Baltic Stratigraphical Association
A.P. Karpinsky All-Russian Geological Research Institute (VSEGEI)
St. Petersburg State University

THE SIXTH BALTIC STRATIGRAPHICAL CONFERENCE

6th Baltic Stratigraphical Conference

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ABSTRACTS

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and Tatiana Tolmacheva

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Contents

DEVONIAN CONODONT BIOGEOGRAPHY (GIS-PROJECT)

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The database on geochronological and global geographic distribution of Devonian conodonts was compiled. It embraces about 1090 species (and subspecies) from more than 180 localities (Aristov, Lubnina, 2005). A time of appearance and extinction of each species as well as their present day geographic position were determined. In Devonian the diversity of conodonts was the following (Fig. 1): in the Lochkovian – 117 species, Pragian – 76, Emsian – 177, Eifelian – 118, Givetian – 124, Fransian – 239 and Famennian – 417 species. At the beginning of the Carboniferous a wide variety of conodonts still persisted but then decreased drastically.

All the data were put on the present day map in the Mercartor projection with boundaries of the main continental blocks (Fig. 1). The localities of conodonts are situated asymmetrical at the present day reconstruction: the most part of them was found in the Northern hemisphere from equatorial up to high latitudes. There are a few localities in the northern and eastern Australia margins.

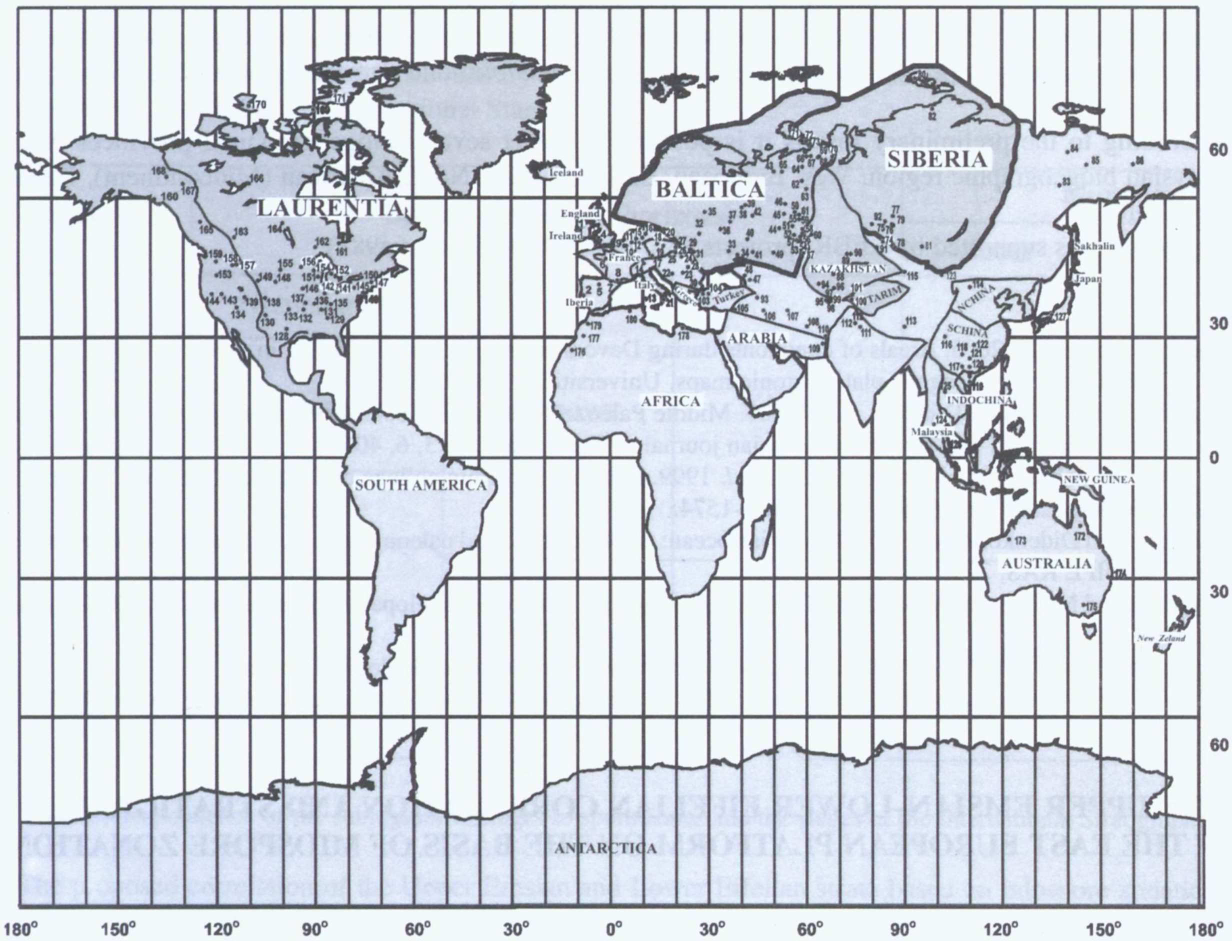

Fig. 1. Present day distribution of Devonian conodonts in geographical coordinates.
Number of localities after Aristov and Lubnina (2005)

In addition 296 Late Silurian to Early Permian paleomagnetic results for main continental blocks were taken from the Global Paleomagnetic Data Base (Pisarevsky, McElhinny, 2003). We separate the most reliable results according to Van der Voo criteria (1993): 126 paleomagnetic data for Baltica, 87 – for Siberia, 147 – North America, 18 – North China, 37 – South China, and 64 – for Australia. For each continent the new APWP was calculated. As a result the position of the main continents during the Devonian time have been rigidly fixed. The location of another continental blocks and terrains reconstructed after Golonka (2000), Filippova *et al.* (2001), Parfenov *et al.* (1999), Pechersky and Didenko (1995), Van der Voo (1993), and Scotese and McKerrow (1991).

Global maps based on the recent paleomagnetic records show areas of the conodont distribution in each of seven stages of the Devonian (Fig. 1). According to these the distribution of conodonts was within the following latitudes: in the Lochkovian–Pragian – 50th S–20th N, in the Emsian – 30th S–30th N, in the Eifelian – 40th S–40th N, and 50th S–50th N in the Givetian–Famennian. The majority of species lived in near-equatorial and tropical basins. It is testifying the hypothesis that conodonts were warm-water marine organisms. According to our data, during Devonian time high percentage composition of endemic species with respect to the overall picture was constant. In percentage terms amount of endemic species was the following: 44–50 % – in the Lochkovian, Pragian and Eifelian, 31–40 % – in the Emsian, Givetian, Fransian and Famennian. The low percentage of endemic species indicates a high sea level and better connection between the basins during specific time intervals.

Now we can preliminary separate two biogeographical regions: a bounded region of the space – Siberian and vast expanses – PaleoTethysian. Siberian biogeographical region was containing basins located around the Siberian Craton (excepting its Northern margin). In the Early Devonian it included Laurentia area of water (Canadian Arctic Archipelago). At the same time the Novaya Zemlya Archipelago was ecotone zone to the East, where mixed fauna of both biogeographical regions was abundant. As a result of northward movement of the Siberian Craton in the Middle Devonian a connection of the Siberian and North Canadian faunas decreased. Siberian biogeographical region contain the endemic genera: *Bouckaertodus*, *Fungulodus*, *Jukagiria*, *Gigantolus* and numerous endemic species of icriodids and polygnathids.

According to the preliminary results it is possible to select several biogeographical provinces within the PaleoTethysian biogeographic region: West European, East European, North American (Midcontinent), Kazakhstan and South China.

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THE UPPER EMSIAN–LOWER EIFELIAN CORRELATION AND STRATIGRAPHY OF THE EAST EUROPEAN PLATFORM ON THE BASIS OF MIOSPORE ZONATION

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Certain stratigraphic intervals in the regional Devonian stratigrafic chart of the East European Platform and its subregions are currently needed to be elucidated (Resolution..., 1990). In particular, the correlation of the Upper Emsian (Lower Devonian) and Lower Eifelian (Middle Devonian) is problematic.

In the Eastern subregion the intervals under question include the Koiva, Biya, and Klintzy subregional stages (horizons). These are carbonates containing zonal assemblages of brachiopods and other numerous fossils. In the

Central Subregion the interval is started with the terrigenous deposits of the Ryazhsk Subregional Stage (Horizon) poor in fossil remains. The overlaying deposits are referred to the Morsovo Subregional Stage (Horizon) or, according to the latest stratigraphic chart, the Dorogobuzh and Klintzy subregional stages. Their sections are rich in sulfates galogenous that are replaced upwards by dolomite-clayish, calcareous-clastic or clastic deposits, at places containing ostracodes. In the North-Western Subregion the Rezekne, Pyarnu, and Niznenarova subregional stages were dated by vertebrate remains and assigned to the same stratigraphic interval (Lyarskaya, 1981). The multifacial deposits of the three subregions are difficult to be compared on the basis of obtained fossils; conodonts are not found. Therefore, the zonal palynological assemblages are crucial for the correlation.

The interval under consideration is assigned to the *Diaphanospora inassueta* and *Periplecotriletes tortus* miospore zones (Arkhangelskaya, 1974; and others). The latter zone is subdivided in many areas into the *Elenisporis biformis* and the *Grandispora naumovae* subzones. The study of the borehole sections from more than 65 areas substantiates the zonal subdivision and intersubregional correlation of the Upper Emsian and Lower Eifelian.

In the East Subregion the *inassueta* zone includes the Koiva (with the *Apiculiretusispora sterlibaschevensis* epibole) and Bija subregional stages; in the Central Subregion it includes the lower and middle parts of the Ryazhsk Subregional Stage. The *tortus* zone on the east includes the Klintzy Subregional Stage with the *biformis* and *naumovae* subzones. In the Central Subregion upper layer (5–12 m) of the Ryazhsk Subregional Stage (*biformis* subzone) and the entire Morsovo Subregional Stage are assigned to the *tortus* zone. In the Northwest this zone embraces the Rezekne, Pyarnu, and Niznenarova subregional stages (miospore subzones are not established in this area).

The Figure 1 shows the correspondence of the subreginal stages to spore zones and the stages of the International Stratigraphic Chart. The Emsian/Eifelian boundary coincided with the base of the conodont zone *Polygnathus costatus partitus* is placed within the Bija Subregional Stage.

Substage	Subregional stages (horizons)			Miospore Zones	Miospore Subzones
Lower Eifelian	Niznenarova	Morsovo	Klintzy	*tortus*	*naumovae*
	Pyarnu				
	Rezekne				*biformus*
		Ryazhsk	Bija	*inassueta*	
Upper Emsian		?	Koiva		

Fig. 1. The correspondence of the subreginal s.r.stages to spore zones and the stages of the International Stratigraphic Chart

The proposed correlation of the Upper Emsian and Lower Eifelian strata based on miospore zonation differs from the chart that was adopted by the Stratigraphic Committee of Russia (Resolution..., 1990) and published by the International Subcommission on Stratigraphy of Devonian System (Rzhonsnitskaya, 2000). In the latter the lower part of the Ryazhsk and Bija as well as the lower parts of the Klintzy, Resekne, and Pyarnu subregional stages were erroneously correlated to the miospore zones. As a consequence, that paper presented the erroneous correlation between the Bija Subregional Stage, Lower Morsovo Beds, and Pyarnu Subregional Stage); Klintszy Subregional Stage and Upper Morsovo Beds; and Rezekne Subregional Stage with the Ryazhsk, Koiva, Vyazovaya, and Takata subregional stages. The new chart unjustifiably abolished the Morsovo Subregional Stage and accordingly Lower Morsovo and Upper Morsovo beds. The substitution of the Morsovo Subregional Stage by the Dorogobuzh and Klintzy subregional stages seems to be an unfortunate choice because the Dorogobuzh Subregional Stage is poorly based from the point of view of paleontological data; moreover, the Klintzy Subregional Stage of the chart of the Central Subregion does not correspond to the type sections in the Eastern Subregion, where this unit was originally introduced.

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THE SECTION ORLETSY (MOSCOVIAN–BASAL KASIMOVIAN, CARBONIFEROUS, ARKHANGELSK REGION): DISTRIBUTION OF FUSULINOIDS, CORRELATION WITH TYPE MOSCOVIAN SUCCESSION, AND STRATIGRAPHIC CAPABILITY OF THE LATE MOSCOVIAN FUSULINOIDA

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The main Orletsy Quarry (Fig. 1) is situated in the Severnaya Dvina-Pinega outcrop area of the western flank of the Mezen Syneclise (the north-eastern part of the Russian Platform). The fusulinoids from Orletsy quarries and adjacent natural exposures were studied by M.N. Solovieva, however, her data have not been published. In 2002, the authors restudied the Moscovian–basal Kasimovian limestones and dolostones of the Severnaya Dvina-Pinega area and found the subaerial unconformities dividing the succession into transgressive-regressive sequences or cyclothems (Kabanov and Baranova, in press). The fusulinoid assemblage of the Orletsy section is impoverished in comparison to the typical Moscovian assemblages. Three intervals are recognized: below the Orletsy Unconformity, between the Orletsy and Nizhnyaya Palenga unconformities, and above the Nizhnyaya Palenga Unconformity. The first interval is characterized by numerous *Fusulinella* (*F. famula* Thompson and *F. bocki* Moeller) and rare *Fusulina*, which is a feature of the *Fusulinella bocki* Zone of the Moscow Region (Kabanov and Baranova, 2003). This interval may correspond to the *Fusulinella eopulchra* Zone (the Nansen Formation) of the Canadian Arctic Archipelago, which is dominated by diverse *Fusulinella* including *F. famula* and contains no *Fusulina* (Lin *et al.*, 1991). The assemblage of the second interval is dominated by *Fusulinella* (*F. bocki* Moeller group) and *Fusulina* (*F. cylindrica* Fischer group), the latter becoming numerous just above the Orletsy Unconformity. Thus, the second interval can be correlated with the *Fusulina cylindrica* Zone, and the cyclothem between the Orletsy and Nizhnyaya Palenga unconformities – with the Peski Formation. The third interval is extremely poor in fusulinoids, which are diagnostic for the Suvorovo Formation of Central European Russia. New data obtained by the authors suggest that the fusulinoid genera which include zonal index species (*Putrella, Fusulinella, Fusulina, Fusiella*) span the entire upper Moscovian (Podolskian and Myachkovian) interval, and the index species always occur outside their zones. *Protriticites ovatus* Putrja cannot be used as an index species of the terminal Moscovian zone because it is extremely rare in the Moscow Region and unknown in the Kasimov and S. Dvina-Pinega sections, and its appearance corresponds to the base of the *Fusulina cylindrica* Zone. The recognition of species is often impeded by the uncertain criteria of differentiation between the species of one genus and the individual and populational variability within one species. In this situation, the quantitative approach to zonal characterization may be the winning strategy over the commonly used presence/absence of the species.

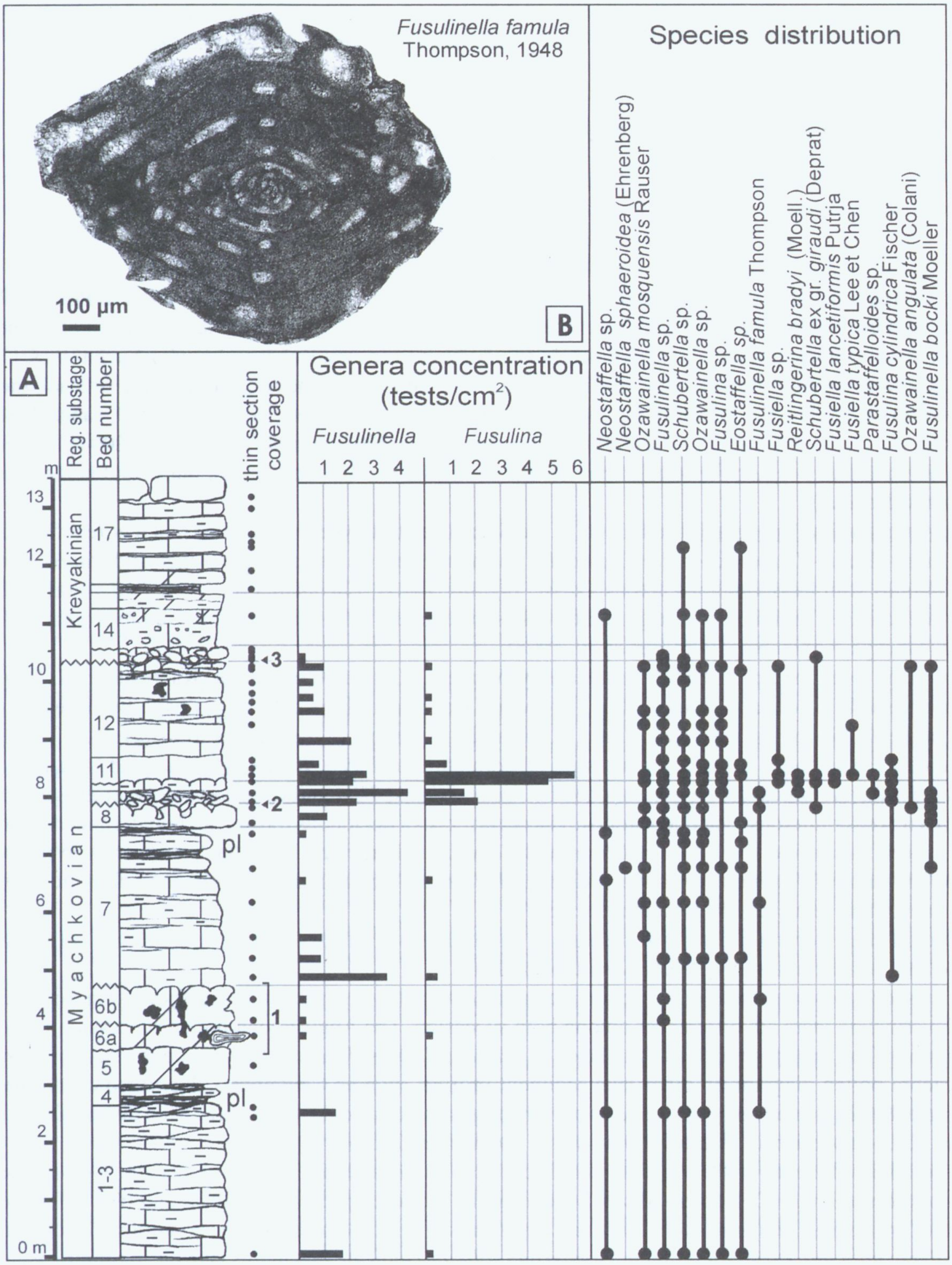

Fig. 1. A – Fusulinoid distribution of Orletsy Section along the Severnaya Dvina River; values below 0.3 test/cm² are shown out of scale; main unconformities are marked with bold numbers: 1=Rozhevo (here expressed in several karstic surfaces), 2=Orletsy, 3=Nizhnyaya Palenga; B – *Fusulinella famula* Thompson, 1948, axial section of the small form; bed 3, thin section ORL-3

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LOWER MIDDLE PLEISTOCENE IN NE POLAND – A NEW DATA

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In the last ten years detailed geologic-cartographic studies have been carried out in northeastern Poland. Within the framework of these studies 41 full-cored boreholes were drilled in the Quaternary sequence (the thickness of the deposits to 300 m) that reached the older substrate. In boreholes at Szczebra, Kalejty, Janówka, Sucha Wieś, Czarnucha, Żarnowo, Komorniki and Zielone Królewskie interglacial lake deposits of the Augustovian Interglacial, the oldest in Poland, were evidenced by the results of palynological and geological studies (Ber, 1996, 2000; Janczyk-Kopikowa, 1996; Ber *et al.*, 1998; Nitychoruk *et al.*, 2000; Kacprzak *et al.*, 2002, Lisicki and Winter, 2004). At present, the Augustów Plain is a key region for stratigraphy of the Lower Middle Pleistocene in Poland and neighbouring areas (Lithuania and Belarus).

The Augustovian Interglacial sediments in the **Szczebra** stratotype profile represent a boreal floristic succession with *Pinus–Betula–Larix* and *Azolla filiculoides* during the first (I) temperate substage and *Pinus–Azolla–Picea (Azolla–Salvinia)* with thermophilous taxons *Carya*, *Juglans*, *Celtis*, *Eucommia*, *Salvinia*, *Trapa* during the second (II) temperate (climatic optimum) substage. Three cold substages are generally characterized by boreal and subarctic vegetation (Janczyk-Kopikowa, 1996; Ber *et al.*, 1998).

Also in the recent pollen diagrams from **Kalejty** (Winter, 2001) and **Czarnucha** (Kacprzak *et al.*, 2002; Winter, 2003 – unpublished, Lisicki and Winter, 2004) two warm stages and three cold stages have been distinguished. As explained in the Kalejty pollen diagram (Winter, 2001) at the beginning of the older warm stage (Kal 2–Kal 4) pollen spectra indicate *Pinus* pollen to be dominant with an admixture of *Picea*, *Betula, Quercus* and high frequencies of Cyperaceae. Gradually boreal forest got enriched by *Alnus*, *Ulmus*, *Tilia* and *Corylus*. The assemblage indicates the presence of a mixed coniferous–deciduous forest. The occurrence of deciduous forest with high frequencies of *Quercus, Carpinus* as well as considerable share of *Ulmus* and *Corylus* is characteristic for the younger warm period (Kal 6–Kal 8). The presence of *Juglans, Carya*, *Ilex, Viscum*, *Hedera* and *Azolla* indicates temperate climatic conditions. In the upper part of this sequence *Tsuga* pollen occurs.

The cold stage separating two warm stages is marked by very high values of *Betula* and herb: Cyperaceae, Gramineae and *Artemisia*, also by *Betula nana* type pollen.

Pollen succession from the Kalejty section is correlated with the Augustovian pollen succession from the Szczebra section. Nevertheless there are differences among both succesion. The Augustovian pollen succession from Szczebra is discontinuous. The first stage with its abundance of *Quercus*, *Ulmus*, *Tilia* and *Corylus* pollen has not been recorded in the Szczebra pollen diagram. In other lake sediment profiles such as **Czarnucha**, **Komorniki** and **Sucha Wieś** according to palynological investigation also two warm stages and three cold stages have been distinguished (Janczyk-Kopikowa, 2003–unpublished; Winter, 2001; Lisicki and Winter, 2004).

In the lake sediments of the Augustovian Interglacial at **Szczebra** 11 bivalve species, 7 gastropod species, fragments of other animals (Coleoptera, Pisces, Aves) and 14 ostracod species (Skompski and Ber, 1999) were found. Some molluscan species (*Bithynia leachi*, *Pisidium supinum*) suggest moderate climatic conditions. Another molluscan species (*Valvata naticina*, *Pisidium supinum*, *Sphaerium solidum*) indicate that in this lake basin running water existed. However, in the interglacial lake sediments at **Komorniki** borehole the first time in Poland shells of the *Fagotia* cf. *acicularis* (Ferrusac) and rests of the small vertebrates: *Microtus* (*Pallasiinus*) *protoeconomus* Rekovets and *M. (Pallasiinus)* ex gr. *economus* Pall have been found (Sanko, 2003 – unpublished).

The isotope $\delta^{18}O$ and $\delta^{13}C$ values were examined at Kalejty and Szczebra profiles from organic lake sediments of the Augustovian Interglacial (Jędrysek, 1997 – unpublished; Nitychoruk *et al.*, 2000). The isotope composition indicates considerable redeposition of older sediments during lower lake levels mostly during the cool intervals.

The interglacial series at Szczebra and Kalejty and in other profiles are underlain by a thick layer of the lodgement till and covered by a thick lodgement till. The lowermost (older) till at Szczebra is characterized by the following petrographical coefficients: K/W = 0.86; O/K = 1.23; A/B = 1.12 and Dp/Wp = 0.46 where: O – sedimentary rocks; K – crystalline rocks and quartz; W – carbonate rocks; A –unweathered rocks; B – weathered rocks; Wp – limestones of northern origin and Dp – dolomites of northern origin. Typical local rocks in this till are Palaeocene marls and their content is very high (up to 32.2 %). For the upper (younger) till horizon petrographical coefficients are: K/W = 0.61; O/K = 1.70 and A/B = 1.58. The dominant local rocks are Palaeocene and Cretaceous marls and limestones (up to 5.8 %).

The Augustovian Interglacial sediments are underlain by a till of the Narevian (Menapian) Glaciation and are overlain by the till of the Nidanian (Glacial A – Cromer Complex) Glaciation. Till stratigraphy is based on petrographic and lithologic studies (Czerwonka and Krzyszkowski, 1995 – unpublished), results are correlated with results of the palynological studies.

Palaeomagnetic evidence suggests that the Augustovian Interglacial lake sediments at Kalejty borehole were developed at the Bruhnes/Matuyama boundary. Therefore these sediments correlate to MIS 18/19 i.e. with the Cromer I (Waardenburg) Interglacial (Turner, 1996). Recently, the presence of the Brunhes/Matuyama boundary into the Augustovian Interglacial sediments is also confirmed in Czarnucha borehole (Nawrocki, 2003–unpublished).

However, the Augustovian Interglacial sediments according to lithologic and petrographic study (Czerwonka and Krzyszkowski, 1995–unpublished) as well as by geologic setting are underlain by till of the Narevian (Menapian) Glaciation and are overlain by the till of Nidanian (Glacial A – Cromer Complex) Glaciation. It allows also to correlate the Augustovian Interglacial sediments with Bavelian (Leerdam) Interglacial (West, 1996; Zagwijn and De Jong, 1984).

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YAPTIKNYRD FORMATION – A NEW STRATIGRAPHICAL UNIT RECOGNIZED IN THE UPPERMOST ORDOVICIAN STRATA IN THE SUBPOLAR URALS

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In the Subpolar Urals, the strata in the Ordovician–Silurian boundary interval are represented by various, mainly bioclastic dolomitised limestones. Due to strong recrystallisation of rocks the fossils, as a rule, are unidentifiable. The position of the Ordovician–Silurian boundary in the region has been problematic for a long time (Beznosova and Männik, 2002). In the latest version of the stratigraphical charts of the Urals (Antsygin *et al.*, 1993) the Ordovician–Silurian boundary in the Subpolar Urals was considered to correspond to the upper contact of the Yaptikshor Beds.

The Yaptikshor Beds were defined as the strata corresponding to the interval of total range of *Proconchidium muensteri* (St. Joseph) (Antoshkina, Beznosova, and Mel'nikov *in* Tsyganko and Chermnykh, 1987). Later, the strata corresponding to the Yaptikshor Beds were proposed to include in the regional stratigraphical chart as the Yaptikshor Stage (Antoshkina *et al.*, 1989). The unit proposed as the Yaptikshor Beds was accepted but, for some reasons, in the charts it is indicated as the Yaptikshor Formation. The name Yaptikshor Stage was declined and the Yaptikshor Formation was correlated with the Kyr'ya Stage. Unfortunately, in later publications we can find references to the Yaptikshor Formation as well as to the Yaptikshor Beds. To avoid further confusion, below we will refer to the original definition of the unit and use the term Yaptikshor Beds.

During the last decade, detailed studies of the Ordovician–Silurian boundary were carried out in the Kozhym-108 section (Beznosova, 1994; Beznosova and Männik, 2002; Fig. 1). In this section, the contact between thin-bedded light-coloured micritic dolostones of the Malaya Tavrota Formation below and massive grey bioclastic dolostones of the Yaptikshor Beds above is marked by a distinct erosional surface. At the base of the Yaptikshor Beds an interval with *P. muensteri* (St. Joseph) coquinas occurs. The *P. muensteri* (St. Joseph) interval is overlain by thin-bedded micritic dolostones with lenses of brachiopod, gastropod and echinoderm fragments. Stromatoporoids and tabulate corals are common. Higher in the section, massive bioclastic dolostones with variable faunas dominate.

The uppermost specimens of *P. muensteri* (St. Joseph) in the section were found just above the base of bed 20 (Fig. 1). Fossils are rare above this level in the section. Only few strongly recrystallised, sometimes partly silicified tabulate corals and stromatoporoids have been recognised. The strata are mainly represented by massive light-grey to grey dolomitised limestones. The boundary between beds 20 and 21 is marked by appearance in the section of dark-grey thin-bedded bioturbated dolostones. From the basal part of these strata (sample C 01-49; Fig. 1) Silurian conodonts *Oulodus*? aff. *nathani* McCracken et Barnes, *Walliserodus* cf. *curvatus* (Branson et Branson) and *Ozarkodina* sp. (Beznosova *et al.*, 2004) have been found. Higher in the section, at the base of bed 22A, *Virginia* (?) sp. appear.

Carbon isotope studies in the Kozhym-108 section revealed a $\delta^{13}C$ curve almost identical with that from the Dob's Linn section (Scotland) (Beznosova *et al.*, 2004). It appeared that the strata between the upper boundary of the Yaptikshor Beds below and the lowermost part of bed 21 above correspond to the Hirnantian. Summarizing the $\delta^{13}C$ and biostratigraphical data it is also evident that the Ordovician–Silurian boundary in the Kozhym-108 section lies in the lower part of bed 21, probably just below sample C 01-49 (Fig. 1).

The data we have indicate that 1) the Yaptikshor Beds are followed in the section by an interval of lithologically almost identical strongly dolomitised limestones; 2) this interval, so far considered to correspond to the lowermost part of the Dzhagal Formation and of being of Early Silurian in age in reality correlates with Hirnantian; 3) the Ordovician–Silurian boundary lies in the lower part of bed 21.

As the boundary between the Yaptikshor Beds and Dzhagal Formation (as the units were understood up till now) is lithologically unrecogniseable, and as the massive dolomitised limestones in the lowermost part of the Dzhagal Formation appeared to be of Late Ordovician in age, we propose:

1. Redefine the lower boundary of the Dzhagal Formation and consider the massive dolomitised limestones between the upper contact of the Malaya Tavrota Formation below and the contact of massive light-coloured dolostones and dark-grey thin-bedded dolomitised limestones above (the boundary between beds 20 and 21 in Kozhym-108 section) as one lithological unit.
2. To name this unit as the Yaptiknyrd Formation.

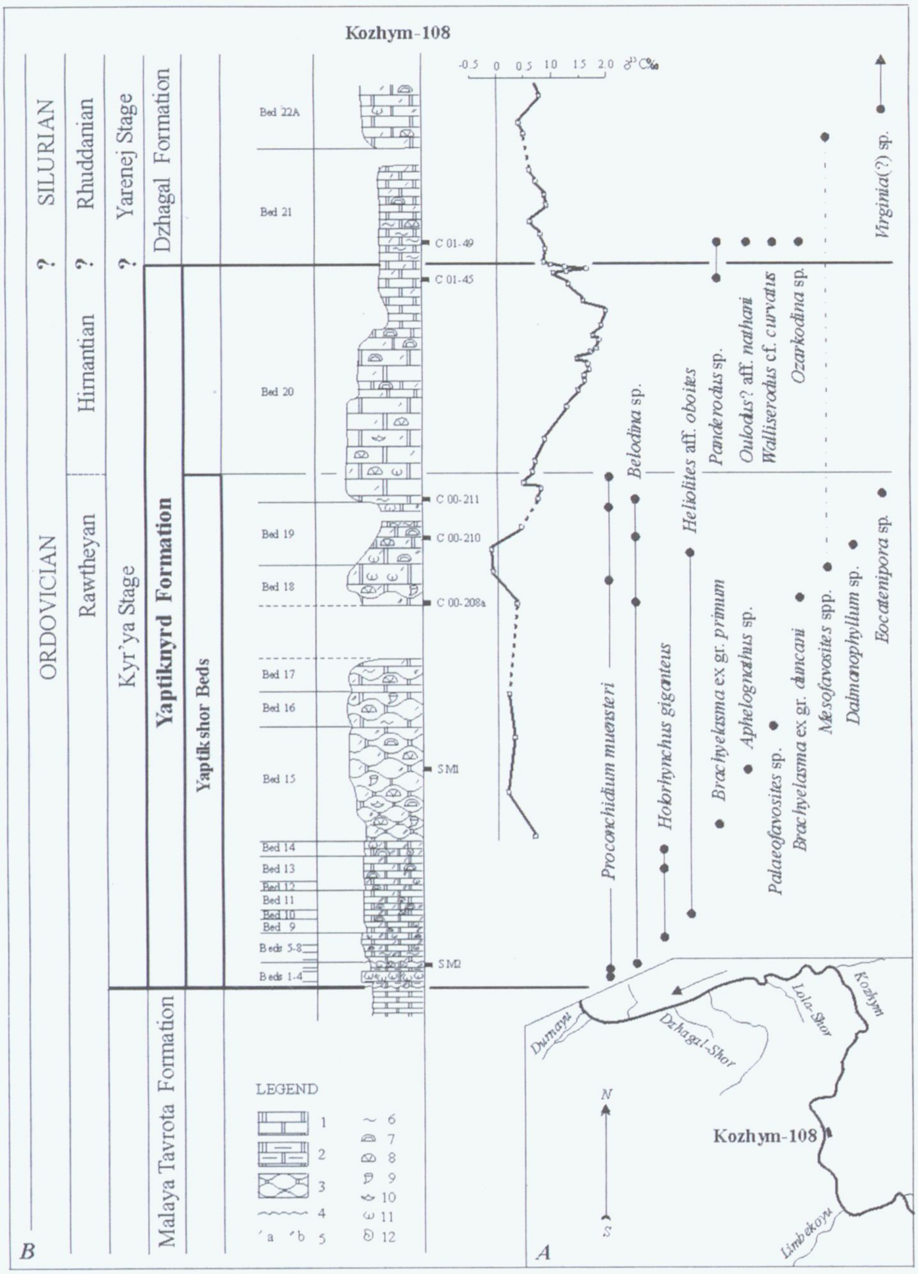

Fig. 1. A – location of the Kozhym-108 section. B – the Kozhym-108 section. From left to right: stratigraphy; numbers of described beds; lithological log; samples with conodonts; $\delta^{13}C$ curve (from Beznosova et al., 2004); distribution of taxa. Legend: 1 – bedded dolostones; 2 – argillaceous dolostones; 3 – nodular dolostones; 4 – erosional surface; 5 – bioclastic material (a – unsorted, b – sorted); 6 – bioturbation; 7 – stromatoporoids; 8 – tabulate corals; 9 – rugose corals; 10 –brachiopods in general; 11 – Pentamerid-brachiopods; 12 – gastropods

3. To deal the strata with the brachiopods *P. muensteri* (St. Joseph) and *H. giganteus* Kiaer as the Yaptikshor Beds (as they were originally defined).

The name of the formation is derived from the Yaptiknyrd Range close to which its type section is located. Both boundaries of the Yaptiknyrd Formation, particularly the lower one, are lithologically distinct in the section. In its stratotype, in the Kozhym-108 section, the total thickness of the Yaptiknyrd Formation is about 138 m (precise measuring is not possible due to some covered intervals and some minor faults in the section). With some reservations, the Yaptiknyrd Formation correlates with the Kyr'ya Stage. In case of occurrence in the section of *P. muensteri* (St. Joseph) and/or *H. giganteus* Kiaer, the Yaptikshor Beds (up to 85 m thick in the Kozhym-108 section; Fig. 1) can be recognized in the lower part of the Yaptiknyrd Formation. The strata of the Yaptiknyrd Formation are well represented in the sections in the Subpolar Urals.

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EARLY FRASNIAN OSTRACODS FROM DEVILS GATE (NEVADA, USA) AND THEIR ENVIRONMENTAL SETTING – RELATION WITH THE ALAMO EVENT

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The Alamo Event was responsible for the deposition of a huge carbonate megabreccia in the eastern part of the Great Basin (Southeastern Nevada). For several searchers this breccia dated early Frasnian and more precisely *punctata* conodont Zone (Sandberg *et al.*, 1997) was the result of an extraterrestrial impact and may have been part of a comet shower (Sandberg *et al.*, 2002). In order to contribute to the knowledge of this event and to appreciate its influence we have undertook the study of ostracods and a sedimentological analysis from the Late *falsiovalis* to the Early *hassi* conodont Zones in the Devils Gate Pass section. This section is located in the Pilot Basin, close to the mining town Eureka, in Nevada (Fig. 1).

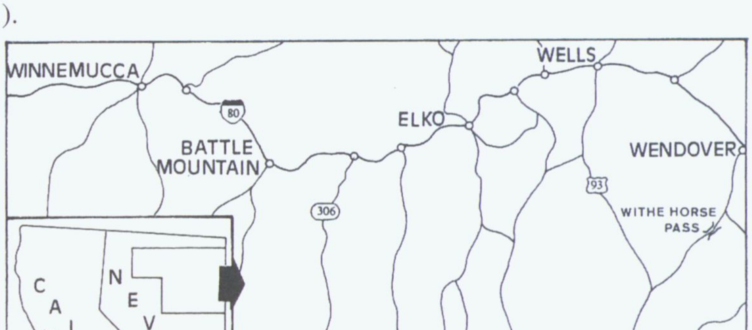

Fig. 1. Locality map of the Devils Gate section

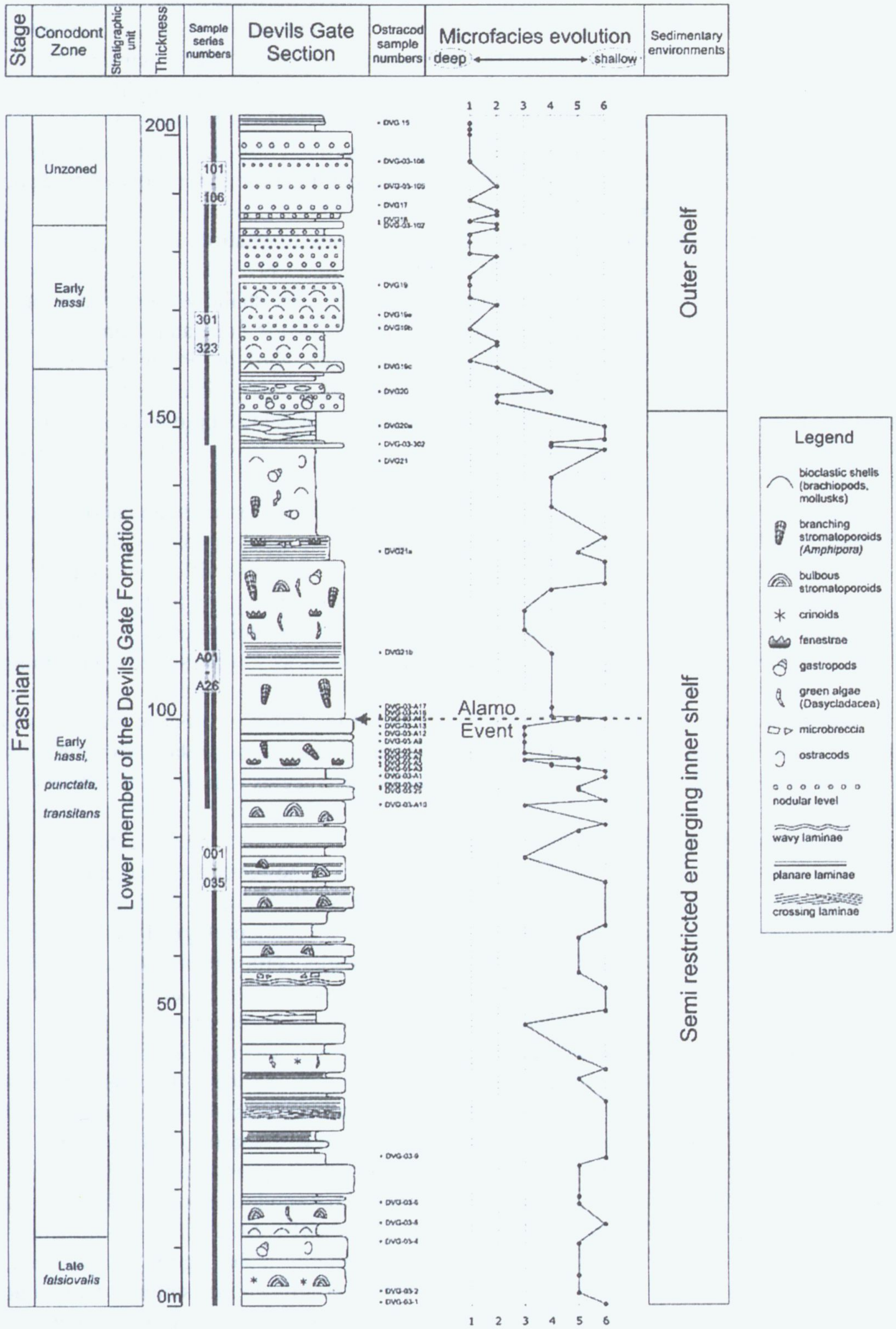

Fig. 2. Lithological column of the lower member of the Devils Gate Limestone Formation in the reference section. Other columns indicate the conodont zones of Sandberg *et al.* (2003), the positions of sedimentological and ostracod samples, the palaeoenvironmental interpretations and the microfacies evolution

Two thousands carapaces, valves and fragments of ostracods have been extracted, and 26 taxa identified, in the lower member of the Devils Gate Limestone Formation (Fig. 2). Ostracods are generally rare or absent, and they belong to the Eifelian Mega-Assemblage indicative of shallow and well oxygenated environments.

The ostracod fauna of the lower member of the Devils Gate Limestone Formation differs greatly from the very rich and diversified ostracod fauna described by Casier and Lethiers (1997, 1998) in the Frasnian part of the upper member of this formation where they suffered an abrupt mass extinction close to the Frasnian/Famennian boundary (Casier *et al.*, 1996). In the investigated part of the lower member, ostracods are poorly diversified and their distribution is greatly influenced by strong salinity variations.

In the base of the lower member of the Devils Gate Limestone Formation, and below the 29-cm thick bed interpreted as a tsunamite related to the Alamo Event (Sandberg *et al.*, 1997; 2003), ostracods are present in three tenths of samples with a relative abundance of platycopids indicating very shallow water conditions. Ostracods are only abundant in one sample collected in the upper part of the Late *fasiovalis* Zone and in another collected probably in the *transitans* Zone. A new species belonging probably to the genus *Voronina* Polenova, 1952, is quasi the sole species present in the first one. This mono-specificity is indicative of semi-restricted water conditions. The second sample contains five species of podocopid, three of platycopid and one of palaeocopid indicating very shallow marine waters. The rarity of ostracods in all other samples indicates shallow and semi-restricted water conditions; their absence could indicate stressful real lagoonal conditions.

In the upper part of the lower member of the Devils Gate Limestone Formation, and above the 29-cm thick bed interpreted as a tsunami related to the Alamo Event, ostracods are present in all samples with only one exception. The platycopids indicative of shallow environments are relatively abundant and diversified until sample DVG-19. In this sample, *Youngiella* cf. *mica* Rozhdestvenskaja, 1972, and a new species belonging to the genus *Serenida* Polenova, 1953, dominate greatly the ostracod fauna. However, the presence of several species of podocopids in all these samples is indicative of strong marine influence. The environment was always very shallow, becoming progressively more marine.

The rarity and poor diversification of ostracods at the base of the lower member of the Devils Gate Limestone Formation is not favourable to display prominently any extinction close to the bed related to the Alamo Event. Nevertheless the greater abundance and diversity of ostracods above this bed seems to indicate the absence of extinction in this shallow setting.

Roughly, the ostracod fauna of the lower member of the Devils Gate Limestone Formation displays more affinities with faunas described by Braun (1967) from Western Canada or, however in a smaller extent, from Baschkiria by Rozhdestvenskaja (1972), comparatively to western Europe and North Africa.

Around 100 samples have been collected from this profile for a sedimentological analysis (Fig. 2). The lower member of the Devils Gate Limestone Formation is composed of 6 major carbonate microfacies (MF1–MF6) ranging from open marine environments below the storm wave base to pre-evaporitic supratidal lagoons. The general environment below the bed related to the Alamo Event consists of a very shallow carbonate platform system. The series are composed of thin-bedded cyclic subtidal-supratidal sequences showing a clear shallowing-upward evolution (from MF3–MF4 to MF5–MF6). The environments are well oxygenated open marine in the base of the sequences with abundant stromatoporoids, brachiopods and crinoids (MF3), and become semi-restricted to hypersaline at the top, with numerous *Calcisphaera*, ostracods and cryptalgal mats associated with loferites (MF5–MF6). The environment remains the same above the bed related to the Alamo Event despite the sequences are thicker and the cyclicity less pronounced. The major change occurred later, during the Early *hassi* conodont Zone *ss* where deeper open marine facies appear with cricoconarides, trilobites, corals and brachiopods (MF1–MF2). The Alamo Event has affected a semi-restricted lagoon colonized by cryptalgal mats. The event brought in the lagoon coarse-sized, well rounded quartz grains (0.5 mm) and microbreccia of the same sizes deriving from lagoonal settings. Consequently the facies analysis reveals that no important sedimentological changes occurred during the Alamo Event. The environment stayed the same (a semi-restricted lagoon), the input of detrital material and of lithoclasts are the only sedimentological records of the fact that a particular or abnormal event or process occurred.

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PROBLEMS OF THE PLEISTOCENE STRATIGRAPHY IN LATVIA

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The Pleistocene sedimentation on the territory of Latvia is seriously influenced by the glacier activity of the Scandinavian Ice Sheet. Extensive studies on Pleistocene stratigraphy in 1960–1980ties have resulted in biostratigraphic subdivision of interglacial sediments and their correlation with other regions. However, our knowledge on Pleistocene fossil assemblages, sediments composition and character of sedimentation even in type sections remains unsatisfactory poor.

This paper is focused on some of the problems of Pleistocene stratigraphy in Western Latvia: 1) the lithostratigraphy of the Satiki Paleolake section, which represents the most complete and typical Felicianova (Eemian, Mikulino) interglacial sequence in Western Latvia; 2) the structural position of the Middle Pleistocene sediments in the Letiza River valley; 3) taxonomic composition of floral remains from the Latvian (Weichselian, Valdai) interstadial sediments.

Satiki site is located in the western part of the Eastern Kursa Upland on the territory of an undulated till plain, close to the Imula River valley. The thickness of the Pleistocene deposits is less than 15 m. Interglacial sediments occur occasionally in places of bedrock depressions. The sequences composed of gyttjas, silts and clays rich in organic matter, including plant macroremains was found in 1977 (Meirons, Straume, 1979). In 1980–1982 test drillings shown that the basin sediments were accumulated in the buried valley-like depression (Meirons and Mūrniece, 1982). The obtained palynological data indicate the sedimentation in the interglacial conditions. Pollen taxonomic composition, character of pollen curve changes and the presence of indicator species pointed on the vegetation dynamic common for the Felicianovian (Eemian) Interglacial (Meirons, Straume, 1979; Kalnina, Juškevičs, 1998; Kalnina *et.al.*, 2004). The following sequence of the Interglacial forest succession has been recognized: *Betula→Pinus→Quercus→Ulmus→Corylus→Alnus→Tilia→Carpinus (Hedera, Vitis, Sambucus nigra, Brasenia* sp. and *Viscum) →Picea→Pinus→Betula.*

The macroscopic studies of plant remains in gyttja resulted in finds of a number of warm demanding plants including *Carpinus betulus* L., *Tilia tomentosa* Moench., *T.* cf. *platyphyllos* Scbp. and *Corylus avellana* L. Numerous aquatic plant, such as *Najas marina* L., *Nymphaea alba* L., *Nuphar lutea* (L.) Smith., *Salvinia natans* (L.) All., *Brasenia* sp., *Trapa* sp., and a lot of different species of *Potamogeton* remains were found (Cerina, 1984).

Biostratigraphic studies clearly confirmed that 3.2 to 14.8 m thick lake sequence (gyttja, silt and clay rich in plant remains and organic matter) located to southeast from the gravel pit at Satiki was accumulated during the Felicianovian (Eemian).

The recent investigation of sedimentary structures of interglacial and glacial deposits exposed along the northern edge of the abandoned gravel pit arouses suspicion on former interpretation of the test drilling data. New observation reveals that bedrock represents by the rafted blocks translocated and altered to some extent (Kalnina *et al.*, 2004). These blocks vary from 1.5 to 4 m in thickness and stretch in a distance of 2–6 m even up to 10–30 m along the northern wall of the gravel pit, previously interpreted as the slope of the buried pre-Quaternary valley sequence. Glaciotectonically rafted and deformed, in places brecciated, the Upper Devonian sandstones, siltstones, clays and dolomites are overlain by glacial deposits, including local tills that have a thickness from some ten centimeters to a few meters. Obviously, in previous investigations the bedrocks in boreholes have been erroneously considered as a sub-Quaternary surface. The Satiki palaeobasin sediments accumulated during the Felicianovian Interglacial do not occur in any outcrop of the gravel pit, but located at a 1.5–6 m depth from surface southeasterly and east-southeasterly from gravel pit. Observed glaciotectonic deformations of the Late Pleistocene deposits in the outcrops of gravel pit and cores (Murniece, 1982) indicate that basin sediments can be deformed and may be altered to some extent. Therefore, it is a question how far paleolake sediment massive (150 x 15 m) has been moved and how it can preserve structure. Can the results of paleobotanical investigations from Satiki sediment sequence be used although cautiously for stratigraphy, or just for lake development? To answer these question the new investigation are needed.

Letiza River valley is located in the southwestern part of Latvia, where number of outcrops and boreholes Latgale (?), Letiza (Elsterian), Pulvernieki (Holsteinian, Lihvin), Kurzeme (Saalian), Latvian (Weichselian, Valdai) were studied. The area is determined as an aerial type site for the Letiza and Kurzeme glacial deposits, therefore there are a number of important sites: the Pulvernieki stratotype site, Deseles Lejnieki, Oglukalns, Jaunskieri etc. Studies of sites were performed during the 1960ties but data on plant macrofossils were poor. In 1980s Z. Meirons have started new studies on glacial and interglacial deposits including the Pulvernieki stratotype (Meirons, Cerina, 1986). Plant remains were studied in details later at the Jaunskieri (Laukgali) and Deseles Lejnieki sections (A. Cerina, 1993). New data provided the stratigraphic subdivision of the section and correlation with the Pulvernieki age (Holsteinian, Lihvian) deposits from the other regions. According the palynological data there is no fixed climate optimum in the borehole Pulvernieki No.7, but there were recognised the basic zones PAZ P2a and P2. As a whole the remains of 75 different plant forms were found including a number of extinct exotic forms e.g. *Aracites interglacialis*, *Caulinia goretskyi*, and *Brasenia borysthenica var. nemenensis*, which are typical for the Lihvin (Holsteinian) interglacial. The significant changes in the taxonomic composition of the macro-remains have been not observed; the thermophylous dominate in the entire succession. A relative homogeneous composition of plant assemblages demonstrates probably the local conditions of sedimentation in basin coastal area.

In the Jaunskieri and Deseles Lejnieki sections the changes in taxonomic composition of macroplant complexes demonstrate several phases and climate changes during the sedimentation. In the basal part of the sections the grey clay and silts contains the remains of Subarctic flora: leaves of *Dryas octopetala*, *Betula nana, Arctostaphylos uva-ursi, Potamogeton filiformis.* At the Jaunskieri site a number of freshwater lake molluscs were found.

At the Deseles Lejnieki site 17 plant forms are recognised as a whole. Its major part is concentrated in silty sediments above the arctic complex and at the base of the gyttja layer. Lake plants are dominant in the assemblages. Nuts of *Eleocharis* are numerous as well as six representatives of *Potamogetonaceae*. The majority of remains are deformed, compressed and indeterminable to the species level due to its scarcity. Gyttja is very strong and hard without any plant macro-remains, but according the palynological data, corresponds to PAZ P2 and P3. Layers overlying the gyttja, are poor in aquatic plants remains, they are much less fossilized, then layers described above. The second layer at the Jaunskieri site, covering the clay with the arctic macrofossil complex, is characterised by silt with Pre-optimum complex, rich in *Picea* needles and seeds. This layer yields the *Larix* needles and seeds, a number of *Betula alba*, *Rubus idaeus* nuts and some aquatic plants as *Characeae, Najas marina* and *Caulinia goretskyi.*

The overlying layer represented by peat gyttja, probably, was accumulated during the climatic optimum. Number of *Trapa* whole nuts, megaspores of *Salvinia natans*, and *Stratoites aloides, Nuphar luteum, Caldesia parnassifolia, Caulinia goretskyi, Aldrovanda cf. vesiculosa* seeds are typical for this part of the section. The overlying sandy silt layer contains *Potamogeton filiformis, Batrachium, Selaginella selaginoides* and fragments of ostracodes. Upward the section deposits become sandy with gyttja and silt interlayers. The studies data confirm arctic conditions during sediment formation. On the basis of plant macro-remains this part of section represent coastal sediments of the new phase in the Jaunskieri Lake development.

New investigations on the Quaternary cover structure in this area cause some doubts in the "*in situ*" location of all mentioned sites. The slope of the Letiza River valley at the Legernieki is heavily slumped and the inclined SSE–NNW trending fold composed of reworked, thinly laminated sands of local bedrock, Quaternary silty material with finely foliated diamicton is nicely exposed. They are underlie Jurassic quartzose sand with inclusions of brown coal pieces of charred wood. The entire sequence below the thin quartzose sand band is heavily compacted, but gravel grains are commonly well rounded (Aboltins *et al.*, 2004). The Legernieki exposures with strongly expressed glaciotectonic activities are located close to the mentioned sites. Therefore, the obvious relocation of large Jurassic rock blocks evokes the doubts on the Pleistocene stratigraphy in the area.

New problems have arisen from the recent glaciotectonic studies and dating with OSL method. One of it is a problem concerning possibility of macroplant remains redeposition and its preservation after repeated redeposition. Thus, problem is mainly concern the finds of *Azolla interglacialica* megaspores in the Latvian (Weichselian, Valdai) in the Early Latvia sediments located above Eemian Sea deposits in the Grini section.

The Gudenieki outcrop in the Baltic Sea Cliff is well investigated and regarded as one of the Ulmale Member parastratotype section (Danilan, 1973). It contains a rich plant macroremain complex (*Azolla interglacialica*, *Selaginella helvetica*, *Caulinia goretskyi*, *Salvinia natans*, *Najas*, *Selaginella selaginoides* and other). A similar complex was found in the Holsteinian Sea sediments in the Akmenarags-45 section in the depth 63.6–55.5 m (pollen zones P4–P5) according to recent investigations and OSL dating from glaciolacustrine sediments 45±5.0 ka (TL 553) (Dreimanis *et al.*, 2004).

There is a great need for a complex of multidisciplinary investigation to solve the Pleistocene stratigraphy problems in Latvia.

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MID–ASHGILL GLOBAL WARMING IN BALTICA – THE BODA EVENT

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The end-Ordovician glacial event has been well-known to geologists for more than twenty years. However, there has been less appreciation of the period of mid-Ashgill global warming which preceded the glaciation, which is now termed the Boda Event (Fortey and Cocks, 2005). During that time there was an increase in the areal distribution of carbonates, with bryozoan mud mounds known even from the then-polar areas of North Africa. Many fossil species, including those of trilobites, brachiopods and graptolites, extended their geographical ranges to higher latitudes during the event.

In Baltica, whose then northern extremity had just crossed the palaeoequator by mid-Ashgill times, the global warming was characterised by the widespread formation and distribution of very substantial carbonate mud mounds, such as the Boda Limestone of Sweden, after which the Boda Event is named, and the Pirgu Horizon mud mounds of Estonia, as well as the mid-Ashgill mud mounds recorded from Novaya Zemlya and the Ural Mountains. There are even some mud mounds recorded geophysically from under the Baltic Sea and Gotland (Nestor, 1995).

The Boda Event is also reflected in the biological radiation of some animal groups. For example, the strophomenoidean brachiopods were already recorded (Harper, Cocks, Popov *et al.*, 2004) to be at their all time global maximum diversity in the mid-Ashgill; and it is now further known (Cocks, 2005) that in the Boda Limestone itself there are over twenty strophomenoidean species, with at least five endemic genera, further enhancing that peak. The plectambonitoidean brachiopods from the Boda Limestone, although not including endemic genera, are also very diverse.

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NEW DATA ON STRATIGRAPHY AND TRILOBITES FROM THE JÕHVI STAGE (UPPER ORDOVICIAN, CARADOC) OF THE LENINGRAD REGION, RUSSIA

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The study of the Upper Ordovician strata in the vicinity of St. Petersburg has a long history that starts at the second half of the 19th century (Schmidt, 1881, 1885, 1898, 1901, 1907; Asatkin, 1931, Lutkevich, 1928, 1939; Rõõmusoks, 1970; Balashova, 1976). However, up till now our knowledge on the Upper Ordovician stratigraphy and fauna of the Russian part of the Glint area is unsatisfactory poor. Sediments of the Jõhvi Stage are among the less studied in the St. Petersburg region especially in comparison with the relatively well-studied contemporaneous strata in Estonia. The stratotype of the Jõhvi Stage is the section in the Kambrmagi Quarry situated near the town Jõhvi (former name) in the northeastern Estonia (Decisions of MSK…, 1987; p. 28). The Jõhvi Stage is recognised in the type area as the beds with *Clitambon anomalus, Toxochasmops maximus, Rollmops wenjukowi, Porambonites schmidti, Hemicosmites extraneus* and some other fossils. The Stage corresponds to the formation of same name with a lower boundary marked by the bed of bentonite (bed b) that overlain by carbonate succession with *Amplexograptus* cf. *fallax*. Thickness of the Jõhvi Formation in the type area is 9–12 m, whereas in the Russian part of the basin it comprises more than 15 m. In the vicinity of St. Petersburg the sediments of the Jõhvi Stage are assigned to the Khrevitsa Formation having a stratotype on the right bank of the Khrevitsa River (Decisions of MSK…, 1987; p. 35).

The present paper is focused on trilobite biostratigraphy of the Jõhvi Stage from the western part of the Leningrad Region. During several field trips the type section of the Khrevitsa Fm. and the section exposed in the small quarry near the village Slobodka were studied. Both these localities and especially the first one were briefly described by previous investigators (Asatkin, 1931: p.7; Bok, 1868, Lutkevich, 1939: p. 138), however they were studied in details and sampled systematically bed-by-bed on macrofossils for the first time. The collection comprises more than two hundreds of trilobite specimens as well as numerous brachiopods, echinoderms, sponges, bryozoans, gastropods, cephalopods, bivalves and graptolites. Stratigraphic column of the Khrevitsa River section and ranges of selected fossils found in the section are shown in the Field Guide of the 6th BSA Conference (August, 2005). The less known section in the Slobodka Quarry is briefly described in this paper.

The Slobodka Quarry is situated in 1 km to the southwest from the village Slobodka in two km from the highway connecting St. Petersburg and Tallinn (Fig. 1). The section of the Khrevitsa Fm. is composed of 21 massive beds of yellowish-grey clayey limestones and dolstones (Fig.1). The observed succession is rather monotonous with the only one distinctive layer in the medium part of the section. This layer (Bed 7) is represented by strongly leached massive dolomite with the bright-red coloured bedding surface on it top bearing numerous trace fossils including traces of boring. Thin layer of clay covers the bedding surface that more likely represents the hard ground surface.

