

Advances in the Ordovician graptolite biostratigraphy of the St Petersburg area, Russia

Anna A. Suyarkova and Tatyana N. Koren'

A. P. Karpinskij Russian Geological Research Institute (VSEGEI), Srednij pr. 74, 199106 St Petersburg, Russia; Tatyana_Koren@vsegei.ru

Received 8 September 2008, accepted 10 February 2009

Abstract. The Ordovician shallow-water shelf deposits rich in benthic fauna are exposed along the Russian part of the Baltic–Ladoga Klint. Graptolites occur only at some stratigraphic levels, being comparatively numerous in marls and clays and very rare in carbonate layers. Since the 19th century graptolites have been collected from exposures of the Pakerort, Hunneberg, Billingen, and Volkhov regional stages (Tremadocian–Dapingian), while in the Uhaku–Idavere stratigraphic interval (Darriwilian–lower Sandbian) rare graptolites have been found in boreholes. Up to now, only some collections have been systematically studied. On the basis of new graptolite finds, recently the *Pterograptus elegans* Biozone was established in the upper Aseri Stage and the *Nemagraptus gracilis* Biozone in the lower Kukruse Stage. Detailed sampling of the Shundorovo Formation (upper Idavere Stage) resulted in the discovery of numerous diplograptids at five stratigraphic levels, in association with various dendroids. These diplograptids were provisionally assigned to *?Archiclimacograptus antiquus lineatus* Elles & Wood. A systematic description of the late Darriwilian and early Sandbian diplograptids is under preparation.

Key words: Ordovician, graptolites, biostratigraphy, St Petersburg area.

INTRODUCTION

The Ordovician shallow-water shelf deposits with an abundant benthic fauna and conodonts are exposed along the Russian part of the Baltic–Ladoga Klint. Graptolites occur at some stratigraphic levels, being occasionally numerous in marls and clays and very rare in carbonate layers.

Graptolites in the Ordovician sections of the St Petersburg area are known since the 19th century. During the 20th century they were collected by M. Yanishevskij, A. Lesnikova, V. Prinada, T. Alikhova, V. Goryanskij, and Yu. Dmitrovskaya among other researchers. The main graptolite sites are located along the Popovka, Lava, Volkhov, Lomashka, Syas', Nazya, Izhora, and Narva rivers, also near Lake Duderhof. Graptolites are also found in some drill cores near Vaskelovo, Siverskaya, and Chudovo villages and other core sections (Fig. 1). However, old collections have not been systematically studied and graptolite samples not always reliably tied to the sections. Graptolites, collected by different geologists in the 1950s–1970s, were mainly identified by Prof. A. Obut (Obut et al. 1991). For the first time the authors summarized all graptolite finds, known by that time from drill cores and exposures. Although graptolites were not described and some old collections had no precise stratigraphic documentation,

some zonal levels were recognized, among them the levels with *Rhabdinopora flabelliformis s.l.* in the Pakerort Stage, and *Pseudophyllograptus densus* Törnquist and *Ps. angustifolius tenuis* Monsen in the upper Billingen Stage. Some rare Late Tremadocian specimens, such as *Araneograptus aff. murrayi* (Hall), *Kiaerograptus* sp., *Clonograptus aff. tenellus* (Linnarsson), also *Gymnograptus linnarssoni* (Moberg) from the Uhaku Regional Stage, were recorded from drill cores. The presence of the *Nemagraptus gracilis* and *Diplograptus foliaceus* biozones was recognized in the upper part of the Ordovician succession (Fig. 2).

