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Lithostratigraphy, graptolites and brachiopods communities of the Ludlow (Silurian) of the Eastern slope of the Baltic Syneclise

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Milaičiai-103 well is located on the East slope of the Baltic Sineclise. Dubysa, Mituva and Ventspils formations of the Ludlow Stage were defined within the slope. The Šešupė and Nova beds are distinguished in the Dubysa Formation. The Šešupė Bed is composed of ten sedimentation cycles of limestone and marl rhythmical interbedding. The lower boundary of the Šešupė Bed is unclear in the Milaičiai-103 well because the borehole was drilled without core sampling starting from the depth of 1 301.0 m. The Nova Bed is composed of two cycles composed of limestone in the lower part and marlstone in the upper part. The Mituva Formation is composed of four cycles of limestone and marlstone rhythmical interbedding. The Ventspils Formation is composed of three limestone layers showing different features.

The Ludlovian biostratigraphy is based on graptolite fauna. There are distinguished *progenitor-scanicus*, *incipiens* graptolite biozones of the Gorstian and *praecornutus*, *cornutus*, *bohemicus tenuis*, *balticus* and *valleculosus* biozones of the Ludfordian. The description of zonal species *Monograptus valleculosus* Tsegelnuk is given like *Pristiograptus dubius* cf. *frequens* Jaekel. There are distinguished *Lissatrypa obovata–Jonsea grayi, Isorthis amplificata–Lissatrypa obovata, Gypidula–Atrypoidea, Atrypa reticularis–Shaleria ornatella* and *Isorthis parvulus* – Atrypoidea brachiopod communities in the Ludlow section of the well Milaičiai-103. According to the lithological composition and described graptolites and brachiopods the Milaičiai-103 well contains different ecostratigraphic levels.

Key words: Ludlow, lithostratigraphy, graptolites, brachiopods community, Milaičiai-103 well, Baltic Syneclise

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INTRODUCTION

The carbonate facies (limestones, biomorphic limestones, scars, clayey limestones, marls) are distributed in the upper Ludlow of the southeastern part of the Baltic Syneclise (Fig. 1). In these facies, the benthic fauna becomes more abundant. Graptolites are rare in this part. Yet it points to their migration from the central part of the Baltic Syneclise even in the shallow water carbonate facies. There are a number of deep wells drilled within these facies that well delineate these facies (Paškevičius, 1994). The carbonate facies belt of about 70 km wide extends from South to North in the north–south direction. In the West, the belt boundary is traced at about the Kelmė Town longitude; in the East it is mapped near eastern Panevėžys. In 1984 the Milaičiai-103 well was drilled within this belt, which crossed the whole Silurian succession, including Ludlow, with good

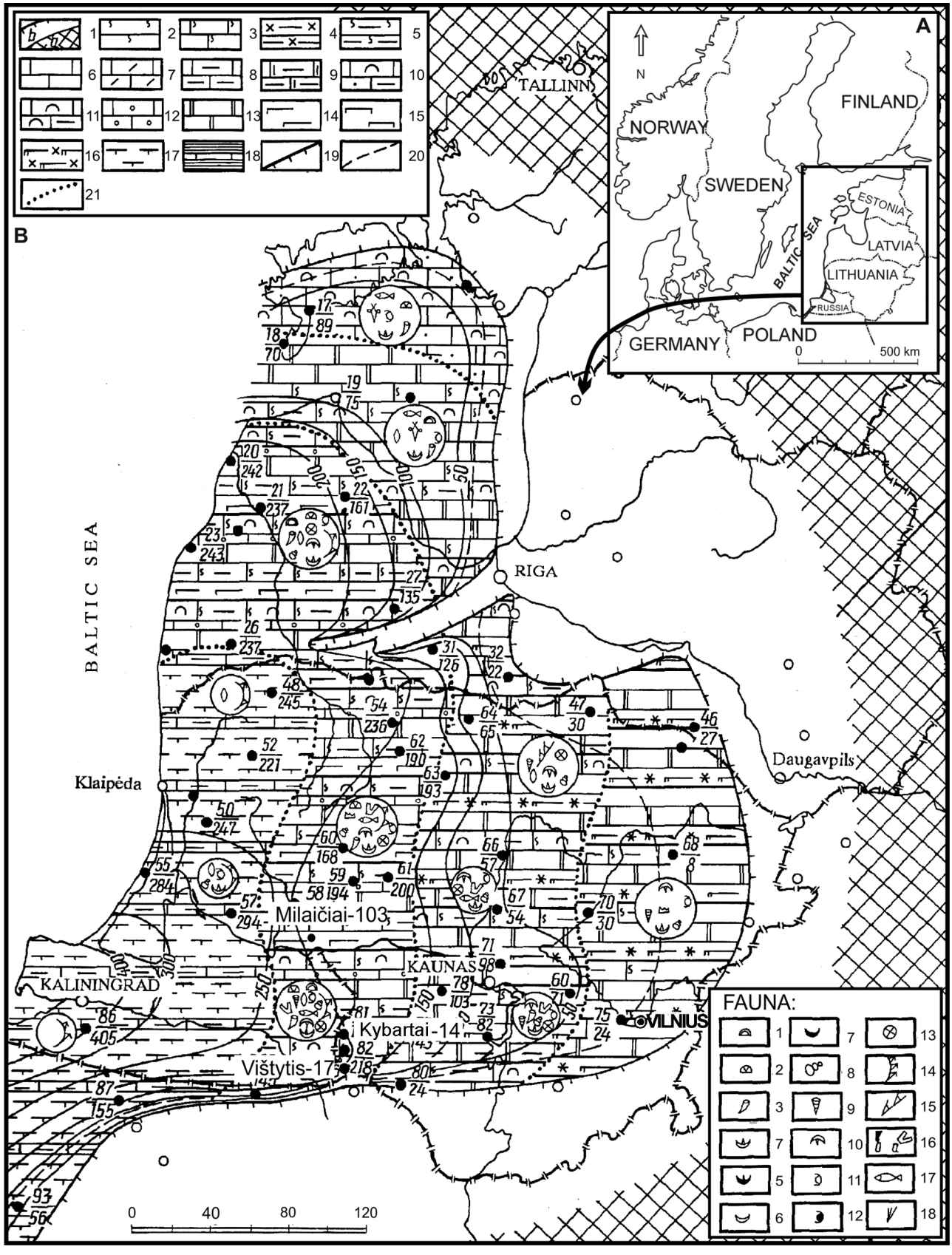

Fig. 1. Ludlow lithofacies and palaeogeography of the East Baltic Region (Paškevičius, 1997). *1a* – land, *1b* – denudated Ludlow rock area; *2* – yellowish-grey fine (aphanitic) calcareous silt; *3* – nodular calcareous silt; *4* – red clayey carbonaceous deposits; *5* – stratification of nodular carbonaceous silt with clayey carbonaceous deposits; *6* – calcareous silt; *7* – detritic calcareous deposits; *8* – grey clayey carbonaceous silt; *9* – clayey grains carbonaceous silt;