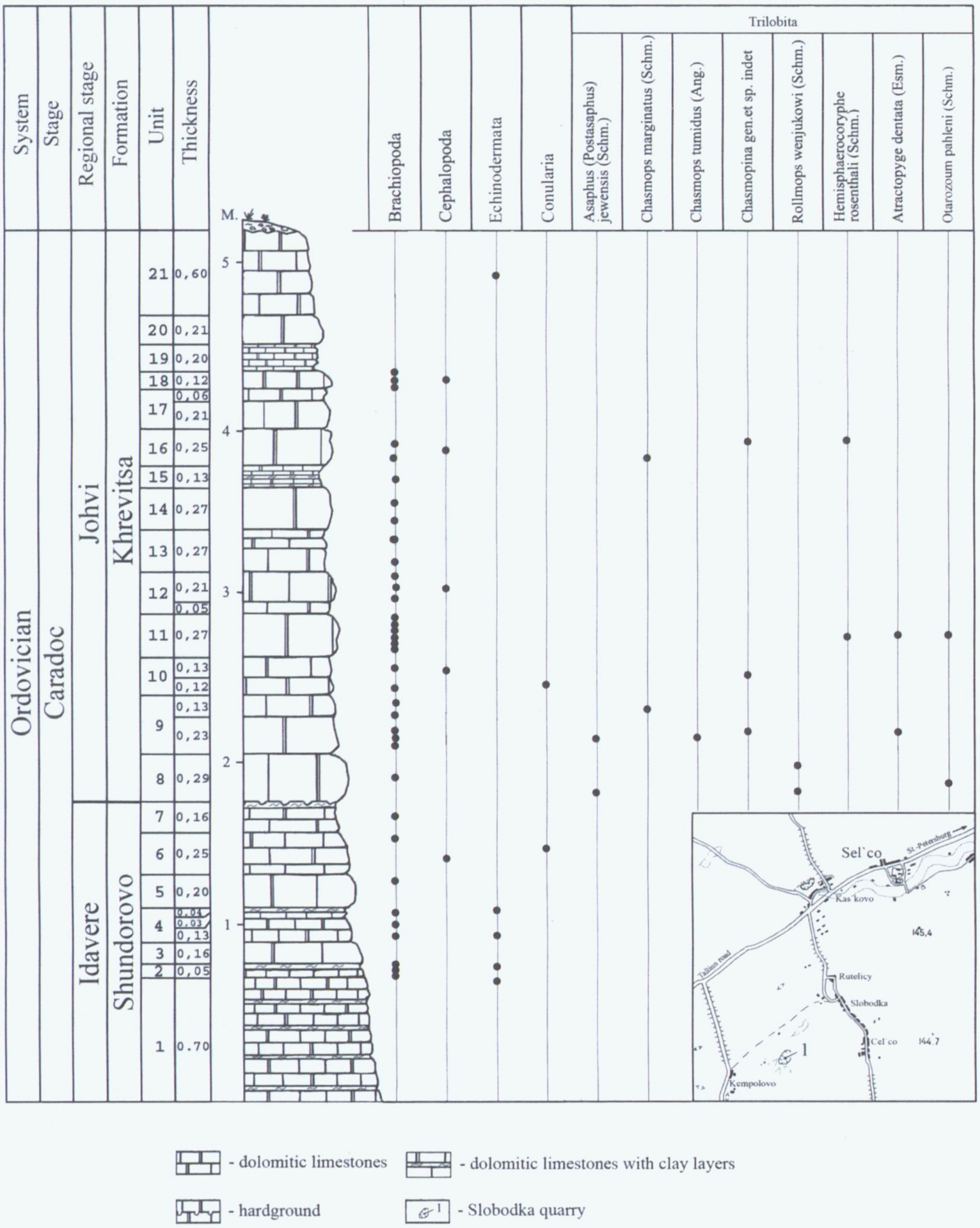

Fig. 1. Schematic drawing of the Slobodka Quarry section and distribution of selected macrofossils

The overlying succession (from Bed 8 and above) is composed of grey slightly dolomitesed limestones (Fig. 1). The fossil remains are randomly distributed through the section and represented mainly by internal moulds and imprints. As a whole more than several hundred specimens were collected, among them are brachiopods, echinoderms, sponges, conulariids, cephalopods and trilobites. The following trilobites were identified: *Asaphus* (*Postasphus*) *jewesis* (Schm.), *Chasmops marginatus* (Schm.), *Chasmops tumidus* (Ang.), *Rollmops wenjukowi* (Schm.), *Hemisphaerocoryphe* *rosenthali* (Schm.), *Atractopyge dentata* (Esm.), *Otarozoum pahleni* (Schm.), *Toxochasmops* (*Schmidtops*) sp., *Chasmopina* sp. and Lichoidea. Some taxa were found in St. Petersburg Region for the first time that allows us to extend the range of their geographic distribution. All trilobites were found above the distinctive red layer at the top of the Bed 7, whereas in the underlying sediments trilobites are absent. In the strata underlying Bed 7 we have found only numerous brachiopods and sponges. The trilobite assemblage listed above is typical of the Jõhvi Stage; therefore the lower boundary of the Jõhvi Stage in the section can be tentatively placed between the Bed 7 and 8. However the position of the stage boundary is definitely uncertain, as we do not know if the appearance of the specific trilobite assemblage is evolutionary or connected with the facies shift.

The studies of the Jõhvi Stage sections are going to be continued and I hope that integration study of the different fossil groups including microfossils will help to identify the Jõhvi Stage boundaries in the section in the vicinity of St. Petersburg.

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SEA–LEVEL CURVE FOR THE ORDOVICIAN OF BALTOSCANDIA: CONTRADICTIONS, PROBLEMS AND APPROACHES

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First estimates of water depth in the Ordovician palaeobasin of Baltoscandia go back to the times of V. Lamansky (1905), but regional sea-level curves for the whole system appeared only recently (Nestor and Einasto, 1997; Dronov and Holmer, 2002; Nielsen, 2003; 2004). For the Volkhovian stratigraphic interval more detailed sea-level curves have been elaborated (Nielsen, 1992; Dronov, 1997). Comparison of the curves displays disagreements between curves constructed for the shallow-water part of the basin (Dronov, 1997; Nestor and Einasto, 1997; Dronov and Holmer, 2002) and those based on relatively deep-water sections (Nielsen, 1992; 2003; 2004).

The deep-water model for the whole Ordovician assumes a prominent sea level drop at the base of the Middle Ordovician and a long-term lowstand throughout the "Volkhovian" and Darriwilian (80–100 m lower than in the Lower and Upper Ordovician). In contrast, the shallow-water models suggest only moderate sea-level drop at the base of the Middle Ordovician (base of Volkhov Regional Stage), without any prominent erosion of the underlying deposits, and a long-term highstand during the Middle Ordovician.

Detailed sea-level curves for the Volkhovian interval are also different. According to the deep-water model, $B_{II}\alpha/B_{II}\beta$ boundary marks a shallowing (regressive) event. In the shallow-water model this boundary marks a deepening (transgressive) event. In the deep-water model the sea level is assumed to be higher during the $B_{II}\alpha$ to compare with $B_{II}\beta$. In shallow-water model it is vice versa.

These disagreements are due to major differences in facies and stratigraphic interpretations and can be summarized as follows:

1) Differences in facies interpretations. In particular, high clay content in the carbonate sediments is regarded as an evidence for sea level drop in the deep-water models and as an evidence for sea level rise in the shallow-water models.

2) Problems of biostratigraphic correlation. Lack of high resolution biostratigraphic framework for some stratigraphic intervals and/or in some parts of the palaeobasin enables different correlation hypotheses. List of controversies in the Upper Ordovician correlations has been published recently by A. Nielsen and T. Meidla (2004);

3) Uneven coverage of palaeobasin area with detailed litho- and biofacies analyses. Ordovician carbonates in the East Baltic area has been studied by facies analyses in different stratigraphic intervals, while scattered distribution pattern or deep burial of sediments has made difficult to do similar analyses in other parts of the palaeobasin. Also, the facies distribution details collected during the century need to be re-evaluated within the concept of sequence stratigraphy.

4) Shortage of information on stratal geometry and shifts of depocentres. Only for the kukersite oil shale-bearing succession (Uhaku and Kukruse stages) and for the overlying Haljala–Keila interval in northern Estonia a progradational stacking patterns has been clearly demonstrated (Saadre and Suuroja, 1993; Nemliher and Ainsaar, 2002). Stratal geometry and shifts of depocentres for the whole Viru Series (from the Aseri to Rakvere stages) in Estonia is presented by R. Nemliher and L. Ainsaar in this volume.

5) Different approaches to sea-level curve reconstruction. Deep-water model is based on ecostratigraphy and event stratigraphy concepts, being presented in terms like "drowning event", "transgressive event", "regressive event", "highstand interval", "lowstand interval" etc (Nielsen, 1992; 2003; 2004). The shallow-water models have been developed from litho- and biofacies analyses (Männil, 1966; Nestor and Einasto, 1997) to models based on sequence stratigraphy concept with its terminology (depositional sequences, parasequences, sequence boundaries, transgressive and maximum flooding surfaces, systems tracts etc; Dronov and Holmer, 1999; 2002; Harris *et al.*, 2004).

All topics listed above can be addressed via complex studies on selected sections (drill-cores and outcrops). The authors have scheduled detailed investigation along several East Baltic facies profiles. For the crucial stratigraphic intervals (Billingen-Aseri, Haljala, Vormsi stages) detailed lithofacies analysis will be performed and specific depositional models will be tested. The stratal geometry and shifts of depocentres and facies will be documented throughout the succession. The main goal of the study is to elaborate a relevant sequence stratigraphic framework and to develop an enhanced sea-level reconstruction for the Baltoscandian area.

This investigation will be a contribution to the IGCP project 503 "Ordovician Palaeogeography and Palaeoclimate".

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COMPOSITION OF CLAY MINERALS IN THE LOWER ORDOVICIAN (THE VARANGU, HUNNEBERG AND BILLINGEN REGIONAL STAGES) SEDIMENTS FROM THE PUTILOVO QUARRY

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Clay minerals are considered to be one of the most important components in sediments and are used as tracers for very different purposes: for example, they are paleoenvironmental indicators and stratigraphic markers. In this study, the clay samples from the Lower Ordovician (the Varangu, Hunneberg and Billingen regional stages) strata exposed in the Putilovo Quarry have been examined (Fig. 1). The minerals have been identified based on X-ray diffractometer patterns recorded from airdried and ethylene-glycol treated smear slides. In order to achieve good reproducibility powder diffractometer with filtered Co Kα radiation were used. The determination of clay mineral contents was based on weighed integrated intensities of XRD reflections. Eight samples were investigated. Only two clay minerals: illite and Mg-chlorite were determined. Illite accounts for the majority of clay minerals in the study whereas chlorite ranges from 0 to 20 percents. Such an association of clay minerals is usually characteristic of the temperate climatic belt.

The amount of chlorite tends to increase in the Lakiti and Mjaekule beds. This tendency might have been connected with a short-time episode of a climate cooling.

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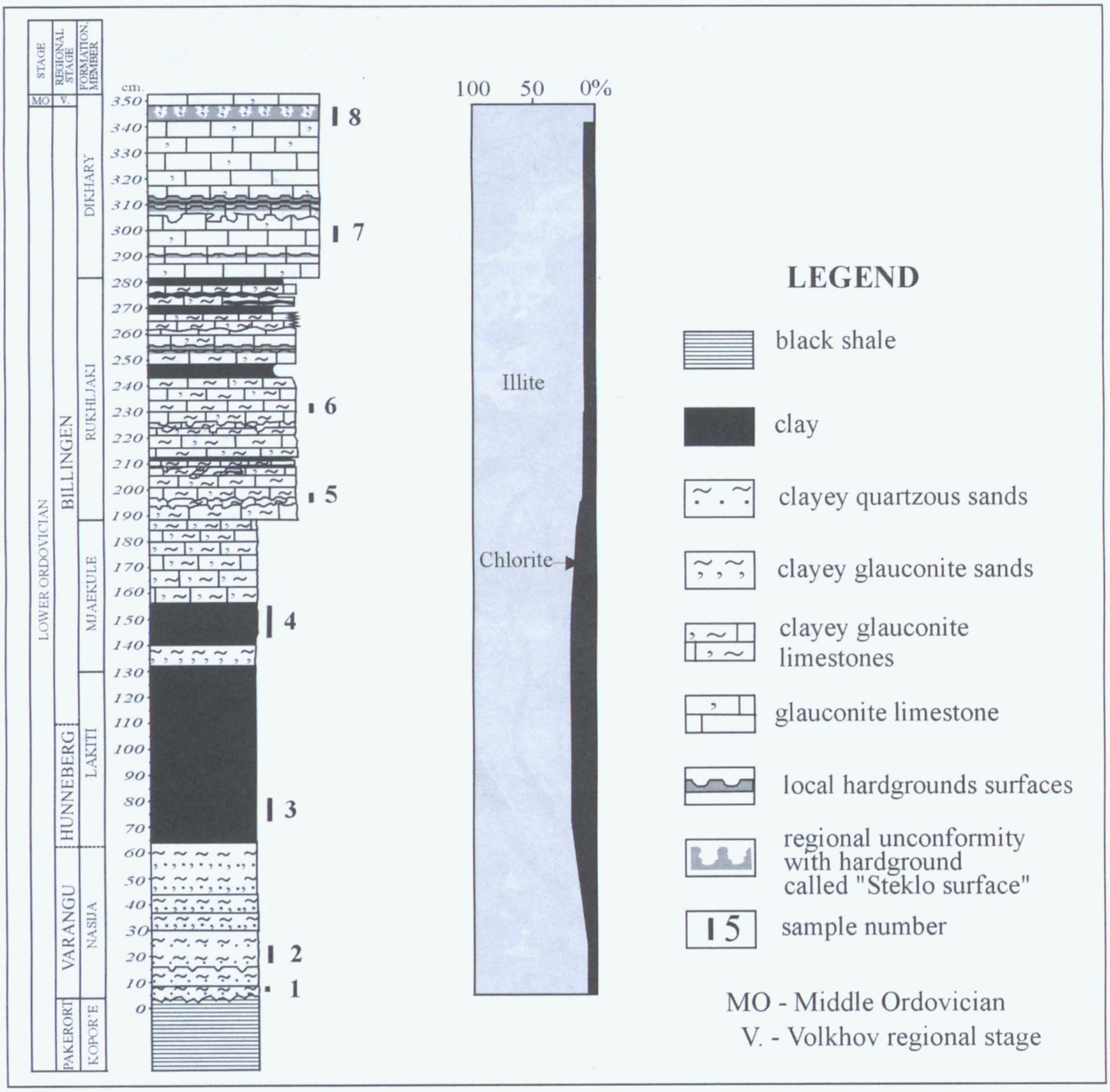

Fig. 1. Distribution of clay minerals in the section of the Putilovo Quarry (Varangu, Hunnneberg and Billingen Regional Stages)

WEICHSELIAN TILL PETROGRAPHY IN THE SOUTH–WESTERN MAZURY LAKELAND, NORTHERN POLAND

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Petrographic methods perform still significant part in investigations of glacial tills, making possible litostratygraphic correlation of sediments. Iława region (Fig. 1) is a classic area of glacial and fluvioglacial deposition resulting from the interaction of two large lobes of the ice sheet that advanced over this area in Late Weichselian time and then gradually receded to the north. Stillstands of the margins of these two lobes – Vistulian lobe on the west and Mazurian lobe to the east – are marked by prominent terminal moraines and/or a diversity of ice-contact and outwash deposits that range in thickness from 10 to 80 m.

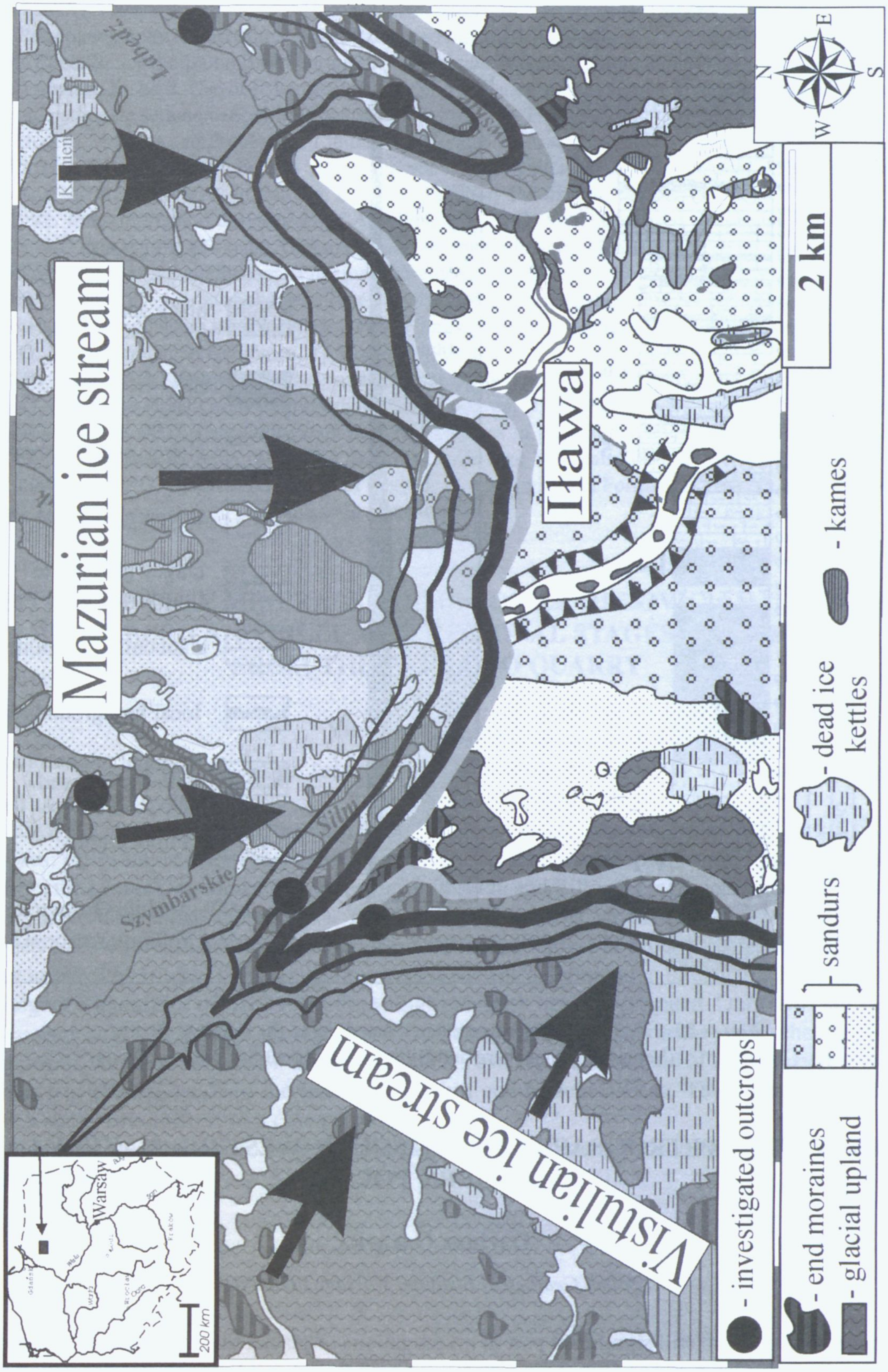

Fig. 1. Geomorphological sketch of the interlobate zone between Vistulian and Mazurian ice streams in the vicinity of Iława city, SW Mazury Lakeland

In the test-area (South-Western Mazury Lakeland, Northern Poland) there are only 2 till horizons (T1, T2) available in small outcrops, which characterised by different petrographic composition of boulder (erratic) and gravel. This differentiation results probably from egzaration of different parts of Fennoscandia by glacier during the Pleistocene. Two till horizons in tested outcrops belonging to different glacial advances. Each advance should receives material (boulders and gravel) from different part of Fennoscandia.

The detailed objectives of the research comprised analysis of: gravel coefficient (Lisicki, 2003), **t**heoretical **p**ebble **c**entre (**TPC**; Lüttig, 1958), composition of indicator erratic (Smed, Ehlers, 2002).

Indicator (trace) erratic were grouped in ten petrographic provinces: Bornholm, Bohuslän, Småland, Dalarna, Uppland, Ångermanland, Central Baltic, Åland, SW Finland and SE Finland.

Petrographic analysis of about 10000 erratic from 11 outcrops in this area points on unique petrographic composition (Tab. 1, Fig. 2) in two youngest till horizons due to its position in the two glacial ice streams: Vistulian and Mazurian during the last glaciation (Leszno-Poznań Phase and Pomeranian Phase).

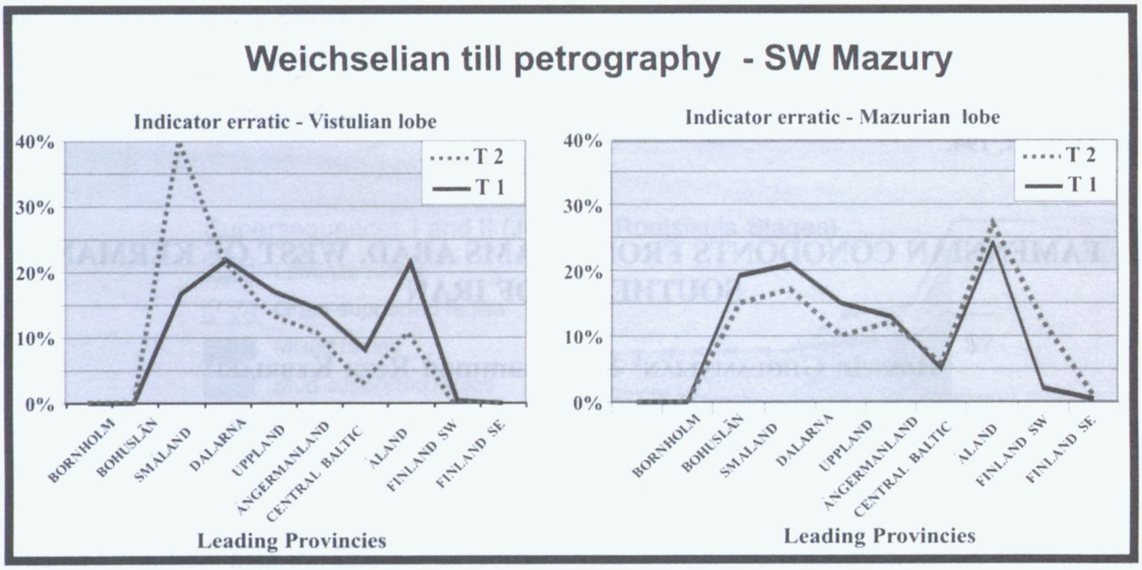

Fig. 2. Unique petrographic composition of indicator erratic (Leading Provinces method; Nunberg, 1971) from two youngest Weichselian tills due to its position in different glacial lobes (T1, T2 – see tab. 1)

Table 1

Till (Lithostratigraphy)	Features		Chronostratigraphy
	Erratic boulders main differences	Gravel main differences	
T2 – Mazurian lobe	Åland + Dalarna	Wp+Dp	Weichselian Pomeranian Phase
T2 – Vistulian lobe	Småland	Kr+Qp	
T1 – Mazurian lobe	Åland	Wp+Dp+M1	Weichselian Leszno-Poznań Phase
T1 – Vistulian lobe	Småland + Uppland	Kr+Pp+Qp	

In petrographic composition of gravel we can observe slightly variability of petrographic features – this means variability in contain of main petrographic groups (Kr – crystalline rocks; Wp – limestone Dp– dolomite; Pp– sandstone; Qp– quartz; Lp – shale and additional: M1 – Palaeogene mudstone – local rock) and in value of so-called petrographic coefficients (mathematical proportion between sum of petrographic group): **O/K**; **K/W**; **A/B,** where:

O = Wp + Dp + Pp; **K** = Kr + Qp; **W** = Wp + Dp;

A = Wp + Dp+ Lp; **B** = Kr + Pp + Qp

Values of each petrographic feature (for gravel and boulders) have a normal distribution with characteristic dominant. In all cases each till horizon characterised by different distribution described by mean and standard deviation. These differences have statistic meanings. Considerably more strong differentiation of petrographic features is observed in perpendicular profile (between two till horizons) than lateral within one till horizons in the same glacial lobe but additionally there is also petrographic difference (with statistic meanings) between tills of the same age investigated in the different glacial lobes.

Applied both methods let me device these tills into some lithostratigraphic units and then, based on general knowledge about stratigraphy in the SW Mazury Lakeland region correlate them with chronostratigarphic units (Tab. 1).

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FAMENNIAN CONODONTS FROM SHAMS ABAD, WEST OF KERMAN, SOUTHEAST OF IRAN

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The conodont investigations in Shams Abad section, west of Kerman (SE Iran) proved the Early Famennian age of this section. The presence of *Icriodus alternatus alternatus, I. cornutus, I. iowaensis iowaensis, I. iowaensis ancylus, Polygnathus semicostatus, P. comunis, Pelekysgnathus serradentatus* and *Pele. inclinatus* confirm that the section studied encompass the middle and upper parts of the *crepida* zones, so the Frasnian age that was proposed by previous authors for the lower part of the section is failed. Some polygnathids similar to *P. alatus* are associated with the other conodont fauna.

THE LOWER SILURIAN OF ESTONIA: FACIES, SEQUENCES AND BASIN FILLING

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The lower Silurian (Llandovery to Wenlock) section of Estonia spans the transition from the Baltic Shield to the Livonian Basin (Fig. 1). The section can be divided into seven depositional sequences that comprise two larger-scale "supersequence" packages with different styles of basin filling (Fig. 2 and 3). Facies within sequences reflect both intra-sequence patterns and variations related to position within the supersequences. Sequence-by-sequence analyses delineate paleogeographic patterns linked to changes in the position of the shelf edge and localized slope erosion.

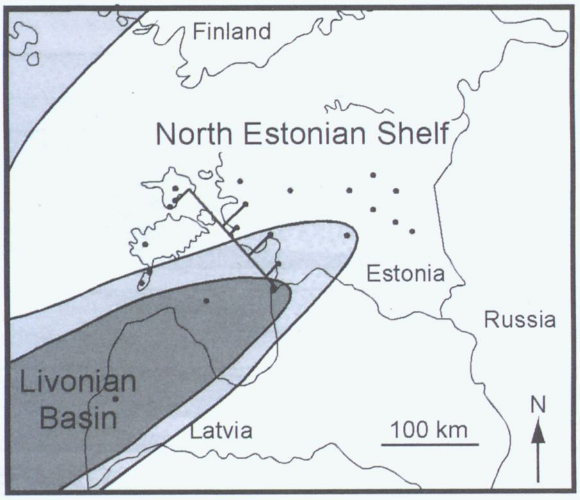

Fig. 1. Earliest Silurian (Juuru) facies belts, modified from Kaljo and Hints (1996) and Baarli *et al.* (2003), with the locations of described wells (circles) and cross-section of Figure 2

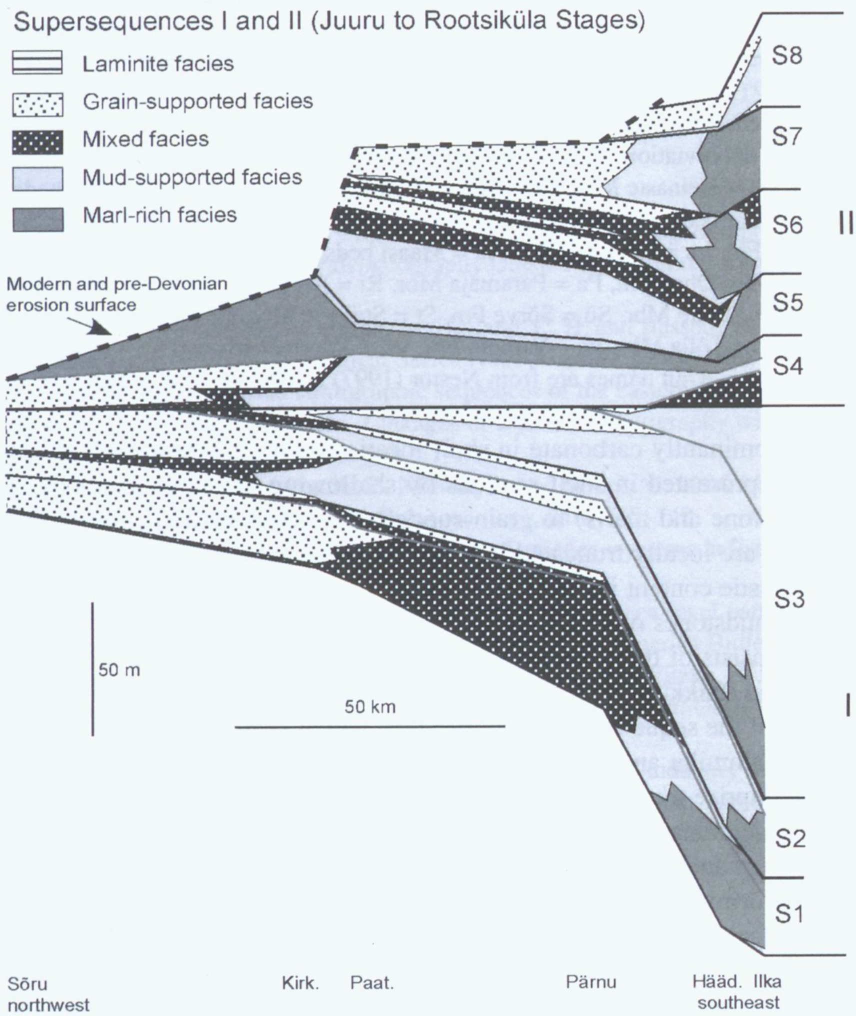

Fig. 2. Facies cross-section of Juuru through Rootsiküla stages. Cross-section location indicated in Figure 1 and wells are labeled along the base of the figure

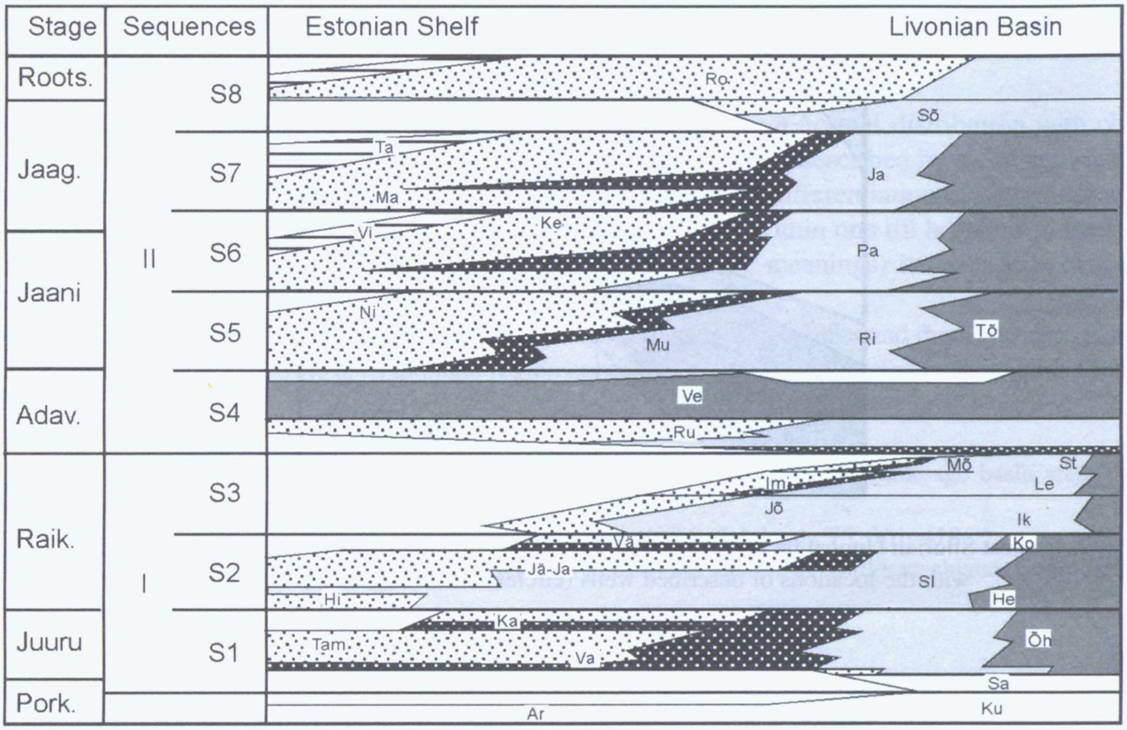

Fig. 3. Time space chart for Juuru through Rootsiküla stages based on the entire network of described wells. The two-letter abbreviations indicate the approximate position of the following stratigraphic units: Är = Ärina Fm, He = Heinaste Mbr, Hi = Hilliste Fm, Ik = Ikla Mbr, Im = Imavere beds, Ja = Jamaja Fm, Jä-Ja = Järva-Jaani beds, Jõ = Jõgeva beds, Ka = Karinu Mbr, Ke = Kesselaid Mbr, Ko = Kolka Mbr, Ku = Kuldiga Fm, Le = Lemme Mbr, Ma = Maasi beds, Mõ = Mõhküla beds, Mu = Mustjala Mbr, Ni = Ninase Mbr, Õh = Õhne Fm, Pa = Paramaja Mbr, Ri = Riga Fm, Ro = Rootsiküla Fm, Ru = Rumba Fm, Sa = Saldus Fm, Sl = Slitere Mbr, Sõ = Sõrve Fm, St = Staicele Mbr, Ta = Tagavere Beds, Tam = Tamsalu Fm, Tõ = Tõlla Mbr, Va = Varbola Fm, Vä = Vändra beds and Ve = Velise Fm. Unit names are from Nestor (1997) and Nestor et al. (2003)

The section is predominantly carbonate in shelf locations with increasing siliciclastic content in downdip facies. The sequences are represented in shelf sections by shallowing-upward successions that grade from mud-supported (wackestone, mudstone and marls) to grain-supported (grainstone and packstone) facies. Slope sections are mud-supported facies that are locally truncated by submarine erosion surfaces. Basinal deposits are mudstones and marls with greater siliciclastic content in more distal areas. Lowstand deposits can be recognized in some sequences and consist of grain-rich mudstones or packstones.

Supersequence I consists of three sequences that include the uppermost Porkuni (Ordovician) Saldus Formation and the entire Juuru and Raikküla Stages. The redeposited debris of the basinally-restricted Saldus is the lowstand of Sequence S1. The rest of the sequence is the Juuru Stage which shallows upward into the skeletal grainstones and lagoonal deposits of the Tammiku and Karinu units. The Raikküla Stage consists of two sequences: (1) The Järva-Jaani and Vändra beds comprise the shelf deposits of Sequence S2 with a localized updip transgressive unit (Hilliste Formation). The Slitere (including the basal Heinaste beds) and Kolka are the basinal equivalents. (2) Sequence S3 includes the Jõgeva, Imavere and Mõhküla beds in updip locations and the downdip Ikla, Lemme and Staicele members. A basin-wide unconformity caps all shelf and slope sections, and is marked by a notable hiatus in updip locations. The thickness and facies patterns of sequences S1 to S3 indicate lateral basin infilling to the southeast that builds outward from the late Ordovician (Pirgu) shelf edge (Harris *et al.*, 2004). The sequences are more argillaceous and thicker than underlying Ordovician units but the facies patterns are similar. Facies relations suggest a slight high in the northwest (Hiiumaa Island).

A major flooding event marks the base of Supersequence II, as reflected in the facies and systems tract development within Sequence S4 (equivalent to the Adavere Stage). Well-defined lowstand and trangressive deposits (Rumba

Formation) occur in basin and outer-to-mid shelf locations, and are overlain by the regionally-extensive Velise marls. The upper sequence boundary is marked by submarine erosion (or slumping) above the buried paleoslope and local deposits of redeposited ooids. (This gap increases to the northeast of Figure 2.) Sequences S5 to S7 contain shallowing-upward shelf successions that consist of marls capped by shallow-water shoal or tidal flat deposits. In places, beds below the inferred sequence boundaries are marked by moldic porosity and/or dolomitization. Sequence S5 comprises the bulk of the Jaani Stage, with a shelf section capped by the shoals of the Ninase Member. Sequence S6 includes upper Jaani Stage (Paramaja), and lower Jaagarahu Stage (Vilsandi beds and Kesslaid Member). Another shallowing-upward package (Maasi to Tagavere beds and their equivalents) comprises Sequence S7. The Sõrve Formation (uppermost Jaagarahu Stage is the lowstand and transgressive system tracts of the overlying Sequence S8 that also includes some or all of the Rootsiküla Stage. Sequences S4 to S7 thicken to the south or southwest but facies patterns indicate that significant facies progradation not occurring until Sequence S8. The aggradational facies pattern appears to be the result of the shelf topography inherited from Late Ordovician strata.

The major differences between Supersequence I and II are the southeast to southwest shift in primary location of sediment accumulation, the geometric change from lateral sequence progradation to a pattern dominated by vertical aggradation (due to increased subsidence), and the increase in siliciclastics at the onset of Supersequence II. The change in sediment accumulation pattern appears due, in part, to depositional infilling of the northeast end of the Livonian Basin as a result of sediment accumulation in the Late Ordovician and Early Silurian. The increased subsidence and siliciclastic influx that began in the Adavere (late Llandovery) is probably due to tectonic changes (loading) along the western or southwestern (modern orientation) parts of Baltica that caused regional tilting and increased supply of siliciclastics (Bassett *et al.*, 1989; Baarli *et al.*, 2003). Despite the effects of local basin topography, the sequences appear broadly correlative to those in Laurentian successions (Harris and Sheehan, 1998). The sequence analysis presented here is more detailed than that of Johnson *et al.* (1991) and Johnson (1996) but the major flooding and exposure events coincide.

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PROPOSAL FOR THE BOUNDARY STRATOTYPE OF THE PIRGU REGIONAL STAGE (UPPER ORDOVICIAN) IN THE EAST BALTIC

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During the last decades the activities of the IUGS commissions on stratigraphy have focused on the elaboration of a single set of global series and stages, and the standardised global units have been defined by the boundary-stratotype sections and points (GSSP). The use of the same principle in defining the regional units should contribute to more precise correlation of sections. Most of the Ordovician stages in the East Baltic have been established by the stratotype sections, which define a body of rock typical for the unit. In many cases these type sections represent only part of the total thickness of the stage (see Hints, L. *et al.*, 1995, fig. 3). The main criteria for the use of the regional stages in practice have been worked out during complex lithological-biostratigraphical studies.

The studies of the Pirgu Stage during the last years and its correlation by different authors have revealed a need to define that stage more precisely. Following the practice of the determination of global units by the GSSP and application of that principle in the redefinition of the Upper Ordovician Keila Stage (Hints, O. & Nõlvak, 1999) in the East Baltic, we propose to define the Pirgu Stage by its lower boundary in the Paluküla old quarry in Hiiumaa Island (Fig. 1).

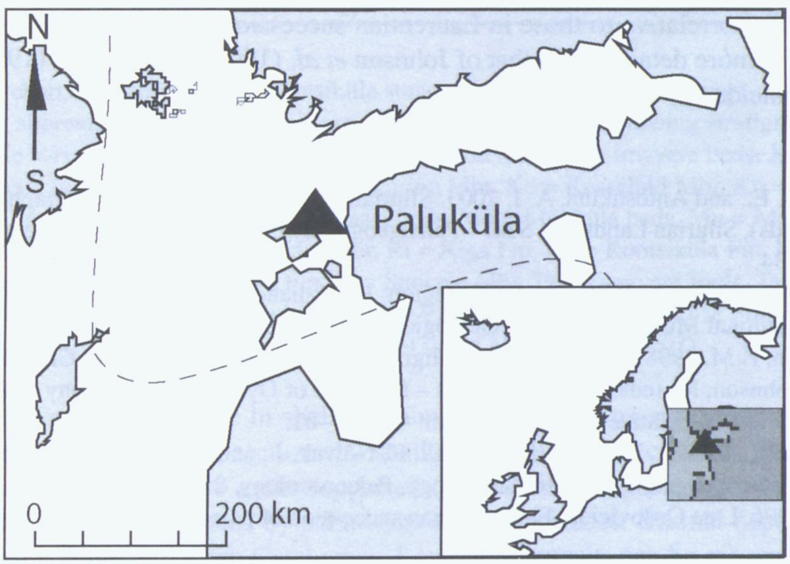

Fig. 1. Location of the Paluküla quarry

The 3.2 m thick Paluküla quarry section is the only section in Estonia where the boundary beds between the Pirgu and Vormsi stages are exposed. Oraspõld (1991) describes three intervals in the upper three quarters of the section (2.4 m). The uppermost 1.2 m of the section (interval 0–1.2 m from the top of the quarry) is represented by brownish grey seminodular very fine to fine-crystalline limestone. The content of insoluble residue is about 5 %, and skeletal debris accounts for 19–30.9 % (on average 25.1 % by 10 samples). Fragments of chlorophyte algae (*Paleoporella*?) form the main part (about 76 %) of skeletal debris. The middle 0.6 m part of the section (interval 1.2–1.8 m from the top) consists of brownish-grey seminodular fine to very fine-crystalline limestone with insoluble residue up to 12 %. Skeletal debris forms on average 20 % of the rock and consists predominantly (42 %) of skeletal fragments of echinoderms in association with fragments of algae (28 %), bryozoa (20 %) and other groups of fossils (ostracodes, brachiopods, trilobites). The lowermost 1.4 m (interval 1.8–3.2 m from the top) consist of grey to weakly brownish, microcrystalline medium-bedded limestone containing 5–10 % insoluble residue and 22–32 % skeletal debris. The last component consists mainly of fragments of echinoderms (42.2 %), algae (*Vermiporella*?) (27.9 %) and bryozoa (20.2 %). Two discontinuity surfaces with pyritic impregnation occur in the lower unit – one on the top and the other 0.5 m lower. Oraspõld (1991) includes the uppermost of the described units in the Pirgu Stage (Moe Formation); the middle unit is transitional (Pirgu Stage by Meidla, 1983) and the lower unit represents the Vormsi Stage (Kõrgessaare Formation).

The Moe Formation in the Paluküla section in Hiiumaa differs from those on the mainland of Estonia in the absence of coarse-grained debris of algae (*Paleoporella*), sometimes forming algal limestone interlayers (e.g. in Central Estonia). However in Paluküla, the same algae make up an essential part of the fine-grained skeletal debris in the uppermost interval (0–1.2 m) and is not represented in the lower part of the section (1.8–2.4 m) characterized by debris of vermiporellids (Fig. 2).

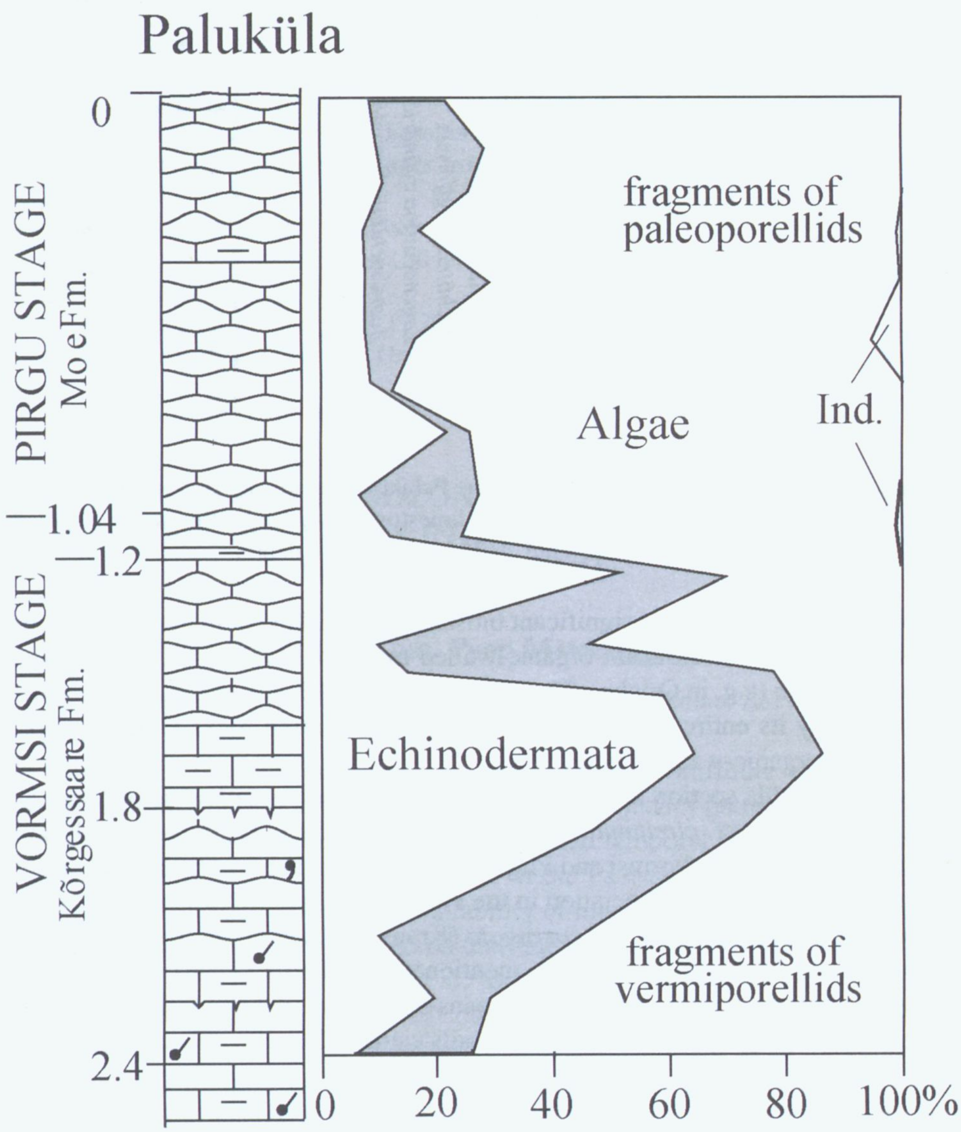

Fig. 2. Composition of the skeletal debris (in %) in the Paluküla section by Oraspõld (1991). Grey area marks relative amount of the fragments of ostracodes, brachiopods, bryozoans and trilobites together. Ind. – unidentified fragments

The study of chitinozoans in the Paluküla quarry and drill core sections, including the Orjaku core in Hiiumaa (see Kaljo *et al.*, 2004, fig. 4), revealed that the boundary interval between the Vormsi and Pirgu regional stages corresponds to the chitinozoan *Tanuchitina bergstroemi* Biozone (Nõlvak & Grahn, 1993). In the middle of this zone the *Acanthochitina barbata* Subzone forms a distinct biostratigraphical unit in the upper part of the Kõrgessaare, Tudulinna and Fjäcka formations, which represent the Vormsi Stage in different facies belts of the Baltic palaeobasin. By the distribution of *A. barbata*, in the Paluküla section the transitional interval by Oraspõld should be included to the Vormsi Stage.

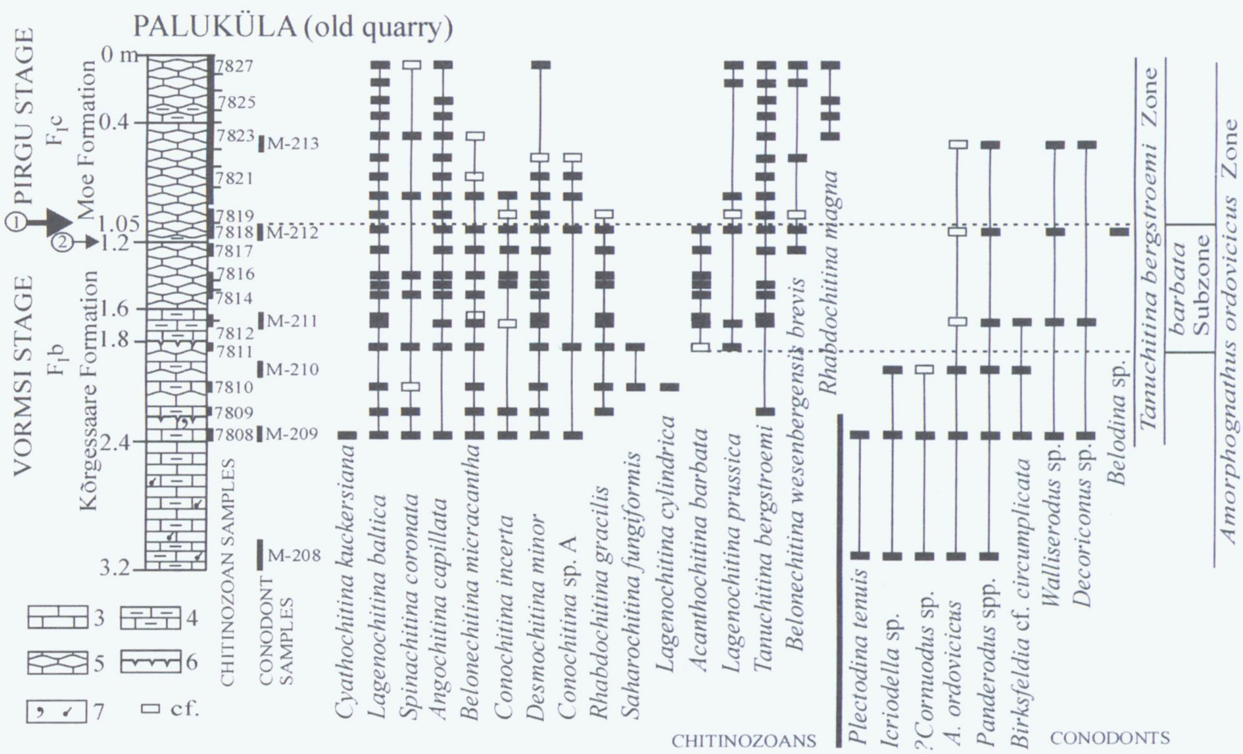

Fig. 3. Distribution of chitinozoans and conodonts in the Paluküla section. 1 – disappearance level of *A. barbata*; 2 – lithological boundary; 3 – limestone; 4 – argillaceous limestone; 5 – nodular limestone; 6 – discontinuity surface; 7 – glauconite and pyritic skeletal debris

The disappearance of *A. barbata* is a significant biostratigraphical event in the Vormsi–Pirgu transition, characterized by a rich assemblage of acid-resistant organic-walled microfossils (Fig. 3). The thickness of the *A. barbata* Subzone does not exceed 4.5 m (e.g. in Orjaku). The changes in the thickness of that subzone allow us to suppose that *A. barbata* is represented by its entire range also below the red-coloured rocks (Jonstorp Formation) of the Pirgu Stage, which are barren of organic-walled microfossils.

By conodonts the Paluküla section belongs to the *Amorphognathus ordovicicus* Zone. Some species, such as *Plectodina tenuis* and *Birksfeldia* cf. *circumplicata*, have been identified preliminarily only in the lower part of the section, but conodonts common to the Vormsi and Pirgu stages are found above the last occurrence of *A. barbata*. The ostracodes are represented by a diverse association in the Paluküla section (Meidla, 1983). Above the last *A. barbata* there appear ostracodes *Ectoprimitia corrugata corrugata* (Krause) (*Parabolbina costata* sp. n., in Meidla, 1983) and *Foramenella parkis* Neckaja, which in all sections mentioned by Meidla (1996) occur in the Pirgu Stage. A rich association of shelly fossils: brachiopods, corals, bryozoans and others, is known from the Paluküla section, but the exact ranges of particular species are not clear because fossils were collected without being exactly tied to certain beds of the section.

The level of the last occurrence of *A. barbata* coincides quite well with the traditional understanding of the boundary between the Pirgu and Vormsi stages in Estonia, enabling fairly precise determination of the stage boundary. In the Paluküla section *A. barbata* disappears at a depth of 1.05 m from the top of the section, which is 0.75 m above the upper discontinuitysurface and 0.15 m above the level of the lithological change on the boundary between the Kõrgessaare and Moe formations (Fig. 3).

In the international practise of establishing the stratigraphical units the first appearance datum (FAD) defines the boundary. In our case the disappearance (the last appearance datum; LAD) of the subzonal species *A. barbata*, widely distributed in Baltoscandia, is proposed as the event defining the lower boundary of the Pirgu Stage in the East Baltic and the Paluküla quarry section represents the boundary stratotype. We have preferred the LAD to FAD of *A. barbata* because it coincides with or lies close to the Vormsi–Pirgu boundary used up to now.

The proposed boundary level of the Pirgu Stage is correlated by chitinozoans with the base of the *complanatus* graptolite Zone (Nõlvak and Grahn, 1993, fig. 2; Webby *et al.*, 2004, Fig. 2.1).

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FREQUENCY PATTERNS OF CHITINOZOANS AND SCOLECODONTS ACROSS THE LLANDOVERY–WENLOCK BOUNDARY INTERVAL IN THE PAATSALU DRILL CORE, WESTERN ESTONIA

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Quantitative data are extensively used in palaeoecology but may also contribute to a better understanding of environments and deposition regime, palaeobiology and stratigraphy. Frequency patterns of different Early Palaeozoic fossil groups are nevertheless seldom studied jointly and in a detailed temporal and spatial framework. Our present study focuses on the Llandovery–Wenlock boundary interval in the Paatsalu drill core, western mainland Estonia. This interval was selected for a pilot study due to the availability of much background information and the presence of several event levels in the succession of the upper Raikküla, Adavere and Jaani regional stages (Aeronian to lower Sheinwoodian). First, the transition from the Rumba Fm. to the Velise Fm. embraces a rapid facies change that reflects the most extensive flooding of the Baltic Shelf during the Silurian. Second, it covers the much debated Llandovery–Wenlock boundary and the Ireviken Event that has been recognised as an important isotope event and extinction level for several fossil groups. The primary aim of this study was to document and mutually analyse frequency patterns of three common microfossil groups – chitinozoans, scolecodonts and conodonts – representing different modes of life and largely different ecological niches.

Broadly the studied succession is composed of nodular limestones of the Nurmekund and Rumba Fms and dolomitic marls of the Velise and Mustjala Fms (see Fig. 1). Scolecodonts and conodonts were extracted by acid digestion from ca 300–500 g samples, whilst 5–50 grams of each sample was treated separately for chitinozoans. All microfossils were then picked, identified and counted from the residues. At the time of writing this summary, the conodont data were still being assembled and thus they are not discussed here except for the biostratigraphical background.

Chitinozoans. The chitinozoan collection consists of nearly 50 different species. One sample contains usually 5–8 but occasionally 12 species. Chitinozoan frequency per gram varies from less than 1 to about 20 in the Llandovery and from 30 to 170 in the Wenlock. A marked increase in abundance is registered at the Llandovery–Wenlock boundary.

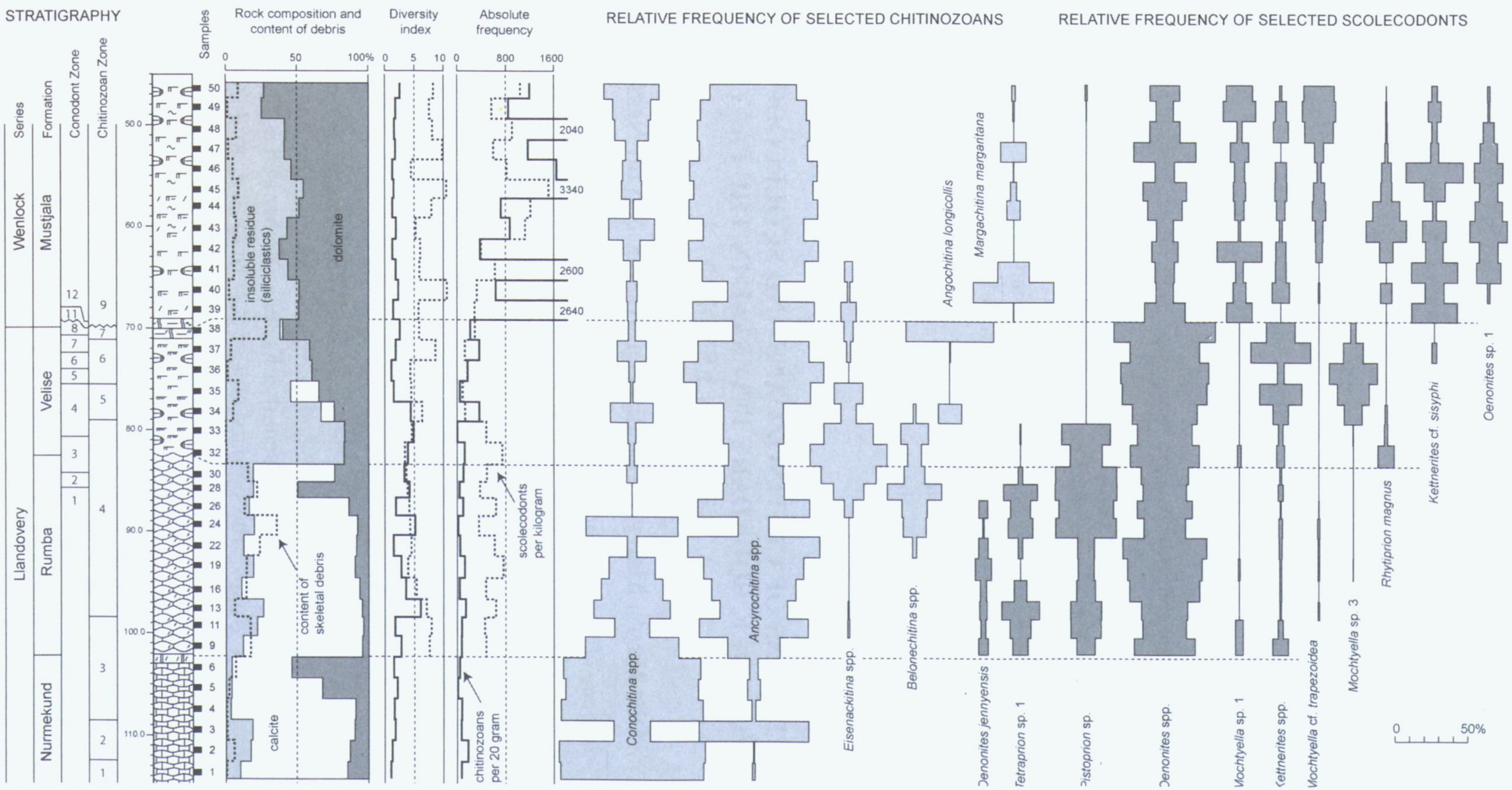
STRATIGRAPHY
Series
Formation
Conodont Zone
Chitinozoan Zone
Wenlock
Mustjala
Llandovery
Velise
Rumba
Numekund
Samples
Rock composition and content of debris
insoluble residue (siliciclastics)
dolomite
content of skeletal debris
calcite
Diversity index
Absolute frequency
chitinozoans per 20 gram
scolecodonts per kilogram
RELATIVE FREQUENCY OF SELECTED CHITINOZOANS
Conochitina spp.
Ancyrochitina spp.
Eisenackitina spp.
Belonechitina spp.
Angochitina longicollis
Margachitina margaritana
RELATIVE FREQUENCY OF SELECTED SCOLECODONTS
Oenonites jennyensis
Tetraprion sp. 1
Pistoprion sp.
Oenonites spp.
Mochtyella sp. 1
Kettnerites spp.
Mochtyella cf. trapezoidea
Mochtyella sp. 3
Rhytiprion magnus
Kettnerites cf. sisyphi
Oenonites sp. 1
0 50%

Fig. 1. Stratigraphy, lithology and distribution of selected chitinozoans and scolecodonts in the Paatsalu (527) drill core, western mainland Estonia. Conodont zones: 1 – *Distomodus staurognathoides*?, 2 – *Pterospathodus eopennatus* ssp. n. 1, 3 – *Pt. eopennatus* ssp. n., 2, 4 – *Pt. amorphognathoides angulatus*, 5 – *Pt. amorphognathoides lennarti*, 6 – *Pt. amorphognathoides lithuanicus*, 7 – *Pt. amorphognathoides amorphognathoides*, 8 – Lower *Pseudooneotodus bicornis*, 11 – Lower *Kockelella ranuliformis*, 12 – Upper *Kockelella ranuliformis* (note that 9 and 10, Lower and Upper *Pt. pennatus procerus* and Upper *Pseudooneotodus bicornis* are missing). Chitinozoan zones: 1 – *Euconochitina electa*, 2 – *Ancyrochitina convexa*, 3 – *Conochitina alargada*, 4 – *Eisenackitina dolioliformis*, 5 – *Angochitina longicollis*, 6 – *Conochitina proboscifera*, 7 – *Conochitina acuminate*, 9 – Interzone IV (note that 8, *Margachitina margaritana* zone s. str. is missing). The diversity index is calculated using the well-known Simpson's formula. The counts of scolecodonts were obtained by the most common diagnostic element in the sample. Full sample numbers are preceded by "OM4-".

The most common genera occurring abundantly, but in varying proportions, throughout the studied interval are *Conochitina* and *Ancyrochitina*. In some intervals *Eisenackitina*, *Angochitina* and *Margachitina* may reach considerable relative frequency, accounting for more than 50 % of vesicles in a sample. The frequency patterns are rather fluctuating at the species level, which is partly due to the fact that several species are stratigraphically restricted and the sampling density was not high enough. One species may ultimately make up more than 95 % of the assemblage (*Euconochitina electa* in sample 1). It is common, however, that the dominant species accounts for 50–70 % (e.g., *Ancyrochitina ancyrea* s. lato, *Conochitina elongata*, *Angochitina longicollis*, *Margachitina margaritana*).

Scolecodonts. The jawed polychaete fauna was very rich for the most of the interval studied. Although detailed taxonomic study of the collection is still going on, it is evident that it contains no less than 60, and possibly more than 70 apparatus-based species. Up to 27 species were recorded in one sample. The absolute frequency reaches from about 100 to 1500 per kilogram (the counts are obtained by the most frequent diagnostic element of every taxon identified in a sample; taken that polychaete jaw apparatus may consist of tens of elements, the total number of all scolecodonts may be several times higher). The fauna is generally dominated by polychaetaspids, mochtyellids and paulitinids, and occasionally by rhytiprionids. Particularly common is the genus *Oenonites*, which accounts for 15–70 % of all specimens (see Fig. 1). *Pistoprion*, *Mochtyella* s. lato, *Rhytiprion*, *Kettnerites* and *Tetraprion* are also very common but their frequency displays marked variations. For instance, *Pistoprion* predominates in the Rumba Fm. and the lowermost Velise Fm., but is subsequently absent until the few uppermost samples in the Mustjala Fm. As indicated by the studies from elsewhere, particularly Gotland, the ranges of several jawed polychaete species are apparently longer than those recorded in the Paatsalu core.

