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Silurian graptolite biozones of Lithuania: present and perspectives

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Graptolites are a group of extinct colonial invertebrate organisms, which belong to hemichordates. They are the most important organism group of Silurian biostratigraphy in Lithuania. A lot of new material appeared recently that made possible the potential for the improvement of the graptolite biozonation of Lithuanian Silurian. In Lithuania graptolites are distributed from *Coronograptus cyphus* (upper Ruddanian) to *Neocolonograptus lochkovensis* (lower Pridolian). The intervals of Rhuddanian–Aeronian, Telychian–Sheinwoodian, Gorstian–Ludfordian and Ludlow–Pridoly boundaries are still problematic in Lithuania and further studies are necessary.

Key words: Silurian, graptolite biozones, Lithuania

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INTRODUCTION

Graptolites are the most important organism group for Silurian biostratigraphy in Lithuania. They are a group of extinct colonial invertebrate organisms, which belong to hemichordates. The graptolites appeared in the middle Cambrian and became extinct in the Carboniferous. The biggest diversity of graptolites was in the Ordovician. The diversity of graptolites is less in the Silurian period but such groups as diplograptids and monograptids have been widespread in the world and quickly evolved in the Silurian. This allows a very detailed dating of the Silurian rocks and the Silurian deposits correlation between the different regions. Therefore the global Silurian stratigraphic scale is based on graptolite fauna. The pioneer of graptolites investigation in Lithuania was A. Obut (Paškevičius, Radzevičius, 2006). The graptolite studies started in the beginning of the fifties, when first deep wells have been drilled in Lithuania (Obut, 1953). Later, J. Paškevičius (1958) began detailed graptolite studies and provided the first graptolite biozonation for the Silurian of Lithuania. The last summarized graptolite biozonation of Lithuania was done at the end of the nineties (Paškevičius, 1997). Similar works were in Latvia and Estonia and in the middle of the eighties the generalized graptolite biozonation has been given for the East Baltic (Estonia, Latvia, and Lithuania) region (Kaljo et al., 1984). Since then, a lot of new material has appeared and the potential for the improved graptolite biozonation is possible for the Silurian of Lithuania. Recently, intensive investigations of the Silurian rocks for shale gas have been started. The purpose of this article is to provide the recommended graptolite biozonation of the Silurian of Lithuania; discuss its advantages and disadvantages; provide future plans and give recommendations.

GRAPTOLITE BIOZONES

Graptolite biozones of Llandovery

Rhuddanian

In Lithuania the lowest graptolites occur in the dark argillite and graptolite assemblage indicating the upper part of the Rhuddanian *Coronograptus cyphus* Biozone (Paškevičius, 1997). The base of the *cyphus* Biozone is unclear. It is assumed that this biozone is incomplete and the range of the index species represents only its upper part. The *cyphus* Biozone in Lithuania was defined by J. Paškevičius (1968).

Aeronian

The *Demirastrites triangulatus*, *Demirastrites pectinatus*, *Campograptus millepeda*, *Lituigraptus convolutus*, *Stimulograptus sedgwickii* biozones have been distinguished in the Aeronian of Lithuania (Figure).

The *triangulatus* Biozone was first described by J. Paškevičius (1963) in Lithuania. Previously, this interval was named after the *Coronograptus gregarius* Biozone with *Demirastrites triangulatus* (Harkness) in Lithuania (Paškevičius, 1961). J. Paškevičius (1979) differentiated three subzones: the *pectinatus* Subzone in the lower, the *millepeda* Subzone in the upper and an unnamed subzone in the middle part of the *triangulatus* Biozone. These subzones are now treated as an independent biozones (Paškevičius, 1997). The base of the *triangulatus* Biozone is marked by the appearance of *D. triangulatus*. Other new graptolite taxa appearances are, e. g. *Glyptograptus sinuatus* (Nicholson), *Orthograptus stonishkensis* Paškevičius, *Petalolithus ovatoelongatus* (Kurck), *Pet. minor* (Elles) and *Pribylograptus argutus* (Lapworth). The graptolite assemblage is rich, with a number of species continuing from the *cyphus* Biozone.

The *pectinatus* Biozone is defined by the appearance of *Demirastrites pectinatus* (Richter) (Paškevičius, 1997) in Lithuania. The graptolite assemblage of this biozone is very similar to that of the *triangulates* Biozone.

