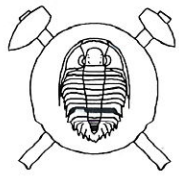
Cephalopod limestone biofacies on the northern slopes of the Silurian volcanic archipelago in the Prague Basin containing re-described benthic *Cardiola donigala–Slava cubicula* Community (Bivalvia, Barrandian, Bohemia)



Biofacie hlavonožcových vápenců na severních svazích silurského vulkanického souostroví v pražské pánvi obsahující benthické mlžové společenstvo *Cardiola donigala–Slava cubicula* (Barrandien, Čechy) (Czech summary)

(*5 text-figs.*)

JIŘÍ KŘÍŽ

Czech Geological Survey, P.O.B. 85, Praha 011, 118 21, Czech Republic

Origin and palaeoecology of the upper Gorstian (Silurian) cephalopod limestone biofacies on the northern slopes of the Silurian volcanic archipelago in the Prague Basin (Barrandian, Bohemia) and the benthic *Cardiola donigala–Slava cubicula* Community is described. The history of the old collector's pits at the locality of the cephalopod limestone Loděnice-Sedlec is discussed.

Key words: Bohemia, Silurian, Gorstian, Barrandian, Prague Basin, Cephalopod Limestone, Palaeoecology, History

Introduction

A volcanic archipelago developed around several volcanic centres in the Prague Basin (Text-Fig. 1) during the upper Wenlock and lower Ludlow, following the deep synsedimentary Tachlovice and Tobolka Faults between the Northern, Western and the Central Segments of the basin (Kříž 1991). The most active volcanic centre sited on the south-western part of the Tachlovice Fault (Horný 1962, 1965) was represented by the large Svatý Jan Volcano partly emerged during the upper Wenlock and lower Ludlow. On the submarine slopes of the archipelago elevation volcaniclastics sedimented and were re-deposited on deeper parts of the slopes as tuffites. In the