At the beginning of the 1990s, biostratigraphic studies of the Ordovician in the St Petersburg area became more intensive and systematic due to close collaboration between the stratigraphers and palaeontologists from the VSEGEI and St Petersburg University. The lower part of the Ordovician succession, spanning the Pakerort, upper Hunneberg–lower Billingen, and Volkhov regional stages, was studied more thoroughly. Numerous graptolites were collected by P. Fedorov, A. Ivantsov, L. Popov, A. Dronov, and T. Koren' from the well-studied sections at several localities along the Russian part of the Baltic–Ladoga Klint (Putilovo, Babino, Ivangorod, and Kingisepp quarries, on the Popovka and Lava rivers) (Fig. 1). Presently, this stratigraphic interval is covered by comparatively complete graptolite data. Based on the



Fig. 1. Map of the St Petersburg District showing localities with the occurrences of graptolites.

systematic descriptions and biostratigraphic analysis, the *Tetragraptus phyllograptoides* and *Expansograptus hirundo* biozones of Baltoscandia were established (Tolmacheva et al. 2001; Koren et al. 2004) (Fig. 2). However, the Middle and Upper Ordovician exposures above the Volkhov Regional Stage have not been sampled for graptolites, although rare specimens are known from drill cores.

In recent years the present authors made an attempt to fill this gap in the graptolite knowledge. Field work at the Ordovician sections of the St Petersburg area was aimed at collecting graptolites from the middle Darriwilian and Sandbian stages, where only sporadic occurrences of rare specimens were known (Männil 1976; Obut et al. 1991; Nõlvak & Goldman 2004). Some new levels with graptolites were found in sections of the Aseri, Uhaku, Kukruse, and Idavere regional stages.

BIOSTRATIGRAPHY

Lower Ordovician

The graptolite biostratigraphy of the Lower Ordovician deposits was studied in more detail. The Pakerort stratigraphic interval usually attracts much attention among stratigraphers. Clays of the Tosna and Koporye formations bear numerous specimens of the *Rhabdinopora flabelliformis* group. Substantial collections of L. Popov and N. Borovko have been studied and described by

D. Kaljo and R. Sobolevskaya (Kaljo et al. 1986), who recognized several subbiozones in the *Rhabdinopora flabelliformis* Biozone: *Rh. f. socialis*, *Rh. f. norvegica*, *Rh. f. multithecata*, and *Rh. f. anglica* (Fig. 2).

The *Tetragraptus phyllograptoides* Biozone is the next well-documented level within the Lower Ordovician of the region. This biozone has been recognized in the upper Hunneberg and lower Billingen corresponding to the Floian Stage. It was better studied in the Putilovo quarry and in the well-exposed section along the Lava River (Fig. 1). Glauconitic sands and silty clays of the Lakity Beds of the Leetse Formation (Fm.) contain graptolites, conodonts, brachiopods, and other groups. Dichograptids described by T. Koren' include *Tetragraptus phyllograptoides* Strandmark, *Didymograptus rigoletto* Maletz, Rushton & Lindholm, and *Didymograptus aff. protobalticus* Monsen (Fig. 2). The association is impoverished, however, each species is represented by numerous specimens. Didymograptids form a dominant part of the assemblage (Tolmacheva et al. 2001).

Middle Ordovician

The Dapingian and the lowermost Darriwilian stages yield the graptolite fauna of the *Expansograptus hirundo* Biozone at several stratigraphic levels (Fig. 2). The *hirundo* Biozone was recognized by the presence of the most representative graptolite assemblage in the Babino, Putilovo, and Kingisepp quarries and in sections on the

Lava River and near Ivangorod City (Fig. 1). Numerous graptolites were collected from several layers within the mud-mound clay beds of the Volkhov Fm., in association with the benthic fauna and conodonts. The graptolite diversity is relatively low and the assemblage includes no more than seven species in all localities: *Expansograptus hirundo* Salter, *E. goldschmidti* (Monsen), *Xiphograptus svalbardensis* (Archer & Fortey), *Tetragraptus amii* Elles & Wood, *T. quadribrachiatus* (Hall), *T. reclinatus* Elles & Wood, and *Azygograptus volchovensis* Koren (Koren et al. 2004).