The base of the *millepeda* Biozone (Paškevičius, 1997) is marked by the appearance of monograptids with hooked thecae: *Campograptus millepeda* (M'Coy) and *Cm. lobiferus* (M'Coy). *Pribylograptus leptotheca* (Lapworth) also appear in this biozone. Other graptolites are the same as in the *pectinatus* Biozone.

The *convolutus* Biozone has been described first by J. Paškevičius (1979) in Lithuania. J. Paškevičius (1979) established the *convolutus* Biozone by the appearance of *Lituigraptus convolutus* (Hisinger) together with *Cephalograptus cometa* (Geinitz) in Lithuania. The graptolite assemblage of this biozone include, e. g. *Petalolithus folium* (Hisinger), *Orthograptus parovejensis* Paškevičius, *Monograptus limatulus* (Törnquist) and *Pristiograptus regularis* (Törnquist).

The *sedgwickii* Biozone, first recognized by J. Paškevičius (1958) in Lithuania, is the least represented Aeronian biozone. The lower boundary of this biozone is marked by the appearance of *Stimulograptus sedgwickii* (Portlock). *Petalolithus tenuis primus* (Paškevičius) appears as well and *Metaclimacograptus hughesi* (Nicholson) still persists. The *Stimulograptus halli* Biozone has been defined in the uppermost Aeronian in Latvia (Loydell et al., 2003). The species *St. halli* (Barrande) has not been found in Lithuania yet and the *halli* Biozone is interpreted as the upper part of the *sedgwickii* Biozone. The upper boundary of the *sedgwickii* Biozone marks the base of the Telychian.

Telychian

The Telychian includes the *Rastrites linnaei*, *Spirograptus turriculatus*, *Streptograptus crispus*, *Monoclimacis griestoniensis*, *Monoclimacis crenulata*, *Oktavites spiralis*, *Cyrtograptus lapworthi*

Figure. Correlation of the generalized Silurian graptolite biozones with graptolite biozones of Lithuania and Latvia (* Latvia biostratigraphic chart compiled after Kaljo et al., 1984 (*confertus* Biozone); Loydel et al., 2003, 2010 (*cyphus–lundgreni*); modified after Radzevičius, Paškevičius, 2005 (*parvus–nilssoni* interval); Gailite et al., 1987 (*nilssoni–formosus* interval)) and regional stages (Paškevičius et al., 1994)

Pav. Silūro tarptautinės graptolitų schemos koreliacija su Lietuvos ir Latvijos schemomis (* Latvijos graptolitų biozonos pateiktos pagal Kaljo ir kt., 1984 (*confertus* biozona); Loydell ir kt., 2003, 2010 (*cyphus–lundgreni* intervalas); pagal Radzevičius, Paškevičius 2005 (*parvus–nilssoni* intervalas); Gailite ir kt., 1987 (*nilssoni–formosus* intervalas)) ir regioniniai aukštai (Paškevičius et al., 1994)