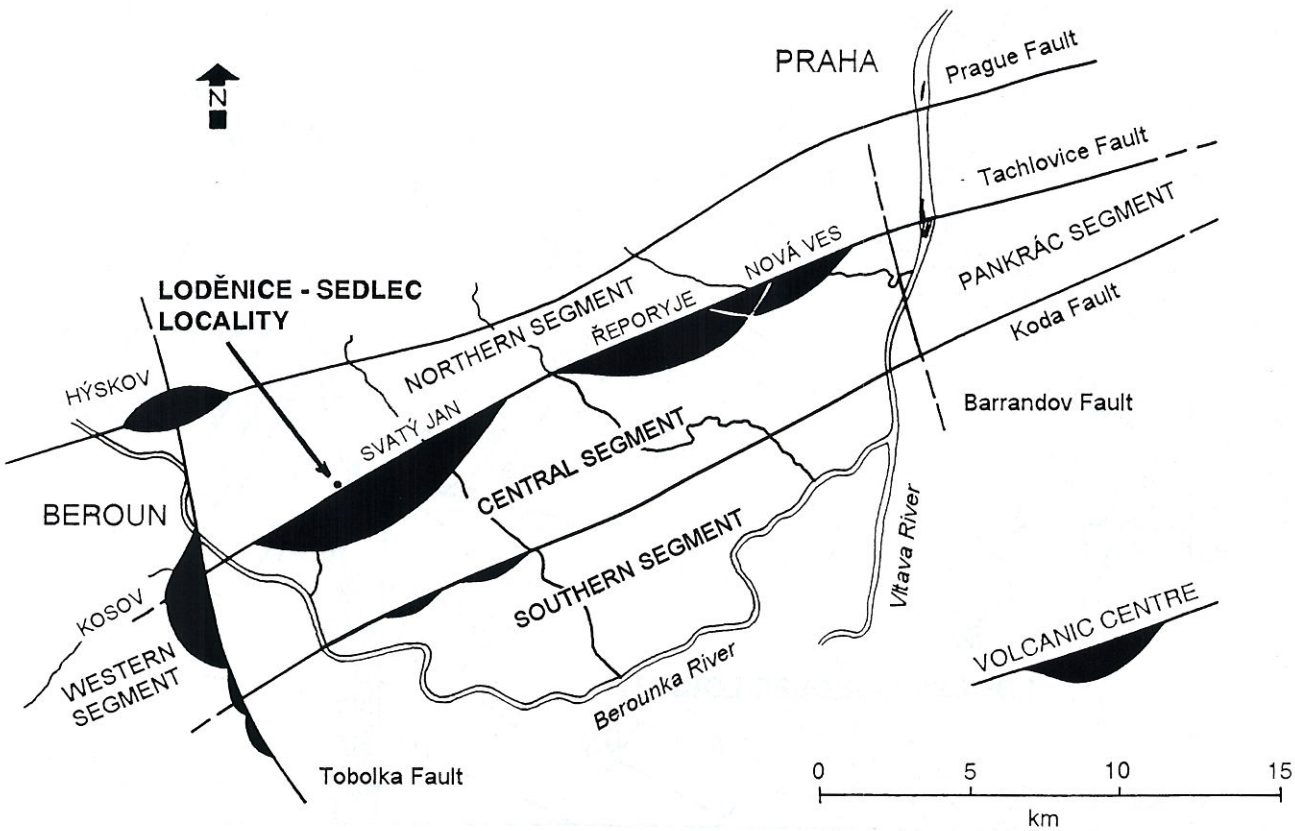


Fig. 1. Silurian synsedimentary tectonics, volcanic centres and segments (sub-basins) in preserved parts of the Prague Basin with the location of the origin of cephalopod limestone from the Loděnice-Sedlec locality.

deepest parts of the Prague Basin the tuffaceous pelitic and pelitic sedimentation of the black graptolite shale facies continued from the Llandovery and early Wenlock (Horný 1962, Kříž 1991).

During the periods of maximal volcanic activity the tuffaceous admixture in the sediments increased but during calm periods development of the coral, brachiopod and trilobite dominated communities (Chlupáč 1987, Havlíček – Štorch 1990) took place under favourable conditions on the shallow submarine slopes. On the deeper bottom, bellow the wave base, favourable conditions for development of the Silurian cephalopod limestone biofacies characterised by occurrence of the bivalve dominated communities and cephalopod associations temporally existed (Kříž 1991, 1998, in press a). The situation prevailed during two different sorts of events: low stands with eustatic oscillations, and uplift of the basin segments with synsedimentary tectonics (Kříž, 1991,