The Middle Ordovician deposits of the Darriwilian Stage have the poorest graptolite record within the whole Ordovician succession in the St Petersburg area. Old unpublished data give evidence of the occurrence of *Undulograptus austrodentatus* (Harris & Keble) within the Kunda Regional Stage, but the location of the sample and its exact stratigraphic position are unknown (Fig. 2). The presence of chemically isolated 3D specimens of *Gymnograptus linnarssoni* (Moberg) has been mentioned by Obut et al. (1991), but they gave no precise information about the location of the drill core (Fig. 2). Nölvak & Goldman (2004) revised nemagraptid finds in limestones of the East Baltic and documented *Nemagraptus subtilis* Hadding in the lower part of the Uhaku Stage in the Chudovo-50 drill core (Fig. 2).

Recently new graptolites were collected in the lower Aseri Stage. On the basis of these finds the *Pterograptus elegans* Biozone was established (Fig. 2). Rare and usually poorly preserved graptolites were found from nodular limestones in the quarry near Vil'povitsy village (Figs 1, 2). However, some good specimens of *Haddingograptus oliveri* (Boucek) in 3D preservation were found in association with fragmentary rhabdosomes of *Pseudamplexograptus* sp. indet. and *Didymograptus* sp. indet. Dendroid graptoloids are much more numerous, but their specimens are too fragmentary, which prevents even genus-level identification (Fig. 3).

A complete and quite well preserved specimen of *Hustedograptus teretiusculus* (Hisinger) was found in the Veltsy Fm., at the top of the Uhaku Stage in the Alekseevka quarry (Fig. 2). Limestones in the quarry bear an abundant benthic fauna, while possibilities of finding graptolites are extremely low.

Upper Ordovician

Based on the dissolved material, Obut et al. (1991) recognized *Hustedograptus uplandicus* (Wiman), *Nemagraptus* sp., *Normalograptus* aff. *euglyphus* (Lapworth), *?Archiclimacograptus antiquus lineatus* Elles & Wood, and *Amplexograptus baltoscandicus* Jaanusson (Jaanusson 1995) within the Kukruse, Idavere, and Jõhvi regional stages (Fig. 2). However, these

graptolites were not illustrated and their exact stratigraphical position was not given. All over the area studied, Upper Ordovician sections are represented by shallow-water carbonate deposits with little potential for systematic graptolite sampling. Nevertheless, rare graptolites occur at some stratigraphic levels.

Current studies by one of the present authors (A. S.) revealed new graptolite finds from well-documented sections of the lower Kukruse and upper Idavere stages.

The Kukruse deposits are well exposed and thoroughly studied in the central part of the Baltic–Ladoga Klint. Numerous benthic fauna including trilobites, brachiopods, bryozoans, and other groups occurs in kukersites and carbonate deposits. In the Alekseevka quarry and in the quarry near Dyatlitsy Village, *Amplexograptus bekkeri* (Öpik) was found in the lower part of the Kukruse succession (Figs 1, 2). Graptolites are exceptionally rare, but comparatively well preserved (Fig. 3). This species, typical of the *N. gracilis* Biozone, is well known in the lower Sandbian of the Baltic (Strachan 1960; Männil 1976).

The complete sections of the Shundorovo Fm. were studied in three locations near Kas'kovo, Paritsy, and Golubovitsy villages (Fig. 1). The most representative one is the Kas'kovo quarry section. Graptolites occur sporadically at some stratigraphic levels, but they are numerous and quite well preserved. The monospecific association is represented by *?Archiclimacograptus antiquus lineatus* in association with numerous dendroid fragments. *Dictyonema* aff. *maennili* Obut & Rytzk is very abundant at some levels. Fragments of acanthograptids, *Desmograptus* sp., *?Ptilograptus* sp., and some unidentified fragments of Pterobranchia, are also present (Fig. 3).

CONCLUSIONS

On the basis of present data on the Ordovician graptolites of the St Petersburg Region, we can draw the following conclusions:

- graptolite associations are impoverished, typical of shallow-water environments, unfavourable for habitation and preservation of graptolites;
- eleven graptolite biostratigraphic zonal assemblages have been recognized; they are tied to the conodont zonation in the same sections and can be correlated with those of Baltoscandia and, especially, of Estonia;
- presently, almost all regional stages are characterized by more or less detailed or sporadic graptolite record;
- the main goal of further studies is sampling in the Lasnamägi Stage sections, where graptolites have not yet been found; deposits of the Kunda, Jõhvi, and Keila stages require additional sampling.