System	Series	Stage	Reg. Stage	Generalized Graptolite biozones (Koren' et al., 1996)	Lithuania Graptolite biozones (Paškevičius, 1997; Radzevičius, 2006; Paškevičius et al., 2012)	Latvian Graptolite biozones*
SILURIAN	Pridoli			*Istrograptus transgrediens*	?	?
				Mnograptus bouceki	?	?
				Neocolonograptus lochkovensis	*Neocolonograptus lochkovensis*	*Neocolonograptus lochkovensis*
				Neocolonograptus branikensis		
				Neocolonograptus ultimus	*Neocolonograptus ultimus*	*Neocolonograptus ultimus*
				Neocolonograptus parultimus	*Neocolonograptus parultimus*	*Neocolonograptus parultimus*
	Ludlow	Ludfordian	Pagėgiai	*Formosograptus formosus*	*Formosograptus formosus* *Monograptus valleculosus*	*Formosograptus formosus*
				Neocuculograptus kozlowskii	*Monograptus balticus*	*Monograptus balticus*
				Bohemograptus b. tenuis	*Ps. tauragensis* *Bohemograptus b. tenuis*	*Pseudomonoclimacis tauragensis*
					Bohemograptus cornutus	
					B. praecornutus	
				Saetograptus leintwardinensis	*Saetograptus incipiens*	
		Gorstian	Dubysa	*Lobograptus scanicus*	*Lobograptus scanicus*	*Lobograptus scanicus*
					Lobograptus progenitor	*Lobograptus progenitor*
				Neodiversograptus nilssoni	*Neodiversograptus nilssoni*	*Neodiversograptus nilssoni*
	Wenlock	Homerian	Gėluva	*Colonograptus ludensis*	*Colonograptus ludensis*	*Colonograptus ludensis*
				Colonograptus deubeli	*Colonograptus deubeli*	*Colonograptus deubeli*
				Colonograptus praedeubeli	*Colonograptus praedeubeli*	*Colonograptus praedeubeli*
				Gothograptus nassa	*Gothograptus nassa*	*Gothograptus nassa*
		Sheinwoodian	Jaagarahu	*Pristiograptus parvus*	*Pristiograptus parvus*	*Pristiograptus parvus*
				Cyrtograptus lundgreni	*Cyrtograptus lundgreni*	*Cyrtograptus lundgreni*
				Cyrtograptus perneri	*Cyrtograptus perneri*	*Cyrtograptus perneri*
				Cyrtograptus rigidus		
				Monograptus belophorus	*Monograptus belophorus*	*Monograptus belophorus*
			Jaani	*Monograptus riccartonensis*	*Streptograptus antennularius*	*Monograptus riccartonensis*
					Monograptus riccartonensis	
				Cyrtograptus murchisoni	*Cyrtograptus murchisoni*	*Monograptus firmus*
						Cyrtograptus murchisoni
	Llandovery	Telychian	Adavere	*Cyrtograptus centrifugus*	*Cyrtograptus centrifugus*	*Cyrtograptus centrifugus*
				Cyrtograptus insectus	*Cyrtograptus lapworthi*	*Cyrtograptus lapworthi*
				Cyrtograptus lapworthi		
				Oktavites spiralis	*Oktavites spiralis*	*Oktavites spiralis*
				Monoclimacis crenulata	*Monoclimacis crenulata*	*Monoclimacis crenulata*
				Monoclimacis griestonensis	*Monoclimacis griestonensis*	*Monoclimacis griestonensis*
				Streptograptus crispus	*Streptograptus crispus*	*Streptograptus sartorius*
						Streptograptus crispus
				Spirograptus turriculatus	*Spirograptus turriculatus*	*Spirograptus turriculatus*
		Aeronian		*Spirograptus guerichi*	*Rastrites linnaei*	*Spirograptus guerichi*
				Stimulograptus sedgwickii	*Stimulograptus sedgwickii*	*Stimulograptus halli*
						Stimulograptus sedgwickii
			Raikküla	*Lituigraptus convolutus*	*Lituigraptus convolutus*	*Lituigraptus convolutus*
				Monograptus argenteus	*Campograptus millepeda*	*Pribylograptus leptotheca*
		Rhuddanian		*Demirastrites pectinatus*	*Demirastrites pectinatus*	*Neodiplograptus magnus*
				Demirastrites triangulatus	*Demirastrites triangulatus*	*Demirastrites triangulatus*
				Coronograptus cyphus	*Coronograptus cyphus*	*Coronograptus cyphus*
		Juuru		*Cystograptus vesiculosus*	?	*Dimorfograptus confertus*
				Parakidograptus acuminatus	?	?

(Paškevičius, 1997) and *Cyrtograptus centrifugus* graptolite biozones in Lithuania.

In Lithuania the *linnaei* Biozone was first described by J. Paškevičius (1968). Previously, this interval was incorporated into the *turriculatus* Biozone (Paškevičius, 1965). The base of the *linnaei* Biozone and the Telychian is marked by the disappearance of *St. sedgwickii* and appearance of *Rastrites linnaei* (Barrande), as in Bohemia (Štorch, Kraft, 2009), and narrow short-range graptolites such as *Streptograptus* (Paškevičius, 1997). The graptolite assemblage of the *linnaei* Biozone includes *Torquigraptus planus* (Barrande), *Monograptus mirus* Perner, *Pristiograptus variabilis* (Törnquist) and others. More detailed investigations are needed for the more precise determination of the position of the Aeronian and Telychian boundary in Lithuania.

According to D. Loydell (2012) the base of the *linnaei* Biozone does not conform to the Telychian basis and *R. linnaei* appears in the upper part of Aeronian. He recommended describing the *Stimulograptus halli* Biozone in the upper part of Aeronian, *Spirograptus guerichi* Biozone in the lower part of Telychian and the *linnaei* Biozone reject (Loydell et al., 2003). The spirograptids are rare in the well core material of Lithuanian, consequently the *linnaei* Biozone is used in Lithuania instead.