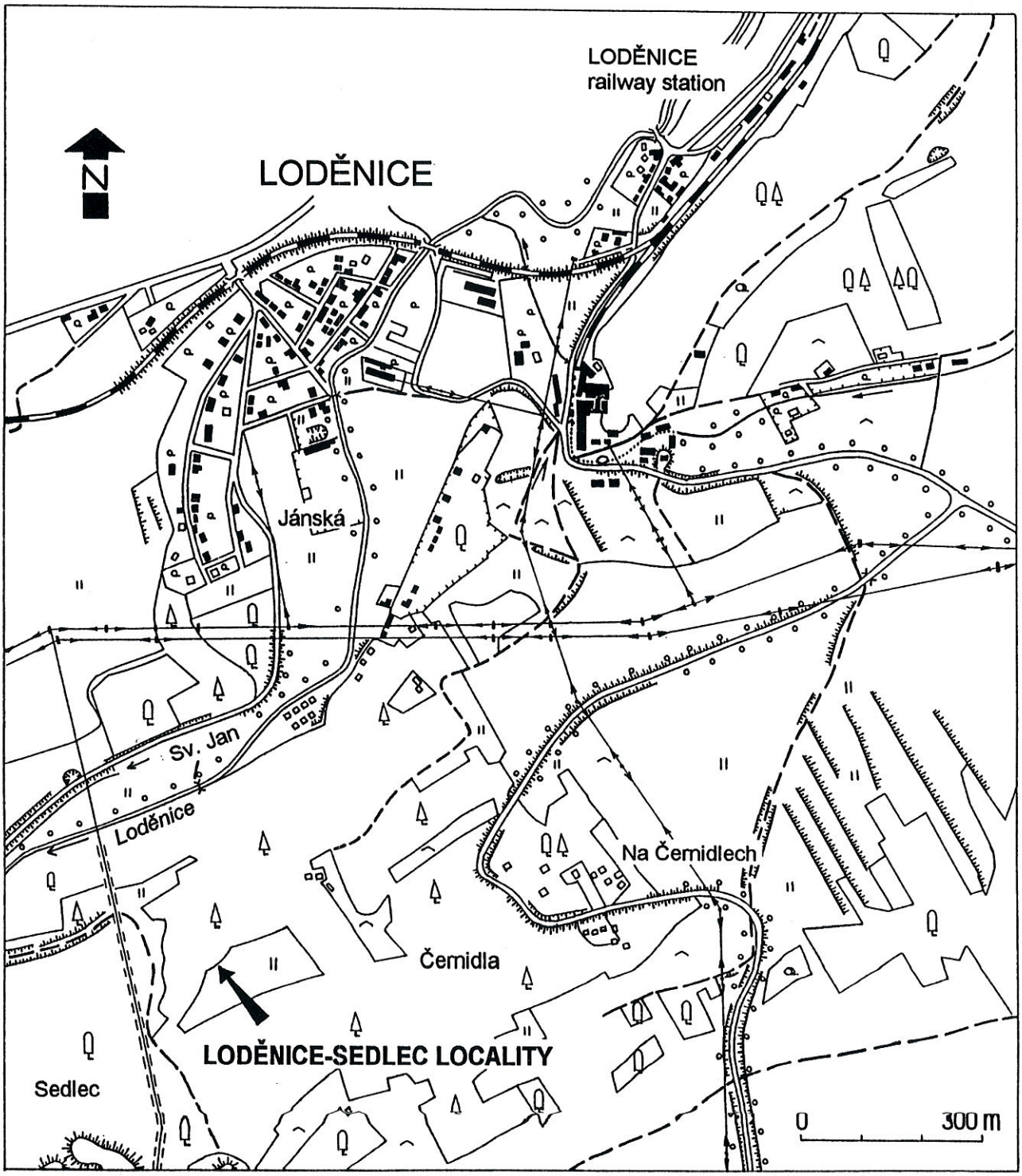


Fig. 2. Sketch map showing location of the Loděnice-Sedlec locality.

1998). Development of molluscan communities and associations during favourable periods depended above all on the temporal ventilation of the bottom by surface currents (Kříž 1998) which connected the Gondwana Basins and Perunica Basins (e.g. Spain, Morocco, the Carnic Alps, the Montagne Noire, Mouthoumet Massif, Sardinia and Bohemian Prague Basin – Kříž 1991, 1998, in press b) and transported planktic larvae of benthic organisms (especially molluscs) for large distances.

Cephalopod limestone biofacies was mainly developed on deeper parts of the slopes of the Kosov Volcano on the Tobolka Fault and Tachlovice Fault intersection and along the south-eastern slopes of the Svatý Jan Volcano, Řeporyje Volcano and Nová Ves Volcano (Text-Fig. 1). Distribution of the biofacies was dependent in the Kosov Volcano area on the surface current direction S–N which continued to the constant SW–NE direction approximately parallel to axis of the Central Segment and along the south-eastern slopes of the archipelago developed along the Tachlovice Fault (Ferretti – Kříž 1995).

The distribution of the cephalopods within the brachiopod and trilobite dominated communities in the upper Wenlock (Chlupáč 1987, Havlíček – Štorch 1990, Manda 1996) on the south-western slopes of the Svatý Jan Volcano is within the direct reach of the S–N surface current in the Kosov Volcano area. On the north-western slopes cephalopod associations occurred at the same time also within the trilobite and brachiopod dominated communities. In the lowermost Ludlow the cephalopod limestone biofacies is developed in the south-western part of the Svatý Jan Volcano (Berounka Valley Section – Horný 1962, 1965; Lištice Section No. 770 and No. 579 – Kříž et al. 1993).