Series	Stage	Regional stage	Graptolite biozone Nölvak et al. 2006	St Petersburg area					
				Fm.	Log	Thick-ness, m	Graptolite biozone	Conodont biozone	
UPPER ORDOVICIAN	KATIAN	Nabala							
		Rakvere	<i>Dicranograptus clingani</i>	Pljussa		up to 15		<i>Amorphognathus superbus</i>	
		Oandu							
	SANDBIAN	Haljala	Keila		Jelizavetino		11-30	<i>Amplexograptus baltoscandicus</i>	<i>Amorphognathus tvaerensis</i>
			Jöhvi		Khrevitsa		up to 21		
		Idavere		Shundorovo		22-50	? <i>Archiclimacogr. antiquus lineatus</i>		
				Grjazno					
				Kukruse	<i>Nemagraptus gracilis</i>	Viivikonna		14-39	
	MIDDLE ORDOVICIAN	DARRIWILIAN	Uhaku	<i>Gymnograptus linnarssoni</i> (<i>Hustedograptus teretiusculus</i>)	Veltsy		up to 15	<i>Hustedograptus teretiusculus</i>	<i>Amorph. inaequalis</i>
					Valim		up to 5.3		<i>Sagittodon kielcensis</i>
DAPIN.		Lasnam.	<i>Pseudamplexogr. distichus</i>	Porogi		up to 8		<i>Eoplacogn. lindstroemi</i>	
		Aseri	<i>Pterograptus elegans</i>	Duboviki		up to 9	<i>Pterograptus elegans</i>	<i>Baltopl. reclinatus</i>	
		Kunda	<i>Nichols. fasciculatus</i> <i>Holmograptus lentus</i> <i>Und. austrodentatus</i>	Obukhovo		up to 12.5	<i>Undulograptus austrodentatus</i>	<i>Yangtzepl. crassus</i>	
				Volkhov	<i>Expansogr. hirundo</i>	Volkhov			up to 8
LOWER ORDOVICIAN	TREMADOCIAN	Billingen	<i>Ph. angustifolius elongatus</i> <i>Pseudophyllogr. densus</i> <i>Didymogr. balticus</i> <i>Tetragr. phyllograptoides</i> <i>Hunnegr. copiosus</i>	Leetse		up to 3	<i>Ph. angustifolius tenuis</i> <i>Pseudophyllogr. densus</i> <i>Tetragr. phyllograptoides</i>	<i>Oepikodus evae</i>	
				Nazya		up to 0.4		<i>Prioniodus elegans</i>	
	FLOIAN	Hunneberg.	<i>Araneogr. murrayi</i> <i>Klaeogr. supremus</i> <i>Adelogr. hunnebergensis</i>	Koporye		up to 6	<i>Rh. f. anglica</i> <i>Rh. f. multithecata</i> <i>Rh. f. norvegica</i> <i>Rh. f. socialis</i>	<i>Paroistodus proteus</i>	
		Varangu						<i>Paltodus deltifer</i>	
		Pakerort		<i>Rhabdinopora</i> spp.	Tosna			up to 5.5	<i>Cordylodus angulatus</i>

Fig. 2. The composite section of the Ordovician in the St Petersburg area, correlation of the graptolite and conodont biozonation for Russia and Estonia, and the overview of the present knowledge on graptolite biostratigraphy (contributions by different authors shown by numbers 1–3). DAPIN., Dapingian; Hunneberg., Hunnebergian; Fm., Formation; Lasnam., Lasnamägi. Vertical ruling marks main gaps in the section.










