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# The Silurian of Sardinia

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## Silurian conodonts from Sardinia: an overview

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**ABSTRACT** - A general review of Silurian conodont data from Sardinia is here presented. Main features of the conodont associations, with special attention to their biostratigraphical implications, are briefly highlighted. All papers dealing with Silurian conodonts from Sardinia are listed, as well as a complete summary of productive localities is given in the appendix.

**KEY WORDS** - Silurian, Sardinia, Conodonts, Biostratigraphy.

### INTRODUCTION AND HISTORICAL OVERVIEW

Conodonts are by long the better known and more documented fossil group from the Silurian of Sardinia. Starting from the first report by Serpagli (1967), more than 35 papers have dealt with this fossil group (for a complete list see appendix 1). Most of the researches, mainly carried out by the palaeontological group of Modena University lead by Enrico Serpagli, were devoted to solving geological and stratigraphical problems in highly tectonized sequences. Only in a few papers a taxonomic and systematic approach to these fossils was made. Nevertheless, several new taxa have been established in Sardinia (Pl. 1).

About thirty localities yielded Silurian conodonts (Figs. 1, 2; appendix 2). For a long time field work was mainly limited to the “*Orthoceras* limestone” occurrences (Fluminimaggiore Formation) of southwestern Sardinia. Only in the last fifteen years researches moved to the southeastern part of the island, where the Ockerkalk limestones there exposed in continuous sections have been the subject of an intensive study. A dozen of sections from the Gerrei tectonic Unit have been investigated and placed in the late Silurian time frame.

### CONODONT FAUNA

Forty-three conodont species and subspecies belonging to sixteen genera (*Amydrotaxis*, *Ancoradella*, *Aspidognathus*, *Belodella*, *Dapsilodus*, *Kockelella*, *Oulodus*, *Ozarkodina*, *Panderodus*, *Pedavis*, *Pelekysgnathus*, *Polygnathoides*, *Pseudooneotodus*, *Pterospathodus*, *Wurmiella* and *Zieglerodina*) have been reported from the Silurian of Sardinia (Fig. 3).

Conodont abundance is in general quite high, with an average of about 30 elements/kg. The preservation varies from time to time and from area to area, but in general it is moderately good. The Colour Alteration Index is constantly between 4.5 and 5.5.

