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The upper Silurian Bivalvia dominated palaeocommunities succession of southwestern Sardinia – correlation with Perunica and the peri-Gondwanan regions of Europe

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ABSTRACT - The upper Silurian Bivalvia dominated palaeocommunities succession of southwestern Sardinia is correlated with Perunica (Prague Basin, Bohemia) and the other peri-Gondwanan regions (the Montagne Noire and Massif Armoricain, France and the Carnic Alps, Austria and Italy). Bivalvia are in all regions closely related and show that recurrent cephalopod limestone biofacies developed in Perunica and peri-Gondwana in the upper Sheinwoodian, lower Homerian (Wenlock), the lower Gorstian and lower Ludfordian (Ludlow) with the homologous and analogous Bivalvia dominated benthic communites. In the upper Ludfordian (Ludlow), lowermost and uppermost Pridoli the cephalopod limestone facies developed only in the Prague Basin on some of the tectonically uplifted basin subsegments. In other peri-Gondwanan regions the Pridoli is characterized mostly by the diversity restricted communities and subcommunities formed by the same or closely related Bivalvia species, characteristic for the Pridoli of Perunica.

KEY WORDS - Silurian, Sardinia, Perunica, peri-Gondwanan Europe, Bivalvia palaeocommunities.

INTRODUCTION

The project "Upper Silurian and lowermost Devonian Bivalvia of Bohemian type from South-Western Sardinia" started in 1981 during the Subcommission on Silurian Stratigraphy field meeting at Gotland. I asked Enrico Serpagli and Maurizio Gnoli about the possibility to collect and to study the Silurian and lowermost Devonian bivalves in Sardinia described by Meneghini (1857) and listed by Gnoli et al. (1980). After a little scepticism about the possibility to find some more bivalves there Enrico Serpagli invited me to visit Sardinia in 1982.

First visit of southwestern Sardinia was very successful and for that collecting "expeditions" followed in 1986 and 1989. During these three collecting trips I made in cooperation with E. Serpagli, M. Gnoli, P. Rompianesi from the Institute of Palaeontology, Modena, S. Barca, F. Leone, G.L. Pillola from the University of Cagliari, V. Havlicek and P. Storch from the Czech Geological Survey, and S. Massole and G. Figus, the friends of "Gruppo Grotte di Fluminimaggiore" extensive collection of more than 750 identifiable bivalves, which is now deposited in the Museum of Palaeontology of the University of Modena and Reggio Emilia, and which made possible to publish in the cooperation with E. Serpagli the monograph on the upper Silurian and lowermost Devonian Bivalvia of Bohemian type from southwestern Sardinia in 1993. In this paper, 69 species of Bivalvia

of Bohemian type and 7 new species and 3 new subspecies were described. Collection was realized at 8 localities from 65 mostly loose blocks of various sizes found on vineyeards and pastures. A fruitful cooperation was financially supported by the University of Modena and the Czech Geological Survey, by grants of the Italian "Ministero dell'Università e della Ricerca Scientifica" and "Consiglio Nazionale delle Ricerche" (CNR).

One of the most important conditions of success to reconstruct the Sardinian original sections strongly tectonized during the Variscan Orogeny was the technique of collecting fossils block by block and to study the associations of bivalves and other fauna separately as if they were collected in individual layers. We used this method for the first time together with F. Paris when studying the Silurian and lowermost Devonian in the vicinity of la Meignanne in the Massif Armoricain in France (Kriz & Paris, 1982). Since the original quarry in la Meignanne was abandoned and filled by water, it was possible to study just a single dark argillitic and limestone blocks in the vineyard walls, built especially from the light Devonian limestones. Based on the analysis of the assemblages from the three different blocks and based on the old museum collections, one ostracode dominated *Entomozoe (Richteria) migrans* Assemblage from the Ludlow, and three Bivalvia dominated *Cheiopteria bridgei, Snoopyia insolita,* and *Antipleura bohemica* assemblages were recognized from the upper Pridoli.

The assemblages described from la Meignanne (Kriz & Paris, 1982) showed very close relationship with the assemblages from the Bohemian Prague Basin and it was obvious that for the further studies of Bivalvia from Perunica (Havlicek et al., 1994) and the peri-Gondwanan regions would be necessary first to describe and analyse the Bivalvia dominated palaeocommunities from the Prague Basin where they are well developed and stratigraphically determined thanks to co-occurrence with graptolites and thus the possibility to correlate them with the classic graptolite zonation described in the Prague Basin (Jaeger *in* Kriz et al., 1986; Storch, 1994, 1995a, b).

