

ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE	66 (2004–2005)	1–8	БЕОГРАД, ДЕЦЕМБАР 2005 BELGRADE, DECEMBER 2005
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On the Graptolite Schists Formation (Silurian–Lower Devonian) in the Carpatho–Balkanides of eastern Serbia

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Abstract. The fabric of the Silurian and a part of the Lower Devonian in the Carpatho–Balkanides of eastern Serbia, i.e. in two large geotectonic units, the Kučaj Unit (Getic) and the Lužnica Unit (West Kraishite), is reviewed in this paper. Silurian sediments of the Serbian part of the Carpatho–Balkanides are made of the Graptolite Schists Formation, from the lower part of the *acuminatus* Zone at the Ordovician–Silurian boundary to the *transgrediens* Zone at the Silurian–Devonian boundary. The presence of all parts of the Silurian is proved on the basis of graptolite faunas: Llandovery (Rhuddnianian, Aeronian, Telychian), Wenlock (Sheinwoodian, Homeric), Ludlow (Gorstian, Ludfordian) and Pridoli. Two Lower Devonian (Lochkovian) zones (*uniformis* and *hercynicus*), with which the deposition of the Graptolite Schists Formation ended in eastern Serbia is also described. Data on the geochemical characteristics of the Graptolite Schists Formation are presented as well.

Key words: graptolite schists, Silurian–Lower Devonian, lithostratigraphy, biostratigraphy, Carpatho–Balkanides, eastern Serbia.

Апстракт. У раду је приказана грађа силура и дела доњег девона у Карпато–балканидима источне Србије и то у две велике алпијске геотектонске јединице – Кучајској (Гетик) и Лужничкој (западно Крајиште). Силурске седименте српског дела Карпато–балканида изграђује формација граптолитских шкриљаца, почев од доњег дела зоне *acuminatus* на граници ордовицијум–силур до зоне *transgrediens* на граници силур–девон. На основу фауне граптолита доказано је присуство свих одељака силура и то: ландоверија (Rhuddnianian, Aeronian, Telychian), венлока (Sheinwoodian, Homeric), ладлоа (Gorstian, Ludfordian) и пшидолија. Описане су и две доњодевонске (Lochkovian) зоне – *uniformis* и *hercynicus*, којима се завршава таложње формације граптолитских шкриљаца у источној Србији. Дати су и подаци о геохемијским карактеристикама формације граптолитских шкриљаца.

Кључне речи: граптолитски шкриљци, силур–доњи девон, литостратиграфија, биостратиграфија, Карпато–балканиди, источна Србија.

Introduction

Research on Silurian sediments of eastern Serbia started in the middle of the last century with the finding of graptolites in the vicinity of Zvonačka Banja in south-eastern Serbia (ZAFIROV, 1942, 1950) and between Garvanica and Čuka on the foothills of the Rtanj Mt. (PETKOVIĆ, 1954). Subsequently, VESELINOVIC (1959) and MIHAJLOVIC (1959, 1961) published results of their research on Silurian graptolites in the vicinity of Zvonačka Banja, while KRSTIĆ (1959, 1960, 1961) published results of his investigations of newly discovered localities

of Silurian in the area of the Kučaj Mts. During the next ten years, investigations were directed toward discovering as many localities with graptolite faunas as possible and the determination of the collected material. VESELINOVIC (1964, cum lit.) published the results of his researches on Lower Paleozoic facies of eastern Serbia and the determination of graptolite faunas which he collected himself. Results of research on the Silurian graptolites collected in the areas of the Zvonačka Banja, the Rtanj Mt. and the Kučaj Mts. were published by MIHAJLOVIC (1974, cum lit.), while those from the area of the Kučaj Mts. were also published by KRSTIĆ (1984, cum. lit.).

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At the beginning of the eighties, research on the Paleozoic sediments of eastern Serbia started within the scope of the Project A₂ of the Thematic Geologic Map 1:50 000. The research was directed toward the determination of the composition and genetic characteristics of sediments of the Caledonian–Hercynian sedimentation cycle (Ordovician–Lower Carboniferous), as well as to the reconstruction of geological columns of certain systems of beds. The column of the Silurian was already relatively well known then, due to the help of experts in graptolites, such as B. BOUČEK (Prague) and H. JAEGER (Berlin). They published results of their research particularly on the upper parts of the Graptolite Schists Formation in eastern Serbia, the Upper Ludlow, Pridoli and Lochkovian (BOUČEK *et al.*, 1976; JAEGER in KRIŽ *et al.*, 1986). Beside graptolites, research was also aimed at Upper Ludlow conodonts (KRSTIĆ & SUDAR, 1990) from the Silurian of the Kučaj Mts.