On the deeper parts of north-western slope of the Svatý Jan Volcano (Northern Segment) the sedimentation of the shale persisted up to the lower Ludlow (Bouček 1941, Přibyl 1941) and it is represented by about 30 m thick sequence of the calcareous shale with tuffitic shale intercalations (Kříž 1991, 1992) terminated by the cephalopod limestone bed on the top (Horný 1965, Kříž 1970). The section here is interrupted by Tachlovice Fault. Above it, the sequence of the upper Wenlock tuffaceous and calcareous shale with the limestone intercalations of the *Testograptus testis* Zone follows (Horný 1965), corresponding to the transition from the shale of the Northern Segment to the tuffites and volcaniclastics of the Central Segment, (Kříž 1991).

The cephalopod limestone in the Svatý Jan area (Text-Fig. 2) were known already to Joachim Barrande (1881) who described a few bivalves from the locality "Collines entre Lodenitz and Bubowitz". During the mapping season 1961, R. Horný and J. Kříž searched for the level of cephalopod limestone and discovered old collectors pits at the locality Loděnice-Sedlec, near the gorge north of height spot 425 m, north of the former Solway Quarries on the Stydlé Vody Hill (Horný 1965).

Detailed section through the westernmost pit was exposed in late sixties (Kříž 1970). The section through the pit shows that the total depth was about 1.5 metre. The layer yielding abundant fauna was exploited up to depth at which the rock was not weathered and difficult to break down for extraction of fossils. The pit was completely filled by the old excavation debris. After the sequence of shale the bottom of the old pit follows consisting of a lenticular layer 6–8 cm thick of dark micritic limestone with rare cephalopods. Than follows 25–30 cm thick bed of bluish to blackish grey, very fine-grained cephalopod limestone overlain by thin-bedded shale with rare brachiopods and graptolites.

Cephalopod limestone at the locality Loděnice-Sedlec

In August 1998 the old row of test pits was again opened in its eastern part on the northern border of the former field. The section through the pit was similar to that described in the late sixties by Kříž (1970). The depth of the old pit was almost 2 m and the fossiliferous bed was quarried down to not weathered portions. The sequence changed when compared with the westernmost pit. Bottom of the old pit is build by the dark grey finely laminated calcareous shale about 200 cm thick which is developed on the top of effusive basalt with calcitic amygdales (Text-Fig. 3 – bed no. 1). The lighter laminae are formed by biodetritus and tuffaceous admixture.

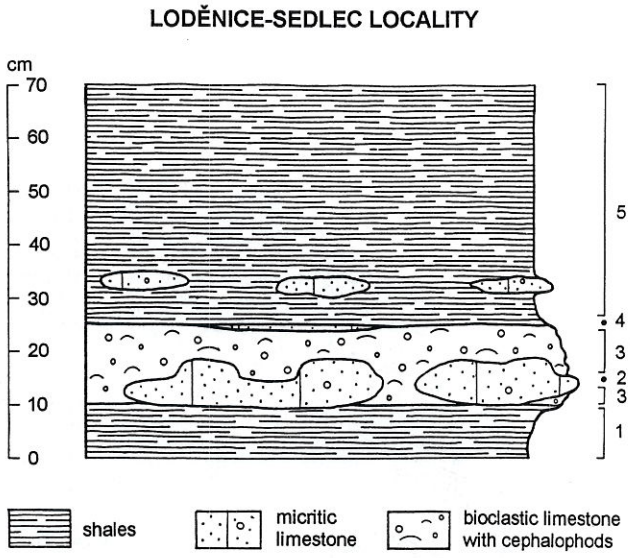


Fig. 3. Loděnice-Sedlec Section.

The section continues by lenticular nodules of dark micritic limestone about 8 cm thick (Text-Fig. 3 – bed no. 2). They contain, especially in their upper part, rare and well preserved cephalopods. The surface of the nodules is very irregular.