The work was realized and the study of the Bivalvia dominated palaeocommunities of Bohemia type from the Silurian and Lower Devonian carbonate facies was submitted as the manuscript before 1989 (see references in Kriz, 1991) to the monograph "Silurian and Lower Devonian paleocommunities", edited by A.J. Boucot and J.D. Lawson as the final publication of I.G.C.P. Project no. 53 Ecostratigraphy published in 1999. The manuscript published eleven years later (Kriz, 1999*a*) made possible to reconstruct and correlate the palaeocommunities recognized in Sardinia with the palaeocommunities already described from Bohemia and from the other parts of the European peri-Gondwana and Perunica.

Relationship between The upper Silurian Bivalvia dominated palaeocommunities of Sardinia and Other peri-Gondwanan Europe and Perunica

The upper Silurian Bivalvia dominated palaeocommunities succession is best known in the Prague Basin in Bohemia, Perunica (Kriz, 1991,1999*a*, 1999*b*, 1999*c*). They form the *Cardiola*, *Cheiopteria*, *Snoopyia* and *Patrocardia* community groups (Kriz, 1999*a*).

Cardiola *Community Group*

The most characteristic Silurian *Cardiola* Community Group, composed mostly by Nephiomorphia Kriz, 2007, originated in the cephalopod limestone biofacies, which developed within the shallow-water, shell-rich carbonate "Prague Basin Facies" (Kriz et al., 2003) at the sea bottom below normal wave base, and temporarily ventilated by

surface currents (Ferretti & Kriz, 1995). All of the communities of the *Cardiola* Community Group are homologous and analogous (Boucot & Kriz, 1999) and all of them contain the evolutionarily related species of the characteristic Silurian families Antipleuridae Neumayr, 1891, Butovicellidae Kriz, 1965, Cardiolidae Hoernes, 1884, Lunulacardiidae Fischer, 1887, Praecardiidae Hoernes, 1884, Slavidae Kriz, 1982, Spanilidae Kriz, 2007 and Stolidotidae, Starobogatov, 2007.

The earliest community of the *Cardiola* Community Group - *Carnalpia nivosa* Community (Kriz, 1999*a*) is known from the Carnic Alps, Austria and Italy (*Cyrtograptus rigidus* Biozone, upper Sheinwoodian, Wenlock). It was described from the biodetrital limestone forming the lenses in the dark graptolitic shale at the Cellon Section, Austria. The community is dominated by the cardiolids *Carnalpia* Kriz, 1974, *Cardiolopsis* Stache in Heritsch, 1929 and *Cardiola* Broderip in Murchison, 1939. Less common are bivalves of the genera *Slavinka* Kriz, 1982, *Patrocardia* Fischer, 1887, and *Maminka* Barrande, 1881. More than 58% are epibyssate, 22% semi-infaunal and 6% reclining forms. Juvenile stages of bivalves and gastropods are common and mostly juvenile cephalopod fragmocones form majority of the firm substrate at the sea bottom. Disarticulated trilobites (aulacopleurids, cheirurids, encrinurids, odontopleurids, and proetids) are rare.

First widely distributed *Cardiola agna agna* Community (Kriz, 1999*a*) of the *Cardiola* Community Group originated most probably in the Prague Basin, Bohemia (*Cyrtograptus lundgreni* Biozone, upper Wenlock) and became quickly distributed together with its *Cardiola agna figusi* Subcommunity (Kriz & Serpagli, 1993) and the *Slava pelerina – Isiola zila* Subcommunity (Kriz, 1999*c*) in the peri-Gondwanan region (Carnic Alps, Austria, Montagne Noire, France, and Sardinia, Italy).

In Sardinia the *Cardiola agna figusi* Subcommunity (Fig. 1) was discovered at the locality Xea Sant'Antonio, near Fluminimaggiore (Kriz & Serpagli, 1993). It occurs in the

MA	ser.	stg.	Graptolite biostratigraphy	Bivalvia dominated communities biostratigraphy	
				Bohemia, Prague Basin	Sardinia
414	PŘÍDOLÍ		*transgrediens - bouceki*	*Joachymia - Cardiolinka - Pygolfia* C. *Snoopyia insolita* C. *Cheiopteria bridgei* C. *Patrocardia - Dualina* C. *Pterinopecten (P.) cybele* C. *Dualina - Cardiolinka - Praecardium* C.	*Patrocardia evolvens gnolii* Sbc. *Cheiopteria bridgei* C. *S. insolita* C. *Joachymia falcata* Sbc. *Pterinopecten (P.) c. nesiotes* Sbc. *Cheiopt. - Patroc. - Cardiolinka* Sbc.
			branikensis - lochkovensis		*Cardiolinka sardiniana* C.
418			*parultimus - ultimus*	*Cardiolinka bohemica* C.	
	LUDLOW	LUDFORD.	*fragmentalis*	*Cardiola conformis* C.	
			latilobus		
			bohem. tenuis - kozlowskii	*Cardiola alata* C. *Cheiopteria glabra* C.	
421			*linearis*	*Cardiola docens* C.	*Cardiola docens* C.
		GORST.	*chimaera - scanicus*	*Cardiola donigala - Slava cubicula* C. *Cardiola donigala - Slava sathon* C.	*Cardiola donigala* Sbc.
423			*colonus - nilssoni*	*Cardiola gibbosa* C.	*Cardiola gibbosa* C.
	WENLOCK	HOMERIAN	*ludensis - gerhardi*		
			praedeubeli - deubeli		
			parvus - nassa		
426			*lundgreni*	*Cardiola agna agna* C.	*Cardiola agna figusi* Sbc.
		SHEINW.	*rigidus - perneri*		
			riccartonensis - belophorus		
428			*centrifugus - murchisoni*		