Comparison of frequency curves of both groups reveals that the absolute frequency of chitinozoans is on average 10–100 times higher than that of scolecodonts. The Nurmekund and Rumba Fms are generally benthos-dominated and accordingly the abundance of scolecodonts is relatively high and that of planktic chitinozoans low. In the Velise Fm., scolecodonts decrease in abundance and chitinozoans increase, hence showing also negative correlation. On the other hand, the Mustjala Fm. is characterised by a high abundance of both groups. That is, the corresponding environment had to be very suitable for both chitinozoans and jawed polychaetes. Besides this large-scale pattern, it appears that a smaller-scale pattern can be recognised and the fluctuations in the abundance of both groups are in a rather good positive correlation, particularly in the Rumba Fm. Moreover, most of the smaller-scale frequency peaks coincide with the increase in siliciclastics, which, together with supposedly different habits of chitinozoans and jawed polychaetes, may indicate fluctuations in compaction and/or deposition rate. Interestingly, however, the most significant change in the carbonate/siliciclastics ratio at the Rumba–Velise transition (between samples 30 and 32) occurs without marked changes in absolute abundance of either chitinozoans or scolecodonts (increased frequency of scolecodonts in sample 32 may be due to inadequate sample size). Moreover, relative abundance of several predominating chitinozoans and scolecodonts changes only very slightly at this boundary (see the patterns of *Ancyrochitina*, *Conochitina*, *Belonechitina*, *Eisenackitina*, *Pistoprion* and *Oenonites* in Fig. 1).

The absence of the *Margachitina margaritana* Chitinozoan Zone, and the Upper *Pseudooneotodus bicornis* and *Pterospathodus pennatus procerus* Conodont zones indicate that most of the Ireviken Event interval (including the Llandovery–Wenlock boundary) corresponds to a gap in the Paatsalu drill core (cf. Nestor, 1994; Jeppsson and Männik, 1993). It is therefore not unexpected that the frequency changes at this level (between samples 38 and 39) are very sharp. Although the changes in polychaete assemblages are less abrupt than in case of chitinozoans, they also display disappearance, appearance and marked decrease/increase in the abundance of several taxa. Particularly notable are the decrease in *Oenonites* spp., disappearance of *Mochtyella* sp. 3 and increase in *Kettnerites* cf. *sisyphi* and *Mochtyella* sp. 1. For detailed study of the Ireviken Event and its effects on chitinozoans and polychaetes, however, a more complete section is needed.

It is also evident that, based on one section only, the frequency changes as documented here cannot always be fully understood and interpreted. Thus it remains currently unclear whether the species-level frequency changes like, e.g., the peaks in *Rhytiprion magnus*, *Kettnerites* cf. *sisyphi*, *Oenonites* sp. 1 and *Mochtyella* sp. 3 ex gr. *fragilis* can be traced spatially and whether they occur in the same stratigraphical position.

Also, current sampling density was insufficient to reveal whether certain abrupt changes in assemblage composition (e.g., *Conochitina*/*Ancyrochitina* ratio and *Pistoprion*/*Oenonites* ratio between samples 22 and 24, see Fig. 1) are actually continuous but rapid, or truly abrupt and marking missing time and rock.

Therefore we plan to extend our research to other localities and increase the stratigraphical resolution at the most intriguing levels.

Acknowledgements. This study is a contribution to IGCP Project 503 and was supported by the Estonian Science Foundation grants Nos 5920, 6127 and 5406.

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MICROFOSSIL DYNAMICS AND BIOSTRATIGRAPHY IN THE UHAKU–KUKRUSE BOUNDARY INTERVAL (ORDOVICIAN) OF NE ESTONIA

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The boundary between the regional Uhaku and Kukruse stages has usually been drawn at the base of the lowest commercially important kukersite seam (bed A) in NE Estonia as proposed already by Bekker (1924). In spite of the fact that the Kukruse Stage as a whole can be widely correlated all over the Baltic Palaeobasin with the help of numerous micro- and macrofossils (e.g., Männil, 1986), precise determination of its lower boundary may be complicated where the corresponding oil-shale beds are missing. Moreover, since the Kukruse Stage has been considered as an approximation of the *Nemagraptus gracilis* Biozone, its lower boundary is commonly correlated with the lower boundary of the global Upper Ordovician Series. Since the formal establishment of the latter GSSP in Fågelsång, Sweden, it has been a tempting task to find criteria for more precise correlation of this level to Estonian sections.

To help solving these questions, we aimed at obtaining new data on the distribution of common acid-resistant fossils, particularly graptolites, conodonts, chitinozoans and scolecodonts across this boundary in the type area in NE Estonia. A new series of samples was collected from the Uhaku–Kukruse boundary interval (with emphasis on frequency patterns in the upper part of the Uhaku Stage) from the Viru Mine, and some older and unpublished collections were re-examined.

The **conodont** fauna in the Viru and Kohtla sections is represented by a rather invariable association throughout the studied interval. The absolute frequency of conodonts (elements per kg) is higher in the lower part of the sequence reaching nearly 500 (Fig. 1). The conodont yield was considerably lower in the samples taken from kukersite beds (those are not shown in Fig. 1). Otherwise there seems to be no clear relationship between, e.g., carbonate content and frequency of conodonts. The conodont fauna is predominated by *Baltoniodus variabilis*, *Semiacontiodus carinatus* and *Panderodus sulcatus* and *Drepanoistodus* that represented by two species. *B. variabilis* is a very common form in the upper Uhaku–lower Kukruse interval in whole Baltoscandia. It is important for stratigraphy although distinguishing from the ancestral *B. prevariabilis* may be complicated. The latter species was not found in the studied sections but occurs in several drill cores. The most important find from the Kohtla section is *Amorphognathus tvaerensis* that first appears ca 30 cm above the base of the Kukruse Stage. This is so far the earliest find of *A. tvaerensis* in Estonia allowing the corresponding biozone to be drawn lower than suggested previously (eventually approximated with the base of the Kukruse Stage). *Pygodus anserinus* – index species of the preceding biozone has not been recovered from

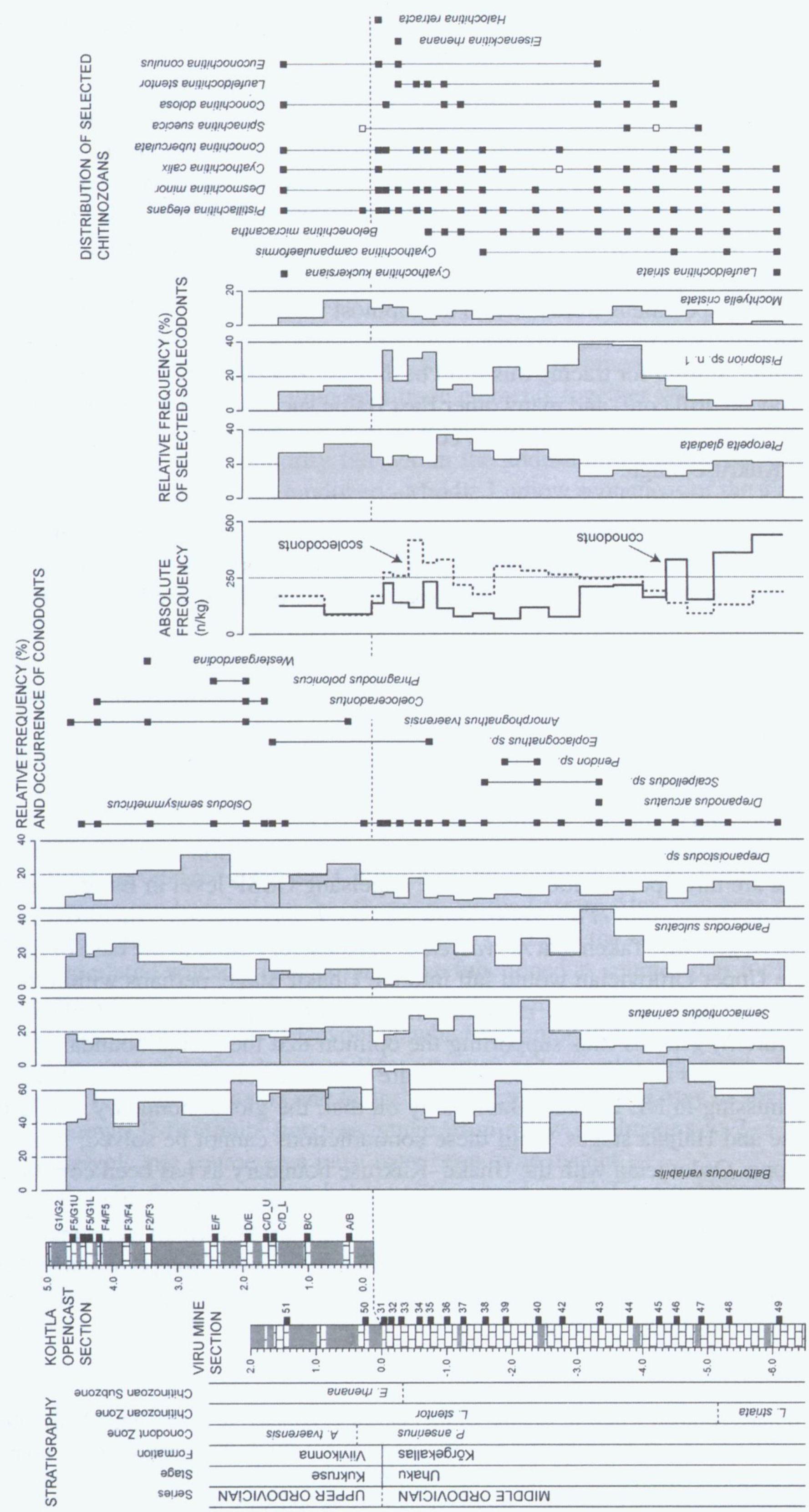

Fig.1. Stratigraphy, lithology and distribution of conodonts, selected scolecodonts and selected chitinozoans in the Viru Mine and Kohtla Opencast sections. The counts of conodonts were obtained by summing all elements, and those of scolecodonts by the most common diagnostic elements in sample. Grey areas in lithological columns stand for kukersite beds. Full sample numbers are preceded by "OMO3-"

the studied sections but occurs in at least 9 Estonian drill cores. There is always a gap between the last occurrence of *P. anserinus* and the appearance of *Amorphognathus* lineage.

In the Viru Mine section, **chitinozoans** are represented altogether by 31 species, but usually 8–10 different species occur in one sample. The taxa recovered are typical of this interval. In the lowest sample *Laufeldochitina striata*, marking the corresponding biozone was found and starting from the sample 45, *Laufeldochitina stentor* appears defining the succeeding biozone (see Fig. 1). A similar short interval barren of *Laufeldochitina* typically occurs between these zones in other sections. In sample 33, just 30 cm below the base of the Kukruse Stage, three specimens of *Eisenackitina rhenana* were recovered. The appearance of this species defines the *E. rhenena* Subzone. Hitherto the earliest finds of *E. rhenena* were from the C/D limestone bed, over 1 m above the boundary. However, it cannot be completely ruled out that the specimens were taken to the topmost Uhaku strata by bioturbation (burrows occasionally reaching 30 cm in depth have been recorded in other localities). Anyhow, *E. rhenena* appears very close to the Uhaku–Kukruse boundary and can be used for tracing this level basinwide. Additionally, in some NE Estonian sections (e.g., Sirgala Opencast and Savala drill core) and many other East Baltic successions two stratigraphically valuable successive species of *Conochitina* occur (*C. savalaensis* in coll. and *C. viruana* in coll.), the former appearing close to the lower boundary of the Kukruse Stage.

Scolecodonts (polychaete jaws) are represented by about 40 species, including ca 10 new ones in the Viru Mine section. The absolute frequency of scolecodonts is comparable to that of conodonts (but note that only the most frequent element of a species is used for counts whilst all elements were summed for conodonts) showing very weak negative correlation with them. The jawed polychaete fauna is usually predominated by *Pistoprion* sp. n. 1, *Pteropelta gladiata*, *Mochtyella cristata*, *Protarabellites* cf. *staufferi*, and several species of *Oenonites*. The frequency variations of different species, like the gradual increase in relative frequency of *Pistoprion* sp. n. 1, show no clear correlation with, e.g., basic rock composition. There are also no marked changes in quantitative composition of polychaete fauna at the Uhaku–Kukruse boundary.

Graptolites appear to be rare and are represented mainly by dendroids (e.g., *Mastigograptus* sp.). The only graptoloid fragments belonging to *Dicellograptus* sp. were recovered from the sample 47, which is at the same stratigraphical level as reported earlier by Männil (1986, fig. 2.1.1).

Current data provide some new insights to the problems of correlation of the base of the Upper Ordovician Series. Principally there are three possibilities to find the Fågelsång GSSP level in Estonian sections. First, the conodont data from Fågelsång (Bergström *et al.*, 2000) show that the *P. anserinus–A. tvaerensis* zone boundary lies well above the appearance of *N. gracilis*. Taken that *A. tvaerensis* appears very close to the base of the Kukruse Stage in NE Estonia, the base of the Upper Ordovician would fall into the Uhaku Stage, perhaps within the limits of the studied Viru Mine section. On the other hand, new chitinozoan data from Fågelsång (Vandenbroucke, 2004) show that *E. rhenana* appears before *N. gracilis* thus supporting the opinion that the global boundary lies within the Kukruse Stage. Occurrences of *N. gracilis* in the eastern Baltic area are recorded from the middle and upper part of the Kukruse Stage, which is partly missing in NE Estonia. Based only on that, the global boundary would possibly fall into the hiatus between Kukruse and Haljala stages. Until these contradictions cannot be solved, it is preferable to approximate the base of the Upper Ordovician with the Uhaku–Kukruse boundary as has been commonly done earlier.

In consequence it should also be noted that generally very monotonous picture of microfossil distribution, the frequency dynamics in particular, indicate that the Uhaku–Kukruse boundary lies within a continuous succession in its type area and is suitable for establishing a regional lower boundary stratotype section and point somewhere in NE Estonia.

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SILURIAN K–BENTONITES FROM THE CARNIC ALPS (AUSTRIA)

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Ninety-five K-bentonite levels have been recorded to date from the Upper Ordovician (Ashgill) to Lower Devonian (Lochkov) sequences of the Carnic Alps. They occur in shallow to deep water fossiliferous marine sediments which suggest a constant movement from a moderately cold climate of approximately 50° southern latitude in the Upper Ordovician to the Devonian reef belt of some 30° south. The reconstructed distribution of the various litho- and biofacies indicates a SW–NE directed polarity from shallow water environments to an open marine and deep sea setting. The discrimination diagrams based on immobile trace elements together with REE data suggest that some sections plot within the ocean ridge field while others mainly plot within the volcanic arc and syn-collisional fields. The samples vary in composition and the majority fall within the andesite, rhyodacite/dacite fields. The abundant presence of these K-bentonite horizons in the Llandovery–Middle Ludlow sequences of the Carnic Alps is similar in the British Isles, Sweden, Canada and North America and documents widespread volcanism related to the closing of the Iapetus Ocean and northward drifting of microplates derived from the northern margin of Gondwana. Silurian K-Bentonites, which are Pridoli in age, may be comparable with those described from Podolia for which a source area in the Rheic Ocean has been indicated.

Huff *et al.* (2000) proposed possible source areas and wind transport directions for known Silurian K-bentonites. During the Llandovery the distribution pattern of K-bentonites in the Iapetus region suggests two source areas: one for the Scottish–Irish–Baltoscandic ash beds and one for the beds in Nova Scotia and eastern and central USA. Volcanoes in the former source area, likely to have been located in a tectonically active setting near the eastern margin of Laurentia, may also have been the source for the K-bentonites of Wenlock to Ludlow age in northwestern Europe. However, the ash beds in southern Poland and Podolia, some of which are Pridoli in age, may have had quite a different source, presumably in the Rheic Ocean near the southern margin of Baltica (Bergström *et al.*, 1998).

The K-bentonite levels recognized from the Carnic Alps may also be placed within this latter scenario. For geological reasons a local origin can be ruled out. In other parts of the Eastern Alps, however, coeval basic volcanism may have occurred, e.g. in Middle Carinthia, the surroundings of Graz and the Greywacke Zone (Schönlaub, 1992). Whether or not these rifting related volcanic centers may have functioned as source areas for the K-bentonites of the Carnic Alps remains a matter of speculation. They belong to a tectonically active terrane dominated by alkaline mafic lavas and pyroclastics in the Silurian and Lower Devonian, which originally was situated north of the Carnic Alps but separated from the latter by an oceanic realm or at least an open sea of unknown width. Hence, any correlation between the thickness of the K-bentonite layers and their distance from the source may be highly speculative. On the other hand, however, all known K-bentonite horizons range from a few millimeters to 2–3 centimeters maximum thickness indicating that the volcanic source area must have been quite distant.

We thus conclude that the majority of the K-bentonites found in the Carnic Alps were rather derived from neighboring peri-Gondwanide terranes than from far distant sources at the eastern margin of the closing Iapetus Ocean. These ash beds suggest widespread rifting related volcanism in the enigmatic PaleoTethys, which opened during the Silurian between the northern margin of Gondwana and the Hun Superterrane. It may have lasted until the end of the Middle Devonian when these terranes amalgamated and closing of the Rheic Ocean began.

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ORDOVICIAN K–BENTONITES AND EXPLOSIVE VOLCANISM

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In northwestern Europe Ordovician K-bentonites are widely distributed in Scandinavia, Poland, the British Isles, and the Baltic states. In North America they are present mainly in the Late (Mohawkian) Series, but a few beds are known from older and younger Ordovician strata. Based on biostratigraphic, geochemical, and petrographic data it is possible that the Millbrig (North America) and the Kinnekulle (Baltoscandia) K-bentonites are, at least in part, distal remnants of the same ash bed. The recognition that the Ordovician K-bentonite can be traced from North America to Europe is of extraordinary interest and provides the first real opportunity to study lateral differentiation of the ash, the location of the source volcano, the volcano, and, indirectly, the width of the Caradocian Iapetus Ocean. Consideration of the areal distribution pattern and volume of the most widespread beds indicates that they were formed during ultraplinian and co-ignimbrite explosive eruptions and that the volcanic sources were located along tectonically active margins of Iapetus during its closure. The event stratigraphic nature of K-bentonites is well known, but upon close inspection their preservation in Paleozoic stratigraphic sequences reveals numerous features that both help and hinder their application to area-wide studies. Examples from North America and Baltoscandia will be used to illustrate the problems that arise and the particular kinds of problem-solving applications to which they can be used. In each of these cases examples of zoned ash beds, associated hardgrounds, mineralogical and chemical variation in primary phenocrysts all provided challenges to their application in stratigraphic and tectonic reconstruction.

Major and trace element analysis of whole-rock Ordovician K-bentonites indicates that the parental magmas consisted of a calc-alkaline suite ranging through andesite, rhyodacite, trachyandesite and rhyolite. The chemical compositions indicate a tectonomagmatic setting characterized by destructive plate margin volcanics. The possibility of a common source for these ash beds was suggested by Huff *et al.* (1992). Recent carbon isotopic studies by Saltzman *et al.* (2003) support the coeval position of the Millbrig and Kinnekulle beds. However, Haynes *et al.* (1995) reported a compositional difference between Kinnekulle and Millbrig biotites with respect to their FeO, MgO, Al_2O_3, MnO, and TiO_2 content. They further suggested that these variations represent separate eruptive events. However, Haynes *et al.* (1995) used data from only one Millbrig site in North America and one Kinnekulle site in Baltoscandia, so they failed to evaluate lateral variation as well as within bed variation in biotite compositions. Here we present a comprehensive study of K-bentonite biotite composition covering a more extensive geographic and stratigraphic range for these Ordovician beds. A total of 666 Kinnekulle biotite analyses, 97 Millbrig biotite analyses and 39 Deicke biotite analyses representing 32 separate localities provide the most comprehensive view to date of the nature and extent of internal compositional variability of these widespread Laurentian and Baltoscandian ash beds. The data show clearly that the Kinnekulle and Millbrig are multiple event ash beds, some parts of which are indistinguishable from one another and most likely had a common source. Published age dates are inconclusive as to the true ages of each bed and are thus permissive of a common age and a common origin in an active magmatic arc bordering the rapidly closing Iapetus Ocean.

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CYCLOTHEMS AND A NEW LITHOSTRATIGRAPHIC SCHEME OF THE UPPER MOSCOVIAN–BASAL KASIMOVIAN (CARBONIFEROUS) OF CENTRAL AND NORTHERN EUROPEAN RUSSIA

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The upper Moscovian–basal Kasimovian shallow-marine predominantly carbonate epicontinental succession has been studied in Moscow, Rjazan, and Arkhangelsk Regions. This succession appears to consist of stacked 1–10 m-scale transgressive-regressive marine cyclothems bounded by subaerial unconformities (Fig. 1; Kabanov and Baranova, in press). The unconformities are marked by relatively mature subaerial exposure profiles (mostly palaeosols) or several closely spaced mature and immature profiles. Deepening and shoaling trends within cyclothems are indicated by lithofacies successions and, correspondingly, decrease and increase in abundance of micritized grains, aggregates, oncoids, and phylloid and dasyclad algae. Facies shifts in response to sea level changes are also evident from ichnofossil, fusulinoid, and brachiopod distribution. The studied cyclothems consist of transgressive, central offshore, regressive, and terrestrial parts (Fig. 1). The latter include the upper clayey parts of palaeosols and extremely rare aeolian grainstones. The regressive limestone part is usually thicker than the transgressive part, so that most cyclothems are moderately asymmetric.

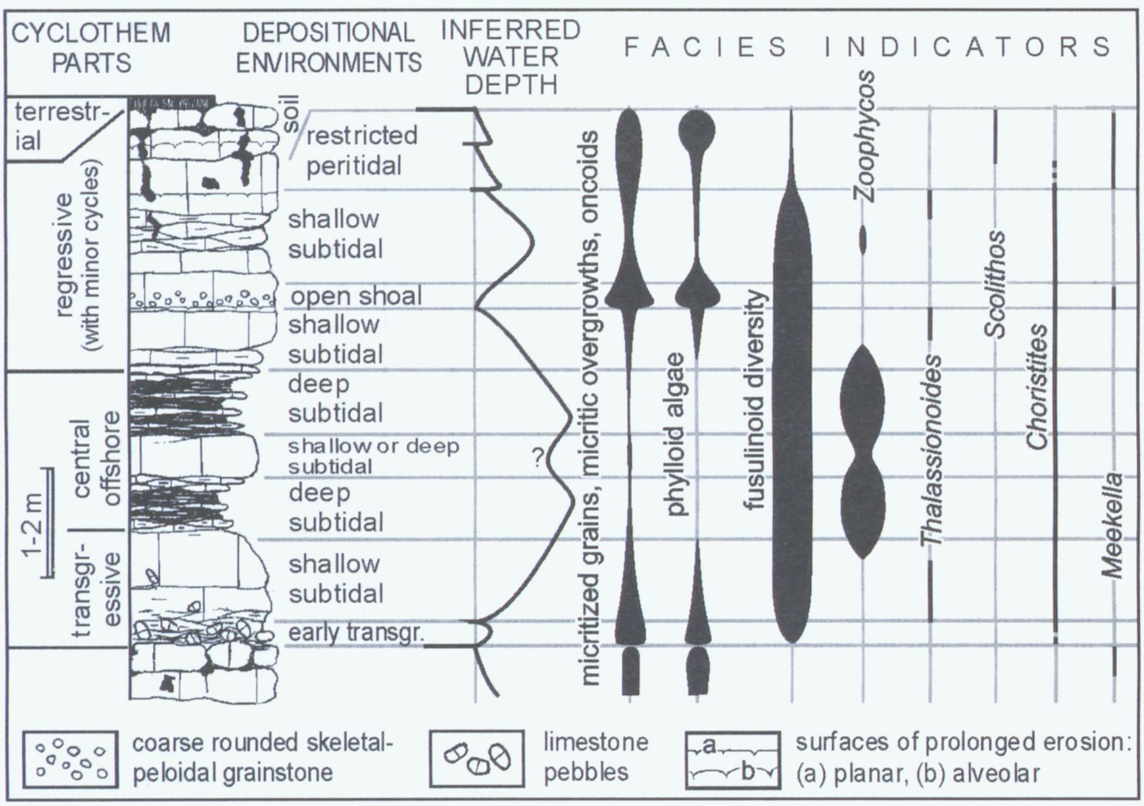

Fig. 1. Synthetic representation of the Late Moscovian cyclothem of the southern Moscow Region

Central offshore parts are more argillaceous and feature tempestites. Transgressive and regressive trends in cyclothems are complicated by smaller-scale cycles, as suggested by surfaces of prolonged erosion and shallowest subtidal or shoal grainstone layers separating deeper-water lithofacies (Fig. 1). Cyclothem correlation across the studied outcrop areas reveals discrepancies in previous correlation schemes (Fig. 2). A new lithostratigraphic scheme proposed for the Podolskian Substage assigns formation status to the Vaskino, Gory, Markovo, and Akatievo cyclothems, while the Ulitino Formation should be abandoned (Fig. 2). The Shurovo Formation consists of the transgressive and central

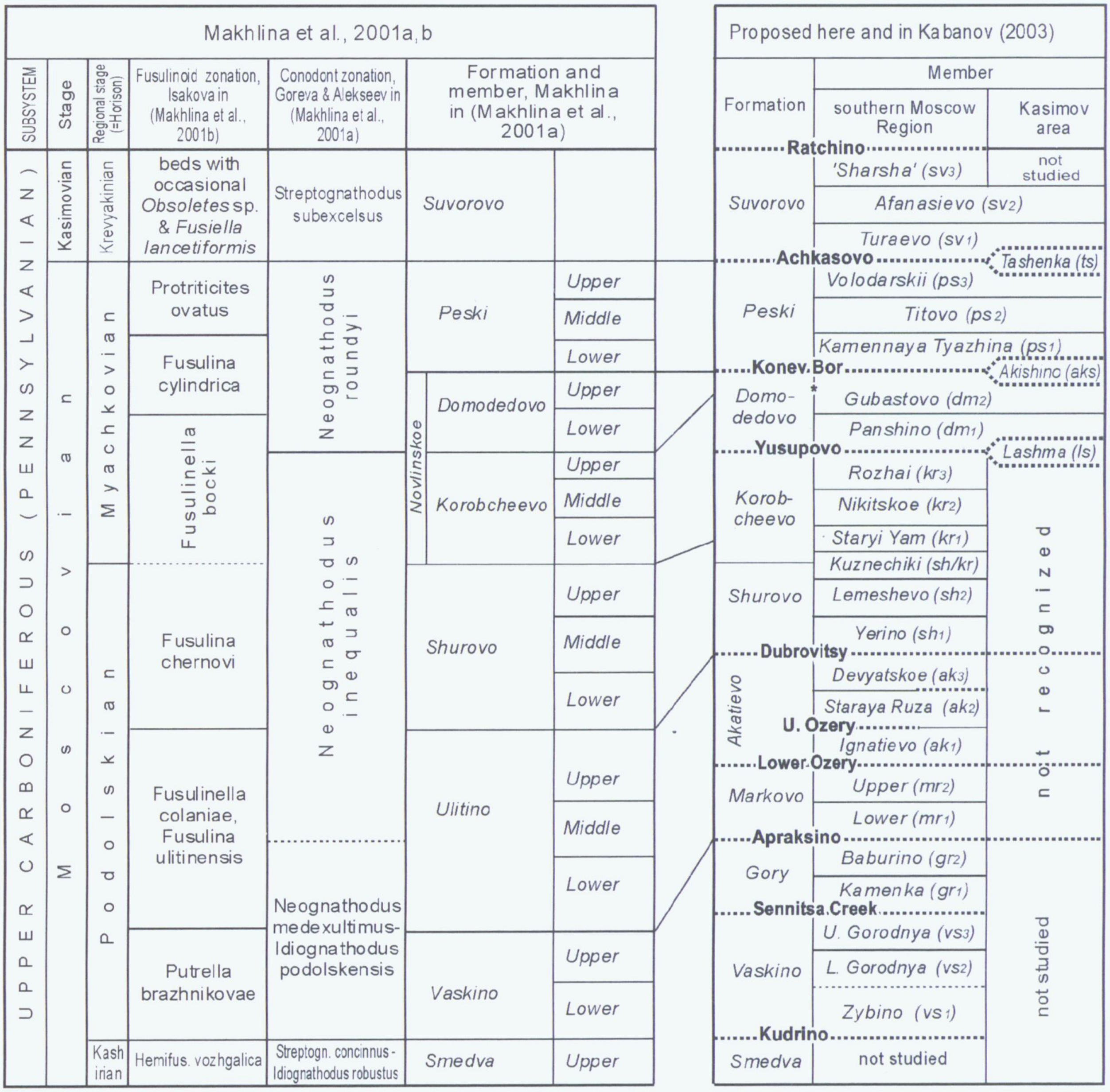

Fig. 2. Currently accepted and proposed stratigraphic schemes and their correlation on the level of formations; subaerial unconformities (bold names) are traced with bold dotted lines and span only half of cell width if they strongly decrease in maturity across the Moscow Region; asterisk indicates the base of *Fusulina cylindrica* zone according to Baranova and Kabanov (2003)

offshore parts of the largest cyclothem in the succession (Shurovo–Korobcheevo). The Myachkovian Substage consists of the Korobcheevo regressive limestone of the latter cyclothem and the Domodedovo and Peski complete cyclothems. The lowermost Kasimovian Suvorovo formation is a well-defined cyclothem. The succession becomes thicker and more complete in the Kasimov area. The cyclothem succession is superimposed by larger-scale cyclicity. A complete large cycle is seen in the Markovo–Peski interval; the Vaskino cyclothem may correspond to the offshore part of another larger-scale cycle. Cyclothems represent the transgressive-regressive stratigraphic sequences with the regressive systems tracts largely deposited during forced regressions.

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A SEA–WAY THROUGH CENTRAL BALTICA IN THE ORDOVICIAN AND SILURIAN (IDEAS AND EVIDENCES)?

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Recently a collection of papers under an intriguing heading "Silurian lands and seas" (Landing and Johnson, 2003) was published. In accord with the title, it included a map "Silurian basins and shields on the Baltic continent" (Fig. 1 in Baarli *et al.*, 2003), showing a sea-way through the entire continent. Contours of this strait were somewhat peculiar and I got interested in what kind of evidence there is available for such a palaeogeographic reconstruction of the continental interior of Baltica. In the paper no evidence was presented.

Ordovician and Silurian rocks in Central Russia have been studied since the 1950s and due to some specific aspects in lithology and fossil content the Moscow Basin has been treated either as an eastward prolongation of the Palaeobaltic Basin or as a separate basin. Igolkina and Bykova (1985) stress ties with the Baltic area, introducing a common tectonic structure, the Baltic-Moscow syneclise, accommodating a latitudinal sea. According to their interpretation, in the Silurian the eastern part of this sea turned into a remnant basin with salty sediments. The dating of the rocks has been problematic due to scarcity of well-preserved fossils and therefore some conclusions may appear doubtful. These authors quote a supposition by Dmitrovskaya (1992) that the Moscow Basin might have had, at least in the early to middle Ordovician, a direct connection with the South Urals sea in the southeast.

In her doctoral theses Dmitrovskaya advocated for an idea that the Moscow Basin represented a separate palaeobasin like the Baltic and Timan-Pechora basins, but had more faunistic ties with seas in the east. This claim is worthy of checking, yet her maps showed no possibilities of any facies contacts.

The facies zonation in the Timan-Pechora Basin is very regular and typical of a rimmed shelf (Antoshkina, 1998 etc.). It begins in the west with a shallow shelf belt of lagoonal rocks and is followed to the east with a littoral, open shelf and reef belt before a deep-water facies begins. The known facies relationships do not leave much room for a westward continuation into the Moscow Basin. Some tectonical arguments should also be considered.

All these data make me sceptical about the existence of a sea-way through the continent, but surely there will be some better informed specialist at the conference who can clear away my doubts. My desire is to initiate a discussion on this essential topic of palaeogeography of the Baltica continent.

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ORDOVICIAN AND SILURIAN CARBON ISOTOPE STRATIGRAPHY OF WESTERN BALTICA: A STATE OF ART REPORT

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Isotopic methods have gained an eminent position in early Palaeozoic palaeoclimatology, palaeoceanology and stratigraphy. Despite good progress achieved in these fields, different environmental interpretations of isotope data are still under debate or uncertain. Success in carbon isotope stratigraphy is more likely to be achieved, but it depends mainly on how complete and detailed a standard trend used as a basis for comparisons is. Of course, correct correlation of sections and biostratigraphic dating of samples are crucial for obtaining reliable results. Despite different complications, we believe that the general pattern of carbon isotope changes can well serve as a stratigraphic, and with some caution, also as a palaeoclimatologic tool for Ordovician and Silurian time.

Isotope studies embracing the southwestern sector of the Baltica continent, including the present East Baltic (Estonia, Latvia and Lithuania), Gotland, Scania and the Oslo region, but also the Anglo-Welsh area, i.e. the part of Avalonia which joined Baltica in the late Ordovician, commenced roughly 20 years ago. The data presently available from the East Baltic allow us to discuss a more or less continuous curve of $\delta^{13}C$ values beginning with the post-Hunnebergian Ordovician until the Silurian–Devonian boundary beds (~58 my).

Carbon isotopes for the present study were determined at the Isotope palaeoclimatology laboratory of the Institute of Geology, Tallinn University of Technology, using the whole-rock method that allows sampling an entire section at more or less regular intervals not depending on the occurrence of bioclasts. In selecting the sampling interval the stratigraphic context (lithology, unit thickness and boundaries) was considered. The quality of the carbon isotope data based on whole-rock analyses has been discussed in several papers. Brenchley *et al.* (2003) investigated in detail the reliability of isotope signals in the Late Ordovician rocks of Estonia and noted that major changes in isotope values reflect primary composition. The comparison of the Baltic latest Ordovician and Silurian whole-rock (Kaljo *et al.* 1998, 2004) and brachiopod shell isotope data (Heath *et al.* 1998) shows only slight difference in $\delta^{13}C$ values but great similarity of the corresponding curves. Study of diagenetically unaltered brachiopods in the lower Silurian of Gotland (Samtleben *et al.* 1996; Wenzel and Joachimski 1996; Munnecke *et al.* 2003) shows that positive $\delta^{13}C$ shifts are correlated with high confidence with East Baltic whole-rock data.

Until very recently most of the Ordovician carbon isotope publications were devoted to the study of the Hirnantian, less of the middle Caradoc and the Cambrian–Ordovician boundary interval. The last year was highlighted by a burst of new data, among them the first report of the middle Ordovician carbon isotope data published by Ainsaar *et al.* (2004). Understandably, this progress could not be considered in the “big biodiversification book”, where the Ordovician $\delta^{13}C$ trend is shown in a very general way (Shields and Veizer 2004). But, considering also the results of the last few years, a nearly complete and more detailed trend for the Ordovician could be compiled based on the data from Baltica and Laurentia, with supplementary data from elsewhere. Here we show the first step in compiling an as complete as possible $\delta^{13}C$ curve for the post-Hunnebergian Ordovician based on a data set from Baltoscandia. Complications caused by several local hiatuses, condensed sections and facies changes were mitigated by the study of overlapping sections.

The following positive carbon isotope events were observed (Ainsaar *et al.* 2004; Kaljo *et al.* 2004; Martma 2005):

(1) the mid-Darriwilian excursion (peak $\delta^{13}C$ value 1.9 ‰) in the Aseri Stage;
(2) the mid-Caradoc excursion (2.2 ‰) at the transition from the Keila Stage to the Oandu Stage;
(3) the first late Caradoc excursion (2.3 ‰) in the lower part of the Rakvere Stage;
(4) the second late Caradoc excursion (2.4 ‰) in the upper part of the Nabala Stage;
(5) the early Ashgill excursion (2.5 ‰) in the lowermost part of the Pirgu Stage;
(6) the mid-Ashgill excursion (2.0 ‰) in the upper part of the Pirgu Stage;
(7) the widely known large Hirnantian excursion (in Estonia the peak value reaches 6.7 ‰) in the Porkuni Stage.

The late Ordovician Hirnantian excursion (Brenchley *et al.* 2003) is usually linked to a major glacial event, even if some carbon cycling mechanisms are not completely understood. The environmental causes suggested for the earlier minor shifts range from global climatic and glacial events to very local changes in basin regime and sea level.

The following positive carbon isotope excursions have been established in the East Baltic Silurian (dating in terms of graptolite biozonation according to Kaljo *et al.* 1998; Kaljo and Martma 2000; Kaljo *et al.* 2003):

(8) the early Aeronian excursion (3.7 ‰) in the *D. triangulatus* Biozone within the Raikküla Stage;

(9) the early Sheinwoodian excursion (5.2 ‰), with the peak in the *M. riccartonensis* Biozone or slightly above it within the Jaani Stage;

(10) the middle Homerian excursion (4.6 ‰), with the main peak in the *M. ludensis* Biozone and one or two smaller shifts below the main shift within the Rootsiküla Stage;

(11) the middle Ludfordian excursion (8.2 ‰), the most prominent one in the Phanerozoic. The last excursion has been correlated with the *N. kozlowskii* Biozone, but conodonts provide a direct dating – the last occurrences of *Polygnathoides siluricus* below the main shift and the appearance of Ozarkodina *wimani* and *O. crispa* above the excursion. Because of a gap this excursion is missing in the Paadla Stage of the Ohesaare core, but is well represented in the Priekule and Vidukle cores (Martma *et al.* 2005).

Most of isotope shifts occur close to levels of biodiversity changes, as shown by the most widely recognized Oandu crisis in the Caradoc, mass extinction in the Hirnantian, and the Ireviken and Lau events correspondingly in the Wenlock and Ludlow.

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PALYNOLOGICAL CONTRIBUTIONS TO THE CHRONOLOGY AND STRATIGRAPHY OF THE BRECON BEACONS AND BLACK MOUNTAINS SOUTH WALES, UNITED KINGDOM

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The Lower Old Red Sandstone sequences occurring in south Wales are poorly age-constrained. This is owing to the rarity of fish fossils which are considered as key to the age of these deposits. Consequently 176 palynological samples were collected from 25 litologic sections consisting of clastic deposits of the dominantly red marl, brownish red sandstone, conglomerate and siltstone and grey to greyish green siltstone/fine grained sandstone and greyish green to green marl of the upper Red Marl Group and Senni Beds of Brecon Beacons and Black Mountains. Of these 103 samples were productive. Most likely the upper Red Marl Group sediments were deposited in more or less 'calm' rivers and less aggressive, whilst the braided streams and channels which carried the Senni Beds sediments attain many peek levels with periods of temporary evacuation. These sediments revealed moderately well preserved, abundant and sufficiently consistent miospores with well stratigraphic control. The obtained biostratigraphic data constrain the age of these formations. Four miospore assemblage Biozones and twelve sub-biozones are recognized. Of these two miospore assemblage biozones and seven subzones are considered as new. Also the obtained microflora is correlated

with similar assemblages from the Dittonian of the Anglo-Welsh Basin and Lower Old Red Sandstone of Scotland. Palynological data indicate that the boundary between Detonian and Breconian age lie within the lower half of the Senni Beds. Comparison of the Dittonian and Breconian miospore assemblage biozones and sub-biozones of the studied area with established regional spore zonation revealed that Dittonian and Breconian of the Brecon Beacons and Black Mountains can be correlated with the standard Europian late Early Lochkovian to late Middle Pragian.

PALEOENVIRONMENTAL SIGNIFICANCE OF SILURIAN CORALS OF OSBAK–KUH (CENTRAL IRAN)

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The carbonate successions of the Niur Formation of the Ozbak-kuh mountains in the northern Tabas area contain rich assemblage of Silurian corals. This lithostratigraphic unit differs significantly from the underlying sandy-calcareous beds of the Shirgesht Formation and the overlying sandy-dolomitic Padeh Formation. Niur Formation is mainly represented by coral limestones ranging in age from the Late Llandoverian to Late Ludlovian. The thickness of the formation is 450 meters.

Up to 10 genera of rugosa and tabulata corals have been found in the Ozbak-kuh region (central Iran). Among them are *Cystiphyllum*, *Palaeofavosites*, *Holmophyllum*, *Masofavosites*, *Favosites*, *Staphylopora*, *Thecia*, *Halysites*, *Heliolites* and *Spongophyllum*. The assemblage consists of dissepimented rugosa and colonial tabulata corals was more probably confined to the shallow areas of an open shelf.

DEVONIAN RUGOSE CORALS BIOSTRATIGRAPHY OF BAHRAM FORMATION, SOUTH OF OSBAK-KUH (IRAN)

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Devonian corals of Bahram Formation in the Cheshme Shir area (South of Osbak-kuh) have been studied. In the studied section more than 18 species belong to 10 genera of rugose corals has been recognized. Among them are the following taxa: *Sinodisphyllum*, *Spinophyllum*, *Glossophyllum*, *Acantophyllum*, *Temnophyllum*, *Cystihexagonaria*, *Marisastrum*, *Hexagonaria*, *Ceratophyllum* and *Pseudozaphrentis*. This assemblage proves the Upper Givetian–Frasnian age of the studied section.

According to corals morphology, two assemblages were distinguished. First occur in the reef areas and is composed of colonial corals which formed patch reefs. Second assemblage is composed of dissepimental corals of median sizes. The latter corals inhabited the shallow areas of an open shelf.

"DEVONIAN LAND-SEA INTERACTION: EVOLUTION OF ECOSYSTEMS AND CLIMATE (DEVEC)" – THE NEW IGCP PROJECT 499

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During the last two decades research on the Devonian period had been included in some of the successful IGCP projects, e.g., in IGCP 216 "Global biological events in Earth history" (lead by O.H. Walliser), IGCP 335 "Biotic recoveries from mass extinctions" (lead by D.H. Erwin and E.G. Kauffman), and IGCP 421 "North Gondwanan Mid-Palaeozoic bioevent / biogeography patterns in relation to crustal dynamics" (lead by R. Feist and J.A. Talent). In these projects, however, the main focus was on the "marine side", i.e., plaeobiological/palaeontological, sedimentological, facial, and other aspects mainly concentrated on areas more of less "well under water". Therefore, an interesting field of investigations has not much been considered: The transition zone between land and sea plus their continuation in both, landward and seaward directions. Of course, IGCP Project 328 "Palaeozoic microvertebrate biochronology and global marine / non-marine correlation" (lead by A. Blieck and S. Turner) dealt with this zone, but focus was exclusively on fish remains and preferably their potential in biostratigraphical use and subsequent correlation. The recently accepted new IGCP Project 499 "Devonian land-sea interaction: Evolution of ecosystems and climate" (DEVEC) aims a broader view of this transitional zone which will be one of the main aspects of the project. But not only the processes within this (limited) area on or immediately near the former continents shall be studied – adjacent areas on the shelves reaching even reef structures that built up in a fair distance from the coast will have to be investigated by the participants of the new project. Especially the interactions between continental/coastal – shallow-water siliciclastics – outer shelf to even reefal settings are to be considered; the evolution of "continental/near-continent areas" may turn out to play a key role influencing all other facies including further details about palaeoecosystems and the Devonian palaeoclimate.

In the following paragraphs the outline of the new project is briefly summarized.

The Devonian was a critical period with respect to the diversification of early terrestrial ecosystems. The geotectonic setting was characterized by the switch from the post-Caledonian to the pre-Variscan situation. Plant life on land evolved from tiny tracheophytes to trees of considerable size in combination with a global increase in terrestrial biomass, and vertebrates started to conquer the land. Extensive shallow marine areas and continental lowlands with a wide range of different habitats existed which are preserved in a large number of basins all around the world. Climate change finally led from greenhouse to icehouse conditions towards the end of the Devonian. Both, rapid evolution of terrestrial ecosystems and climate change had a pronounced influence on sedimentation and biodiversity not only in the terrestrial but also in the marine realm ("Devonian Change"). A major goal of the project will be to focus on controls and interactions of the respective facies parameters in different paleogeographic settings in order to refine the global picture by international co-operation in a number of case studies. Geoscientific co-operation will include a variety of disciplines, such as sedimentology, paleontology, stratigraphy, paleoclimatology, paleogeography, geochemistry, paleooceanography, and structural geology.

The rapid evolution of early life on land and its interaction with sedimentary processes, climate, and paleogeography, both on land and in marine settings, will be covered by studies in different terrestrial and marine facies. Increasing colonization of the land by plants in combination with soil-forming processes and changing runoff led to major changes of sediment input into the marine system. On the other hand, sediment input and climate are major controls for carbonate production and reef development. The study of responses and interactions thus needs detailed characterization of facies and high-resolution correlation which can only be provided by a refined stratigraphy including biostratigraphy, lithostratigraphy, chronostratigraphy, etc. Characterization of facies and correlation of stratigraphic units is especially difficult in marine-terrestrial transitions and will be an important focus of the project. Resolution of sea-level changes will be enhanced by recognition and exact correlation of their effects which may be hidden just in these transitions. On the background of the global geotectonic situation (paleogeography *s.l.*), this will be an important prerequisite for a better discrimination of eustatic, climatic, and biotic controls, both on regional and global scale.

The focus of the project concerns the interrelated evolution of terrestrial and marine paleoecosystems with respect to biotic and abiotic factors in space and time. Studies will include individual paleoecosystems and their components as well as their paleobiogeographic distribution. Biotic and abiotic factors of paleoecosystems are controlled by both, earthbound and extraterrestrial triggers causing either cyclicity and/or distinct events. Thus in turn, such studies may give a clue to underlying causes of global changes. The project will include sedimentologic and climatic controls of reef development and distribution as well as diversity, and paleoecology of reef building organisms throughout the Devonian, because the Middle to Late Devonian was a peak in reef development with reefs spreading into latitudes as high as 45–60 degrees. On the other hand, accomodation space for Early Devonian reefs was greatly reduced due to major input of sediment from the continents in combination with sea-level lowstand(s). A marked decline in reef development towards the end of the Devonian was probably caused by climatic deterioration.

The integrative kind of research which is needed for the success of the project can only be carried out by a worldwide network of research groups representing different disciplines. Such a network can now be based on core groups successfully participating in the recently terminated IGCP 421. Furthermore, the project will extend the results of the former IGCP 328. It will actively interlink with IGCP 491 which is mainly centered around vertebrate research. IGCP 499, however, will concentrate on the correlation and interaction of different ecosystems in a more general way. Special attention will be paid to coupling effects between the terrestrial and marine realm. Co-operation will also put forward with the new IGCP Project 497 "The Rheic Ocean: its origin, evolution and correlatives". Furthermore, an active network is represented by the members of the "Subcommission on Devonian Stratigraphy" (SDS). These existing networks will be integrated and thus providing the necessary base for an improved understanding of the Devonian period. A number of the respective colleagues and working groups have already agreed to contribute to the proposed project (see list of participants on the website).

Leaders of the project are:

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Further information can be obtained from the website: http://www.senckenberg.de/igcp-499. Colleagues interested in participation should contact one of the organizers in Frankfurt (addresses see in the mailing list).

GLAUCONITE BEARING SEDIMENTARY SUCCESSIONS IN THE LOWER ORDOVICIAN OF THE POLAR URALS

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The Ordovician carbonate and terrigenous rocks represented by different facies are widespread in the western slope of the Polar Urals. During more than 10 years the author studied the Lower Ordovician rocks exposed in the middle part of the Paga River basin. Sedimentary succession there is represented by glauconite-bearing sandstones and siltstones with the interbeds of gravel sandstones, calcareous sandstones and limestones. The presumable terrigenous part of the succession is assigned to the Pagatinsk Formation whereas the overlying carbonates to the Kibatinsk Formation.

The Pagatinsk Formation has a thickness of more than 100 m and composed of grey to greenish glauconitic sandstones and siltstones with calcareous beds containing rich brachiopod fauna. The amount of glauconitic grains in generally feldspar-quartz sandstones is 5–10 % (rarely to 30 %). Besides brachiopods the sediments contain also rare trilobites and conodonts. Conodonts *Eoconodontus notchpeakensis* (Mill.), *Cordylodus proavus* Mull., *Oneotodus singularis* Nass, trilobites *Dolgeuloma multicava* Ancig., *Leimitzia bavarica* (Barr.), *Eoorthis* sp., *Micragnostus* sp., and brachiopods *Obolus* sp. and *Lingulella* sp. were found in the basal part of the section. In the middle and upper part of the section were collected numerous brachiopods *Altorthis kinderlensis* Andr., *Apheorthis vicina* (Walk.), *Alimbella* *armata pagaensis* Andr., *Medessia uralica* Andr., *Tritoechia lermontovae* (Lessn.), *Syntrophorthis* sp., and *Obolus* sp. as well as trilobites *Leimitzia pagica* Anc., *L. bavarica* (Barr.) and *Apatokephalus* sp. The biostratigraphic data show that the Pagatinsk Formation was accumulated during the period from the uppermost Cambrian to the upper part of the middle Tremadocian.

The lower boundary of the studied terrigenous succession is not exposed therefore the precise thickness of the Pagatinsk Formation is unknown. However the occurrence of gravel and coarse sandstones at the basal part of the section clearly demonstrate that the lower boundary is just below the basal exposed part of the section. The boundary between the sandstones of the Pagatinsk Formation and overlying carbonates of the Kibatinsk Formation is placed within the thick (10 cm to several meters) lithostratigraphic unit where the amount of carbonate material gradually increasing and sandstone material became finer. The fauna in the transitional layers are represented by microscopical lingulate brachiopods and conodonts *Acodus tetraedron* Lind., *Cordylodus rotundatus* Pan., *Oneotodus altus* Viira, *Oistodus inaequalis* Pand., *Scandodus varanguensis* Viira and some others. The faunal assemblage is similar to those from the Varangu Formation (Varangu Regional Stage) of North Estonia (Viira, 1974).

The more than 50 meter thick section of the Kibatinsk Formation was studied on the left bank of the Paga River. The succession is represented by grey to greenish pelitic limestones that contain rare glauconitic grains. The layers of siltstones are common. The limestones are rich in fossil remains that are represented mainly by brachiopods *Obolus* and *Siphonotreta*. Taxonomic composition of conodont assemblages that were recovered from limestones resembles those from the *Paltodus deltifer* and *Paroistodus proteus* zones of the Varangu and Hunneberg stages of the northeastern part of Russia and Estonia.

The upper part of the Kibatinsk Formation (~ 170 m thick) represented by clayey limestones and carbonaceous siltstones and shales is exposed on the opposite right bank of the Paga River. From this part of the succession the conodonts only were studied. Conodont assemblage consists of simple coniform elements typical for the *Oistodus lanceolatus* Zone *sensu* V. Viira (1974) of the Billingen and Volkhov regional stages of the Baltic region. The ramiform elements are absent or extremely rare. The biostratigraphy data allow considering that the Kibatinsk Formation ranged in age from the upper Tremadocian to the second still unnamed stage of the Lower Ordovician. The overlying stratigraphic unit is not exposed in this area, however it is supposed that the limestones of the Kibatinsk Formation has a conformable contact with the carbonate rocks of the Middle–Upper Ordovician Kachamyl'sk Formation.

The studied successions were accumulated on the margin of open relatively shallow shelf that is indicated by the occurrence of glauconite rich facies, conodonts and brachiopod dominated fauna. At present, these Ordovician successions together with the Silurian black shales compose the separate block of so-called Lemvin allochthon that reflect the history of sedimentation on the eastern margin of the East-European plate.

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SILURIAN GRAPTOLITE SUCCESSION OF THE KALININGRAD DISTRICT, NORTHWEST RUSSIA: NEW INFORMATION FROM DRILL-CORES

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The Silurian fine-clastic deposits bearing graptolites are known in the Kalinigrad District since late 60s, though the first data on graptolite biostratigraphy were published by Ju. Dmitrovskaya, Kh. Rozman and R. Sobolevskaya not earlier than in 1984. In several drilling-cores the Late Ordovician (Ashgillian) benthic fauna and early-middle Llandovery graptolite assemblages of the *vesiculosus, cyphus* and *triangulatus* zones were recognized.

Present biostratigraphic studies are based mainly on rich graptolite collections made in the Gusevskaya-1 drill-core in 2000 by one of the authors (A.A.S.) and on some graptolite samples, collected by Ju. Dmitrovskaya and

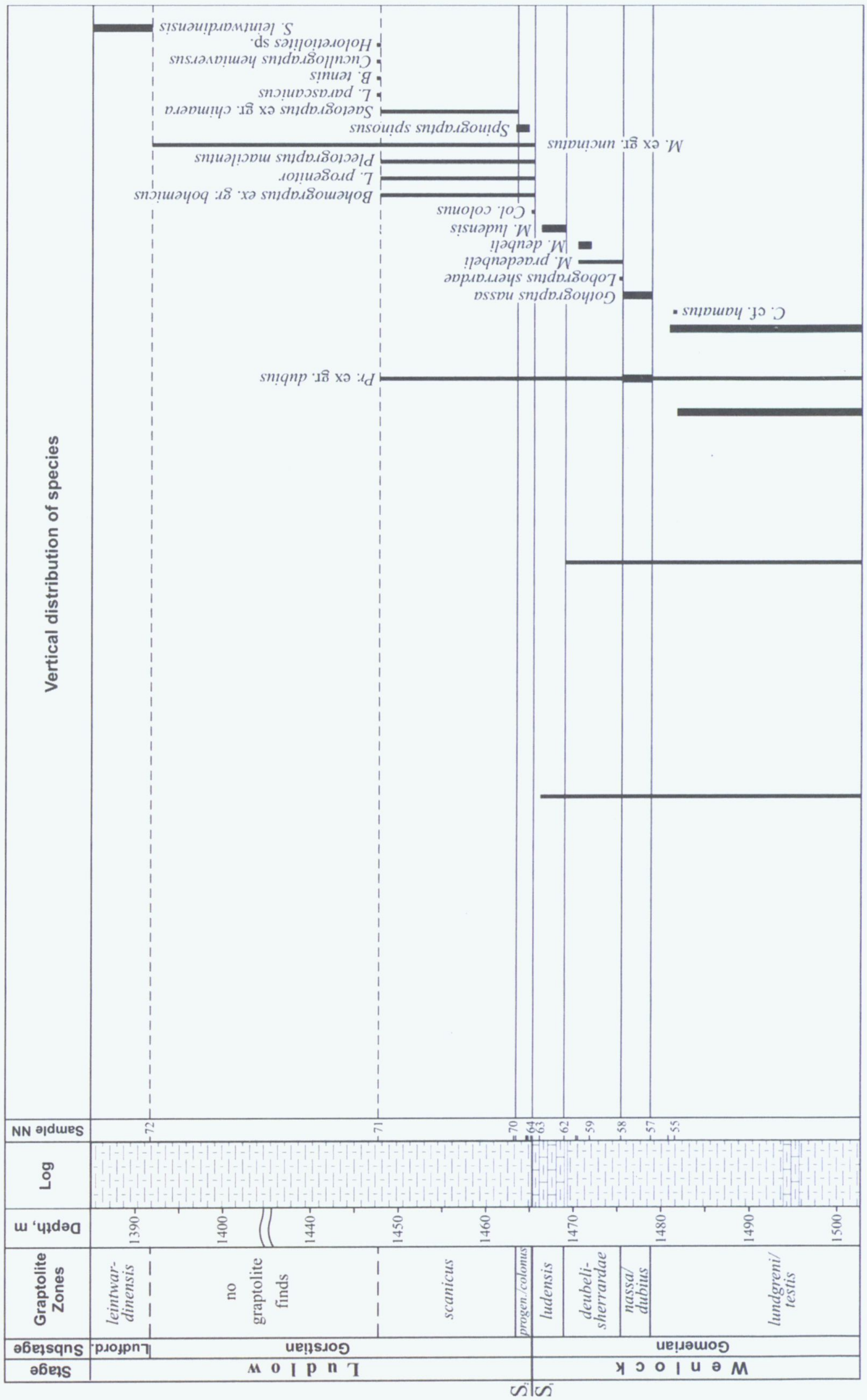
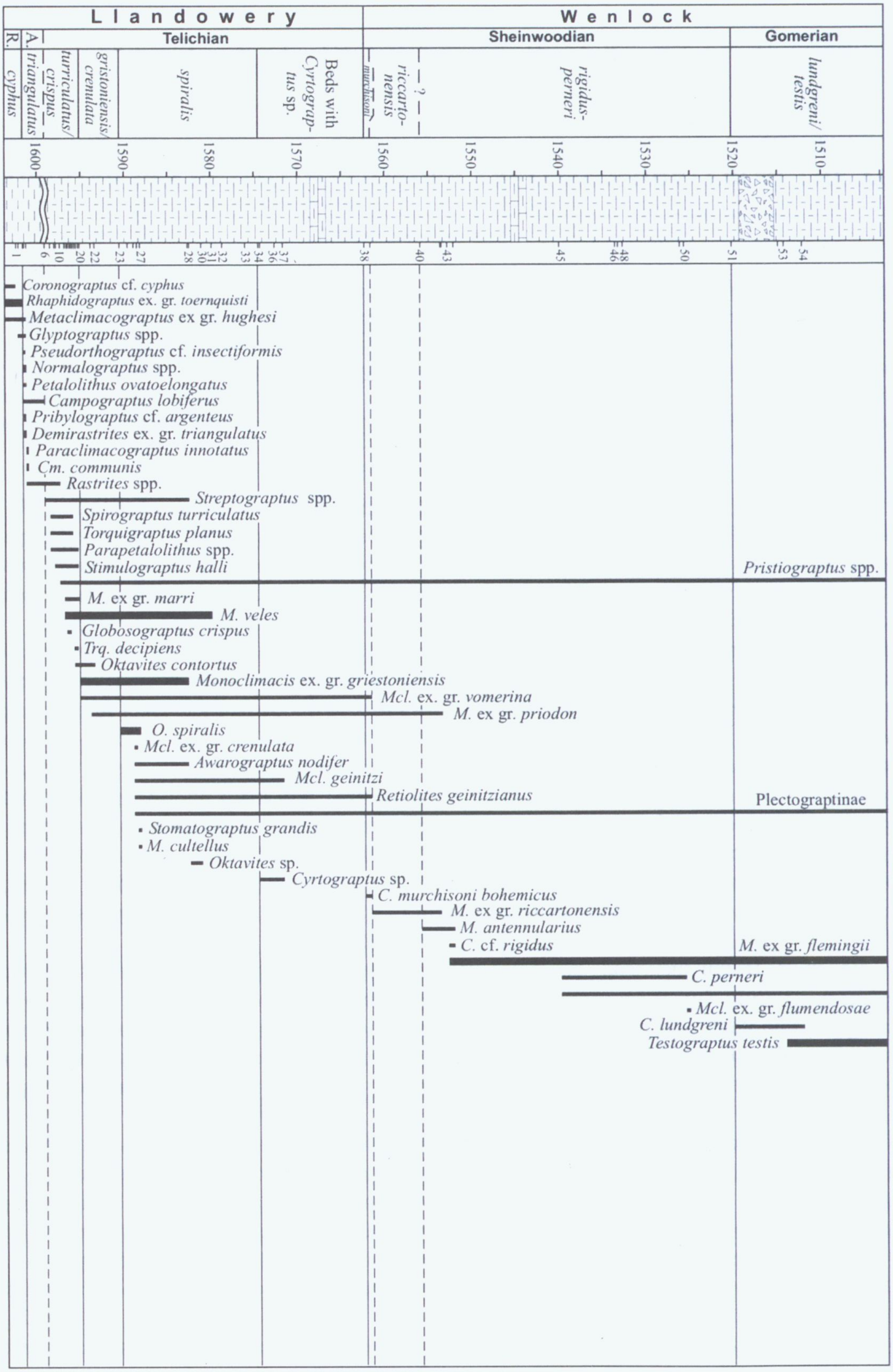


Fig. 1. Stratigraphical distribution of graptolites in the Gussev–1 drill-core



Llandowery
Wenlock
R.
A.
Telichian
Sheinwoodian
Gomerian
cyphus
triangulatus
turriculatus/ crispus
gristoniensis/ crenulata
spiralis
Beds with Cyrtograptus sp.
murchisoni
riccarto- nensis
?
rigidus- perneri
lundgreni/ testis
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
1
6
10
20
22
23
27
28
30
31
32
33
34
36
37
38
40
43
45
46
48
50
51
53
54
Coronograptus cf. cyphus
Rhaphidograptus ex. gr. toernquisti
Metaclimacograptus ex gr. hughesi
Glyptograptus spp.
Pseudorthograptus cf. insectiformis
Normalograptus spp.
Petalolithus ovatoelongatus
Campograptus lobiferus
Pribylograptus cf. argenteus
Demirastrites ex. gr. triangulatus
Paraclimacograptus innotatus
Cm. communis
Rastrites spp.
Streptograptus spp.
Spirograptus turriculatus
Torquigraptus planus
Parapetalolithus spp.
Stimulograptus halli
Pristiograptus spp.
M. ex gr. marri
M. veles
Globosograptus crispus
Trq. decipiens
Oktavites contortus
Monoclimacis ex. gr. griestoniensis
Mcl. ex. gr. vomerina
M. ex gr. priodon
O. spiralis
Mcl. ex. gr. crenulata
Awarograptus nodifer
Mcl. geinitzi
Retiolites geinitzianus
Plectograptinae
Stomatograptus grandis
M. cultellus
Oktavites sp.
Cyrtograptus sp.
C. murchisoni bohemicus
M. ex gr. riccartonensis
M. antennularius
C. cf. rigidus
M. ex gr. flemingii
C. perneri
Mcl. ex. gr. flumendosae
C. lundgreni
Testograptus testis

Fig. 1.

Kh. Rozman in late 60s in the Western Gusevskaya-1, Slavskaya-1, 2 and Malinovskaya-2 partly overlapping drill-cores (Fig. 1).