Reconstruction of the depositional environments of the marine Paleozoic of the Kučaj zone of the Hercynides of eastern Serbia (Getic) was published by KRSTIĆ & MASLAREVIĆ (1990).

Geological setting

Kučaj Unit

Silurian sediments have significant extension within the largest Alpine structural unit of the Carpatho–Balkanides of eastern Serbia – the Kučaj Unit (Getic) (Fig. 1). They are found in the base of two large anticlines – the Kučaj anticline in the north and the Kusa Vrana anticline in the southeast. They are represented by the Graptolite Schists Formation, beginning with the lower part of the *acuminatus* Zone at the Ordovician–Silurian boundary and ending with the Lower Devonian graptolite *hercynicus* Zone (Fig. 2). The sediments are folded in a system of isoclinal folds, in places broken in the hinges parallelly to the axial surfaces. After break-up, reverse movements of the limbs of the faults occurred and imbrication fabric of the Hercynian core was formed. For this reason, the column of Silurian sediments could have been reconstructed exclusively on the basis of graptolite faunas.

The Ordovician–Silurian boundary Llandoverly

These sediments are located in the lower course on the river Bogovina, between Straža and Bogovinski Kamen, about 6 km WNW of Bogovina. They outcrop in the classical Silurian locality of the Kučaj Mts. (KRSTIĆ, 1960; VESELINOVIĆ & KRSTIĆ, 1970; KRSTIĆ, 1984). In addition to the Upper Ordovician (Hirnantian), the same section exposes Lower Llandoverly sediments in a length of tens of meters. The oldest stratigraphic unit is made of grey-green foliated to thin-bedded meta-

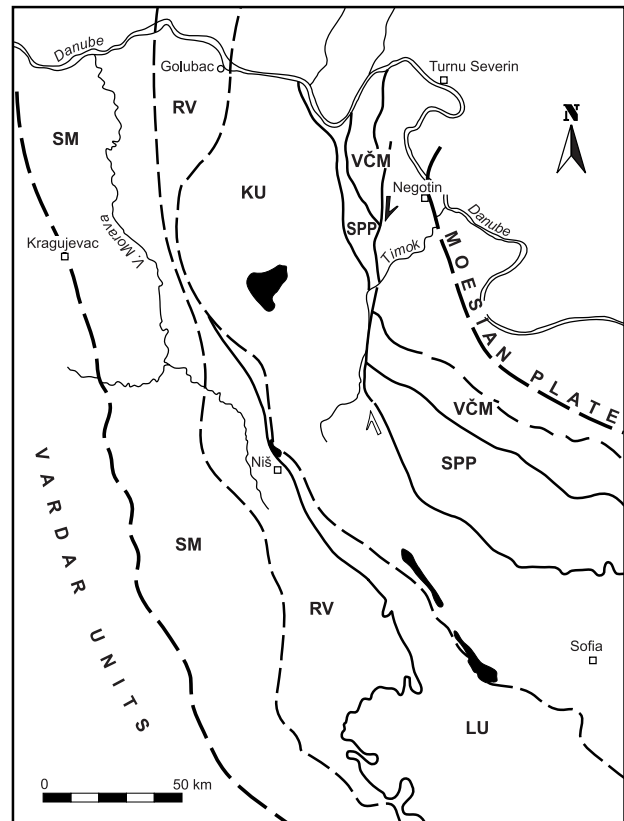


Fig. 1. Main geotectonic units of eastern Serbia (KRÄUTNER & KRSTIĆ, 2001, simplified). VČM = the Vrška Čuka–Miroč Unit (Lower Danubian); SPP = the Stara Planina–Poreč Unit (Upper Danubian); KU = the Kučaj Unit (Getic); LU = the Lužnica Unit (West Kraishite); RV = the Ranovac–Vlasina Unit (Supragetic); SM = the Serbian–Macedonian Unit. Distribution of the Graptolite Schists Formation in KU and LU is marked by the black areas.