Fig. 1 - The upper Silurian Bivalvia dominated palaeocommunities succession of the Prague Basin, Bohemia and correlation with the Bivalvia dominated palaeocommunities succession of southwestern Sardinia (modified after Kriz, 1999b).

dark micrite to biomicritic limestone forming lenses in the dark shales. The subcommunity is dominated by the cardiolids *Cardiola* and *Isiola* Kriz, 1976 accompanied by different species of *Slava* Barrande, 1881, *Stolidotus* Hede, 1915, *Maminka* and *Patrocardia*. More than 59% are epibyssate and 18% were infaunal forms. Fragmented fragmocones of cephalopods are subordinate to bivalves and form majority of the firm substrate at the sea bottom. Disarticulated smooth, articulated brachiopods are very common, together with very common *Monograptus flemingi* (Salter, 1852). The *Cardiola agna figusi* Subcommunity was also recognized in one block from the Xea Sant'Antonio locality together with abundant *Colonograptus colonus* (Barrande, 1850) indicating the lowermost Ludlow.

Kriz (1996) recognized the *Cardiola agna figusi* Sucommunity in the Montagne Noire, France. *Cardiola agna figusi* Kriz, 1993 is also dominant, but the composition of the community is modified. Also here the firm substrate formed by cephalopod fragmocones is suitable for more than 51% of epibyssate bivalves, but micritic sediment was also suitable for infaunal and semi-infaunal bivalves (more than 34%).

Slava pelerina – Isiola zila Subcommunity (Kriz, 1999*c*) was recognized in the Carnic Alps at the Rauchkofel Boden Section. The subcommunity is homologous and analogous with the *Cardiola agna agna* Community described from the Prague Basin. It is characterized by very low diversity indicating restricted living conditions, probably higher energy in comparison with the Sardinia *Cardiola agna figusi* Subcommunity. The dominant bivalves are infaunal *Slava pelerina* Kriz, 1985 and *Isiola zila* Kriz, 1999c. The species of the genera *Slava, Isiola, Cardiola* and *Maminka* were recognized. Majority of bivalves were infaunal.

Cardiola gibbosa Community (Fig. 1) is the lower Ludlow community described from the Prague Basin, Bohemia (Kriz, 1999*a*) and in Sardinia, Italy (Kriz & Serpagli, 1993). In Sardinia the community was discovered at the locality Xea Sant'Antonio, near Fluminimaggiore. It occurs in the dark micritic lenticular limestone, which originally formed a horizon in the calcareous shales. The community is dominated by *Cardiola gibbosa* Barrande, 1881, accompanied by species of *Butovicella*, *Maminka*, *Manulicula* Kriz, 1967, *Procarinaria* Perner, 1911, a.o. More than 68% are epibyssate and the rest are reclining, semi-infaunal, and infaunal forms. Fragmented fragmocones of cephalopods are abundant, forming the firm substrate at the sea bottom. A lower diversity of the *Cardiola gibbosa* Community in Sardinia indicates less favourable condition on a micritic bottom than in Bohemia.

The *Cardiola gibbosa* Community represents most probably the ancestral community for the *Cardiola donigala* Subcommunity described from the locality Sant'Antonio Donigala in Sardinia (Kriz & Serpagli, 1993). This community is characteristic for the upper Gorstian, Ludlow. Kriz (1999a) described the *Slava cubicula – Cardiola docens* Community in the cephalopod limestones of the higher Gorstian in the Prague Basin. In the same year Kriz (1999b) studied this community at the type locality, where the new excavation was realized. He recognized that the supposed species *Cardiola docens* Barrande, 1881 there is in reality *Cardiola donigala* Kriz, 1993 described from Sardinia and represents an ancestral form to *Cardiola docens*. The Bohemian community was renamed for the *Cardiola donigala –Slava cubicula* Community. It is mainly composed of epibyssate forms (more than 74%) the rest is mostly the infaunal forms. More recently was in the Prague Basin recognized in the lower Gorstian the *Cardiola donigala-Slava sathon* Community (Manda & Kriz, 2007). Since the age of the Gorstian *Cardiola donigala* Subcommunity in Sardinia is not exactly known and the very low diversity community was recognized only in one block of rocks from the type locality, well documented *Cardiola*

donigala – Slava cubicula Community from the Prague Basin, Bohemia (Kriz, 1999b) is considered as the typical.