Stratigraphy. The Silurian shales and mudstones with occasional limestone layers, 230–270 m thick, are transgressively overlying carbonate deposits of the upper Ordovician (Ashgillian) yielding Hirnantian brachiopods and ostracods (Dmitrovskaya *et al.*, 1984). Thickness of the Silurian rocks increases in the western direction up to a maximum 1446 m on the Baltic Sea shelf. The local lithostratigraphic subdivisions in the Silurian were established for the first time while mapping of the territory at 1: 200 000 scale (Zagorodnykh *et al.*, 2001). Stratotypes of the Shmelev, Grivin, Brjusov and Dubov Formations are designated at the most complete reference section studied in the Gusev-1 drill-core (Fig. 2).

Graptolite sequence. The most complete Llandovery, Wenlock and Ludlow graptolite zonal sequence was recognized in the Gusevskaya-1 drill core. Graptolites were collected in black shales and carbonaceous mudstones bed by bed at intervals from 30 cm to 1 to 2 m. Well preserved and most numerous graptolites in 3D occur in finely laminated shales within some Llandovery intervals. The rest of samples, especially those from the Wenlock and Ludlow deposits, are represented by flattened, but quite well preserved specimens numerous at some stratigraphic levels.

The lowermost Silurian deposits (the Shmelev Fm) are assigned to the *vesiculosus* Zone (Slavskaya-1, 2 drill cores). The finds of graptolite-bearing mudstones corresponding to the *ascensus* and *acuminatus* zones (the basal Llandovery) in Baltic Syneclise was discovered only in one of the drill-core in the Baltic Sea (Ulst, 1992). Resulting from present studies of core material an almost complete sequence of Llandovery graptolite zones was established in the Kaliningrad District. Among them are: *vesiculosus, cyphus, triangulatus, convolutus, sedgwickii, guerichi, turriculatus–crispus, griestoniensis, spiralis* zones and Beds with *Cyrtograptus* sp. A continuous graptolite succession in Llandovery–Wenlock boundary beds was recognized for the first time in the region. The lower Wenlock boundary is drawn at the level of a first appearance of *Cyrtograptus murchisoni bohemicus*. The higher Sheinwoodian sequence is subdivided into the *riccartonensis* and *perneri–rigidus* zones. The Homerian graptolite sequence, consisting of the *lundgreni/testis, nassa–dubius, deubeli–sherrardae* and *ludensis* zones, is now well established in the Gusevskaya-1 drill-core. The Gorstian Substage is represented by the *progenitor/colonus* and *scanicus/chimaera* zones. The base of Ludlow coincides with the first appearance of *Colonograptus colonus, Lobograptus* cf. *progenitor* and *Bohemograptus bohemicus*. At the upper part of graptolite-bearing rocks *Saetograptus linearis,* marking the base of the Ludfordian Substage, is found. The Ludlow deposits are overlain with the stratigraphic unconformity by red beds of the Tilge Formation of Lochkov age (Zagorodnykh *et al.*, 2001).

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MIDDLE ORDOVICIAN BRYOZOANS (ORDER TREPOSTOMIDA) FROM THE VOLKHOV AND KUNDA STAGES OF THE LYNNA RIVER (LENINGRAD REGION)

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The studied bryozoans were collected from the classic section at the left bank of the Lynna River that encompasses the stratigrafic interval of the uppermost Volkhov ($B_2\gamma$) and the lowermost Kunda ($B_3\alpha$–$B_3\beta$) stages. The thickness of the studied interval that represented by the intercalation of limestone and clay layers is 7.57 m. As a whole, 34 clay layers were sampled and washed; bryozoans were picked from the dry residues. Each sample was represented by

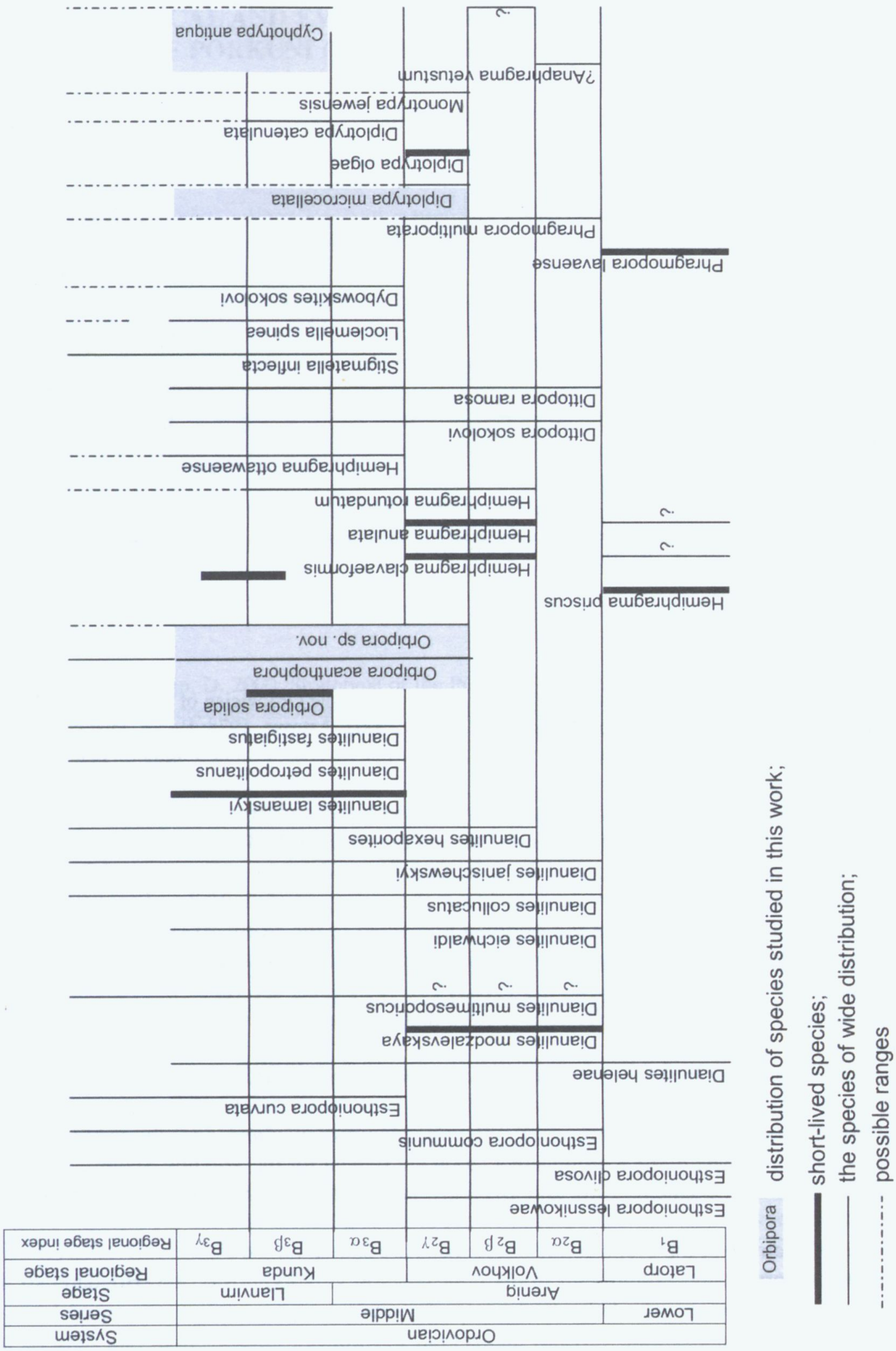

Fig. 1. Stratigraphical distribution of trepostomid bryozoans in the Middle Ordovician of the Leningrad Region (after Modzalevskaya, 1953, 1986; Pushkin, 1973, 2001, 2002; Astrova, 1978; Ropot, Pushkin, 1987; Goryunova, 1996; Pushkin, Popov, 1999; Koromyslova, 2004 with the present auther data)

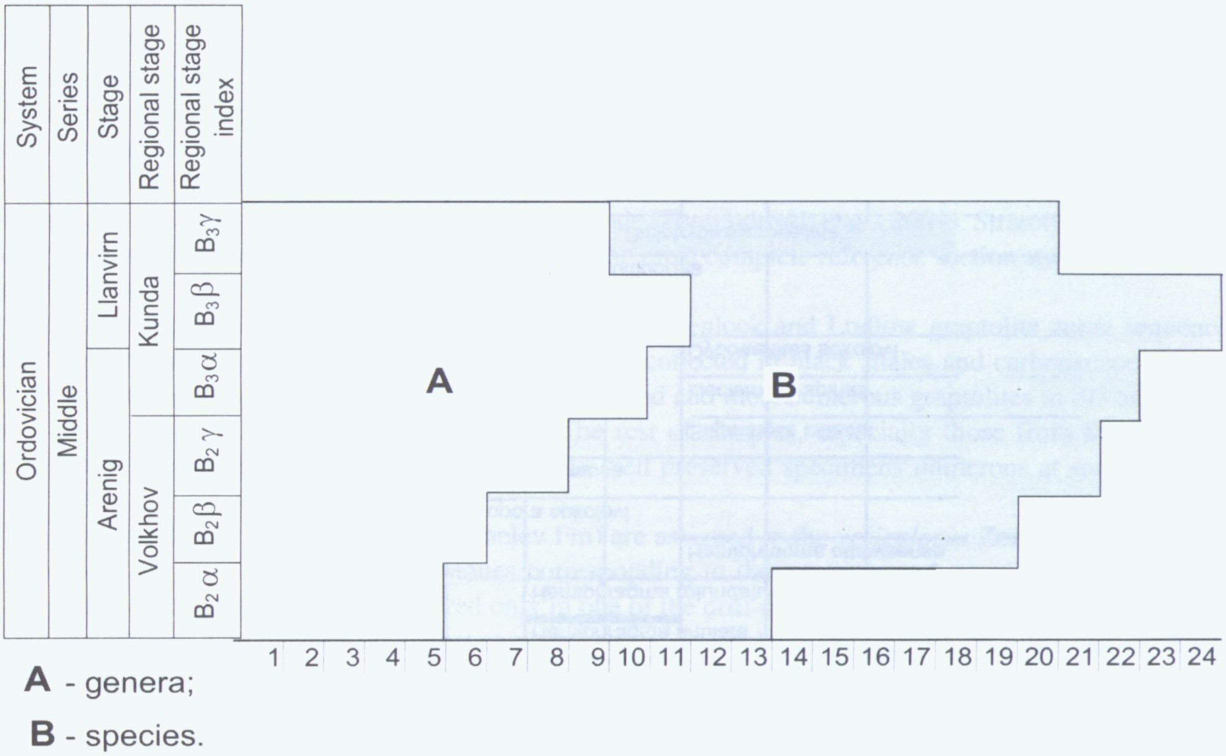

Fig. 2. Taxonomic diversity of trepostomid bryozoans in the Middle Ordovician of the Leningrad Region (after Modzalevskaya, 1953, 1986; Pushkin, 1973, 2001, 2002; Astrova, 1978; Ropot, Pushkin, 1987; Goryunova, 1996; Pushkin, Popov, 1999; Koromyslova, 2004 with new author's data)

2–10 kg of clay. The collection comprises approximately 700 specimens of bryozoan colonies that are from 2 to 10 mm in sizes.Two species *Orbipora solida* ($B_3\beta$) and *O. acanthopora* ($B_3\alpha$–$B_3\beta$) were found in the Leningrad Region for the first time. They were previously reported from the Ordovician deposits of Estonia and Sweden only (Bassler, 1911). New species of genus *Orbipora* were described from the upper part of the Volhov Stage ($B_2\gamma$). The *Diplotrypa microcellata* previously reported only from the Middle Ordovician of the Northern Urals (Astrova, 1945) was also found in that stratigraphic interval. The stratigrafical distribution of the representatives of the order Trepostomida is shown on the Fig. 1.

Our study allowed to indicate the following species that are important for the stratigraphic subdivision of the studied interval:

– *Hemiphragma priscum* Pushkin, 1999 and *Phragmopora lavaense* Pushkin, 1999 are characteristic for the Latorp Stage;

– *Dianulites modzalevskaya* Pushkin, 2001; *Hemiphragma clavaeformis* (Dybowski, 1877); *H.annulata* (Eichwald, 1860) and *Diplotrypa olgae* Koromyslova, 2004 are typical for the Volkhov Stage;

– *Dianulites lamanskyi* Pushkin, 2001 and *Orbipora solida* Bassler, 1911 are characteristic for the Kunda Stage.

The diversity dynamics of the Trepostomida bryozoans are shown on the Fig. 2.

Acknowledgements. I am very grateful to my colleagues R.V. Goryunova, O.B. Bondarenko, I.S. Barskov, T.V. Kuznetsova and A.A. Madison who helped me a lot in my studies.

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THE PALOEOCOLOGICAL AND EVOLUTIONARY IMPORTANCE OF THE CEPHALOPODS OF PORKUNI (LATEST ORDOVICIAN, ESTONIA)

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The quarry of the north Estonian village Porkuni represents a succession of shallow-water limestones and flints spanning the Ashgillian *extraordinarius* graptolite zone, a time interval that reveals inside in the initial pulse of the End Ordovician Extinction (Hints *et al.*, 2000; Webby *et al.*, 2004). The sediments of Porkuni are highly fossiliferous and the fossils are extraordinary well preserved. Cephalopods where collected in Porkuni since more than a century.

Now, a number of approximately 70 specimens are available in museums of Estonia, and Germany. These specimens represent twelve species of eleven genera and five orders.

An extraordinary highly diverse fauna is preserved at Porkuni. Moreover, the fauna is unique because the embryonic shell of the cephalopods is usually preserved, providing insight in the early growth of the taxa.

The extraordinary diverse cephalopod fauna of Porkuni is compared with the Ashgill cephalopod fauna of North America and the worldwide cephalopod diversity (Sepkoski, 2002). The comparison shows that in Porkuni small orthocones cephalopods and oncoceridans are represented far above average.

A comparison of the taxonomic rates of Porkuni with universal trends over the End Ordovician Extinction Event reveals no local peculiarity. However, it can be shown that typical Silurian taxa represent the main group of the Cephalopods at the latest Ashgillian.

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TRILOBITES OF THE OANDU, RAKVERE AND NABALA REGIONAL STAGES FROM THE WESTERN PART OF THE LENINGRAD REGION AND THEIR STRATIGRAPHIC SIGNIFICANCE

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The Oandu, Rakvere and Nabala regional stages are well exposed in the western part of the Leningrad Region (Figs 1-2). The stratigraphical and palaeontological data have been reported by numerous scientists including I. Bok, F. Schmidt, E.M. Lutkevich, B.P. Asatkin, T.N. Alichova, A. Roomusoks & Oraspold, A.V. Dronov among the others. The present paper shows the results of the ten-year studies on the Oandu, Rakvere and Nabala stratigraphy and fauna, made by present authors. Summary of our results is as following:

1. Ten sections and more seventy localities of the Oandu, Rakvere and Nabala stages have been studied and sampled for trilobites (Figs 3–4). The trilobite collection are represented by several hundreds specimens that were assigned to 22 species.

2. The boundary between Oandu and Rakvere stages and the boundary between Rakvere and Nabala stages in studied sections is marked by the appearance of trilobites *Isotella remigium* (Eichwald) and *Isotella platyrhachis* (Steinhardt) correspond to the extensively pyritized surface that easily recognizable in the majority of the sections (Figs 3–8).

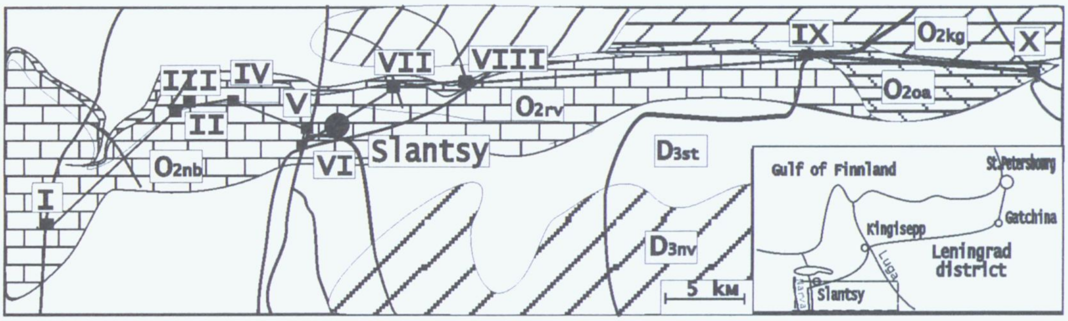


Fig. 1. Sketch-map showing main sections of the Oandu, Rakvere and Nabala stages of the Leningrad Region: I - southern bank of the Narva River near the Perevolok Village, II – western part of the quarry near Pechurki Village, III – eastern part of the quarry near the Pechurki Village, IV – eastern part of quarry near the Kamenka Village, V – northern bank of the Plussa near the Bolshie Polja Village, VI – northern bank of the Plussa River near the Slantsy town, VII - northern bank of the Borovenka River near the Borovenka Village, VIII – northern bank of the Chernaya River near the Chernaya Village, IX - northern bank of the Dolgaya River near the Lozgolovo Village, X- northern bank of the Luga River near the Bolshoi Sabsk Village

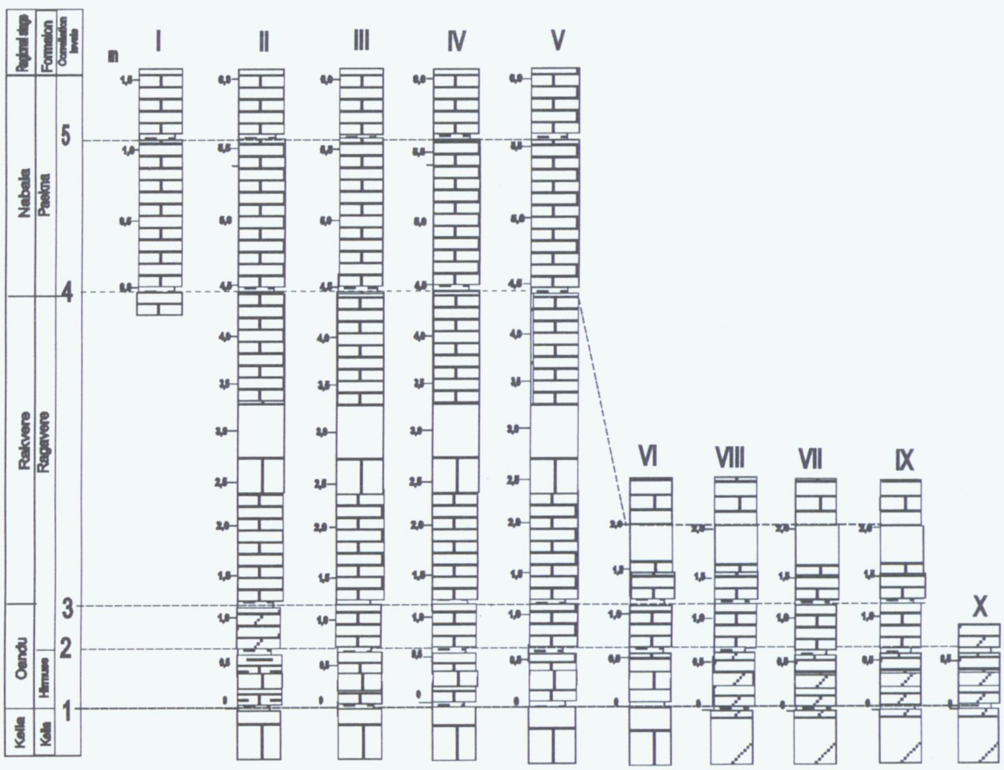
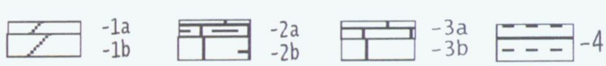


Fig. 2. Correlation scheme of sections I-X

Legend for fig. 2-8.



1a-thin layers of grey and yellow dolomites, 1b - thick layers of grey and yellow dolomites, 2a-thin layers of blue marls, 2b-thick layers of grey and blue marls, 3a - thin layers of white limestones, 3b-thick layers of white limestones, 4 - thin layers of blue and yellow clays and marls

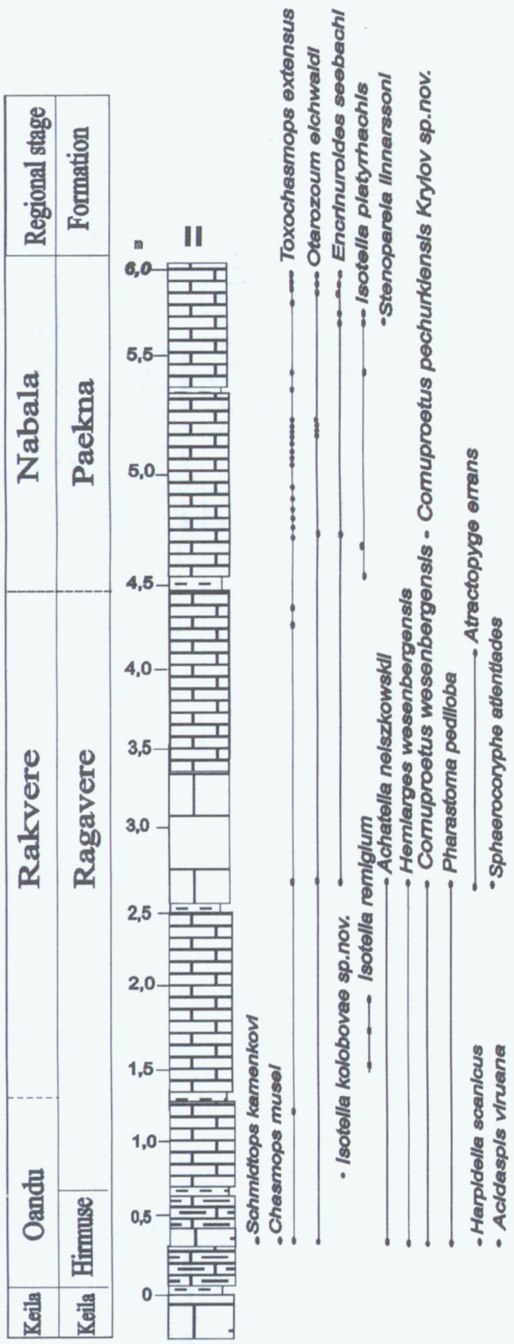


Fig. 3. The section in western part of the quarry near the Pechurki Village

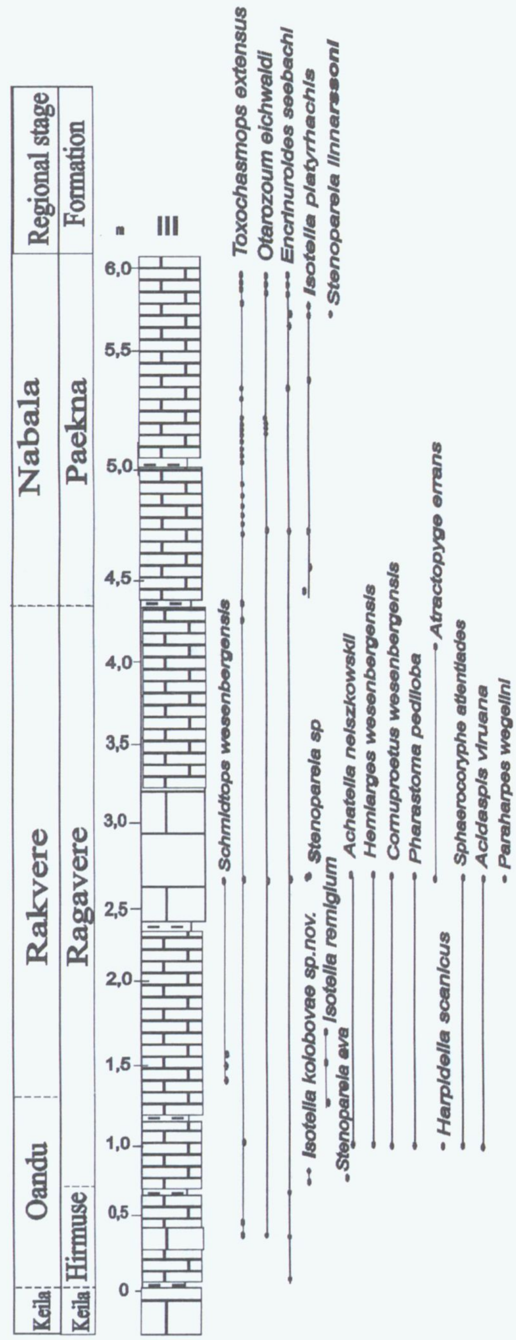


Fig. 4. The section in the eastern part of the quarry near the Pechurki Village

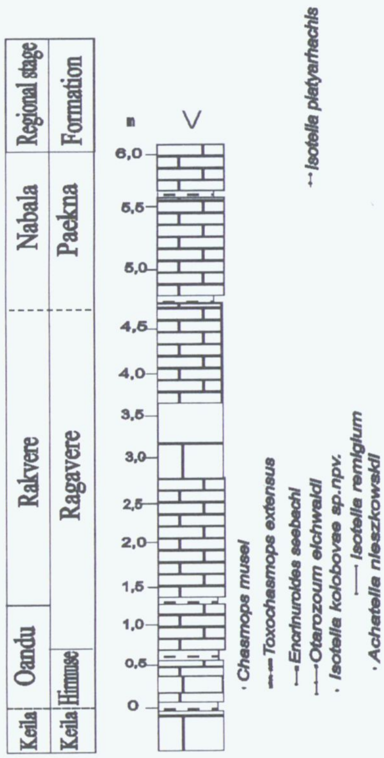


Fig. 5. The section at the northern bank of the Plussa River near the Bolshie Polja Village

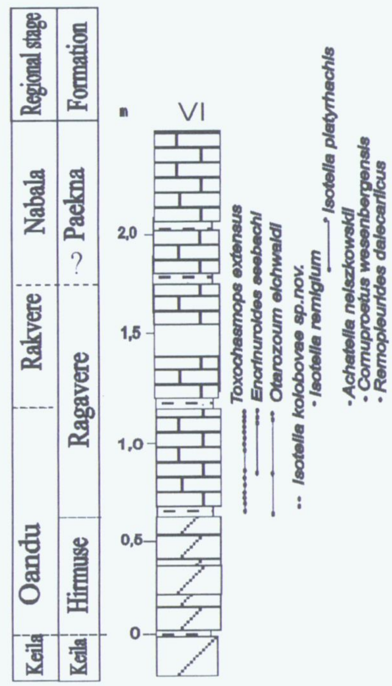


Fig. 6. The section at the northern bank of the Plussa River near the Slantsy town

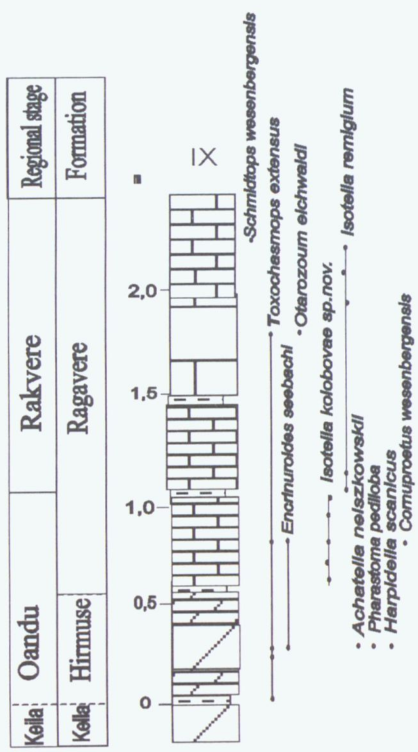


Fig. 7. The section at the northern bank of the Dolgaya River near the Lozgolovo Village

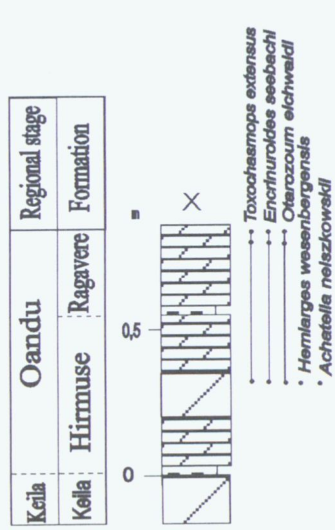


Fig. 8. The section at the northern bank of the Luga River near the Bolshoi Sabsk Village

3. The trilobite fauna of the Oandu, Rakvere and Nabala stages is characterized by representatives of relatively deep–water genus such as: *Schmidtops*, *Pharastoma* and *Harpidella*, middle-water genus such as: *Toxochasmops*, *Achatella*, *Encrinuroides*, *Otarozoum*, *Cornuproetus* and shallow-water genus such as: *Isotella* and *Stenopareia*.

4. The lithology of the Hirmuse Formation, exposed in the western part of the Leningrad Region differs significantly from that of the eastern part. In the western sections this formation consists of blue marls bearing: *Schmidtops kamenkovi* (Krylov), *Pharastoma pediloba* (Romer) and *Harpidella scanicus*? (Olin). In the eastern part of the area deposits of the Hirmuse Formation are composed of white and yellow limestones and dolomites yielding of *Toxochasmops extensus* (Boeck), *Encrinuroides seebachi* (Schmidt), *Otarozoum eichwaldi* (Nieszkowskii) and others.

5. Five thin layers of green marls that can be used as correlative lithological markers were recognized in the sections of the Oandu, Rakvere and Nabala stages (Fig. 2). Three of them (layers 2, 3, 4) are overlain by carbonate layers with an extremely high concentration of fossils (Fig. 2). The layer 2 within the lower part of the Ragavere Formation is marked by numerous trilobites *Isotella kolobovae* Krylov sp. nov. (in press) and brachiopods *Vellamo oandoensis* (Opik). The layer 3 within the middle part of the Ragavere Formation is overlain by limestones that yields numerous fauna including trilobites *Isotella remigium* (Eichwald), *Schmidtops wesenbergensis* (Schmidt), brachiopods *Vellamo wesenbergensis* (Pahlen), heliolitoids and bryozoans. The layer 4 within the lower part of the Paekna Formation is overlain by the limestone that yields numerous trilobites *Isotella platyrhachis* (Steinhardt), brachiopods *Vellamo verneuili* (Eichwald) and bryozoans.

THE PRE-VISEAN HIATUS CHARACTERISTICS IN THE TIMAN-PECHORA SEDIMENTARY BASIN

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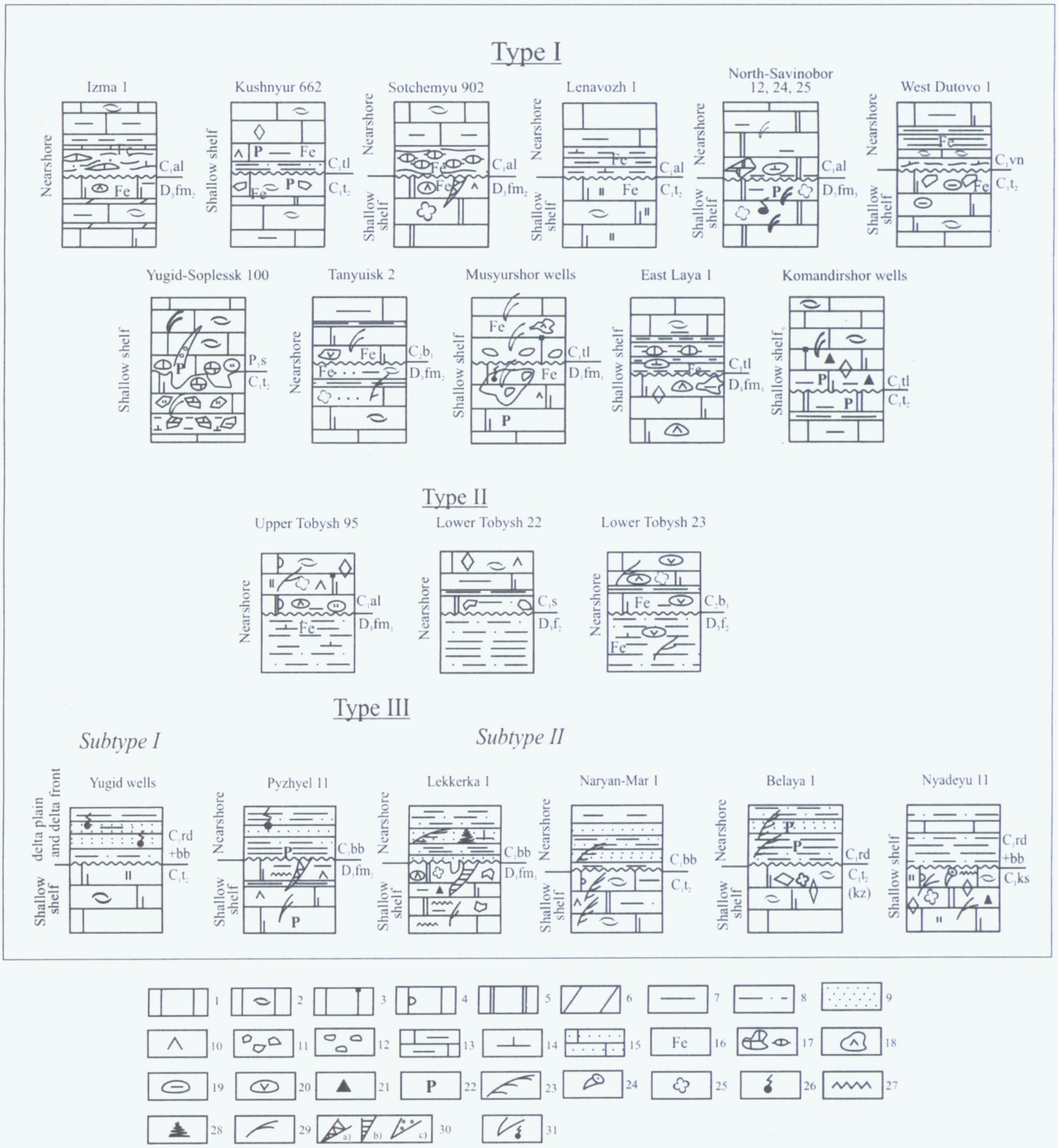
A global sea level fall accounts for a regional pre-Visean hiatus in the Timan-Pechora Sedimentary Basin. More than three-quarters of the basin area was characterized by the subaerial exposure. In general, the marine basin regressed southeastward and northeastward in late Tournaisian–early Visean time. A drastic reduction in sedimentation area has resulted from this regression. During early Visean time some troughs only of the present day Uralian Foredeep (Upper Pechora, Kosyu-Rogov, Korotaikha) and Varandey-Adzva Structural Zone were the local depocenters. At this time, much of the Timan-Pechora Sedimentary Basin was a landmass exposed to erosion. Clastic material was transported by rivers eastward across this area. Rocks eroded were of different lithology and age. In Timan, they were represented by Riphean metamorphic quartzose and clay rocks and also by Devonian clastic, igneous and volcanic basic rocks. In the eastern portion of the basin, Frasnian, Famennian and Tournaisian argillaceous and carbonate sediments were exposed to erosion. Carbonate and clayey-carbonate rocks predominated in much of the area eroded. On the Middle Pechora Uplift, Pechora-Kozhva Megaswell, Denisov Trough and in the northern part of the Kolva Megaswell, terrestrial, lagoon and nearshore clastic and carbonate rocks were deposited at this time. In the Middle and South Timan, during a long period of lateritization, bauxite deposits were formed (Demina, 1977).

The geological age of the basal surface, i.e. the base of rocks overlying a regional unconformity is various. It is explained by the successive progradation of the Visean sea northwestward. The transgressive onlap is well illustrated by the rock pattern. At the base of the section there are sandy and silty clay layers, argillaceous sandstone and siltstone, occasional gravelly sandstone. These deposits grade upward into clayey carbonate. Lagoonal, terrestrial and deltaic sediments change upward to nearshore and shallow marine rocks.

Summarizing the lithology and stratigraphy of rocks underlying and overlying the unconformity surface, three types of rock units may be distinguished (Fig. 1).

Type 1. These are the units with the unconformity (1) inside a carbonate member and (2) at the base of argillaceous and occasional clastic members. The widespread distribution of crumpled, ferruginous, brownish-red, variegated argillaceous clay layers indicates the pre-Visean hiatus in the Izhma-Pechora Depression.

Type 2. These are the units, in which middle Frasnian to lower Famennian clay and clastic nearshore deposits



1 - limestone; 2 - detrital fossiliferous limestone; 3 - grumous limestone; 4 - algal limestone; 5 - dolomite; 6 - marl; 7 - clay or argillite; 8 - siltstone; 9 - sandstone; 10 - anhydrite; 11 - breccia; 12 - pebble; 13 - clay admixture; 14 - carbonatization; 15 - sandy limestone; 16 - Fe-stained rocks; 17 - clasts of carbonate rock; 18 - anhydrite inclusions; 19 - clasts of argillaceous rock; 20 - gypsum inclusions; 21 - bitumen; 22 - pyrite; 23 - carbonaceous plant remains; 24 - corals; 25 - vuggy rock; 26 - oil shows; 27 - stylolites; 28 - burrows; 29 - fractures; 30 - fractures filled in with: a) argillaceous material, b) sulfate, c) siderite; 31 - oil filled fractures.

Fig.1. Types of lithologies resulted from the pre-Visean Hiatus (core data)

are unconformably overlain by the Lower to Middle Carboniferous shallow marine carbonates. The rock lithology changes abruptly indicating the unconformity.

Type 3. These units are represented by sections in which Visean nearshore argillaceous and clastic rocks overlie Tournaisian to Famennian shallow marine carbonates. In these units, the unconformity is marked by a sharp change in lithology resulted from changing depositional environments. Terrestrial, nearshore and shallow marine argillaceous and clastic rocks overlie carbonate sediments deposited in shallow marine environments. Stratigraphic completeness of units underlying and overlying the unconformity increases eastward. Unconformity surface is often accompanied by karst phenomena. This type of units can be further subdivided into two subtypes. Subtype 1 was identified in the Radaevsky-Bobrikovsky-age clastic rocks. This subtype represents deposition in the delta plain and delta front environments. Subtype 2 is common for the areas of the Timan-Pechora Sedimentary Basin where the Radaevsky-Bobrikovsky clastic and argillaceous rocks of nearshore and shallow shelf origin overlie unconformably the Tournaisian and Famennian shelf limestone.

Thus, the pre-Visean hiatus lasted throughout the middle Famennian to Venevsky (late Oksky) time in the Timan-Pechora Sedimentary Basin. In the northern and northwestern Izhma-Pechora Depression, the both pre-Visean and pre-Bashkirian hiatuses were superimposed. The period of erosion encompassed the middle Frasnian to Bashkirian time. On the Yugid-Soplessk Uplift, in a junction area of the Upper Pechora Trough and Khudoel-Voysk Anticline Zone, three hiatuses, pre-Visean, pre-Bashkirian and pre-Permian, were superimposed. The total time of erosion spanned the middle Frasnian to Early Permian time on the Pechora-Kozhva Megaswell, and the Tournaisian to Early Permian times on the Yugid-Soplessk Uplift.

The regressive stage culminated by the end of Kosvinsky time followed by the beginning of transgression in Bobrikovsky time.

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NEW DATA ON THE BLIDENE FORMATION (UPPER ORDOVICIAN) IN THE CENTRAL EAST BALTIC

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The study of the Blidene Formation in its type area, in West Latvia, was initiated by the necessity to get new data for the comparison with the lithologically similar deposits included in the same or in the Variku Formation in South Estonia. For this study the collection of samples from the Latvian sections, housed at the Institute of Geology at Tallinn University of Technology, are used.

The Upper Ordovician Blidene Formation represents a lithostratigraphic unit of calcareous marlstone distributed in West Latvia and Lithuania, and in South Estonia. The unit was established by Männil in 1963 in four West Latvian sections, in the Blidene-5, Sturi-8, Piltene-1 and Remte drill cores (Fig. 1), where the unit lies at the depth of about 1000 m. The stratotype of the Blidene Formation (beds by Männil, 1963) was identified in the Blidene core in the interval of 892.0–895.5 m (Birkis *et al.*, 1976). Later, the interval of 1061.0–1063.0 m in the Saldus-5 PM drill core was proposed as a neostratotype of the Blidene Formation (Brangulis *et al.*, 1989), because the Blidene core was destroyed.

In the type area, in West Latvia the Blidene Formation comprises greenish-grey marls with thin interlayers of organodetrital limestone in the lower part. The thickness of this formation varies from 0.5 m in the Engure up to 4 m in the Skrunda-P 28 core. Its boundaries are distinct. On the lower boundary the organodetrital limestones are replaced by marls or marls with thin interlayers of limestone. On the upper boundary the marls are replaced by black shale of the Mossen Formation.

In South Estonia the Blidene Formation is identified, like in West Latvia, in the sections where the complex of argillaceous rocks is overlain by black shales. In the Valga-10 core (Põldvere, 2001) of South Estonia the Blidene Formation in thickness 3.8 m is represented by argillaceous silty marls with limestone nodules. In SW Estonia in the Ruhnu core the Blidene Formation in thickness 1.4 m consists of dolomitized calcitic marlstone. In South Estonia the Blidene Formation is considered partly contemporaneous with the silty marls of the Variku Formation (Ainsaar *et al.*, 1999) or older than the latter (Ainsaar, Meidla, 2001). In 1966, Männil included the Blidene Formation into the Oandu Stage, but later he and other researchers (Ulst *et al.*, 1982) attributed this formation to the Keila Stage (Fig. 2).

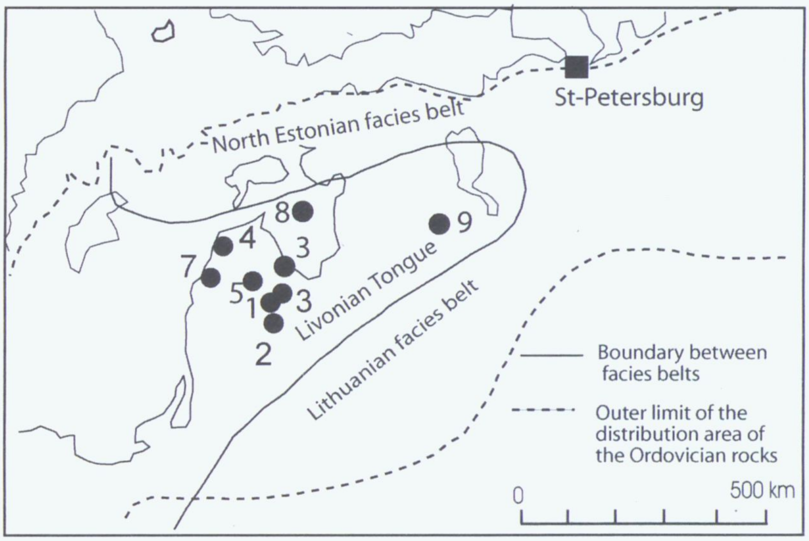

Fig. 1. Location of the drill cores: 1 – Blidene-5, 2 – Sturi-8, 3 – Remte, 4 – Piltene-1, 5 – Saldus-5PS, 6 – Engure, 7 – Aispute-41, 8 – Ruhnu, 9 – Valga

Series & Stage		Männil, 1966 East Baltic		Ulst et al., 1982 West Latvia	Ainsaar et al., 2001 South Estonia	Nõlvak, 1997 South Estonia	Nõlvak, 1997 North Estonia
UPPER ORDOVICIAN	Rakvere	Mossen shale	Rakvere limestone	Mossen Fm.	Räg.Fm.; Variku Fm. / Mossen Fm.	gap; Mossen Fm.	Rägavere Fm.
	Oandu	Blidene marl	Oandu marl		Variku Fm. / Mossen Fm.	Lukstai Fm.	Hirmuse Fm.
	Keila	Skagen limestone; marls	Keila limestone	Blidene Fm.	Blidene Fm.	Blidene Fm.	Kahula Fm.
	Haljala	Dalby limestone	Jõhvi, Shundorovo, Ojamaa lms.	Adze Fm.	Adze Fm.	Adze Fm.	Tatruse Fm.

Fig. 2. Stratigraphic position of the Blidene Formation by different authors

For this study 40 samples from the Blidene-5, Aizpute-41, Priekule and Kandava-26 drill core sections were subjected to sedimentological analyses. The carbonate component in the samples was dissolved and insoluble residue was fractionated by gravity sedimentation and sieving into the fractions of <2, 2–8, 8–16, 16–63 and >63 μm. By the studied samples of the Blidene Formation in the Aizpute-41 core (Fig. 3) the carbonate component forms 18.2–31.8 % of the rock composition. Only the lowermost sample stands out by high content (about 70 %) of $CaCO_3$ in argillaceous limestone. The grain size composition of the insoluble residue is presented in Fig. 3. The clay fraction (grain size < 2 μm; fraction VI in Fig. 3) forms 37.1–47.1 % of the terrigeneous material in the most part of the Blidene Formation. The fine silt (2–8 μm and 8–16 μm) forms up to 30 % and the coarse grained silt (16–63 μm) less than 10 %, except the uppermost sample from the Aizpute core. The occurrence of fine-grained sand (>63 μm in size) is very low (0.5 %) in the Blidene Formation like in South Estonia (Valga core). In the sample from the shale of the Mossen Formation (A on the Fig. 3) the high content of the same fraction may be artificial, as the clay particles have not dispersed in the analysing process.

The studied sections are located in the deeper part of the basin, in the Livonian Tongue of the Central Baltoscandian facies belt, but the grain size composition of the Blidene Formation is rather similar to that in South Estonia. Still, in

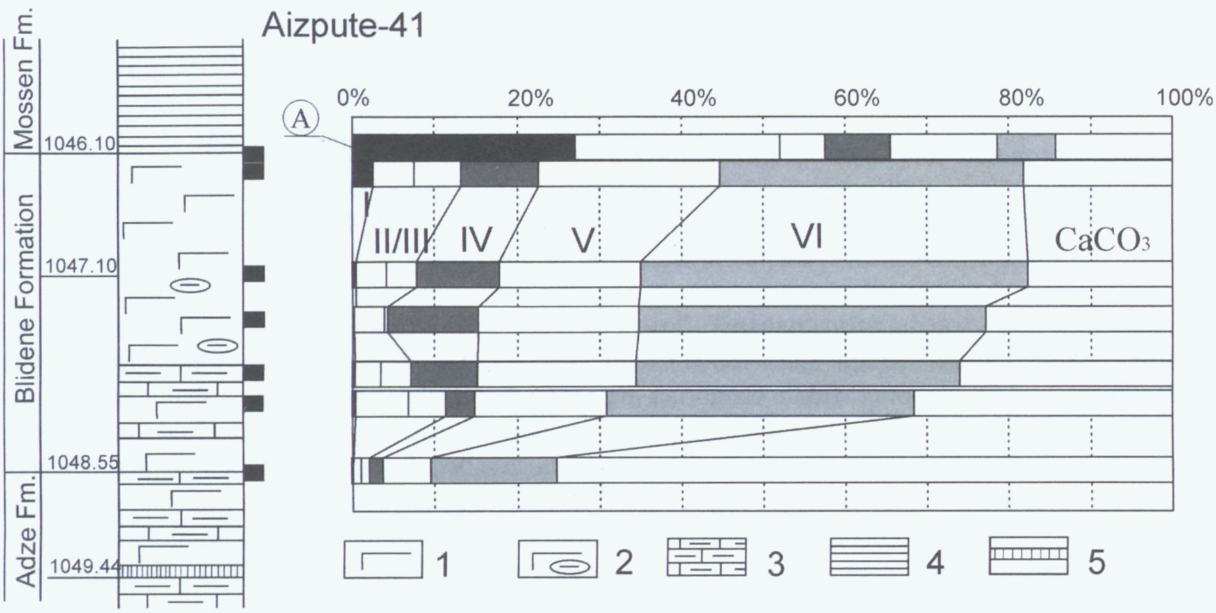

Fig. 3. The insoluble residue grain size distribution in the whole rock samples of the Aizpute-41 core. I – fraction > 63 μm; II/III – fraction 63–32 μm / 32–16 μm, IV – fraction 16–8 μm, V – fraction 8–2 μm, VI – fraction <2 μm. 1 – argillaceous marl, 2 – marl with limestone nodules, 3 – argillaceous limestone, 4 – black shale, 5 – K-bentonite

the Aizpute-41 core the clay content does not exceed 50 %, but in the Valga-10 section it reaches about 70 % below the shale of the Mossen Formation (Ainsaar and Meidla, 2001). By the clay content the Blidene Formation is similar to the uppermost part of the Kahula Formation in the transitional area between the North Estonian facies belt and the Livonian Tongue. The first unit differs from the uppermost Kahula and also from the Variku Formation by the low content of the coarse silt (about 10 %). In the Kahula and Variku formations it reaches up to 30 % and 70 %, respectively.

The presented preliminary data show an essential variation in the composition of the siliciclastic material in the deeper part of the Baltic paleobasin. This complicates the correlation and unambiguous identification of the lithostratigraphical units based on the grain size composition of the rocks.

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LOWER PALAEOZOIC "CARPOID" ECHINODERMS OF BALTICA : PALAEOECOLOGICAL AND PALAEOBIOGEOGRAPHIC IMPLICATIONS

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Such as "eleutherozoans" and "pelmatozoans", "carpoids" are an informal, polyphyletic assemblage of various echinoderm classes : Cincta (Middle Cambrian), Ctenocystoidea (Middle Cambrian), Soluta (Middle Cambrian–Lower Devonian), and Stylophora (Middle Cambrian–Upper Carboniferous). All carpoids share superficially similar "flat-fish" morphologies (flattened body with one or two ambulacra, and no sign of five-fold symmetry) resulting from relatively similar modes of life (almost all of them were unattached, free-living, epibenthic organisms (Lefebvre and Fatka, 2003; Rozhnov, 2002). Although carpoids are relatively common fossils in various peri-Gondwanan (e.g. Australia, Bohemia, France, Morocco) and Laurentian regions (e.g. Oklahoma, Scotland, Utah), very little is known yet on Baltic carpoids. Three classes of carpoids out of four have been documented so far in Baltica: ctenocystoids, solutes, and stylophorans.

One species of primitive ctenocystoids (*Jugoszovia archaeocyathoides*) was described in the early Middle Cambrian (*Eccaparadoxides insularis* Zone) of the Holy Cross Mountains, Poland (Dzik and Orlowski, 1995). Ctenocystoids were infeodated to relatively deep (and cool) palaeoenvironments, and thus relatively widely distributed: they also occured in western Laurentia (Utah), and in eastern (Australia) and western Gondwana (Bohemia, Montagne Noire). *Jugoszovia* shows relatively strong affinities with an undescribed ctenocystoid from Bohemia (Gabasova, Fatka and Zuskova, 1993).

Three species of solutes were reported from the Ordovician of East Baltic regions (Estonia and Russia; Bather, 1913; Hecker, 1940; Rozhnov, 2002; Rozhnov and Jefferies, 1996): "*Dendrocystites rossicus*" (Kunda Regional Stage, Middle Ordovician), *Heckericystis kuckersiana* (Kukruse Regional Stage, early Caradoc), and *Maennilia estonica* (Keila Regional Stage, middle Caradoc). The Baltic solutes occurred massively in relatively shallow waters conditions. *Maennilia estonica* preferred calm waters protected from waves by mud mounds. First, solutes arose in cool or temperate waters of Kunda. They continued existence in warm waters of Kukruse and were abundant in tropical Keila waters near mud mounds. The three Baltic species show stronger affinities with coeval forms from the European–north African sector of Gondwana (*Dendrocystites* spp.; Bohemia, Morocco), rather than with Laurentian solutes (e.g. *Dendrocystoides*, *Girvanicystis*, *Iowacystis*; Iowa, Oklahoma, Scotland). An uncomplete specimen of solute (*Dendrocystites* sp.) was also reported from the early Silurian of Öland, Sweden (Regnéll, 1945; Wiman, 1907).

Although relatively poorly known, stylophorans (cornutes, mitrates) were apparently the most abundant and diverse group of carpoids in Baltic regions. The early Middle Cambrian of south central Sweden (*Baltoparadoxides oelandicus* Zone) has yielded several relatively well-preserved specimens of one of the oldest and most primitive stylophorans known so far (*Ceratocystis* sp.; Franzén-Bengtson *in* Berg-Madsen, 1986). The presence of *Ceratocystis*-like stylophorans in Baltica is significant because these heavily plated forms were infeodated to shallow, warm to temperate seawaters. Their palaeobiogeographic dispersion, restricted to Baltica and West Gondwana (e.g. Bohemia, France, Germany, Great Britain, Italy, and Morocco), supports the view that these two regions were both located at low to intermediate palaeolatitudes in Middle Cambrian times, and not separated from each other by a wide ocean.

Isolated fragments of cornutes were also collected in the late Middle Cambrian of Bornholm, Denmark (*Paradoxides forchammeri* Zone; Berg-Madsen, 1986), and possibly also in the Upper Cambrian of Öland, Sweden (B. Lefebvre, pers. obs.; several isolated plates from Degerhamn Quarry road section, sampled during last IGCP 503 field trip in September 2004).

Various stylophorans were documented in the Ordovician of Baltic regions : disarticulated pieces of the cornute Babinocystis dilabidus (Volkhov Regional Stage, early Middle Ordovician, Russia; Rozhnov, 1990), numerous isolated plates of a diverse assemblage of cornutes (Uhaku to Idavere Regional Stages, late Middle Ordovician to early Caradoc, Poland; Pisera, 1994), fragments of cornutes and of an Ateleocystites-like anomalocystitid mitrate (Middle Ordovician, Russia; Mannil, 1983; Rozhnov, 1990), remains of a Lagynocystis-like mitrate (Caradoc, Russia; S. Terentiev pers. comm., and S. Rozhnov, pers. obs.), and several relatively well-preserved specimens of the anomalocystitid mitrate Barrandeocarpus norvegicus (Hirnantian, Norway; Brenchley and Cocks, 1982; Craske and Jefferies, 1989). In contrast to Ceratocystis-like primitive forms, most Ordovician stylophorans were cool-adapted, widely distributed forms (they occured in shallow to deep settings at high palaeolatitudes, and only in deep settings at low palaeolatitudes; Lefebvre and Fatka, 2003). This interpretation is in good accordance with the stratigraphic distribution of Baltic forms: they are restricted to time intervals corresponding to "cool" palaeoenvironmental conditions (e.g. Middle Ordovician to early Caradoc, and later, Hirnantian), and they are apparently absent, when warmer, tropical conditions prevailed (middle Caradoc to early Ashgill; Rozhnov, 2004). Most Ordovician stylophorans from Baltica are too poorly known to discuss their palaeogeographic affinities. However, the presence of the genus *Barrandeocarpus* in Baltica suggests stronger affinities with both Avalonia (England) and the European–north African sector of Gondwana (Bohemia, Morocco), where this genus is also present, rather than with eastern Laurentian regions, which have yielded a diverse assemblage of Upper Ordovician anomalocystitid mitrates, but where the genus *Barrandeocarpus* is absent.

Finally, a single specimen of the anomalocystitid mitrate *Placocystites* sp. was reported from the Silurian (?Wenlock) of Gotland, Sweden (Lindström, 1888; Regnéll, 1945; Regnéll, 1960). *Placocystites* was also documented in the Wenlock of England. This heavily-plated mitrate was infeodated to warm and shallow settings. Its presence in the Silurian of England and Sweden supports the view that these two regions were both located at low palaeolatitudes and no longer separated by a wide ocean.

In summary, although still imperfectly known (probable strong preservational bias), the distribution of Baltic carpoids seems to be in relatively good agreement with both their inferred mode of life and available palaeogeographic reconstructions.

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CONODONT APATITE $\delta^{18}O$ RECORD ACROSS THE LUDLOW LAU EVENT IN THE PRAGUE BASIN (CZECH REPUBLIC) INDICATES CLIMATIC COOLING

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Oxygen isotope data measured on conodont apatite are presented from the upper Kopanina Formation in the Prague Basin. In the Muslovka Quarry section, an increase in $\delta^{18}O$ is observed parallel to the onset of the significant $\delta^{13}C$ excursion in bed 16 (characterized by abundant *Dayia minor*). $\delta^{18}O$ values vary between 16.6 and 17.4 ‰ (V-SMOW) in the underlying strata, increase to 18.9 ‰ (V-SMOW) in bed 17, and stay high through bed 20 (for position of bed nos. in the section see Kriz and Schönlaub in Chlupac *et al.*, 1980; Lehnert *et al.*, 2003). The increase in $\delta^{18}O$ of conodont apatite translates into a temperature drop of about 7 to 8°C if the change in $\delta^{18}O$ is explained exclusively by a change in palaeotemperature. We are aware that estimated cooling of 7 to 8°C seems unrealistic for low latitidues. A change in salinity or the build-up of polar ice caps are other variables that may have influenced the oxygen isotopic composition of conodont apatite. $\delta^{18}O$ records from other sections will be needed to confirm the global character of this change in $\delta^{18}O$. Most important, the change in $\delta^{18}O$ coincides with the significant positive excursion in $\delta^{13}C$, that might be indicative of major change in the global carbon cycle.

In terms of carbon isotopes, the global Lau event represents the largest excursion in $\delta^{13}C$ during the Phanerozoic (Munnecke *et al.*, 1994). The excursion was recorded from several palaeocontinents including Baltica, Australia, and Laurentia. A first report from peri-Gondwanan Perunica dealed with a $\delta^{13}C$ dataset from Muslovka Quarry (Lehnert *et al.*, 1993) displaying that the $\delta^{13}C$ excursion started within the upper part of *Neocucullograptus kozlowskii* graptolite zone (late *Polygnathoides siluricus* conodont zone). The peak in $\delta^{13}C$ values reaches a maximum at about +4,6 ‰ in strata correlated to the *Monograptus latilobus* graptolite zone and bearing taxa typical of the *Ananaspis fecunda–Cyrtia postera* Community of Havlicek and Storch (1990). A sequence boundary separates these fossil rich beds from underlying strata recording extinctions in various groups and evident faunal changes (Lehnert *et al.*, 2003).

The increase in $\delta^{13}C$ corresponds to the Lau Primo-Secundo Event (Jeppsson and Aldridge, 2000). As expressed by several authors (e.g. Jeppsson, 1990, 1998; Munnecke *et al.*, 2004), changes in the $\delta^{13}C$ record and faunal turnovers at this time in Perunia (Lehnert *et al.*, 2003), Gotland, and other parts of the world presumably have been caused by a combination of changes in palaeoclimate, sea level and sedimentation. The characteristic $\delta^{13}C$ shift correlates especially well with the faunal and isotope data reported from coeval beds in the upper Eke Formation on Gotland, where climatic and environmental changes across the event interval triggered 5 different extinction events affecting various groups including conodonts, chitinozoans, and fishes (Jeppsson, 1998; Calner *et al.*, 2004).

Our interpretation of the prominent shift in $\delta^{18}O$ observed in the Muslovka section is, like for variation recorded for the Late Devonian F-F event (Joachimski and Buggisch, 2002, Joachimski *et al.*, 2004), significant climatic cooling which probably triggered the corresponding sea-level drop and faunal overturns observable on different palaeocontinents.

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RADIATION OF EARLY–MIDDLE ORDOVICIAN ACRITARCHS IN SOUTH CHINA

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Acritarchs are fossilized organic-walled cysts of unicellular protists that cannot be assigned to known groups of organisms. Since 1974, more than 100 scientific articles dealing with Chinese Paleozoic acritarchs have been published. Most of them report acritarchs from southern China and concern Ordovician sections.

Thirty-nine samples of yellow-grey shale from the Meitan Formation from the Honghuayuan section at Tongzi were studied. Other data come from articles about Ordovician acritarchs in South China. The number of acritarch taxa increase from the Tremadocian to the "second stage." There is a maximum diversity of acritarchs in the *A. suecicus* graptolite biozone. The diversity of acritarchs remains high in the "third stage" and in the Darriwilian. However, acritarch diversity sharply declines after the Darriwilian and remains low in "six stage."

Whereas acritarch genera and species diversity is very low in the *D. eobifidus* graptolite biozone, four diversity peaks appear at the upper *C. deflexus* and base of the *A. suecicus* graptolite biozone, the upper *A. suecicus* graptolite biozone, the middle of the *E. hirundo* graptolite biozone, and the base of the *U. austrodentatus* graptolite biozone. Three valleys between diversity peaks appear in the middle of the *A. suecicus* graptolite biozone, the base of the *E. hirundo* graptolite biozone, and the upper middle of the *E. hirundo* graptolite biozone.The four index diversity peaks can be approximately correlated to four sea level peaks, and the three diversity index valleys can be approximately correlated to three sea level lows. These correlations indicate that sea level changes might be affecting acritarch diversity.