10 – bio- and lithoclastic calcareous deposits; *11* – biomorphous clayey deposits; *12* – calcareous ooliths and oncoliths; *13* – dolomite silt; *14* – clayey calcareous deposits; *15* – clayey carbonaceous deposits; 16 – variegated deposits; *17* – grey carbonaceous clayey deposits; *18* – black clay with carbonaceous deposit interlayers; *19* – denudation boundary of Ludlovian sediments; *20* – partial denudation boundary of Silurian sediments; *21* – facies boundary. Fauna: *1* – stromatoporoids; *2* – tabulates; 3 – rugoses; *4* – thin-walled brachiopods; *5* – thick-walled brachiopods; *6* – thin-walled bivalves; *7* – thick-walled bivalves; *8* – gastrapods; *9* – cephalopods; *10* – trilobites; *11* – ostracodes; *12* – large ostracodes; *13* – crinoids; *14* – graptolites; *15* – dendroids; *16a* – bryozoans; *16b* – conodonts; *17* – vertebrata; *18* – primitive vertebrate

1 pav. Rytinių Baltijos kraštų ludlovio facijos ir paleogeografija (Paškevičius, 1997). *1a* – sausuma, *1b* – denuduoti uolienų plotai; *2* – gelsvai pilko smulkaus (afanitinio) klintinio dumblo tarpsluoksniai; *3* – gniutulinio klintinio dumblo tarpsluoksniai; *4* – raudonspalvių molingų karbonatinių nuosėdų tarpsluoksniai; *5* – gniutulinio karbonatinio dumblo ir molingų karbonatinių nuosėdų tarpsluoksniai; *6* – klintinio dumblo tarpsluoksniai; *7* – detritinių karbonatinių nuosėdų tarpsluoksniai; *8* – pilko molingo karbonatinio dumblo tarpsluoksniai; *9* – molingo grūdėto karbonatinio dumblo tarpsluoksniai; *10* – bio/litoklastinių klintinių nuosėdų tarpsluoksniai; *11* – biomorfinių molingų nuosėdų tarpsluoksniai; *12* – karbonatinių oolitų ir onkolitų tarpsluoksniai; *13* – dolomitinių dumblų tarpsluoksniai; *14* – molingų klintinių nuosėdų tarpsluoksniai; *15* – molingų karbonatinių nuosėdų tarpsluoksniai; *16* – margaspalvių molingų karbonatinių nuosėdų tarpsluoksniai; *17* – pilkų karbonatinių molingų nuosėdų tarpsluoksniai; *18* – juodo molio ir karbonatinių nuogulų tarpsluoksniai; *19* – denudacinė ludlovio uolienų paplitimo riba; *20* – dalinė silūro denudacinė riba; *21* – facijų riba. Fauna: *1* – stromatoporai, *2* – tobuliatai, *3* – rugoza, *4* – plonasieniai pečiakojai, *5* – storasieniai pečiakojai, *6* – plonasieniai dvigeldžiai, *7* – storasieniai dvigeldžiai, *8* – pilvakojai, *9* – galvakojai, *10* – trilobitai, *11* – ostrakodai, *12* – stambūs ostrakodai, *13* – krinoidai, *14* – graptolitai, *15* – augalai, *16a* – samangyviai, *16b* – konodontai, *17* – stuburiniai, *18* – primityvūs stuburiniai

drill core recovery. J. Bitinas selected a number of samples with brachiopods and graptolites fauna from the Milaičiai-103 well drill core in 1984.

The graptolites *Monograptus velleculosus* (Tsegelniuk), obtained in the lower part of the Ventspils Formation together with brachiopods and other fauna, allowed correcting and new dating of the lower boundary of this formation, correlating it with the metatarsus of the *valleculosus* biozone, instead of the previously correlated *formosus* biozone.

LITHOSTRATIGRAPHY

Ludlow lithostratigraphy of the Milaičiai-103 well is based on the litological drill core description by Z. Čechavičius (unpublished industrial report). There are described Dubysa, Mituva, and Ventspils formations of the Ludlow in the well.

The Dubysa Formation

For the first time, the Dubysa Formation was defined in the Silurian succession by Lapinskas and Paškevičius (1976). Rocks of the Dubysa Formation are distributed in Middle Lithuania and Central Latvia. The Viduklė-61 well contains the stratotype section of the Dubysa Formation at the depths of 1 167.8–1 282.2 m (Paškevičius, Lapinskas, 1978). The thickness of the Dubysa Formation is 67.5 m (interval 1 301.0–1 233.5 m) in the Milaičiai-105 well. The lower boundary of the formation is not clear in this well because the well was drilled without core sampling from the depth of 1 301.0 m. The Šešupė and Nova beds are distinguished in the Dubysa Formation of the Milaičiai-103 well.

The thickness of the Šešupė Bed exceeds 46 m (the lower boundary is unknown, the upper boundary is defined at the depth of 1 255 m) in the Milaičiai-103 well. It is represented by intercalation of Limestone and Marlstone members:

- The Limestone Member of the Šešupė Bed is composed of grey, massive, wavy-bedded, clayey, cryptocrystalline limestone (1 301.0–1 300.6 m interval).
- The interval from 1 300.6 to 1 296.2 m is defined as the Marlstone Member composed of greenish, dolomitic, clayey marlstone and clayey, microcrystalline, cryptocrystalline, nodular limestone.
- There is the Limestone Member composed of light grey, wavy-bedded, clayey limestone with greenish clayey marlstone interbeds in the 1 296.2–1 295.5 m interval.

• The interval 1 295.5–1 292.7 m represents the Marlstone Member composed of greenish, dolomitic, clayey marlstone with clayey nodular limestone.

• The interval from 1 292.7 m to 1 290.2 m consists of the Limestone Member composed of gray, wavy-bedded, clayey limestone with gray, laminated, dolomitic, clayey marlstone interbeds.

• The Marlstone Member composed of greenish, dolomitic, clayey marlstone with grey, massive, wavy-bedded, clayey limestone layers is defined in the interval 1 290.2–1 273 m.

• The interval from 1 273.0 m to 1 271.3 m comprises the Limestone Member composed of light grey, microcrystalline, nodular limestone with greenish dolomitic marlstone layers.

• The Marlstone Member composed of greenish, dolomitic, clayey marl with gray, microcrystalline, nodular limestone layers is identified in the interval 1 271.3–1 265.9 m.

• The interval from 1 265.9 m to 1 264.8 m is attributed to the Limestone Member composed of light grey, nodular, clayey limestone with dolomitic, clayey marlstone layers containing sand grains.

• The Marlstone Member composed of greenish, dolomitic, clayey marl with horizontally laminated limestone layers comprises the interval 1 264.8–1 255.0 m.

The Nova Bed is defined at the depths of 1 255–1 233.5 m in the Milaičiai-103 well. The thickness of the Nova Bed is 22.0 m. The lithological composition is similar to that of the overlying beds:

• The lower part of the Nova Bed is represented by the Limestone Member composed of light grey, microcrystalline, wavy-bedded, clayey limestone with greenish dolomitic marlstone layers (interval 1 255–1 237 m).

• The Marl Member composed of greenish, dolomitic, wavy-bedded marlstone with gray limestone layers is defined in the upper part of the Nova Bed (1 237.0–1 233.5 m interval).