In the places between nodules grey to dark grey bioclastic cephalopod limestone sedimented (Text-Fig. 3 – bed no. 3), and covered the nodules. The overall thickness of the bed containing nodules and cephalopod limestone is 15 cm (Text-Fig. 4). The following cephalo-

pods are characteristic for the cephalopod limestone: Arionoceratidae gen. et sp. indet., *Pseudocycloceras duponti, Kopaninoceras* sp., *Arionoceras* cf. *affine, Sphooceras truncatum, Cyrtocycloceras* sp. nov., *Oonoceras* sp., *Michelinoceras* cf. *michelini, Kopaninoceras transiens, Peismoceras asperum, Parakionoceras* cf. *originale, Kionoceras electum* and the Bivalvia dominated community described originally as the *Slava cubicula–Cardiola docens* Community (Kříž, in press a) and later renamed as the *Cardiola donigala–Slava cubicula* Community (Kříž 1998).

Slight depressions on the upper bedding plane of the cephalopod limestone layer are filled by up to 1 cm thick dark micritic limestone with articulated brachiopods *Septatrypa caprilupa* and *Septatrypa* cf. *sapho* and *Cyrtia bedya bedya*, common fragments of the plant *Prototaxites,* and abundant well preserved graptolites of the *Saetograptus chimaera* Zone (Text-Fig. 3 – bed no. 4).

The fossiliferous bed is overlain by the sequence of dark brown laminated calcareous shale with thin tuffitic intercalations. More than 110 cm of the shale were exposed (Text-Fig. 3 – bed no. 5). Five to six cm above cephalopod limestone the shale contain the level of micritic limestone nodules with rare cephalopods. Deformed articulated shells of the brachiopod *Septatrypa caprilupa* and *Cyrtia bedya bedya,* flattened orthocone cephalopods and graptolites of the *Saetograptus chimaera* Zone are common in the light laminae of the shale.

A comparison of the section exposed in late sixties and the excavation through the fossiliferous bed shows that the micritic nodules constituting in western part the layer bellow the cephalopod limestone form in the eastern part the layer within the cephalopod limestone. This may be explained by the origin of the cephalopod limestone layer. The layer of diagenetic nodules had to develop very quickly just bellow the bottom within the laminated and still soft sediment. When the bottom became influenced by the surface current, soft shale were washed away and the level of the micritic nodules has been locally exposed on the bottom. When the sedimentation of the cephalopod bioclastic limestone started, it first filled the spaces between the nodules and later covered them.

Benthic *Cardiola donigala–Slava cubicula* Community

Name: Originally described as the *Slava cubicula – Cardiola docens* Community (Kříž, in press a) and *Slava cubicula – Cardiola donigala* Community (Kříž 1998). When the community was previously described, the analysis of the community was based only on the collection from the debris after the old collectors. When the analy-

Fig. 4. Cephalopod limestone from the Loděnice-Sedlec Locality showing SW–NE current isorientation of the cephalopod conchs.

sis is based on the collection in rock exposure the most dominant is *Cardiola donigala.*

Community group assignment: *Cardiola* Group (Kříž – Serpagli 1993, Kříž 1996, in press a).

Age: Kopanina Formation, upper *Saetograptus chimaera* Zone, upper Gorstian, Ludlow, Silurian.

Type locality: Loděnice-Sedlec, northern slope of the Stydlé Vody Hill.

Geographic distribution: Prague Basin, Bohemia.

Community and environment interpretation: The shells occur mostly disarticulated (1.7 % articulated) in a bioclastic limestone forming layer in the sequence of calcareous laminated shale with articulated brachiopods, graptolites and rare cephalopods. Bioclastic limestone contains relatively rich planctic and nektobenthic association of adult and juvenile cephalopods Arionoceratidae gen. et sp. indet., *Pseudocycloceras duponti, Kopaninoceras* sp., *Arionoceras* cf. *affine*, *Sphooceras truncatum, Cyrtocycloceras* sp. nov., *Oonoceras* sp., *Michelinoceras* cf. *michelini, Kopaninoceras transiens, Peismoceras asperum, Parakionoceras* cf. *originale, Kionoceras electum*, rich benthic community of bivalves, common gastropods, rare trilobites (*Cromus* aff. *beaumonti),* rare adult brachiopods (*Striispirifer viator* and *Cyrtia bedya bedya, Septatrypa caprilupa, Atrypa* cf. *fumosa*), rare tabulate corrals (*Favosites*), phyllocarid *Ceratiocaris* sp. and fragments of non-vascular plant (*Prototaxites* sp.).