When sea level changes, acritarch diversity also changes, probably because of differences in acritarch groups having different nearshore-offshore trends, which appears to be the case in the Meitan Formation.The genera *Baltisphaeridium*, *Leiosphaeridia*, *Polygonium*, *Peteinosphaeridium*, *Striatotheca*, *Veryhachium*, and the galeatae and diacromorph groups were selected because of their continuous distribution throughout the Meitan Formation. The Galeata includes the genera *Cymatiogalea* and *Stelliferidium*, and the diacromorph group includes the genera *Acanthodiacrodium, Arbusculidium*, and *Dicrodiacrodium.*

Acritarch diversity in the Meitan Formation in Tongzi increases rapidly, and reaches a maximum in the *A. suecicusi* graptolite biozone. Acritarch diversity trends within the South China Plate provide some useful insights about Ordovician biotic radiation. There is a correspondence between the generalized trend of acritarch diversity and the facies association curve for the same interval at Honghuayuan. Vertical fluctuations in relative abundances of acritarchs appear to be related to changes in depositional facies. High relative abundances of *Leiosphaeridia* and *Striatotheca* indicate lower sea level, and high relative abundances of *Baltisphaeridium*, *Polygonium*, *Peteinosphaeridium*, and the Galeata, and diacromorph group indicates higher sea level.

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PALAEOECOLOGICAL PECULIARITIES OF THE CALLOVIAN MOLLUSC ASSEMBLAGES FROM LATVIA

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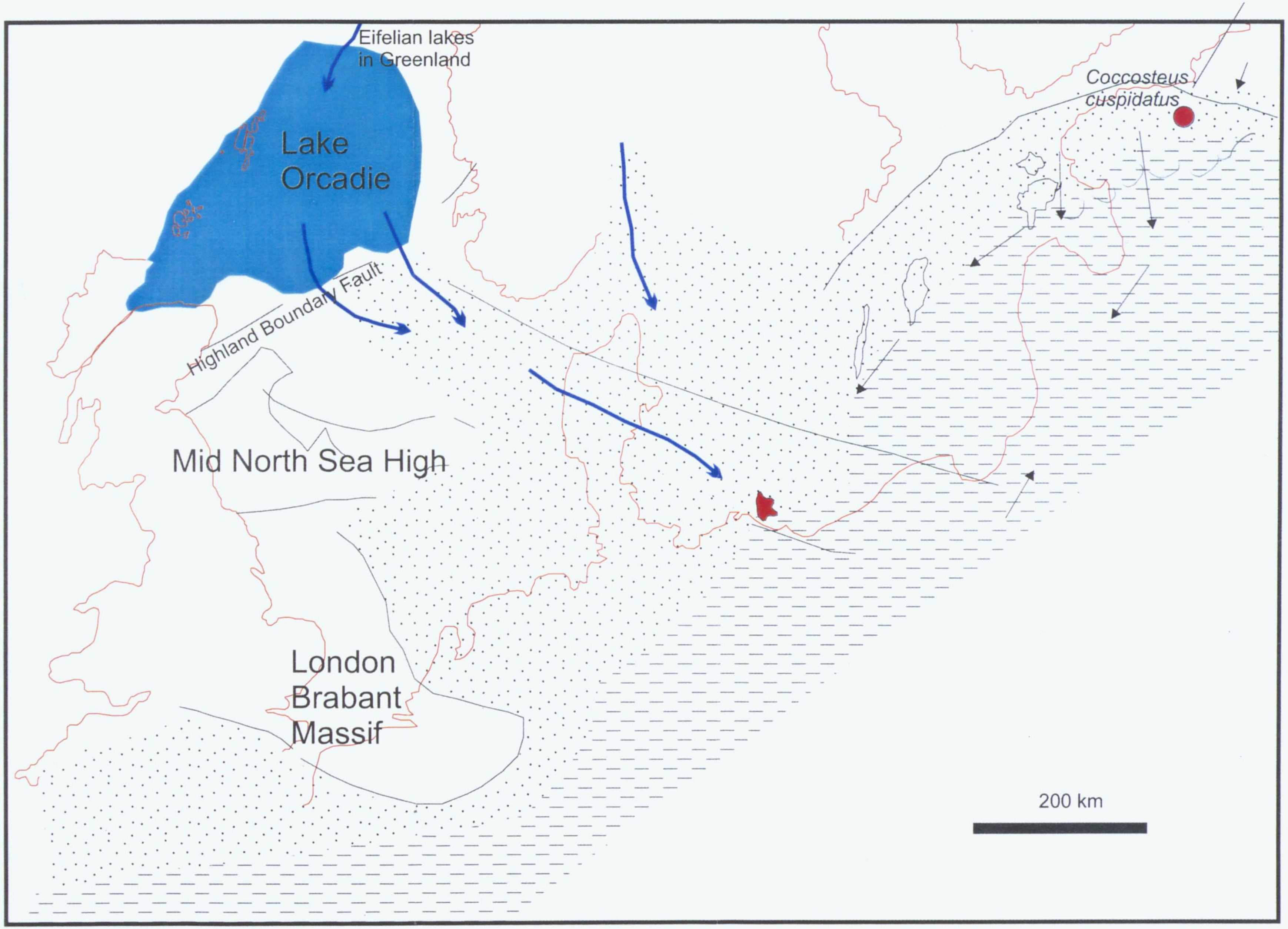
The Callovian (Middle Jurassic) sequence of Latvia is subdivided by lithological properties into two units. The lowermost part of the Callovian section belonging to the Papile Formation consists of mainly siliciclastic rocks: light coloured sand, sandstone with intercalations of siltstone, layers and lenses of brown coal. The middle and upper part of the sequence contains white and yellow sand and sandstone, dark grey and brownish grey limestone, carbonate concretions with goethite oolites and numerous fossils, covered by dark grey and black clay enriched by organic matter and pyrite. Rich assemblages of marine animals yielding ammonites, bivalves, gastropods, scaphopods, belemnites, brachiopods, sea urchins, bryozoans, and rare vertebrates, as well as particles of fossilized wood, reported from southwestern Latvia and north-western Lithuania verify the existence of the open sea at the end of the Callovian.

Carbonate concretions from the middle part of the sequence corresponding to the *Erymnoceras coronatum* and *Kosmoceras ornatum* ammonite zones contain the richest assemblage of molluscs. Six large concretions have been disintegrated for bionomic analysis, 6848 animal macrofossils were determined to species or generic level. The remains of molluscs dominate the assemblage composing more than 90 per cent of fossils on the whole. Among molluscs, bivalves are represented by about 55 taxa, gastropods are also rather diverse (more than 20 species), cephalopods and scaphopods are the rarest components of the mollusc assemblage. Mesozoic and Cainozoic bivalves usually show rather close relations to the substrate. Bivalves from analysed concretions were studied in respect of ecological preferences characterizing relationships with the substrate to restore the sedimentary environment of the Callovian sequence of Latvia. Among collected bivalves, *Lima moeschii* and *Gryphaea dilatata* belong to the ecological group of sessile benthic organisms with the shells cemented to the hard ground. Only some specimens represent this group. More bivalve taxa belong to the epifaunal byssus-attached forms: *Entolium, Meleagrinella, Modiolus, Oxytoma, Pinna, Radulopecten*. Some semi-infaunal byssus-attached forms such as *Gervillella* and *Pteroperna* also have been found. Shallow burrowing infaunal bivalves forms the most diverse ecological group represented by numerous specimens of *Anisocardia, Codakia, Corbulomima, Grammatodon, Mesosaccella, Protocardia, Tancredia,* and *Trigonia*. Deep burrowing infaunal filtrating bivalves are less diverse; they are represented by even more rare *Goniomya, Pleuromya* and *Quenstedtia*. *Paleonucula* is the only taxon within the ecological group of detritophagous deep burrowing infaunal bivalves. It is rather complicated to distinguish different ecological groups within gastropods or cephalopods. Most of gastropods were probably epifaunal or semi-infaunal detritophagous animals or plant eaters, some were predators, but ammonites most probably were nektonic or bentho-nektonic dwellers.

The numbers of specimens belonging to respective ecological group show absolute dominance of infaunal dwellers, the number of epifaunal components is smaller, but number of semi-infaunal and nektonic or nekto-benthic dwellers is much smaller. Faunal composition and relationships of various ecological groups of the Middle-Upper Callovian mollusc assemblage from Latvia show that it could be mixed containing faunas from slightly different shallow marine environments with normal salinity. Most of bivalves, gastropods, brachiopods and sea urchins existed within a moderately shallow basin on the sandy substrate below the wave base; some of bivalves buried together with representatives of this assemblage probably came from shallower environment with more active hydrodynamic regime. The lithological composition of concretions and mixed faunal composition allow judging that concretions were most probably formed due to catastrophic storms.



A first go at a SFB to Kernave palaeogeography

DEVONIAN EVENTS, CLIMATIC STRATIGRAPHY AND TIME IN THE DEVONIAN ORCADIAN BASIN, SCOTLAND

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The Devonian contains a number of distinct events that represent combinations of biotic, palaeoceanographic and climatic perturbations to the earth system. These are now well established in the marine record and recognised from many different areas. What is less understood are how these events are expressed in the continental record and this is particularly important as such sequences contain long climatic records. The Devonian Orcadian Basin contains such a long sequences that is generally developed in lacustrine sediments. The climatic record is a direct representation of times when the lake alternated between deep and permanent or shallow and ephemeral. These lakes cycles are also bundled up into longer intervals of time where the climate was generally more arid or humid.

The Orcadian Basin now has a well established lithostratigraphy based on the lacustrine cycles. Recent work has also enabled recognition in the terrestrial environment of the marine Taghanic and Kačak events. Also significant is the fish fauna of the Achanarras/Sandwick Fish bed level that can be matched to the Kernave Member (Narva Formation) of the Baltic. This gives tie-points positions between which the cycles in the Orcadian Basin can be compared to the marine record. The Milankovitch driven climatic cycles give an understanding of the actual time present within the sequence and thus enable preliminary ideas of the duration of the interval. It is an essential pre-requisite for understanding how successive humid/arid interval can be matched onto the marine record.

SEDIMENTARY FACIES OF THE SEMILUKI HORIZON (FRASNIAN) – USAGE FOR STUDENTS' GEOLOGICAL FIELD TRAINING

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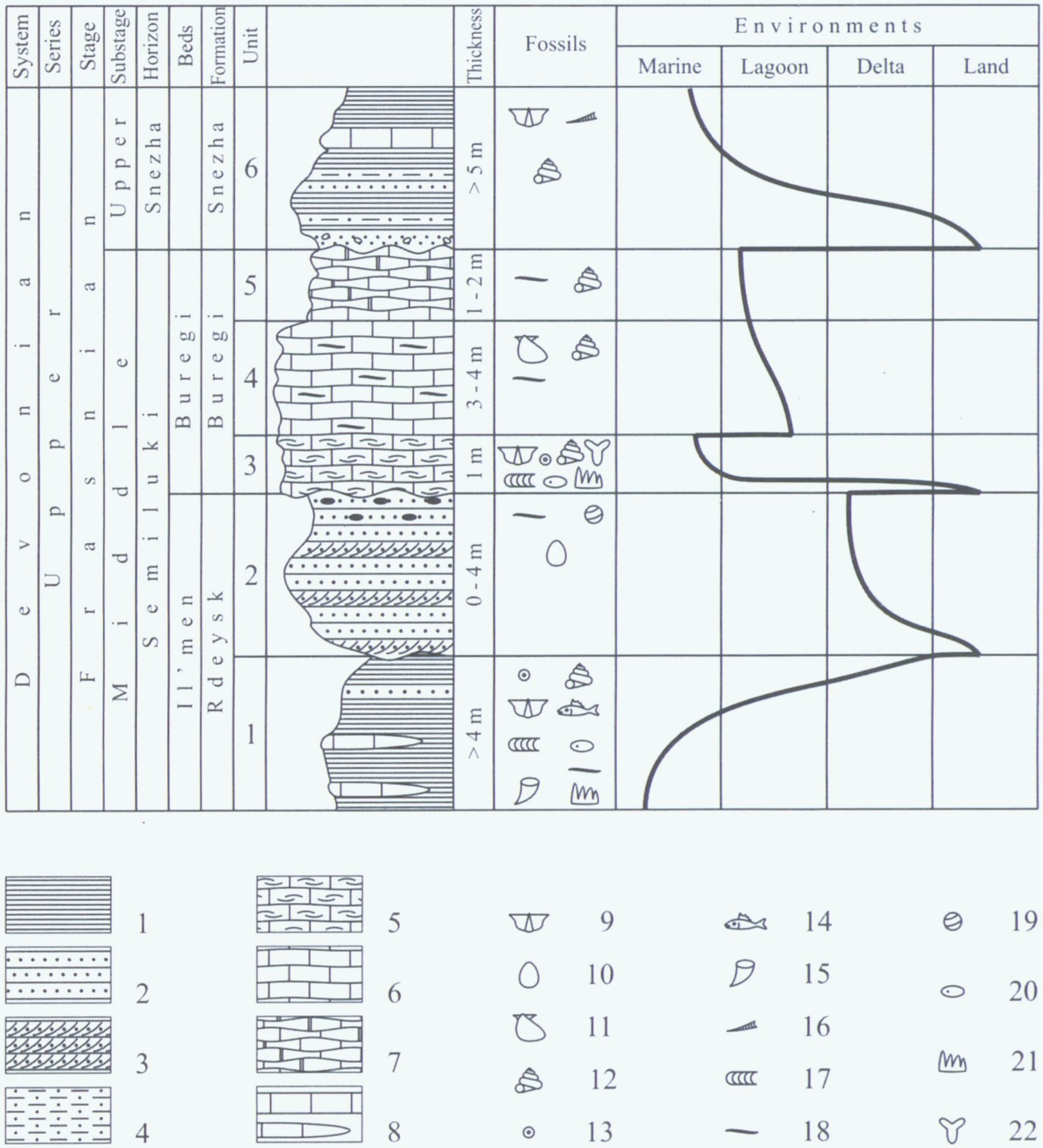
In the South Il'men area, there are unique sections of Semiluki Horizon (Upper Devonian, Middle Frasnian). Beds are exposed in a cliff, about 10 km long, along the south shore of the Il'men Lake; they also crop out in banks of the rivers Perekhoda, Psizha and Savateyka. These sections have been used as an example for correlation of the Upper Devonian between England and West Russia as far back as the XIXth century. The territory along the south shore of the Il'men Lake is a natural reservation called "Il'men Glint". Good exposure and absence of forests are favorable for students' geological field training in mid- and large-scale geological mapping, study of platform tectonic structures and shallow-water facies of the Late Devonian subtropical epicontinental sea basin. Transgressive and regressive parts of sediment cyclices depositional patterns and various unconformity surfaces can be observed as well.

The lower part of the exposed succession is represented by the Il'men Beds (local conodont zone *Polygnathus drucei*) of the Rdeysk Formation which consists of blue clay with thin lenses of bioclastic limestone in the lower part (unit 1). The layers of violet clay and silt also occur in the upper part of the unit. The Beds contain fragments of fish testae, imprints of bivalves, and trace fossils; the bioclastic limestones contain brachiopod valves, crinoids, ostracods, algae, conodonts of *Polygnathus* facies and rare auloporids and rugosa corals. Upper part of the Il'men Beds is represented by white and light red laminated and cross-bedded silty sand and silt (unit 2). A bed of ferruginous sandstone with ferruginous nodules, up to 0.5 m thick, occurs at the top of the Beds. The unit contains rare lingulida, oogonia of charophyta algae, trace fossils and borings. This unit wedges out towards the east and west parts of the Il'men Cliff (Glint). The top surface of this unit is uneven; with score features and ferruginization that suggests the subaerial exposure.

The overlaying Buregi Formation (local conodont zone *Polygnathus efimovae*) is composed of carbonates. Its bottom part is composed of reddish brown brachiopod limestones, which contain, besides numerous brachiopods,



Legend: 1 - clays; 2 - silty sands; 3 - cross-bedded silty sands;4 - silts and siltstones; 5 - brachiopod limestones; 6 - platy dolomitized limestones; 7 - lumpy dolomitized limestones; 8 - seams and lenses of bioclastic limestones; 9 - brachiopods; 10 - lingulids; 11 - bivalves; 12 - gastropods; 13 - crinoids; 14 - fish remains; 15 - corals; 16 - tentaculites; 17 - orthoceratids; 18 - trace fossils; 19 - charophytes; 20 - ostracods; 21 - conodonts; 22 - bryozoans.

Fig. 1. Upper Frasnian stratigraphy and paleoenvironments of South Il'men area

bivalves, gastropods, cephalopods, ostracodes, algae, and conodonts. Fragments of crinoids and bryozoans occur as well (unit 3).

The major part of the formation consists of light brown platy limestones, more or less argillaceous, silty, often dolomitized (unit 4). These limestones obtain a lumpy appearance and lighter color towards the top of the formation (unit 5). Abundant trace fossils and rare external molds of bivalves and gastropods are characteristic for platy limestones. In lumpy limestones, besides trace fossils, very thin laminae of detrital limestones containing conodonts, have been found.

The Buregi Formation is unconformably overlain by variegated carbonates, sands and clays of the Snezha Formation (Snezha Horizon, Upper Frasnian). The contact is quite distinct and sharp. The limestones at the contact are often ferruginized and covered by dark red peel that suggests the break in deposition (unit 6).

Devonian deposits constitute a gentle monocline dipping to the southeast at an angle about 7 minutes. Low amplitude folds and flexures complicate the monocline. Disjunctive structures such as low amplitude normal and reverse faults and thrusts also occur. There are also diapir-like structures formed by injection of plastic Il'men clays in their cores.

Frasnian deposits have been formed in the margin of a vast Late Devonian paleo-basin, which was situated in the subtropical zone. The style of sedimentation exhibits alternations of transgressions and regressions, which evolved in this basin during the Frasnian time. Three sediment cycles can be observed in exposures of the South Il'men area. These cycles have formed the Rdeysk, Buregi and Snezha Formations, respectively. The sedimentary cycles are divided by unconformities that can be traced throughout the broad area of the paleo-basin.

The maximum Rdeysk transgression occurred in pre-Il'men (Svinord) time, and a regressive phase of this sediment cycle has began and developed during the Il'men time. This is confirmed by the prevalence of variegated clays with sand laminae and almost complete absence of carbonates in the exposed part of the Il'men Beds.

Deposits of the Buregi Formation have been formed under conditions of the next transgressive cycle. Smaller scale cyclicity is peculiar to all three units of the formation. Thickness of cycles varies from 0.1 to 0.3 m. Cycles are often separated by hardground surfaces. This cyclic pattern is probably a result of shallow-water environment, bottom unevenness as well as storm activity. Rock fabric and peculiarities of fossil burials suggest a tempestite origin of this cyclicity.

The upper part of the Rdeysk Formation (Il'men Beds) has been formed in a shallow marine environment with relatively low hydrodynamic activity. Gradual increase of sand admixture in clays suggests progressive shallowing of the basin. Upper part of the Il'men Beds has been deposited probably in submarine delta–prodelta environment.

The lower unit of the Buregi Formation has been deposited in marine shoals with strong hydrodynamic activity. The overlaying second unit of platy limestones suggests the deposits in a basin with non-normal salinity and moderate hydrodynamic activity.

The unconformity between the Rdeysk and the Buregi formations is of a regional scale. It has been traced throughout the vast area from the South Onego area to Baltic and Belarus.

TRACE FOSSILS AND ICHNOFABRICS OF THE OBUKHOVO AND DUBOVIK FORMATIONS (KUNDA AND ASERI, MIDDLE ORDOVICIAN) IN THE ST. PETERSBURG REGION

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Compared to the complex and intriguing assemblages of trace fossils and ichnofabric patterns recognized in the Volkhov Regional Stage (Lower Ordovician; cf. Dronov *et al.* 2002), the ichnologic content of the overlying Kunda and Aseri Stages, is relatively monotonous. It, however, does not necessarily mean that it cannot be usefully interpreted in regards to sedimentary settings, substrate consistency, and physical energy of the environment.

Outcrops of the Obukhovo and Dubovik Formations (Kunda and Aseri) were studied in 2004 in two sites at the town of Volkhov: on the left bank of the river below the old road bridge, and on the right bank below the buildings of hydroelectric power. On both the sites, the Obukhovo Formation is built of thin-bedded marlstones, grey, greenish to violet in colour, rich in body fossils (especially conchs of nautiloids) and intensively bioturbated. The ichnofabric index reaches 4–5, i.e. nearly all the primary lamination is destroyed; however, the last inhabitants of the substrate left discernible traces. These are dominated by branching systems of narrow horizontal tunnels. They ramify irregularly at obtuse angles and can be placed to the ichnogenus *Megagrapton*. Less frequently, *Chondrites* isp. can be found as the representative of the deep tier of the trace fossil assemblage. Shells of body fossils bear subtle networks of the burrowing trace *Arachnostega* isp. Previous phases of bioturbation are poorly preserved due to the multiple burrowing but *Planolites* sp. seems to be the most frequent agent of the biogenic activity.

The Dubovik Formation, represented by thicker-bedded to massive, brown, greyish-brown to yellowish-brown marlstones, shows basically similar pattern of ichnofabric. The ichnofabric index reaches also 4–5. In the lower to middle part of the sequence, large tunnels of *Thalassinoides* isp. represent the most frequently preserved trace fossil; *Megagrapton* is less frequent; simple spreiten-structures (?*Teichichnus*) and curved to meandering subvertical shafts occur rarely. The background "mottling" is caused chiefly by *Planolites*. *Chondrites* may be present in the fill of cystoids. In the upper part of the formation, *Megagrapton* predominates among other well-preserved traces.

The ichnofabric patterns show a gradual change of the use of the substrate during its burial, from different feeding strategies to dwelling and chemosymbiosis. The substrate had to be strongly and continuously inhabited. The assemblages of trace fossils are similar to the classical, "Seilacherian" Cruziana Ichnofacies.

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MULTIELEMENT RECONSTRUCTIONS OF THE CONODONTS *ANCYRODELLA* AND *MESOTAXIS* FROM THE VORUTA FORMATION (GIVETIAN–FRASNIAN, DEVONIAN) OF THE KOZHYM RIVER SECTION, SUB POLAR URALS, RUSSIA

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Klapper (1989) and Klapper and Foster (1993) proposed 13 Zones for the Frasnian of Montagne Noire in southern France and defined them using shape analysis of the P_1 element and multielement concepts for *Palmatolepis* along with the distribution of P_1 elements of other co-occurring genera. This Zonal scheme has subsequently been applied to sections in America (Kirchgasser, 1994; Kralik, 1994), Canada (McLean and Klapper, 1998), Australia and the Timan-Pechora region of the Russian Platform (Klapper *et al*., 1996). The competing scheme (Ziegler and Sandberg, 1990) is based entirely on identifications of the P_1 element of *Palmatolepis* and suggests nine conodont zones for the Frasnian. Klapper and Becker (1999) have reviewed these two schemes and suggested a correlation between them. There has been a good history of study of conodont faunas from the Frasnian of the Sub Polar Urals and attempts have been made to correlate the Frasnian of the region with the two zonal schemes (see Klapper *et al*., 1996 and Ovnatanova *et al*., 1998 for summaries).

P_1 elements of the genera *Palmatolepis*, *Polygnathus*, *Ancyrodella*, *Ancyrognathus*, *Icriodus* and *Mesotaxis* have been recovered and illustrated recently from the Kozhym River region of the Sub-Polar Urals (Savage and Yudina, 1999, 2001). Donoghue (2001) presented a review of the genus *Palmatolepis* and suggested that more multielemental studies are needed to clear up some of the taxonomic problems associated with *Palmatolepis* and its phylogenetic relationship to other closely related genera. Three samples from the Givetian–Frasnian Vorota Formation from outcrop 108 of the Kozhym River Section (Tsyganko, 2000, 2002) provide well-preserved conodont elements suitable for this kind of study. The elements are almost all complete and show a range of sizes indicating that little or no sorting of element types has taken place. Ontogenetic series are also present for *Ancyrodella* and *Mesotaxis*, two genera that co-occur with polygnathids and icriodids in varying proportions in each of the samples. Multielemental reconstructions are presented for these genera on the basis of discrete elements and compared with unpublished *Ancyrodella* clusters from the Frasnian of the Montagne Noire region of France. These suggest that the *Ancyrodella* apparatus has 15 elements. The apparatus reconstructions are compared and contrasted with those of Klapper and Philip (1971, 1972), Kralik (1994), Schulke (1997) and Dzik (2002). Multielemental reconstructions have potential for improving correlations between the Devonian of the Urals and other regions of the world.

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A 200,000 YEAR PALYNO-CHRONOSTRATIGRAPHICAL RECORD OF VEGETATION, SEA-LEVEL AND CLIMATIC CHANGES IN NORTHERN EURASIA

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The time span of the past two glacial-interglacial cycles has been marked by many large-scale global and regional climate changes. The environmentally sensitive marginal areas of Northern Eurasia covered by transgressive deposits provide valuable record of such climate and sea-level fluctuations, which can often be successfully correlated with the inland terrestrial records. In combination, the data obtained from the marine and terrestrial climate-related sequences

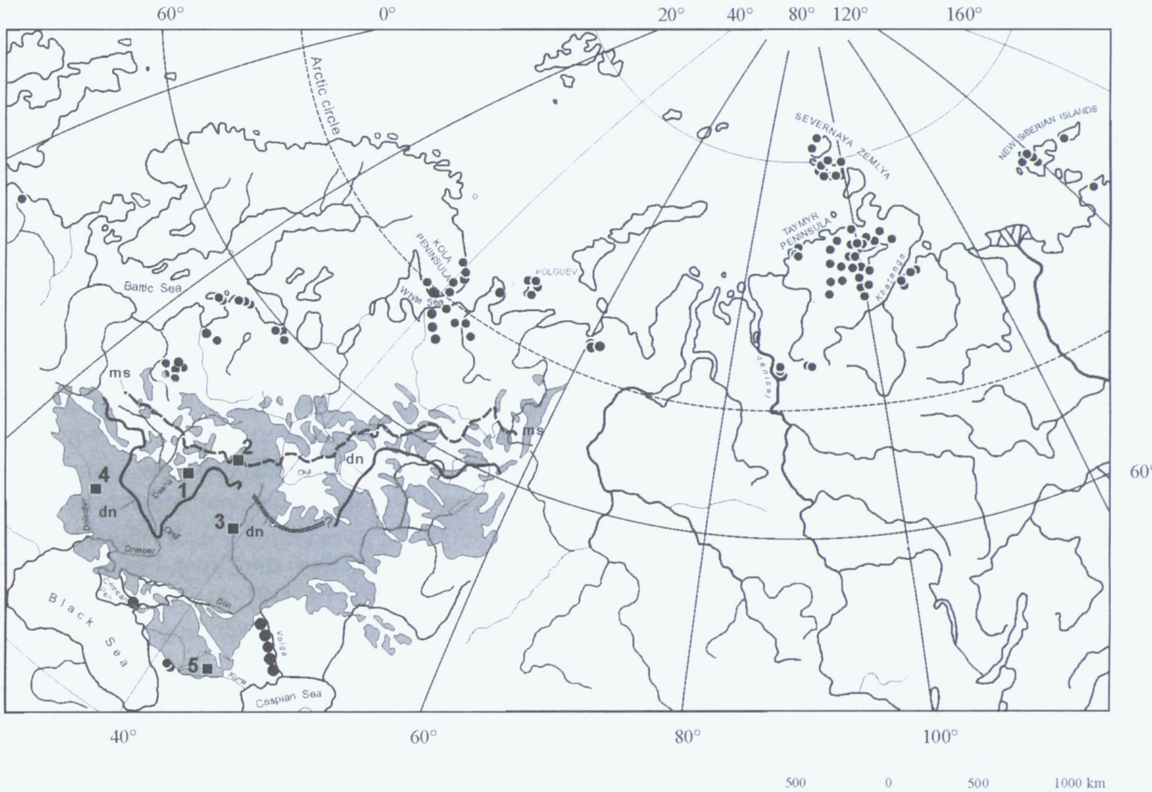

Fig. 1. Map showing the localities of collected shell samples (circles), reference loess-palaeosol sections (squires: 1 – Arapovichi, 2 – Likhvin, 3 – Strelitsa, 4 – Molodova, 5 – Otkaznoe), distribution of loesses on East-European Plain (grey area), limits of Dnieper (II dn) and Moscow (Iims) glaciations (after E.P. Zarrina, 1991)

can potentially form more valuable palaeoenvironmental records providing unique insight into the palaeoenvironmental history of Northern Eurasia during alternating cold and warm climate cycles (Bolikhovskaya and Molodkov, 2002; Molodkov and Bolikhovskaya, 2002).

This paper presents extended data obtained during long-time investigations from onshore and inland terrestrial environments that can promote elucidation of the palaeoclimatic structure of the last two glacial/interglacial periods. Information on climate changes through this time interval was derived from the two independent sources of palaeoenvironmental information: (i) electron spin resonance (ESR) chronostratigraphy of warm-climate-related deposits, and (ii) palynological record of vegetation response to climatic variability and palaeoenvironmental events. To develop palyno-chronostratigraphic framework for the past 200 ka we have attempted to link palaeoclimatic data derived from marine mollusc-based chronostratigraphical record with the pollen-based vegetation signals of terrestrial environment from the East European loess province (Fig. 1). Using pollen and mollusc-based ESR data, we have identified palaeoenvironmental events that we believe to correlate with a number of large-scale late Middle and Late Pleistocene climatic features in Northern Eurasia, including the penultimate glacial period (Dnieper/Saale, OIS 6), last interglacial (Mikulinian/Eemian, OIS 5), and subsequent glacial/periglacial period (Weichselian/Valdai Pleniglacial, OIS 4–OIS 3).

The Dnieper glacial rhythm is divided by an intermediate interstadial into two (Dnieper and Moscow) stages with the Early Dnieper and Late Moscow interstadials within them (Fig. 2). The data obtained for the Dnieper glacial rhythm indicate three episodes of global warming dated at about 183, 172 and 155 ka BP.

The last interglacial event in Northern Eurasia may have been long lasting, correlating most likely with the whole isotope stage 5 and the final phase of stage 6 rather than substage 5e only. During most of the period the vegetation cover has evidently been of interglacial character in Eastern Europe. At the same time, pollen and ESR records suggest that this interglacial was variable rather than stable in nature. During this interglacial period the warm climate was repeatedly interrupted by cold phases.

Our ESR studies show that during these intra-interglacial cold periods of isotope stage 5 coastal areas of Eurasian North were partly occupied by transgressive basins. Time-dependent frequency distribution of all the ESR-dates

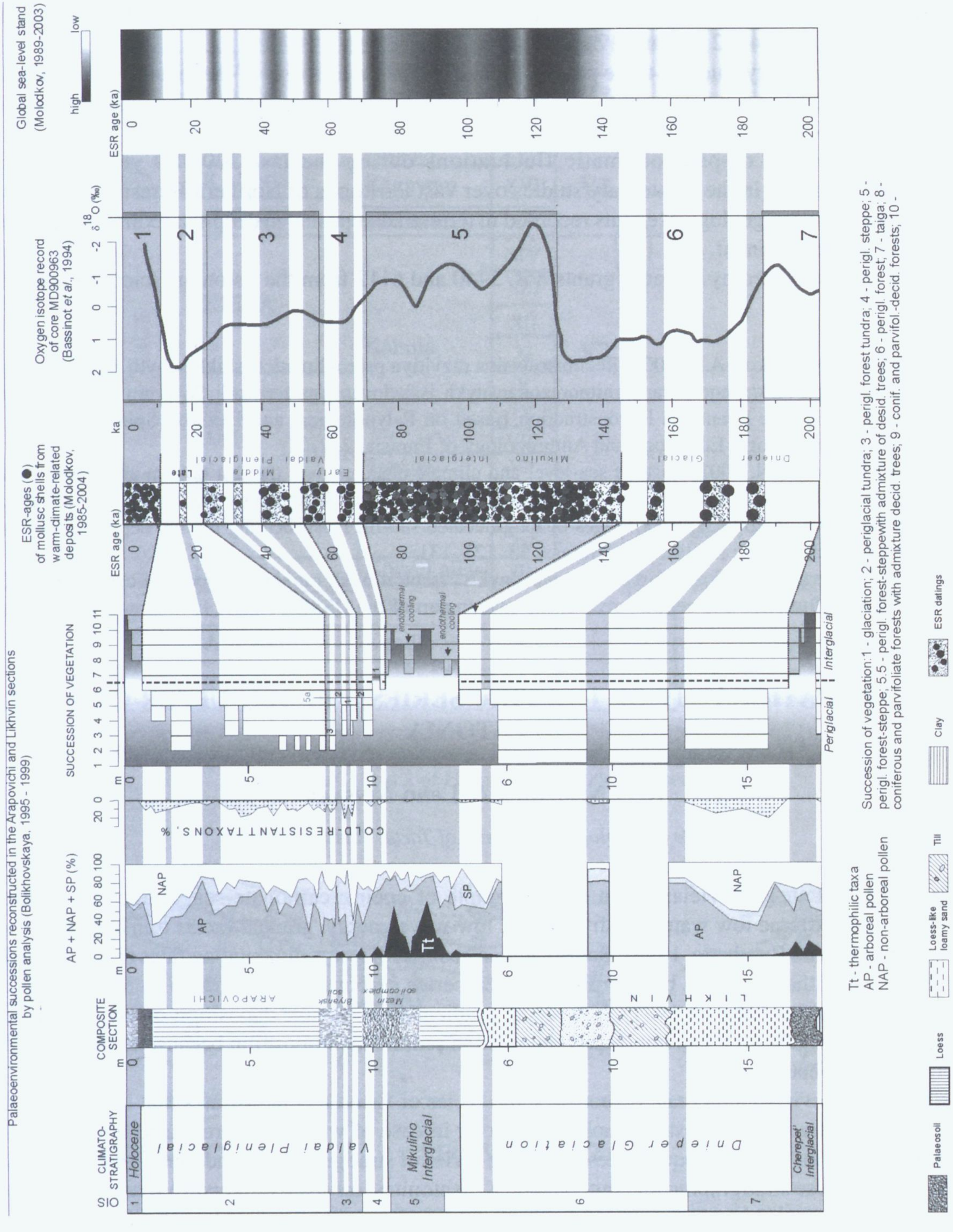

Fig. 2. Palaeoenvironmental changes over the last 200 ka reconstructed from pollen evidence and mollusk-based ESR-chronostratigraphy in Northern Estonia

obtained for the last interglacial (more than 150) also displays several intervals (Molodkov and Yevzerov, 2004) that can likely be correlated with the coolings and phases of sea regression. According to our data the last (Mikulino) interglacial is placed approximately between 145–140 and 70 ka BP.

In many areas studied Weichselian/Valdai Pleniglacial was characterised by a nonglacial palaeoenvironment and rather severe palaeoclimatic conditions. It was established by pollen data that the most complicated climatorhythmics on the East European Plain is typical for the Valdai glaciation. Palynological materials from the reference Arapovichi section and ESR-dated marine formations formed the basis for identification of 6 interstadials within the Valdai Pleniglacial at about 65, 56, 44, 32, 26, and 17 ka BP (Fig. 2).

A new multi-disciplinary study of these palaeoclimatic events on the basis of the recently discovered complete section of the Late Pleistocene deposits from the glacial zone of the north-western part of the East European plain (NE Estonia, the Voka site, N 59°25", E 27°36") is currently in progress.

The revealed system of palaeoclimatic fluctuations during the last 200,000 years may serve as a chronostratigraphic guideline in the Quaternary studies over vast territories of Northern Eurasia; it may also provide a tool for correlation between geological events recorded in terrestrial deposits, in deep sea sediments, and ice cores of Greenland and Antarctic continent.

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SEQUENCE STRATIGRAPHY OF THE VIRU SERIES (MIDDLE–UPPER ORDOVICIAN) IN ESTONIA

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Baltoscandian Middle–Late Ordovician basin is an example of epeiric carbonate sea. Ramps in epeiric seas are characterized by their extreme low water depth gradient, low wave energy, gradual facies transitions and very broad facies belts (e.g. Wright and Burchette, 1998). Baltoscandian basin with low sedimentation rates and broadly distributed wackestone-packstone lithologies can be interpreted as temperate carbonate epeiric ramp in Middle and early Late Ordovician time (Nestor and Einasto, 1997). Low depth gradient should make deposition on such ramp sensitive to sea level changes, which, however, can not clearly recorded in sediment composition because of broad distribution of temperate climate carbonate facies.

The study of Ordovician temperate carbonate ramp facies of Estonia demonstrates that bed geometries can be used as the most indicative sequence stratigraphic parameter in case of weakly differentiated lateral lithologies and small bed thicknesses. This analysis requires description of series of stratigraphic boundaries – marker surfaces. In the Viru series in Estonia these stratigraphic markers include K-bentonites, oil shale (kukersite) seams, prominent discontinuity surfaces (hardgrounds) and some distinct limestone-marl cycle boundaries, beside well-traced biostratigraphical (regional stage) boundaries. Using these markers the studied interval of Aseri to Nabala stages was subdivides to 18 beds (time slices; Fig. 1).

Thickness maps of most of the beds show presence of east-west elongated belt of increased thickness. The axes of these belts, subparallel to middle-outer ramp (or shelf-basin) transition line, can be considered as depositional axes. Comparison of thickness maps shows trends in shift of depositional axis and sedimentation geometry on the ramp or shelf during each sedimentary cycle (Fig. 2). North (landward) from the depositional axis bed thicknesses decrease considerably and some maps show presence of non-deposition or simultaneous erosion area there. South (basinward) from the axis the bed thickness usually decreases slowly until middle-outer ramp transition. Some beds have two areas of increased thickness, possibly because of rapid sea level change or local erosion during the time slice (Fig. 2).

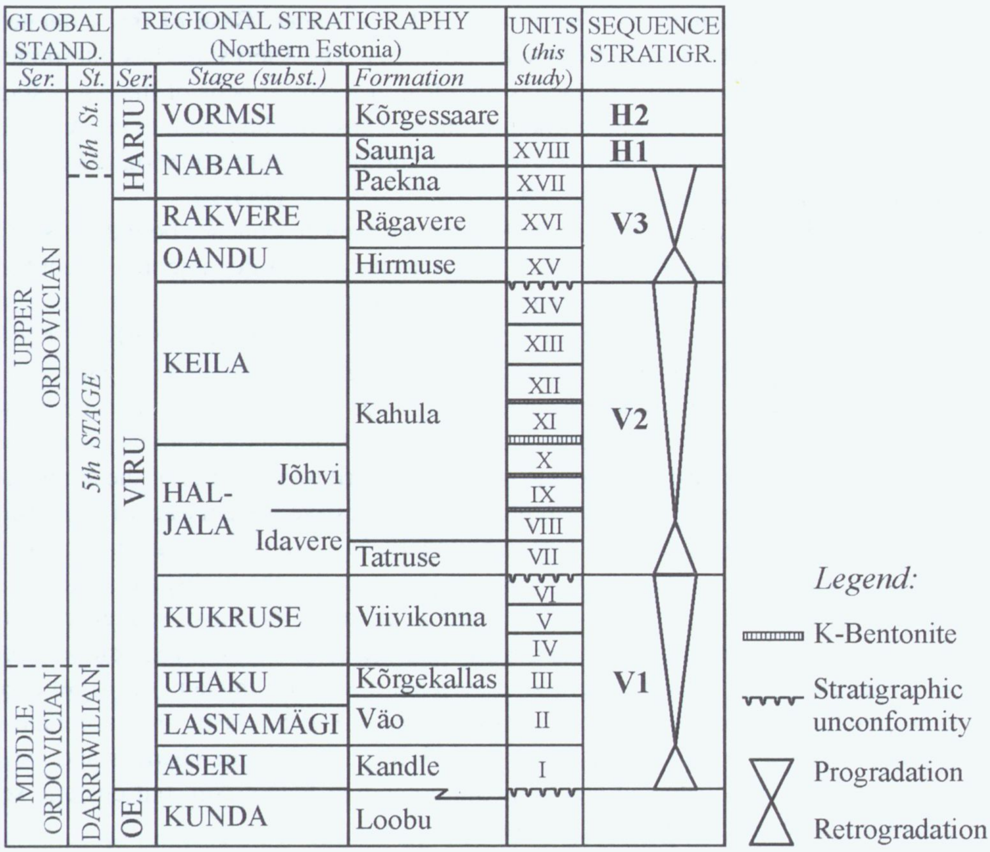

Fig. 1. Stratigraphy of the Viru Series in Estonia. Depositional sequences H1 and H2 are the same as sequences 1 and 2 of Harris *et al.* (2004), respectively

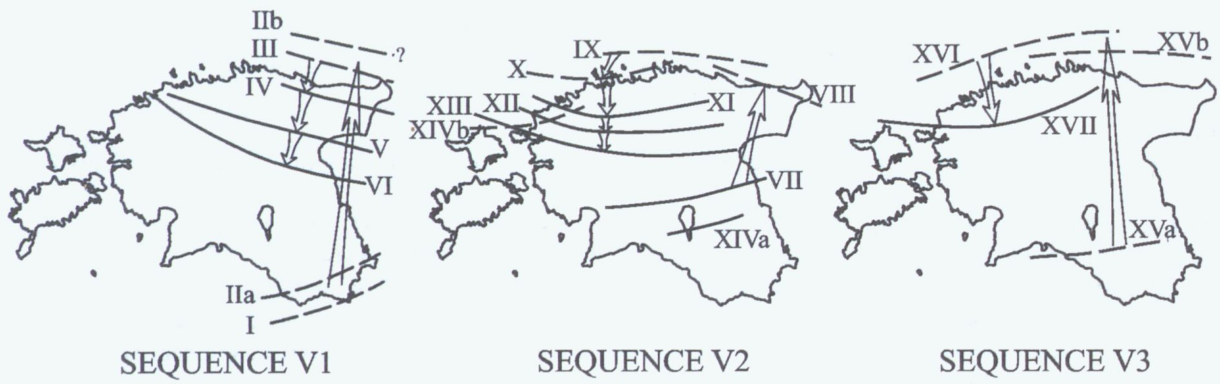

Fig. 2. Positions and shift of depositional axes of chronostratigraphic beds (units in Fig. 1) in three depositional sequences of the Viru Series. Bed geometry of some beds shows two different axes, marked as "a" and "b". Dashed line – axis situated outside the data area

The sedimentation geometry and dynamics indicates that main part of the studied strata (Aseri–lower Nabala) record three depositional sequences, each represented by one of the prograding ramp systems. These sequences are named here as V1, V2 and V3 (abbreviation from the Viru Series; Fig. 1). The sequence interpretation presented here is similar to that of Dronov and Holmer (1999) with differences in some system tract interpretations and boundaries. Sequence V1 is equal to the Tallinn sequence, sequence V2 corresponds approximately to the Kegel sequence and sequence V3 to the lower part of the Wesenberg sequence of Dronov and Holmer (1999). Upper part of the Nabala Stage is described as separate sequence by Harris *et al.* (2004).

Sequence V1 includes Aseri, Lasnamägi, Uhaku, and Kukruse stages. Base of the sequence can be tied to sedimentary cap and unconformity in the Kunda/Aseri stage boundary. The Aseri stage has interpreted as a transgressive system tract. The position of transgressive surface is not clear, lowermost beds of the Aseri stage in outer ramp may represent lowstand system tract. The maximum flooding surface possibly lies close to the Aseri/ Lasnamägi stage boundary. The stacking pattern of Lasnamägi to Kukruse stages shows clear progradation (e.g. Saadre and Suuroja, 1993), and is interpreted as highstand system tract.

Sequence V2 includes Haljala stage and most of the Keila stage. Lower sequence boundary is an iron mineralised discontinuity surface on the Kukruse/Haljala stage boundary marking a well-documented unconformity. Lowstand part of this sequence can not distinguished here also, maximum flooding surface can be positioned inside the Vasavere Mb of the Kahula Fm, which is also more rich in siliciclastic mud than under and overlying beds. Upper Haljala (Jõhvi) and Keila stages represent the highstand system tract with progradational stacking pattern.

Sequence V3 includes the Oandu and Rakvere stages, and lower part of the Nabala stage. Base of sequence is prominent discontinuity surface marking the sedimentary cap in Keila/Oandu stage boundary in northern Estonia. The black shale bed (Mossen Fm) and siliciclastic-carbonate mudstone (Variku Fm) south of the study area together with younger marl bed of Hirmuse Fm in northern Estonia represent transgressive system tract of sequence. The transgressive surface probably lies very close to the basal sequence boundary. Maximum flooding surface may lie close to the Oandu/Rakvere stage boundary. Rakvere and lower Nabala stages comprise the highstand system tract.

The study demonstrates that bed geometries can be used as the most indicative sequence stratigraphic parameter in case of weakly differentiated temperate ramp facies and small bed thicknesses. Depositional sequences include relatively thin (up to 5 meters) lowstand to transgressive systems tracts and thicker (up to 30 meters) prograding highstand tracts. It is evident that there existed a depth belt of optimal mixed bioclastic and carbonate-siliciclastic mud deposition, where accumulation was controlled by accommodation space. Climate changes and antecedent topography influenced the deposition of carbonate sediments in Baltoscandian Paleobasin, but eustatic sea-level changes were the dominant factor influencing the deposition in Basin.

The existence of correlative sequence boundaries in Estonia and eastern North America suggests that eustatic sea-level changes were the dominant control on sequence formation during the Middle and Late Ordovician in the Baltoscandian area. V1/V2 boundary can be correlated with the base of M1 sequence of Holland and Patzkowsky (1996) according to the *N.gracilis/M.multidens* graptolite zone boundary in Estonia (Nõlvak, 1997) and North America (Webby *et al.*, 2004). The V2/V3 sequence boundary can be correlated to M4/M5 boundary of Holland and Patzkowsky (1996) according to the K-bentonite bed correlation in Estonia and North America (Huff *et al.*, 1992).

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EARLY AND EARLY MIDDLE ORDOVICIAN FORAMINIFERS FROM ST. PETERSBURG AREA, RUSSIA

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Classic sections of the Lower and Middle Ordovician have recently been restudied in the eastern part of the Leningrad District in connection with the biostratigraphic substantiation of the regional scheme of the Ordovician stages. It was discovered during this study that some of these deposits contain a large numbers of agglutinated foraminifers.

The general area of study is located about 100 km to the east of St. Petersburg where deposits of the Lower and Middle Ordovician crop out along the Lava River Canyon (Lava River section) and also are exposed in the Putilovo Quarry. Agglutinated foraminifers have been studied from a succession of strata of the Early Ordovician Latorp (Lower Arenig in the British Series or Hunneberg/Bellingen stages of Baltoscandia) and Middle Ordovician Volkhov regional stages.

Deposits of the Latorp Regional Stage crop out in the Lava River section and in the Putilovo Quarry. Foraminifers appear to be restricted to the strata of the Lakity Beds of the Leetse Formation (lower substage of the Latorp Stage) in these sections. In both sections studied, the Lakity Beds consist of a basal bed of fine to medium grained, quartzose glauconitic sand and an overlying greenish gray, silty clay, in total about 1.15m thick (Tolmacheva *et al.*, 2001). The lower boundary of the clayey layer is marked by the first appearance of *Tetragraptus phyllograptoides* Strandmark. This stratigraphic level is considered to be a local lower boundary of a yet unnamed second stage of the Lower Ordovician defined by the first appearance of *Tetragraptus approximatus* Nicholsen in the international stratigraphic scheme. Foraminifers are represented by a diverse assemblage of monothalamous agglutinated tests. The species *Amphitremoida asperella* Nestell and Tolmacheva 2004, *A. orbicularis* Nestell and Tolmacheva 2004, *A. longa* Nestell and Tolmacheva 2004, *A. rugosa* Nestell and Tolmacheva 2004, *Lakites ordovicus* Nestell and Tolmacheva 2004 (Nestell and Tolmacheva, 2004), and also *Psammosphaera* sp. occur in the lower part of clays of the Lakity Beds as well as in the upper part. The species *Amphitremoida laevis* Nestell and Tolmacheva 2004, *A. batuliformis* n. sp., *Lavella cucumeriformis* Nestell and Tolmacheva 2004, and *Arenosiphon*? sp. appear for the first time in the upper part of the clay.

Foraminifers of the Volkhov Stage have been collected from the clay core of a microbial mud mound in the Putilovo Quarry. This mud mound is one of several unique buildups that occur in the vicinity of St. Petersburg. They are characterized by a main clay core overlying the hard-ground surface of the base of the Volkhov Stage and two-three smaller clay lenses within the lower part of the Volkhov Stage (Fedorov, 2003). The most diverse assemblage of agglutinated foraminifers was recovered from the *Baltoniodus triangularis* zone that yields representatives of the following genera *Amphitremoida* Eisenack 1938, *Lakites* Nestell and Tolmacheva 2004, *Thuramminoides* Plummer 1945, *Sorosphaerella* Conkin and Thurman 1979, *Tholosina* Rhumbler 1895, *Ammolagena*? Eimer and Fickert 1899, *Saccammina* M. Sars 1869, *Lagenammina* Rhumbler 1911, and *Hyperammina*? Brady 1878. The clay of the *Paroistodus originalis* zone contains very small, compressed and poorly preserved tests of *Amphitremoida* and *Thuramminoides*.

In the analysis of the distribution of foraminifers throughout the upper Lower Ordovician and lower Middle Ordovician in the sections of eastern part of the Leningrad District, we note that the first appearance of the genera *Lakites*, *Amphitremoida*, *Lavella* is in the upper part of the Lower Ordovician, and that *Tholosina*, *Sorosphaerella*, *Ammolagena*?, *Saccammina*, *Lagenammina*, and possibly *Hyperammina*? first appear at the base of the Middle Ordovician.

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ORDOVICIAN CHRONOSTRATIGRAPHY IN ESTONIA: CURRENT STATE AND FUTURE PROSPECTS

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Historically the Ordovician stages in the East Baltic area have been defined by their content rather than the boundaries (and hence unit- rather than boundary stratotypes). However, the international practice of defining chronostratigraphical units in the Phanerozoic follows the concept of "golden spike" (GSSP) that defines a point in time in a suitable reference section (for a review see, e.g., Walsh *et al.*, 2004). This practice has several clear advantages also in regional stratigraphy, however, only few attempts have been made so far to re-define the current stages using their boundaries (Pakerort and Keila stages). The reasons for this are obvious and lie mainly in the fact that the Ordovician sequence is sliced by numerous gaps in the outcrop area where the stages are traditionally established. More continuous sequence in South Estonia and Latvia is known only by drill cores. Nevertheless, for several Ordovician stages, more or less suitable sections could be found in North Estonia (see examples on Pirgu and Kukruse stages in this volume). For others, boundaries of which definitely fall into extensive gaps in North Estonia (e.g., Haljala and Oandu stages), serious considerations should be made whether advantages of fixed boundaries could outweigh the disadvantages of drillcores (most importantly the limited amount of rock material available for study). At least it would be desirable to clearly determine the criteria, which are the best for drawing the boundaries in sections more complete than those in the outcrop area.

In recent years questions have also been risen whether the current stage-level subdivision of the Ordovician used in Estonia is too precise or, instead, too coarse. Nielsen *et al.* (2004) proposed to reduce the rank of some stages to substages, resulting in 8 or 10 stages instead of 17, to enhance the usability of the regional units. However, regional units of similar size and bounds already exist, although not in the stage rank – the regional subseries that are shown in various stratigraphical schemes, e.g., Männil, 1990 and Meidla and Ainsaar (2004). The regional series and subseries are currently as follows:

Öland Series (there is no need to use the Latinized Oeland) composed of **Iru** (Pakerort and Varangu stages) and **Ontika** subseries (Hunneberg, Billingen, Volkhov and Kunda stages),

Viru Series is composed of **Purtse** (Aseri, Lasnamägi, Uhaku, Kukruse stages), **Kurna** (Haljala and Keila stages) and "unnamed" subseries (Oandu and Rakvere stages),

Harju Series made up of **Kohila** (Nabala and Vormsi stages) and "unnamed" subseries (Pirgu and Porkuni stages).

To enhance the usability of the regional subseries rank, it is necessary to provide all units with appropriate names. Herein we propose two new names, **VINNI** for the third subseries of the Viru Series, and **ATLA** for the second subseries of the Harju Series. The name Vinni comes from the Vinni (T-112) borehole that has been selected as the hypostratotype for the Rakvere Stage (Põlma *et al.* 1988). The Atla subseries is designated after the Atla River that runs near the Pirgu Manor and on the banks of which the Pirguan rocks are exposed. The lower boundaries of these and other subseries (and series) are, indeed, defined as those of the lowest stage they contain.

The regional units are beneficial only if they provide better resolution than the units of the global scale. If the latter were fine enough and the global units precisely identifiable regionally, the regional chronostratigraphic scale would turn redundant. Currently the global scale is in most part of the Ordovician inferior to the current Baltoscandian scheme for everyday regional usage. Thus we believe that instead of decreasing chronostratigraphical resolution, or abandoning regional chronostratigraphy, more efforts have to be put into finding new and improving old criteria for inter- and intraregional correlations since, eventually, not the names are what matter, but the correlations.

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STUDYING OF MODERN GEOLOGICAL PROCESSES AS ONE OF THE FACTORS TO PRESERVE THE ILMEN KLINT – A UNIQUE NATURE MONUMENT

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Geological monuments – geosites – are the unique objects of a special importance in educational, scientific, sanitary, cultural and aesthetic respect. Though they are protected by the state, the measures to preserve them are often reduced to prohibiting economic activities in the adjoining territory and restricting the use of nature. Very little or nothing at all is done to register the influence of unfavorable geological processes, to observe the speed of their development, to analyze the causes of their origin and to fight them.

The distribution area of the Devonian rocks in the NW of the Russian Platform is known as the Main Devonian Field. Within the study area, the Devonian is represented only by the Middle and Upper Devonian strata. They are characterized by considerable complexity of stratigraphy and great changeability of lithology. The Ilmen' Lake, one of the largest lakes of the Russian Plain, is situated here. It is an original spacious shallow water basin with unstable area of water mirror. In spring numerous tributaries fill the lake over causing extensive inundations. During draughts the water level drops considerably and the lake area reduces in a great deal. According to hydrologists, the Ilmen' Lake is the biggest centre receiving salty artesian waters from water-bearing horizons and complexes of the Middle and Upper Devonian in Europe. In former times, these waters with a high content of dissolved mineral salts provided a good material for producing salt (Korotkov, 1963).

The lake depression and the surface of the adjoining Ilmen' Lowland began to develop in pre-glacial time. However, in the formation of modern topography the leading role was played by the latest Valdaian glaciation, during which the whole Ilmen' Lowland was covered by ice. Due to the warming of climate the glacier melted and a big body of water was formed at the spot of the Ilmen' depression. The water basin was connected with the Pskov Lake and Baltic-Ladoga basin, its level reaching 70 meters. In post-glacial time the water level dropped, which led to the formation of Ilmen' and a number of other lakes (the absolute mark of modern level equals +18 meters). More than 90 % of the lake depression is filled with glacial and post-glacial deposits.

The Ilmen' Lake is characterized by a variety of shores. In the south-western part of the lake there is a steep bluff up to 12–14 meters high and more than 10 kilometers long; a continuous outcrop of Upper Devonian rocks bares itself lengthwise. This is the so-called Ilmen' Klint, which is particularly picturesque in the section between the mouths of the Savateika and Psizha rivers, in the adjoining parts of Shimsk and Staraya Russa regions of the Novgorod district. The openness of the territory enables to get acquainted with the complex of carbonate and terrigenic sedimentary rocks of the Upper Devonian (Frasnian Stage, Semiluki and Snezha horizons) and with various genetic types of the Quaternary deposits. The deposits of Rdeisk (Ilmen Beds), Buregi (Buregi Beds) and Snezha (Snezha Beds) formations crop out on the surface. The Quaternary complex is represented with the Upper Pleistocene (glacial, glaciolacustrine and glaciofluvial) and Holozene (deluvial, lake, alluvial, eluvial, marsh and technogenic) deposits. It should be noted that educational geological field surveying practical work of the students of Saint-Petersburg Mining Institute is carried out in the examined territory.

The present condition of the Ilmen' Klint is complicated due to the development of exogenic processes and phenomena (screes, taluses, landslides, erosion and weathering) at its whole length. Gravitational processes are most dangerous, while the others prepare the ground for their appearing and spreading. According to local inhabitants, the shore bluff of the Ilmen Lake is in a danger of destruction. That is why in studying geological conditions of the examined territory it is important and necessary to reveal the laws of the formation, dynamics, morphology, scale and intensity of modern geological processes by carrying out specific engineering and geological field surveying.

According to G.S. Zolotarev, landslides of squeezing out of block structure of solid rocks with creeping deformations in clay deposits are widely spread. The upper part of the steep slope is formed by joint-rich horizontal limestones of Buregi Beds with well developed systems of fissures with up to 15 cm opening width, orientated parallel and perpendicular to the surface of the slope, underlain by loose sands in the middle part and clays at the base of the slope of the Ilmen'layers. It is clearly traceable how the fault surface goes through limestones in accordance with well-developed jointing being steep and vertical in this part, and then, crossing the sandstones goes along their contact with clays. In the sections with thick fluvioglacial and glacial deposits there are glutinous and plastic landslides-streams formed as a result of plastic deformations of water-saturated sandy and clay masses.

As is known, landslides are due to different factors. Negative effect on the slope is produced by the presence of disjoint and plicate breaches, dislocation of rocks, fluctuation of the lake level, growth of slopes with deluvium, etc. In the area immediately south of the Ilmen' Lake regional zones of increased jointing occur. Tectonic fissures, connected with particular plicate and interrupted structures as well as litogenetic, exogenic and technogenic varieties are distinguished. The presence of numerous fissures in rocks increases the activity of weathering processes, defines lower solidity and higher permeability of rocks, which affects the stability of the whole shore area. It should be noted that gravitational processes are activated in autumn and spring. Underground water greatly affects the stability of the Ilmen' Klint. In the precipice of the klint, the non-pressure water from the Buregi Horizon finds its way out to the surface in the form of numerous springs. The stability of clay rocks decreases because of the change in their physical state due to moistening, swelling, seal failure, melting after freezing, fault in natural structure.

To estimate the stability of the Ilmen' Klint the composition, conditions and characteristics of clay varieties must be studied, and geological processes and phenomena forecasted. During the studies, clay samples were taken from an unaffected structure in the valley of the Psizha River and at the bottom of landslide slope of the Ilmen'Lake; as a result, data on the lithological composition and physical condition of rocks were obtained.

Devonian clays in their natural bedding are rather consolidated; they have rather moderate natural humidity, half-hard and hard consistency, extra high strength (Lomtadze, 1962). At the same time, in the zone of seal failure, according to the data from the research of clay samples, the indicators of condition and physical mechanical features characterize the rock as very humid, low solid, of extraplastic and low plastic consistency (Table1). Hydromicas and kaolinite prevail in mineral composition of finely dispersed part of clays.

Table 1

Main indicators of conditions and physical features of the Upper Devonian Ilmen' clays

Humidity, %	Density, g/sm^3	Humidity on the top limit, %	Humidity on the bottom limit, %	Plasticity number, %
35	1.92	56	27	29

The varieties of the examined clays swell and are characterized as middle water resistant. According to the data obtained on single samples, the quantity of free swelling reaches 11 %; the more intensive swelling slowly later (Table 2). Swelling weakens connections in nature even more, leads faster to abrupt dropping of solidity.

Table 2

Sampling point	Primary humidity, %	Humidity of swelling, %	The increase of humidity at swelling, %	The quantity of free swelling, %
The valley of the Psizha River	35.1	44.1	9.0	11.3
The bottom of the slope of the Ilmen' Lake	36.5	43.5	7.0	5.2

The primary acquaintance with geodynamical conditions of the shore part of the Ilmen' Lake showed the necessity of making a special program to found and organize the complex monitoring of conditions of this natural heritage.

The monitoring must include the geological, geomorphological, hydrogeological, hydrological and geodetic observations along the whole geosite. Special attention should be focused on the processes and phenomena capable of ruining this nature monument. These observations may serve a basis for substantiating the sizes of nature conservation areas as well as for working out the criteria to provide this territory with the status of natural landscape reserve. The monitoring data will enable to work out preventive and restricting measures aimed at protecting the Klint against modern dangerous exogenic geological processes. The research is recommended to be carried out on the basis of an integral scientific centre to preserve the natural riches of the Ilmen' area. Such centre will also contribute to arranging the educational and scientific research practical work of the students of higher educational establishments specializing in geology.

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THE SUBSTAGE DIVISION OF THE EIFELIAN AND GIVETIAN OF BELARUS

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The differentiation of substages stimulates the more refined division and correlation of the different facies deposits on a planetary scale. Therefore, a consistency of basic principles of their differentiation and the highest degree of synchronization of the accepted substage boundaries are necessary.

The International Subcomission on the Devonian Stratigraphy (SDS) gives preference to using conodonts as representatives of the pelagic fauna for boundary definition. Conodonts are considered to be a good means for correlation of pelagic and neritic facies. Within the area of Eastern Europe (including Belarus), where the Middle Devonian section is represented largely by terrigenous and evaporite deposits conodonts are of limited distribution. Miospores and also fish fauna remains are often basic groups of organisms used for division and correlation of these deposits. Therefore, the authors of the improved stratigraphic chart of Devonian deposits of Belarus were based on a cyclic recurrence in the development of sedimentation basins and on the stage evolution of some representatives of the organic life to define substages in deposits of the Eifelian and Givetian stages. The biological markers of the boundaries in Belarussian sections are more often species of miospores, which appearance is correlated with the conodont biomarkers.