shales (equivalent to the Cerecel beds of Bulgaria) in a visible thickness of about 30 meters. It is overlain by a set (about 8 m) of grey or 30–50 cm thick dark grey fine-to-medium-grained quartzose metasandstone beds, interstratified by thin metasiltstones. The sandstones exhibit gradation: medium-grained metasandstone-metasiltstone, and load casts with distinct lower surfaces. The metasandstones contain Upper Ordovician acritarchs: *Lophosphaeridium citrinum*, *L. parverarum*, *L. cf. papilatum*, *Lophosphaeridium* sp., *Brochopsophosphaera* cf. *uralica*, *Trachipsophosphaera* sp., *Leiosphaeridia* sp. type C, *Leiomarginata simplex*, *Priscogallea* sp., *?Tylotopallia* sp., *Michrystrium palidum* (ERCEGOVAC & ĐAJIĆ, 1996). In the uppermost part of the metasandstone set of beds, there are fragments from deeper Ordovician levels: metasandstones, metasiltstones and metashales. The metasandstones are overlain by graphitic metapelites (0.5 m) bearing graptolite *Glyptograptus* sp. and graphitic metapelites and lydites of the *acuminatus* Zone (association: *Climacograptus*

SYSTEM PERIOD	SERIES EPOCH	STAGE AGE	GRAPTOLITE BIOZONES	
			HARLAND <i>et al.</i> (1989)	EASTERN SERBIA (this paper)
D ₁	Lower	Lochkovian	<i>Monograptus hercynicus</i> <i>Monograptus uniformis</i>	<i>hercynicus</i> <i>uniformis</i>
SILURIAN	Pridoli S ₄		<i>Monograptus transgrediens</i> <i>Monograptus parultimus</i>	<i>transgrediens</i> <i>parultimus</i>
		Ludfordian	<i>Bohemograptus</i> <i>Saetograptus leintwardinensis</i>	<i>inexpectatus</i> <i>leintwardinensis</i>
	Ludlow S ₃	Gorstian	<i>Pristiograptus tumescens</i> <i>Saetograptus incipiens</i> <i>Lobograptus scanicus</i> <i>Neodiversograptus nilssoni</i>	<i>nilssoni-scanicus</i>
		Homerian	<i>Monograptus ludensis</i> <i>Gothograptus nassa</i> <i>Cyrtograptus lundgreni</i>	<i>nassa</i> <i>lundgreni-testis</i>
	Wenlock S ₂	Sheinwoodian	<i>Cyrtograptus ellesae</i> <i>Monograptus flexilis</i> <i>Cyrtograptus rigidus</i> <i>Monograptus riccartonensis</i> <i>Cyrtograptus munchisoni</i> <i>Cyrtograptus centrifugus</i>	<i>murchisoni</i> <i>centrifugus</i>
		Telychian	<i>Monoclimacis crenulata</i> <i>Monoclimacis griestoniensis</i> <i>Monograptus crispus</i> <i>Monograptus turriculatus</i>	<i>grandis</i> <i>spiralis (crenulata)</i> <i>griestoniensis</i> <i>turriculatus-crispus</i>
	Llandovery S ₁	Aeronian	<i>Monograptus sedgwickii</i> <i>Monograptus convolutus</i> <i>Coronograptus gregarius</i> <i>argentus</i> <i>magnus</i> <i>triangulatus</i>	<i>linnaei</i> <i>triangulatus</i>
		Rhuddanian	<i>Coronograptus cyphus</i> <i>Cystograptus vesiculosus</i> <i>Akidograptus acuminatus</i>	<i>cyphus</i> <i>vesiculosus</i> <i>acuminatus</i>
		Hirnantian	<i>Glyptograptus persculptus</i>	
O	Upper			

Fig. 2. Correlation of the graptolite zones of eastern Serbia with the graptolite biozones according to HARLAND *et al.*, 1989 and subdivision of the Silurian from the International Stratigraphic Chart of ICS (GRADSTEIN *et al.*, 2004).

trifilis, *Cl. scalaris miserabilis*, *Mesograptus modestus*, *Parakidograptus acuminatus*, *Dimorphograptus*, as well as *Cystograptus vesiculosus*). (BOUČEK, 1965; MIHAJLOVIĆ, 1974; KRSTIĆ, 1984; KRSTIĆ & MASLAREVIĆ, 1998).

The set of sandstone beds underlying the graptolite schists of the *acuminatus* Zone is definitely at the top of the Upper Ordovician, Hirnantian, and it is correlatable with similar deposits of the Kosovo Formation of the Czechish Barandium (STORH, 1986) or the Sirman Formation of the Sofia Stara Planina in Bulgaria (SAČANSKI, 1993, 1994).

Little information is available about the depositional environments of the Upper Ordovician sediments. The Upper Ordovician is likely to be equivalent to glacial marine deposits. Evidently, a sudden change in material, i.e. rapid input of detrital materials, and probably a climate change occurred in the Upper Ordovician.

