Institute of Geology, University of Latvia
Faculty of Geographical and Earth Sciences, University of Latvia
State Geological Survey of Latvia
Latvian Museum of Natural History
Baltic Stratigraphical Association
UNESCO IUGS IGCP 406 Project

THE FOURTH BALTIC STRATIGRAPHICAL CONFERENCE

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PROBLEMS AND METHODS OF MODERN REGIONAL STRATIGRAPHY

4th Baltic
Stratigraphical
Conference

Jūrmala '99
September 27-30

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ABSTRACTS

A joint Baltic Stratigraphical Association/IGCP 406 Project meeting
Jūrmala, Latvia, September-October 1999

Edited by Ervīns Lukševičs, Ģirts Stinkulis and Laimdota Kalniņa

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FROM THE PREFACE TO THE THIRD BALTIC STRATIGRAPHICAL CONFERENCE

Kaljo, D. & Nestor, H.

Baltic co-operation in geology, particularly in the field of regional stratigraphy has been many-sided and active during the last decades since the foundation of the Baltic Regional Stratigraphical Commission (BRSC) in 1969 under the leadership of Prof. J. Dalinkevičius (Vilnius University) and vice-chairmen from each Baltic republic. Long-term contribution of Prof. A. Grigelis (Lithuanian Geological Institute, Chairman of the BRSC from 1973 to 1993) should be specially emphasised.

The Commission has convened regular meetings, organised field excursions, palaeontological examinations, *etc*., which have served for better understanding between geologists and for the elaboration of unified stratigraphical classifications of geological systems on the East Baltic territory. As a regional unit of the Interdepartmental Stratigraphical Committee of the USSR, the BRSC played an important role in promoting stratigraphy in the former Soviet Union, especially that of the East European Platform.

In October 1990 ... the Baltic Regional Stratigraphical Commission was reorganised by its membership into a freer organisation – the Baltic Stratigraphical Association (BSA). The latter unites the national stratigraphical commissions of Estonia, Latvia and Lithuania, with the main goal of ensuring co-operation in the field of stratigraphy.

Scientific conferences have been the most important (decision making) events in the stratigraphical co-operation in the Baltic States. The First Baltic Conference in Vilnius in 1976 adopted the primary version of the East Baltic unified stratigraphical classification and a full set of correlation charts. The second version of these documents, embracing the USSR part of the East European Platform, was adopted at wider meetings (Vendian and Cambrian in Vilnius, 1983, Ordovician and Silurian in Tallinn, 1984, Devonian – in Leningrad, 1988).

The Second Baltic Stratigraphical Conference in Vilnius, 1993, was a true international meeting, open for everybody. At that conference different issues were discussed, but no binding decisions were taken. Since then the organisation of the Baltic stratigraphical conferences has been considered as the main task of the BSA. Rotation of the chairmanship of the BSA and the site of the stratigraphical conferences were introduced. Tallinn was selected as the place for the Third Baltic Stratigraphical Conference and H. Nestor was nominated for the Chairman of the BSA.

PREFACE

Lukševičs, E.

Latvia was selected as a site for the Fourth Baltic Stratigraphical Conference during the previous conference which was held in Tallinn, 1996. The Latvian Stratigraphical Commission has decided to organise this conference in conjunction with the IUGS IGCP 406 Project meeting "Lower-Middle Palaeozoic Events Across the Circum-Arctic" and has chosen Jūrmala as the place for this event. The joint Fourth Baltic Stratigraphical Conference/IGCP 406 Project Meeting has attracted an interest of more than 130 delegates from 14 European countries, Australia and Canada.

This issue presents the abstracts of the Fourth Baltic Stratigraphical Conference, which was held in Jūrmala from 27th till 30th September 1999 under the auspices of the Baltic Stratigraphical Association (BSA). The main topic of the conference is "Problems and Methods of Modern Regional Stratigraphy".

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LATE ORDOVICIAN-EARLY DEVONIAN LEPERDITICOPID OSTRACODES OF THE EAST BALTIC AND PODOLIA

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Leperditicopida is a specific extinct order of the class Ostracoda. They were characterised by a large carapace, of a length reaching 10 cm. Leperditicopids existed during the Ordovician-Devonian. In most regions they characterized lagoonal and marine shallow-water environments, although in Ordovician of some areas (North America) their facies range could be wider. Leperditicopids were first described from the Silurian of the East Baltic (Hisinger, 1837; Eichwald, 1860; Kolmodin, 1880) and Timan (Keyserling, 1846). Collections of this group from the mentioned areas were later studied by Schmidt (1873, 1883, 1900). Chmielewski (1900) described a rather large collection of the leperditicopes from the glacial boulders of Kaunas government. During subsequent decades this group of ostracodes was not studied specially in eastern Baltic area.

Leperditicopid ostracodes are important for biostratigraphy of the deposits formed in lagoon-type environments. In such sediments, formed under specific conditions, the representatives of this group are often the only fossils present.

Leperditicopids are most widespread in Estonia. They are recorded in the Ordovician and Silurian: in the Oandu-Rakvere stages (*Eoleperditia*), Raikküla Stage (*Hisingeria, Herrmannina*?, *Tollitia*, *Hogmochilina*, *Gibberella*), Adavere Stage (*Hisingeria*), Jaagarahu Stage (*Herrmannina*), Paadla Stage (*Herrmannina, Schrenckia*), and Ohesaare Stage (*Leperditia, Tollitina*). The genus *Eoleperditia* is also recorded in the Oandu-Rakvere stages of the northwestern Russia (several core sections of the Pskov Region).

In Latvia leperditicopids are not recorded, but in Lithuania they are known in the upper Silurian (*"Leperditia" borussica*, Prenai borehole, depth 384.5 m) and Lower Devonian (*Herrmannina* sp., Tilze Formation).

In the south-west of the East European Platform (Podolia), leperditicopids are abundant in the interval of upper Llandovery-Lochkovian (Abushik, 1971). The generic composition of leperditicopids in this area is generally the same as in the East Baltic. The highest similarity of species composition in the East Baltic and Podolia is related to the early Silurian transgressive epoch. This is expressed as a high similarity of species composition of the Adavere Stage in Estonia and Teremtsy Stage in Podolia (distribution of *Hisingeria hisingeri abbreviata*), as well as similarity between the Jaagarahu and Late Kitaigorod (accordingly) stages (occurrence of *Herrmannina baltica*). The late Silurian leperditicopid associations of Estonia and Podolia show a more different species composition, as a result of environmental differentiation and separation of the basins.

The succession of late Ordovician-Early Devonian leperditicopid genera in the East Baltic and Podolia is fairly similar to that of Novaya Zemlya-Urals and rather similar to the Siberian record also. The difference from the first one is expressed in a lower diversity of associations. The Siberian record differs from the eastern Baltic/Podolian one in the absence of *Sibiritia* in Llandovery.

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MIDDLE AND UPPER DEVONIAN CORRELATION OF THE BALTIC AREA AND SCOTLAND BASED ON FOSSIL FISHES