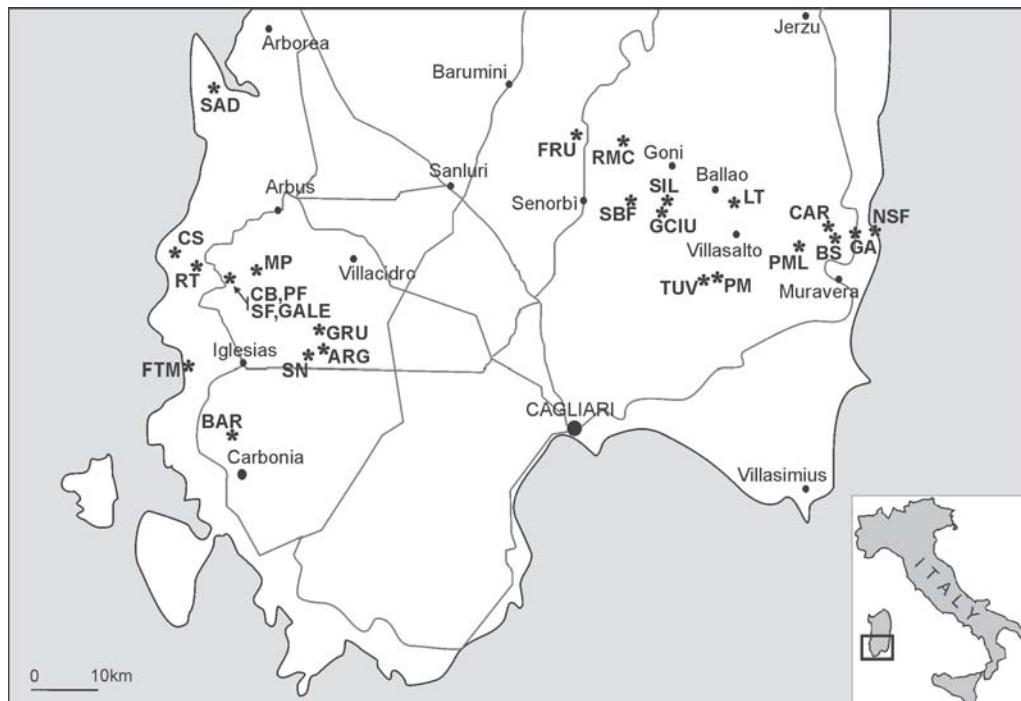


Fig. 1 - Location map of the localities yielding Silurian conodonts in Sardinia. Locality abbreviations: ARG: Argiola; BAR: Barbusi; BS: Baccu Scottis; CAR: Punta Carroga; CB: Corti Baccas; FTM: Funtanamare; FRU: Monte Fruccas; GA: Genna Arrela; GALE: Galemму; GCIU: Genna Ciuerciu; GRU: Gruttixedda; LT: Lantini Tunnel; MP: Mason Porcus; NSF: Nuraghe su Franzesu; PF: Perd'e Fogu; PM: Pala Manna; PML: Ponte Monte Lora; RMC: Rio Murru de Callus; RT: Roia is Tintionis; SAD: Sant' Antonio Donigala; SBF: San Basilio Fenugu; SF: Sentiero Flumini; SIL: Silius; SN: Su Nuargi; TUV: Tuviois.

Ozarkodinids are almost always largely dominant in the conodont faunas and in several samples *Wurmiella excavata* may represent more than half of the association. Within this range, also *Ozarkodina sagitta sagitta*, *Oz. confluens* and "*Oz.*" *eosteinhornensis* are common.

The genus *Kockella* is abundant in the Gorstian and early Ludfordian, when it became extinct within the *siluricus* Zone, in connection with the Lau event. A revision of *Kockellids*, based on rich collections from Sardinia, was proposed by Serpagli & Corradini (1999). The authors revised the phylogeny of the genus, proposed a reconstruction of the apparatuses of *K. variabilis variabilis* and *K. crassa*, and described three new taxa: *K. variabilis ichtusae*, *K. maenniki* and *K. absidata sardoa* (Pl. 1).

The long ranging *Dapsilodus obliquicostatus* is relatively abundant in the late Silurian. Serpagli (1971) proposed for the first time a reconstruction of the apparatus of this species, based on material from Sentiero Flumini, in the Fluminimaggiore area.

*Pseudooneotodus* has very irregular occurrences, being in some levels very abundant and in some others, even stratigraphically very close, completely absent. Corradini (2008) suggested a possible ecological control to explain such irregular distribution.

Beside *Dapsilodus* and *Pseudooneotodus*, other conform conodonts (mainly Panderodids) are curiously quite rare in the Silurian conodont associations reported from Sardinia.

Anomalous conodont elements, mainly ramiforms with branched processes or extra bars, were collected from several sections, always from the *siluricus* Zone. Corradini et al. (1996) referred these occurrences to “pre-event” P-episodes, characterized by abundant and diverse planktonic communities.

EPOCH/AGE	GRAPTOLITE zones	CONODONT zones	CONODONT LOCALITIES		
			SW Sardinia	SE Sardinia	
<b>Devonian</b> 416.0	M. uniformis	w. woschmidti			
<b>Pridoli</b>	M. bouceki - transgrediens - perneri	elegans detortus			
	M. branikensis - lochkovensis	eosteinhornensis <i>interval Zone</i>			
	M. parultimus - ultimus				
<b>Ludlow</b>	M. formosus	crispa			
	N. kozlowskii - P. podoliensis	snajdri <i>i.Z.</i>			
	S. lentwardinensis	latialata			
		siluricus			
	<b>Gorstian</b>	L. scanicus	ploeckensis		
		N. nilssoni	hamata v. variabilis <i>i.Z.</i> crassa		
<b>Wenlock</b>	Co. ludensis	bohémica			
	Co. praedeubeli - deubeli				
	Pr. parvus - G. nassa				
	C. lundgreni	sagitta sagitta			
	<b>Sheinw.</b>	C. rigidus - perneri	sagitta rhenana		
M. ricc. - bel. - ant.					
C. centrif. - murch.		ranuliformis			
<b>Llandovery (p.)</b>	C. lapworthi - insectus	amorphognath.			
	O. spiralis				
	M. griestoniensis - crenulata				

Fig. 2 - Age of main conodont localities in Sardinia. Numerical age and graptolite zonation after Ogg et al. (2008); conodont zones modified after Corradini & Serpagli (1999).

## BIOSTRATIGRAPHY

A Silurian conodont zonation based on Sardinian data was proposed by Corradini & Serpagli (1998, 1999). The authors discriminated fifteen biozones in the top Llandovery-end Pridoli interval, with a much more detail for the Ludlow than any other scheme. 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, even if the base of Silurian is not included. A perfect timing between conodont and graptolite zonations was possible in some intervals thanks to some joint occurrences in the graptolite limestones of the Fluminimaggiore area (Corradini & Serpagli, 1999).