An identical Upper Ordovician and Lower Silurian section, which includes the uppermost Ordovician, the Ordovician–Silurian boundary and the lowermost Silurian, is recognized west of the Kučaj Mts. in the Gornjak–Ravanica structural unit (nappe), in the valley of

the river Krčeva Reka, south of Samanjac. It is from this section that KRSTIĆ (1966, 1984) described green mottled argillaceous schists (equ. the Cerecel beds of Bulgaria), Upper Ordovician greenish medium-grained sandstones (about 6 m) and the overlying graptolite schists, lydites and sandstones bearing an association of the lowest Silurian *acuminatus* Zone, viz.: *Glyptograptus* cf. *persculptus*, *Diplograptus modestus modestus*, *Climacograptus* sp. (from the lower *acuminatus* Zone) and *Climacograptus medius*, *Cl. scalaris miserabilis*, *Cl. scalaris normalis*, *Cl. rectangularis*, *Cl. trifilis*, *P. acuminatus acuminatus* and *Climacograptus* sp. (from the upper *acuminatus* Zone).

At the cross-section in the river Bogovinska Reka, between Straža and Bogovinski Kamen, besides the *acuminatus* Zone, there is an association of graptolites of the following, *vesiculosus* Zone of the Lower Llandovery – (Rhuddanian): *Cystograptus vesiculosus*, *Dimorphograptus confertus*, *D. confertus swanstoni* and *D. cf. extenuatus*; as well as an association of the *cyphus* Zone: *Diplograptus modestus* *Cystograptus vesiculosus*, *Climacograptus longespina*, *Cl. medius*, *Cl. scalaris normalis*, *Pseudoclimacograptus hughesi*, *Rha-*

phidograptus törnquisti, *Rastrites longispinus*, *Pernero-graptus revolutus austerus*, *Dimorphograptus confertus*, *D. confertus swanstoni*, *Pristiograptus argutus*, *Pr. concinnus*, *Pr. sandersoni* and *Coronograptus cyphus*.

The Llandovery in the cross-section in the river Bogovinska Reka ends with the first zone of the middle part of the Llandovery (Aeronian) – the *triangulatus* Zone, with the following association: *Climacograptus longespina*, *Cl. medius*, *Cl. scalaris normalis*, *Rhaphidograptus törnquisti*, *Demirastrites triangulatus*, *Rastrites longispinus*, *Pristiograptus concinnus*, *Coronograptus cyphus*, *Pr. sandersoni*, and others (MIHAJLOVIĆ, 1974).

The upper parts of the Aeronian are found northwest from Bogovinski Kamen, on the right and left riverbanks of the river Bogovinska Reka. Platy, in places, laminated lydites were found here in alternation with black siliceous metaclaystones with a rich association of graptolites from the *linnaei* Zone (VESELINOVIĆ & KRSTIĆ, 1970; KRSTIĆ, 1973; MIHAJLOVIĆ, 1974): *Glyptograptus* cf. *incertus*, *Petalolithus elongatus elongatus*, *P. giganteus*, *P. palmeus*, *P. cf. conicus*, *P. ovatus*, *Retiolites (Pseudoretiolites) dentatus*, *Monograptus halli*, *M. becki*, *M. marri*, *M. (Streptograptus) exiguus primulus*, *M. (Streptograptus) pseudobecki*, *Cephalograptus cometa extrema*, *Climacograptus scalaris*, *Pseudoplegmato-graptus longispinus*, *Spirograptus circularis*, *Spirograptus planus*, *S. proteus*, *S. turriculatus minor*, *Diversograptus capilaris capilaris*, *Rastrites linnaei*, *R. distans*, *R. fugax*, *Pristiograptus jaculum*, *Pr. nudus* and *Pr. variabilis*.

The fossiliferous level of this zone is about 2 meters thick and, in the next 1.5 meters, there is an association of the following, younger zone of the Upper Llandovery – from the base of the Telychian – the *turriculatus* Zone. Association of this Zone is composed of: *Petalolithus altissimus*, *P. elongatus*, *P. giganteus*, *P. palmeus*, *Retiolites robustus*, *Monograptus becki*, *Monograptus (Monograptus) marri*, *M. galaensis*, *M. (Monograptus) pandus*, *M. (Monograptus) dextrorsus*, *M. (Globosograptus) crispus*, *M. (Streptograptus) exiguus exiguus*, *Spirograptus turriculatus turriculatus*, *S. planus*, *S. proteus*, *Rastrites distans*, *Demirastrites pragensis ružičkai*, *Pristiograptus nudus* and *P. variabilis* (VESELINOVIĆ & KRSTIĆ, 1970; KRSTIĆ, 1973; MIHAJLOVIĆ, 1974).