In Sardinia the *Cardiola donigala* Subcommunity (Fig. 1) occurs in the dark micritic lenticular limestone, which originally formed a horizon in the calcareous shales. The subcommunity is dominated by *Cardiola donigala*, accompanied by the species of *Cardiola*, *Slavinka* Kriz, 1982, *Maminka*, and *Patrocardia*. All of the bivalves are considered epibyssate. Fragmented fragmocones of cephalopods are common. A lower density and diversity indicate less favourable condition on a micritic bottom.

The *Cardiola donigala* Subcommunity was also discovered in the Montagne Noire in France (Kriz, 1996) but the dominant species is known only from old collections and is preserved together with common cephalopods and pristiograptids.

The *Cardiola donigala* Subcommunity is ancestral to the *Cardiola docens* Community described by Kriz (1999a) from the uppermost Gorstian and lower Ludfordian of the Prague Basin in Bohemia (Fig. 1). In Sardinia, Italy (Kriz & Serpagli, 1993) the *Cardiola docens* Community was discovered at the localities Galemmu near Fluminimaggiore, in Sant'Antonio Donigala and Funtanamare. In Sardinia the community is dominated by *Cardiola docens* and occurs in the grey to dark micritic and biomicritic or unsorted biodetrital limestones, which form larger lenticular horizons within the sequence of the calcareous shales. Current oriented nektobenthic orthocone cephalopod fragmocones are very common in the limestones. Epibyssate bivalves are dominant (82%).

The *Cardiola signata* Subcommunity described from the uppermost Gorstian, Tajmyr, Russia (Kriz & Bogolepova, 1995) and the *Cardiola consanguis* Subcommunity from the upper Gorstian, Rauchkofel Boden Section, Carnic Alps (Kriz, 1999c) represent the low diversity Gorstian subcommunities of the *Cardiola docens* Community.

The *Cardiola docens* Community in Bohemia is also characterized by epibyssate bivalves (95 - 99%) and occurs in the cephalopod limestone biofacies. Kriz (1996) described the *Cardiola docens* Community from the Montagne Noire, France (85% of epibyssate bivalves) and in 1999c from the Carnic Alps, Austria (100% of epibyssate bivalves). The *Cardiola docens* Community is distributed also in Morocco (Anti-Atlas), Russia (Caucassus), and Spain (Kriz, 1999c).

The higher Ludfordian (*Neocucullograptus kozlowskii* Biozone) *Cardiola alata* Community from the Prague Basin, Bohemia (Kriz, 1998) and its *Cardiola alata – Cardiola pectinata* Subcommunity from the Carnic Alps (Kriz, 1999c) are not known from Sardinia (Fig. 1).

Upper Ludlow and lowermost Pridoli *Cardiola conformis* Community (*Monograptus latilobus* Biozone – *Monograptus ultimus* Biozone) developed in the Prague Basin, Bohemia (Kriz, 1998, 1999a) is not known in Sardinia. *Cardiolinka bohemica* Community characteristic for the lowermost Pridoli occurs in the Prague Basin (Kriz, 1998, 1999a) and in the Carnic Alps (Kriz, 1999*c*) and was also not found in Sardinia (Fig. 1).

Cheiopteria *Community Group*

The *Cheiopteria* Community Group (Kriz, 1999a) is characterized by very high dominance of the semi-infaunal pterineid *Cheiopteria* Pojeta & Kriz, 1976, occurring in very high-density populations, and occurs in the micritic limestone facies which was a deeper water facies than the contemporary cephalopod limestone biofacies. The earliest known *Cheiopteria glabra* Community described from the Prague Basin (Kriz, 1999a) is contemporary to the *Cardiola alata* Community (Ludfordian) (Fig. 1). It is ancestral to the *Cheiopteria bridgei* Community, first described as assemblage from the upper Pridoli of the Massif Armoricain, France (Kriz & Paris, 1982) and later as the community known

from the Turkey and Florida (Pojeta et al., 1976), Massif Armoricain, Prague Basin, Bohemia (Kriz, 1999a), and Sardinia (Kriz & Serpagli, 1993). Kriz (2004) described analogous and homologous latest Frasnian, Upper Devonian *Cheiopteria feisti* Community

Plate 1

Dominant and characteristic bivalves from southwestern Sardinia (IPUM: collections of the Museum of Palaeontology of the University of Modena and Reggio Emilia, Italy).