The lower part of the scheme, up to the *K. variabilis* interval Zone, is based on reports from several localities in southwestern Sardinia, whereas data from the upper part mainly derive from the Ockerkalk limestones of southeastern Sardinia, integrated with a few of Pridoli age from the Fluminimaggiore Fm.

Recently, the upper part of the Sardinian biozonation scheme has been updated by means of a graphic correlation method (Gouwy & Corradini, 2006), demonstrating that the *detortus* Zone, the final zone of the Silurian, is definitely longer in Sardinia than elsewhere. Later on, an analogous longer range of *Oul. el. detortus* was documented from the Czech Republic and Bavaria by Carls et al. (2007).

The scheme by Corradini & Serpagli (1998, 1999) is slightly updated here (Fig. 2) in respect of the lower Pridoli interval: their “*Oz. rem. remscheidensis* interval Zone” is here named “*eosteinhornensis* s.l. interval Zone” after a recent taxonomical revision of late Silurian Ozarkodinids by Murphy et al. (2004) and Carls et al. (2007). According to the new, restricted, definition of *Zieglerodina remscheidensis* (Ziegler), the species is missing

## Plate 1

Holotypes of conodont taxa established in Sardinia. All specimens x80.

Fig. 1 - *Kockelella maenniki* Serpagli & Corradini, 1998, Pa element; sample GCIU 3; upper (a) and lower (b) views of the holotype.

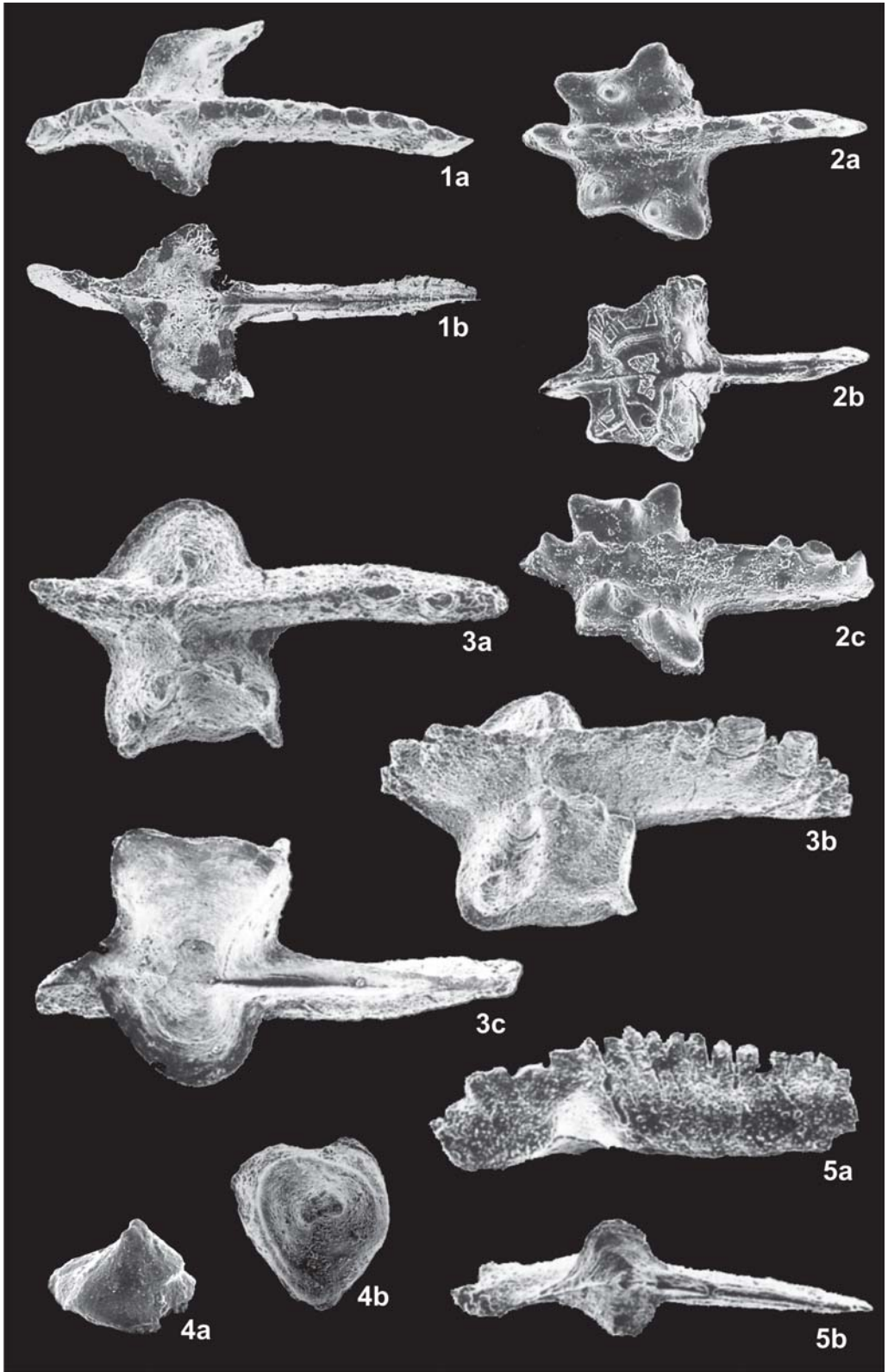
Fig. 2 - *Kockelella crassa* (Walliser, 1964), Pa element; sample SAD-BK 2; upper (a), lower (b) and upper-lateral (c) views of the Pa element [specimen figured as *K. circaquadra* n. sp. in Serpagli & Corradini, 1998, and then identified as Pa element of *K. crassa* by Serpagli & Corradini, 1999].