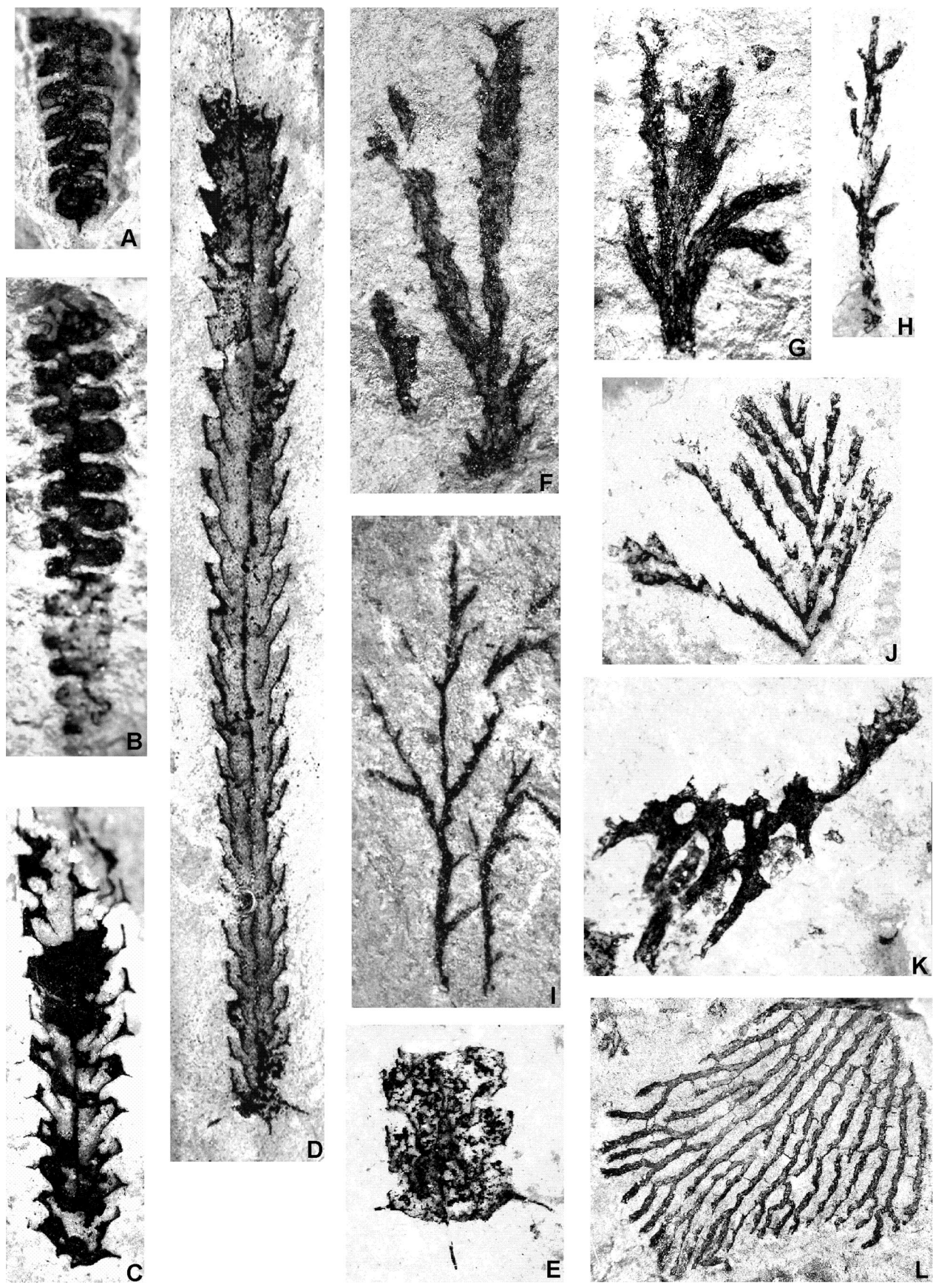
1 Kaljo et al. 1986; Tolmacheva et al. 2001; Koren' et al. 2004; Nölvak & Goldman 2004 2 Obut et al. 1991 3 new data 2004-2008	Locality	Legend
		 dolomite
2 <i>Climacograptus</i> sp., <i>Glyptograptus</i> sp., <i>Orthograptus</i> sp.	Vaskelovo-20 d. c.	 clayey dolomite
2 <i>Amplexograptus baltoscandicus</i>	drill core No. 1927	 bituminous shale, kukersite
3 ? <i>Archiclimacograptus antiquus lineatus</i>	Kas'kovo Paritsy Golubovitsy	 iron oolites
2 <i>Normalograptus</i> aff. <i>euglyphus</i> , ? <i>Archiclimacogr. antiquus lineatus</i> , <i>Hustedograptus</i> ex gr. <i>teretiusculus</i>	Vaskelovo-20 d. c.	 clayey limestone
2 <i>Hustedogr. uplandicus</i> , <i>Pseudoclimacogr. sp.</i> , <i>Nemagraptus</i> sp.	Chudovo-50 d. c.	 limestone
3 <i>Amplexograptus bekkeri</i>	Aleksееvka, Dyatlitsy	
3 <i>Hustedograptus teretiusculus</i>	Aleksееvka	 glauconitic clay
1 <i>Nemagraptus subtilis</i>	Chudovo-50 d. c.	
2 <i>Gymnograptus linnarssoni</i>	drill core	 bituminous shale, <i>Dictyonema</i> shale