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The present Middle - Upper Devonian correlation of the Baltic area and Scotland (see table) is based on several publications: Ahlberg (1998), Lyarskaya (1981) and Mark-Kurik (1991; in press). It also draws on revised identifications of the Scottish fish species produced during a visit by Ivanov, Lukševičs and Mark-Kurik to the UK during the summer of 1997, as part of NATO Linkage Grant Project 961235. Ahlberg was the project leader. A thorough revision and redescription of the Baltic *Bothriolepis* species by Lukševičs, and revision of Upper Devonian fish zones, preceded this visit (Lukševičs, 1996; Ivanov & Lukševičs, 1996). Representatives of the psammosteid heterostracans, placoderms (antiarchs and arthrodires), and sarcopterygians, which dominate these fossil fish assemblages, have proved particularly valuable for correlating the two regions. However, the utility of the different groups varies between regions and stratigraphic intervals. Thus, in the Eifelian and most of the Givetian, psammosteid heterostracans are very common in the Baltic sections and give a number of index species from the Pärnu to Amata Formations, whereas in Scotland the earliest psammosteid, *Psammolepis undulata*, comes from the Nairn Beds which are probably equivalent to the Amata Fm. In the Middle Devonian, various coccosteid arthrodires appear to be useful for interregional correlation. An interval from Pärnu to Burtnieki (inclusive) and the contemporary Scottish units contains the characteristic large arthrodire *Homostius*. The Kernavę Fm, the upper part of the Narva Regional Stage, and the Achanarras limestone with its coeval units at the top of the Lower Caithness Flagstone Group, contain *Coccosteus cuspidatus* and the ptyctodont *Rhamphodopsis* (rare in the Baltic area). Abava, the John o'Groats Sandstone and Eday Flags can be correlated by the arthrodire *Watsonosteus* and the small antiarch *Microbrachius*. The Gauja Fm with its *Asterolepis* species, *A. ornata*, appears to have no equivalent in Scotland. The Scottish species *A. maxima* from the Nairn Sandstone appears very similar to *A. radiata* from the Amata Fm. *A. maxima* and *A. radiata*, together with *Psammolepis undulata* and the sarcopterygian *Laccognathus*, characterise the Nairn Sandstone and Amata Fm. We cannot exclude that the Givetian/Frasnian boundary is situated somewhere within these units. In the lower part of the Frasnian, the Dubniki-Daugava interval and the Alves Beds contain the psammosteid *Psammosteus megalopteryx*. The underlying Pļaviņas and Whitemire can be correlated using the arthrodire *Plourdosteus mironovi*. At Edenkillie, in the Whitemire Beds, a species close to *P. mironovi* has been identified. *Bothriolepis maxima* characterises the Pamušis - Snezha interval in the Baltic area; the occurrence of the almost identical *B. gigantea* in the Alves beds, alongside *Psammosteus megalopteryx*, suggests that the Alves beds may correlate with the upper part of the Daugava or the base of the Snezha. The Pamušis - Snezha interval is characterised by *Psammosteus falcatus*. A closely similar form, *Psammosteus* cf. *falcatus*, occurs at Scat Craig along with *Bothriolepis paradoxa*, suggesting that this unit correlates with some part of the Pamušis - Snezha interval. In the lower Famennian, *Bothriolepis leptocheira leptocheria* from the Bracken Bay Beds (Miles 1968) correlates with *B. leptocheira curonica* from the Eleja Formation. A significant Baltic interval, the Kursa - Švėtė Fms, contains the arthrodire *Phyllolepis*; in Scotland it is restricted to Rosebrae and Dura Den. The Mūri and Tērvete fms

Series	Stage	Baltic area			Scotland	
		Ketleri	***B. ciecere***			
		Žagare				
		Švėtė			Rosebrae +	***B. hydrophila***
	Famen-nian	Mūri	***Phyllo-***	***B. ornata***	Dura Den	***Phyllolepis***
		Akmene	***lepis***			
		Kursa				
Upper Devonian		Joniškis				
		Eleja	***B. leptocheira curonica***		Bracken Bay	***B. leptocheira leptocheira***
		Amula + Stipinai				
		Pamušis	***Psammosteus falcatus***		Scat Craig	***Ps. cf. falcatus***
	Frasnian	Snezha	***Bothriolepis maxima***			***B. gigantea***
		Daugava	***Psammosteus***		Alves Beds	***Psammosteus***
		Dubniki	***megalopteryx***			***megalopteryx***
		Pļaviņas	***Plourdosteus mironovi***		Whitemire	***P. mironovi?***
?	?	Amata	***Psammolepis undulata*** ***Asterolepis radiata*** ***Laccognathus***		Nairn	***Psl. undulata*** ***A. maxima*** ***Laccognathus***
		Gauja	***Psammolepis paradoxa***		?	
	Givetian	Abava	***Watsonosteus***		Eday +	***Watsonosteus***
Middle Devonian		Burtnieki + Aruküla	***Microbrachius*** ***Dickosteus?*** ***Millerosteus?*** ***Homostius***		John o'Groats U. Caithness Flagstone Group	***Microbrachius*** ***Dickosteus?*** ***Millerosteus?*** ***Homostius***
		Kernavė	***Coccosteus cuspidatus*** ***R. cf. threiplandi***		Achanarras & equivalents	***C. cuspidatus*** ***R. threiplandi***
	Eifelian	Narva Leivu Vadja	***Homostius***		L. Caithness Flagstone Group	***Homostius***
		Pärnu			?	

Abbreviations: A., Asterolepis, B., Bothriolepis, C., Coccosteus, P., Plourdosteus, Ps., Psammosteus, Psl., Psammolepis, R., Rhamphodopsis; L., Lower; U., Upper.

contain *Bothriolepis ornata* and *B. jani*, whereas the roughly coeval Scottish unit Dura Den yields *B. hydrophila*. The Upper Famennian *B. ciecere*, from the Ketleri Fm, has no closely related species in Scotland.

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KEILA, OANDU AND RAKVERE STAGES IN SOUTHERN ESTONIA: FACIES CHANGES AND STRATIGRAPHY IN THE ZONE OF CONFACIES TRANSITION

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Carbonate and argillaceous sediments of the Keila, Oandu and Rakvere stages were formed during an episode of remarkable increase of facies differentiation in Baltoscandia. In this stratigraphical interval both the sediment composition and fauna are changing remarkably along the facies gradient, particularly in transitional zone between North Estonian Confacies Belt (NECB) and Central Baltoscandian Confacies Belt ((CBCB) southern Estonia). Some types of sediments are specific to the transitional belt. High variability of lithology and fauna remarkably complicates stratigraphic correlation in this stratigraphical interval.

Facies transition between argillaceous limestones of the Kahula and Adze formations, main part of the Haljala and Keila stages in NECB and CBCB, respectively, is fairly gradual, but the differentiation increased in late Keila time. Claystone and argillite of the Blidene and Mossen formations, overlying the Adze limestone within the CBCB, are restricted only to this particular confacies. In transitional zone, the richly argillaceous sedimenary rocks grade into the silty beds which in latest stratigraphic schemes were called the Lukštai Fm (Nõlvak, 1997).

Lukštai Fm is defined in the Central Lithuanian Depression, and it is characterized by the alteration of marl and biomorphic limestones (Laškov *et al.*, 1984). In Estonia this type of rock is missing. We propose a new name for silty beds within the confacies transition in southern Estonia – the Variku Formation.

Variku Fm is characterized by the alteration of dolomitic argillaceous quartzose siltstone, silty marl and dolomitic claystone (Figure; Ainsaar *et al.*, 1996). As the type section we propose the interval 401.1-409.9 m in the Ristiküla-174 core. The Variku Fm is present in a number of South Estonian core sections: Kaagvere (259.6-267 m; Männil, 1966), Tartu (Variku)-453 (288.3-299.1 m), Laeva-18 (234.2-240.9? m), Viljandi-91 (325.5-333.9 m), Häädemeeste-172