All bivalves are filtrators, 74.4 % of which are epibyssate (*Cardiola donigala, Maminka innotata, Mila complex, Patrocardia* sp., *Slavinka damona, Cardiola signata, Cardiola consanguis, Spanila aspirans, Spanila* sp., *Slavinka iduna, Butovicella migrans*, 25.9 % infaunal (*Slava cubicula, Modiolopsis* sp.) and 0.8 % semi-infaunal (*Cardiola pectinata, Actinopteria* sp.). The *Cardiola donigala – Slava cubicula* Community is homologous and analogous (Boucot & Kříž, in press) with other communities of the *Cardiola* Community Group (Kříž, in press a). The *Cardiola donigala – Slava cubicula* Community is characterised by relatively high population density and diversity. Well-oriented cephalopod shells document current activity favourable for epibyssate, semi-infaunal and infaunal byssate filtrators bivalves. The unidirectional current from SW is evidenced by the SW–NE cephalopod shells orientation (Ferretti – Kříž 1995). High diversity and presence of common juvenile bivalves indicate, at least periodically, a well-ventilated sea bottom. Sediment type and fossil preservation suggest an environment below wave base. The *Cardiola donigala – Slava cubicula* Community is very close to the *Cardiola agna* Community and *Cardiola gibbosa* Community which occur earlier in the upper Wenlock and lowermost Ludlow in the Prague Basin (Kříž in press a), Sardinia (Kříž – Serpagli 1993), Montagne Noire (Kříž 1996) and in the Carnic Alps (Kříž in press b). Contemporaneous in the Prague Basin is the shallow water Coral – Crinoid Community forming biostrome characterised by prevalence of crinoids, corals and stromatoporoids, accompanied brachiopods, bivalves, gastropods, trilobites and other fauna in the protected environment and on the top of a submarine elevation build up by volcanic rocks of the Wenlock and lowermost Ludlow age. In the slightly deeper environment in the Prague Basin the brachiopod dominated *Atrypoidea renitens* Community and the *Cromus beaumonti* – Smooth Atrypid Community developed (Havlíček – Štorch 1990). The *Cardiola donigala – Slava cubicula* Community most probably occupied even deeper environment when relatively shortly ventilated by surface water current. Normally the environment of calcareous laminated shales with *Septatrypa caprilupa* and *Cyrtia bedya bedya* corresponding to the Benthic Assemblage 4 life zone according to Boucot (1975) and Havlíček – Štorch (1990) existed here. Contemporaneous to the *Cardiola donigala – Slava cubicula* Community in the Montagne Noire (Kříž 1996) and Sardinia (Kříž – Serpagli 1993) is the *Cardiola donigala* Community, also representing the cephalopod limestone biofacies.

Table 1. Numerical and ranked abundance of bivalves in the *Cardiola donigala – Slava cubicula* Community, Ludlow, upper Gorstian, upper Saetograptus chimaera Zone, Loděnice-Sedlec locality

Species, species group genus	Life habits	R+L	A	RA	AA	R
Cardiola donigala	epibyssate	62	–	26.7	–	1
Maminka innotata	epibyssate	61	–	26.3	–	2
Slava cubicula	infaunal	57	–	24.6	–	3
Mila complexa	epibyssate	13	–	5.6	–	4
Patrocardia sp.	epibyssate	8	–	3.3	–	5
Slavinka damona	epibyssate	7	–	3.0	–	6
Cardiola signata	epibyssate	5	–	2.2	–	7
Cardiola consanguis	epibyssate	4	–	1.7	–	8
Spanila aspirans	epibyssate	2	1	1.7	50	8
Spanila sp.	epibyssate	2	1	1.7	50	8
Slavinka iduna	epibyssate	3	–	1.3	–	9
Modiolopsis sp.,	infaunal	3	–	1.3	–	9
Butovicella migrans	epibyssate	2	–	0.9	–	10
Cardiola pectinata	semi-inf.	1	–	0.4	–	11
Actinopteria sp.	semi-inf.	1	–	0.4	–	11
totals		228	2	101.1	1.72	