Fig. 3 - *Kockelella variabilis ichnusae* Serpagli & Corradini, 1998, Pa element; sample SIL 5; upper (a), upper-lateral (b) and lower (c) views.

Fig. 4 - *Pseudooneotodus bicornis contiguus* Corradini, 2008, Pa element; sample SIL 23; upper (a) and upper-lateral (b) views.

Fig. 5 - *Kockelella absidata sardoa* Serpagli & Corradini, 1999, Pa element; sample GCIU 3; lateral (a) and lower (b) views.

1-3 refigured after Serpagli & Corradini (1998); 4 refigured after Corradini (2008); 5 refigured after Serpagli & Corradini (1999).





in the lower part of the Pridoli. As a consequence, it is not appropriate to name a zone by an absent taxon. It should be pointed out, nevertheless, that this name variation does not change the biostratigraphical meaning of the zone.

#### LLANDOVERY-WENLOCK

Early Silurian conodonts are quite rare in Sardinia: Llandovery and Wenlock sediments are in fact mainly represented by black graptolitic shales, with some scattered calcareous lenses only in southwestern Sardinia.

The oldest Silurian conodonts have documented the *amorphognathoides* Zone from one isolate block in the Capo Frasca area (Barca et al., 1992). Also the next zone, the *ranuliformis* Zone, is reported from only one isolated block at Argiola, near Domusnovas (Corradini et al., 1998a). No other Sheinwoodian data are up to now available.

Early Homeric data from the *sagitta sagitta* Zone are relatively abundant, mainly from Argiola (Corradini et al., 1998a) and the Fluminimaggiore area (Serpagli, 1971; Ferretti et al., 1998; unpubl. data). However, the fauna is not very differentiated and only a few taxa are reported, even if the abundance is relatively high.

In contrast with the *sagitta sagitta* Zone, records of the following *bohemica* Zone are limited to a few loose blocks in the Fluminimaggiore area.

#### LUDLOW

Ludlow sediments are definitely better exposed and well documented both in southwestern and in southeastern Sardinia. More precisely, Gorstian and early Ludfordian conodonts occur in the Fluminimaggiore Fm., while good and continuous upper Gorstian-Pridoli sections are well exposed in southeastern Sardinia as Ockerkalk limestones.

The conodont zonation is very detailed, being the Ludlow subdivided into eight zones, with a time average of about 0.5 Ma *per* zone.

The *crassa* Zone is well documented both in the *Orthoceras* and in the graptolitic limestones of the Fluminimaggiore Fm. either in some localities of the Fluminimaggiore area (Serpagli, 1971; Ferretti et al., 1998; unpubl. data) or the Capo Frasca area (Barca et al., 1992). Among other taxa, representatives of the genus *Kockelella* start to be abundant and differentiated within this interval.

The same localities where the *crassa* Zone is documented yielded also conodonts from the *variabilis* Interval Zone. This zone is defined as the interval “between the last occurrence of *Po. crassus* [now *K. crassa*] and the first occurrence of *Oz. excavata hamata* [now *Wurmiella hamata*], without any really characteristic taxon, except *Kockelella v. variabilis*...” (Corradini & Serpagli, 1999, p. 262).