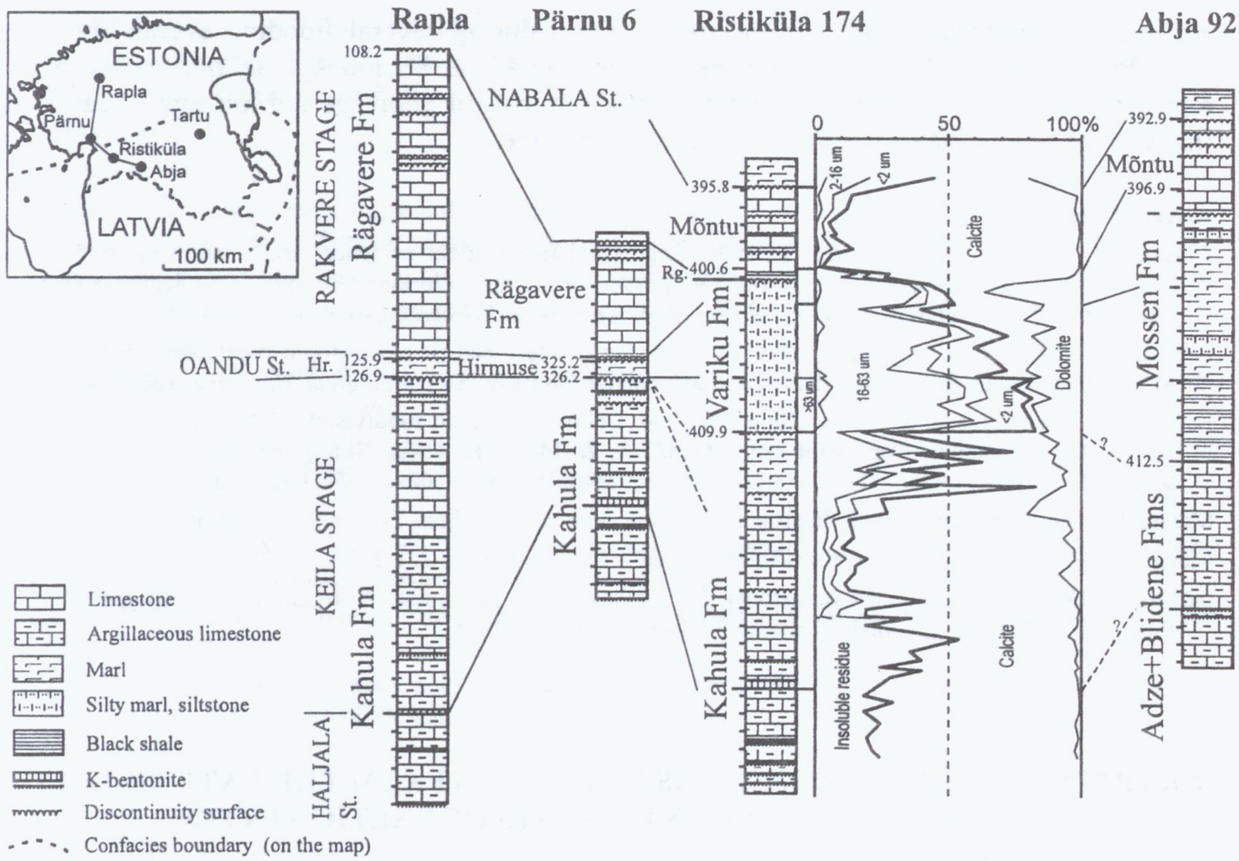

Figure. Lithostratigraphy and correlation of core sections across the confacies boundary and composition of rocks in the Ristiküla section. Correlation is based on ostracode data (Meidla, 1996) and stable isotope stratigraphy (Ainsaar et al., 1999).

and Ruhnu-500. Thickness of the formation is 6-11 m. Lower part of the Variku Fm contains ostracode fauna of late Keila age, specifically *Tetrada pseudoiewica* and taxa common with the sections of NECB (Meidla, 1996). Changes in ostracode fauna in the middle and upper part of the Variku Fm are similar to those described from the Mossen Fm in southern Estonia (Meidla, 1996) and refer to the Oandu and Rakvere age of the corresponding intervals.

According to ostracode data and correlation of the stable carbon isotope curves (Ainsaar *et al.*, 1999) the uppermost beds of the Keila Stage are missing in central and northern Estonia (e.g. in Pärnu and Rapla core sections). Correlation of these beds with a part of the Vasalemma Fm in north-western Estonia is not clear yet. A marl layer of Oandu age - Hirmuse Fm - is distributed in central and northern Estonia, within the two separated distribution areas. The northeastern area (with the stratotype sections) is located between Rapla and Narva River. The western area includes western Estonia (Haapsalu and Pärnu sections) and the West Estonian islands, and within this area the Hirmuse Fm grades southward into the Variku Fm.

The siliciclastic rich beds of the Keila and Oandu stages in northern and central Estonia are overlain by aphanitic limestone (calcareous mudstone) of late Oandu and Rakvere age (Rägavere Fm), which is replaced southward grades into the argillaceous deposits (upper part of the Variku Fm or Mossen Fm).

The formation of silty beds of the Variku Fm in southern Estonia is supposedly related to a late Keilan-Oanduan sea level fall. Low sea level is responsible also for gaps and bioclastic shoal accumulations at the boundary of the Oandu Stage in northern Estonia (Ainsaar *et al.*, 1996). The silty accumulations may also be considered as reworking products of soft argillaceous sediments eroded from onshore areas during several flooding events after sea level lowstands. In this case the gaps of late Keila and Oandu age in northern Estonia represent the drowning unconformities formed during a short period of rapid sea level fluctuations before major transgression in Rakvere time.

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CRYPTOSPORE AND MIOSPORE ASSEMBLAGES FROM THE LATE SILURIAN AND EARLY DEVONIAN DEPOSITS OF BALTIC STATES

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Cryptospore and miospore assemblages from Late Silurian and Early Devonian deposits of Baltic area are studied:

1. Ludlow, Kuressaare Beds, Saaremaa island, near Kuressaare, Estonia. Characteristic sporomorphs: monads, dyads, "permanent" tetrads; miospores: *Retusotriletes* spp., *Ambitisporites* cf. *dilutus* (Hoffmeister) Richardson *et* Lister, *Archaeozonotriletes chulus* (Cramer) Richardson *et* Lister var. *nanus*. (Aristova & Arkhangelskaya, 1976).

2. Pridoli, Kaugatuma and Ohesaare Beds, Saaremaa island, klint (Aristova & Arkhangelskaya, 1976). Characteristic sporomorphs: cryptospores - *Laevolancis divellomedia* (Chibricova) Burgess *et* Richardson, *Cheilotetras* cf. *caledonica* Wellman *et* Richardson, *Tetrahedraletes* cf. *medianensis* Strother *et* Traverse, emphanoid monads; miospores - *Retusotriletes* cf. *varringtonii* Richardson *et* Lister, *Ambitisporites* cf. *avitus* Hoffmeister, *Archaeozonotriletes chulus* var. *chulus* Richadson *et* Lister, *Leiotriletes* spp.

3. Siegenian, Viešvile Formation, lower (Šešuvis) part, borehole Kunkojai-12 (Arkhangelskaya, 1978) and borehole Salantai-59 (Arkhangelskaya, 1980), Lithuania. Characteristic spores: *Retisotriletes explicatus* Vaitekunene, *Emphanisporites rotatus* McGregor, *E. robustus* McGregor, *E. salantaicus* Archangelskaya, *Convolutispora bella* Archangelskaya, *Oculatisporis mirandus* Archangelskaya, *Dictyotriletes emsiensis* Allen, *D. subgranifer* McGregor, *Brochotriletes* cf. *hudsonii* McGregor, *B. rarus* Archangelskaya.

4. Emsian, Viešvile Formation, upper part, borehole Salantai-59 (Arkhangelskaya, 1980). Characteristic spores: *Emphanisporites annulatus* McGregor, *E. schultzii* Mcgregor, *E. decorus* Allen, *Apiculiretusispora* spp., *Acanthosporites singularis* Archangelskaya, *Vallatisporites annosus* Archangelskaya.

Correlation of cryptospore and miospore assemblages from Late Silurian and Early Devonian sediments of Baltic states and adjacent regions of Europe (Allen, 1965; Richardson & Lister, 1969; Schultz, 1968; Steemans, 1981; Turnau, 1974; Riegel, 1973) is discussed.

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PETROGRAPHY OF BALL SANDSTONE GESCHIEBES (DEVONIAN) AND THEIR APATITE REMAINS

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Ball Sandstone ("Kugelsandstein") is one of the most typical Devonian rocks found as an geschiebe. This concretionary sandstone is usually considered to be almost free of fossils.

Examination of geschiebes from North Germany shows the following characteristics: Ball Sandstones are mostly quartz sandstones (silt and fine sand), one in ten is made up of coarse sand with some fine gravel constituents. Coarse sandstones sometimes contain quite large clasts of unweathered minerals and rock (e.g. pink feldspar, slate, granite). In most cases the sand is colourless, only a few sandstones are partly or completely stained red by iron oxyde.

In contrast to the absence of glauconite in Ball Sandstone outcrops in Latvia, glauconite is widespread as traces one in four geschiebes. Feldspar is common. Mica is also common, but in some cases it is absent. Biotite is the predominant mica. Ore grains may be absent or enriched in layers (placer).

Mud cakes often somewhat rounded occur in one in ten of the Ball Sandstone geschiebe. Stratification occurs only in one in ten of the geschiebes, so that in many layers the stratification must have been destroyed, perhaps by bioturbation, also burrows are only visible in 3 %. In a very few cases, casts of salt cubes are visible.

There are two types of heavy mineral suites: the garnet-rich suite (up to 60 % garnet) and the zircon-rich suite (up to 98 % zircon). In the latter case, one in ten zircon grains is pink coloured. The heavy mineral content of the rocks varies widely: in some cases almost no heavy minerals are present and in other cases they are enriched (placers up to 4 %).

Ball Sandstones are mainly cemented by calcite. Calcite is developed in large crystals, which enclose the detritus (poikilotopic cement). In some cases (10 %), quartz cement is also developed. In rare cases, phosphorite and limonite are also present as cement.