The Mituva Formation

The Mituva Formation was distinguished by Lapinskas and Paškevičius (1976). The formation is distributed in Middle Lithuania, Central Latvia and in the eastern part of the Kaliningrad District. The stratotype of the Mituva Formation is defined at the depth 1 134.2–1 167.8 m in the Viduklė-61 well (Paškevičius et al., 1994). The thickness of the Mituva Formation is 51.4 m in the Milaičiai-103 well (1 233.5–1 182.2 m). It is represented by intercalation of limestones and marlstones:

• The Limestone Member is composed of light grey, microcrystalline, nodular limestone with greenish dolomitic marlstone layers at the depths 1 233.5–1 228.0 m.

• The interval from 1 228 to 1 202.5 m is represented by the Marlstone Member composed of greenish, dolomitic, clayey marlstone containing gray nodules of clayey limestone.

• The Limestone Member, composed of light grey, microcrystalline, detritical, nodular limestone with dolomitic marlstone layers, is defined in the interval 1 202.5–1 189.5 m.

The interval from 1 189.5 to 1 182.2 m is composed of the Marlstone Member consisting of greenish, dolomitic, clayey marlstone with interlayers of light grey, microcrystalline, nodular limestone.

The Ventspils Formation

The Ventspils Formation was distinguished by R. Ulst (1976) in Latvia. The stratotype is defined at the depth of 412.5–426.5 m in the Ventspils-3 well. The formation is distributed in Central Lithuania and Central Latvia. The thickness of the Ventspils Formation is 18.7 m in the Milaičiai-103 well (depth 1 182.2–1 163.5 m).

• The lower Limestone Member is composed of light grey, microcrystalline, wavy-bedded, clayey limestone with dark, dolomitic, clayey marlstone layers in the interval 1 182.2–1 181.1 m.

• The overlying Limestone Member consists of light gray, biomorphic, microcrystalline, clayey, wavy-bedded limestone containing nodules of dark, greenish, clayey, dolomitic marlstone lenses in the interval 1 181.1–1 173.8 m.

• The interval from 1 173.8 m to 1 163.5 m is composed of biomorphic, light gray, microcrystal, clayey, nodular limestone and dolomitic, nodular marlstone with dark, dolomitic, clayey marlstone layers.

The Ventspils Formation is underlain by the Minija Formation in the Milaičiai-103 well. The base of the Minija Formation, attributed to the Pridolianstage, is defined at the depth of 1 163.5 m (Fig. 2).

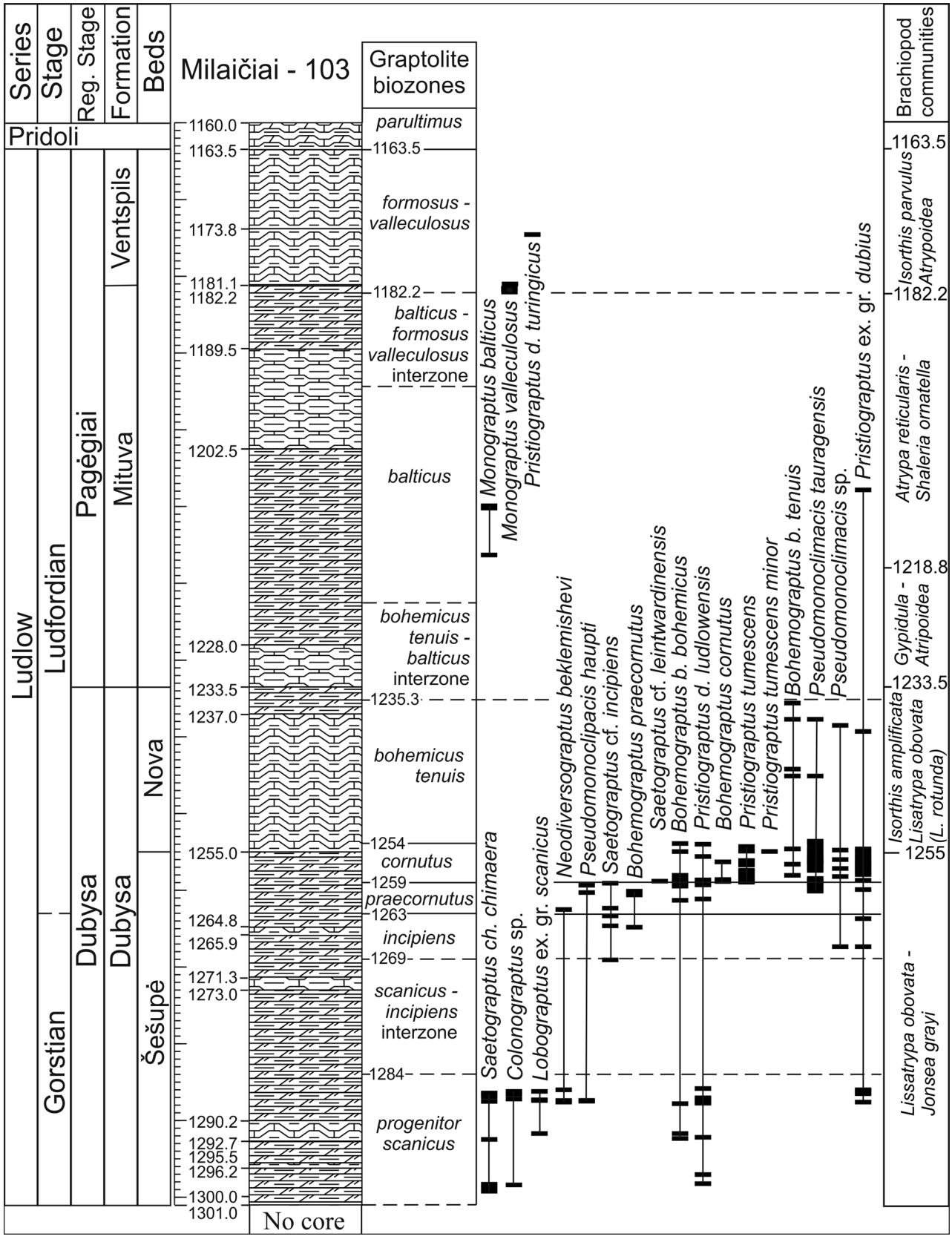

Fig. 2. Geological section of the Ludlow Stage of the well Milaičiai-103 showing distribution of graptolites and brachiopod communities

2 pav. Milaičių-103 gręžinio ludlovio geologinis pjūvis su graptolitų paplitimu ir brachiopodų bendrijomis

GRAPTOLITE BIOZONES

Resulting from the present study of the Milaičiai-103 well there are *progenitor-scanicus*, *incipiens*, *praecornutus*, *cornutus*, *bohemicus tenuis*, *balticus* and *valleculosus* biozones distinguished in the Ludlow succession.