The *hamata* Zone is documented both in southwestern and southeastern Sardinia, respectively from a few blocks, both *Orthoceras* and graptolitic limestones, of the Fluminimaggiore area (Ferretti et al., 1998) and from the base of the Ockerkalk in a few sections (Corradini & Olivieri, 1997; Serpagli et al., 1998).

The following *ploeckensis* and *siluricus* zones are probably the better documented in Sardinia, being reported in several localities either in the southwestern or in the southeastern of the island. Conodont associations of the *ploeckensis* Zone are characterized by abundance of specimens of *Kockelella* and *Wurmiella*. *Wurmiella posthamata* occurs only in the lower part of the Zone, where *W. inflata* has its last occurrence. Within the *siluricus* Zone, conodont abundance and diversity decrease progressively, due to the effects of the Lau Event. *Kockelella maenniki* is exclusive of the lower part of the zone, where also the other last representatives of the genus (*K. variabilis ichnusae* and *K. absidata sardoa*)

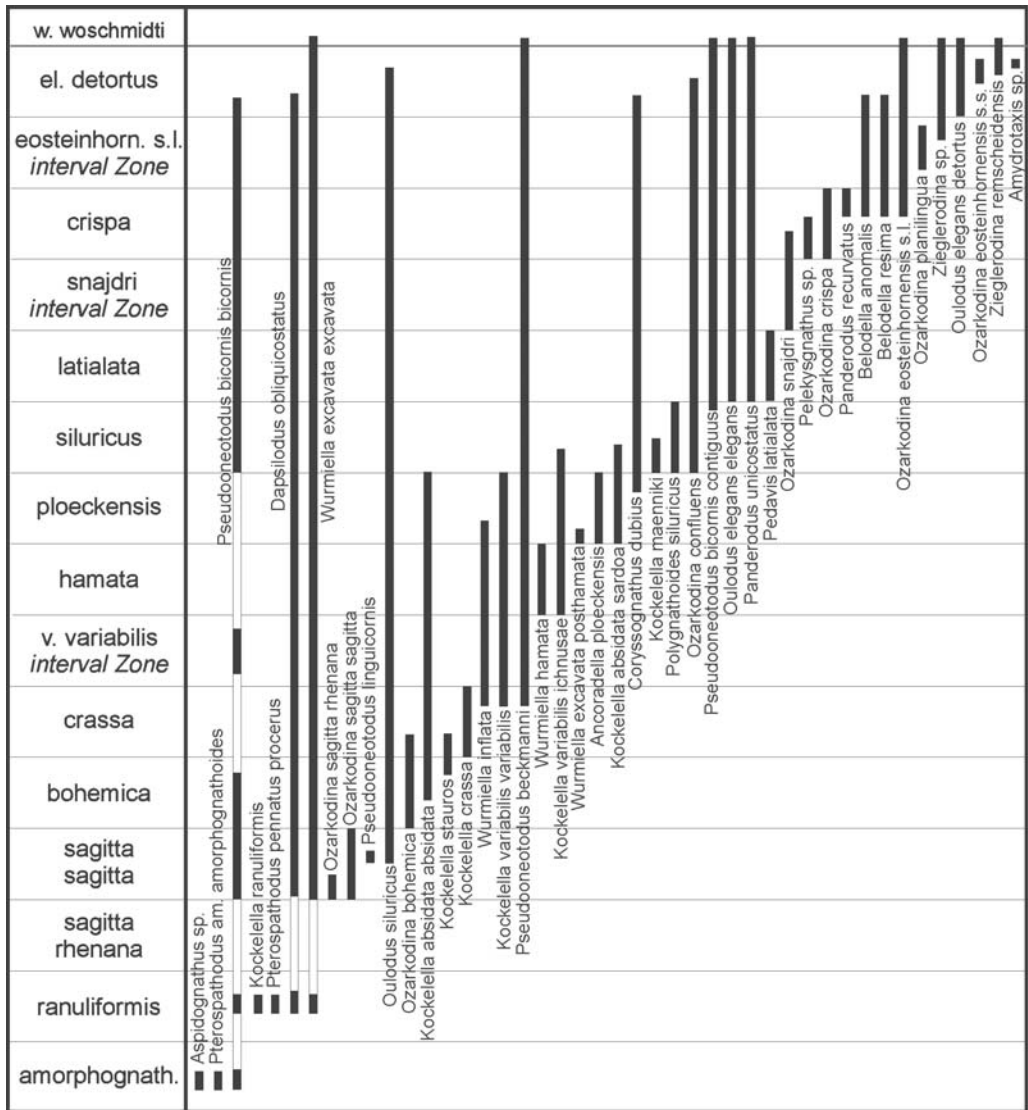


Fig. 3 - Distribution of Silurian conodont taxa in Sardinia, plotted against the conodont zonation.

became extinct. *Ozarkodina confluens*, an important taxon for the late Ludlow and Pridoli, makes its entry in the lower part of the zone.