The *turriculatus* Biozone was defined by J. Paškevičius (1958) by the appearance of *Spirograptus turriculatus* (Barrande), *Monograptus priodon* (Bronn) and *Streptograptus exiguus* (Nicholson) in Lithuania. The graptolite assemblage of this biozone includes, e. g. *Parapetalolithus tenuis* (Barrande) and *Pristiograptus nudus* (Lapworth) among other species.

The lower boundary of the *crispus* Biozone, established by J. Paškevičius (1965) in Lithuania, is marked by the appearance of *Streptograptus crispus* (Lapworth). The graptolite fauna of the biozone includes *Cochlograptus veles* (Richter) and *Retiolites angustidens* (Elles et Wood).

The *griestoniensis* Biozone was recognized by Paškevičius (1958) by the appearance of *Monoclimacis griestoniensis* (Nicholson) in Lithuania. The biozonal species are rare in Lithuanian sections. The graptolite assemblage of the biozone is composed of *Stomatograptus grandis* (Suess) and others accompanied by relatively long-lived taxa, e. g. *M. priodon* ranging from the previous biozones.

The *crenulata* Biozone, defined by J. Paškevičius (1997), was previously treated as a subzone of the *spiralis* Biozone (Paškevičius, 1979) in Lithuania. The base of the *crenulata* Biozone coincides with the appearance of *Monoclimacis crenulata* (Törnqust) and *Monoclimacis* of the *vomerina* group. The assemblage includes taxa from underlying biozones.

J. Paškevičius (1963) first distinguished the *spiralis* Biozone, but later (1997) subdivided it into two subzones – *crenulata* in the lower part and *spiralis–geinitzi* in the upper part. These subzones are now treated as an independent biozones. The graptolite fauna of the *spiralis* Biozone is characterized by common *Oktavites spiralis* (Geinitz), *Monoclimacis geinitzi* (Bouček) and other longer-range graptolite species.

The *lapworthi* Biozone was established by J. Paškevičius (1997) by the appearance of the biozonal species *Cyrtograptus lapworthi*. *Cyrtograptus lapworthi* Tullberg has been found only in the Kurtuvėnai-161 well (Motuza et al., 2002; Kaminskas et al., 2006). The assemblage contains relatively long-lived taxa ranging from lower biozones. The *Cyrtograptus insectus* Biozone has not been defined yet since no findings of *Cyrtograptus insectus* Bouček are known in Lithuania. The *insectus* Biozone is tentatively included into the *lapworthi* Biozone in Lithuania. The *insectus* Biozone is distinguished in the Kaliningrand District (Suyarkova, 2012). This interval must be investigated in detail in the future in Lithuania.

The last Telychian graptolite biozone is the *centrifugus* Biozone, which in Lithuania was first described by J. Paškevičius (1997). The base of that biozone is marked by the appearance of *Cyrtograptus centrifugus* Bouček and is considered as the base of the Wenlock (Paškevičius, 1997; Zalasiewicz et al., 2009). This biozone ranges through the uppermost part of the Llandovery (Loydell, 2012). The graptolite assemblage of this biozone is similar to that of the previous biozones, with no significant changes in graptolite fauna.

GRAPTOLITE BIOZONES OF WENLOCK

Sheinwoodian

The *Cyrtograptus murchisoni*, *Monograptus riccartonensis*, *Streptograptus antennularius*, *Monograptus belophorus* and *Cyrtograptus perneri* biozones

have been distinguished in the Sheinwoodian of Lithuania (Paškevičius, 1997).

The base of the *murchisoni* Biozone (the base of the Sheinwoodian) was initially defined by J. Paškevičius (1961) in Lithuania, and it is marked by the appearance of *Cyrtograptus murchisoni* Carruthers. The graptolite assemblage of this biozone is the same as in the *centrifugus* Biozone, containing the index species together with *M. priodon*, *Monoclimacis vomerina* (Nicholson) and various *Retiolites*. It is the first appearance of *dubius*-type graptolites such as *Pristiograptus praedubius* (Bouček) in Lithuania (Radzevičius et al., 2008).