R + L = right and left valves (disarticulated); A = articulated shells; RA = percentage relative abundance; AA = percentage relative abundance of articulated shells; R = rank abundance

History of the old pits

Author was also interested in the technique used to dig out fossils from the old pits at the locality Loděnice-Sedlec and by whom and at what time the pits were opened. In 1865 Barrande didn't describe from this locality a specimen of most characteristic species *Peismoceras asperum* (Barrande, 1865). Barrande described only a few specimens of bivalves in 1881 from the cephalopod limestone exposed close to the northern branch of the Tachlovice Fault from the locality "Collines entre Lodenitz

and Bubowitz". It is interesting that among them the most distinct species *Slava bohemica* Barrande, 1881 (synonymum of *Slava cubicula* Kříž, 1985), other species of the genera *Cardiola, Maminka* and *Slavinka* are missing. On the contrary, most of the specimens of *Slava cubicula*, which represent in the world Museums the genus *Slava* known from the Prague Basin, were collected at this locality. On the labels Čeněk Marek is mostly mentioned as the collector. The locality was also not excavated for collector J. M. Šáry, owner of the Prague brewery "U Virlů" and a contemporary of Joachim Barrande. The present author have seen Šáry's collection deposited since the last century in the Museum of Comparative Zoology in Harvard University, Cambridge, during his stay in the United States in 1972–1973. Also here the specimens of *Slava cubicula* are not the part of the collection.

Most probably the pits were opened around 1879–1880 by old collector Čeněk Marek, according to data on the oldest known labels in the Charles University geological collections. It is probably that excavations by Čeněk Marek were conducted only for the business reason – to obtain and sell specimens of *Slava* and *Peismoceras* to collectors and museum collections. National Museum in Prague purchased a single specimen of *Peismoceras asperum* from the locality Lodenitz in 1899 (according to note by J. Perner in accession catalogue it was most probably bought from Čeněk Marek).

The old pits followed the northern margin of the narrow field on the northern slope of the Stydlé Vody Hill at least for about fifty meters. They were about 1.5 to 2 m deep and followed the bed of limestone rich in cephalopods and bivalves up to its unweathered portions. Because it was very difficult to dig out the quickly increasing thickness of dipping tuffaceous shales above the fossiliferous bed, only fossiliferous bed was extracted as deep as possible. During the research undertaken at the locality Loděnice-Sedlec in late sixties by Kříž (1970) we found even several instruments used by old workers. Right in the bedrock were left two iron wedges (Text-Fig. 5) and within the broken fossiliferous rock which filled old pit a pair of broken tongs or pincers used for making smaller rock pieces with the fossils by pinching has been found.

Acknowledgments: Many thanks to Štěpán Manda for determination of cephalopods and a special thanks to Radoslava Horčíková for assistance with the graphic work and to Martin Kříha for assistance in the field.

Submitted March 29, 1999

References

Barrande, J. (1865): Systême silurien du centre de la Bohême. Iere partie: Recherches paléontologiques, 2, 1–107. Praha, Paris.

– (1881): Systême silurien du centre de la Bohême. Iere partie: Recherches paléontologiques, 6, 1–342. Praha, Paris.

Bouček, B. (1941): O novém odkryvu siluru u Loděnic. – Zpr. Geol. Úst. Čechy Mor., 17, 165–172. Praha.

Boucot, A. (1975): Evolution and extinction rate controls.– Developments in Paleontology and Stratigraphy, 1. Elsevier

Fig. 5. Two iron wedges (up) and a pair of broken tongs or pincers (down) found in the old pits at Loděnice-Sedlec locality.

Scientific Publishing Company, 1–427. Amsterdam, Oxford, New York.

Boucot, A. J. – Kříž, J. (in press): Definition of the terms "homologous" and "analogous" community. – Cambridge University Press, 6, 32, Cambridge.

Chlupáč, I. (1987): Ecostratigraphy of Silurian trilobite assemblages of the Barrandian areas, Czechoslovakia. – Newsl. Stratigr., 17, 3, 169–186. Berlin, Stuttgart.