Apatite fossil remains occur in 7 % of the Ball Sandstones. These are exoskeletal elements of fish and invertebrates (arthropods).

BRACHIOPOD AND CONODONT COMMUNITIES IN THE ORDOVICIAN OF NORTHERN POLAND

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In the Ordovician, the northern and central Poland formed the southern part of the Baltic basin. To the north-west, this marine epicontinental basin bordered the Caledonian deformation zone of Scandinavia. Its western boundary is unclear because Ordovician deposits are not preserved at the Jutland Peninsula in Denmark. In the south-west, the Trans-European Fault Zone separates the East European Craton and the Baltic Basin from the Pomerania Terrane (the Rügen - Koszalin - Chojnice Zone) which are tectonically and depositionally different (Bednarczyk, 1974). In the south-east the Baltic Basin extended to the Małopolska Terrane.

The majority of Poland was occupied by the coexisting red and grey carbonate facies comparable to the Central Baltoscandian confacies belt which was distinguished by Jaanusson (1982).

The conodont elements and brachiopods discussed here permit to recognise several communities through time. In the north-eastern part of Poland (the Kętrzyn Region) the Klewno Glauconities Formation (Bednarczyk, 1998), the facies equivalent of the *P. elegans* - *O. evae* zones is characterised by frequently found elements of *Protopanderodus* and *Paroistodus*. The next, the Łankiejmy Red limestone Member of the Pieszkowo Limestone Formation that corresponds to the *O. evae* - *P. anserinus* zones is characterised by frequent elements of conodonts belonging to the genera *Baltoniodus* and *Drepanoistodus*. Elements of *Drepanoistodus* and *Protopanderodus* are more frequent in the central part of the area.

Within the brachiopod (Lingulata) communities valves of *Biernatia* and *Paratreta* are more frequent.

The Łankiejmy Member may be related to the Latorp and Lanna Limestone of Sweden (Jaanusson, 1982). It graded upward and laterally into the marly limestone of the Kielno Member (the *B. navis* - *A. tvaerensis* zones) and in places into the oolithic limestone of the Aniołowo Member (the *P. anserinus* - *A. tvaerensis* zones) of the Pieszkowo Limestones Formation. The Kielno Member is characterised by abundant elements of *Baltoniodus* and *Dapsilodus*. In contrast the Aniołowo Member is characterised by numerous elements of *Scabbardella*. Among the Lingulata, the *Numericoma* community is characteristic one for two above mentioned members.

In the southern part of the Scanian - Łeba confacies belt, the Upper Cambrian black ferrugineous claystones of the Piaśnica Formation grade upwards into the Lower Tremadoc marly claystones. However, in the Łeba area the Ordovician begins with the Upper Tremadocian marly strongly bituminous claystone of the Gardno Formation with intercalations of glauconitite and glauconitic limestone. The boundary between these two formations is a glauconite lamina. However a little further eastward in the Gdańsk

Depression, the Gardno Formation is separated from the Upper Cambrian (*Peltura scarabaeoides* Zone) by a thin conglomerate consisting of sandstone pebbles.

Lithofacially and stratigraphically, the Gardno Formation corresponds to the Björkasholmen Limestone of South Öland. The deposits of this formation are characterised by abundant elements of *Drepanodus* and *Paroistodus* and valves of *Pomeraniotreta* and *Myotreta*.

The deposits of the Gardno Formation gradually grades upwards into the Słuchowo Formation which consists of grey-green marly claystones with glauconite laminae and grey brownish claystones with scattered glauconite grains with graptolites of the *D. balticus* to *Ph. angustifolius elongatus* zones, and with carbonate intercalations in which conodonts *Drepanodus*, *Paroistodus* and *Drepanoistodus* are common. Valves of *Broeggeria* and *Lingulella* are characteristic for this formation.

The Słuchowo Formation can be regarded as a southern extension of the Toyen Shale of Scandinavia (Bergström, 1982). Grey-beige to dark-grey marly limestones with scattered glauconite grains, intercalated with black claystone and veins or nests of calcite of the Kopalino Member, overlie the deposits of the Słuchowo Formation. The elements of *Drepanoistodus* and *Protopanderodus* are very common in this succession. Valves of *Conotreta, Myotreta* and *Scaphelasma* are sporadically found also.

The Kopalino Member may be considered as a western tongue of the Pieszkowo Formation between the Słuchowo Formation and the Sasino Graptolite Claystones Formation. A similar model of sedimentation was presented by Jaanusson (1982) for the Swedish part of the Baltic Basin where the Komstad Limestone Formation occurs between the Toyen Formation and the Upper *Didymograptus* Shale (Bergström, 1982).

The Kopalino Member and its equivalents in the Pieszkowo Formation are succeeded by the Sasino Formation in the whole area under discussion. In places, these claystones contain thin interbeds of grey limestone. Numerous bentonite and tuffitic intercalations also occur within this succession. The elements of *Scabbardella, Amorphognathus* and *Hamarodus* and valves of *Paterula* are very common.

The facies equivalent of the Sasino Formation may be the clayey complex of the Upper *Didymograptus* and *Dicellograptus* shales in Scania. In the other part of the area under discussion the Sasino Formation is represented be grey or dark-grey claystone with organodetritic laminations. In the Łeba area, the Sasino Formation is succeeded by marly limestones of the Kaszuby Formation. The deposits contain an admixture of terrigenous material consisting of grains of quartz and feldspar. The deposits of the *Normalograptus persculptus* Zone end the Ordovician in the westernmost part (the Lębork section) of the Łeba area.

Locally, the topmost part of the formation is the sandy limestone of the Kokoszki Member. In the other part of the Baltic Basin, the Kaszuby Formation begins with rust-coloured, brown or red-brown limestones, or claystones. In Västergötland such red deposits are represented by the mudstones of the Jonstorp Formation (Jaanusson, 1982). The facies is characterised by frequent *Hamarodus* and *Scabbardella* elements and valves of *Paterula, Hisingerella* and *Orbiculoidea*.

Locally stratigraphic gaps end the sedimentation of the Ordovician in the Polish part of the Baltic Basin.

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PLEISTOCENE STRATIGRAPHY OF NORTHEASTERN POLAND BASED ON RECENT DATA

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In the northeastern Poland the up to 282 m thick Quaternary sediments are underlain by rocks of Upper Cretaceous (Maastrichtian) age: gaizes, marls and marly limestones, and of Lower Palaeocene age: marly gaizes. Upper Palaeocene (*Turborotalia cerroazulensis* zone) glauconitic sands and sandstones only occur as thin patches (up to 18,0 m thick). The distribution of the Maastrichtian and Lower Palaeocene rocks is in general connected to the structural pattern of the crystalline basement.

Stratigraphy of the Pleistocene deposits in the northeastern Poland was established on the base of analyses of the older and new boreholes, palaeobotanical analyses and lithologic-petrographical investigations. There are 8 glacial horizons of the Narewian (Menapian), Nidanian, Sanian 1 (Elsterian 1), Sanian 2 (Elsterian 2), Liwiecian (Fühne), Odranian (Drenthe), Wartanian (Warthe) and Vistulian (Weichselian) glaciations. The stratigraphic data are now sufficient to distinguish in this area the glacial horizon of the oldest - Narevian (Menapian) Glaciation.

On the other hand, there are organic sediments of the Augustovian (Bavelian - Leerdam), Mazowian (Holstein), Zbójno (Dömnitz) and Eemian interglacials.

The oldest in Poland Augustovian Interglacial sediments were for the first time recognised in the borehole at Szczebra (Augustów Plain, NE Poland) and represent a vegetation succession with *Pinus* - *Betula* - *Larix* and *Picea* during the first climatic optimum (PAZ 3, 4, 5, 6, 7) and the maximum of *Quercus* - *Ulmus* - *Carpinus* (PAZ 9) and PAZ 10 *Pinus* - *Azolla* - *Picea* (*Azolla* - *Salvinia*) during the second climatic optimum.

The organogenic interglacial sediments are underlain by a till of the Narevian (Menapian) Glaciation, also recognised in superposition in Poland for the first time, and are overlain by the till of the Nidanian (Elsterian) Glaciation. The lithostratigraphy of the tills was established on the base of petrographic and lithologic studies.