The *riccartonensis* Biozone was recognized by J. Paškevičius (1963) in Lithuania. The base of the biozone is marked by the mass appearance of the dominant species *Monograptus riccartonensis* Lapworth. The graptolite assemblage is poor, containing the index species together with *Pristiograptus dubius dubius* (Suess) and *M. priodon*. The diversity of graptolites increases notably at the end of the *riccartonensis* Biozone and the picture is completely different in the upper biozone.

The *antennularius* Biozone was distinguished by J. Paškevičius (1979) in Lithuania. The base of the biozone is defined by the appearance of *Streptograptus antennularius* (Meneghini). Long-ranging taxa *Monograptus flemingii flemingii* (Salter), *Monoclimacis flumendosae* (Gortani) appear, and *P. d. dubius* still persists. The biozonal index species dominates.

The *Monograptus belophorus* Biozone, formerly known as the *Monograptus flexilis* Biozone, was first described by J. Paškevičius (1963). The base of the *belophorus* Biozone is marked by the appearance of *Monograptus belophorus* (Meneghini) (= *Monograptus flexilis* Elles). *Pristiograptus pseudodubius* (Bouček) appears in this biozone. Other elements of the assemblage include taxa ranging from the *antennularius* Biozone, such as *M. f. flemingii*, *Mc. flumendosae*.

The *perneri* Biozone, first described by J. Paškevičius (1976) in Lithuania, is the last graptolite biozone in the Sheinwoodian. The base of the biozone coincides with the appearance of *Cyrtograptus perneri* Bouček. The interval from the *belophorus* to the *lundgreni* Biozone needs additional studies. Graptolites of the genus *Cyrtograptus* are very rare in comparison with more long-ranging pristiograptids, monoclimacids and monograptids. Together with biozonal index taxa the "Holy Trinity" is found: *M. f. flemingii*, *Mc. flumendosae* and *P. pseudodubius*.

Homerian

The Homerian Stage begins with the *Cyrtograptus lundgreni* graptolite Biozone and includes also the *Pristiograptus parvus*, *Gothograptus nassa*, *Colonograptus praedeubeli*, *Colonograptus deubeli* and *Colonograptus ludensis* biozones.

In Lithuania the *lundgreni* Biozone was first described by S. Radzevičius and J. Paškevičius (2000). Previously this biozone was formally known as the *Monograptus testis* Biozone (Paškevičius, 1997). For a long time the *testis* Biozone was synonymous with the *lundgreni* Biozone, but it is not correct because *Testograptus testis* (Barrande) appeared later than *Cyrtograptus lundgreni* Tullberg. The interval between the last appearance of *Cyrtograptus perneri* and the first appearance of *T. testis* was known (Paškevičius, 1997) as the *Cyrtograptus radians* Biozone. The base of the *lundgreni* Biozone is marked by the appearance of *C. lundgreni*. The graptolite assemblage of the lower part of the *lundgreni* Biozone is the same as in the *perneri* Biozone. The upper biozonal assemblage includes *T. testis*, *Pristiograptus lodenicensis* Přibyl, *P. d. paezerensis* Urbanek, Radzevičius, Kozłowska et Teller, *Gothograptus kozlowskii* Kozłowska–Dawidziuk and other taxa. The diversity of graptolites in the upper part of the *lundgreni* Biozone in Lithuania is very high.

S. Radzevičius (2006) established the *parvus* Biozone in Lithuania. Previously the *parvus* Biozone was attributed to the lower part of the *nassa* Biozone. R. Ulst (1974) distinguished the *Pristiograptus parvus–Pristiograptus piltenensis* local Biozone in Latvia, which included the entire interval of the *nassa* Biozone. The lower boundary of this biozone was placed at the level of disappearance of *C. lundgreni*, *T. testis*, *M. f. flemingii*, *Mc. flumendosae* and *G. kozlowskii* and appearance of *P. parvus* Ulst and *Gothograptus nassa* (Holm). Only two species *P. parvus* and *G. nassa* are found in this biozone.

J. Paškevičius (1974) first distinguished the *nassa* Biozone in Lithuania. This biozone includes the interval with *P. parvus*. The lower boundary of the *nassa* Biozone is marked where *P. parvus* disappears. The graptolite assemblage of the *nassa*

Biozone is composed of *G. nassa* and *Pristiograptus dubius ludlowensis* (Bouček).