The *progenitor-scanicus* and *icipiens* biozones have been distinguished in the Gorstian. The lower boundary of the *progenitor-scanicus* Biozone is unclear because of lack of drill cores bellow the depth of 1 301.0 m. The graptolite assemblage of the *progenitor-scanicus* Biozone includes *Saetograptus chimaera chimaera* (Barrande), *Pristiograptus dubius ludlowensis* (Bouček), *Bohemograptus bohemicus bohemicus* (Barrande), *Lobograptus* ex. gr. *scanicus* (Tullberg) and *Neodiversograptus becklemishevi* Urbanek. The upper boundary of *progenitor-scanicus* Biozone is unclear because the interval from 1 284.3 m to 1 269 m has the lack of graptolites in the Milaičiai-103 well. There is the *incipiens* Biozone in 1 269–1 263 m interval in the Milaičiai-103 well. The graptolite assemblage of the *incipiens* Biozone is *S. incipiens* (Wood), *Pseudomonoclimacis haupti* (Kühne) and *B. b. bohemicus*. There is distinguished *scanicus-incipiens* Interzone between *progenitor-scanicus* and *incipiens* biozones.

The *praecornutus*, *cornutus*, *bohemicus tenuis*, *balticus* and *valleculosus* biozones have been identified in the Ludfordian in the Milaičiai-103 well. The first appearance of the *B. praecornutus* Urbanek marked the lower boundary of the Ludfordian and the *praecornutus* Biozone. *Praecornutus* Biozone is in 1 263–1 259 m interval and is represented by *P. d.* cf. *frequens* Jaeckel, *B. b. bohemicus*, *B. praecornutus*, *S. incipiens*, *Ps. tauragensis* (Paškevičius) and *Ps. haupti*. According to data from the Kaliningrad District (Koren', Suyrkova, 2007) *S. incipiens* and *B. praecornutus* are found together in the narrow interval below the *leintwardinensis* Biozone and in the lower part of the *leintwardinensis* Biozone. Totally different situation is in the Mielnik-1 borehole (Poland). Here the first *B. praecornutus* appears above the *leintwardinensis* Biozone (Urbanek, 1970). Lithuania, Kaliningrad District and the East part of Poland are in the west part of the East Europe platform. So, these three regions were components of the Baltic Siluarian paleobasin.

The only difference is that in the eastern part of Poland deeper facies vary in the Ludlow time than in Lithuania and the Kaliningrad District. The differences also appear in other regions. In Arctic Canada, which is the part of another Laurentia paleocontinent, *B. praecornutus* appears above the *leintwardinensis* Biozone, in a similar way like in the Melnik-1 borehole (Lenz, Kozlowska-Dawidziuk, 2004). But in Central Asia *B. praecornutus* appears below the *leintwardinensis* Biozone (Koren', Sujarkova, 1998) like in Lithuania and Kaliningrad. Such significant discrepancy is difficult to explain. It could be that different authors differently interpreted the *B. praecornutus* taxon, but it is doubty as well.

Above the *praecornutus* Biozone there is the *cornutus* Biozone in the Milaičiai-103 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) in the 1 **259–1 255 m in**terval. So, *S. leitwardinensis* and *B. cornutus* were found together in the Milaičiai-103 borehole.

These two species were also found together in Central Asia (Koren', Sujarkova, 1998). But according to material from the Melnik-1 well, the first *B. cornutus* appears later than *S. leintwardinensis* disappears.

Bohemicus tenuis Biozone is in the 1 255–1 235.3 m interval. The lower boundary of the *bohemicus tenuis* Biozone is marked by the extinction of *B. cornutus*. The graptolite assemblage of that biozone includes *P. tauragensis* and *B. b. tenuis*. The interval from 1 235.3 to 1 616.42 m is without graptolites. *Monograptus* (*S*) *balticus* (Teller) was found in the 1 216.42–1 210 m interval. So, *balticus* Biozone was separated in this interval. The interval from 1 210 to 1 182.2 is without graptolites. *Valleculosus* Biozone has been described in 1 182.2–1 163.3 m interval of the Milaičiai-103 well (Brazauskas et al., 2005). The graptolites are very rare in this biozone. *Monograptus velleculosus* Tsegelniuk has been identified in the 1 182.2–1 181 m interval and *P. d. thüringicus* (Jaeger) in the 1 181.5 m depth. These two graptolites mark the Ludfordian age (Fig. 3).

SYSTEMATICAL PART

Monograptus (*Uncinatograptus*) *valleculosus* Tsegelniuk, 1976, Fig. 4.

Wolynograptus valleculosus Tsegelniuk, 1976, p. 110, Table 33, Figs. 1–4.

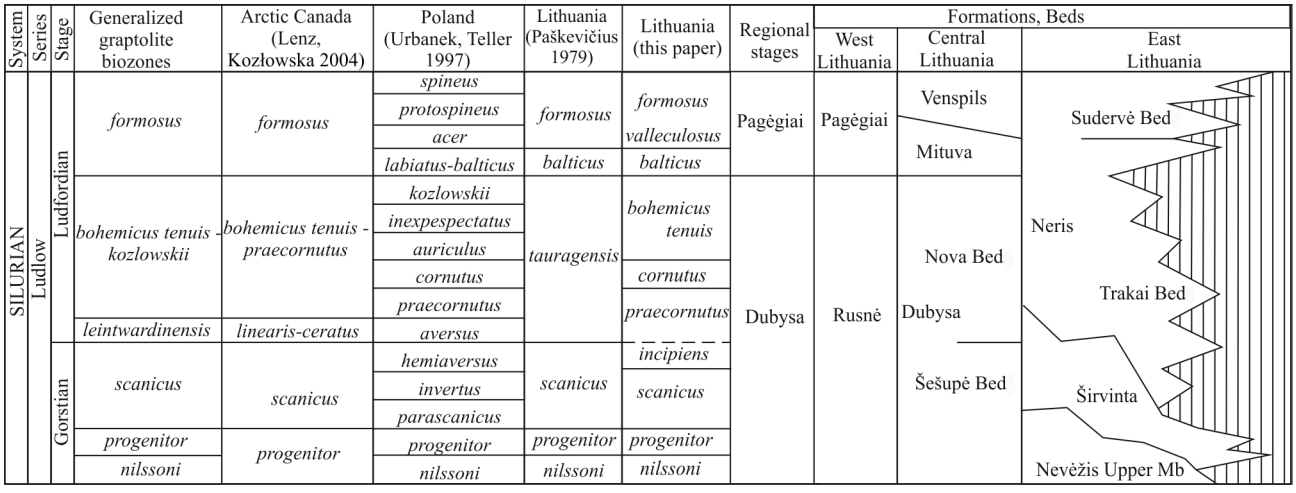

Fig. 3. Correlation of the generalized Ludlow graptolite biozonation with graptolite biozones (Koren' et al., 1996) of Arctic Canada, Poland, East Baltic and regional stages and formations

3 pav. Generalizuotų ludlovio graptolitų biozonų (Koren' ir kt., 1996) koreliacija su arktinės Kanados, Lenkijos, rytinės Baltijos dalies graptolitinėmis biozonomis ir regioniniais aukštas bei svitomis

Holotype. *Wolynograptus valleculosus* Tsegelniuk, 1976, No. 1788/46, plate XXXIII, Fig. 1, Gushcha-4015 well, depth 758.5–763.0 m, Ludlow, lower part of the Milovanskaya Formation, Volhynia, Ukraine.

Material. About 120 presented three-dimensional and semi-flattened fragments of rhabdosomes, including proximal parts with the sicula from the 1 182.2–1 181 m interval in the Milaičiai-103 borehole.