Fig. 1 - *Snoopyia insolita* (Barrande, 1881), Galemmu, block 29, the *Snoopyia insolita* Community, upper Pridoli; IPUM 22923, left view, x9.5.

Fig. 2 - *Cardiolinka sardiniana* Kriz in Kriz & Serpagli, 1993, Argiola, block 29, the *Cardiolinka sardiniana* Community, upper Pridoli; IPUM 23157, left view, x6.0.

Fig. 3 - *Joachymia falcata* (Barrande, 1881), Barbusi, block 1, the *Joachymia falcata* Community, upper Pridoli; IPUM 23181, right view, x6.5.

Fig. 4 - *Cheiopteria bridgei* Pojeta & Kriz, 1976, Argiola, block 32, the *Cheiopteria bridgei* Community, upper Pridoli; IPUM 23165, left view, x6.5.

Fig. 5 - *Pterinopecten (P.) cybele nesiotes* Kriz in Kriz & Serpagli, 1993, Galemmu, block 9, the *Petrinopecten (P.) cybele nesiotes* Community, upper Pridoli; IPUM 22863, left view, x5.3.

Fig. 6 - *Paracardium eremita* Barrande, 1881, Argiola, block 17, the *Cheiopteria bridgei* Community, IPUM 23086, right view, x2.0.

Fig. 7 - *Cardiola cornucopiae* (Goldfuss, 1837), Mason Porcus, block 2, ?*Cheiopteria-Patrocardia-Cardiolinka* Community, upper Pridoli; IPUM 22993, left view, x2.0.

Fig. 8 - *Cardiola docens* Barrande, 1881, Fontanamare, block 1, the *Cardiola docens* Community, Ludlow; IPUM 23072, left view, x2.3.

Fig. 9 - *Mila parvula* Kriz in Kriz & Serpagli, 1993, Argiola, block 21, the *Cardiola docens* Community, Ludlow; IPUM 23119, right view, x3.5.

Fig. 10 - *Butovicella galemmu* Kriz in Kriz & Serpagli, 1993, Galemmu, block 3, the *Cardiola docens* Community, Ludlow; IPUM 22833, left view, x6.1.

Fig. 11 - *Cardiola donigala* Kriz in Kriz & Serpagli, 1993, Sant'Antonio Donigala, block 7, the *Cardiola donigala* Community, Ludlow; IPUM 23050, left view, x2.0.

Fig. 12 - *Butovicella migrans* (Barrande, 1881), Xea Sant'Antonio, block 11, the *Cardiola agna figusi* Community, Wenlock; IPUM 22658, right view, x4.4.

Fig. 13 - *Manulicula manulia* (Barrande, 1879), Argiola, block 25, the *Cardiola gibbosa* Community, Ludlow; IPUM 23124, left view, x5.4.

Figs. 14-15 - *Maminka comata* Barrande, 1881, articulated shell, Argiola, block 24, the *Cardiola gibbosa* Community, Ludlow; IPUM 23120, 14) left view, x2.2, 15) dorsal view, x1.6.

Fig. 16 - *Cardiola gibbosa* Barrande, 1881, Xea Sant'Antonio, block 1, the *Cardiola gibbosa* Community, Ludlow; IPUM 22621, right view, x4.6.

Fig. 17 - *Tenka aspirans* (Barrande, 1881), Galemmu, block 46, the *Cardiola docens* Community, Ludlow; IPUM 22971, left view, x3.2.