On the same cross-section, MIHAJLOVIĆ (1974, p. 157) adds another, younger – *crispus* Zone, with the following association: *Retiolites robustus*, *Pseudoplegmato-graptus* sp. aff. *obesus*, *Monograptus* cf. *acus*, *M. galaensis*, *M. marri*, *M. veles*, *Globosograptus* cf. *barrandei*, *G. crispus*, *Streptograptus exiguus*, *Spirograptus proteus* and *Pristiograptus nudus*, to the above mentioned zones.

Younger zones of the Telychian are found on the section of the Silurian in the river Vejska Reka on the Kučaj Mts., but they are not sufficiently studied. This part of the Upper Llandovery is made of grey thin-bedded metaclaystones with *Spirograptus spiralis* cf. *contortus* and *Globosograptus singularis singularis*, ac-

ording to which the part of the column between the *crispus* and *crenulata* zones can be determined with a certain reserve. Several meters further, there are *Retiolites geinitzianus angustidens* and *Demirastrites* cf. *pragensis*, which indicate the presence of the *griestoniensis* Zone (KRSTIĆ, 1966, 1984).

The upper part of the Lower Silurian – Telychian is well documented on the section of Bačište in Zvonačka Banja, from where MIHAJLOVIĆ (1974) proved the presence of the following zones of this part of the Silurian – *turriculatus*, *crispus*, *griestoniensis*, *crenulata*, *spiralis* and *grandis*.

In the association of the *turriculatus* Zone (thickness 1 m), there are *Pseudoplegmato-graptus obesus*, *Monograptus becki*, *M. veles*, *M. marri*, *Spirograptus proteus* and *Spirograptus turriculatus*. In the next 2 meters, there is a rich association of graptolites from the *crispus*, *griestoniensis* and *crenulata* zones which have not been separated. The following association has been found in this part: *Retiolites geinitzianus angustidens*, *Orthograptus pigmeus*, *Pseudoplegmato-graptus obesus*, *Monograptus galaensis*, *M. tortilis*, *M. veles*, *Globosograptus singularis*, *Streptograptus exiguus*, *Monoclimacis griestoniensis*, *M. crenulata*, *Spirograptus arcuatus*, *S. tullbergi*, *S. flagelaris*, *S. tullbergi spiralooides*, *Pristiograptus nudus*, *P. pergratus*, *P. prandtli*, *Diversograptus capilaris pergracilis*.

This association is followed by the next one which is found in the *spiralis* Zone: *Retiolites geinitzianus*, *Pseudoplegmato-graptus obscurus*, *Monograptus praecedens*, *M. priodon*, *M. probosciformis*, *Globosograptus sartorius*, *G. singularis mancki*, *G. wimani*, *Streptograptus nodifer*, *Monoclimacis vomerina*, *Spirograptus spiralis*, *Cyrtograptus lapworthi*, *Barrandeograptus pulchellus*, *Pristiograptus largus* and *Diversograptus ramosus*.

The Llandovery ends with 1 m of thick black slaty siltstones with the association of the *grandis* Zone: *Retiolites geinitzianus*, *Stomatograptus grandis*, *S. grandis imperfectus*, *Monograptus priodon*, *M. probosciformis*, *Monoclimacis linnarsoni*, *M. vomerina* and *Barrandeograptus pulchellus*.

The Wenlock

Sediments of the Lower Wenlock (Sheinwoodian) are documented in the vicinity of Zvonačka Banja and on the Kučaj Mts.

In the vicinity of Zvonačka Banja (creek Zajednica, i.e. creek Dupski Potok), the thickness of the beds of the Lower Wenlock do not exceed 2 m. This part of the Silurian is composed of black metasiltstones, graphitic in places, with graptolites coated with gymbelite, which gives them a silvery shine. In these beds, MIHAJLOVIĆ (1974) described the following association of graptolites: *Retiolites geinitzianus*, *Monograptus priodon*, *M. pseudocultellus*, *Stomatograptus grandis maior*, *Mediograptus kodymi*, *M. kolichai*, *Monoclimacis*

cf. *linnarsoni*, *M. vomerina*, *Cyrtograptus centrifugus*, *C. insectus*, *Barrandeograptus pulchellus* and *Pristiograptus praedubius*. This association corresponds to the first zone of the Lower Wenlock, the *centrifugus* Zone.