S. Radzevičius (2006) defined the *praedeubeli* and *deubeli* biozones in Lithuania. The interval of the *praedeubeli–deubeli* biozones was previously called the *virbalensis–deubeli* Biozone (Paškevičius, 1997; Radzevičius, Paškevičius, 2000). Later it was referred to the lower part of the *virbalensis* Biozone with *Colonograptus praedeubeli* (Jaeger) and the upper part with *Cl. deubeli* (Radzevičius, Paškevičius, 2005). The base of the *praedeubeli* Biozone is marked by the appearance of *Cl. praedeubeli*, *Pristiograptus virbalensis* Paškevičius and *P. idoneus* (Koren'). The graptolite assemblage of the biozone is much more diverse than that of the lower biozones. The pristiograptid and retiolitid taxa show high radiation. The retiolitids are not well investigated in Lithuania.

The interval of the *deubeli* Biozone was previously treated as the upper part of the *virbalensis–deubeli* Biozone (Paškevičius, 1997; Radzevičius, Paškevičius, 2000).The base of the *deubeli* Biozone coincides with the appearance of *Colonograptus deubeli* (Jaeger). The graptolite assemblage of this biozone is the same as in the previous biozone.

The *ludensis* Biozone was established by J. Paškevičius (1979), who included it within the interval from the *nassa* to the *nilssoni* Biozone. J. Paškevičius (1997) recognized it in its present meaning. The base of the *ludensis* Biozone is drawn by the appearance of *Colonograptus ludensis* (Murchison). The graptolite assemblage of the *ludensis* Biozone is similar to that of the previous biozone, just *Colonograptus gerhardi* (Kühne) appears in its upper part.

Graptolite biozones of Ludlow

Gorstian

The *Neodiversograptus nilssoni*, *Lobograptus progenitor*, *Lobograptus scanicus* and *Saetograptus incipiens* biozones have been established in the Gorstian.

The *nilssoni* Biozone was first described by J. Paškevičius (1958) in Lithuania. The base of the biozone coincides with the appearance of *Neodiversograptus nilssoni* (Barrande). Other taxa such as *Monograptus uncinatus* Tullberg, *Bohemograptus bohemicus bohemicus* (Barrande), *Colonograptus colonus* (Barrande), *Saetograptus varians* (Wood) and *Pristiograptus dubius frequens* Jaekel also appear close to this level. The *nilssoni* Biozone shows a much greater species diversity than the preceding Wenlock biozones. The lower part of the biozone contains *Colonograptus gerhardi.*

The *progenitor* Biozone, the base of which is marked by the appearance of *Lobograptus progenitor* Urbanek, was defined first by J. Paškevičius (1976) in Lithuania. The graptolite assemblage of this biozone includes *Monograptus uncinatus* Tullberg. The saetograptids diversify rapidly increase in this biozone with the incoming of the *Saetograptus chimaera* (Barrande) group. Other graptolites in this biozone are the same as in the previous biozone.

The *scanicus* Biozone, established by J. Paškevičius (1963) in Lithuania, begins with the appearance of *Lobograptus scanicus scanicus* (Tullberg). The graptolite assemblage is the same as in the previous biozone. The diversity of lobograptids increases in this biozone.

The interval from the upper boundary of *scanicus* to the lower boundary *balticus* has been called *Pseudomonoclimacis tauragensis* Biozone (Paškevičius, 1982). The base of the *tauragensis* Biozone (first recognized by J. Paškevičius, 1974) is marked by the appearance of *Pseudomonoclimacis tauragensis* (Paškevičius). The graptolite assemblage of this biozone is similar to that of the previous biozone. *Saetograptus leintwardinensis* (Hopkinson), *S. linearis* (Bouček), *Bohemograptus bohemicus tenuis* (Bouček) and *Pristiograptus tumescens* (Wood) appear in the lower part of the *tauragensis* Biozone. The identification of this biozone is not very reliable because (1) *Ps. tauragensis* has a long biostratigraphical range, (2) *Ps. tauragensis* is hardly distinguishable from *Ps. haupti* (Kühne), (3) it is impossible to trace the Gorstian and Ludfordian boundary using *Ps. tauragensis*, (4) there exist better biozonal index species such as *S. leintwardinensis*, *S. linearis*, *B. b. tenuis* and others with short biostratigraphical ranges. In view of the above mentioned facts and the emergence of new material the *tauragensis* Biozone was rejected and has been identified *incipiens* (upper Gorstian), *Bohemograptus praecornutus*, *Bohemograptus cornutus*, *Bohemograptus bohemicus tenuis* (lower Ludfordian) graptolite biozones (Paškevičius et al., 2012).