Ferretti, A. – Kříž, J. (1995): Cephalopod limestone biofacies in the Silurian of the Prague Basin, Bohemia. – Palaios, 10, 3 , 240–253. Tulsa.

Havlíček, V. – Štorch, P. (1990): Silurian brachiopods and benthic communities in the Prague Basin (Czechoslovakia). – Rozpr. Ústř. Úst. geol., 48, 1–275. Praha.

Horný, R. (1962): Das mittelböhmische Silur. – Geologie, 11, 8, 873–916. Berlin.

– (1965): Tektonická stavba a vývoj siluru mezi Berounem a Tachlovicemi. – Čas. Mineral. Geol., 10, 2, 147–155. Praha.

Kříž, J. (1970): Stratigraphy of some Barrande's paleontological localities of Silurian age, central Bohemia. – Věst. Ústř. Úst. geol., 45, 5, 295–298.

– (1985): Silurian Slavidae (Bivalvia).– Sbor. geol. Věd, Paleont., 27, 47–111. Praha.

– (1991): The Silurian of the Prague Basin (Bohemia) – tectonic, eustatic and volcanic controls on facies and faunal development. *In*: *M. G. Bassett – P. D. Lane – D. Edwards* (eds.): The Murchison Symposium: proceedings of an international conference on The Silurian System. – Spec. Pap. Palaeontol., 44, 179–203. London.

– (1992): Silurian field excursions: Prague Basin (Barrandian) Bohemia. National Museum of Wales. – Geol. Ser., 13, 1–111. Cardiff.

– (1996): Silurian Bivalvia of Bohemian type from the Montagne Noire and Mouthoumet Massif, France. – Palaeontographica, A. A, 240, 29–63. Stuttgart.

– (1998): Recurrent Silurian–lowest Devonian cephalopod limestones of Gondwanan Europe and Perunica. *In*: *E. Landing – M. E. Johnson* (eds.), Silurian cycles: Linkages of dynamic stratigraphy with atmospheric, oceanic, and tectonic changes. – N. Y. St. Mus. Bull. 491, 183–198. Albany.

– (in press a): Bivalvia dominated communities of Bohemian type from the Silurian and Lower Devonian carbonate facies. – Cambridge University Press, 16, 225–248. Cambridge.

– (in press b): Silurian and lowermost Devonian bivalves of Bohemian type from the Carnic Alps. – Jb. Geol. B.-A. Wien.

Kříž, J. – Dufka, P. – Jaeger, H. – Schönlaub, H. P. (1993): The Wenlock/Ludlow boundary in the Prague Basin (Bohemia). – Jb. Geol. B.-A., 136, 4, 809–839. Wien.

Kříž, J. – Serpagli, E. (1993): Upper Silurian and lowermost Devonian Bivalvia of Bohemian type from South-Western Sardinia. – Boll. Soc. paleont. ital., 32, 3, 289–347. Modena.

Manda, Š. (1996): *Cyrtograptus lundgreni* Biozone in the southwestern part of the Svatý Jan Volcanic Centre (Wenlock, Prague Basin, Bohemia). – Věst. Čes. geol. Úst., 71, 4, 369–374. Praha.

Přibyl, A. (1941): Příspěvek k poznání svrchního siluru v okolí Loděnic. – Zpr. Geol. Úst. Čechy Mor., 17, 2–3, 50–59. Praha.

Biofacie hlavonožcových vápenců na severních svazích silurského vulkanického souostroví v pražské pánvi obsahující benthické mlžové společenstvo *Cardiola donigala – Slava cubicula* (Barrandien, Bohemia)

Jsou popsány vznik a paleoekologie biofacie hlavonožcových vápenců (gorstian – silur) na severním svahu silurského vulkanického souostroví v pražské pánvi (Barrandian, Čechy) a mlžové bentické společenstvo *Cardiola donigala – Slava cubicula.* Diskutována je historie vzniku starých sběratelských jam na nalezišti hlavonožcových vápenců Loděnice-Sedlec.