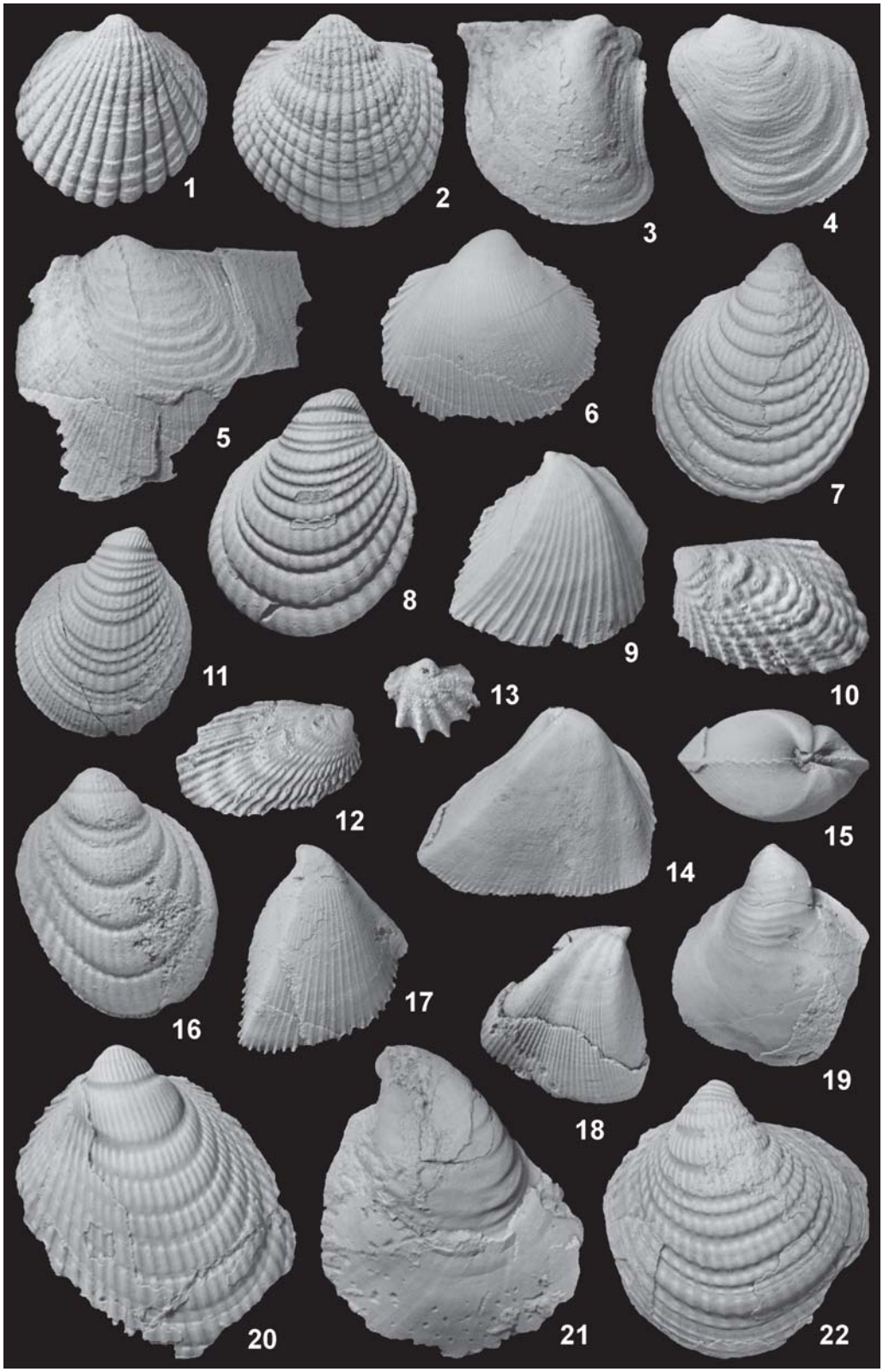
Fig. 18 - *Stolidotus cactus* Kriz, in Kriz & Serpagli, 1993, Xea Sant'Antonio, block 11, the *Cardiola agna figusi* Community, Wenlock; IPUM 22702, right view, x2.4.

Fig. 19 - *Slava cubicula* Kriz, 1985, Galemmu, the *Cardiola docens* Community, Ludlow; private collection, right view, x0.6.

Fig. 20 - *Cardiola agna figusi* Kriz in Kriz & Serpagli, 1993, Xea Sant'Antonio, block 11, the *Cardiola agna figusi* Community, Wenlock; IPUM 22685, right view, x2.7.

Fig. 21 - *Slava fibrosa* (Sowerby in Murchison, 1839), Xea Sant'Antonio, block 11, the *Cardiola agna figusi* Community, Wenlock; IPUM 22693, left view, x1.5.

Fig. 22 - *Isiola lyra* Kriz, 1976, Xea Sant'Antonio, block 11, the *Cardiola agna figusi* Community, Wenlock; IPUM 22659, right view, x1.9.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from the Montagne Noire, which is also related to the micritic limestone nodules in dark grey calcareous shales.

In Sardinia, Italy (Kriz & Serpagli, 1993) the *Cheiopteria bridgei* Community (Fig. 1) was discovered at the localities Galemmu and Mason Porcus near Fluminimaggiore, and at the locality Argiola. The community is dominated by *Cheiopteria bridgei* Pojeta & Kriz, 1976 (95% of all individuals) and occurs in the dark micritic to biomicritic lenticular limestones in the calcareous shales of the upper Pridoli, *Monograptus transgrediens* Biozone.