The next, younger zone of the Lower Wenlock was proved on the Kučaj Mts., in the area of the origin of the river Bogovinska Reka, between Brošće and Kraku Janoš. KRSTIĆ (1984) cited the following association of graptolites in thin-bedded metaclaystones: *Monograptus (Mediograptus) kolihai kolihai*, *M. (Monograptus) priodon*, *Monoclimacis vomerina*, *M. vomerina gracilis*, *Cyrtograptus (Cyrtograptus) murchisoni murchisoni*, *C. (Cyrtograptus) murchisoni bohemicus*, *C. (Barrandeograptus) pulchellus*, *Retiolites geinitzianus*. Such association of graptolites can be found in the Lower Wenlock, in the *murchisoni* Zone.

Sediments of the Upper Wenlock (Homerian) were found on numerous localities on the Kučaj Mts. and in the vicinity of Zvonačka Banja.

In the area of the Kučaj Mts., sediments of the Upper Wenlock are found in the river Bogovinska Reka (NW from Bogovinski Kamen), in the areas of the origin of the rivers Bogovinska Reka (east of Brošće) and Radovanska Reka, in Vejska Reka (spring Klencuški Potok), and in the river Krčeva Reka. The following fossils are most often found: *Cyrtograptus lundgreni lundgreni*, *C. hamatus*, *Monograptus flemingi flemingi*, *M. testis testis* and *Pristiograptus pseudodubius*, which points to the Upper Wenlock – the *lundgreni-testis* Zone. In the area of Zvonačka Banja, sediments of the Upper Wenlock were found on several localities. They are represented by platy metasiltstones and black graphitic metaclaystones with associations of graptolites of the *lundgreni-testis* and *nassa* zones, which have not been separated, even the fossiliferous level is about 6 m thick. MIHAJLOVIĆ (1974) cited the following association of graptolites from the cross-section of the Upper Wenlock in the river Blatanica, south of Zvonačka Banja: *Monograptus flemingi*, *M. subflexilis*, *M. testis*, *Monoclimacis flumendosae*, *Cyrtograptus hamatus*, *C. lundgreni*, *Pristiograptus ex gr. dubius*, *P. pseudodubius* and *Diversograptus gracilis*, as well as *Plectograptus praemacilentus*, *Monograptus testis inornatus*, *Cyrtograptus radians*. They are replaced by an association with *Gothograptus nassa*, *Monograptus flemingi*, *M. testis*, *Cyrtograptus hamatus*, *C. lundgreni*. A similar association has also been found on Bačište, in the springs Dupski Potok, Šuškovica, Jasenov Do, and in the spring Blatna Dolina.

The Ludlow

The Lower Ludlow (Gorstian) is present in all localities where sediments of the Upper Wenlock, which gradually transit into sediments of the Lower Ludlow, are documented. This part of the Ludlow is proved on the Kučaj Mts. and in the vicinity of Zvonačka Banja. It is represented by associations of graptolites of the

nilssoni and *scanicus* zones, which have not been separated. This part of the Silurian is most completely developed in Zvonačka Banja, from where MIHAJLOVIĆ (1974) cited the following association, from the valley of the river Blatanica: *Monograptus uncinatus*, *Neodiversograptus nilssoni*, *Pristiograptus bohemicus*, *P. vulgaris*, *Colonograptus colonus*, *Saetograptus himmaera*. There are also *Globosograptus crinitus*, *Lobograptus scanicus*, *Neodiversograptus nilssoni*, *Pristiograptus bohemicus*, *P. butovicensis*, *P. dubius ludlovensis*, *Saetograptus himmaera*, *Lobograptus scanicus*, *Linograptus posthumus tenuis*, *Pristiograptus bohemicus*, *P. dubius ludlovensis*. A somewhat more varied association was found in the vicinity of Zvonačka Banja, on the line of a former mine track, where, besides the above mentioned species, there are also: *Plectograptus macilentus*, *Spinograptus spinosus*, *Monograptus uncinatus*, *Globosograptus crinitus*, *Lobograptus scanicus*, *Neodiversograptus nilssoni*, *Pristiograptus gotlandicus* and others.

In the area of the Kučaj Mts., at the well-known cross-section of Silurian sediments in the river Vejska Reka (spring Klencuški Potok), above the schists with graptolites of the *nilssoni-scanicus* Zone, there is about 60 cm of thick stratified limestones with rich association of conodonts, composed of the following multielements: *Kockelella variabilis*, *Ozarkodina confluens*, *Ozarkodina excavata excavata*, as well as of the “form species” forms: *Polygnathoides siluricus*, *Ligonodina salopia*, *Lonchodina walliseri* and *Pseudooneotodus beckmanni*. This association of conodonts comes from the *siluricus* Zone (KRSTIĆ & SUDAR, 1990), which is in the base of the Upper Ludlow (Ludfordian) – the equivalent of the graptolite *leintwardensis* Zone.