The other three upper Ludlow conodont zones (*latialata*, *snajdri* i.Z. and *crispa*) are documented in southwestern Sardinia only, and all are represented by low sedimentation rate intervals (less than 2.5 metres of limestone include the three zones). Diversity is relatively high in these intervals, without significant faunal variation, apart from the marker occurrences. In the lower part of the *crispa* Zone, a peculiar *Pelekysgnathus* is present, unfortunately left up to now in open nomenclature owing to the scarcity of the material. Similar forms have been recently reported in the Carnic Alps from the same stratigraphical position (Corriga & Corradini, in press), suggesting a possible biostratigraphical significance for this taxon. Higher in the zone *Belodella anomalis* enters: curiously no other



representatives of the genus are present in older Silurian rocks in Sardinia. Also "*Oz.*" *eosteinhornensis* s.l. has its first occurrence within the same zone.

The extinction of *Ozarkodina crispa* is considered to mark the Ludlow-Pridoli boundary.

## PRIDOLI

Pridoli is subdivided in two conodont zones: the *eosteinhornensis* s.l. interval Zone and the *detortus* Zone. Conodonts are quite abundant in the Ockerkalk limestones of southeastern Sardinia (Barca et al., 1995; Corradini et al., 1998b; Corradini & Olivieri, 1997; Serpagli et al., 1998; unpubl. data), and have been reported also in a few localities of southwestern Sardinia (Gnoli et al., 1981; Olivieri & Serpagli, 1990; Corradini et al., 1998a; unpubl. data).

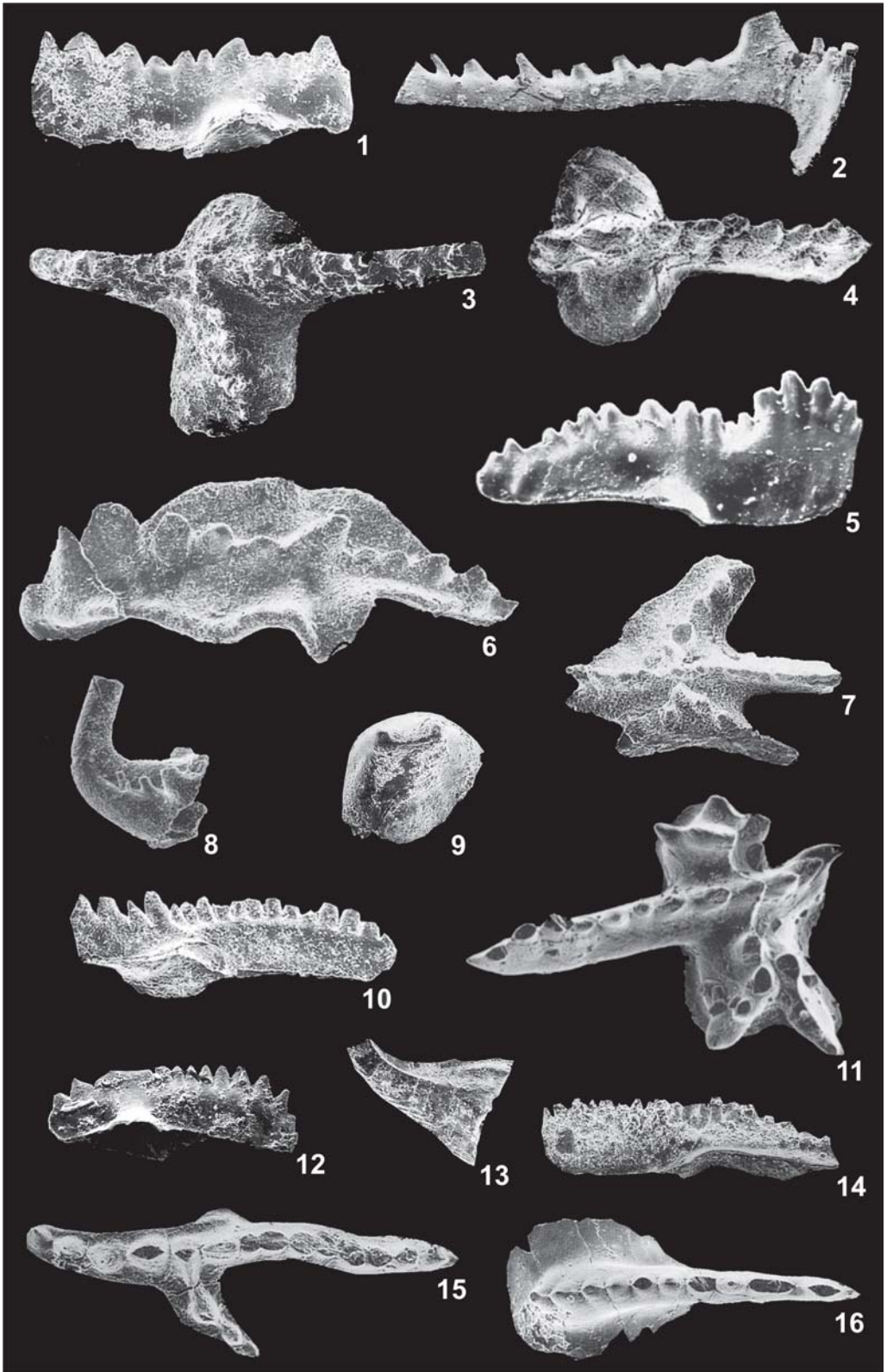
The *eosteinhornensis* s.l. interval Zone is defined as the interval between the Last Occurrence of *Oz. crispa* and the First Occurrence of *Oulodus elegans detortus*. "*Oz.*" *eosteinhornensis* s.l. is the most characteristic taxon of this interval, together with *Oulodus el. elegans*.