Diagnosis. The length of the rhabdosome is 29 mm. The proximal end of the rhabdosome is curved at the third theca to the dorsal side. The rhabdosome gains width rapidly. The width of the rhabdosome at the first theca is 1–1.1 mm, at the fifth theca it is 1.3–1.4 mm and at the tenth theca 1.65 mm. The maximal width of the rhabdosome is 1.8 mm. The sicula is narrow, straight. Its length is 1.95 mm with the virgula. The apex of the sicula is near the second theca. The width of the sicula aperture is 0.5 mm with a distinct dorsal process. Thecae are cylindrical. The light of th_1 is 1.1 mm; width is 0.25 mm; th5 – 1.65 mm and 0.35 mm; th10 – 1.75 mm and 0.35 mm; in the distal part of the rhabdosome – 1.8 mm and 0.35 mm. The neck of the theca is curved with the pronounced apertural hood. The hood covering aperture has pronounced binary antenular processes. There are 13 thecae in 10 mm in the proximal part of the rhabdosome and 10.5 in the distal part of the rhabdosome.

Comparison. *M. valleculosus* species is similar to *M.* (*Uncinatograptus*) *protospineus* (Urbanek). These two species have different sicula. The *M. valleculosus* secular dorsal process is more distinct and curved dorsally. The sicula of *M. valleculosus* is 1.95 mm long and the apex of the sicula is near the aperture of the second theca, whereas the sicula of *M.* (*Uncinatograptus*) *protospineus* is 1.5 mm long and the apex of the sicula is immediately above the aperture of the first theca. The difference between *M. valleculosus* and *M.* (*Uncinatograptus*) *spineus* (Tsegelniuk) is in the form of the theca aperture. The thecae of *M.* (*Uncinatograptus*) *spineus* have spines. The spines are situated on the antero lateral process of thecae. The spines on the antero lateral process of *M. valleculosus* thecae are absent.

According to the thecae apertural form, *M. valleculosus* surely belongs to the *M.* (*Uncinatograptus*) *spineus* group. The species *M.* (*Uncinatograptus*) *acer* (Tsegelniuk), *M.* (*Uncinatograptus*) *protospineus* and *M.* (*Uncinatograptus*) *spineus* are in this group, within the *acer-spineus* lineage (Urbanek, 1995; 1997). So, *M. valleculosus* is a transient form between *M.* (*U.*) *protospineus* and *M.* (*U.*) *spineus*.

Association. According to material from the Milaičiai-103 borehole, *M. valleculosus* is find alone.

Age and geographic distribution. *M. valleculosus* is known from the *valleculosus*

Fig. 4. *Monograptus* (*Uncinatograptus*) *valleculosus* Tsegelniuk, well Milaičiai-103, Ludfordian, Pagėgiai Regional Stage, Ventspils Formation, *valleculosus* Biozone, depth 1 182.2 m. A – No. VU.P.MIL-103-01; A_1 – general view of rhabdosome; A_2 – lateral process on apertural lobes of the third theca (alp); A_3 – ventral view of two thecaes; A_4 – ventral view of rhabdosome and depression (dep) between the lateral process on apertural lobes. B – No. VU.P.MIL-103-02 sicula with the dorsal process (dp) and the first theca lateral process on apertural lobes (alp). C – No. VU.P.MIL-103-03; C_1 – dorsal end of rhabdosome; C_2 – lateral process on apertural lobes of thecae in the distal part of rhabdosome (alp) and depression (dep) between the lateral process on apertural lobes. D – VU.P.MIL-103-04; D_1 – general view of the proximal part of rhabdosome with the dorsal process (dp) of sicula; D_2 – ventral view of sicula and the first theca

4 pav. *Monograptus* (*Uncinatograptus*) *valleculosus* Tsegelniuk, Milaičių-103 gręžinys, ludfordis, Pagėgių regioninis aukštas, Ventspilio svita, *valleculosus* biozona, 1 182,2 m gylis. A – Nr. VU.P.MIL-103-01; A_1 – bendras rabdosomos vaizdas; A_2 – trečiosios tekos žiotelių šoninės ataugos (alp); A_3 – dviejų tekų vaizdas iš rabdosomos pilvo pusės; A_4 – rabdosomos vaizdas iš pilvo pusės ir įlinkis (dep) tarp tekų žiotelių šoninių ataugų. B – Nr. VU.P.MIL-103-02 sikula su ryškia dorsaline atauga (dp) ir pirmosios tekos žiotelės su šoninėmis ataugomis (alp). C – Nr. VU.P.MIL-103-03; C_1 – dorsalinė rabdosomos dalis; C_2 – distalinės dalies tekos apertūros krašto šoninės ataugos (alp) ir įlinkis tarp jų (dp); D – Nr. VU.P.MIL-103-04; D_1 – rabdosomos proksimalinės dalies bendras vaizdas ir sikula su dorsaline atauga (dp); D_2 – sikulos ir pirmosios tekos vaizdas iš rabdosomos pilvo pusės

Biozone, Ventspilis Formation, Upper Ludlow in the Milaičiai-103 well (West Lithuania), 1 182.0 m–1 181.5 m interval. Also this species is known from the Gushcha-4015 borehole, depth 758.5–763, Lodlow, the lower part of the Milovanskaia Formation, Volhynia, Ukraine.

Pristiograptus dubius cf. *frequens* Jaekel, Figs. 5, 6.