Only one, but very significant and guide zonal species – *Neocuculograptus inexpectatus inexpectatus*, which appears in association with *Bohemograptus cf. tenuis* and *Pristiograptus* sp. (BOUČEK *et al.*, 1976), is described from the Upper Ludlow (Ludfordian) of Zvonačka Banja.

The Pridoli

Sediments of the Pridoli have been proved only in the vicinity of Zvonačka Banja (Zajednica i.e. Dupski Potok). This part of the Silurian is made up of black silty metaclaystones with anthracite, which contain an association of graptolites that form the *parultimus* Zone from the base of the Pridoli: *Monograptus parultimus*, *M. fragmentalis*, *Formosograptus formosus*, *Pristiograptus cf. kolednikensis* and *Linograptus posthumus* (BOUČEK *et al.*, 1976; JAEGER in: KRIŽ *et al.*, 1986).

The Silurian–Devonian Boundary

The uppermost zone of the Pridoli – the *transgrediens* Zone was found on the hill Varniče above Zvonač-

ka Banja. The top of the Silurian is made up of black metaclaystones which contain *Pristiograptus transgrediens* (JAEGER in KRIŽ *et al.*, 1986). The Silurian–Devonian boundary is also present on this cross-section, because the *transgrediens* Zone is continually replaced by graptolite associations of the following, Lower Devonian (Lochkovian) *uniformis* Zone: *Monograptus uniformis*, *M. uniformis angustidens*, *M. aequabilis aequabilis*, *M. microdon microdon*, *Linograptus posthumus posthumus*, *Abiesgraptus* sp. (BOUČEK *et al.*, 1976). Above the *uniformis* Zone, there is the last graptolite zone in eastern Serbia, marked with occurrence of the species *Monograptus hercynicus* (VESELINOVIĆ, 1973), with which the deposition of the Graptolite Schists Formation ends (*Akidograptus acuminatus* – *Monograptus hercynicus*). After the *hercynicus* Zone, the conditions of sedimentation rapidly changed and sediments of a balanced basinal facies prograde upwards in an association of unbalanced preflysch sedimentation (lack of balance between sedimentation and deposition). Preflysch is represented by siliceous metaclaystones, laminated lydites and cherts, metasiltstones, dolomitic limestones, thick beds of sandstones and, occasionally by turbidites. These sediments are about 100 meters thick and they are located between the graptolite schists and the Upper Devonian–Lower Carboniferous flysch (Famennian–Viséan) (KRSTIĆ & MASLAREVIĆ, 1990).

The Lužnica Unit

The Silurian Formation of Graptolite Schists has also been found in the Lužnica structural unit (West Kraishite), which is located west of the Kučaj Unit (Getic) (Fig. 1). It should be emphasized that the Paleozoic sediments of the Lužnica Unit were deposited in an independent sedimentary basin. This basin was located west of the Getic one from which it was separated by the Ozren–Baikalian paleostructure (land) (KRSTIĆ, 1984). There was no sedimentation on this land during the Lower Paleozoic and, in the whole territory of eastern Serbia, over the Upper Proterozoic crystalline schists there are lacustrine sediments of the Upper Carboniferous or the Permian Red Sandstones.

Sediments of the Lower Paleozoic of the Lužnica Unit are today in a zone of nappes. In most part of their extension, they make a tectonic footwall of Paleozoic schists of the Supragetic, which are metamorphosed under conditions of greenschist facies and thrust over them. As they themselves were moving eastwards and thrusting over a large number of geological units of different age, the Lower Paleozoic sediments of the Lužnica Unit are very much altered kinematically and significantly metamorphosed in places.

The Silurian of the Lužnica Unit is made up of metasiltstones, siliceous metaclaystones and lydites, which were discovered between Miljkovac and Rujnik, north of Niš (Fig. 1). An association of graptolites

composed of: *Retiolites geinitzianus angustidens*, *Monograptus veles*, *M. cf. parapriodon*, *M. (Globosograptus) cf. singularis*, *Monocliacis crenulata*, *Monocliacis griestoniensis griestoniensis*, *Monocliacis vomerina vomerina*, *Spirograptus falx*, *S. spiralis spiralis*, *S. tullbergi tullbergi* and *S. tullbergi spiralooides* (this is the typical association of graptolites of the uppermost zone of the Upper Llandovery, *crenulata* Zone) comes from an about 0.5 m thick fossiliferous level (KRSTIĆ, 1984).