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## Plate 2

- Fig. 1 - *Zieglerodina remscheidensis* (Ziegler, 1960), Pa element; sample ARG 03; lateral view, x65.  
Fig. 2 - *Oulodus elegans detortus* (Walliser, 1964), Sc element; sample MP 10E; lateral view, x80.  
Fig. 3 - *Ozarkodina eosteinhornensis* s.s. (Walliser, 1964), Pa element; sample MP 11; upper view, x80.  
Fig. 4 - *Ozarkodina crispa* (Walliser, 1964), Pa element; sample GCIU 11; upper view, x50.  
Fig. 5 - *Ozarkodina confluens* (Branson & Mehl, 1934), Pa element; sample SBF 4; lateral view, x50.  
Fig. 6 - *Polygnathoides siluricus* Branson & Mehl, 1934, Pa element; sample SF 9; upper-lateral view, x50.  
Fig. 7 - *Ancoradella ploeckensis* Walliser, 1964, Pa element; sample SBF 5; upper view, x50.  
Fig. 8 - *Coryssognathus dubius* (Rhodes, 1953), Sc element; sample SBF 9; lateral view, x80.  
Fig. 9 - *Pseudooneotodus bicornis bicornis* (Drygant, 1974); sample ARG 01; upper view, x80.  
Fig. 10 - *Wurmiella inflata* (Walliser, 1964), Pa element; sample SIL 4; lateral view, x80.  
Fig. 11 - *Kockelella variabilis variabilis* Walliser, 1957, Pa element; sample GALE-BK 23; upper view, x66.  
Fig. 12 - *Ozarkodina bohémica* (Walliser, 1964), Pa element; sample SAD-BK 2; lateral view, x90.  
Fig. 13 - *Dapsilodus obliquicostatus* (Branson & Mehl, 1933), Sa element; sample PF 1A; lateral view, x80.  
Fig. 14 - *Ozarkodina sagitta sagitta* (Walliser, 1964), Pa element; sample PF 1; lateral view, x80.  
Fig. 15 - *Pterospathodus pennatus procerus* (Walliser, 1964), Pa element; sample ARG C; upper view, x90.  
Fig. 16 - *Kockelella ranuliformis* (Walliser, 1964), Pa element; sample ARG C; upper view, x80.

1, 9, 15-16 refigured after Corradini et al. (1998b); 2-3 refigured after Olivieri & Serpagli (1990); 4 refigured after Corradini et al. (1998b); 5, 7-8 refigured after Corradini et al. (2001); 10 refigured after Serpagli et al. (1998); 11 refigured after Serpagli & Corradini (1999); 12 refigured after Barca et al. (1992); 13-14 refigured after Serpagli (1971).



As already pointed out above, the *detortus* Zone is longer in Sardinia than in other regions, and, consequently, the use of *Oul. el. detortus* for long distance correlations could be inappropriate (Gouwy & Corradini, 2006). Very useful for this purpose is “*Oz.*” *eosteinhornensis* s.s., that marks a narrow interval in the upper part of the zone.