During the Wisla (Vistulian) Glaciation (Nemunas Glaciation in Lithuania) the northeastern part of Poland was covered with a mantle of sediments and marginal features of two stadials: Swiecie which extent is contemporaneously of the maximum extent of the Wisla (Weichselian, Nemunas) Glaciation and Leszno - Pomeranian ones. In turn, the Leszno - Pomeranian Stadial marginal features are differentiated into one marginal, recessional phase (Pomorska) and three marginal oscillate - recessional subphases - Wigry, Hancza and Szeszupa ones.

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THE MIDDLE PLEISTOCENE FLORA FROM LĒTĪŽA RIVER VALLEY

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The sediments of the Latgale (Menapian), Lētīža (Elsterian), Pulvernieki (Holsteinian), Kurzeme (Saalian) and Latvia (Weichselian) formations are found in the outcrops and test drillings in the Lētīža River valley, south-western Latvia. This region is considered to be as stratotype area of Lētīža and Kurzeme formations. The stratotype and parastratotype sections of Pulvernieki Formation are located here. For the first time interglacial sediments were established at the Dēseles Lejnieki in 1925 (Galenieks, 1925). The above mentioned and other sections afterwards were investigated in details by A. Dreimanis (1947, 1949), V. Pērkons and K. Spriņģis (1960). During 60ties the investigations of the till lithology and palynological studies of the interglacial sediment were done (Spriņģis, Konshin & Savvaitovs 1964; Danilāns, Dzilna & Stelle 1969; Danilāns, 1966, 1973; *etc*). Data of the macroremains were scanty.

Reinvestigations of the till and interglacial sediments in this area were done in 80ties by Z. Meirons. A new borehole No.7 was drilled in the Pulvernieki stratotype area (Meirons & Ceriņa, 1986). Parallel to palynological studies (palynologist L. Kalniņa), macroremains were investigated in details in the mentioned section and also Jaunšķieri (Laugaļi) and Dēseles Lejnieki (Segliņš, 1987). Results obtained from the studies enable to make a detailed subdivision of the sediment stratigraphy and to correlate them with sediments of the equivalent age in other regions.

Yet, the new problems arise. The climatic optimum does not appear in the Pulvernieki section No.7 according to palynological data. After interval where pollen zones P2a and P2 are distinguished, obviously, the second part of the interglacial appears. By studies of macroremains there are 54 taxa determined. Extinct exotes *Aracites interglacialis*, *Caulinia goretskyi*, *Brasenia borysthenica* var. *nemenensis* characteristics for Lihvin (Holsteinian) Interglacial are found. The complexes of the plant macroremains are not changing considerably in vertical section. The presence of the warm demanding plant remains is found everywhere. Such uniformity of the plant composition could be explained by the formation of the sediments in the coastal zone of the basin.

There are several complexes of macroremains found in the Jaunšķieri and Dēseles Lejnieki sections, which indicate different stages of development of the basin and climatic changes during them. The remains of the subarctic flora: leaves of the *Dryas octopetala, Betula nana, Arctostaphylos uva-ursi* and *Potamogeton filiformis* are found in the grey clay and silt at the foot of both sections. The lake molluscs *Valvata trichoidea, V. depresa, V. antiqua, Euglesa scholtzi* (determined by H. Kessel and V. Tamm from Estonia and J. Starobogatov from St. Petersburg) are found in the Jaunšķieri section. This assemblage from the Jaunšķieri section corresponds to the palynological subzones P1a, P1b and P1c, but in the Dēseles Lejnieki section, to the lower part of zone P1. Sediments in this part of sections are divided as Lētīža (Elster) Late Glacial (marine analogue - Sudrabi Beds)

In result of the macroremains studies in the Dēseles Lejnieki section 17 plant taxa are found. Mostly they are concentrated in the silt, located above sediments containing subartic flora, and in the lower part of gyttja. The lake plants dominate. Six taxa of the genus *Potamogeton* and abundant *Eleocharis palustris* nuts have been found. The remains are strongly deformed, compressed and lot of them is not possible to determine up to species. There are no seeds found in the very dense gyttja, which according to pollen data corresponds to zones P2 and P3. Small number of less fossilised aquatic plant remains is found in the sediment layer above gyttja.

The dominance of the *Picea* seeds and needles, presence of the *Larix* seeds and needles, abundance of the *Betula alba* and *Rubus idaeus* nuts characterise plant macroremain complex from the silt, which overlay clay layer with subarctic plant remains. This macroremain complex indicates pre-optimum vegetation. The Characeae, *Najas marina* and *Caulinia goretskyi* have been found among aquatic plants.

Upper part of the peaty gyttja layers has formed, probably, during climatic optimum. The undamaged nuts of *Trapa*, megaspores of *Salvinia natans*, seeds of *Stratoides aloides*, *Nuphar luteum, Caldesia parnassifolia, Caulinia goretskyi, Aldrovanda* cf. *vesiculosa* are found here. Sandy silt rich in ostracode shells covers the gyttja layer, where *Potamogeton filiformis, Batrachium* and *Selaginella selaginoides* dominate.

Upward sediments become more sandy and contain pebbles of gyttja and silt. Content of the same macroremains as occurs in gyttja layer increases, obviously, as a result of redeposition. V. Stelle has found seeds of *Papaver mudicaule* in this part of section. According to previous investigations, these sediments are formed under subarctic conditions. Macroremains from this interval of section indicate that sediments have been formed in the coastal zone during new development stage of the palaeolake. Interpretation of the macroremain complex is different from current estimation of pollen data.

Described sediment layer does not contain diatom. They have been found in 6 samples from sediment interval 2.84-7.1 m, where the silt layer contains small pebbles and gravel laminas. M. Sakson (Estonia) studied diatom flora from these sediments. She found typical Lihvin Late Glacial diatom assemblage with *Stephanodiscus astraea* and *St. astraea+St. niagare.* The ancient taxa *Melosira islandica* f. *curvata, M. italica, M. granulata* are found in small numbers. According to M. Sakson, this sediment layer has been formed under conditions, when glacier already influenced development of the water and land vegetation.

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GLAUCONITE FROM LOWER CRETACEOUS AND CENOMANIAN SILICICLASTIC SEQUENCE OF SOUTH-EASTERN LITHUANIA: PALAEOENVIRONMENTAL SIGNIFICANCE

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The Albian and Cenomanian deposits in Lithuania are represented by glauconitic sands and silts. The Albian composes the basal portion of Cretaceous succession in Lithuania, sediments attaining 65 m in thickness, while the overlying Cenomanian deposits are 6-25 m thick. A content of glauconite in the Albian and Cenomanian sediments range in order of 10-35 per cent (Radzevičius, 1998).

Glauconite is a reliable indicator of depositional environment. The presence of glauconite implies low sedimentation rates, semi-confined marine basin and warm tropic climate. The later is in agreement to palaeoclimatic studies showing that the Middle Cretaceous was globally the warmest period of Phanerozoic. In south-eastern Lithuania sedimentation rates during Early Cretaceous ranged in order of 0.5-1 cm/Ka, which for glauconite sedimentation should be regarded as a moderate. Abundance of glauconite in the Lower Cretaceous and Cenomanian sediments persuades marine sedimentation environment and shallow bathimetry in Lithuania. Within the tropics sedimentation of glaucony takes place in present-day water depths of 15-60 m (Odin, 1988).

Glauconite was sampled from three different sites of south-eastern Lithuania, i.e. raft near Akmuo village, outcrop in the valley of Šventoji River and well N437 (Figure). Diffractometrical, trace and bulk chemical element analysis of glauconite grains were carried out in order to define their maturity. Intensity and rapidity of glauconitization depends upon the rate of granules burial, thus the maturity of glaucony indicates the sedimentation rates in the basin. Burial prior to the glaucony became mature preserve the immature state (Hugget & Gale, 1997). Additional important factors are composition of substrate and physiochemical (pH, Eh) properties (Amorosi & Centineo, 1997). Potassium content is regarded as an indicator of glauconite maturity. The sampled glauconite indicates rather persistent content of K_2O of 4.5-5.9 both in Lower Cretaceous and Cenomanian sediments (Table). Following the classification by Odin and Matter (1981), it points to the slightly evolved stage of glauconite formation (4-6%). The obtained abundance of the iron oxide of 17-20% is also characteristic for medium evolved glauconite. Just one sample from Šventoji outcrop is an exception showing 43% of iron oxide and depletion of K_2O up to 2.2%. Heat is related to weathering. Following the diffractometrical analysis, the studied glauconite is of mica structure, which also points out to quite high degree of evolution of the glauconite. Glauconitization starts from a K-poor glauconitic smectite which progressively evolves to a K-reach glauconitic mica (Amorosi, 1997). Just some samples exposed to weathering (Šventoji outcrop) show illite portion due to epigenetic processes.