3 <i>Hadd. oliveri</i> , <i>Pseudamplexogr. sp. indet.</i> , <i>Didymograptus sp. indet.</i>	Vil'povitsy	 quartzose sand
1 <i>Ex. hirundo</i> , <i>Ex. goldschmidti</i> , <i>Tet. reclinatus</i> , <i>Tet. quadribrachiatus</i> , <i>Tet. amii</i> , <i>Xph. svalbardensis</i> , <i>Psph. cf. a. tenuis</i> , <i>Az. volchovensis</i>	Babino, Kingisepp Ivangorod, Putilovo	
2 <i>Ph. a. tenuis</i> , <i>Ph. anna longus</i> , <i>Phyllograptus</i> sp., <i>Corymbogr. sp.</i> , <i>Acrograptus</i> sp., <i>Dch. octobrachiatus</i> , <i>Tet. bigsbyi ascendens</i>	Lava River Popovka River	
1 <i>Tetragraptus phyllograptoides</i> , <i>Did. rigoletto</i> , <i>Did. aff. protobalticus</i>	Putilovo, Lava River	
2 <i>Araneogr. aff. murrayi</i> , <i>Kiaerograptus</i> sp., <i>Clonogr. aff. tenellus</i>	Pestovo d. c.	
1 <i>Rh. f. flabelliformis</i> , <i>Rh. f. rossica</i> , <i>Rh. f. bryograptoides</i> , <i>Rh. f. anglica</i> , <i>Rh. f. parabola</i> , <i>Rh. f. graptolithina</i> , <i>Rh. f. multithecata</i> , <i>Rh. f. norvegica</i> , <i>Rh. f. socialis</i>	Lomashka, Nazya, Syas' rivers	