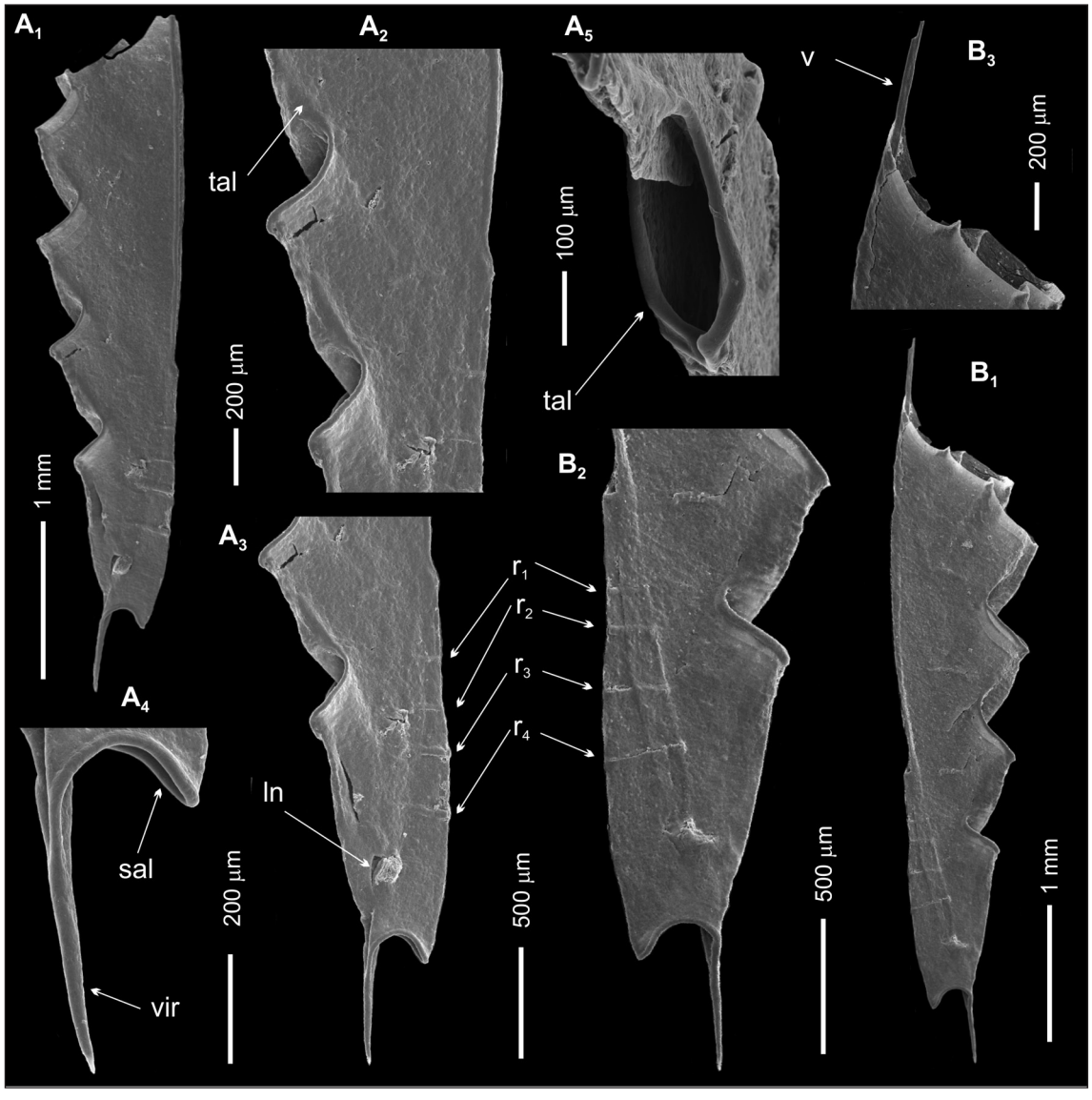

Fig. 5. *Pristiograptus dubius* cf. *frequens* Jaekel. A – No. VU.P.V17-247, well Vištytis-17, Ludfordian, Dubysa Regional Stage, Dubysa Formation, *scanicus* Biozone, depth 908.0–4 m; A_1 – general view; A_2 – end of the second thecal apertural lip (tal); A_3 – initial bud (ib) and rings of sicula (r); A_4 – virgella (vir) and the apertural lip of sicula (sal); A_5 – apertural lip of the first theca (tal); B – No. VU.P.K14-277, well Kybartai-14, Ludfordian, Dubysa Regional Stage, Dubysa Formation, *scanicus* Bizone, depth 986.3 m; B_1 – general view of rhabdosome and four rings of sicula; B_2 – proximal end of rhabdosome with rings (r) of sicula; B_3 – distal end of rhabdosome with virgula (v)

5 pav. *Pristiograptus dubius* cf. *frequens* Jaekel. A – Nr. VU.P.V17-247, Vištyčio-17 gręžinys, gorstis, Dubysos svita, Dubysos regioninis aukštas, *scanicus* biozona, gylis 908,0–4 m; A_1 – bendras rabdosomos vaizdas; A_2 – antrosios tekos žiotelių krašto volelio pabaiga (tal); A_3 – pradinis pumpuras (ib) ir sikulos žiedai (r); A_4 – virgela (vir) ir sikulos žiotelių krašto volelis (sal); A_5 – pirmosios tekos žiotelių krašto volelis (tal). B – Nr. VU.P.K14-277, Kybartų-14 gręžinys, ludfordis, Dubysos regioninis aukštas, Dubysos svita, *scanicus* biozona, gylis 986,3 m; B_1 – bendras rabdosomos vaizdas; B_2 – proksimalinis rabdosomos galas su sikulos žiedais (r); B_3 – distalinis rabdosomos galas su virgula (v)