Snoopyia *Community Group*

Communities grouped to the *Snoopyia* Community Group occur in generally uniform environment of the Pridoli characterized by laminated limestones and calcareous shales (Kriz et al., 1986, 2003). The group consists of the communities, which are partly homologous but not analogous with the *Cardiola* Community Group.

From Sardinia the oldest known *Cardiolinka sardiniana* Community (Fig. 1) of this group was described (Kriz & Serpagli, 1993) from the early Pridoli at the locality Argiola. The community was also recognized at the locality Combe d'Yzarne in the Montagne Noire, France (Kriz, 1996), and in the Chelm Borehole, Poland (Korejwo & Teller, 1964). At the Sardinian type locality the community is characterized by relatively high diversity and low population density and by more than 62% of infaunal and semi-infaunal forms in contrast to the upper Ludlow *Cardiola* dominated communities with prevailing epibyssate forms.

The descendant *Dualina-Cardiolinka-Praecardium* Community occurs in the similar laminated limestone facies of middle and upper Pridoli and is characterized by relatively higher diversity. It was described from the Prague Basin (Kriz, 1999a), Chelm borehole in eastern Poland (Korejwo & Teller, 1964), Normandy (Babin & Robardet, 1974) and eastern Serbia (Kriz & Veselinovic, 1975). In Sardinian uppermost Pridoli this community is developed as the *Cheiopteria – Patrocardia – Cardiolinka* Subcommunity (Fig. 1). It is also characterized by prevailing infaunal and semi-infaunal forms (more than 64%) and by similar diversity and lower density at the locality Mason Porcus near Fluminimaggiore.

Other late Prídolian *Snoopyia* Community Group communities and subcommunities mostly occupied less favourable parts of the sea bottom with restricted living conditions (limited current activity, low oxygen, etc.). They are characterized by very low diversity and mostly by very high population densities. The *Snoopyia insolita* Community was described from the upper Pridoli of the Massif Armoricain, locality la Meignanne, France (Kriz & Paris, 1982). It also occurs in Chelm borehole, eastern Poland (Korejwo & Teller, 1964), Prague Basin, Bohemia (Kriz, 1999a), and in the Montagne Noire, France (Kriz, 1996).

In Sardinia the *Snoopyia insolita* Community (Fig. 1) was described (Kriz & Serpagli, 1993) from the upper Pridoli at the localities Galemmu near Fluminimaggiore and at the locality Argiola. It is characterized by more than 77% of dominant infaunal species.

The upper Pridoli *Joachymia falcata* Subcommunity (Fig. 1) discovered in Sardinia at the locality Barbusi (Kriz & Serpagli, 1993) is analogous and homologous with the *Joachymia – Cardiolinka – Pygolfia* Community described from the upper Pridoli of the Prague Basin (Kriz, 1999a). The *Joachymia falcata* Subcommunity is characterized by epibyssate forms (100%) and generally by very low diversity and high density.

Another Sardinian monospecific *Pterinopecten (Pterinopecten) cybele nesiotes* Community (Fig. 1) (Kriz & Serpagli, 1993) is most probably related to the *Pterinopecten (Pterinopecten) cybele cybele* Community described by Kriz (1999a) from the Prague

Basin, Bohemia, from Podolia, Ukraine (Sinicyna, 1968), Normandy, France (Babin & Robardet, 1974), and Chelm borehole, Eastern Poland (Korejwo & Teller, 1964). Both communities are monospecific and dominated by epibyssate species in mass occurrence.

Patrocardia *Community Group*

In the upper Pridoli of Sardinia the *Patrocardia evolvens gnolii* Subcommunity (Fig. 1) was discovered at the Galemmu locality near Fluminimaggiore (Kriz & Serpagli, 1993). This monospecific subcommunity is most probably related to the *Patrocardia – Dualina* Community described from the uppermost Pridoli of the Prague Basin, Bohemia by Kriz (1999a). It is the oldest known community of the *Patrocardia* Community Group and it is characterized by dominance of infaunal bivalves together with epibyssate representatives of the family Lunulacardiidae. The Sardinian monospecific community is due to restricted living conditions represented by the species probably forming clumps of individuals attached directly to the fragments or to each other on the soft bottom.

Conclusions

Bivalvia dominated communities described from the Silurian of Sardinia (Kriz & Serpagli, 1993) represent useful tool to correlate precisely Sardinian upper Wenlock, Ludlow and Pridoli cephalopod limestone biofacies and micritic facies with other European peri-Gondwana regions in spite of the fact that the graptolites occur in the upper Silurian of southwestern Sardinia only in the upper *Cyrtograptus lundgreni* Biozone (lower Homerian, upper Wenlock) and in the *Neodiversograptus nilssoni* Biozone (lowermost Ludlow).

