed by

2. the first occurrence of *Zieglerodina remscheidensis* and *Zieglerodina eladioi* and

3. the first occurrence of *Icriodus hesperius* and *Icriodus woschmidti* (base of the Devonian). In a few sections (*i.e*: Monte Cocco II) the two species enters together, whereas elsewhere (*i.e*. Mason Porcus) *Icr. hesperius* has a slightly older first occurrence.

4. *Belodella coarctata*, *Dvorakia amsdeni* and *Zieglerodina klonkensis* have their last occurrence just above the entry of icriodids.

Conclusions

Nine conodont zone have been discriminated in the Přídolí and Lochkovian of the Carnic Alps and Sardinia: *eosteinhornensis* s.l. interval Zone, Lower *detortus* and Upper *detortus* zones in the Přídolí, *hesperius*, *carlsi*, *transitans*, *eleanorae*, *trigonicus* and *pandora* β zones in the Lochkovian.

The main differences with the schemes in use are:

1. In the Přídolí, the *detortus* Zone is subdivided into two parts, a Lower *detortus* Zone and an Upper *detortus* Zone;

2. In the Lochkovian the *hesperius* Zone (including the *postwoschmidti* subzone in the upper part) is expanded to include most of the *eurekaensis* Zone;

3. The *carlsi* Zone, here introduced, corresponds to the upper part of the *eurekaensis* Zone and to the lower part of the *delta* Zone (*omoalpha* Zone *sensu* Murphy & Valenzuela-Ríos, 1999); the base of this zone is a good marker for the base of the middle Lochkovian, as already proposed by Slavík (2011);

4. The zonation proposed by Murphy & Valenzuela-Ríos (1999) to substitute the central and upper part of the *delta* Zone and the *pesavis* Zone is accepted: in this interval the *transitans*, *eleanorae*, *trigonicus* and *pandora* β are discriminated.

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