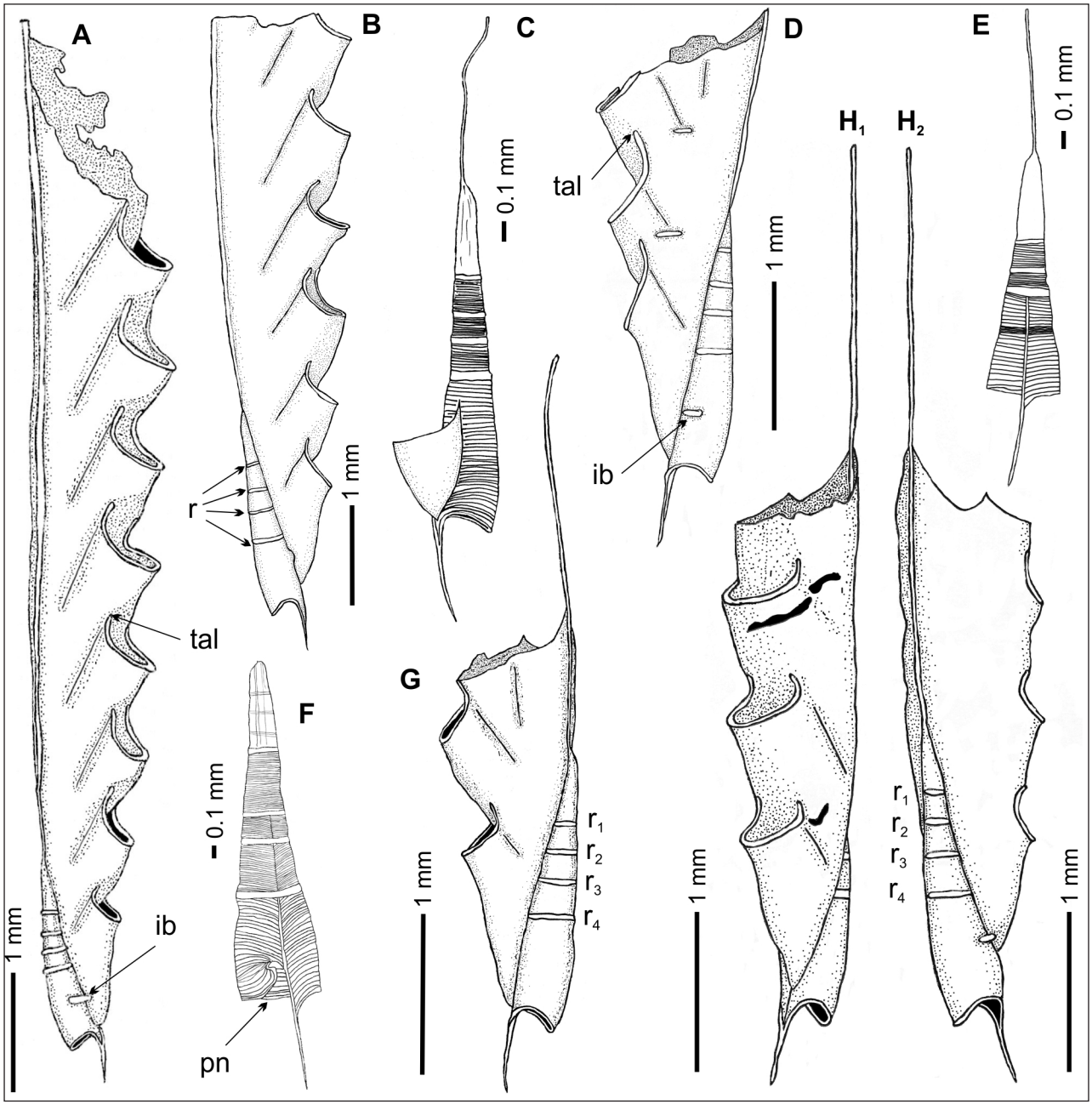

Fig. 6. *Pristiograptus dubius* cf. *frequens* Jaekel, Ludlow, Gorstian, Dubysa Regional Stage, Dubysa Formation, *cornutus* Biozone. A – No. VU.P.V17-249, general view of rhabdosome, thecal apertural lip (tal) and initial bud (ib), Vištytis-17 borehole, depth 908 m; B – No. VU.P.V17-247, the proximal end of rhabdosome and four rings of sicula (r), Vištytis-17 borehole, depth 908 m; C – No. VU.P.K14-263a, sicula with virgula (v) and the first theca (th_1), Kybartai-14 borehole, depth 939.5 m; D – No. VU.P.K14-277, sicula with the first two thecaes, the apertural lip of the second theca (tal), the inner margin of the interthecal septum (is), initial bud (ib), Kybartai-14 borehole, depth 939.5 m; E – No. VU.P.V17-248b, early growth of sicula with four rings (r), Vištytis-17 borehole, depth 908 m; F – **No. VU.P.V17-248a, the sinus stage of sicula, formation of the open primary notch (pn), Vištytis-17 borehole**, depth 908 m; G – No. VU.P.K14-260, the proximal end of rhabdosome, Kybartai-14 borehole, depth 940.6 m; H – No. VU.P.M103-255a, the proximal part of rhabdosome with long virgula (v), thecal apertural lip (tal) and with four sicular rings (r) seen ventrally (H_1) and dorsally (H_2), Milaičiai-103 borehole, depth 1 256.5 m

6 pav. *Pristiograptus dubius* cf. *frequens* Jaekel, ludlovis, gorstis, Dubysos regioninis aukštas, Dubysos svita, *cornutus* biozona. A – Nr. VU.P.V17-249, bendras rabdosomos vaizdas, tekos žiotelių apertūros krašto volelis (tal) ir pirmasis pumpuras (ib), Vištyčio-17 gręžinys, 908 m gylis; B – Nr. VU.P.V17-247, proksimalinė rabdosomos dalis ir sikula su keturiais žiedais (r), Vištyčio-17 gręžinys, 908 m gylis; C – Nr. VU.P.K14-263a, sikula su virgula (v) ir

pirmąja teka (th_1), Kybartų-14 gręžinys, 939,5 m gylis; D – Nr. VU.P.K14-277, sikula su pirmosiomis tekomis, antrosios tekos žiotelių apertūros krašto volelis (tal), tarptekinės septos krašto vidinis ratas (is), pirminis pumpuras (ib), Kybartų-14 gręžinys, 939,5 m gylis; E – Nr. VU.P.V17-248b, ankstyvosios augimo stadijos sikula su keturiais žiedais (r), Vištyčio-17 gręžinys, 908 m gylis; F – Nr. VU.P.V17-248a, kūgio stadijos sikula su atviru, besiformuojančiu pirminiu pumpuru (pn), Vištyčio-17 gręžinys, 908 m gylis; G – Nr. VU.P.K14-260, proksimalinė rabdosomos dalis, Kybartų-14 gręžinys, 940,6 m gylis; H – Nr. VU.P.M103-255a, proksimalinė rabdosomos dalis su ilga virgula (v), tekos žiotelių krašto volelis (tal) ir keturi sikulos žiedai (r), vaizdas iš rabdosomos pilvo pusės (H_1) ir nugaros (H_2), Milaičių-103 gręžinys, 1 256,5 m gylis

Pristiograptus frequens Jaekel, 1889; Přibyl 1943: 24–25, pl. 3:13, text–Fig. 3A.

Monograptus dubius frequens Jaekel, 1889; Jaeger 1991: 314, Fig. 25: 9, 11, 15.

Pristiograptus frequens Jaekel, 1889; Urbanek, Radzevičius, Kozłowska, Teller 2012; p. 600, 602, 603, Figs. 5M, 11A–C, F–H.

Holotype. *Pristiograptus frequens* Jaekel, 1889, erratic boulders, North Germany, *Lobograptus scanicus* Biozone, Lower Ludlow.

Material. About 50 rhabdosomes and some fragments from the Vištytis-17 (908 m) and Kybartai-14 wells (940.6–908.0–4 m interval).

Diagnosis. The rhabdosome is narrow and slightly curved ventrally at the proximal end. The rhabdosome widens gradually from 0.65 mm at th1, to 0.75 mm at th2, 0.9 mm at th3. The inter-apertural width is 0.45 mm at th1, 0.55 mm at th2, 0.6 mm at th3. There are 10–12 thecae in 10 mm. The ß angle is obtuse. Th1 is 0.9 mm long and 0.2 mm wide. The free part of each theca is half of its whole length. The thecal apertural lip is distinct, not extending onto the ventral wall of the succeeding theca and ending in the beginning of the ventral wall. The sicula length is 1.7 mm and width is 0.25 mm. The apex of the sicula reaches the base of th3. There are four sicular rings.

P. d. cf. *requens* is similar to *P.* d. *postfrequens*. *P. d.* cf. *frequens* number of sicular rings is 4, *P. d. postfrequens* has fixed 3 sicular rings. The thecal apertural lip of *P. d.* cf. *frequens* is ending at the beginning of the ventral wall of the succeeding theca, whereas the end of the thecal lip of *P. d. postfrequens* may continue up to the half length of the free part of the succeeding theca or above. *P. d.* cf. *frequens* is more narrow than *P. d. postfrequens*. *P. d.* cf. *frequens* is also similar to *P. d. frequens*. The difference is in the number of sicula rings. *P. d.* cf. *frequens* has 4 sicular rings whereas in *P. d. frequens* the number of sicular rings varies from 3 to 8.

Association. In the East Baltic region, *Pristiograptus d.* cf. *frequens* is found together with *L. s. scanicus*.

Age and geographic distribution. *P. d.* cf. *frequens* is known from the *scanicus* Biozone, Gorstian, Dubysa Regional Stage, Dubysa Formation, in the Vištytis-17 and Kybartai-14 wells.

BRACHIOPOD COMMUNITIES

There are distinguished 5 brachiopod communities in the Ludlow section of the Milaičiai-103 well.

Lissatrypa obovata-Jonsea grayi community is distinguished in the 1 430–1 255 m interval of the Milaičiai-103 borehole. The community is composed of *Lissatrypa obovata* (J. Sow.) and *Jonsea grayi* (Daw.), *Leangella segmentum* (Lindstr.), *Septarypa subaequalis* Bas., *Emartiniopis* sp., *Dayia navicula* (J. Sow.) and others. Specimens of other community members are both articulated and disarticulated. It shows low turbulence in the dysaerobic and soft substrate environments of the BA4 zone (Boucot, 1979).