Following the diffractometrical and chemical analysis, the glauconite from the Lower Cretaceous and Cenomanian sediments of SE Lithuania is classified as slightly mature. It agrees well with calculated sedimentation rates of 0.5-1 cm/Ka, i.e. the several decimetres burial stage (uptake of Fe and K is confined to just several decades of near-surface interval) is in order of 10^4 years typical for slightly evolved glauconite.

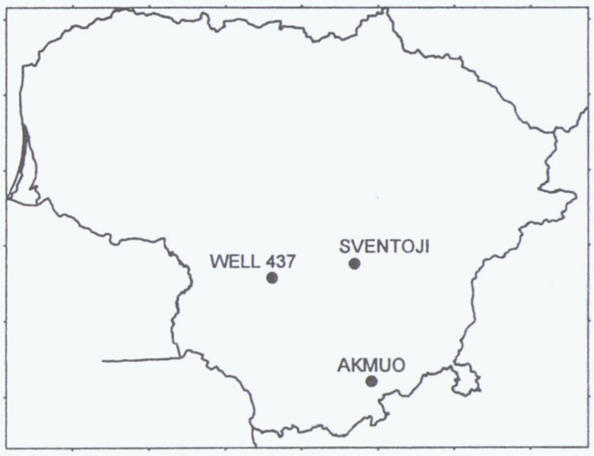

Figure. Sampling sites

Table. Chemical composition of glauconites from Lower Cretaceous and Cenomanian sediments of South – Eastern Lithuania

Sampling side	Samples	H_2O	KN	SiO_2	FeO	Fe_2O_3	Al_2O_3	TiO_3	CaO	MgO	K_2O	Na_2O	MnO
Šventoji outcrop	average glauconite	3.31	6.14	49.98	1.68	16.60	8.92	0.40	4.88	2.70	5.06	0.24	0.023
	light green glauconite	1.88	5.20	68.00	3.84	3.02	10.45	0.90	1.44	1.74	4.40	1.20	0.03
	ferriferous with pyrite glauconite	0.92	19.50	24.69	8.64	34.00	7.70	0.50	1.28	0.77	2.20	0.30	0.25
Akmuo raft	average glauconite	5.20	5.08	51.98	3.26	12.30	7.14	0.08	10.02	3.47	5.80	0.20	0.10
Janukiškes-437 well 10928	average glauconite	6.41	4.20	55.0	0.96	19.20	10.05	0.74	1.11	4.01	4.50	0.30	0.07
10929	average glauconite	6.40	4.96	55.50	1.68	16.25	10.54	0.60	1.11	4.07	5.10	0.30	0.04
10930	average glauconite	5.10	4.64	54.80	3.12	15.00	10.79	0.74	1.11	3.47	5.90	0.30	0.10

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EARLY MIDDLE PLEISTOCENE INTERGLACIAL: DEVELOPMENT STAGES AND UNIFICATION OF POLLEN ZONES IN THE BALTIC STATES AND POLAND

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Development of the Eemian and Holsteinian Interglacial is well studied and their history is certain. Pollen assemblage zones of these interglacials are satisfactory determined and basically unified for the region. Regarding the oldest interglacials they are more complicated and are of the most poorly known in Quaternary. Reason for that is the infrequent occurrence of oldest interglacial sediments and their extremely fragmentary character. In the European part, that includes the Baltic States and Poland, there are only two sites where sediment sequence of the early Middle Pleistocene reflecting records of all or almost all development stages of interglacials are found.

In the south-eastern Latvia the early Middle Pleistocene Interglacial sediments were found in 1961 at Žīdiņi site. The obtained sediment core II was thoroughly investigated. Published results of the investigations (Danilāns, Dzilna & Stelle, 1964) demonstrate the evidence of a 'double' interglacial with two vegetation climaxes, each showing development of temperate mixed deciduous forest, representing a climatic optimum, separated by a cooler, even cold conditions with taiga and tundra vegetation. In the pollen diagram the lower climatic optimum is characterised by the pollen spectra indicating high content of *Quercus, Ulmus*, notably of *Corylus* and absence of *Carpinus,* but the upper one, in opposite, demonstrate clearly expressed *Carpinus* pollen curve and a small presence of *Corylus* pollen.

The pollen spectra from the lake sediments of core II indicate an interglacial conditions and quite different vegetation sequence in comparison with all that time (1964) already known pollen sequences of studied Eemian (Felicianova) and Holsteinian (Pulvernieki) interglacial sediments in Latvia. Besides, the studied lake sediments were covered by the three different till horizons. The researchers considered all the mentioned preconditions and found the sediment sequence in the Žīdiņi section as formation of a new interglacial and named it as Žīdiņi Interglacial. The geological age of interglacial was correlated with that of Günz-Mindel Interglacial according to Alpine scheme. Reinterpretation of that material (Danilāns, 1973, Kondratiene, 1996) and also data from new sediment core 43, carried out in 1976 (Kalniņa, Juškēvics & Segliņš, 1995; Kalniņa, 1995, 1996) and core 570, carried out in 1979 (Kondratiene, Hursēvič & Loginov, 1985) generally agree to the main features and peculiarities of the Žīdiņi Interglacial development stages established in the previous investigations (Danilāns, 1997, 1999).

Other site of the early Middle Pleistocene Interglacial, in the area discussed here, is Ferdynandów in the Middle Poland, which was discovered in 1960 during investigation of brown coal deposits. Additionally, three cores - A, B, C, were taken in 1963 there. However, interpretation of the age of these interglacial sediments varied and was different before publishing of the palynological results of Z. Janczyk-Kopikowa (1975). Although Ferdynandovian Interglacial have been obtained from quite a large number of sites in Poland (Rzechowski, 1996), the most complete section is only Ferdynandów B, where all interglacial development stages were recorded in the sediments. Rzechowski (1996) published the latest overview regarding the investigations of Ferdynandovian Interglacial sediments including publication list of early Middle Pleistocene studies in Poland. Totally in the overview 10 palynologically investigated cores of the Ferdynandovian Interglacial sediments from different sites of the Middle Poland were described, and nine from them contain sediments corresponding only to some of the interglacial fragments. From them to the Szczebra site from north-eastern Poland (Ber, 1996; Janczyk-Kopikowa, 1996) could be point out, which by

Table. Development stages of the Žīdiņi Interglacial and the correlation of their pollen assemblage zones (PAZ) in the Baltic region.

Characteristics of vegetation and climate according pollen data during different development stages of Žīdiņi Interglacial	PAZ of section II	PAZ of section 43	PAZ of section570	PAZ of section Kudre-915	PAZ of section Vaitkūnai-914	PAZ of section Ferdynandów B	Proposals for unified PAZ of region
Significant deterioration of the climate, increase of herb pollen, dominance of *Betula* and presence of *Selaginella,* tundra vegetation	7 (8)	*LK XII a, b	**OK X	***T 9?	-	****F 11	Ž 8?
Last amelioration of the climate, wide spreading of *Pinus* forest with admixture of deciduous trees	6 (7)	LK XI a, b, c	OK IX	T 8 a, b, c	-	F 10	Ž 7
Deterioration of the climate, increase of herb pollen, dominance of *Betula* and *Pinus*	5 (6)	LK X a, b	OK VIII upper part	T 7 a,b	-	F 9	Ž 6
Development of the *Pinus* forest, with expressed *Betula* dominance in the middle of the interval, taiga vegetation	4 (5)	LK IX a, b	OK VIII lower part	T 6, T 5	T 5	F 8	Ž 5
Second climatic optimum, well expressed *Carpinus* pollen curve and low amount of *Corylus,* expansion of temperate trees	3 (4)	LK VIII	OK VII	T 4, T 3	T 4, T 3	F 7	Ž 4
Cool climate, sediments contain *Betula nana* pollen, *Selaginella* spores and significant amount of herb pollen, expansion of forest-tundra vegetation	2 (3)	LK VII a, b; LK VI, LK V, LK IV	OK VI, OK V OK IV, OK III	T 2, T 1	T 2, T 1 a, b, c, d	F 6, F 5	Ž 3
Lower climatic optimum, high content of *Corylus*, absence of *Carpinus*, spreading of *Quercetum mixtum* forest	1 (2)	LK III a, b	OK II	-	-	F 4, F 3, F 2 upper part	Ž 2
Gradual amelioration of climate, starting of the forest development, dominance of *Pinus*	-	LK II b	-	-	-	F 2 lower part	Ž 1
Latgale (Menapian) Late Glacial, pollen of pioneer plants indicate open landscape	(1)	LK II a, LK I a, b, c	OK I	-	-	F 1	Ž 0