Eifelian stage. Three parts of the section are distinguished in deposits of the Eifelian stage within the territory of Belarus. These had been accumulated during three phases of the Eifelian transgression.

The lower part of the stage conformably overlying sediments of the Vitebsk Horizon of the Upper Emsian is represented by rocks of the Adrov and Osveya horizons. It corresponds to the first phase of the Eifelian transgression. The section is composed of dolomites and sandstones with oolites in the bottom part (Adrov Horizon), clayey-sulphate rocks in the middle part and variegated clays, marls and sandstones in the upper part (Osveya Horizon). By miospore evidences deposits of these horizons correspond to the *Periplecotriletes tortus - Elenisporis biformis* zone (Obukhovskaya, 1999) and are correlated with the upper grey-coloured strata of the Ryazhsk Horizon and deposits of the Dorogobuzh Horizon in the central areas of the Russian Plate (Arkhangelskaya, 1985). The fish fauna remains (*Cheiracanthoides estonicus* zone) permit the correlation of the Osveya Horizon with the Vadja Subhorizon of the Narov Horizon in the Baltic region (Valiukevičius, 2002). An appearance of *Grandispora velata* and *Acinosporites acanthamammilatus* at the lower boundary of the Adrov Horizon allows a correlation of the *tortus–biformis* miospore zone of Belarus with some miospore zones of Western Europe: with *Grandispora velata* First Occurrence Biohorizon from the basal part of the Eifelian stage characterized by conodonts of the *costatus–partitus* zone, as well as with *Acinosporites acanthamammilatus*, *A. macrospinosus* potential First Occurrence Biohorizons characterized by conodonts of the *costatus* zone (Streel, Loboziak and Chapter, 1996).

Deposits of the Gorodok Horizon correspond to the middle part of the Eifelian Stage in Belarus. These deposits formed during the second phase of the Eifelian marine transgression. The section is represented by a grey-coloured member of clay, marl and sandstones in the bottom, dolomites in the middle part and variegated clays and marls in the upper part. By miospore evidences the horizon corresponds to the *Grandispora naumovii* zone (Abukhovskaya, 1999) and is correlated with the Klintsy Horizon in the central regions of the Russian Plate. The fish fauna remains permit the correlation of the Gorodok Horizon with the Leivu Subhorizon of the Narov Horizon in the Baltic region (Valiukevičius, 2002). An indirect correlation suggests that deposits of both the Gorodok horizon in Belarus and Klintsy horizon in Russia could belong to the *australis* conodont zone (Kim-Son-Eng, 2001).

The upper part of the Eifelian stage section in Belarus is represented by the Kostiukovichi horizon which deposits correspond to the third thickest phase of the Eifelian transgression. Clayey-siltstone, sometimes clayey-sandy rocks occur in the bottom part of the horizon. Limestones, often bioaccumulated ones with marl and clay interlayers are overlying. The upper part of the horizon is composed of thinly laminated clays with siltstone interlayers.

The Kostiukovichi Horizon corresponds to the beds with conodonts of *P. parawebbi* (Kruchek, 1974) and the *Rhabdosporites langii–Convolutispora timanica* miospore zone (Abukhovskaya, 1998), by the fish fauna remains – to the *Nostolepis kernavensis* zone. Abundant spherical, thorny and polygonal acritarchs are typical. This horizon correlates with the *Chelinospora timanica* potential First Occurrence Biohorizon determined in deposits of the *ensensis–obliquimarginatus* conodont zone of Western Europe (sensu Valiukevičius, 2002). The Kernave Subhorizon of the Narov Horizon corresponds to it in the Baltic region, and the Mosolovo and Cherny Yar horizons where *kockelianus* conodont zone was identified – in the central regions of the Russian Plate (Kim-Son-Eng, 2001).

Considering good possibilities of correlation of the above three parts of the Eifelian Stage section provided by using miospore, fish fauna and partly conodont evidences, it is suggested to consider them as three independent substages. In such a situation, deposits of the definite phase of the Eifelian transgression will correspond to each substage.

The lower substage corresponds then to the *Periplecotriletes tortus–Elenisporis biformis* zone by miospores, *Cheiracanthoides estonicus* zone by fish fauna remains, and the *costatus–partitus* zone by conodonts. The first appearance of miospores *Grandispora velata* (Eisenack), *Acinosporites acanthamammilatus* Richardson, *Retusotriletes fragosus* Archangelskaya will serve as biomarkers of the lower substage boundary.

The middle substage corresponds to the *Grandispora naumovii* zone by miospore evidences, the *Ptychodictyon rimosum* zone by fish fauna remains, and the *australis* conodont zone. An appearance of miospores *Grandispora naumovii* (Kedo), *Hystricosporites* (al. *Archaeotriletes*) *setigerus* (Kedo), and the maximum development of the *Ancyrospora* and *Hystricosporites* genera are considered to be the biomarkers of the lower boundary of the substage.

The upper substage corresponds to the *Rhabdosporites langii–Chelinospora timanica* zone by miospores, the *Nostolepis kernavensis* zone by the fish fauna evidences, and the *kockelianus* conodont zone. An appearance of

Convolutispora timanica (Naumova), *Retispora archaeolepidophyta* (Kedo) and the maximum abundance of the *Rhabdosporites langii* (Eisenack) species are biomarkers of the lower boundary.

Givetian stage. The Givetian stage, as presented in the new version of the Stratigraphic Chart of Belarus (2005), includes terrigenous deposits of the Polotsk Horizon corresponding to the *Geminospora extensa* miospore zone and those of the Ubort Beds (the Lan Horizon) distinguished in the Devonian chart of Belarus, 1981 and correlated with the *Ancyrospora incisa–Geminospora micromanifesta* regional miospore zone of Eastern Europe. The section of this stage also exhibits a three-membered composition.

Its bottom part (the Goryn Beds and lower part of the Stolin Beds of the Polotsk Horizon) is represented by rhythmically alternated sandstones, siltstones and variegated clays. It corresponds to the *Geminospora vulgata–Retispora archaeolepidophyta* subzone. An appearance of miospores *Geminospora lemurata* at the lower boundary of this subzone permits its correlation with the *Geminospora lemurata* First Occurrence Biohorizon of Western Europe (Streel, Loboziak and Chapter, 1996). By the fish fauna remains these deposits belong to the *Diplacanthus gravis* zone and are correlated with the Arukula Horizon of the Baltic region (Valiukevičius, 2002).

Rocks in the upper part of the Stolin Beds and in the Moroch Beds of the Polotsk Horizon form the middle part of the stage and correspond to the *Cristatisporites triangulatus–Corrystisporites serratus* miospore subzone. Marl and dolomite interlayers contribute to their structure together with terrigene rocks. Spinulose and polygonal acritarchs appear for the first time at this level of Givetian deposits in Belarus among plant microfossils. Their presence is indicative of sedimentary environment similar to the normal marine one that were due to the Givetian transgression. It seems likely that just this part of the Givetian section in Belarus corresponds in time of its deposition to the Pelchin clayey-carbonate strata of the Lvov Depression and southeastern Poland, where conodonts typical of the Taghanic global event were identified (Milaczewski and Kruchek, 2002; Narkievicz and Narkievicz; 1998).

Deposits of the Ubort Beds (*Ancyrospora incisa–Geminospora micromanifesta* zone) previously included the Lan Horizon of the Frasnian stage are built by sandstones and siltstones with small variegated clay interlayers. These beds form the upper part of the section of the Givetian Stage. Most miospore species typical of the older rocks become extinct at the lower boundary of these beds and the *incisa–micromanifesta* zone. Earlier appeared species *Geminospora micromanifesta* (Naumova), *Chelinospora concinna* Allen, *Cristatisporites triangulatus* (Allen), *Contagisporites optivus*, *Perotrilites spinosus* (Naumova) increase in abundance. New species of miospores are very few in number. Similar changes in miospore assemblages are also observed in the bottom of the upper part of the Fromellen (Flc) formation of the Givetian in the Ardenno-Rhenish region (Loboziak and Streel, 1980). In Poland miospores of the *incisa–micromanifesta* zone were identified somewhat above the conodonts of the *hermanni–cristatus* zone in deposits related to the Givetian stage (Turnau and Racki, 1999).

Hence, the section of both the Givetian and Eifelian stages in the territory of Belarus has been subdivided into three parts, which, probably, should be given a rank of substages. In this case, an appearance of miospores *Geminospora lemurata* will serve as a biomarker of the lower substage boundary, an appearance of *Cristatisporites triangulatus* – a biomarker of the middle substage boundary, and an appearance of *Ancyrospora incisa* – a biomarker of the upper substage (an analogue of the upper part of the Fromellen formation). As presented in the new version of the Stratigraphic Chart of Belarus, 2005, the lower boundary of the overlying Upper Devonian (Frasnian) deposits is placed at the base of the Zhelon Beds of the Lan Horizon.

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THE PALYNOLOGICAL CHARACTERISTIC OF THE ZHELON MEMBERS (LOWER FRASNIAN, GLOBIN REGION)

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Zhelon members correspond to the upper part of the Lansk Horizon (Decisions..., 1983). These deposits are widely distributed in Belarus and correspond to the miospore *Raistrickia* (al. *Acanthotriletes*) *bucera–Archaeozonotriletes variabilis insignis* zone (Avkhimovich *et al.*, 1993). The detailed study of miospore assemblages from the Zhelon members in Globin region resulted in establishment of two subzones. Lower boundaries of these units are defined by the first appearances of the index species.

The *Raistrickia* (al. *Acanthotriletes*) *bucera* zone corresponds to the lower part of the Zhelon members, which is represented by sandstones, siltstones and clays. Sandstones are thin-grained with dolomite cement. Clays are greenish-gray, lilac and brown-red, with mirrors of slips. Sometimes thin layers of marl and dolomite are present.

Species of the *Geminospora* genus (*G. notata*, *G. rugosa*, *G. micromanifesta*) dominate in the miospore assemblages. *Raistrickia bucera* (Tschibrikova) V. Obuchovskaya, *Apiculatisporis eximius* (Naumova) Oshurkova, *Archaeozonotriletes variabilis* Naumova, *A. variabilis* Naumova var. *insignis* Sennova, *A. timanicus* Naumova are also present. This miospore assemblage is comparable to the miospore assemblage of the Djersk Horizon of the Timano-Pechora province (Menner, Larionova, Araslanova *et al.*, 1989; Verbova, 2004).

The predominantly carbonate upper part of the Zhelon members is assigned to the *Sinuosisporis* (al. *Perotrilites*) *vermiculatus* subzone. This part of the section is interpreted as the large transgressive rhythm with a layer of thin-grained sandstone with carbonate cement at the base. Upwards the section the sandstone is replaced by siltstones and carbonate clays of greenish-gray, brownish-red and lilac colors. Greenish-gray carbonate clays with frequent layers of marls and dolomites represent the upper part of the rhythm.

A presence of *Sinuosisporis* (al. *Perotrilites*) *vermiculatus* (Medyanik) V. Obuchovskaya, *Archaeoperisaccus verrucosus* Paschkevich, *Chelinospora digitata* (Araslanova) V. Obuchovskaya and *Ancyrospora zhelonica* V. Obuchovskaya is characteristic for the miospore assemblages of the *S. vermiculatus* subzone. *Densosporites sorokinii* V. Obuchovskaya appears at the upper part of Zhelon members. The species mentioned above allow us to correlate the upper part of the Zhelon members with the Timan Horizon of Timano-Pechora province.

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UPPER ORDOVICIAN (HIRNANTIAN) RADIOLARIANS FROM THE GORNY ALTAI (SOUTH OF WEST SIBERIA)

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There are still few data on the Upper Ordovician radiolarians. First they were reported from carbonate and siliceous-volcanic rocks of Kazakhstan by B.B. Nazarov (1975, 1988). Caradocian and Ashgillian species were also described from Nevada, Estonia, Australia, Baltic region, Newfoundland and Arctic Canada.

Radiolarians belong to families Entactiniidae, Inaniguttidae and Haplentactiniidae have been recovered from the siliceous-carbonate Khankhara Formation (Gorny Altai), dated by graptolites and conodonts (identified by Dr. T.A. Moskalenko) as Ashgillian in age (Sennikov, 1976, 1998).

Upper Ordovician Khankhara Formation is exposed on the left bank of the Chagyrka River, Tachalov Creek, near Ust'-Chagyrka Village (Fig. 1). Radiolarian association was recovered from the grey, greenish-grey, thin siliceous mudstones. It includes the specimens with lattice spherical shells constrained of the primary unites with ectopically placed spicule and rod-like spines that are assigned to *Secuicollacta cassa* Nazarov et Ormiston and *S. sceptri* McDonald, and with two latticed spherical shells of *Diparvapila* sp. Specimens with robust reticulate pylomate spherical shells belong to *Kalimnasphaera* cf. *maculosa* Webby et Blom, small thick-walled single shelled radiolarians with thin long strait or curved spines are assigned to *Entactinia subulata* Webby et Blom. The association also includes *Secuicollacta* cf. *esthonica* (Nazarov), *Secuicollacta* sp., and Entactinia sp.

Recovered association possesses great similarity with radiolarians described from the Caradocian Hanson Creek Formation, Nevada (Dunham, Murphy, 1976; Renz, 1990), *Kalimnosphaera* and *Entactinia* from the Latest Caradocian–Early Ashgillian Malongulli Formation, NSW, Australia (Webby, Blom, 1986), with *Secuicollacta* figured in Nazarov & Nõlvak (1983) and Gorka (1994), Caradocian Baltic and Ashgillian Pomerania erratic boulders, and Haplentactiniidae described from the Llandovery Cape Phillips Formation, Arctic Canada (McDonald, 1998).

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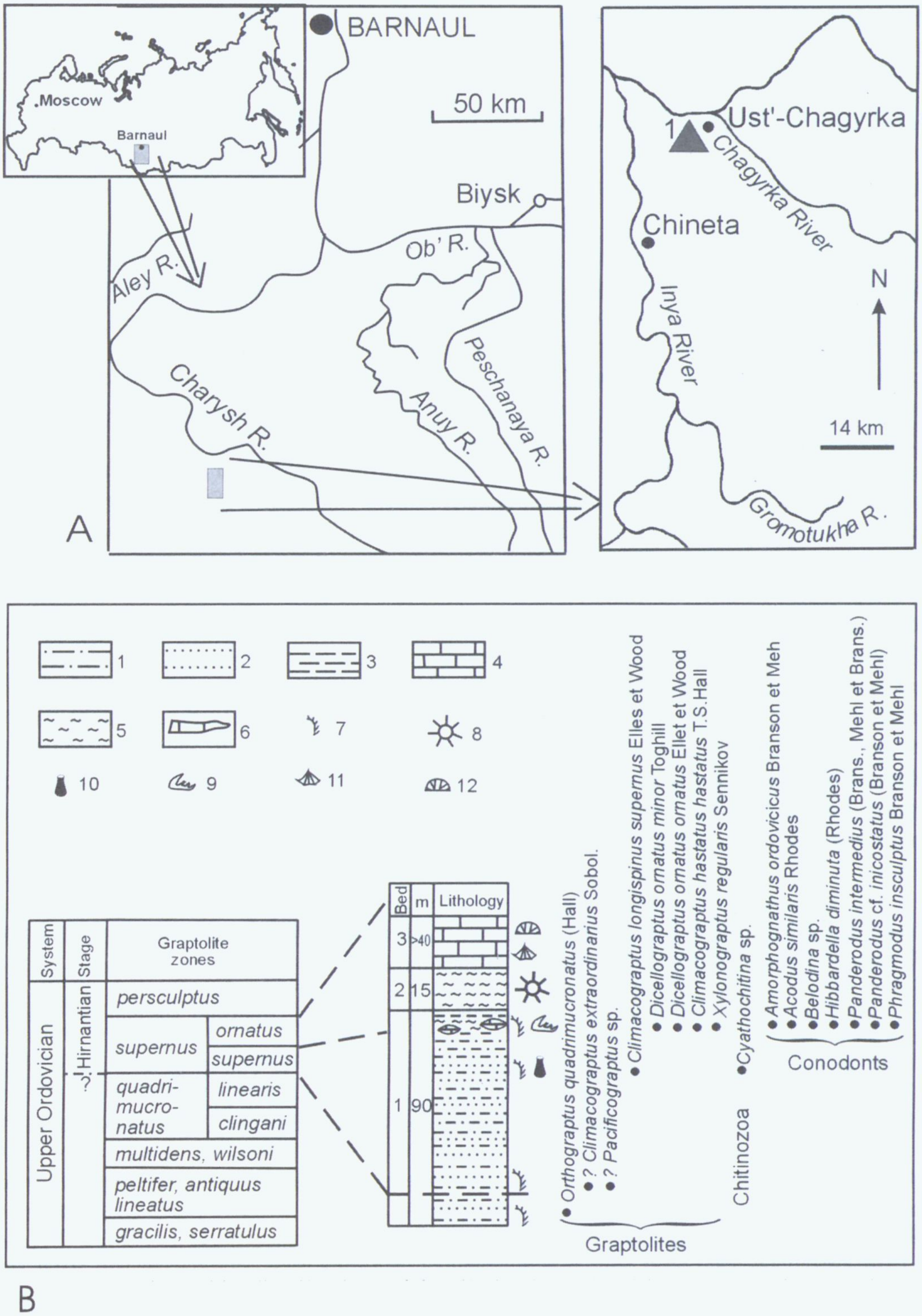

Fig. 1. A. Sketch-map of the studied area. 1 – the locality of Khankhara Formation section. B. Stratigraphic distribution of fossils in the Khankhara Formation section along the Tachalov Creek, left bank of the Chagyrka River. 1– siltstones, 2 – sandstones, 3 – mudstones, 4 – limestones, 5 – siliceous mudstones, 6 – carbonate lenses, 7– graptolites, 8 – radiolarians, 9 – conodonts, 10 – chitinozoans, 11 – brachiopods, 12 – corals

ON THE CORRELATION OF THE UPPER DEVONIAN REGIONAL STAGES OF THE EAST EUROPEAN PLATFORM WITH STANDARD AND LOCAL CONODONT ZONAL SCALES

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The standard zonal conodont scales of the Devonian that were established by Ziegler, Klapper, and Sandberg are important for the interregional stratigraphy and correlation. Although these scales were long calibrated and improved, they still need further development. The current standard zonal scale is based on the sections of basin lithologic facies of Rheinesche Schiefergebirge and actually is a regional scale, since its intervals are applicable only in some regions and for depression (basin) facies. On the territory of East European Platform the standard conodont scale works well in subdividing the Upper Devonian domanikoid (depressive) lithologic facies. Thus, the study of the conodont assemblages from the Upper Devonian domanikoid beds of the Volga-Urals and Timan-Pechora provinces has revealed that the zones *transitans*, *punctata*, Late *rhenana*, and *linguiformis* are well distinguishable by contrast to the zones Early *hassi*, Late *hassi,* and *jamieae*. *Palmatolepis hassi* was found only over the level of the disappearance of *Mesotaxis*, approximately within the standard zone Late *hassi*. However, *Ancyrognathus triangularis* was not detected within this interval, appearing only in the zone Early *rhenana*. We failed to reveal the zone *jamieae*, since the index-species appears only in the zone Early *rhenana*. The base of the latter is also difficult to determine. Special zonal scales or successions of local conodont assemblages are developed for the Frasnian shallow lithologic facies that contain different conodont biologic facies.

The outlined problems bring up the necessity of developing a subregional scale for the Frasnian of the East European Platform (Timan-Pechora Province, TPP, and Volga-Urals Province, VUP) that combines standard and local conodont zones (Lz). We propose the following succession (from bottom to top) of conodont zones correlated to regional and subregional stages (horizons). The *Polygnatus pennatus–Po. lanei* Lz corresponds to the upper part of the Timan and lower part of the Sargaevo stages. Since the assignment of a shallow assemblage to a standard zone is impossible, the position of the standard lower boundary of the Frasnian remains unknown. The *Ancyrodella rotundiloba* Lz is referred to as the middle part of the Sargaevo Stage; and the *Ancyrodella alata–Mesotaxis bogoslovsky* Lz is the upper part of this stage. These two zones correspond to the Lower *asymmetricus* zone; the upper one corresponds to the *transitans* zone of the standard scale. The *Polygnatus brevilamiformis–Palmatolepis punctata* Lz represents the lower part of the Domanik Stage; the *Ancyrognathus ancyrognathoideus–Palmatolepis domanicensis* Lz is the middle part of the Domanik Stage; and *Palmatolepis proversa–Pa. amplificata* Lz is the upper Domanik Stage and lower Vetlasyan Stage of TPP and upper Domanik–lower Mendym stages of VUP. The correspondence between Lz of the middle and upper parts of the Domanik Stage and the bases of the Vetlasyan Stage (TPP) and Mendym Stage (VUP) and the standard zones *hassi*, *jameae*–Early *rhenana* needs to be refined. The *Ancyrognathus triangularis–Palmatolepis semichatovae* Lz is referred to as the Sirachoy and Mendym subregional stages and as the standard zone Early *rhenana*. Upward the standard zones Late *rhenana* (Evlanovo Stage) and *linguiformis* (Livny Stage) are distinguished with confidence. We refer to the integral stratigraphic interval of these zones as to Askyn Subregional Stage. Special zonal scales or succession of local conodont assemblages are developed for shallow deposits that are dominated by polygnathid and icriodid conodont facies. As new data are accumulated, these scales have been added, refined, and improved over many years.

A zonal scale that was correlated to the regional stages was proposed for the Frasnian shallow deposits of the Central Devonian Field that contain polygnathid biofacies (Ovnatanova and Kononova, 2001). The *Polygnatus alata* Lz is corresponded to the upper part of the Timan Stage; *Po. reimersi* Lz – to the Sargaevo Stage; *Po. efimovae* Lz – to the lower part of the Semiluki Stage; Beds with *Po. aspelundi* – to the upper part of the Semiluki Stage; the *Po. subincompletus* Lz – to the Petino and lower Voronezh stages; the *Po. maximovae* Lz – to the Voronezh and Evlanovo stages; and Beds with *Po.* aff. *brevilaminus* – to the Livny Stage. The presence of *Ancyrodella* in the Sargaevo Stage, *Pa. semichatovae* in the Voronezh Stage, and *Po. brevis* in the Evlanovo Stage facilitates the correlation of this local scale and the standard zonation.

Standard palmatolepid zonation of the Famennian is well traced in the sections of depression and slope facies, and is also detectable in some intervals of shallow marine lithofacies.

The Volgograd Stage is correlated with the Lower and Middle *triangularis* zones; Zadonsk Stage – with the Upper *triangularis* (?) and *crepida* zones; and Eletz Stage with the *rhomboidea* zone. The base of the interval of *marginifera* zone is corresponded to the bases of the Lebedyan and Ust'-Pechora subregional stages. The upper boundary of this interval is situated within the Plavsk or Dzebol subregional stages. The sections of shallow lithofacies are successfully subdivided on the basis of polygnathids and icriodids.

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TRILOBITES DESCRIBED BY W. W. LAMANSKY

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A hundred years ago, Lamansky (1905) wrote about the oldest "Silurian" layers of Russia, using trilobites as index fossils of the stages. Starting from the lowest, the following stages were established: $B_I\beta$ with *Megalaspides*, $B_{II}\alpha$ with *Megalaspis planilimbata*, *Megalaspis limbata* and *Asaphus priscus*; $B_{II}\beta$ with *Asaphus bröggeri* and *Onchometopus volborthi*; $B_{II}\gamma$ with *Asaphus lepidurus* and *Megalaspis gibba*; $B_{III}\alpha$ with *Asaphus expansus* and *Asaphus lamanskii*; $B_{III}\beta$ with *Asaphus raniceps*; and $B_{III}\gamma$ with *Asaphus eichwaldi* and *Ptychopyge globifrons*. In general this subdivision is still in use (Kaljo, 1987; Popov, 1997).

He also discussed briefly some characters or variation of different taxa when showing their geographical and stratigraphical distribution. Unfortunately some of the newly named trilobite species were not figured and therefore remained *nomena nuda* e.g. *Onchometopus schmidti*, *Amphion brevicapitatus* and *Asaphus priscus*. Lesnikova (*in* Lesnikova and Weber, 1949, p. 284, 396, pl. 19, fig. 1) figuring the original of Lamansky appeared to be the author of the last mentioned species (Balashova, 1976, p. 34). *Amphion brevicapitatus* was separated from *A. fisheri* (=*Pliomera fisheri*) by only one character, that shows no stratigraphical dependence. However, the variation of *Pliomera* throughout the B_{II}–B_{III} indicates occurrence of several species.

Lamansky paid more attention to the trilobites from the oldest part of succession: the Glauconite Sandstone ($B_I\beta$), giving also the drawings of the new material. This material includes six taxa: *Triarthrus angelini* Linnarsson, 1869, *Megalaspis leuchtenbergi*, *Megalaspis pogrebovi*, *Megalaspides schmidti*, *Ptychopyge* (?) *inostranzewi* and *Megalaspis* (?) sp. The first (Lamansky, 1905, p. 6, pl. 1, fig. 1) actually represents a fragmentary glabella of *Evropeites lamanskii* Balashova, 1966 (Pärnaste, 2004). The two following most probably represent a single taxon related to both *Megistaspis* and *Rhinoferus* (Pärnaste, 2004). They co-occur in the lowest nodular beds of the Mäeküla Member in several localities (Maardu, Nõmmeveski, Popovka, Tosna). However, the first of them was assigned to *Paramegistaspis* Balashova, 1976 and second to *Rhinoferus*? (*Popovkiaspis*) Balashova, 1966 by Balashova (1976). Despite the finding of the Tremadocian "*Triarthrus angelini*" Lamansky suggests that the calcareous Glauconite Sandstone ($B_I\beta$) is roughly correlative to the *Phyllograptus*–Shale (Arenigian) in Sweden and Norway rather than to *Ceratopyge*- Limestone or Shale (Tremadocian), which I agree (Pärnaste, 2004) but was earlier disagreed by several authors (e.g. Balashova, 1966).

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LITHOLOGIC CHARACTERISTICS OF THE GERTOVSKAYA MEMBER IN THE TOSNA RIVER VALLEY

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The Gertovskaya Member of the uppermost part of the Sablinka Formation of the Middle Cambrian was established and characterized by fauna by L.V. Popov, K.K. Khazanovich, N.G. Borovko and other investigators (Khazanovich, Popov, Melnikova, 1984; Popov, Khazanovich, Borovko *et al.*, 1989). Sandy deposits of this stratigraphic unit are exposed along the Tosna River banks between the villages of Pustynka and Gertovo. The Gertovskaya Member is based on an erosive surface within the sandstones of the upper subformation of the Sablinka Formation. It is overlain with unconformity by low-cemented sandstones of the Upper Cambrian Ladoga Formation or by the Lower Ordovician Tosna Formation. The thickness of the Gertovskaya Member in the Tosna River valley, the characters of its lower and upper boundaries and the fossil assemblages were reported in details in publications mentioned above. However, the lithology and fabric of the Gertovskaya Member sandstones were studied unsatisfactorily. The very brief description had been published by S.E. Zubtsov (Zubtsov, 1995) till now. It is especially strange, as the Gertovskaya Member differs significantly by lithology from an underlying rocks of the Sablinka Formation.

The type section of the Gertovskaya Member is located in the right side of the Tosna River above the stream from the deserted sand quarry near the south suburb of the Pustynka village (Khazanovich, Popov, Melnikova, 1984). During our studies on the lithology of the Gertovskaya Member we described the section situated on the opposite left side of the Tosna River not far from the local swimming bath. At present this section is better exposed and easily accessible than the type section. The outcrop extends along the low riverbank for 100–150 meters. The complete thickness of the Gertovskaya Member is approximately 2 m.

The Gertovskaya Member is represented by intercalation of cross-bedded sandstones. The lower and upper parts of the member are slightly different by their sedimentary structures that can be easily observed in two benches (Fig. 1). In the lower bench that is 1.2 m thick the cross-bedded series invariably dip to the north-northeast. Single series are extended, have a length from 3–5 to 10–15 m, and an insignificant thickness about 10–40 sm. The sandy seams occurred between series are extended, smooth, slightly concave, often are inclined aside bed dip. Beds have a concave camber, border to a roof and very strongly flatten out to a foot flange. Such texture can be characterized as plane parallel unidirectional cross bedding. Besides the crushing and stirring-up texture are periodically observed and look like the series with incorrectly bent, crumpled, and broken off slanting beds. Thus, sedimentary structure of the

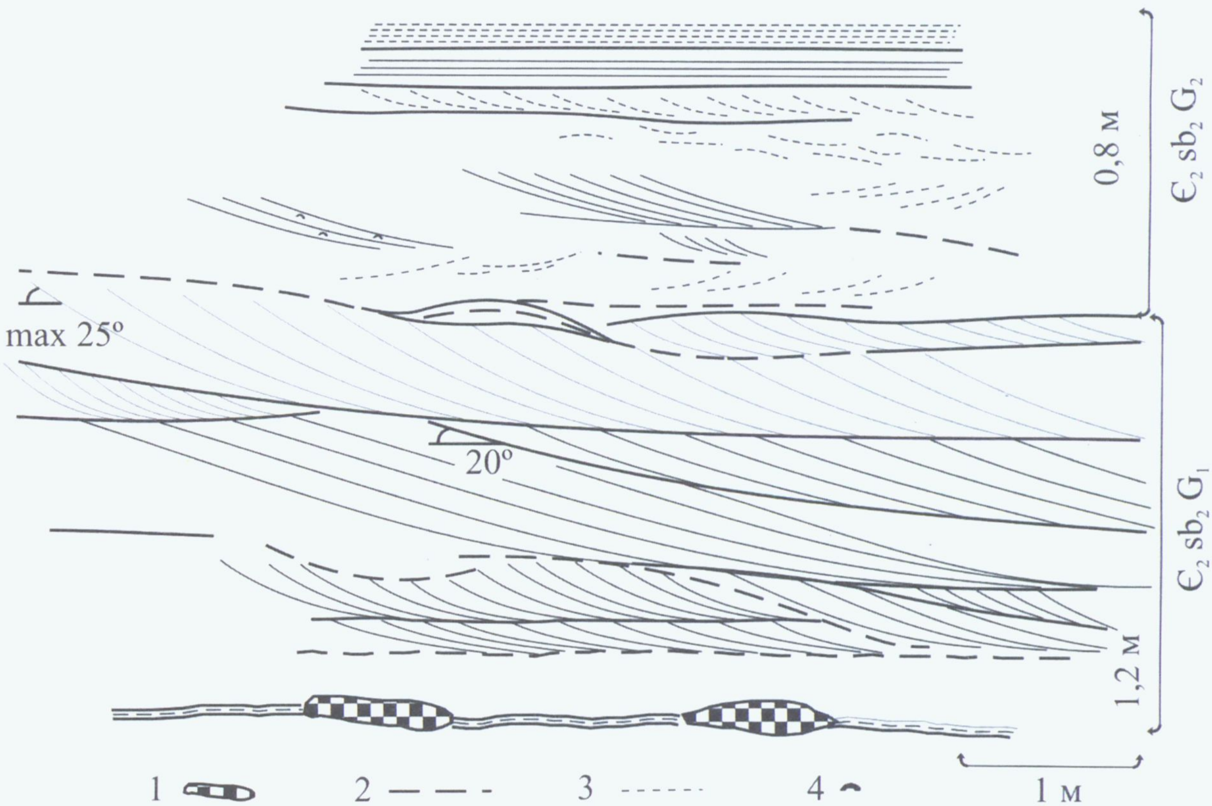

Fig. 1. The composition and textures of Gertovskaya member, Tosna River. Legend: 1– concretions of closely cemented sandstones; 2 – clays in layering seams; 3 – clays marking foliations; 4 – intact Obolus shells

Gertovskaya Member differs significantly from those of the lower Sablinka subformation. The latter have cross-bedded series smaller in size (1–1.5 m in length), less thick (5–15 cm) and dipping in different directions (Tugarova, Platonov, Sergeeva, 2001).

The upper part of the Gertovskaya Member is different from its lower part. The length of slanting series is significantly less (1.5–2 m), it average thickness is about 15 cm and the bedding is practically invisible as well as the foliation which is discernible only due to clay admixture. In the upper part of this part of the member the cross-bedding series become flat. The uppermost layer (16 cm) is represented by flag flat-bedding sandstones. Nevertheless, the over-all dip direction remains constant except some series with the opposite dip direction.

Granulometric composition of sands of the Gertovskaya Member is rather homogeneous and despite of difference in sedimentary structures does not change significantly, the hardly coarsening to the roof is detected. Sands and sandstones are well graded with the modal sizes 0.29 mm, and the fraction of 0.25–0.315 mm compose about 50 % of all grains. In some samples the second additional moda with sizes of 0.11–0.12 mm is observed. Bimodal granulometric distributions are well developed in the lowermost layer of the member. Sand are well washed – the content of fraction less than 0.05 mm does not exceed 0.3 %. There are small amounts of the more coarse grains up to 1 mm in sizes whereas 5 % of grains do not exceed 0.45 mm. Within the individual cross-bedded series the coarse badly graded polymodal sands have median sizes 0.35 mm. The finest flat-bedding sands are in the upper bench; their modal size makes 0.11 mm.

For comparison we represent the granulometric data of the lower Sablinka subformation sandstones. They are well graded, unimodal, the modal size of grains is 0.17–0.18 mm, value of 5 % quantile makes 0.34 mm.

The sands of the Gertovskaya Member are quartzose with a negligible (1–3 %) amount of feldspars. The composition of heavy minerals was studied in dimensional fraction of 0.1–0.25 mm (finer fraction in sand is practically absent) in samples from the upper and lower benches of the Gertovskaya Member. The main minerals are ilmenitite and leucoxene (45–77 %), zircon (14–24 %), tourmaline (5–11 %), staurolite (1.9–2.1 %) and rutile (0.3–1.1 %). Topaz, indigolite, sphene, anatase, almandine are less common (up to 1%). In the upper layers authigenic hematite and limonite are identified (up to 17 %). The heavy fractions without the phosphate shells of inarticulate brachiopods make 0.33 % of the sands of lower bench and 0.02 % of the upper one.

Thus, the terrigenous deposits of the Gertovskaya Member in the Tosna River differ significantly from the underlying rocks of the Sablinka Formation by its sedimentary structures and textures that clearly specifies their accumulation in essentially distinguished lithodynamic conditions.

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FOSSIL ASSEMBLAGES AND STRATIGRAPHY OF THE ORDOVICIAN/SILURIAN TRANSITION BEDS IN THE SOUTHERN PART OF THE HOLY CROSS MOUNTAINS, POLAND

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The Ordovician/Silurian transition deposits discussed in this study are exposed in the Bardo Syncline in the southern Holy Cross Mountains (Kielce region).

The material used for paleontological investigation comes from two sections: Zalesie Nowe and Bardo Stawy. Our investigations have focused on the graptolite fauna and microphytoplankton (acritarch) assemblages from the Ordovician/Silurian transition beds. We have revised the biostratigraphy of these sections, and investigated diversity and sedimentary facies patterns (Masiak *et al.*, 2003).

The gradational decrease in detrital quartz and in grain size is characteristic of the latest Ordovician and earliest Silurian strata. The deposits of the Ordovician/Silurian boundary zone change gradually in texture from non-bedded, very fine-grained sandstones and siltstones to laminated claystones and shales. There is also a change of colour from beige to brown-grey and dark grey. Both may indicate a gradational change from periods of better ventilation and increased circulation to a more sluggish, hypoxic environment. Thus, these features of the uppermost Ordovician–lowermost Silurian sequence indicate a gradual slowdown in sedimentation marked by a progressive restriction of terrigenous sediment supply related either to the post-glacial eustatic sea level rise or to a decrease in erosion on the adjoining land.

The first graptolites appear in strata preceding the final change from light silty and sandy facies into dark clayey facies, with graptolites unequivocally indicating the base of the Silurian. They appeared still before the near-cessation of sedimentary activity in oxic or, at most, suboxic conditions.

The typical lower Silurian deposits are dark but not black, clayey shales with only small amounts of coarser quartz grains and organic matter. Within the monotonous Lower Silurian clayey succession there occur silica-rich laminae with chalcedony spherolites.

Our study of the graptolite fauna focuses on the biodiversity of the graptolite assemblages, their occurrence, stratigraphic range and associations, from around Ordovician/Silurian boundary (Fig. 1).

First graptolites appear 20 cm below the typical dark, clayey "graptolite shales". Close sampling of the Bardo Stawy section allowed distinction of the ?*persculptus*, *ascensus–acuminatus* and *vesiculosus* biozones.

? *Persculptus* Biozone

The oldest graptolite fauna contains only biserial graptolites, predominately normalograptids. The following

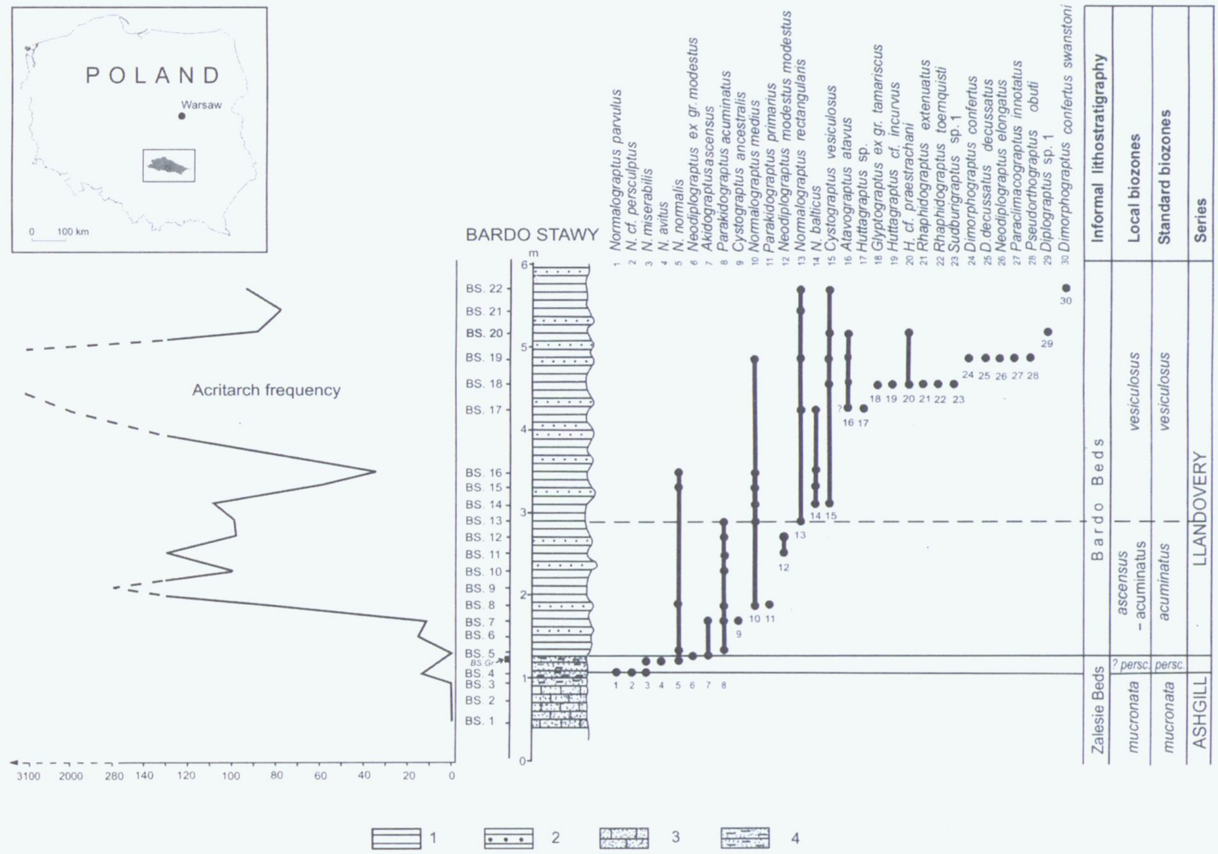

Fig. 1. Lithology and range chart of the graptolites together with acritarch frequency:
1 – clayey shales, 2 – black laminated cherts, 3 – fine-grained sandstones to siltstones,
3 – silty to sandy claystones and shales

graptolite species are recorded from this level: *Normalograptus parvulus* (H. Lapworth), *N.* cf. *persculptus* (Elles and Wood) a form very close to those described and illustrated by Štorch and Loydell (1996) from Bohemia, *N. miserabilis* (Elles and Wood), *N. avitus* (Davies) with its distinctive bifurcated virgella, and the long-ranging *N. normalis* (Lapworth).

***Ascensus–acuminatus* Biozone**

The abundance and diversity of graptolites clearly increase in this interval. Poorly preserved specimens, seemingly juvenile *A. ascensus* Davies, together with other, undetermined juvenile graptolites appear in beige intercalations still occurring between the dark shales. This level is slightly below that of the appearance of P. acuminatus. At the same level, the early Silurian *Neodiplograptus* ex.gr. *modestus* appears. It is the equivalent of the entire standard *acuminatus* Biozone determined in the GGZ as the lowermost Silurian graptolite biozone (Koren' *et al.*, 1996) and its lower boundary here represents the system boundary.

Other species present are: *Cystograptus ancestralis* Štorch, *Normalograptus normalis*, *N. medius* (Törnquist) and, in the upper part of the biozone, *Neodiplograptus modestus modestus* Lapworth and *Normalograptus rectangularis* (McCoy). The graptolite assemblage found in this biozone is similar to the assemblage known from Łeba Elevation, northern Poland (Podhalańska 1999, 2003).

***Vesiculosus* Biozone**

The lowermost part of the zone is characterized mainly by a normalograptid fauna: *N. normalis*, *N. medius, N. rectangularis* and *N. balticus* (Pedersen) and *Cystograptus vesiculosus* (Nicholson).

In sample BS.17, the monograptids appear for the first time. They may belong to the new genus *Huttagraptus* erected by Koren' and Bjerreskov (1997).

The most diverse and numerous monograptid fauna have been found in sample BS.18. It comprises *Huttagraptus* sp., *Huttagraptus incurvus* Koren', *H.* cf. *praestrachani*, together with *Atavograptus atavus* (Jones).

The succession of graptolites of the *vesiculosus* Biozone including the oldest monograptids in the Bardo Syncline is very similar to the succession known from Bornholm, Great Britain and Bohemia (Bjerreskov, 1975; Hutt, 1975; Koren' and Bjerreskov, 1997; Rickards, 1970; Štorch, 1994; Zalasiewicz and Tunnicliff, 1994).

In the upper part *Dimorphograptus decussatus decussatus* Lapworth, *Dimorphograptus confertus* (Nicholson), *Paraclimacograptus innotatus* (Nicholson), *Pseudorthograptus obuti* (Rickards and Koren'), *Rhaphidograptus extenuatus* (Elles and Wood), *R. toernquisti* (Elles and Wood) and *Neodiplograptus elongatus* Churkin and Carter have been found.

The latest Ordovician palynological assemblage includes only long ranging acritarchs, mainly of simple morphology. The acritarch frequency is moderate. At the Ordovician/Silurian boundary a considerable decrease of acritarch frequency was observed. The frequency and diversity increase in the lower part of the *ascensus–acuminatus* biozone. In the Bardo Stawy section, the maximum acritarch frequency is attained in the lower part of the *vesiculosus* Biozone although the diversity does not change. The change in acritarch assemblages is not related to lithology.

The peak in acritarch frequency noted in the lower part of the *ascensus–acuminatus* Biozone coincides with a considerable increase in chitinozoa abundance as well as trace fossils.

The peak in acritarch frequency noted in the lower part of the *vesiculosus* Biozone coincides with a huge increase in chitinozoa abundance, and the occurrence of bioturbation, brachiopods, and conodonts.

The diversity of fossils and microfossils as well as ichnofauna throughout the interval studied runs counter to the notion of monotonous "black graptolitic shales" in the Holy Cross Mountains.

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BRYOZOAN ASSOCIATIONS IN THE LOWER–MIDDLE ORDOVICIAN OF THE LENINGRAD DISTRICT

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The results of studies on the Lower–Middle Ordovician Bryozoa from the Leningrad District are shortly discussed. The bryozoan colonies from the Putilovo and Babino quarries and outcrops on the banks of the Lava Volkhov, Popovka, Lynna and Syas' rivers were studied in detail (Pushkin, Popov, 1999, text-figs 1–3). The oldest Bryozoa were sampled from the sections of the Billingen Stage (Early Arenig) (Pushkin, Popov, 1999; 2001). The collection from this stratigraphic interval includes the following taxa of Trepostomida: *Esthoniopora*? *lessnikowae* (Modzalevskaya), *Dianulites helenae* (Modzalevskaya), *Revalotrypa eugeniae* Gorjunova, *R.*? *arborea* (Modzalevskaya), *Phragmopora lavaense* Pushkin, *Hemiphragma priscum* Pushkin (Pushkin, 1997).

A taxonomic diversity of Bryozoa increased considerably in the Volkhov Stage, where it comprises the following species: *Dittopora clavaeformis* Dybowski, *Revalotrypa gibbosa* (Bassler), *Dybowskites annulatus* (Eichwald), *Hemiphragma subirrasum* Männil, *Esthoniopora lessnikowae* (Modzalevskaya), *Hexaporites hexaporites* Pander,*Dianulites multimesoporicus* Modzalevskaya, *D. collucatus* Pushkin, *D. helenae* (Modzalevskaya), *D. eichwaldi* Pushkin, *D. modzalevskae* Pushkin, and *Stictoporella gracilis* (Eichwald).

In the Kunda Stage taxonomic diversity of Bryozoa is higher as to compare with that in the Volkhov Stage. More than 15 species were found, among them are the following: *D. collucatus* Pushkin, *D. multimesoporicus* Modzalevskaya, *D. fastigiatus* (Eichwald), *D. helenae* (Modzalevskaya), *Revalotrypa gibbosa* (Bassler), *Hemiphragma rotundatum* (Bassler), *H. pygmaeum* Bassler, *H. subirrasum* Männil, *Orbipora solida* Bassler, *O. acanthopora* Bassler and *Stictoporella gracilis* (Eichwald). The Volkhov and Kunda bryozoans are the most diverse and better studied than the Lower and Middle Ordovician bryozoan associations in the other regions.

Almost all bryozoan species and most of genera that are widely spread in the Volkhov and Kunda sections have disappeared in the overlying sediments of the Azeri, Lasnamjagi and Uhaku stages. In contrast, the representatives of *Mesotrypa* and *Diplotrypa* genera have their first appearances at the Kunda/Azeri boundary. The following species are dominated in the Azeri, Lasnamjagi and Uhaku stages: *Mesotrypa bystrowi* Modzalevskaya, *M. excentrica* Modzalevskaya, *Esthoniopora communis* Bassler, *Orbipora distincta* Eichwald, *Dianulites petropolitanus* (Pander), *D. janischewski* Modzalevskaya and *D. fastigiatus* (Eichwald). All listed species are widely spread in the East European Platform.

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REVISION OF LATE WENLOCK BIOSTRATIGRAPHY IN LITHUANIA

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The new Lithuanian material is from the Vilkaviškis-131 borehole from the 1052–1100 m interval (60 samples) and from the Šiupyliai-69 borehole. Graptolites were studied from the 966–1010 m interval (50 samples), in the Kurtuvėnai-161 borehole and also in the 1274–1330 m interval (45 samples), while the Sutkai-87 borehole 760–805 m interval (25 samples) was also studied. All boreholes are from north and south Lithuania. In total about 180 samples were collected and investigated. Recent detailed information from the Upper Homerian allows the distinction of the *lundgreni*, *parvus*, *nassa*, *praedeubel*, *deubeli* and *ludensis* graptolite Biozones in Lithuania (Fig. 1).

The *lundgreni* taxon-range Biozone was adapted by Paškevičius (1997). This interval was formally included in the *tests* Biozone (Paškevičius, 1979, 1981, 1991). The upper boundary of this Biozone is marked by disappearance of genera *Cyrtograptus, Monograptus* and *Monoclimacis*. In Lithuania this Biozone includes: *Cyrtograptus lundgreni* Tullberg, *Monograptus t. testis* (Barrande), *M. t. inornatus* Elles, *M. f. flemingi* (Salter), *Monoclimacis flumendosae* (Gorthani), *P. lodenicensis* Přibyl, *P. pseudodubius* (Bouček), *Gothograptus* cf. *kozlowski* Kozlowska-Dawidziuk. These species do not disappear at the same time. *P. lodenicencis* disappears first, and then – *M. t. testis*, *M. t. inornatus* and *M. flumendosae*. The last three species disappear before *C. lundgreni* in boreholes of Lithuania. But *C. lundgreni* disappears earlier than *M. t. testis* (Porębska *et al.*, 2004) in the Bartoszyce borehole (Poland). *C. lundgreni* disappears together with *M. f. flemingi*, *P. pseudodubius* and *G.* sp., in the lower part of Ančia member.

A graptolite free interval and the *parvus* concurrent-range Biozone recognized for the first time in Lithuania (Fig. 2). Previously the *parvus* Biozone interval was attributed to the lower part of the *nassa* Biozone. Ulst (1974) first separated a *P. parvus–P. piltenensis* local Biozone in Latvia, was first separated by Ulst (1974) and included the entire interval of the *nassa* Biozone (Ulst, 1974). The lower boundary of this Biozone is placed where *C. lundgreni*, *M. t. testis*, *M. t. inornatus*, *M. f. flemingi*, *M. flumendosae*, *P. lodenicensis*, *P. pseudodubius*, *G.* cf. *kozlowski* disappear. *P. parvus* Ulst and *G. nassa* (Holm) appear in the upper part of the Ančia member. Only two species are found in this Biozone, other graptolites are absent. The graptolite-free interval ranges from 0.7 m (Šiupyliai-69) to 2 m (Vilkaviškis-131) in thickness. The upper Biozone boundary is recognized where *P. parvus* disappears. The vertical extent of *P. parvus* ranges from 5 m in the Kurtuvenai-161 to 2.4 m in the Vilkaviškis-131 borehole.

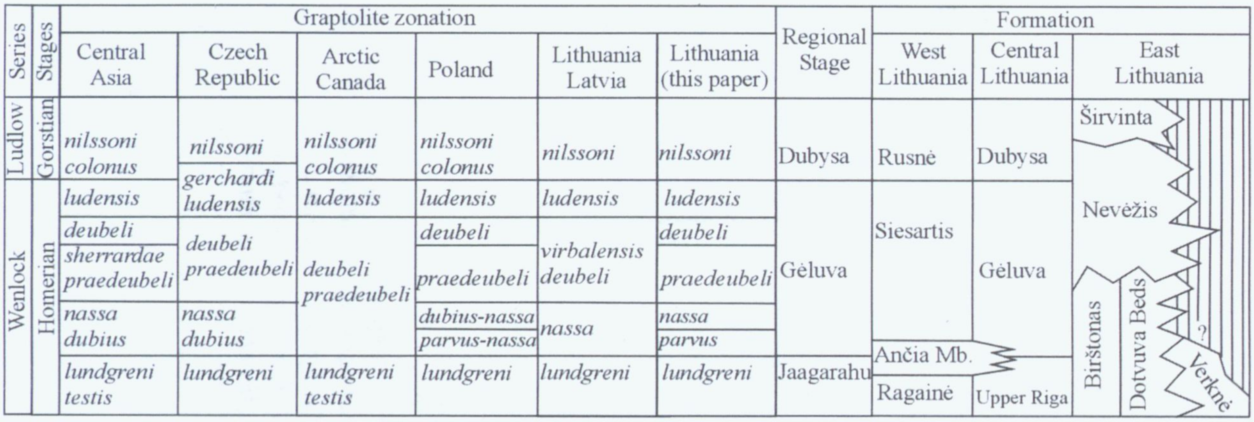

Fig. 1. Correlation of the revised Lithuanian Upper Wenlock graptolite biozonation with those of Central Asia (Koren and Suyarkova, 1994); with that of Czech Republic (the gerchardi-ludensis zonal boundary is higher because *C. gerchardi* disappers in the Lower Ludlow – Kozlowska-Dawidziuk *et al.*, 1998); with that of Arctic Canada (Lenz, 2002); with that of Poland (Szymanski and Teller, 1998; Lenz and Kozlowska-Davidziuk, 2002); with that of Lithuania and Latvia (Paškevičius and Radzevičius 2000; Radzevičius, 2004); and with regional stages and formations

Paškevičius (1965) recognized the *nassa* Biozone, which included the interval with *P. parvus*. Later this Biozone was divided into two intervals: a lower *nassa* part with *P. parvus* and an upper *nassa* part with *P. d. ludlowensis* (Bouček) (Radzevičius, 2004). These two parts are shown as independent Biozones in this paper. The lower boundary of the Biozone is marked where *P. parvus* disappears and the upper boundary where *P. virbalensis* Paškevičius and *P. praedeubeli* (Jaeger) appear. This Biozone, as well as the *parvus* Biozone, has few species, which though are larger than those in the *parvus* Biozone: they comprise *G. nassa* and *P. d. ludlowensis*. This Biozone is 6.5 m thick in Vilkaviškis-131 borehole.

The *praedeubeli* range Biozone is established here for the first time in Lithuania. Previously this interval was called the *virbalensis - deubeli* Biozone (Paškevičius, 1996; Radzevičius and Paškevičius, 2000) later it was referred to as the lower part of the *virbalensis* Biozone with *P. praedeubeli* (Radzevičius and Paškevičius in press). The lower boundary is marked where *P. praedeubeli* and *P. virbalensis* appear, while the upper boundary is drawn when *P. deubeli* (Jaeger) appears. This Biozone also includes *G. nassa* and *P. d. ludlowensis*. *P. idoneus*? (Koren) has been found in the lower part of the Biozone for the first time, while *P. jaegeri* (Holland, Rickards, Warren) is in the upper part. The thickness of the *praedeubeli* Biozone is 5.8 m in the Vilkaviškis-131 borehole and 8 m in the Šiupyliai-69 borehole.

The *deubeli* range Biozone is also established for the first time in Lithuania. Previously this interval was called *virbalensis–deubeli* Biozone (Paškevičius, 1997; Radzevičius and Paškevičius, 2000). The lower boundary is drown at the appearance of *P. deubeli*. The upper boundary is drawn where *P. ludensis* appears. The assemblage comprises *P. jaegeri* (in the lower part), *P. deubeli*, *P. praedeubeli*, *P. virbalensis* and *P. d. ludlowensis*. We have been unable to determine the thickness of this Biozone in the Vilkaviškis-131 borehole, because the upper part of the Wenlock is not graptolitic. The thickness of the *deubeli* Biozone is 5 m in the Šiupyliai-69 borehole.

The *ludensis* range Biozone was established by Paškevičius (1979). Previously this Biozone encompassed the interval from the *nassa* to the *nilssoni* Biozones (Paškevičius, 1979) while Paškevičius (1997) recognised it in its present meaning. The lower boundary of the Biozone is drawn where *P. ludensis* (Murchison) appears, and the upper boundary where *Neodiversograptus nilssoni* (Barrande), *Colonograptus colonus* (Barrande) and *Bohemograptus b. bohemicus* (Barrande) appear. The graptolite assemblage of this Biozone includes *P. ludensis*, *P. praedeubeli* and

P. d. ludlowensis; in the upper part *C. gerchardi* (Kűhne) appears, and this taxon is also found in the upper *nilssoni* Biozone.

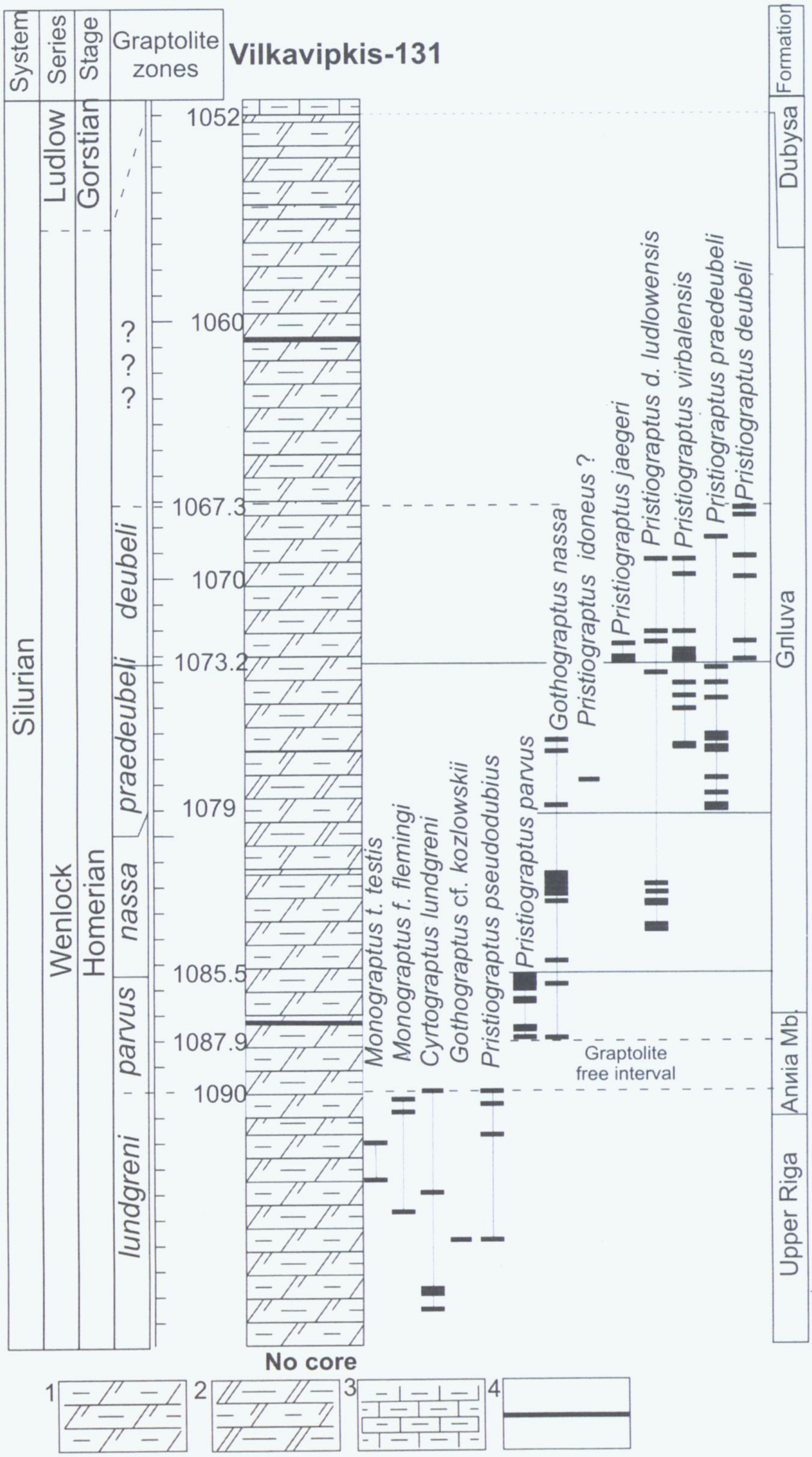

Fig. 2. Distribution of graptolites near the Wenlock–Ludlow boundary in the Vilkaviškis-131 borehole, Legend: 1 – dolomitic, clayey marl, 2 – calcareous, dolomitic, clayey marl, 3 – clayey dolomite

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QUANTITATIVE DISTRIBUTION AND EVOLUTION OF PALYNOMORPHS ASSOCIATED WITH KUKERSITE DEPOSITS IN THE MIDDLE–UPPER ORDOVICIAN OF THE EAST-EUROPEAN PLATFORM

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Middle–Upper Ordovician Kukersite-type deposits occur in an area of about 100 000 square kilometers of the eastern part of Baltic basin, and they constitute important hydrocarbon source rocks for the region, exploited since the beginning of the last century. These organic-rich shales are dominated by a concentration of *Gleocapsomorpha prisca* Zallesky, 1917, for which the biological affinity (based on optical and geochemical characteristics) remains under discussion. Periodic blooms of this colonial marine microorganism were related to environmental changes, what was also influencing the diversity of associated phytoplankton communities. The present palynological study is focused on the qualitative and quantitative evolution of palynomorph distribution, below, within and above the kukersite-beds in the Alekseevka Quarry section (St. Petersburg region). Here, 3 m of the Mednikovo Formation, consisting of bluish-grey marlstone, and 6 m of the overlying Solets Formation, represented by four productive kukersite beds intercalated with clay, yellowish-grey limestone with kerogen and clayey limestone, have been sampled. The sequence, embracing the Middle–Upper Ordovician transition (the Uhaku and the Kukruse Stages respectively), corresponds to the interval of the *Glyptograptus teretiusculus–Nemagraptus gracilis* graptolite Zones.

In the upper part of the Mednikovo Formation "normal" phytoplankton community, comprising more than 25 different taxa belonging to *Baltisphaeridium*, *Leiofusa*, *Leiosphaeridia*, *Micrhystridium*, *Ordovicidium*, *Pachysphaeridium*, *Peteinosphaeridium*, *Polygonium* and *Veryhachium* becomes dominated by *Gleocapsomorpha prisca* (92 %). Then, in the kukersite beds at the base of the Solets Formation, palynomorph assemblage is characterised by almost a monospecific association with more than 99.5 % of *G. prisca*. Very few specimens of *Leiosphaeridia*, *Micrhystridium*, or small finely ornamented *Baltisphaeridium* are present in palynological slides made from kukersite. In the overlying sediments, however, together with *G. prisca* still in a remarkable quantity of 60–70 %, all previously identified acritarch species occur again.