Isorthis amplificata-Lissatrypa obovata community is distinguished in the 1 255–1 233.5 m interval. The community is composed of *Isorthis amplificata* Walms., *Lissatrypa obovata* (J. Sow.), *L. rotunda* Ryb., *Mesopholidostrophia laevigata* (Dav.), *Atrypa reticularis* sub. sp., *Jonesea graiy* (Daw.), *Eospirifer radiatus* (J. Low.), *Emartinospis sidoni* Ryb., *Dayia navicula* (J. Saw.). Specimens of community members are articulated. It indicates moderate turbulence, well-aerated water. This is the BA3 zone.

Gypidula-Atrypoidea community is distinguished in the 1 233.5–1 218.8 m interval. The community indicates the shallow water (III) facial zone. The community is composed of *Isorthis amplificata* Walms., *Leptaena depressa* (J. Sow.), *Atrypa reticularis* (Linn.), *Coelospira pusilla* (His.), *Homoeospira* sp., *Ancillotechia bidentata* (Hisi.),

Delthyris elevata (Balm.) and others. It allows suggesting that the described community existed under the normal oxygen level and moderate turbulence environment of BA2-3.

Atrypa reticularis-Shaleria ornatella community is distinguished in the 1 218.8–1 182.2 m interval. Species *Atrypa reticularis* (Linn.) and *Shaleria ornatella* (Daw.) dominate in this community. The community is composed of *Isorthis* sp., *Brachiprion*? *ezerensis* Ryb., *Strophonella euglypha* (Dalm.), *Protochonetes* sp., *Coelospira pussilla* (His.), *Homoeospira* sp., *Lissatrypa obovata* (J. Saw.), *Morinorhynchus rubeli* Must. et Cocks, *Delthyris elevata* (Dalm.), Lingulidae and others. Specimens of community members are articulated and existing under the normal oxygen level, moderate turbulence environment of the BA2-3 benthic complex.

Isorthis parvulus-Atrypoidea community is distinguished in the 1 182.2–1 163.5 m interval. There dominated *Isorthis parvulus* Ryb. and species of *Atrypa* genus. The community is composed of Lingulidae, *Homoeospira baylei* (Daw.), *Lissatrypa* sp., *Dayia navicula* (J. Sow.) and stromatopores, bryozoans, rugosa. The presence of organic material suggests that sedimentation took place in very shallow water bays that might even had been separated from the sea. This is the BA2 benthic complex.

CONCLUSIONS

There are 5 marlstone (dominating lithology) and 5 limestone rhythmically layered members in the Šešupė Bed of the Dubysa Formation. They possibly reflect the cyclical sea level fluctuations. The *progenitor-scanicus* Biozone is defined in the lower part of the Šešupė Bed (Brazauskas et al., 2005). Therefore, the lower part of the Šešupė Bed is attributed to the Gorstian age. There are determinate *incipiens*, *praecornutus* and *cornutus* graptolite biozones in the upper part of the Šešupė Bed. These biozones are of the Ludfornian age. There is distinguished *Lissatrypa obovata-Jonsea grayi* brachiopod community in the Šešupė Bed. Here, the thin-walled brachiopods dominate. It is considered as the BA4 benthic complex.

There are Limestone (lower part) and Marlstone (upper part) members in the Nova Bed of the Dubysa Formation. *B. b. tenuis* is obtained in the Nova Bed, indicating the *bohemicus tenuis* Biozone. *Isorthis amplificata-Lissatrypa obovata* brachiopod community is distinguished in the Nova Bed. It is defined as the BA3 benthic complex.

The Mituva Formation is composed of rhythmically layered two members of marlstone and two members of limestone. The graptolite fauna is very rare there. Only few fragments of *M. balticus* and *Pristiograptus* sp. are found indicating the *balticus* Biozone. Brachiopod community of the Mituva Formation is very similar to the brachiopod community of the Nova Bed. We distinguish the *Gypidula-Atrypoidea* brachiopod community in the lower part. It is the BA2-3 benthic complex. There is distinguished *Atrypa reticularis-Shaleria ornatella* brachiopod community in the upper part of the Mituva Formation. This community suggests the shallower water environment, representing the BA3-2 benthic complex.

There are 3 members of limestones defined in the Ventspils Formation. Graptolite species of *M. valleculosus* and *P. d. thuringicus* are found here. These graptolite species indicate the upper part of Ludfordian. *Isorthis parvulus*-Atrypoidea community is distinguished in the Ventspils Formation. Most of brachiopod valves are articulated, indicating the low level of turbulence. The presence of organic mater and interbeds containing stromatopores, bryozoans and rugosa suggests that sedimentation took place in the very shallow water bays.

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BALTIJOS SINEKLIZĖS ŠLAITO LUDLOVIO (SILŪRAS) LITOSTRATIGRAFIJA, GRAPTOLITAI IR PEČIAKOJŲ BENDRIJOS

S a n t r a u k a

Milaičių-103 gręžinys yra išgręžtas Baltijos sineklizės rytiniame šlaite. Ludlovyje išskirtos Dubysos, Mituvos ir Ventspilio svitos. Dubysos svitoje išskirti Šešupės ir Novos sluoksniai. Šešupės sluoksnius sudaro dešimt ritmiškai persisluoksniuojančių klinties ir mergelio sluoksnių. Apatinė Šešupės sluoksnių riba Milaičių-103 gręžinyje nėra žinoma, nes gręžinys buvo gręžiamas be kerno nuo 1 310 m gylio. Novos sluoksnių apatinę dalį sudaro klintis, o viršutinę – mergelis. Mituvos svitą sudaro keturi ritmiškai persisluoksniuojantys klinties ir mergelio sluoksniai. Ventspilio svitą sudaro trys ritmiškai persisluoksniuojantys skirtingos tekstūros klinties sluoksniai. Ludlovio stratigrafija Milaičių-103 gręžinyje yra paremta graptolitų fauna. Gorstyje yra išskirtos *progenitor–scanicus*, *incipiens* graptolitų biozonos, o ludfordyje – *praecornutus*, *cornutus*, *bohemicus tenuis*, *balticus* ir *formosus–valleculosus* biozonos. Pateikti šių svarbių graptolitų rūšių – *Monograptus velleculosus* Tsegeluk ir *Pristiograptus dubius* cf *frequens* Jaekel – paleontologiniai aprašymai. Milaičių-103 gręžinio ludlovyje yra išskirtos *Lissatrypa obovata–Jonsea grayi, Isorthis amplificata–Lissatrypa obovata, Gypidula–Atrypoidea, Atrypa reticularis–Shaleria ornatella* and *Isorthis parvulus – Atrypoidea* brachiopodų bendrijos.

Remiantis Milaičių-103 gręžinio geologiniu pjūviu ir jo litologijos, graptolitų bei brachiopodų faunos tyrimais, buvo išskirti ir kai kurie paleobaseino šios facijų zonos ekostratigrafijos elementai.

Raktažodžiai: ludlovis, litostratigrafija, graptolitai, pečiakojų bendrijos, Milaičių-103 gręžinys, Baltijos sineklizė