* LK- Pollen assemblage zones (PAZ) according to palynologist Laimdota Kalniņa

** OK- Pollen assemblage zones according to palynologist Ona Kondratiene

*** T- Pollen assemblage zones of Turgeliai Interglacial, analogue of Žīdiņi Interglacial in Lithuania (according to O. Kondratiene, 1996)

**** F- Pollen assemblage zones of Ferdynandów Interglacial, analogue of Žīdiņi Interglacial in Poland (according to Z. Janczyk-Kopikowa, 1975, Rzechowski, 1996) mentioned authors are interpreted older that Ferdynandovian. However, in accordance with the pollen characteristics of this site, probably, it corresponds to the upper climatic optimum of the Ferdynandovian Interglacial.

Altogether, the data from the investigation of the Žīdiņi and Ferdynandovian sections are sufficient base to make unification of the pollen assemblage zones and development stages in the region. For proposal see in 1. Table.

The sediments from Kudre-915 and Vaikunai-914 studied in Lithuania by O. Kondratene (1996) were correlated with that from Žīdiņi (Ferdynandovian) Interglacial. Unfortunately, no complete interglacial sequence was recorded in the sediments of these sections. Due to the very different stratigraphical interpretation of the sediment sequence from the sections of Belarus (Nizhninsky Rov) and Smolensk Region of the Russia it is complicated to correlate them with Žīdiņi (Ferdynandovian) Interglacial. Reinterpretation and revaluation of the investigation data is necessary.

Eastern England and the Netherlands are regarded as classic areas for the early Middle Pleistocene stratigraphy, but as the key sections are extremely fragmentary (Turner, 1996), it is difficult to correlate them with the Žīdiņi and Ferdynandovian Interglacial sections. Several early Middle Pleistocene sites have been known for a long time from Germany, but there are only few sites which might be correlated with Žīdiņi Interglacial. The pollen data and sediment characteristics of Bilshausen section suggest that two periods of temperate vegetation are separated by a very short interval, when temperate trees quite suddenly were replaced temporally by *Pinus* and *Betula*, and provide vegetation comparable with Žīdiņi Interglacial.

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STRATIGRAPHY AND GEOCHRONOLOGY OF LAST GLACIAL IN LITHUANIA

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The stratigraphic subdivision of the Quaternary in Lithuania is based on climatostratigraphic principles: on its characteristic long-term phases (cold levels - glacials and warm levels - interglacials). During the last megaglacial there were many lasting deteriorations and ameliorations of climate which should be recognised as stadials and interstadials with the phasials and interphasials (Stankowski, 1995).

The last interglacial (Merkinė, Eemian) and the last glacial (Nemunas, Weichselian) together form a whole macrocycle in the system of climatic rhythms of the Pleistocene in Lithuania. There are three stages of Nemunas (Vistulian=Weichselian) glaciation: Early (70-60 thousand years), Middle (60-30 kyrs) and Late (30-10 kyrs). The glacial activity was different at each stadial stage: Varduva (70-65 thousand years), Bičiai (50-45 kyrs) and main glacial advance (25-15 kyrs). These stadials were separated by interstadial warming of the climate: Rokai - before 60-50 kyrs, Biržai - 45-30 kyrs and Pavytė - 18-17 kyrs (Table).

Table. Division of Nemunas stage

Glacial stage	Substage	Age kyrs		Stadials	Age kyrs	Interstadials
				Baltija	15.3	
					17.5	
						Pavytė
			Main		18.6	
				Žiogeliai		
NEMUNAS	Late		glacial	(phasial)	19.7	
					20.5	
			advance	Grūda		
or					25	
Vistulian		30				
or						Biržai
Weichselian	Middle			Bičai	45	
or						Rokai
Valdaian		60				Jonionys II
	Early			Varduva		Jonionys I
		70				

Evidently, the ice sheet did not penetrate into the south-eastern Lithuania region during the Early and Middle Nemunas interval of time. Ice-free intervals at the Early and Middle of the Nemunas were identified in many sites of West and East Europe, where the last glaciation maximum took place between 25,000 and 12,000 BP. In Lithuania lithological research led to the recognition of two independent Late Nemunas Grūda and Baltija till horizons, which were correlated with the Brandenburgian and Pomeranian glacial stadials. The last Nemunas inland ice reached the south-eastern Lithuania for a limited number thousand years from 23,000 to

15,000 BP. The data already obtained from the study of the Medininkai section (borehole 117A) located in south-eastern Lithuania confirm the absence of an ice sheet in this region during the Early, Middle and Late Nemunas (Gaigalas & Satkūnas, 1996). The deposits of the Nemunas glacial maximum are not of glacial origin and are presented by periglacial sediments - limnoglacial silt and clay (25,000 - 15,000 years BP). This silt and clay was formed in aquatic conditions under the influence of melting ice water of Late Nemunas (Grūda and Baltija stadials). The glacial sediments in the coverage of the Late Pleistocene in south-eastern Lithuania have not yet been detected. The south-eastern part of Lithuania was not covered by continental ice of either the Grūda or Baltija stadials of the Late Nemunas glacial. Radiocarbon datings have confirmed the conclusions received by palynological research (Kondratienė, 1996). There were more palynological data indicating the presence of organic sediments of the Merkinė interglacial, lying on the surface of relief not covered by the sediments of Late Pleistocene. The petrographical composition of the till of the Grūda stadial of Nemunas glacial indicate a Central Swedish source for erratic boulders and material (Gaigalas, 1995). The Grūda till was enriched with Mesozoic sedimentary rocks. Apart from Mesozoic marl clasts, this till is rich in crystalline rock from Central Sweden, the Åland Island and the Baltic sea floor. The Grūda ice sheet moved therefore from north-west to south-east. During retreat a minor readvance, the Žiogeliai phasial, occurred. The Baltija till deposited by the stadial glacial advance notably contains increased frequencies of dolostones derived from the Devonian rocks of the East Baltic region. The direction of this ice movement varied regionally and was apparently controlled by topography. The inland ice of the Baltija stadial transgressed the area of Lithuania in three distinct lobes: West-Lithuanian, Central-Lithuanian and East-Lithuanian. The glacial deposits of each of the three lobes differ in the petrographic composition of the erratics of crystalline rocks and clasts of sedimentary rocks. However, the main mass of the ice moved from north to south over East Baltic Palaeozoic rocks. The till of Baltija stadial has specific association of Palaeozoic sedimentary rocks and crystalline rocks from South Finland. Retreating and recessing for some times the glacier of Baltija stadial has left its phasial tills, which are distributed by tracks of East-Lithuanian, South-Lithuanian, Middle-Lithuanian and North-Lithuanian phasial tills on the surface of Lithuania. The phasial tills are spread locally, in recession zones of phasial glaciers, so their full lithostratigraphical sequence may be revealed only by carrying out successive investigation and correlation of Baltija tills on whole area of Lithuania.

The maximum of Baltija stadial is called the East-Lithuanian phasial. In the next zone of the South-Lithuanian recessional phase the three oscillational branches of end moraines are found. Immediately after the each retreat of the ice sheet, vast areas of the Lithuania in interphasials were covered with big ice-dammed lakes. The peculiar conditions came to dominate in this area. At present in Lithuania some basins of glaciolacustrine clay of dammed periglacial lakes are established. Water of periglacial lakes was dammed near the edge of recessing glacier every time. Varvometric measurements of varved clays from these periglacial lakes enable to determine geochronology of recessions of glacier, varved clay sequence and peculiarities of glaciolacustrine sedimentation (Gaigalas & Kazakauskas, 1997). Geochronometric counts of varved clay bands of phasials, oscillations and facial complexes, separated by stratigraphical boundaries of different categories, enable us to evaluate duration of recessions and oscillations, progressive, stable and regressive state of glacier of Baltija stadial.