When compared with the Prague Basin, the Bivalvia dominated communities are in Sardinia characterized by the lower diversity. Some of Bohemian communities are thus developed in Sardinia as the *Cardiola agna figusi, Cardiola donigala, Cheiopteria–Patrocardia–Cardiolinka, Pterinopecten (P.) cybele nesiotes, Joachimia falcata,* and *Patrocardia evolvens gnolii* subcommunities.

The distribution of the Cardiolidae in the European peri-Gondwanan regions (the Montagne Noire, the Carnic Alps and southwestern Sardinia) and Perunica (Prague Basin) demonstrated changes in relationships between these regions (Kriz, 1999*c*).

First carbonate sediments of the Silurian cephalopod limestone biofacies in southwestern Sardinia occurred during the late Wenlock, early Homerian low stand when the close relationships are documented between the Montagne Noire, France and Sardinia by the common occurrence of two Cardiolidae species (*Isiola lyra* and *Cardiola agna figusi*) and other species [*Butovicella migrans* (Barrande, 1881), *Maminka comata* Barrande, 1881, *Procarinaria zephirina* (Barrande, 1881), and *Slava sathon* Kriz, 1985].

The close relationship between Bohemia and Sardinia is well documented by the common occurrence of *Isiola lyra* and other bivalves [*Butovicella migrans*, *Maminka comata*, *Stolidotus trimerus* Barrande, 1881, *Stolidotus elongans* (Barrande, 1881), *Slava fibrosa* (Sowerby *in* Murchison, 1839), *S. pelerina* Kriz, 1985, and *S. discrepans* Barrande, 1881]. Close relationships are also between Sardinia and the Carnic Alps evidenced by common occurrence of the species *Slava pelerina, S. fibrosa, S.* cf. *sathon,* and *Maminka comata*. In Sardinia the carbonate sedimentation of the cephalopod limestone biofacies was interrupted in the late Homerian post-*lundgreni* times.

The close relationships continued in the earliest Gorstian (*Neodiversograptus nilssoni* Biozone) between southwestern Sardinia and the Perunican Bohemia and are documented by common occurrence of *Cardiola gibbosa* Barrande, 1881 and other bivalves

[*Butovicella migrans, Maminka comata, Manulicula manulia* (Barrande, 1879), *Modiolopsis senilis* Barrande, 1881, and *Procarinaria zephirina*].

In the late Gorstian (*Saetograptus chimaera* Biozone) the very close relationship between Sardinia and Bohemia document common occurrence of *Cardiola donigala, Cardiola consanguis* Barrande, 1881, *Cardiola* cf. *signata* Barrande, 1881, *Cardiola* aff. *docens, Slavinka amarygma* Kriz, 1985, and *Maminka comata.*

The close relationship between Sardinia and the Perunican Bohemia continued also in the early Ludfordian when it is documented by common occurrence of *Cardiola docens, Cardiola consanguis* Barrande, 1881 and other species (*Butovicella galemmu* Kriz, 1993, *Tenka aspirans* (Barrande, 1881), *Slava sathon, Slava cubicula,* and *Tetinka* aff. *cuneus* Barrande, 1881). Carbonate sedimentation in southwestern Sardinia was during low stand characterized by the cephalopod limestone biofacies.

In the upper Ludfordian (Ludlow) and the lowermost Pridoli the cephalopod limestone facies is characteristic only for the Prague Basin where it developed in some of the basin subsegments (Kriz, 1991) which were tectonically uplifted in the late Ludfordian, earliest and latest Pridoli.

During the late Ludfordian and Pridoli high stand in southwestern Sardinia the carbonate sedimentation with cephalopod limestone biofacies was interrupted. It occurred again during the latest Pridoli when similar carbonates as in other European peri-Gondwanan and Perunican regions sedimented.

In general, the Pridolian Bivalvia dominated communities in southwestern Sardinia have very similar character as in Perunica. The earliest *Cardiolinka sardiniana* Community shows very high diversity and has numerous species common to Bohemia and Sardinia [*Cardiolinka fortis* (Barrande, 1881), *Dualina* aff. *socialis* Barrande, 1881, *Cheiopteria bridgei, Butovicella* aff. *medea* Kriz, 1969, *Cardiola* aff. *conformis* Barrande, 1881, *Dualina* aff. *secunda* Barrande, 1881, *Patrocardia* cf. *eximia* Barrande, 1881), *Majda* aff. *bohemica* (Barrande, 1881), *Praecardium* cf. *adolescens* Barrande, 1881, and *Praeostrea* cf. *moror* Kriz, 1966]. In the Pridoli, communities and subcommunities are characterized by generally lower diversity in Sardinia. Similar situation is in the Montagne Noire and the Carnic Alps.

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