G. prisca is clearly major contributor of kerogen-rich deposits of the kukersites. Its accumulation is probably not a result of selective preservation, because of accompanying acritarchs in the kukersites beds association, but better due to particular paleoenvironmental and depositional conditions, related to sea-level changes in Baltica and/or higher salinity situations as suggested elsewhere.

DEGLACIATION CHRONOLOGY IN ESTONIA

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The deglaciation history of Estonia has been a subject of research for about a century. Despite the great number of publications devoted to this subject and marked improvements in study methods many problems of topical interest in the history of deglaciation have still not been solved yet, especially due to the lack of good direct dating methods.

The most promising is the radiocarbon method but it has also limited application due to the lack of good interstadial sections for dating. Often interstadial and interphasial sediments are contaminated by redeposited older organogenic material and the dates are inconsistent with each other. On the other hand, in several cases anomalously high ages even in Holocene sections have been obtained due to the "hard-water" effect.

During the last decade much attention in Estonia has been paid to the varve chronology, but as proglacial lakes were isolated from each other, many caps exist between Estonia and the neighbouring countries. Therefore, the accuracy of the estimated rate for the ice recession in the areas where glaciolacustrine sediments are absent is extremely disputable. The lack of absolute and even semi-absolute dates beyond the radiocarbon dating range has been hampering the development of the Pleistocene stratigraphic charts and the correlation of ice marginal formations.

At the beginning of the last century G. de Geer (1912) divided the deglaciation history in Scandinavia into three major stages: Daniglacial (20 000–13 000), Gotiglacial (13 000–10 000) and Finiglacial (10 000–8000 years ago), which had different palaeoglaciological conditions. The author together with Leonid Serebryanny made some modifications to this scheme with new transbaltic correlations (Serebryanny and Raukas, 1966, 1967 a.o.).

In 1938 A. Tammekann compiled a map of glacial landforms of Estonia and presented five zones of ice-marginal formations (Tammekann, 1938), which were renamed and modified later by A. Raukas with co-authors. The names Haanja, Otepää, Sakala, Pandivere and Palivere are used up to now (Raukas *et al.*, 2004). The first attempt to date the ice marginal formations with modern methods was made already in 1969 (Raukas *et al.* 1969). It was concluded that the territory of Estonia was freed from the continental ice in Gotiglacial time during a time span lasting approximately 2000 years. The ice cover began to retreat from the south-eastern part of Estonia some 13 000 years ago, from the Otepää belt about 12 600 years ago and from the Pandivere belt about 12 500 years ago. The territory of Estonia was finally cleared of ice in the Allerød. This was proceeded by a new temporary advance of glaciers approximately 11 200 years ago, which led to the formation of the Palivere marginal zone.

Traditionally, the beginning of the late-glacial interval in Estonia is placed at the time span, when the deposits of the Raunis Interstadial below Haanja till started to accumulate in Central Latvia (dated by different laboratories as 13 390 ± 500: Mo-196, 13 250 ± 160: TA-177, 13 320 ± 250: Ri-39 conventional ^{14}C ages). The Raunis section together with the Kurenurme section in South Estonia (piece of wood dated 12 650 ± 520, TA-57 and organic detritus 12 420 ± 100, Tln-35) allowed to establish the age of the Haanja and Otepää zones. However, new datings (9302 ± 83, Tln-2319 and 9227 ± 70, Tln-2322) allow us to conclude that in the Raunis section organic deposits accumulated in the Early–Holocene and are probably covered with pseudotill (slope deposits). The majority of the ^{14}C dates obtained from submorainic and intermorainic sequences with organic remains in Estonia (Petruse, Viitka, etc) are younger than one would expect on the basis of the conventional radiocarbon method (Raukas, 1986). Therefore, the real geological age of main ice-marginal zones is rather questionable.

To improve the situation and wishing to establish a more accurate deglaciation chronology for Estonia, during the last years we have paid much attention to using the most modern dating techniques, including the OSL and ^{10}Be methods. OSL analyses were mostly made in the Radiometrical Dating Laboratory of the Institute of Geology at Tallinn University of Technology (former Institute of Geology of the Estonian Academy of Sciences) by Dr. Galina Hütt, during the last years in the frames of scientific cooperation between the Estonian and Polish Academies of Sciences (Institute of Geology of the Poznan University, Department of Radioisotopes of the Silesian University in Gliwice). ^{10}Be analyses were mainly performed at Oregon State University, Washington State University, and at the Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay Campus, France, under the leadership of P. U. Clark and V. R. Rinterknecht (USA) in the frames of collaborative research "Developing an improved chronology of the southern margin of the Scandinavian ice sheet".

For OSL dating we used samples from all genetical varieties of glaciofluvial deposits, from sandurs, glaciofluvial deltas, eskers and kames and ancient valley fillings. The results did not prove satisfactory. Alongside reliable dates between 11,000–15,000 OSL years BP, a lot of entirely unreliable dates from 8,000 ± 300 to 114,000 ± 8,000 OSL years BP were obtained (Raukas, 2004).

Turbidity and different water depth, velocity of outwash streams and transport length, possible fast sedimentation at night hours or below the ice, incorporation of older, unbleached particles a.o. factors affected the extent of bleaching of the TL-signal in different ways, causing great variability of dates. As glaciofluvial deposits exhibit a wide range of sedimentary characteristics the assumption that the TL signal is completely zeroed prior to final deposition is not only arguable but in many cases impossible and, what's also important, even the errors of dating in OSL years are often bigger than the duration of the whole deglaciation of Estonian territory. To our mind, the possibilities of the OSL method in dating glaciofluvial sediments are highly overestimated. Especially complicated is the dating of intermorainic deposits of unknown genesis.

The usage of the cosmogenic ^{10}Be method for establishing boulder exposure ages on the top of end moraine belts also gave great variations from 5464 ± 615 to 16 251 ± 1121 yr BP (Raukas, 2004).The relatively young weighted mean age of the Palivere zone (10 000 ± 1300 ^{10}Be yr BP) between that of the Pandivere zone immediately to the south (13 000 ± 1100 ^{10}Be yr BP) and Salpausselkä I zone to the north (11 800 ± 900 ^{10}Be yr BP) is readily explained by submergence of the boulders by the Baltic Ice Lake, Ancylus Lake, Litorina Sea and Limnea Sea, which would have substantially reduced the production rate for that period of time (Rinterknecht *et al.*, 2003). Also the vegetation and snow cover exerted much influence because we do not know how long the investigated boulders have been in the forest or under snow cover.

This means that two modern dating methods (OSL and ^{10}Be) recently used could not help to improve the existing Late-glacial stratigraphical chart of Estonia (Raukas and Kajak, 1995) and deglaciation chronology in the northern Baltic area. Up to now the main conclusion is that Estonia became ice-free at about 13,500–11,000 ^{14}C years BP. In the light of pollen analytical interpretations, the retreat of the ice margin from the Haanja zone (the oldest in Estonia) began in the Bølling, whereas Estonia was finally free of ice in the second half of the Allerød chron (Pirrus and Raukas, 1996).

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WEST SIBERIA: BARREMIAN PALYNOSTRATIGRAPHY

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Barremian sediments said to be the most complicated strata among the West Siberia Mesozoic formations (Resolution of the 5th Interdepartmental Regional Stratigraphy Meeting, Tumen, 1990). A combination of the heterogametic rocks cause detailed stratification of the various section types with interrelated transfers at the different levels. Among the Neocomian strata we have got only the Berriasian, Valanginian and Lower Hauterivian stages that were verified with fauna data for minute separation by substages and zones. The Upper Neocomian strata were described by spore and pollen, but still no detailed elaboration or only conventional subdivision was given. Though the Barremian–Aptian boundary that shows drastic change in vegetation is clear and unique in all places.

Significant facial variety determine considerable amount of the section types with the formation as the basic unit. Some palynologists who have studied the Hauterivian–Barremian strata noted that Barremian sediments could be determined by the method; however facial variety of the rocks specified various complexes of the spore and pollen. Also this complicated the issue. Therefore, single foraminifera finds became more important and may reveal distinctive features of the spore and pollen complexes.

Drill hole Cheurskaya 12-p gives modest foraminifera complex with most typical *Ammoscalaria difficilis* Kuz., *Miliammina* sp., *Gaudryina* sp., *G. neocomiana* Tairov. Reffering to the General Startigraphy Scheme (1967), *Ammoscalaria difficilis* Kuz consider to be typical of the Upper Hauterivian Age. In latest years other opinion about younger age of the species prevails among specialists: A.A. Bulynikiva and E.F. Trandafilova (1975) consider it typical of Barremian. As well as L.V. Alekseeva (oral presentation) consider *Gaudryina neocomiana* Tairov to be typical of the Barremian strata of Mangyshlack and West Turkmenistan.

Similar foraminifera complex was observed within Pokrovskaya area (drill hole 4-p, interval 1353–1384 and somewhat depleted in1420.1–1427.7). More data is given in the Fig. 1.

Together with microfauna the following palynocomplex was found in the drill hole Cheurskaya 12-p: important variation of *Gleichinia* (up to 30 %) including species *Gleicheniidites senonicus* Bolch., *Gl. echinata, Gl. rasilis* Bolch. *Schzsceae* gives 10–15 % with species *Klukisporites* sp., *Cicotricosisporites* sp., *C. perforata*, *Anemia* sp., *Pilosisporites* sp. Moreover it has a lot of *Sphagnumsporites* sp., single spores of *Staplinisporites.* Pollen part of the complex gives majority of *Pinaceae* and *Classopollis*. *Gnetaceapollenites*, *Taxodiaceae*, *Cupressaceae*, and *Cedrus* sp. are also presented.

The similar complex is known from Barremian sediments of the Berezovskaya area (Northwest of West Siberia) and Yamal area (North of West Siberia) (Rovnina, Glushko, 1976). Also complex named above is well correlated with the Barremian complexes of the Russian Platform, Caucasus and other regions where they are surely dated by fauna. All together this gives grounds to consider Cheursky and similar complexes to be Barremian.

In Poikinskaya 51-p we have lagenides complex with *Astacolus antis* Mjatluk. Originally the species was described from the Barremian strata of the North Emba region. The similar complex was found in Uvat 1-op (2176–2159). Again spore and pollen composition is similar to that obtained from Cheurskaya 12-p.

Upper Substrata of the Vartovskaya Starta (Shorotnoye Preob Area) characterized by palynocomplex with major composition and variation of *Schzsceae.* In the drill hole Ust-Balykskaya 80 (1960–1890) such a spore and pollen complex was supported by finds of microfauna – *Miliammina* sp. The latter is typical of the Barremian Strata. I would like to note that the Shorotnoye Preob Area gives the richer and more diversified spore complexes especially *Schzsceae* (Rovnina, 1976). Probably this is due to the facial peculiar properties.

Hence Hauterivian–Barremian (Barremian in my interpretation) has palynocomplex with *Schizaeaceae* fern spores majority (Z.A. Voitsel, E.A. Ivanova, S.A. Klimenko, 1971). It increases up to 70 % in the South and has 40 % in the Northern (Shorotnoye Preob) Area. The species are presented as follows: *Lygodium, Anemia* and *Pellitieria* (*Lygodium horridum* Sach. *et* E. Jv., *L. mirabilis* Bolch., *L. hirsutum* E. Jv., and others. As well as *Anemia tricostata* Bolch., *A. pseudomacrorhyza* Mark., *A. chetensis* K.-M., *A. caucasica* Bolch.). The complex has less *Classopolis* pollens: only 5 % in the northwest complexes and increased amount in the south complexes – 30 % and more. Therefore my colleagues and I can talk about lateral variation of the Barremian complexes of spore and pollen in West Siberia (Yu.F. Shirokova, N.S. Bochkareva, 1971; L.V. Rovnina, T.S. Bezrkova, Z.I. Yushinskaya, 1973).

Complexes:						
With lagenides (N.A .Belousova, M.K. Rodionova)	Upper Ghoterivian-(?): with *Haplophragmoides* sp., *Trochammina* sp. with Lagenides (E.D. Bogomyakova, G.E. Rylkova and others)	With *Miliammina* sp. (N.F. Dubrovskaya, M.K. Rodionova)	With *Mliammina problemutica* Agalarova (T.N. Gorbachik)	With *Ammoscaldria difficilis K.*, *Miliammina* sp., *M. rasilis* B., *Gaudryina* sp,, *G.neocomiana bulloides* T. and others (Z.I. Bulatova, N.A. Belousova, E.D. Bogomyakova, M.K. Rodionova)	With *Throkhamines* and *milliamines* (Z.I. Bulatova)	With *Sarospnaera* (?) sp. (M.K. Rodionova)
Find points: drill hole # (interval, m)						
Пойкинская 51-р (2111,5-2100,8); Уватская 1-оп (2176-2157)	Salymskaya 2-p (2220,9-2198,3); Salymskaya 8-p (2216,5-221,5); Salymskaya 3-p (2254,9-2245,0); Poikinskaya 52-p (2151,1-2135,8); Poikinskaya 53-p (2217,6-2147,8)	Ust-Balykskaya 80-p (1895,4-1891,5); Ust-Balykskaya 80-p (1906-1902)	Ingi-Soinmskaya 15-p (1283-1276)	Cheurskaya 12-p (984-978); Pokrovskaya 4-p (1384,6-1350); Pokrovskaya 3-p (1380,5-1352)	Zarechnaya 3-пр (941-938)	Poikinskaya 51-p (2027-2068); Vyginskaya 7-p (1959,5-1956,0) Vyeginskaya 7-p (1988,5-1987) Samburgskaya 152-p (2505-2495)

Fig. 1. Barremian Foraminifera from some West Siberia sections

Ust-Balykskaya 80 (T.S. Bezrkova, S.I. Purtova, 1968) along with *Miliammina* foraminifera has palynocomplex with *Lygodium* spore majority in the bottom part and *Pelletieria* and *Anemia* – in the upper part. Here Barremian interval 1906–1936 shows taxa changing (see Tab. 2).

Table 2. Barremian spore and pollen

Spore and pollen (%)	Depth interval (m)				
	1931-1936	1921-1917	1917-1913	1913-1910	1910-1906
Aequitriradites sp.sp	—	2.6	1.4	22.5	0.9
Schizaeaceae (*Cycatricosisporites* sp., *Pellitieria* sp., *Anemia* sp.)	4.8	48.7	67.8	19.2	28.4
Lygodium sp., *Pilosisporites* sp.	61.6	12.8	8.5	9.5	4.2
Classopolis sp.	—	—	0.9	0.4	0.9

By the example of the "A" beds within the Surgut and Nizhnevatrovsk arches I have developed choose and stratification principal for narrow startigraphy intervals using palynology data. "Flash" increase of the *Aequitriradites* spores usually presented in one or in two-three samples at the certain level. Increased amount of *Aequitriradites* spores that referred to *Marchantiopsida* means, to some extend, waterlogged environment during the Barremian time because most spices of the modern *Marchantiopsida* are growing in a wet and overflow environments making up single brushwood. "*Aequitriradites*" palyno-ecozone is known from upper part of the Vartovskaya subsuit (so-called greenstone bed) and could be well correlated in central part of West Siberia. In the absence of this stratum we can talk about the erosion in-between "A_2" and "A_6" layers within the Nizhnevatrovsk arch.

Another example is a sharp increase of *Gleicheniidites* spores at the bottom of the Pimskaya patch (3–5 m layer) that can be referred to transgression cycle and climate warming. The facts proved by microfauna (*Lenticulina*) as well as lithology (increase of $CaCO_3$ and boron deposition). Therefore "*Gleicheniidites*" palyno-ecozone marks out the Pimskaya patch.

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CORRELATIONS OF TILLS FROM SEVERAL BOREHOLES IN NE POLAND

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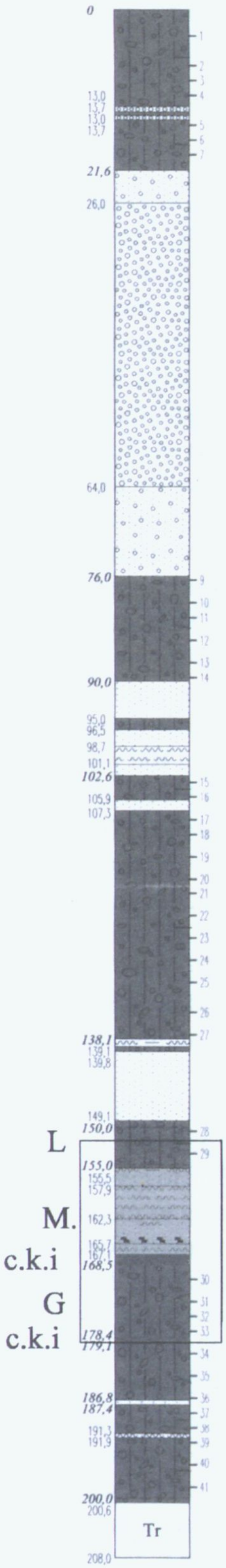
The boreholes studied are located at the Ełk Lakeland and Szeskie Hills in north-eastern Poland. Thickness of the Quaternary sediments in these boreholes is about 200 m. Pleistocene sediments are corresponds to 6 glaciations. Lithological and petrographical composition of gravel was studied and the statistic and pollen analyses were performed during the detailed geological mapping of Poland (1:50000), (Gronkowska-Krystek 2002, 2004, Honczaruk 1998,



2000, Rychel 2003). The so-called '*red clay complex*' (**c.k.i**) accumulated during the Wilgian glaciation (Lisicki and Winter, 2004) is one of the most interesting and important sedimentary successions in the Quaternary of Poland (Fig.1). It is represented by 5–10 m thick till overlain and underlain by layers of red clays. Till contain numerous blocks of Devonian dolomites, Palaeozoic limestones and local components (in average about 20%). Clays were accumulated during advance and retreat phases of Wilgian glaciation (**G**). The range of '*red clay complex*' is the same as range of Wilgian glaciation (Kenig 1998). Red colour of clays (and also till in some boreholes) is descended from intensively crushed red Devonian siltstones. The ice sheet during the glaciation moved more easterly, from East Scandinavia via Baltic Sea depression. The described complex was found in the same stratigraphic level in a lot of boreholes located in the north-eastern Poland. In the most of boreholes '*red clay complex*' is covered by sandy-silty sediments with peat and another younger till above them that is commonly correlated with Mazovian Interglacial (**M**) and Livecian (**L**) glaciation (Pochocka-Szwarc and Winter, 2001).

General characters of '*red clay complex*' very closely resemble red tills in North Germany, but they occur in three different stratigraphic levels: uppermost unit of the Elsterian, Older Saalian, Younger Saalian (Ehlers 1992). So, could we assign the '*red clay complex*' in NE Poland to a certain stratigraphic level in spite of it occurrence in one litostratigraphical position (uppermost unit of the Elsterian) – below sediments assigned to the Mazovian Interglacial?

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TREE ARRIVAL AND SPREAD IN ESTONIA AND ADJOINING AREAS

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Estonia belongs to the boreal-nemoral forest zone. Forests cover 47 % of its total land area. The most common tree species are *Pinus sylvestris* (41 %), *Betula pendula* and *Betula pubescens* (28 %), *Picea abies* (23 %), *Alnus incana* (4 %), *Populus tremula* (2 %) and broad-leaved trees (1 %). Numerous biostratigraphic studies have shown that during the Holocene forest composition has considerably changed. Several tree species arrived, culminated and for the present lost their importance in the forest composition. The purpose of the present study is to provide insight into the arrival and expansion pattern of tree taxa into Estonia, to follow their immigration routes and visualise this pattern with isochrone maps. The role and position of Estonia on the dispersal route of the boreal and nemoral tree species is important as several broad-leaved trees meet here their northern range limit. The timing and pathways of *Picea*, *Alnus*, *Corylus*, *Ulmus*, *Tilia*, and *Quercus* dispersal into Estonia and the surrounding areas were summarised on the basis of 49 radiocarbon dated pollen diagrams from Estonia and 54 diagrams from adjoining areas. Kriging point approach provided by Surfer software was applied to visualise the arrival and expansion of the mentioned tree species.

Picea appeared in south-eastern pollen spectra of Estonia at the end of the Late Glacial and surpassed 10 % in several pollen profiles. As *Picea* pollen is underrepresented in pollen rain, the above-mentioned frequency of pollen confirms the possibility of *Picea* survival in south-eastern Estonia at the end of the Late Glacial. A new arrival of *Picea* occurred ca 8500–8000 BP. Radiocarbon dates from the macro-remains evidence of the presence of local small *Picea* stands 1000 years before the *Picea* forest front reached the area, being in some places delayed due to unfavourable ecological and soil conditions. The piece of *Picea* wood dated to 8490±85 (TA-98) proved to be ca 1700 years older from the sediments comprising *Picea* pollen. The discovery of *Picea* macro-remains and pollen in Swedish Scandes shows the same pattern and presence of *Picea* already between 9000–5000 BP (Segeström and Stedingk, 2003). Still, the isochrone map displays the well-defined Picea forest front invasion from the south-east towards north-west and west and arrival in the south-western coastal areas of Sweden at about 2000 BP (Fig. 1). *Picea* invaded into Estonia slowly and by 7000–6500 BP its forest front had reached central Estonia, between 5000–5600 BP the Island of Saaremaa and several hundred years later the Island of Hiiumaa. The slow expansion of *Picea* in Estonia (about 100 m yr^{-1}) was due to rather warm climate and its inability to compete in the dense forest canopy formed by broad-leaved trees. The reconstructed isochrone map of *Picea* arrival shows its time-transgressive spread and immigration from the south-eastern and eastern areas, from the Russian refugia.

Alnus appeared in the pollen spectra at about 9000 BP, but macrofossil remains refer to its arrival *ca* 700 years earlier. *Alnus* first invaded the western and northern parts of the studied area and since 7000 BP onwards its groves were frequent all over the country, being more abundant around 6500 BP when it expanded further north to Fennoscandia than today. The maximum occurrence of *Alnus* is dispersed between 8300–3400 BP. It is interesting to mention that also in Finland *Alnus* was abundantly present first in northern areas (Birks, Saarnisto, 1975). The macrofossil finds from the Scands Mountains evidence that *Alnus* occupied spatially limited habitats considerably earlier than it was suggested on the pollen spectra only (Kullman, 1998). Isochrone map displays a patchy character of *Alnus* distribution in Estonia and adjoining areas caused by edaphic demands (nutrient-rich wet soils) and relatively mild climate (Bennett, Birks, 1990). Besides climate, local topography, hydrology, and factors influencing seedling establishment also determined the distribution of *Alnus*. The second reason could be the overgrowth of the coastal shallow lakes, providing suitable habitats for *Alnus* to colonise. *Alnus* penetrated into Estonia from the east, from the north Russian refugia.

Corylus immigrated into Estonia almost simultaneously with *Alnus*. In southern Sweden *Corylus* was established between 9700–9300 BP, in Estonia about 500–1000 years later (Fig. 1). First it colonised western and north-western areas and by 8000 BP it had spread also in eastern Estonia. *Corylus* maximum occurrence is very diffuse, intermittent between 8500 and 3100 BP. It migrated into Estonia from the south-west and west, partly due to nuts, carried by currents over the Baltic Sea. In present-day forest *Corylus* has maintained its position as an understorey bush mostly on western Estonian mainland and archipelago.

The early Holocene is characterised by the successive arrival of broad-leaved trees in Estonia. Comparison of the dispersal of *Ulmus*, *Tilia* and *Quercus* manifests their different pathways, response to climate, edaphic conditions and competition. By 6000 BP *Ulmus*, *Tilia* and *Quercus* had reached their present-day range limit or were near to it.

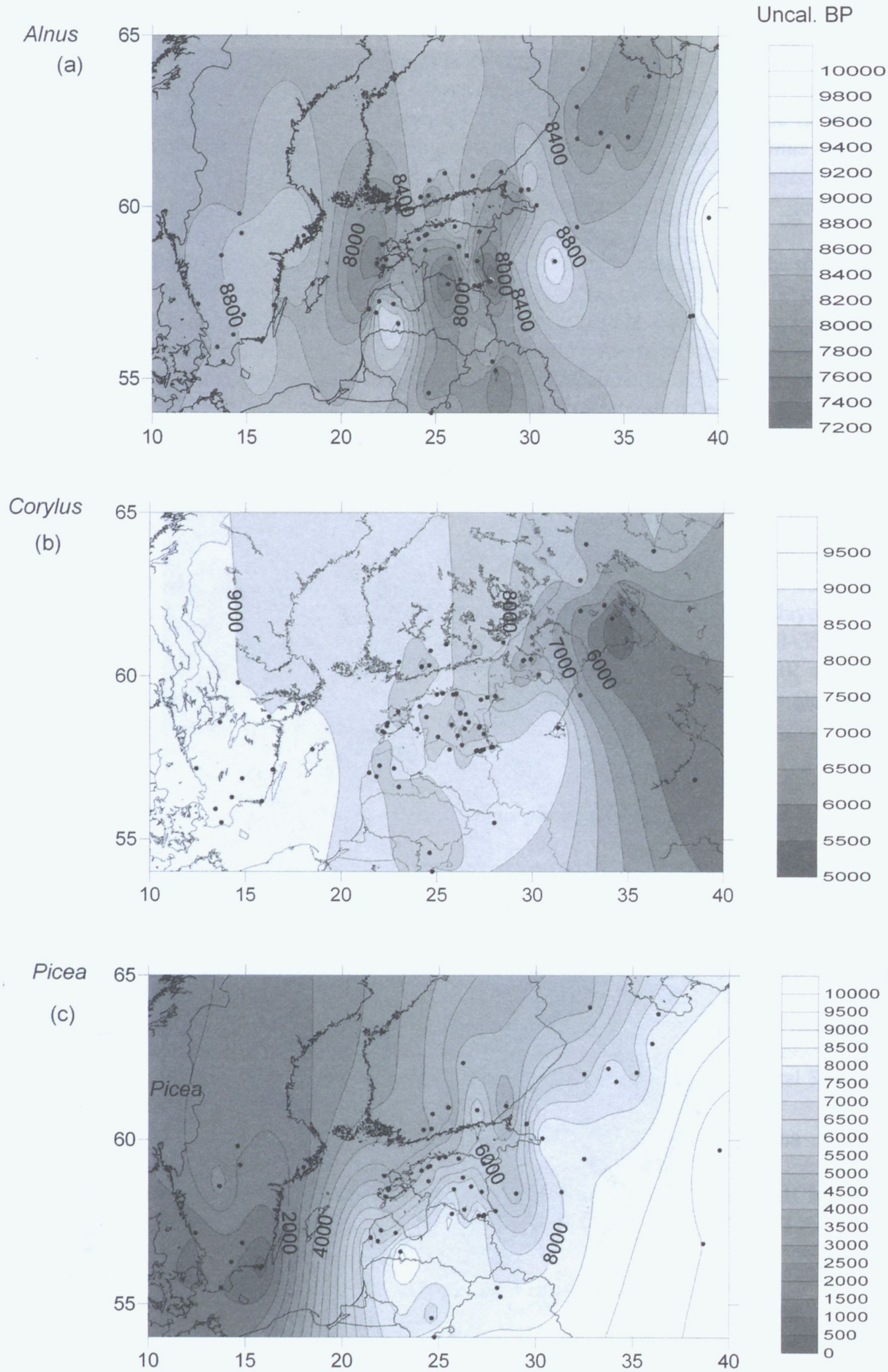

Fig. 1. Isochrone maps of *Picea*, *Corylus* and *Alnus* arrival in Estonia and the area around the Gulf of Finland

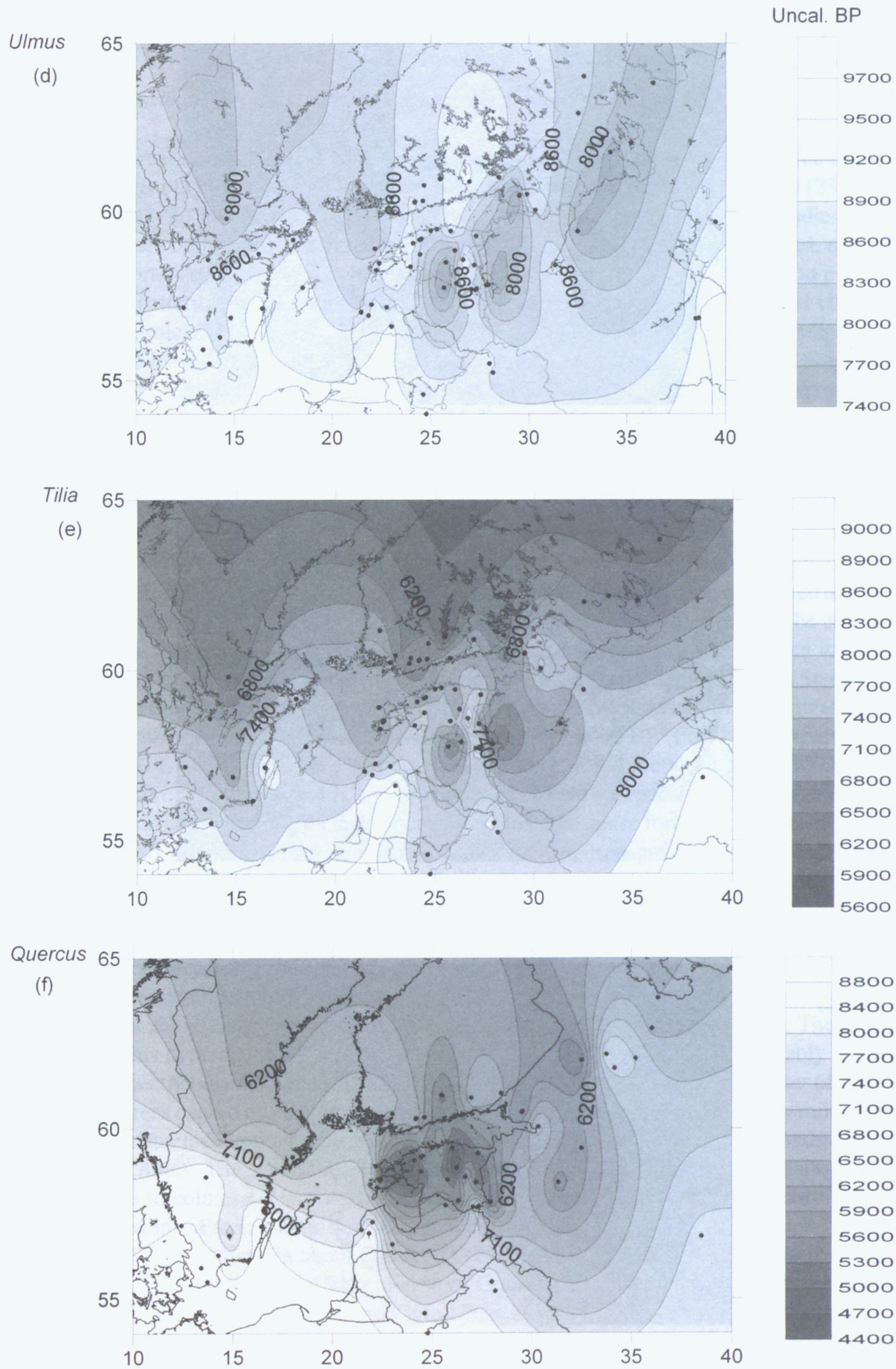

Fig. 1. Isochrone maps of *Ulmus*, *Tilia* and *Quercus* arrival in Estonia and the area around the Gulf of Finland

Ulmus became locally established between 9300–8700 BP almost simultaneously in scattered sites of Estonia, occupying some single spots of southern Finland as well. The arrival and spread of *Ulmus* into Estonia was rapid. It quickly occupied western areas, later central and eastern ones (Fig. 2). *Ulmus* prevailed in the forest as a dominant broad-leaved tree up to 7000 BP. The gradual retreat of *Ulmus* started at about 6000–4500 BP, which was asynchronous in Estonia, caused by the coincidence of different reasons. At several sites *Ulmus* decline is followed by a new recovery and new declines, obviously caused by human interference. The sparse increase in *Ulmus* pollen representation *ca* 2000–1000 could be the result of increased pollen dispersal in more open landscape. *Ulmus* immigrated from the south (Fig. 2). The migration rate of *Ulmus* in Estonia was generally between 100–200 m yr^{-1} that is comparable with its average in Europe (Huntley, Birks, 1983).

Tilia. At about 8500 BP *Tilia* colonised small spots in the south-east. In the western sites the spread and culmination of *Tilia* delayed for about 500–1000 years what makes the approximate migration rate of 160 m yr^{-1} in Estonia. The highest extent of *Tilia* pollen is recorded between 6000–4400 BP, when *Tilia* became the most abundant broad-leaved species. The maximum distribution of *Tilia* pollen resembles expansion pattern, culminating first in the same region, where it had appeared first. This does not exclude that *Tilia* could have occupied single suitable habitats at its northern range limit significantly earlier (Kullman, 1998). Afterwards it started to retreat. At several sites the decline of *Tilia* was coherent with that of *Ulmus,* at others it was registered several hundred years later. A noticeable reduction in *Tilia* pollen occurred after 4500 BP and by 1000 BP it had disappeared from most of the examined pollen diagrams. *Tilia* arrived to Estonia from south, from the European Russia refugia. Even today *Tilia* extends father east in Russia than most of the broad-leaved species.

Quercus was the next tree to arrive Estonia at about 7400–7000 BP from south-west. Apparently single *Quercus* trees were present earlier, because already at 8000 BP *Quercus* pollen forms a continuous curve in several sites. *Quercus* expanded slowly and unevenly. The spread of *Quercus* was rather irregular being delayed in several regions. Between 5000–3000 BP *Quercus* met its maximum occurrence with a peak between 4100–3500 BP as the other broad-leaved trees declined. The culmination phase of *Quercus* came to an end at about 3000 BP, when *Picea* occupied its main habitats. Unlike *Ulmus* and *Tilia*, modern surface pollen data show the presence of *Quercus* pollen in low values in almost all studied sites.

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SOME ADDITIONS AND REMARKS TO DISCUSSION ABOUT THE RAUNIS INTERSTADIAL SEDIMENTS OF THE RAUNIS RIVER SITE

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Periglacial flora (Danilāns, 1961; Savvaitov and Straume, 1963; Stelle, 1968) and ^{14}C-datings (Punning, Liiva, Ilves, 1968; Veksler and Stelle, 1973; Vinogradov *et al.*, 1963; Gerasimov and Chebotareva, 1963) of the Raunis sediments

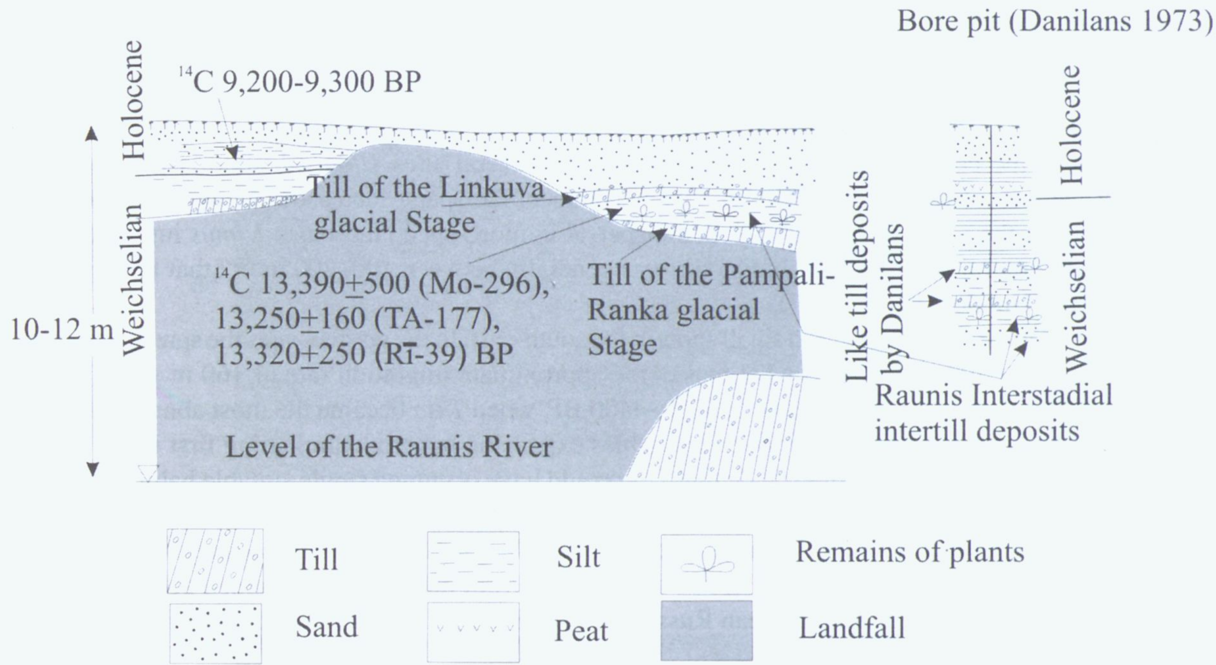

Fig.1. Layering of the Raunis interstadial sediments at the Raunis River key site

are very important for reconstruction of the Late Weichselian. Raunis interstadial was recognized in the Eastern Europe (Chebotareva *et al.*, 1965, Chebotareva and Malygina, 1965) and used for correlation of glacial events between continents (Dreimanis, 1966; Dreimanis, 1967; Dreimanis, 1970; Dreimanis, 1970a; Dreimanis, 1977). In N. America Cary-Port Huron interstadial took place between the Cary retreat and the Port Huron readvance (Dreimanis, 1970a). In Latvia at the same time the Pampāļi-Ranka glacial stage was interrupted by the Raunis interstadial and the Linkuva readvance took place after all (Jakubovska *et al.*, 1999; Savvaitovs, Veinbergs, 1996).

The interstadial sediments at the Raunis site are represented by thin lens of sandy silts with numerous plant remains (Fig.1). The location of site in proximal side of the Veselava End moraine and bedding interstadial sediments under the upper till allows as to date the maximum extent of the Linkuva glacial Stage and as well as to correspond the origin of the upper till with this stage (Āboltiņš *et al.*, 1972). Raunis interval in Latvia exposed in the Līdumnieki site also. The clays and silts of this interstadial lying between the Pampāļi-Ranka and Linkuva till beds are also widespread in the Zemgale (Āboltiņš, 1963). At present the Raunis interval of the Late Quaternary is recognised in other places of the Eastern Baltic. It is the Kammeri interstadial deposits in Estonia (Liivrand *et al.*, 1999). The ^{14}C date obtained from the gyttja at the Mančiagire outcrop in the Ūla River (Lithuania) is 13,430±140 BP (Blažauskas *et al.*, 1998). The pollen spectra as well as the composition of plant macro remains at Raunis had been discussed before (Cerina, 1995; Ceriņa *et al.*, 1998; Ceriņa and Kalniņa, 2000; Stelle *et al.*, 1999; Savvaitov and Straume, 1963). The finds of interstadial sediments at Raunis have evoked some problems that were discussed. The controversy in questions connected with the origin of upper till was mentioned by Danilāns (Ceriņa *et al.*, 1998; Danilāns, 1961; Danilāns, 1973). He considered this till is like till diamicton. However taking into account the lithology and wide distribution of the upper till at the neighbouring outcrops (Savvaitov and Straume, 1963) as well as orientations of debris in the till, it is became evidently, that it has a glacial origin. The second controversy reflects the opinion that the Raunis sediments are much older than thought and their structural position layering is not «in situ» (Dreimanis and Zelčs, 1995; Dreimanis *et al.*, 1994). According to this point of view the very compact peat up to 55 cm thick might be considered as raft of some older sediments. However peat and underlying silt have clearly the Pre-Boreal age (Ceriņa, 1995; Ceriņa and Kalniņa, 2000; Jakubovska *et al.*, 1999); in addition the ^{14}C dates showed absolute age of peat as 9,200–9,300 years BP (Raukas, 1999). The upper till in the region of Raunis is not deformed. The orientations of debris there are from 350° NW–170° SE to 10° NE–190° SW. The investigations of sediments overlying the upper till at the Raunis site (Dreimanis *et al.*, 1994) are important for reconstruction of the post-Raunis time. Pollen diagram between Pre-Boreal sediments and upper till (Danilāns, 1973) reflect cycles of the vegetation connected with glacial readvances (Plieņi, *etc*) after the Linkuva Stage.

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THE DEVELOPMENT OF THE ICE-SHEET DURING WEICHSELIAN GLACIATION IN LATVIA

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The fluctuations of the ice edge during the last glaciation have been studied early (Vītiņš, 1929; Zāns, 1937). Studies of Pērkons (Pērkons, 1957) led to the recognition of tills (Daugava, Kaibala II, I) that were correlated with the Upper Pleistocene. Weichselian ice characters (till beds, intertill sediments, marginal moraine) were recognised later (Āboltiņš, 1970; Āboltiņš, 1963; Āboltiņš *et al.*, 1972; Dreimanis and Zelčs, 1995; Meirons, 1992; Meirons, 1986; Savvaitov *et al.*, 1964; Savvaitov and Straume, 1963). The development of the ice-sheet is shown in Fig. 1. For correlation with Estonia we used the following data: Liivrand (1991, 1999), Liivrand *et al.* (1999), Pirrus and Raukas (1996).

The Early Weichselian sediments overlying the Eemian are recognizable in many sites and different from the Eemian in biostratigraphy (Ceriņa, 1984; Kalniņa, 1997; Meirons, 1992; Meirons, 1986). During the same time the ice sheet occurred in Scandinavia (Lundqvist, 1992). The occurrence the Early Weichselian marine shells (Dreimanis *et al.*, 1998) in the Ličupe and Daugmale allowed to determine the age of the Portlandia Sea (Zāns and Dreimanis, 1936). The narrow bay of this Sea probably have been entered to central Latvia through ancient valleys (Konshin *et al.*, 1969). The Weichselian ice-sheet recovered the territory of Latvia twice in the Middle Weichselian – the Baltic and Pre-Lejasciems stadials and at least once in Late Weichselian – Major glacial advance (term of Danilāns (Danilāns, 1973). The periods of stadials were interspaced by interstadials – Židiniupīte and Lejasciems, when the ice mass has retreated to back. The age of the Baltic Stadial till (Augšzeme Till (Meirons, 1986) is determined by Tl-dating at Rogaļi and probably Robeznieki. The till of the Židini has possible the same age (early identified as Saalian (Danilāns *et al.*, 1964). Overlying intertill glaciolacustrine deposits (Meirons *et al.*, 1981) indicate the beginning of the Židiniupīte retreat of the ice edge in Estonia. These sediments seem to be the oldest and after them came those at Valguta in Estonia. Pre-Lejasciems readvance have removed the ice margin from Estonia to Latvia. The low till at the Lejasciems (Savvaitov *et al.*, 1964) was formed by the Pre-Lejsciems readvance. Lejasciems Interstadial is ranged in age from 32,000 to 36,000 years ago (Arslanov *et al.*, 1975; Meirons, 1992). The Middle Weichselian ice cover haven't been distributed further far to south and did not reach the southeast Lithuania (Gaigalas and Melešite, 1999).

The curve of the Major advance reflects the series of fluctuations of the ice margin (Savvaitovs and Veinbergs, 1996; Stelle and Savvaitov, 2002). The disappearance of this advance is shown in Fig. 2. The Weichselian glacial curve is correlated with palaeotemperature curve that was obtained in Greenland (Dreimanis and Karrow, 1972).

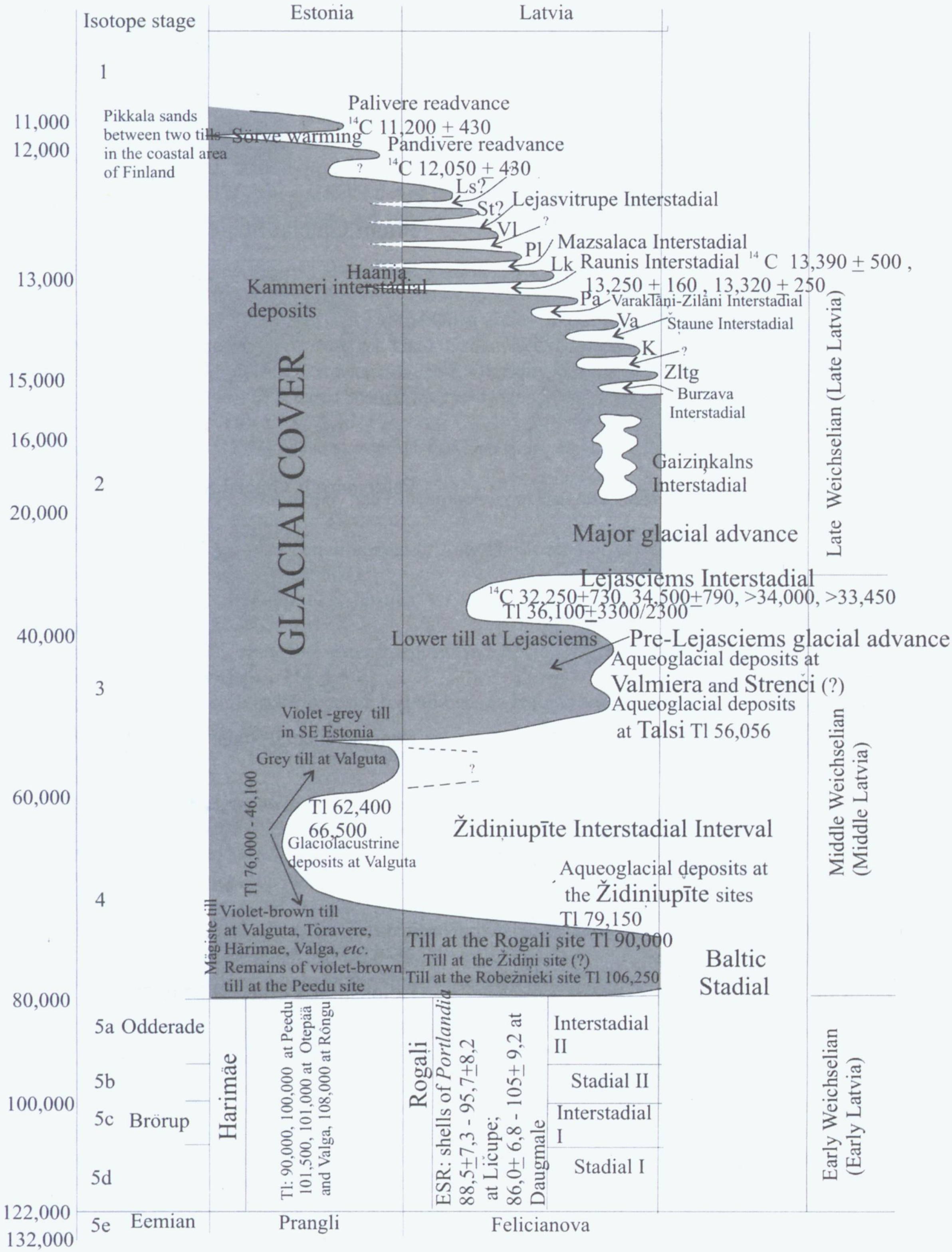

Fig.1. The Weichselian Glaciation curve in Latvia. (Zltg – Ziemeļlatgale glacial Stage, K – Kaldabruņa Stage, Va – Vaiņode-Gulbene Stages, Pa – Pampāļi-Ranka Stage, Lk – Linkuva Stage, Pl – Plieņi Stage, Vl – Valdemārpils Stage, St – Staicele Stage, Ls – Lejassalaca Stage)

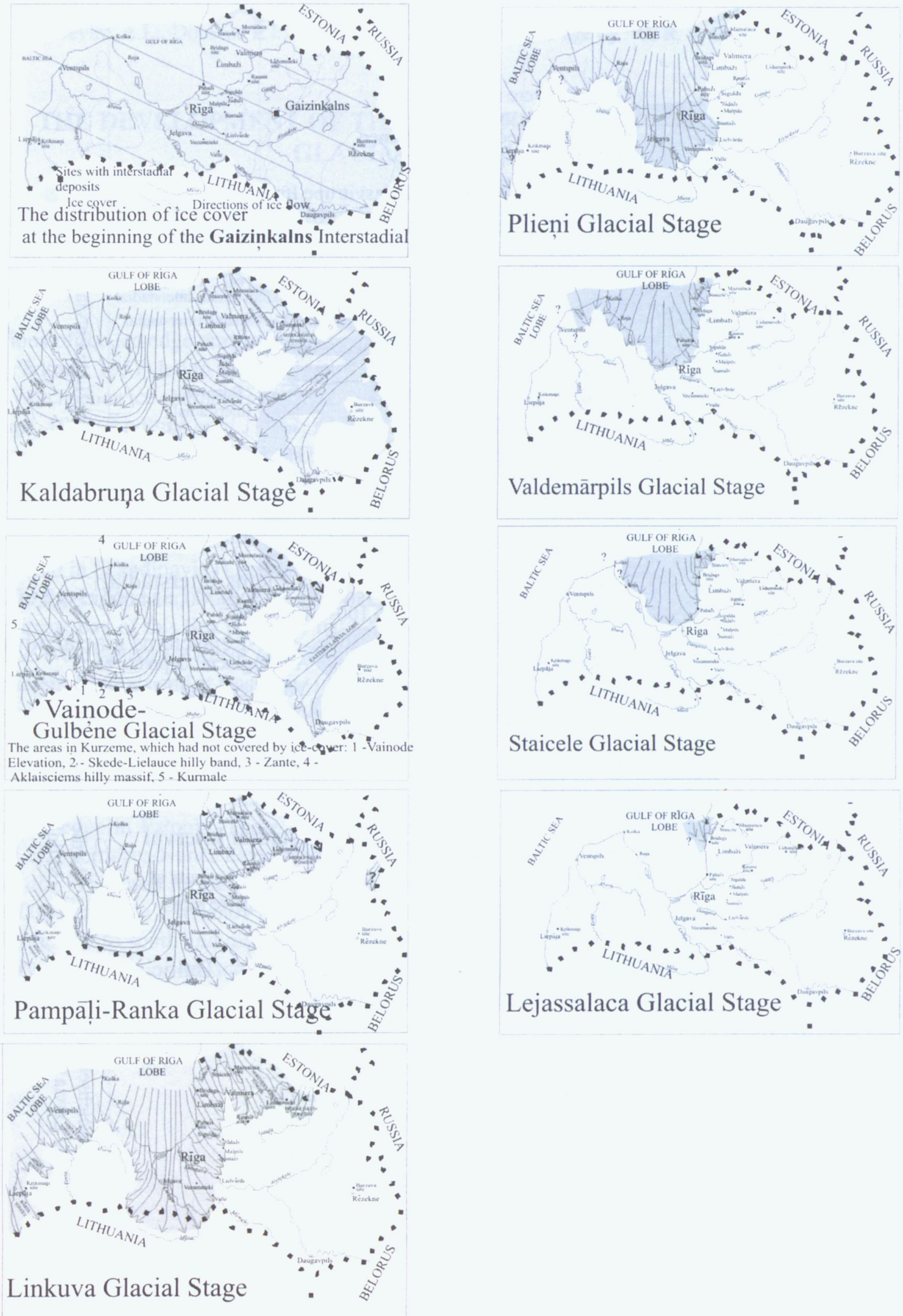

Fig. 2. The distribution of the ice cover during different glacial stages of Late Weichselian in Latvia

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BALTICA AND NORTHERN INDIA: FAUNAL RELATIONS WITHIN PALEOTETHYS DURING THE LATE ORDOVICIAN

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During the Late Ordovician several provinces are discriminated according to the distribution of each systematic group. In case of conodonts: (1) North American Midcontinent Province and (2) North Atlantic Province. As for bryozoan: (1) North American–Siberian Province and (2) Baltic–Mediterranean Province. The idea that Baltica in the north-western part of the Paleotethys ocean could have been a centre of major faunal radiation during Ordovician times arises from the distribution pattern of marine organisms (Bergström, 1973; Spjeldnaes, 1981; Tuckey, 1990; Webby, 1992; Gorjunova, 1996). The relation of Baltica, especially with respect to northern India, is indicated by the distinctive faunal elements of the Upper Ordovician Pin Formation of Spiti, Himachal Pradesh, northern India.

The northern Gondwana Pin Formation is a 280 m sequence, the lower part (90–220 m) having been dated as Upper Ordovician (*A. ordovicicus* Zone), the upper part (220–280 m) as Lower Silurian. Most of the fossils have come from shallow marine carbonates in the lower part of the formation. This contribution will set out the biogeographic affinities of the principal groups – conodonts, bryozoans, ostracodes and brachiopods – compared especially with coeval faunas from Baltica.

Elements of *Amorphognathus ordovicicus*, *Belodella* sp., *Belodina confluens*, *Drepanoistodus suberecta*, *Icriodella superba*, *Ozarkodina* sp., *Panderodus* sp., *Plectodina* sp. and *Pseudobelodina dispansa* were obtained. This assemblage (except for *B. confluens*, occurring from 190–220 m associated with *Am. ordovicicus*) is indicative of a widespread cold-water fauna (Sweet and Bergström 1984) within the Paleotethys.

Bryozoa from the Upper Ordovician part of the Pin Formation include taxa from all the main stenolaemate orders. Most abundant and diverse are bifoliate cryptostomes (*Oanduellina*, *Insignia*, *Phaenopora*, and *Cladodictya*). Trepostome bryozoans are represented by a few species of *Eridotrypa*, *Cyphotrypa* and *Prasopora*. Two phylloporinids (*Enallopora* and ?*Pesnastylus*), one cosmopolitan Upper Ordovician cyclostome (*Kukersella borealis*), cystoporids, represented by the genera *Lichenalia* and *Ceramopora*, and a few species of rhabdomesid bryozoans also occur in the Late Ordovician part of the Pin Formation.

Closer investigation of the radiation of Ordovician bryozoans accords with a connection between the faunas of Baltica (Bassler, 1911) and northern India faunas. The cosmopolitan *Kukersella borealis*, which appeared in the Middle Ordovician of the Baltic Province, is known from many locations in Baltic region and North America. It had disappeared finally by the end of Ordovician (Buttler, 1991). The earliest occurrence of *Lichenalia concentrica* is in the Ashgill of Estonia and South Wales, and *Eridotrypa suecica* was described from the uppermost Ordovician (Hirnantian) of Sweden. These and species *Enallopora ulrichi*, known from Llandeilo to Caradoc of Estonia and Belorus and *Stellatodictya plana*, first described from the Caradoc of Lithuania and NW Russia, but recently found in the Lower Ashgill of Vormsi Island, Estonia (unpublished data) accord with the Baltica–northern India connection.

Though the ostracodes of the Pin Formation are limited to 5 or 6 taxa (still under investigation), the presence of *Eurychilina* aff. *monticuloides*, *Krausella* cf. *shianensis* and *Glossomorphites* sp. indicate a similar Baltic connection. *Glossomorphites* is well known from the Lower and Middle Ordovician of Baltoscandia (Tinn *et al*., 2004) and Bohemia.

The brachiopods include many dalmanellids some orthids and strophomenids, a porambonitid, and one, perhaps two species of lingulids. Most of the brachiopod taxa occur elsewhere in Late Ordovician cold-water faunas of the Eurasiatic Province.

Though taxonomic work is still in progress, it is clear that for all groups there was a high level of identity with faunas previously described from Baltica and thus ease of communication between the Baltic region and northern India during the Late Ordovician – presumably along a middle to low latitude migration path indicated by palaeogeographic reconstructions (Fig. 1).

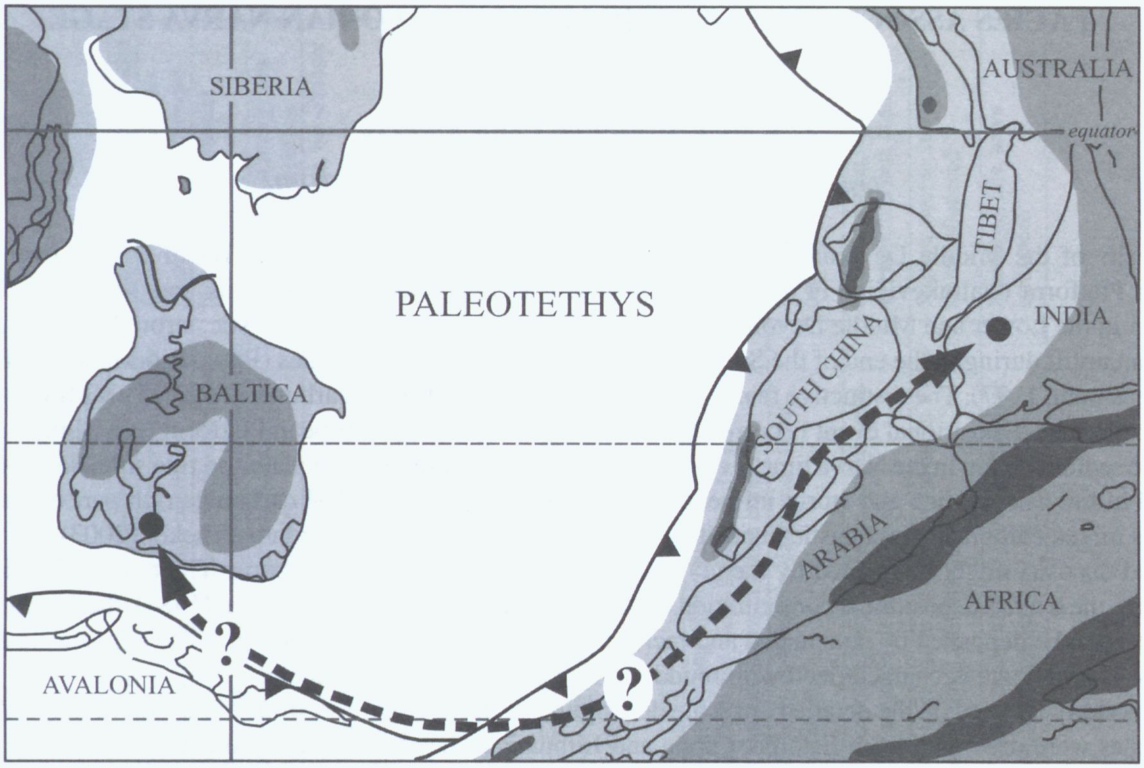

Fig. 1. Reconstruction of the Paleotethys Ocean (after Scotese, 2000) and the inferred principal migration path of Baltic faunas along the northern Gondwana shallow shelf to India

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FACIES ASSOCIATIONS OF THE MIDDLE DEVONIAN NARVA STAGE IN THE BALTIC BASIN

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The deposits of the Middle Devonian Narva Stage are widely distributed in Baltic Basin and all over the East-European Platform (Valiukevičius *et al.*, 1986; Kleesment *et al.*, 1987; Valiukevičius and Kruchek, 2000). The deposition in the Lower and Middle Devonian in the Baltic Basin was mostly siliciclastic, strongly influenced by the Caledonian uplift during in the end of the Silurian and beginning of Devonian times (Plink-Björklund and Björklund, 1999; Kleesment, 1997). The distinctive feature of sediments in Narva time is carbonate factor. This Middle Devonian Eifelian carbonate depositional event is correlated over large area of East European Platform (Nikishin *et al.*, 1996).

The sedimentation in the Narva time is characterized mostly by muddy carbonate and fine siliciclastic sediments, deposited in low energy, tide and storm influenced zones of the epeiric sea. The carbonate rich part of Narva Stage represents mixed carbonate-siliciclastic deposits. Following the facies classification by Tucker (2003), the carbonate rich mixed deposits might be formed by the (1) temporal and (2) spatial facies mixing. The temporal facies mixing characterize the overall depositional configuration of the Narva Stage. According to Mount (1984), the mixed sediments are supposed to be deposited by punctuated and facies mixing during the deposition time. The siliciclastic dominated part of the Narva Stage is characterized with muddy to fine grained mixed sediments.

This study is based on the detailed cm scale description of the drill-core sections of the Narva Stage. Altogether 10 boreholes were described from Estonia, Latvia and Lithuania. The studied part of the basin is divided into three zones: northern (Estonia), middle (Latvia and northern Lithuania) and southern (central Lithuania) part of the basin. This zonation of the basin is based on the main facies characteristics thought the Narva time. Based on the facies analysis of 10 logs, 12 facies associations were distinguished (Fig. 1). These facies associations are not strongly related to formal lithostratigraphic units (Formations, Members) of the Narva Stage and can be followed through the strata. Based on the lateral and vertical variation of facies associations the sedimentary environmental conditions and basin evolution during the Narva time was explained.

The deposition in Narva time started with shallow water storm influenced mixed carbonate sediments over entire basin. Locally, in the southern part of the basin, tidally influenced siliciclastic dominated deposition occurred.

In the middle part of the Narva Stage the depositional centre was in the middle and southern side of the basin, were thicker sedimentary packages formed. Possibly increased sedimentation rate, in that period, was caused by transgression and subsidence in the middle and southern part of the Baltic Basin. The basin configuration was clearly divided into three zones. In the northern and southern part of basin shallow marine mixed carbonate-siliciclastic and carbonate transitional peritidal environments occurred. In the middle part of the basin relatively deeper, mixed shallow and mixed deep subtidal deposits formed.