The *incipiens* Biozone was distinguished by J. Paškevičius (2012) in Lithuania. This biozone is

distinguished in one Milaičiai-103 well. The graptolite assemblage of the *incipiens* Biozone is *S. incipiens* (Wood), *Ps. haupti* (Kühne) and *B. b. bohemicus.*

Ludfordian

Bohemograptus praecornutus, *Bohemograptus cornutus*, *Bohemograptus bohemicus tenuis*, *Monograptus balticus* and *Monograptus* (*Uncinatograptus*) *valleculosus–Formosograptus formosus* biozones have been established in the Ludfordian of Lithuania (Paškevičius et al., 2012).

The *praecornutus* Biozone was distinguished in the Milaičiai-103 well (Paškevičius et al., 2012). The first appearance of the *B. praecornutus* Urbanek marked the lower boundary of the *praecornutus* Biozone. The *praecornutus* Biozone is represented by *P. d*. cf. *frequens* Jaeckel, *B. b. bohemicus*, *B. praecornutus*, *S. incipiens* and *Ps. haupti*.

The *cornutus* Biozone was distinguished in the Milaičiai-103 well as well. The lower boundary of the *cornutus* Biozone is defined by the appearance of the *B. cornutus* Urbanek. The graptolite assemblage of the *cornutus* Biozone consists of *P. tumescens* (Wood), *Ps. tauragensis* and *S. leintwardinensis* (Hopkinson). *S. leitwardinensis* and *B. cornutus* were found together and this complicates the situation. Therefore, revision of the Gorstian–Ludfordian boundary interval is needed.

Above the *cornutus* Biozone there is the *bohemicus tenuis* Biozone (Paškevičius et al., 2012). The lower boundary of the *bohemicus tenuis* Biozone is marked by the extinction of *B. cornutus*.

The *balticus* Biozone was distinguished by J. Paškevičius (1974) by the appearance of *Monograptus balticus* Teller. Graptolites are rare here, in fact, they start to decrease from the *tauragensis* Biozone. The graptolite assemblage of this biozone is composed of biozonal index taxa, *B. b. tenuis* and pristiograptids of *dubius* type.

The *formosus* Biozone was identified by the appearance of *Formosograptus formosus* (Bouček) and *Monograptus* (*Uncinatograptus*) *valleculosus* (Tsegelniuk) (Paškevičius, 1997). Graptolites are rare also in this biozone and the graptolite assemblage of this biozone consists of *F. formosus*, *M. valleculosus* and *P*. ex. gr. *dubius*.

Graptolite biozones of Pridolian

The graptolites in the Pridolian are very rare. Just the lowermost *Neocolonograptus parultimus–N. ultimus* and *Neocolonograptus lochkovensis* biozones are distinguished in the Pridolian of Lithuania (Paškevičius, 1997). The lower boundary of the *parultimus–ultimus* Biozone is marked by the appearence of *N. parultimus* (Jaeger). The thickness of the biozone is more than 200 m and the upper boundary of the *parultimus–ultimus* Biozone is unclear. The appearence of the *Monograptus similis prusensis* Paškevičius indicates the lower part of the *lochkovensis* Biozone (Paškevičius, 1997).

CONCLUSIONS AND RECOMMENDATIONS

- *Coronograptus cyphus* biozone is distinguished in the Rhuddanian of Lithuania. The lowermost Rhuddanian graptolite biozones are not established because graptolites are absent. *Demirastrites triangulatus*, *Demirastrites pectinatus*, *Campograptus millepeda, Lituigraptus convolutus* and *Stimulograptus sedgwickii* biozones are distinguished in the Aeronian.
- *Rastrites linnaei*, *Spirograptus turriculatus*, *Streptograptus crispus*, *Monoclimacis griestoniensis*, *Monoclimacis crenulata*, *Oktavites spiralis* and *Cyrtograptus lapworthi* biozones are distinguished in the Telychian.
- There are *Cyrtograptus murchisoni*, *Monograptus riccartonensis*, *Streptograptus antennularius*, *Monograptus belophorus* and *Cyrtograptus perneri* biozones are distinguished in the Sheinwoodian of Lithuania.
- *Cyrtograptus lundgreni*, *Pristiograptus parvus*, *Gothograptus nassa*, *Colonograptus praedeubeli*, *Colonograptus deubeli* and *Colonograptus ludensis* biozones are distinguished in the Homerian.
- *Neodiversograptus nilssoni*, *Lobograptus progenitor*, *Lobograptus scanicus* and *Saetograptus incipiens* biozones are distinguished in the Gorstian.
- *Bohemograptus praecornutus*, *Bohemograptus cornutus*, *Bohemograptus bohemicus tenuis*, *Monograptus balticus* and *Formosograptus formosus–Monograptus* (*Uncinatograptus*) *valleculosus* biozones are distinguished in the Ludfordian.