Geochemistry

The Graptolite Schists Formation are deep water sediments (LJ. MASLAREVIĆ, unpublished data). DT and TG analyses proved a content of 3–4% of bituminous organic matter of coaly-anthracitic character, which originates from the graptolites. An increased content of uranium, from 7 to 16 g/t, was determined by chemical analyses. High V/Cr (12–20) and V/Mo (20–120) ratios, according to KUKAL (1971), represent a characteristic of deep-water sapropel. The content of Ba rises, however, with salinity, so the found quantity, according to this author, corresponds to the salinity 34–35‰, while the low Cr/V (0.05–0.08) and Cr/Ni (0.7–0.8) ratios point to sedimentation far from the coast. The sediments originated by a calm and slow deposition in an environment poor in free oxygen. The sea bed was poorly fed and flows along the sea bed were weak so they occasionally moved just mud and organic matter for laminar sedimentation.

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Резиме

О формацији граптолитских шкриљаца (силур–доњи девон) у Карпато–балканидима источне Србије

У раду је приказан силур и део доњег девона у Карпато–балканидима источне Србије који учествују у грађи две велике Алпијске структурне јединице – Кучајске (Гетик) и Лужничке (западно Крајиште). У овом временском интервалу у Кучајској јединици стварана је формација граптолитских шкриљаца, почев од базе силура – доњег дела зоне *acuminatus*, на граници ордовицијум–силур, закључно са зоном *hercynicus* доњег девона (Lochkow-a). На основу граптолитске фауне у овој јединици је доказано присуство свих одељака силура и то: ландоверија (Rhuddanian, Aeronian, Telychian), венлока (Sheinwoodian, Homerian), ладлоа (Gorsian, Ludfordian), пшидолија као и доњокарбонског лохкова, са којим се завршава таложње формације граптолитских шкриљаца у источној Србији.

Седименти формације граптолитских шкриљаца (метаалевролити, метаглинци, ређе и лидити) убрани су у систем изоклиних набора, местимично раскинутих у темену паралелно аксијалним површинама. Крила набора (dm–hm димензија) су после

раскидања реверсно кретана чиме је створена краљушаста грађа херцинског језгра. Због тога је стуб формације граптолитских шкриљаца могао бити реконструисан искључиво помоћу фауне граптолита, чији многи родови и врсте имају мало вертикално а широко хоризонтално распрострањење, па представљају глобалне руководеће фосиле.

Седименти формације граптолитских шкриљаца Лужничке јединице откривени су на малој површини. Палеозојски седименти ове јединице таложени су у независном седиментационом басену који је од Кучајског (Гетског) био одвојен копном (Озренско-бајкалско копно), на коме током старијег палеозоика није било седиментације. На Озренском копну, широм источне Србије, преко кристаластих шкриљаца горњег протерозоика леже језерски седименти горњег карбона или творевине пермских црвених пешчара.

Седименти старијег палеозоика лужничке јединице данас се налазе у зони навлака. Они у највећем делу свог распрострањења чине тектонску подину палеозојским шкриљцима Супрагетикума, метаморфисаним у условима фације зелених шкриљаца, који су на њих навучени. Пошто су и сами кретани ка истоку и навлачени преко читавог низа геолошких јединица различите старости старопалеозојски седименти Лужничке јединице су јако кинематски измењени и знатно метаморфисани.

Па ипак, метаалевролити, силициозни метаглинци и лидити, откривени између Миљковца и Рујника северно од Ниша садрже релативно богату граптолитску асоцијацију горњег дела доњег силура, из зоне *crenulata*.

Формација граптолитских шкриљаца представља седimente дубље воде. DT и TG анализама утврђен је садржај од 3–4% битуминозне органске материје угљевито-антрацитског карактера пореклом од граптолита. Хемијским анализама утврђен је повећан садржај урана, од 7–16 gr/t. Висок однос V/Cr (12–20) и V/Mo (20–120), по KUKALU (1971) представља карактеристику дубоководног сапропела. Садржај Ва расте, пак, са салинитетом, тако да нађена количина, по овом аутору, одговара салинитету од 34–35%, а низак однос Cr/V (0,05–0,08) и Cr/Ni (0,7–0,8) указује на седиментацију далеко од обале. Седименти су настали мирним и лаганим таложењем, у средини сиромашној слободним кисеоником. Морско дно је било слабо храњено, а течења при дну слаба, тако да су повремено покретала само муљ и органску материју за ламинарну седиментацију.

Све асоцијације граптолита цитиране су у претходном, енглеском делу текста. У литератури су наведени само неопходни радови, док се у монографијама М. ВЕСЕЛИНОВИЋА (1964), М. МИХАЛЛОВИЋА (1974) и Б. КРСТИЋА (1984) налазе комплетни спискови коришћене литературе.