Several taxa have their last occurrence in Sardinia within the *detortus* Zone, however it could not be excluded that at least a few may have a longer range. Earliest Devonian conodont data are, in fact, still scarce in Sardinia due to a facies change to typical shaley sediments in southeastern Sardinia and to the existence of only one mainly calcareous section in the southwestern spanning the Silurian/Devonian boundary (Mason Porcus; Gnoli et al., 1988; Olivieri & Serpagli, 1990).

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## APPENDIX 1 - List of papers related to Silurian conodonts in Sardinia, arranged by year of publication.

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## APPENDIX 2 - Index of localities

- ARG: Argiola; 39°20'02"N, 8°41'50"E, about 4 km East of Domusnovas. Locality described by Corradini et al. (1998).
- BAR: Barbusi; 39°12'20"N, 8°30'11"E, about 500 m East of Barbusi.
- BS: Baccu Scottis; 39°27'38"N, 9°34'21"E, about 2 km North of Villaputzu.
- CAR: Punta Carroga; 39°29'02"N, 9°33'47"E, about 4.6 km North of San Vito.
- CB: Corti Baccas; 39°26'49"N, 8°29'34"E, about 1 km North of Fluminimaggiore.
- CS: Case Scivu; 39°26'01"N, 8°24'59"E, about 1 km North of Fluminimaggiore.
- FTM: Funtanamare; 39°17'30"N, 8°26'20"E, about 2.3 km South of Nebida.
- FRU: Monte Fruccas; 39°37'26"N, 9°11'19"E, about 2.2 km North of Siurgus Donigala. Locality described by Corradini & Olivieri (1997).
- GA: Genna Arrela; 39°28'31"N, 9°36'19"E, about 4.5 km North of Villaputzu, in a road cut. Locality described by Corradini & Olivieri (1997).
- GALE: Galemму; 39°26'42"N, 8°29'47"E, about 700 m North of Fluminimaggiore.
- GCIU: Genna Ciuerciu; 39°30'53"N, 9°17'01"E, about 900 m West of Silius. Locality described by Barca et al. (1995) and Corradini et al. (1998, 2002).
- GRU: Gruttixedda; 39°22'45"N, 8°41'03"E about 6.5 km North-West of Domusnovas. Locality described by Gnoli et al. (1981).
- LT: Lantini Tunnel; 39°32'21"N, 9°23'19"E, about 2.5 km East-South-East of Ballao.
- NSF: Nuraghe su Franzesu; 39°28'41"N, 9°38'36"E, about 6.8 km North-East of Villaputzu.
- MP: Mason Porcus; 39°26'51"N, 8°31'19"E, about 2.1 km East-North-East of Fluminimaggiore. Locality described by Gnoli et al. (1988), Olivieri & Serpagli (1990).
- PF: Perd'e Fogu; 39°26'37"N, 8°30'02"E, about 600 m North-East of Fluminimaggiore. Locality described by Ferretti et al. (1998).
- PM: Pala Manna; 39°23'35"N, 9°20'23"E, about 5.6 km North of Burcei. Locality described by Barca et al. (1986).
- PML: Ponte Monte Lora; 39°28'45"N, 9°29'24"E, about 6 km North-West of San Vito. Locality described by Corradini & Olivieri (1997).
- RMC: Rio Murru de Callus; 39°35'53"N, 9°13'25"E, about 3 km East of Siurgus Donigala.
- RT: Roia is Tintionis; 39°27'18"N, 8°28'35"E, about 2.5 km North-West of Fluminimaggiore.
- SAD: Sant'Antonio Donigala; 39°41'58"N, 8°29'37"E, about 1.6 km South of Sant'Antonio di Santadi. Locality described by Barca et al. (1992).
- SBF: San Basilio Fenugu; 39°32'03"N, 9°12'43"E, about 1.2 km East of San Basilio. Locality described by Corradini et al. (2001).
- SF: Sentiero Flumini; 39°26'32"N, 8°30'20"E, about 800 m North-East of Fluminimaggiore. Locality described by Serpagli (1971).
- SIL I°: Silius I°; 39°31'02"N, 9°17'13"E, about 500 m West of Silius. Locality described by Barca et al. (1995) and Serpagli et al. (1998).
- SN: Su Nuargi; 39°19'37"N, 8°40'25"E, about 2 km East of Domusnovas.
- TUV: Tuviois; 39°23'27"N, 9°19'25"E, about 5.9 km North of Burcei. Locality described by Barca & Olivieri (1991).