Fig. 2. Continued.



Acknowledgements. Our thanks are due to Dr T. Tolmacheva, O. Dolgov, G. Iscul', and A. Fedkovets for help in the field, and to Ch. Mitchell for valuable advise on diplograptid taxonomy. Our paper benefited greatly from remarks and corrections suggested by Dr J. Maletz and an anonymous reviewer.

REFERENCES

- Jaanusson, V. 1995. Confacies differentiation and upper Middle Ordovician correlation in the Baltoscandian basin. *Proceedings of the Estonian Academy of Sciences, Geology*, **44**, 73–86.
- Kaljo, D., Borovko, N., Heinsalu, H., Khazanovich, K., Mens, K., Popov, L., Sergeeva, S., Sobolevskaya, R. & Viira, V. 1986. The Cambrian–Ordovician boundary in the Baltic–Ladoga clint area (North Estonia and Leningrad Region, USSR). *Proceedings of the Estonian Academy of Sciences, Geology*, **35**, 97–108.
- Koren, T., Gorshenina, V. & Tolmacheva, T. 2004. Volkhov graptolites from the Lower–Middle Ordovician boundary beds of the St. Petersburg region, Russia. *Paläontologische Zeitschrift*, **78**, 195–212.
- Männil, R. 1976. Distribution of graptoloids in the Ordovician carbonate rocks of the East Baltic area. In *Graptolity i stratigrafiya [Graptolites and stratigraphy]* (Kaljo, D. & Koren, T., eds), pp. 105–118. Academy of Sciences of the Estonian SSR, Tallinn [in Russian, with English summary].
- Nölvak, J. & Goldman, D. 2004. Distribution of *Nemagraptus* in the East Baltic Ordovician. In *WOGOGOB-2004 Conference Materials* (Hints, O. & Ainsaar, L., eds), pp. 75–76. Tartu University Press.
- Nölvak, J., Hints, O. & Männik, P. 2006. Ordovician timescale in Estonia: recent developments. *Proceedings of the Estonian Academy of Sciences, Geology*, **55**, 95–108.
- Obut, A. M., Sennikov, N. V. & Dmitrovskaya, Yu. E. 1991. Graptolite complexes in the Ordovician of the Leningrad Region. *Izvestiya Akademii Nauk SSSR, Seriya Geologicheskaya*, **4**, 14–20 [in Russian].
- Strachan, I. 1960. Graptolites from the Ludibungus Beds (Middle Ordovician) of Tvären, Sweden. *Bulletin of the Geological Institutions of the University of Uppsala*, **38**, 47–70.
- Tolmacheva, T., Koren, T. N., Holmer, L. E., Popov, L. E. & Raevskaya, E. 2001. The Hunneberg Stage (Ordovician) in the area east of St. Petersburg, north-western Russia. *Paläontologische Zeitschrift*, **74**, 543–561.

Ordoviitsiumi graptoliitse biostratigraafia progress Sankt-Peterburgi piirkonnas Venemaal

Anna A. Suyarkova ja Tatyana N. Koren'

Ordoviitsiumi madalaveelise šelfi settekivimid, milles leidub rikkalikult põhjafauna kivistisi, paljanduvad Venemaal Balti-Laadoga klindivööndi alal. Graptoliite leidub ainult mõnel stratigraafilisel tasemel, kusjuures on neid suhteliselt rohkesti merglites ja savikivimites ning väga harva karbonaatsetes kivimites. Alates 19. sajandist tänini on neid kogutud Pakerordi, Hunnebergi, Billingeni ja Volhovi lademe paljanditest, kuna graptoliitide leiud Uhaku, Kukruse ning Idavere lademest on pärit puursüdamikest. Seni on ainult väike arv kollektioone süstemaatiliselt uuritud (Kaljo *et al.* 1986; Tolmacheva *et al.* 2001; Koren' *et al.* 2004). Äsjased uued leiud võimaldasid määratleda *Pterograptus elegans*'i biotsooni Aseri lademe ülaosas ja *Nemagraptus gracilis*'e biotsooni Kukruse lademes. Detailse fossiilide otsinguga Idavere lademe Šundorovo kihistus tehti kindlaks viis stratigraafilist taset, millel esineb rikkalikult diplograptiidid *?Archiclimacograptus antiquus lineatus* Elles & Wood koos eri dendroidsete graptoliitidega. Diplograptiidide täpsem uurimine on kavandatud lähiajale.

Fig. 3. A, B, *Haddingograptus oliveri* (Boucek); *P. elegans* Biozone, Aseri Regional Stage, Vil'povitsy Village, ×10. **C,** *Amplexograptus bekkeri* (Öpik); *N. gracilis* Biozone, Kukruse Regional Stage, Alekseevka quarry, ×10. **D, E,** *?Archiclimacograptus antiquus lineatus* Elles & Wood; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village; D ×10, E ×20. **F, G,** *Thallograptus* sp.; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village, ×8. **H,** *?Acanthograptus* sp.; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village, ×10. **I,** *?Acanthograptidae*; *P. elegans* Biozone, Aseri Regional Stage, Vil'povitsy Village, ×8. **J,** *?Ptilograptus* sp.; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village, ×8. **K,** *Desmograptus* sp.; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village, ×8. **L,** *Dictyonema* aff. *maennili* Obut & Rytzk; *?A. antiquus lineatus* Biozone, Idavere Regional Stage, Kas'kovo Village, ×3.