At the end of the Narva Stage the sedimentation in Baltic Basin changed from the mixed carbonate-silcicilastic, transitional peritidal and transitional subtidal to the muddy mixed siliciclastic-carbonate offshore mud, tidally influenced siliciclastic intertidal and tidal flat deposition. Finally, deltaic deposition from the northern part of the basin started.

Facies association	Description of facies association	Cyclicity, channeling	Lateral and stratigraphical position	Environmental interpretation
I Delta front/mouth bar	vf to f corss-laminated sand, silt	channel-form deposits	Northern part of the basin: Kernave Substage in Tartu and Mehikoorma boreholes	Distal and proximal delta front, fluvially influenced
II Siliciclastic nearshore	mud to al., mostly homogeneous,rarely bioturbated		Northern part of the basin: Vadja and Leivu Substage in Tartu and Mehikoorma boreholes	Nearshore environment
III Siliciclastic tidal flat	vf to f sand, mud-drapes, current, rare wave ripples, sandy interlayers	cyclic packages	In the upper part of Kernave Substage, in Valga and Kriukai boreholes	Nearshore, low energy tidal flat, channel incisions
IV Siliciclastic intratidal	vf. to f. sand, current, rare wave ripples, mud-drapes, herring-bone, lenticular, flaser, wave bedding, reactivation surface	channel form deposits and coarsening upwards packages	Over the entire basin, in the Kernave Substage. Almost in all boreholes, exept Ludza, Svedosai and Ledai	Shallow marine, bar-channel complex
V Offshore mud	mud to al., lack of structures, rare storm beds (sandy interlayers), bioturbated	channel-form deposits	Middle and southern part of the basin. Mostly marks the boundary between Leivu/Ledai and Kernave Substage	Shallow marine, low energy, storm influenced
VI Transitional subtidal	muddy, homogeneous, rare siliciclastic interbeds, rarely bioturbated	decrease of carbonate content to upward	Mostly in the southern part of the basin: upper part of Leivu/Ledai Substage	Shallow marine, low energy, storm influenced
VII Transitional peritidal	muddy, sandy current, wave ripples, mud-drapes, wavy, lenticular, horizontal bedding, tempestites, breccia, fenestriae, mud-cracks, oids, carbonate clasts and vugs	shallowing upward cycles (siliciclastic mud to carbonate mud; sandy rich mud to carbonate mud)	Northern and southern part of basin: upper part of Leivu and lower, middle part of Ledai Substage	Shallow marine, micro tidal with terrigeneous material influx
VIII Mixed peritidal	muddy, wavy, horizontal bedding, mud-drapes, tempestite, breccia, mud-cracks, oids, carbonate clasts and vugs	shallowing upwards cycles	Northern part of the basin. In Vadja Substage in Tartu and Valga boreholes. In Vadja and Leivu Substages In Ludza borehole	Shallow marine, low energy micro tidal (storm) wave influenced
IX Lagoonal	muddy, storm beds (sandy interlayers) rare bioturbation, , mud-cracks, ripples		In Leivu Substage in Valga and Ludza boreholes	Shallow marine, low energy, back barrier and open lagoon
X Mixed shallow subtidal	muddy, mostly homogeneous, lack of structure, tempestite (sandy interlayers)	shallowing upward cycles, channels	Over entire basin, in Vadja, Leivu/ Ledai Substages in all boreholes	Shallow marine, low energy, storm influenced, channels
XI Mixed deep subtidal	muddy, homogeneous, structureless, rare storm beds (sandy interlayers)	shallowing upward cycles	Northern and middle part of the basin: Vadja and Leivu/Ledai Substage	Shallow marine, low energy, storm influenced
XII Breccia	carbonate, muddy matrix, carbonate and clay clasts with size up to 7 cm		In the lower part of Vadja/Ledai Substage except Valga borehole	Nearshore, tide, wave influenced

Fig. 1. Facies associations of the Narva Stage in the Baltic Basin

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STRATIGRAPHY, AGE, CLIMATE AND FACIES OF THE DEVONIAN DIAMONDIFEROUS DEPOSITS FORMATION IN TIMAN

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Generally, Devonian in the Timan-Pechora province is represented by sedimentary rocks, however in some areas (especially in the Timan) the basalt covers and diabase dikes connected with the certain tectonic zones are widely developed as well. The majorities of sedimentary formations are terrigenous, but carbonate rocks become more abundant in the eastern and southeastern parts of the region.

The Middle Devonian age of the terrigenous deposits of the Pizhma Formation in the Middle Timan was established on miospores exclusively as they do not contain any other fossils. On the Pechora Pizhma River and in the Umba-Pizhma interstream area the miospora bearing deposits overlie the Maloruchey Formation with a stratigraphic unconformity or cover the rocks of the Upper Proterozoic basement with a sharp angular nonconformity.

The Pizhma Formation is represented by three rhythms with psephitic lower and clayey top parts. The top parts contain rare coal lenses. In the clayey layers (0.3 m in the lower and 0.15–0.1 m in the middle and top rhythms) a diverse and rich Mosolovo-Chernoyar palynocomplex has been found. Palynocomplexes with a dominance of fine and rare large forms occur in the monotypic grey sericite-kaolinite clays from all rhythms of productive series (Malkov and Telnova, 1991). Distribution of miospores in the Pizhma Formation productive deposits does not resemble those from the seawater basins. Apparently, the formation of palynocomplexes is a result of the periodic climate fluctuations. The palynological analysis of clays from the productive member allows us to assert, that producers of the described miospores grew in warm, damp climate of tropical zone. The palynocomplex is taxonomically diverse and contain more than 60 species of 17 genera. Sporoderms with thin, often filmy perispore with various sculptures are dominated.

One of the reliable indexes of climate is a composition of clay (Sinitsyn, 1967). In order to reconstruct the environment during the accumulation of the productive diamondiferous horizon formation we have carried out the complex processing of clay samples in the area of Ichetiu deposit (Telnova, Makeev, Gorbunov, 2002). All investigated samples contain similar maceration remains with miospores, rare coal particles and fragments of plants. The miospore assemblages were assigned to *Rhabdosporites langii* palynozone that characterize the Masolov-Chernoyar deposits of the Eifelian Stage of the Russian platform.

Mineral composition of clays was studied by methods of roentgenofluorescence, roentgenophases, thermal and microprobe analysis. It was estimated that structures of clays collected from different stratigraphic levels from the section of the Ichetyu depression differs significantly. The most ancient sediments from the Maloruchey Formation besides the main rock-forming clay minerals contain chlorite-chamosite and hydromica, the top part of the lower subformation of the Pizhma Formation contain kaolinite and hydromica, the Listvenitsa Formation of the Upper Devonian - chlorite and hydromica and the carbonate-clay section of the Tsilma Formation - montmorillonite, chlorite, hydromica. The clays of the Late Devonian deposits contain volcanogenic ash trap material.

The data on mineral composition of clays demonstrate that accumulation of Devonian deposits in the Ichetiu depressions took place in essentially various environments. The productive sediments of the Pizma Formation were deposited in the continental, relatively small and closed water reservoirs in reduced conditions. The taxonomic variety and good preservation of miospores demonstrate their fast burial and short transportation time. Probably, miospores were transported by wind and were buried in thin bedding clays in small stagnant lakes.

Our study is in agreement with the current conception that the Pizhma deposits have a continental genesis. S.V.Tihomirov (1948) was the first who pointed out the possibility of occurrence of large ancient river systems. A.M.Sklovskim (1980) described lithological types and facies of the Devonian deposits in the middle Timan in details.

The Middle Devonian was characterized by general rising of Timan structure. On the Middle Timan the peneplain surfaces of the epibaikalian basement of the Pizhma paleograben was gradually filled out by continental sediments – by products of laterite crust. However, some separate blocks of the basement remained exposed on the earth surface and were not covered by deposits of the Pizhma time. V.B.Kostyleva and L.M.Simanovich (1991) on the base of lithological characters have assumed, that vertical sequence of facies in cyclites of the Pizhma Formation is corresponds to various alluvial facies. The majority of sandstones are fluvial, the flood plain facies are rare or absent.

Our data suggest that the clastics in the Pechorskaya Pizjma River area were mainly povenanced from a thick weathering crust after pelitic and calcareous Riphean basement rocks. Unlike that area, in the Tsylemsky Kamen region some quartz debris was transported by a system of large rivers, which run from west and northwest.

In the Middle Devonian the territory of the Tsylma Kamen was a zone of meandering, probably, passing to the north through the alluvial-deltoid plain. It is possible, that deposits of the underwater part of delta are also occur, but it is difficult to distinguish them from the continental fluvial facies.

The accumulation of sedimentary successions took place in the tectonically unstable conditions. The area of sedimentation was enlarged during the process of formation of tectonic structure. The **immersing** of the various parts of the Middle Timan did not occurred simultaneously that is resulted in different stratigraphic completeness of deposits of the Middle Devonian on the relatively small territory of studied geological structure. The most full stratigraphic sequence of the Middle Devonian deposits is exposed in headwaters of the Tzilma River (Raskatova and Shishova., 1985).

The Devonian terrigenous deposits are diamondiferous along the Timan ridges from the Northern Timan Severotimanskiy horst to the Poludovo-Kolchim raisings. The most steady stratigraphic diamondiferous level is the Eifelian top (Volsko-Vymsk ridge and Jegimparma) and Emsian (Poludovo-Kolchim raising). The Frasnian terrigenous deposits of the Tsilma Kamen, Ochparma and Jegimparma localities are diamondiferous also (Tereshko, Kazantseva and Kirillin, 1991).

As the study of diamondiferous deposits are of interest it is important to study stratigraphical and facies analogues of the Middle Devonian diamondiferous deposits in the Middle Timan as well as in the northern and southern continuation of this geological structure.

The lower part of the Middle Devonian Assivogh Formation overlain unconformably the Riphean rocks and have different stratigraphic completeness. It composed of conglomerates, coarse and medium-grained quartz sandstones with layers of gritstones, siltstones, light and black colored clays on the upper part of the section.

Miospores are rare in the maceration rests obtained from the Middle Devonian sands. Siltstones and shales yield usually more spores and sometimes contain large fragments of plants with the preserved cellular structure. The obtained miospore assemblages correspond to the *Rhabdosporites langii* zone and taxonomically similar to the miospore assemblages from the productive deposits of the Pizhma Formation from the Middle Timan (Telnova, 1999).

The miospore assemblages from the Upper Eifelian deposits of the Middle and Southern Timan besides the identical taxonomic structure have a very similar structure of the maceration rest. It is, in turn, can testify similar environments of sedimentation. The basal layers of the Asyvvog Formation on the Southern Timan are characterized by the same continental facies as the productive deposits of the Pizhma Formation in the Middle Timan. In both cases the Upper Eifelian deposits with a stratigraphic break are overlain by the analogues of the Ardatov layers of the Givetian.

The Middle Devonian deposits of the Northern Timan are represented by the Travianka Formation. Its stratigraphic position is constructed exclusively on the base of micro- and macrofloristic rests found as in the Northern Timan as well as in the Middle and Southern Timan (Menner, Ljarskaja, Petrosjan *et al.* 1986). The structure and composition of the Middle Devonian and the Lower Frasnian deposits of the Northern Timan are very similar to those of the Middle Timan. The Travianka and Pizhma formations are represented by carbonate free and quartzose sandstones and kaolinite clays rich in macro- and microplant fossils. The sea fauna is absent.

All productive Upper Devonian deposits of Timan were formed in similar climatic terrestrial environment. Large stratigraphic gaps and patchy distribution of these deposits are connected with the unstable tectonic conditions of sedimentation in the Late Eifelian time in the area.

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UPPER ORDOVICIAN SEDIMENTARY RECORD IN THE NORTHERN HOLY CROSS MTS. (POLAND): RESPONSE TO SEA-LEVEL CHANGES

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The northern Holy Cross Mts. (Łysogóry unit – LU) is located in the south-eastern part of central Poland, and to the south contacts with the Małopolska Block (MB) along the Holy Cross Fault. The LU is considered to be part of the passive margin of the East European Craton (Baltica) (Dadlez *et al.*, 1994) or a Gondwana-derived terrain (Valverde-Vaquero *et al.*, 2000). On the contrary, Cocks (2002) claims that both the LU and MB were parts of Baltica throughout entire the Early Palaeozoic.

Bulk of the Caradoc sedimentary record in the LU is composed of dark-coloured mudstones of the Jeleniów Formation, reaching 120 m in thickness. This succession is divided into two horizons separated by a thin package of grey/green bioturbated mudstones (up to 2 m thick), which correspond to the boundary zone between the lower and middle Caradoc (Trela, 2003). The overlying Wólka Formation (up to 80 m thick) refers to the grey/green bioturbated mudstones corresponding to the lower and middle Ashgill, and grade upward into unnamed siltstones and marls of the upper Ashgill (up to 10 m thick) (Trela, 2003).

The dark-coloured mudstones refer to as massive (homogenous) dark grey to black mudstones and claystones with locally preserved millimeter-scale lamination. Thin beds or even laminae display mottled bioturbation with rare burrows represented by *Chondrites* specimens. A common component of these deposits is pyrite occurring predominantly as framboids and subordinate microscale aggregates.

The bioturbated mudstones are characterized by an abundant but low-diversity trace fossil assemblage dominated by *Chondrites* specimens. The distinctive burrows in this community are sparsely distributed straight but unlined and unbranched traces referable to *Taenidium* due to the meniscate backfill structure (see D'Alessandro and Bromley, 1987; Bromley *et al.*, 2000). The unrecognizable biogenic structures with irregular outward morphologies and sometimes diffused rather than sharp outlines may locally predominate the sedimentary record, and thus, the most significant textural feature of the facies is a marble- or swirl-like mixture of grey and black mudstones.

The available graptolite data indicate that occurrence of the dark-coloured mudstones in the LU was coeval with the rise of relative sea-level during the late Llanvirn and a rapid increase of basin subsidence (Trela, 2003). These mudstones are interpreted as an indicator of oxygen-depleted conditions (dysoxic rather than anoxic type) associated with the expansion of water stratification within the LU basin. However, the active role of seasonal/periodic brakedown of this stratification resulted in the frequent environmental fluctuation indicated by rare burrows (*Chondrites*) and mottling bioturbation. The relatively thin horizon of the grey/green bioturbated mudstones within this succession expresses a short-term increase of the benthic oxygen-level due to the weakening of water stratification, and colonization of substrate by soft-bodied infaunal organisms. Thus, this facies corresponds to a short-term drop of relative sea-level close to the early and middle Caradoc boundary and increased intensity of frequent storm mixing. The overlying dark-coloured mudstones record subsequent water stratification and related oxygen depletion during the late Caradoc, widespread along the present south-western margin of Baltica (Modliński, 1982; Trela, 2003).

The bioturbated mudstones of the Wólka Formation reflect a progressive contraction of the water stratification and persistent benthic oxygenation triggered by a major change in oceanic circulation. The rise of benthic oxygenation contributed to the extensive colonization of the highly enriched sediment by pioneering opportunistic inhabitants. The overlying unnamed siltstones and marls enhance the progradational character of the Ashgill succession in the LU coeval to the Late Ordovician glacio-eustatic sea-level drop (see Brenchley, 2004).

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NEW STRATIGRAPHIC, TECTONIC AND FACIES DATA FROM THE UPPER CAMBRIAN OF THE NORTHERN MALOPOLSKA BLOCK (POLAND)

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The Upper Cambrian clastic succession has been drilled in the Lenarczyce PIG-1 well located in the southern Holy Cross Mts. (Kielce region – KR), where deposits of this age hitherto have been unknown. The KR represents the northern segment of the Małopolska Block (MB) located within the Trans-European Suture Zone (Dadlez *et al.*, 1994; Cocks, 2002). Thus, new stratigraphic, tectonic and facies data from the Lenarczyce PIG-1 well may provide new insight into the evolution of this major tectonic zone of Europe.

The Upper Cambrian sedimentary record in the studied well is composed of conglomerates, sandstones, mudstones/shales and heterolithic deposits forming up to 90 m thick succession underlain by the Middle Cambrian mudstones with thin siltstone/fine sandstone interbeds (undrilled succession). The Cambrian deposits are overlain by the Upper Tremadocian glauconite-rich sandstones resting on a conglomerate bed (40 cm thick) interpreted as a transgressive lag deposit (Trela, 2004).

The palynological studies indicate that acritarchs from the lowermost part of the well are rare and badly preserved, and correspond to the lower part of the Middle Cambrian (see (Volkova, 1990). They include *Cristallinium cambriense* (Slavikova), *Eliasum* sp., *Celtiberium* sp., *Adara alea* Martin, and badly preserved *Skiagia, Comasphaeridium, Micrhystridium, Lophosphaeridium* and *Leiosphaeridia*.

The overlying deposits yield a completely different assemblage with specimens referable to *Diacriodae* and the "galeate" group including *Acanthodiacriodium, Dasydiacrodium, Polygonium, Solisphaeridium, Ladogiella, Calyxiella, Vulcanisphaera* and others. This assemblage is indicative for the middle and upper portion of the Upper Cambrian (Vanguestaine, 1974; Martin, 1981; Volkova, 1990). The numerous specimens represented by the *Dasydiacrodium caudatum* Vanguestaine, *Leiofusa stoumonensis* Vanguestaine, *Veryhachium dumontii* Vanguestaine and *Trunculumarium revinium* (Vanguestaine) clearly indicate that the lower portion of the Upper Cambrian succession (see Volkova, 1990) of the studied section corresponds to the *Leptoplastus* and *Protopeltura preacursor* zones. Scandinavian division. Most of these taxons disappear upwards in the succession where a significant morphological variability within the *Diacrioidae* forms is observed, however numerous specimens of *Polygonium* and *Solisphaeridium* occur as well. In the northern Holy Cross Mts. (Łysogóry region) such a taxonomic assemblage is distinctive for the *Peltura* and *Acerocare* zones. There is no evidence of *Arbusculidium* and *Nellia*, i.e., acritarchs diagnostic for the uppermost Cambrian and the Cambrian/Tremadocian transition indicating the lack of coeval deposits in the Lenarczyce PIG-1 well.

Two tectonically different structural levels have been recognized in the Cambrian succession of the Lenarczyce PIG-1 well. The lower level includes intensely folded Middle Cambrian and lowermost part of the Upper Cambrian deposits. The folds are thrust-related in character and occur on the bedding planes indicating their formation in primarily horizontal strata. The accompanying thrust faults and slide surfaces occurring in accordance with the bedding planes are referred to as shear zones and display an anchimetamorphic overprint. During the last episode of deformation, the folded rocks were cut by numerous steep thrust faults. The described deformation took place in the Late Cambrian, and was accompanied by the formation of carbonate veins. The upper level is deformed to a lesser degree, which is enhanced by the predominance of interbedding slide surfaces and subordinate thrust faults cutting the bedding planes at low angles. This level lacks any evidences of folds associated with faulting and traces of vein mineralization. The rare low-amplitude trust faults have been reported as well. This level includes the upper portion of the Upper Cambrian succession, as well as the Ordovician and Silurian rocks. Despite of the erosional surface, there is a lack of an angular disconformity between the Upper Cambrian and Ordovician deposits in the studied succession, which indicates that these rocks have been inclined together after Silurian.

The sedimentary environments recognized in the Upper Cambrian succession include: 1) sand ridges/waves accumulated under storm and tidal influence, 2) heterolithic deposits accumulated in a transitional zone between the shoreface and offshore environments under low-energy conditions, and affected by weak and rare strong bottom currents (distal storm beds and storm surge ebb), 3) open shelf muds represented by dark grey mudstones interbedded by rare sandstones interpreted as storm-surge channel-fills.

An overall vertical facies stacking pattern and related sedimentary environments recorded in the Lenarczyce PIG-1 well appears to reflect the oscillating sea level rather than incremental rise, within an overall transgressive trend. The transgressive surfaces of erosion (ravinement surfaces) recognized in the studied succession suggest a complex history of the Late Cambrian transgression, culminating in the maximum inundation and deposition of dark mudstones. Traces of erosion recorded within the sandstones from the basal part of the Upper Cambrian succession seem to be crucial in the reconstruction of the structural evolution of the Holy Cross Mts. The poorly rounded mudstone and siltstone clasts of variable diameter within these sandstones point to erosion of the underlying Middle Cambrian rocks by the ensuing transgression. It is noteworthy that this part of the sedimentary succession subjected to the same phase of deformation as the underlying Middle Cambrian deposits (see above). The subsequent flooding is marked by sandstones with a few thin conglomerate lag beds composed of well-rounded sandstone pebbles derived from the underlying deposits. These sandstones delineate the base of the next structural level (see above) and sedimentary cycle truncated by a pronounced erosional surface produced by the Middle/Upper Tremadocian flooding (Trela, 2004).

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USE OF THE INDEX OF SIMILARITY FOR THE ASSESSMENT OF FOSSIL SPORE-POLLEN SPECTRA

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With the purpose of assessing fossil spore-pollen spectra (SPS) the author has introduced an absolutely new criterion – an Index of Similarity. This is the criterion, which allows us to express an objective connection, which exists between fossil SPS components and corresponding components of modern surface samples. The Index of Similarity can be calculated for any taxon of fossil SPS, but provided that the research of sediment samples, surface samples and modern vegetation is carried out in conjugation. This index is calculated with the formula: $X/Y = Is$, where: X is the percentage content of pollen and spore of any taxon in the composition of a fossil SPS sample; Y is the percentage content of the same taxon in the composition of a recent SPS sample; Is is the Index of Similarity.

In the numerical form it is a decimal fraction, expressed in the following way: $Is \geq 0$ (Table 1); graphically it is a point with the coordinate axes. The Index of Similarity graphs are then built on the basis of the data obtained from calculations with the use of the above formula. Such graphs are more informative, compact and more obvious than traditional spore-pollen diagrams. The introduced index allows us to make an assessment of fossil SPS on the zonal and coenotic levels. The use of the Index of Similarity helps to reconstruct paleogeographic phenomena and events in time and in space with more confidence, and, consequently, to make a better correlation of sediment sequences, containing fossil SPS. We suppose that this index can also be used in the diatom analysis, in the foraminifer analysis and in the study of other groups of organisms.

Table 1

Sample, no.	Pollen								
	Trees			*Larix dahurica* s.l.			Long distance pollen		
	Number	%	**Is**	Number	%	**Is**	Number	%	**Is**
1,surface sample	78	18.6	**1**	53	12.6	**1**	25	5.9	**1**
2, peat	91	16.0	**0.86**	68	12.0	**0.95**	23	4.0	**0.67**
3, peat	63	20.0	**1.07**	42	13.4	**1.06**	21	6.6	**1.1**
4, peat	60	13.4	**0.72**	50	11.2	**0.88**	10	2.2	**0.37**
5, peat	18	4.6	**0.25**	14	3.6	**0.28**	4	1.0	**0.17**
6, peat	14	4.3	**0.23**	12	3.7	**0.29**	2	0.6	**0.10**
7, peat	29	5,9	**0,32**	28	5.7	**0.45**	1	0.2	**0.03**
8, peat	20	4.2	**0,22**	19	4.0	**0.32**	1	0.2	**0.03**
9, loamy sand	31	5.9	**0.31**	17	3.3	**0.26**	14	2.6	**0.44**

FACIES ZONATION OF THE BASHKIRIAN CARBONATE SUCCESSION OF THE OZERNYI LOCAL UPLIFT WITHIN THE SOLIKAMSK DEPRESSION (PRE-URALIAN FOREDEEP)

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During the Bashkirian, the eastern margin of the Russian Plate was covered by an epicontinental sea with carbonate sedimentation. Within the Solikamsk Depression, the seafloor relief was complicated by the highs inherited from the isolated Late Devonian reef complexes. Examination of the material from the deep drillings in the Ozernyi Local High reveals the lithofacies (lithogenetic types) sequences arranged into cyclic units (elementary cyclites). The Bashkirian stage in the Ozernyi area is represented by the Voznesenskian, Prikamian, Cheremshanian, and Melekessian Horizons of 38 to 62 m in total thickness. The Krasnopolyanian and Severokeltmaian Horizons are missing in the succession. The Prikamian overlays unconformably the thin and discontinuous Voznesenskian beds. During the early Bashkirian (pre-Prikamian) sea-level lowstand, the Voznesenskian limestones (6 m) and the underlying Serpukhovian strata have been subaerially exposed, karstified, chertified. During the Prikamian time, the several cyclites composed of *shallow-marine high-energy calcarenites* have accumulated in the western and southeastern parts of the high. This horseshoe-shaped shoal belt rimmed the high from three sides. To the west, the thickness of the Prikamian increases (up to 11–12 m) due to oolite bar formation. The *zone of tidal flats* occurs in the central, northern, and northeastern parts of the high. Within this zone, the thickness of the Prikamian is reduced to 5 m. Intensive evaporation and increase in salinity on the tidal flats resulted in precipitation of microcrystalline dolomite. Two types of elementary cyclites have formed: (1) tidal flat dolostones and (2) argillaceous limestones of the isolated basins (pools) of the upper shelf. The third facies zone of *the open shallow shelf* occurred on gentle slopes of the high and behind the high. The normal-marine subtidal conditions prevailed in this zone, which is suggested by the facies spectrum and rich fossil assemblages. The thickness of the Prikamian here increases to 12–13 m. The Cheremshanian (7–12 m) generally inherits the facies zonation of the Prikamian-age basin. The early Melekessian facies of the studied area generally succeed those of the Prikamian and Cheremshanian, though outlines of the facies zones and sedimentary environments were changing due to net sea level rise. The shoal zone was divided in two (western and eastern) isolated areas, and oolite formation ceased. The bioclastic calcarenites in the elementary cyclites occur in lesser proportion. The shallow subtidal limestones become thicker. The tidal flat zone shrank and became less restricted, which is seen from the dolomites becoming less important in the section. Shallow-water conditions and strong tidal currents, however, have caused formation of the tidal flat limestone breccias. The late Melekessian (25–32 m) in the studied area features the relatively uniform facies of the middle shelf with the argillaceous mudstones intercalated with distal tempestites.

QUATERNARY STRATIGRAPHIC SCHEME AND CLIMATIC SCALE OF WESTERN SIBERIA

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General zoning of the West Siberian plain is carried out taking to account the major paleoclimatic and paleogeographic events of the Quaternary period. From north to south there were recognized four latitudinal paleogeographic zones: Arctic (glacial–marine); Northern (glacial); Central (periglacial); Southern (extraglacial) (Uniform stratigraphic scheme.., 2000). These zones are subdivided into 13 regions based on the type of geological structure of Quaternary mantle.

The Quaternary System in West Siberia is subdivided into two series: Pleistocene and Holocene (Fig. 1). The Pleistocene series embraces two subseries: Eopleistocene (1.8–0.8 Ma) and Neopleistocene (0.8–0.01 Ma). Eopleistocene was subdivided in turn into two divisions (Lower and Upper) while Neopleistocene into three divisions (Lower, Middle and Upper). It was suggested to distinguish steps within divisions: two in the Eopleistocene, one step in both the Lower and Middle Neopleistocene and four in the Upper Neopleistocene.

In West Siberia the boundary is arbitrarily accepted at the base of the Kochki Formation or Barnaul beds containing theriofauna which are comparable with the Odessa faunal assemblage, that allowed the comparison with Olduway episode at the level of 1.65 Ma. The boundary was lowered to the level of 1.8 Ma at Interdepartmental Stratigraphic Meeting in 1999. The subdivision of deposits is presented according to resolutions adopted by ISC on Quaternary System.

The basic units in regional scale for the Quaternary System are considered to be horizon and beds with geographic names. In West Siberia from quaternary deposits described six glacial and six interglacial horizons (Volkova, Arkhipov *et al.*, 2002).

Intrazonal subdivision of the Quaternary System is provided by climatostratigraphic methods (Volkova, 1989), that expects paleoclimatic interpretation of initial geological data. In recent years new geophysical methods (paleomagnetic and radiometric) were used in interregional correlation.

The radiocarbon dating permitted the Pleistocene and Holocene chronostratigraphy to be developed for entire Siberia. The application of thermoluminescence method and pioneering experience in the use of electron paleomagnetic resonance method for the dating enabled one to provide a chronostratigraphic basis for the North Siberia Pleistocene, glaciation zone and marine glacioeustatic transgressions.

Paleomagnetic researches suggested the stratigraphic position for Brunhes/Matuyama (B/M) as the most important correlation level. It is proved that the Quaternary System lower boundary lies lower of B/M boundary at the level of Kharamilio episode. The combination of all methods provided the stratigraphic basis for West Siberia and enabled the correlation with isotope-oxygen scale of World Ocean.

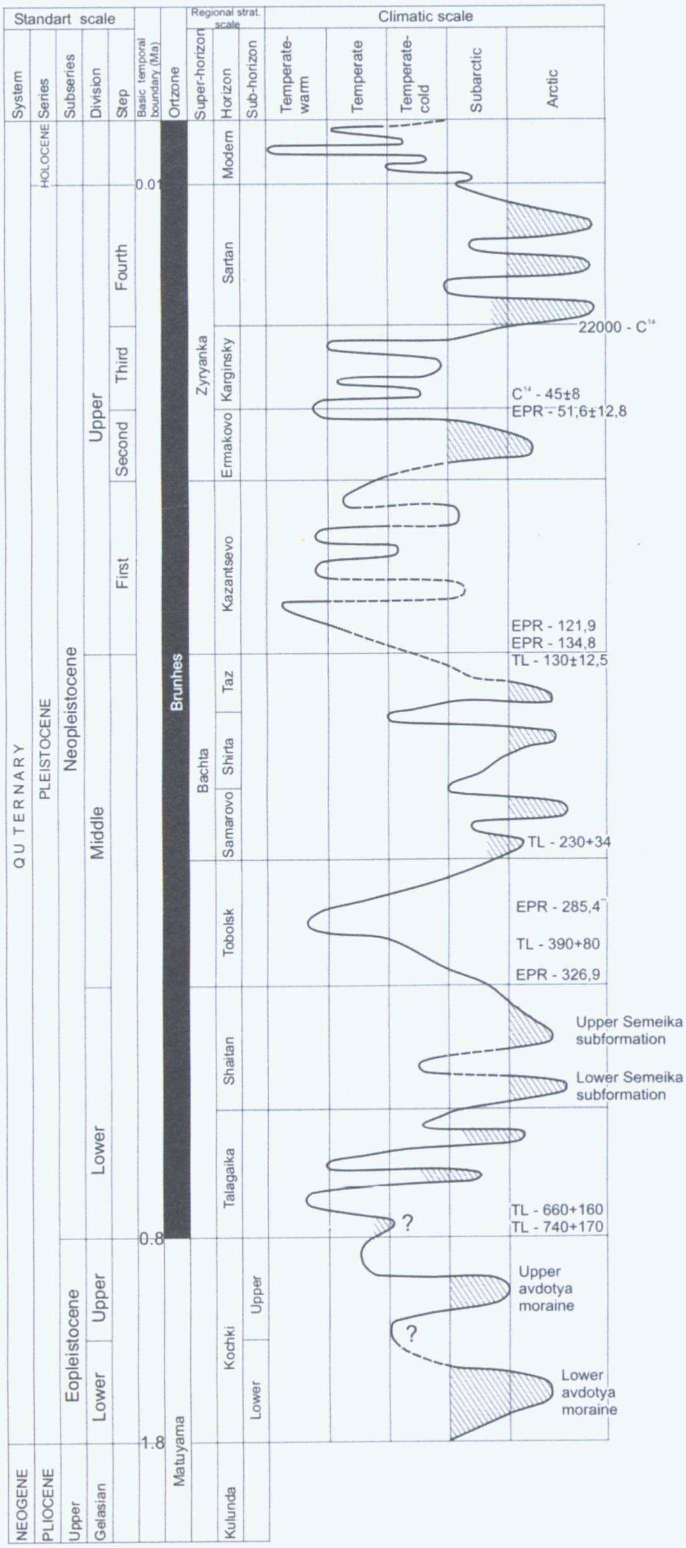

Fig. 1. Quaternary stratigraphic sheme and climatic scale of Western Siberia

For the Quaternary biostratigraphy, migratory-climatic model was proposed as the key one, that permitted us to identify paleogeographic types of faunal and floral complexes as migratory successions dictated by climate variation during the Quaternary period.

For regional stratigraphic correlation was used faunal and floral complexes: mammals, foraminiferes, ostracodes, spore-and-pollen.

The climato-stratigraphic zoning of the Quaternary deposits is based on paleobotanical data which reflect the succession of events supported by physical methods. Three types of flora are described from vegetal formations. Arctic flora is characteristic of the Arctic and periglacial vegetation and may be found in deposits of glacial horizons. The second type of flora is characterized by the presence of boreal-taiga elements which are the components of various taiga formations have been representative of vegetation of interglacial epochs. The spectra of three vegetal formations were recognized in them: South Taiga, Middle Taiga and North Taiga.

The third type of flora (periglacial) is characteristic of deposits of late glacial epochs. Arctic, subarctic and periglacial flora were repeatedly found in all glacial horizons of West Siberia. Palynologic evidence allowed the description of climate types. Temperate, cold and boreal climates fell on late interglacial period, interstadials and more rarely on early glacial period. Temperate-warm climate correlated with climatic optima. Subarctic, arctic and periglacial-cold climates were typical of glacial periods.

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NEW PALYNOLOGICAL AND RADIOMETRICAL DATE ON THE SEDIMENTS OF THE MURAVA STRATOTYPICAL SECTION (BELARUS)

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The Murava section (Borisov region of the Minsk area) for the first time found by G.F. Mirchink in 1928 and palynological studied by O.P. Leonovich, N.A. Macknach, I.E. Krasavina-Savchenko and Ya.K. Yelovicheva, was recognized as stratotypical for the deposits of the Murava interglaciation of Belarus. It is arranged to the south from the border of the Poozerje (Valdai, Wisla) glacier and its deposits are not bridged over moraine. In the clearing 5, opening 6.78 m of the deposits, bottom-up are submitted consequently the grey sand with the gravel and pebbles (power 0.46 m), limnetic grey and yellow-grey sand (0.10 m), dark-brown gittja (0.26 m), dark-brown and yellow-brown sand (0.84 m), dark-brown peat (0.93 m), limnetic brown- and dark-brown, light- and dark-grey sand with peat (0.99 m), dark-brown peat (0.2 m), deluvial yellow-grey sand (3.0 m), a talus.

Detail palynological analysis of the old-limnetic sediments in clearing Murava-5 (Fig.1) has allowed us to establish, that the general structure of spectra (the dominance on the all section of the AP (69–100 %, except for the lowermost and upper parts) at a noticeable role of Spores (up to 25 %) is determined by their belonging to the wood types vegetation, and the formation of the deposits – in the interglacial epoch. The small (up to 12 %) quantity of the NAP indicates on the development of the old lake in a wood landscape. The high contents in the deposits of the mezofilous (*Alnus* – 34 %) and termofilous (*Quercus*, *Tilia*, *Ulmus*, *Acer*, *Carpinus* – up to 91 %, *Corylus* – up to 270 %) breedrocks testifies about the existence of the considerably warmer climatic conditions as contrasted to by modern phase. Series culmination of the wood in the main cherikov climatic optimum (*Quercus+Ulmus→ Corylus+Alnus→Tilia→Carpinus*) and presence of the such warm exotic plants, as *Tilia platyphyllos* and *Osmunda cinnamomea* establish the age of the deposits as Murava (Mikulino), adequate to the 5e circle of a isotopic-oxygen scale of the Northern hemisphere. Uranium-thoria (^{230}Th/U) dating of the four samples from a peat on a depth 4.57–4.77 m (phases *Carpinus* and *Picea*) previously has defined its age in 91±6 (LU-5210U) thousand y.a. (Sanko *et al.*, 2004a), and after refinement – in 102,6±11,9 (LU-5210U) thousand y.a. (Sanko *et al.*, 2004b). Last dating is closer to the termolum date in 105±10 (TLM-437) thousand y.a., obtained earlier in MSU from the Murava interglacial sands underlayer of the lower stratum of peat (Sanko *et al.*, 2004b).

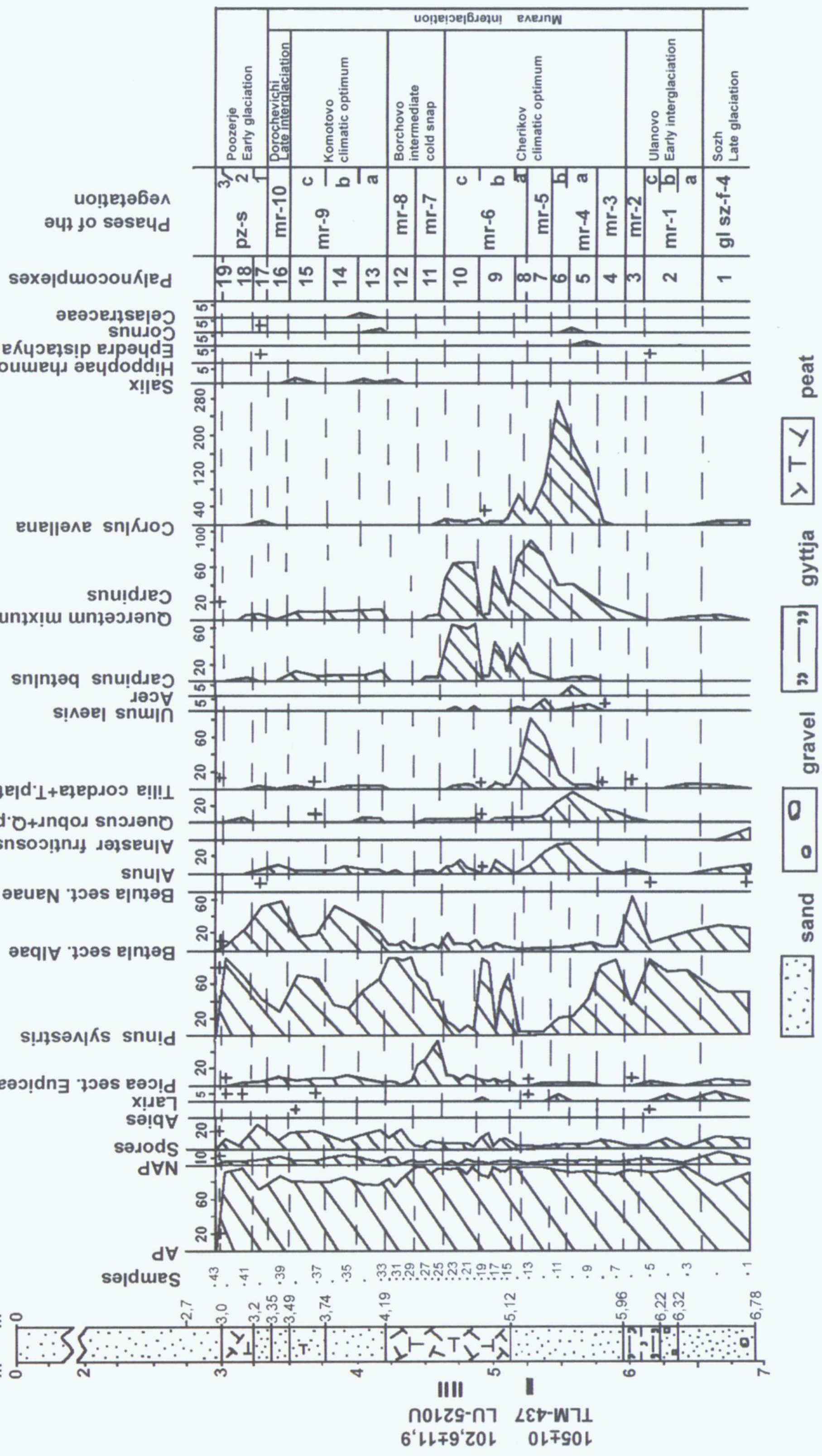

Fig. 1. Palynological diagram of the old- lake sediments of the vil. Murava-5. Analysis by Ya.K. Yelovicheva

The basal part of the deposits of this section (NAP up to 13 %) contains the arcto-boreal elements of flora (*Betula sect. Nanae*, *Alnaster*, *Larix*) and was accumulated at the end of the Sozh (Warta) glacial epoch. The presence of the *Hipphopha¸ rhamnoides* in the sediments of the beginning of the Murava interglaciation, and *Selaginella selaginoides*, *Ephedra distachya* – in the early climatic optimum, and also *Larix* in the separate time intervals of the interglaciation are considered as a relict form of the Sozh glacial. In a top part of the section (NAP up to 0.5–6 %) the quoters of the periglacial green (*Betula sect. Nanae*, *Larix*, *Hipphophae rhamnoides*, *Selaginella selaginoides*) beginning of the Poozerje (Valdaj, Visla) glaciation also are detected.

The almost 7-m strata of the deposits of the palaeolake Murava-5 formed in different climatic conditions and reflected a composite regime of the lake-bog sedimentation. The sand with the gravel in the basis of the section were accumulated in the end of the Sozh glaciation (gl-sz-f), when were the herbaceous associations of the open places and rarefied pine forests. In the beginning Murava interglaciation in the lake went sedimentation of the sand (mr-1) and gittja (mr-2), and palaeolake already was completely surrounded by the wood (pine and birch) massifs. A beginning of the Cherikov optimum (mr-3–mr-6-a) was marked by the accumulation of the stratum of a humuc sand in the conditions of the intensification of the running of the palaeolake, surrounded by the changinng oak with the elm, hazel, alder and lime formations. Since second half of this optimum (mr-6-b-c), the lake quickly pool fast was over and has turn into wood sphagnum-hypnum bog, which one developed alongside with the distribution in a landscape of the hornbeam forests, and then existed during the borchov intermediate cooling-down of the Murava interglaciation (mr-7-8), when in the region studied spruce and pine formations sequentially were replaced by gittja. The subsequent warmer of a climate in the Komotovo optimum of the interglaciation promoted to the increase of the water regime of the bog and renewinng of the limnetic stage of the sedimentation (mr-9), aborted by the short intervals of its overgrowing at the distribution of the mixed-broad-leaved forest. The deterioration of the climate in the end interglaciation was expressed in the continuation of the limnetic regime of the sedimentation (thin humic sand – mr-10) and development in a landscape of the birch-pine forests with the spruce. Later in this lake surrounded by the pine and birch forests, in the conditions of a further cooling-down began to be stored the rough sand with gravel (pz-s-1), and the following change of a hydrological regime has resulted in an overgrowing of the lake and formation of the sphagnum bog (pz-s-2), around of which one grew the pine with a larch association. The formation of the deluvial strata is connected already to the development of the Poozerje glacier in a north of Belarus (pz-s-3).

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WATER-LEVEL FLUCTUATIONS IN PALEOLAKES DURING LATE GLACIAL AND HOLOCENE (BELARUS)

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Palynological study of bottom sediment 9 reservoirs was used for reconstruction of their water level in various geomorphological provinces and belongs to different river basins of the Baltic and Black seas (Yelovicheva, 2001; Tarasov *et al.*, 1996).

The large amplitude of water level fluctuations was peculiar to shallow reservoirs and small rivers. Smaller one for deep-water reservoirs and large rivers. In lateglacial time extensive periglacial lakes had high level (DR-I, BL, DR-II, Al), which tended to sharp decrease already in DR-III (Richi, Naroch, Zabolotje). The reservoirs situated in the centre of region (Sudoble) were characterised by low level in Al and increase of it in DR-III.

Large quantity closed lake kettle was appeared in early Holocene. All this modifications were connected with increase of heat, recession of the Poozerijen glacier on north-west and descent of basic water weight through the Vilija valley on the west, and also through Dnieper and Pripjat water systems on the south. Thus the lakes of the Byelorussian Poozerje (Richi, Naroch, Krivoje) in PB-1 was kept a low water level, at the centre of region (Sudoble, Zatsenje) – it was high, and in the south (Peschanoje, Oltush, Chervonoje, Zabolotje) – low. The increase of humidity in PB-2 has resulted in increase of water weight practically in all investigated reservoirs. Only in Richi, Zatsenje and Oltush its size was kept low. In BO-1-2 the increase of heat was expressed in former stability of a low water level in lake Richi and in section Zatsenje, downturn it in southern reservoirs (Chervonoje, Zabolotje), increase of this size quite often up to maximal in lakes of north (Naroch, Krivoje) and centre (Sudoble) of region. Also difficult mode in lakes Oltush and Peschanoje: rise of a level in BO-1 and its sharp fall in BO-2. The subsequent reduction of heat and humidity of a climate in BO-3 has resulted in universal downturn of a water level in all reservoirs.

The heterogeneity of climatic conditions of an optimum Holocene (AT) was showed on character of their water mode. The increase of heat and humidity in AT-1 was marked by essential growth of water weight in the majority of reservoirs (Peschanoje, Zatsenje, Oltush, Chervonoje, Zabolotje), at the same time lowered level of water was kept in Naroch, Krivoje and Sudoble. Subsequent some decrease of climatic parameters in middle of the Atlantic period (AT-2) was reflected differently. It increased was peculiar to Richi, Krivoje, Zatsenje, the preservation of lowered level in Naroch, Sudoble, reduction of a level in Peschanoje, Oltush, Chervonoje, and Zabolotje. Second half of Atlantic (AT-3) was characterised by growth of heat and humidity. This time was expressed in preservation of former levels of reservoirs in the majority of the investigated reservoirs and increase of water weight in Sudoble, Oltush, Zabolotje, downturn in Peschanoje and Zatsenje.

The general downturn of heat with variation of humidity was peculiar for postoptimal time. The hydrous change of reservoirs had smaller amplitude of fluctuations in comparison with suboptimal time. So, the universal growth of a level of lakes and only in was adequate to downturn of temperature and humidity in SB-1. Peschanoje, Krivoje and Oltush it was lowered a little. Already in SB-2 with some increase of heat and significant growth of humidity the increase of water weight in reservoirs behind exception was peculiar. Naroch, Peschanoje, partly Zatsenje.

During the Subatlantic period the stability of levels in reservoirs has increased considerably, though the climatic parameters changed repeatedly. In Richi, Krivoje, Sudoble, Chervonoje, Zabolotje and Zatsenje water weight in SA-1-3 essentially has decreased and remained constant, and only in Naroch it considerably has increased. At the same time, in SA-2 the sandy low level of water was replaced on raised, and in Oltush in – on lowered.

Thus, the water mode of reservoirs and river systems was closely connected to general climatic changes and local features of development of each separate reservoir in aggregate with geomorphological features of its arrangement. Increase of heat and humidity was practically synchronous to that of the reservoir level, which in the majority of reservoirs occured in AL, PB-2, BO-1, AT-1, SB-1, SB-2. The absolute maxima of water weight in different reservoirs were as follows: in Richi – AT-1-2 and SB, Naroch – SB-1, Krivoje – AT-2-3, SB-2, Sudoble – PB-2-BO-2, Sandy – AT-1, Zatsenje – PB-1, Oltush – BO-1, Chervonoje – PB-2, AT-1, SB-2, Zabolotje – AL. The reduction of heat and the increase of dryness of climate in most cases is also adequate to downturn of the reservoir level . The absolute minimal levels also were in Richi, it is an interval with DR-3 on BO-3, in Naroch and Krivoje – with DR-3 on PB-1, Sudoble and Peschanoje – in one of phases AL, Zatsenje – PB-2-BO-2, beginning of AT-3, end of SB-1, end of SB-2-SA-1, Oltush – PB-2, Chervonoje – PB-1, Zabolotje – BO-2-3, AT-2-3, SA. As a whole, from time of occurrence of lakes and up to present stage of their development the level of water in them tended from primary low to maximal with various versions and subsequent downturn as result of evolution of natural environment for climate-stratigraphic interglacial cycle of Holocene.

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PALEOZOOGEOGRAFIC AFFINITIES OF THE BALTIC *TABULATOMORPHA* IN THE LOWER PALEOZOIC (LATE ORDOVICIAN, SILURIAN)

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Three paleozoogeographical regions (European, Canadian–Siberian and Central-Asian) have been recognized in Late Ordovician based mainly on a distribution of coral families (Kaljo *et al.*, 1970; Leleshus, 1972; Bondarenko, 2003). Many taxa of the *Tabulatomorpha* previously reported from Baltoscandia (Klaamann, 1964, 1966, 1986; Mõtus, 1997) were identified from the Lower Paleozoic in the North Urals (Chekhovich, 1965; Dubatolov *et al.*, 1968; Dembovski *et al.*, 1991; the present author's preliminary data), Northeast of Russia (Sokolov, Tesakov, 1963; Volkova *et al.*, 1978) and Taimyr Peninsula (Zhizhina, Smirnova, 1957; the present author's preliminary data). An attempt has been made to examine taxonomic affinities of *Tabulatomorpha.* For this purpose the Czekanowski–Sørensen index of faunal similarity (Ics) has been used:

$$Ics\ (g;\ s) = 2a/\Sigma b,$$

(***Ics*** is a generic (*Ics (g)*) or species (*Ics (s)*) index of similarity in two faunas compared, ***à*** is the number of species (genera) common for both faunas, ***Σb*** – sum total of species (genera) in faunas compared (Czekanowski, 1932; Sørensen, 1948; Pesenko, 1982). The present study aims at an analysis of faunal similarity on generic and species levels. Dendroid dendrograms of taxonomic affinities have been constructed (Fig.1) using the average linkage method (Sokal, Michener, 1958). They show that the Ics (s) never reaches 0.5 while Ics (g) might be as high as 0,75.

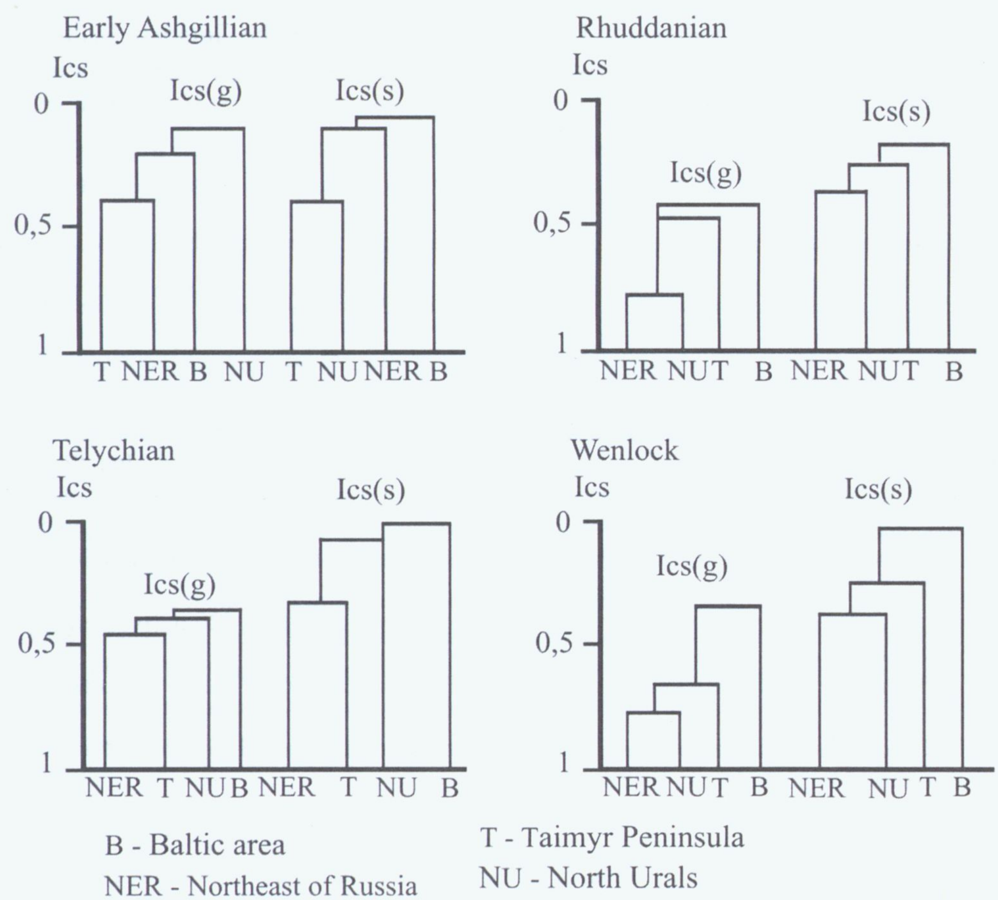

Fig. 1. Dendrograms of taxonomic similarity of the *Tabulatomorpha* in the Lower Paleozoic

Several lower and middle Late Ordovician tabulatomorphic genera are widely spread but their species composition differs from region to the other. This can be exemplified by the species of *Eofletcheria* known in Baltoscandia, Taimyr Peninsula and North Urals. In Early Ashgill (the *linearis*, possibly *complanatus* zones) the coral diversity as well as the number of taxa in common increase significantly. The Early Ashgill tabulatomorphes of Taimyr comprising about 86 species, 26 genera and 15 families are among the most diverse. In Baltic no more than 25–26 species belonging to 11 genera, 7 families are documented. The most significant similarity at species level is supposed to be between the *Tabulatomorpha* known from Taimyr and the Northeast of Russia. Several Baltic species are also typical for the North Urals while generic composition of Baltic corals closer resembles that from the Northeast of Russia and Taimyr. As for families, *Sarcinulidae, Halysitidae* and *Favositidae* are typical for Baltic area, while the *Billingsariidae* family is dominating in Siberia, Taimyr, Northeast of Russia and the *Tetradiidae* family is common for the North Urals and Siberia. Similar distribution pattern persists within late Ashgill.

Thus, taxonomic structure of the Late Ordovician *Tabulatomorpha* of Baltoscandia (European faunal Region) differs substantively from that of the Canadian–Siberian faunal Region and of the North Urals. A suggestion can be made that that coral fauna of the North Urals has closer affinity with the Central-Asian tabulatomorphes.

The Hirnantian biotic changes (Koren', 2000) have resulted in the extinction of the majority of genera though some taxa such as *Paleofavosites, Mesofavosites* and *Catenipora* became widely spread to the beginning of the Silurian. Both Czekanowski–Sørensen coefficients for genera and species increase sharply in Rhuddanian. High rates of diversification and geographic expansion are typical of the Aeronian and Telichyan *Tabulatomorpha.* The most widespread species belong to the *Catenipora, Halysites, Cystihalysites, Favosites, Paleofavosites, Parastriatopora, Subalveolites,* and *Multisolenia* genera. The Sheinwoodian tabulatomorphes from the Northeast of Russia, North Urals, Siberia and Taimyr most probably belonged to a single province. They displayed substantial differences from the European tabulatomorphic assemblages. Only a few cosmopolitan species, like *Favosites hisingeri* Milne-Edwards et Haime or *F. gothlandicus* Lamarck are common. Data on the distribution of the Gorstian, Ludfordian and Přidolian *Tabulatomorpha* are unequal for different paleobasins and insufficient for discussing coral taxonomic similarity. Certain faunal affinities between the Baltic and North Urals regions resulted in distribution of common species belonging to *Syringopora, Parastriatopora, Thecia, Laceripora* and *Favosites* genera.

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DISTRIBUTION OF LOWER SILURIAN THELODONTS AND ACANTHODIANS IN CENTRAL ASIA AND SIBERIAN PLATFORM

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Endemic early vertebrates occure in the Lower Silurian of Central Asia and five subregions of Siberian Platform. Outcrop material from Lower Silurian (Llandovery and Wenlock) of north-west Mongolia, Central Tuva and Siberian Platform yields numerous thelodont and acanthodian microremains. Two endemic genera of thelodonts as well as two endemic genera of acanthodians are established in the Lower Silurian of the region (Karatajute-Talimaa, 1997; Karatajute-Talimaa and Meredith Smith, 2003; Zigaite, 2004). The acanthodians are extremely abundant in the Lower Silurian of Siberian Platform where they form almost pure 'bone beds'. Two early acanthodian genera are most common in the region. Genus *Lenacanthus* Karatajute-Talimaa et Smith, 2003 same as the only species *Lenacanthus priscus* Karatajute-Talimaa et Smith, 2003, is common to restricted shallow shelf facies of Siberian platform though it is absent in lagoon, beach and submarine – deltaic facies. While genus *Tchunacanthus* Karatajute-Talimaa et Smith, 2003 is widespread in each of the facies mentioned above (including the bar belt facies) of Siberian platform, Tuva (Karatajute-Talimaa, Ratanov, 2002) and north-west Mongolia (Karatajute-Talimaa, Novitskaya, Rozman, Sodov, 1990).

All the thelodont micromaterial is ascribed to four genera – *Angaralepis* Karatajute-Talimaa, 1997, *Loganellia* Turner, 1991, (?) *Paralogania* Karatajute-Talimaa, 1997 and *Talimaalepis* Zigaite, 2004. *A. moskalenkoae* is found in Siberian Platform only, whereas *L. tuvaensis* (Karatajute-Talimaa, 1978) is restricted to Wenlock deposits of Central Tuva. Genera *Angaralepis* and *Loganellia* are common in shallow water sediments such as shallow shelf, marine delta and brackish lagoon facies, whereas genus *Talimaalepis* is present both in shallow and deeper shelf sediments. *Talimaalepis rimae* Zigaite 2004, first described in Llandovery series of Central Asia, joins the Early Silurian palaeobasins of the region, as it is common in North West Mongolia, Siberian Platform and Tuva as well. Presumptive new species of genus *Paralogania* (or even a new thelodont genus) is present in the Upper Llandovery–Wenlock molasse – type sediments of north-west Mongolia. The facies is rich in benthic fauna including the endemic *Tuvaella* brachiopods (Minjin, Ch., 2001).

Endemic thelodont and acanthodian taxa in the Silurian sections of the region refer to warm and productive basins, which existed in Siberian palaeocontinent during its supposed journey through the Equator during the Silurian (Cocks and Torsvik, 2002). The abundance and richness of endemic species in the region indicates it as a proper place for genesis and radiation of the earliest vertebrates (Blieck and Janvier, 1993). The summary distribution of thelodonts and acanthodians is presented in Fig.1.

	Llandovery			Wenlock		Series		
	Rhuddan	Aeron	Telychian	Sheinwoodian	Homerian	Stage		
	Moyerocanian	Khaastyrian	Agidyan	Khakomian		Regional Stage		
Formation	Chamba	Talikit	Omnutakh	Uragdan		Turukhansk district	Šiaurės Prienissey subregionas	Siberian Platform
			Talimaalepis rimae gen. et sp. nov. *Tch. obruchevi*	*Tchunacanthus* sp. indet.				
Formation	Kochumdek	Kulinna	Razvilka	Usas		Kochumdek district	Pritunguska Subregion	
	L. sibirica *Len. priscus*	*Loganellia sibirica* *Len. priscus*	*Angaralepis moskalenkoae* *Lenacanthus priscus*	*Tl.rimae* gen. et sp. nov. *Tch.* sp. indet				
Formation	Melichan	Utakan		Niuya		Niuya – Beresovo dissrict	Niuya - Beresovo Subregion	
	L. asiatica *L. sibirica* *Len. priscus*	*A.moskalenkoae* *L. sibirica* *Len. priscus*	*A.moskalenkoae* *L. sibirica*	*Tch.*? sp. indet.				
Outcrop/ sample	155/1-156/12 156/13 156/28	156/2938-157/23 157/24-42-159/7	159/7-158/5	158/5-151/18				
Formation	Rassokha			Deshyma		Ilim district	Irkutsk Subregion	
	A. moskalenkoae, *L. asiatica* *L. sibirica* *Tch. obruchevi* *Len. priscus*	*L. asiatica* *L. scotica* (?) *L. sibirica* *Tch. obruchevi* *Len. priscus*	*A. moskalenkoae* *L. asiatica* *L. sibirica* *Tch. obruchevi* *Len. priscus*					
Outcrop/ sample	141/3 - 22	141/23 - 38	141/39 - 48					
Formation	Balturino					Balturino district		
	L. asiatica *L. sibirica* Acanthodii indet. *Tch.*? sp. indet.	*L. asiatica* Acanthodii indet.	*L. asiatica* *Tl. rimae* gen. et sp. nov. Acanthodii indet. *Tch. obruchevi*	*L. asiatica* *Tl. rimae* gen. et sp. nov. *Tch.obruchevi*				
Outcrop/ sample	135/1 - 22	135/23-41-43	135/42 - 62	135/63 - 64				
Formation	Alash		Kyzyl-Tchiraa Anga-tchi	Akcha-lym	Dashty-goi	Tuva		
	L. asiatica *L. sibirica* *Tch.* sp. indet.		*L. asiatica Tl. rimae* gen. et sp. nov. *Tch.* sp. indet. *L. asiatica Tl. rimae* gen. et sp. nov. *Tch.* sp.indet.		*L .asiatica L. tuvaensis,* *Tl. rimae* gen. et sp. nov. *Tch.* sp. indet.			
Outcrop/ sample	694		702;253 -271R 660/1-660/4		224-226; 662,663			
Formation			Tchargat			North West Mongolia		
			L. asiatica *Paralogania*?cf. *L. sibirica* *Tl. rimae* gen. et sp. nov *Tch. obruchevi*					
Outcrop/ sample			1009-16/3; 1009/1 – 1009/5					

Fig.1. The summary distribution of thelodonts and acanthodians

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