It should be stated, however, that the future studies should focus on the distribution of graptolites near the stages boundaries. The adjustment of the Aeronian–Telychian boundary needs special

attention. It must be very accurately determined by the *Rastrites linnaei* first appearance. It is also important to determine the distribution of graptolites at the Llandovery–Wenlock boundary. Currently, the Llandovery–Wenlock boundary is marked by the appearance of *Cyrtograptus murchisoni* (Loydell, 2012). Another important interval is the Gorstian–Ludfortian boundary. It is necessary to revise this interval and to cut the "Gordian Knot". It is also important to establish a detailed graptolite distribution in the Pridolian. This is complicated because graptolites are very rare here.

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SILŪRO GRAPTOLITŲ BIOZONOS LIETUVOJE: DABARTIS IR PERSPEKTYVOS

S a n t r a u k a

Graptolitai yra kolonijiniai išmirę jūros gyvūnai, gyvenę nuo vidurinio kambro iki karbono periodo. Tai yra viena svarbiausių gyvūnijos grupių Lietuvos silūro biostratigrafijai. Pirmieji graptolitų tyrimai Lietuvoje buvo pradėti praėjusio amžiaus šeštajame dešimtmetyje. Per pastaruosius dvidešimt metų buvo surinkta daug naujos su silūro graptolitais susijusios faktinės medžiagos, todėl atsirado būtinybė apžvelgti ir apibendrinti naujus graptolitų tyrimų rezultatus Lietuvoje. Prasidėję nauji ir intensyvūs silūro uolienų tyrimai Lietuvoje paskatino patikslinti graptolitų biozonų skalę.

Seniausia viršutinio rudanio graptolitų biozona yra *Coronograptus cyphus*. Senesnės graptolitų biozonos Lietuvoje nežinomos, nes čia vyrauja karbonatinės facijos, kuriose nėra graptolitų. *Demirastrites triangulatus*, *Demirastrites pectinatus*, *Campograptus millepeda, Lituigraptus convolutus* ir *Stimulograptus sedgwickii* biozonos yra išskirtos aeronyje; *Rastrites linnaei*, *Spirograptus turriculatus*, *Streptograptus crispus*, *Monoclimacis griestoniensis*, *Monoclimacis crenulata*, *Oktavites spiralis* ir *Cyrtograptus lapworthi* biozonos – telyčyje; *Cyrtograptus murchisoni*, *Monograptus riccartonensis*, *Streptograptus antennularius*, *Monograptus belophorus* ir *Cyrtograptus perneri* biozonos – šeinvudyje; *Cyrtograptus lundgreni*, *Pristiograptus parvus*, *Gothograptus nassa*, *Colonograptus praedeubeli*, *Colonograptus deubeli* ir *Colonograptus ludensis* – homerio aukšte; *Neodiversograptus nilssoni*, *Lobograptus progenitor*, *Lobograptus scanicus* ir *Saetograptus incipiens* – gorstyje; *Bohemograptus praecornutus*, *Bohemograptus cornutus*, *Bohemograptus bohemicus tenuis*, *Monograptus balticus* ir *Formosograptus formosus – Monograptus valleculosus* biozonos – ludfordyje. Pržidolio skyriuje yra išskirtos *Neocolonograptus ultimus – N. parultimus* ir *Neocolonograptus lochkovensis* biozonos. Pržidolyje graptolitai yra labai reti, jų radiniai pavieniai, todėl vėlesnės jo biozonos nežinomos, o išskirtų graptolitų biozonų ribos yra santykinės.

Raktažodžiai: silūras, graptolitų biozonos, Lietuva