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ENVIRONMENTAL RECORD (SEDIMENTOLOGICAL, GEOCHEMICAL AND ISOTOPIC) FROM THE LOWER-MIDDLE TRIASSIC SEQUENCE OF THE WESTERN PERIBALTIC SYNECLISE (NORTHERN POLAND)

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Clastic deposits cored in the western part of the Peribaltic Syneclise area represent the early (Middle Buntsandstein; Malbork and Elblag Formations) and middle (Lower Muschelkalk; Frombork Formation) Triassic age. They record an environmental interplay of nearshore marine and inland facies. Structural, textural and geochemical (borium content) data enabled distinction of five facial assemblages: [I] marine lagoon, [II] brackish basin/pan, [III] coastal plain, [IV] meandering river and [V] lacustrine.

Vertical and lateral succession of these facies indicated that the most of Buntsandstein section has developed within the coastal-deltaic sedimentary environments, with maximum marine influxes (thick lagoon facies) during Upper Buntsandstein/Röt (Elblag Formation). They contain carbonate (calcite) interbeds, caliche horizons, and both vadose and phreatic early to late diagenetic cements forming numerous layers. The carbonate fraction is characterised by $\delta^{18}O$ from -1.08 to -8.89‰ and $\delta^{13}C$ from -1.53 to -10.28‰. Both diagenetic and geochemical features of the series support marine influences within a generally continental succession.

All facial, petrologic and geochemical data indicated that climate was warm, seasonally humid, and whole studied Triassic sequence have formed generally in continental conditions (coastal plain and meandering river) with local marine influxes. These influxes register the most NE extent of late Buntsandstein epicontinental sea, which invaded onto Poland area from the south (Dadlez *et al.*, 1998).

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POLLEN STRATIGRAPHY OF THE PLEISTOCENE IN UKRAINE

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The Pleistocene in Ukraine is subdivided into 18 stratigraphical units (Veklitch *et al.*, 1993). The general palynological characteristics of the stratigraphic horizons of the Ukrainian

Stratigraphical Framework have been provided by Turlo (1982, 1986) and Atryushenko (1970). They demonstrated the alternation of forest and forest-steppe vegetation (warm palaeosol units) with steppe vegetation (cold loess units). The present study shows the vegetational successions typical for different stratigraphical units of the Ukrainian Pleistocene within western, northern and eastern parts of Ukraine.

The Lower Pleistocene (below Brunhes/Matuyama boundary) includes three cold loess and three warm soil units. Loess units were characterised by boreal *Pinus* and *Betula-Pinus* parklands in the northern regions, those with admixture of *Abies* and *Picea* in the western regions and by xero-mesophilic steppe in eastern regions. The upper parts of units show more xerophilic vegetation types, up to steppe in the northern part and xeric steppe in the eastern part of Ukraine. The middle part of the oldest Berezan horizon is characterised by the more mesophilic and thermophilic vegetation, which corresponds to the palaeosol of a temperate climate, embedded in the loess unit. The typical feature of Lower Pleistocene loess units is a presence of a few broad-leaved species and Tertiary relics in the pollen spectra.

The Lower Pleistocene warm palaeosol units are noticeable for complicated vegetation history: in each of them, two warm subunits with forest or subtropical parkland ecotones are separated by more cool and dry time span with boreal forest-steppe or mesophilic steppe vegetation. The lower subunit of the oldest Kryzhanivka horizon in its climatic optimum is characterised by less mesophilic vegetation (*Quercus, Tilia-Ulmus-Quercus* and *Carpinus-Quercus* forests), whereas the optimum of the upper subunit - by more mesophilic one (in corresponding regions by *Quercus-Carpinus*, *Tilia-Carpinus* and *Fagus-Carpinus* forests). The lower subunits of the Shyrokyno and Martonosha horizons are distinct with more mesophilic vegetation, comparing with the upper subunits. For instance, in the western and northern regions, *Abies-Picea*, *Picea-Carpinus* and pure *Carpinus* forests (the climatic optima) were typical for the lower subunit, whereas polydominant broad-leaved forests and even broad-leaved forest-steppe - for the upper subunit of the Shyrokyno horizon. The characteristic feature of Lower Pleistocene warm palaeosol units is an admixture of Tertiary relics. *Celtis, Ostrya, Nyssa, Carya* and *Castanea* disappear from pollen spectra of the younger Pleistocene units. The richest composition of Tertiary relics is typical for the Kryzhanivka unit, the highest share and most significant advance to the east of *Abies* for the Shyrokyno unit, the most diverse floristic composition for the Martonosha unit.

The Middle Pleistocene in Ukraine includes two warm and three cold units. The last Dnieper unit corresponds to the Saale glaciation of Western Europe. The older Sula and Tiligul loess units still include a few broad-leaved species in their lower part, especially at the level of embryonic soils, whereas their upper parts are characterised by more xerophilic vegetational types. The Sula unit shows the first appearance of steppe vegetation in the western regions of Ukraine and of xeric steppe - in the northern regions. The Tiligul unit is marked by the first appearance of periglacial vegetation (*Betula* sect. *Nanae et Fruticosae* and *Alnaster*) in the northern part of Ukraine. At the Dnieper stage, periglacial steppes and forest-steppe occupied much larger areas.

The Middle Pleistocene Lubny and Zavadivka warm palaeosol units show complicated vegetational successions with broad-leaved-coniferous forests at the initial phases, broad-leaved forests with predominance of *Carpinus* (pure *Carpinus* forest in the western regions) at the optimal stages, the second increase of coniferous and a spread of meadow steppe at the final stages. In the western regions, at the Zavadivka stage, two phases of *Carpinus* were separated by the phase of polydominant broad-leaved forest. In the eastern region, at the Lubny stage, a phase of mesophilic steppe separated two climatic optima of forest and forest-steppe vegetation. Zavadivka unit is the last one characterised by a presence of Tertiary relics. By Sirenko and Turlo (1986), *Pterocarya*, *Rhus* and *Morus* still exist in the floristic composition, whereas pollen of *Juglans* is rather typical for the Lubny unit.

The Upper Pleistocene consists in Ukrainian Stratigraphical Framework of three warm and three cold loess units. The Kaydaky-Pryluky palaeosol unit shows the typical vegetation successions of the Eemian interglacial, though with much higher share of non-arboreal pollen in the eastern part of Ukraine. In the western regions of Ukraine, *Ilex* and *Hedera* were present at the climatic optima (Sirenko & Turlo, 1986), in the southern regions - *Juglans*. The Vytachiv palaeosol unit (possible equivalent of the Early Weichselian interstadial) represents the alternation of forest and forest-steppe subunits with steppe and cold forest-steppe subunits.

Polydominant forest composition, presence of *Picea* and absence of *Abies* are typical. In the northern and eastern regions a rather high share of *Tilia* is observed at the upper part of the unit. Vytachiv unit is the last one in the Pleistocene with noticeable portion of broad-leaved species.

The Dofinivka unit is subdivided by a subunit with periglacial steppe vegetation into two subunits with light forest and forest-steppe ecotones, the lower one shows the warmer and wetter conditions. The Dofinivka palaeosol unit is distinguished by a high content of *Betula* and almost permanent presence of *Betula* sect. *Nanae et Fruticosae*, especially in the upper subunit. On the contrary, broad-leaved species are rather few, if any. In the northern and eastern regions, the upper subunit is noticeable by a large amount of *Artemisia*.

The loess units of the Upper Pleistocene are characterised by periglacial forest-steppe and steppe spectra in the western and northern parts of Ukraine, whereas by spectra of xeric steppe in the eastern Ukraine. There, the fragments of periglacial vegetation have been distinguished only for the last Prychernomorsk loess unit. The older Uday loess unit (Early Weichselian) is distinct with the more mesophilic vegetation, especially in its lower part. For the western Ukraine, the presence of *Abies* is indicative. During the next loess Bug stage, in the northern Ukraine, periglacial Gramineae steppe were replaced for 4 times by meadow steppes, with few *Picea* and even *Corylus*. A typical feature of the last Prychernomorsk loess stage is an abundance of *Artemisia* and shrub *Betula*. The Ukrainian equivalents of Bølling and Allerød interstadials are distinguished by pollen data at the upper part of the Prychernomorsk loess, showing higher content of arboreal and mesophilic herbaceous pollen, presence of *Picea* and few broad-leaved species.

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LITHUANIAN STRATIGRAPHIC GUIDE: A CONCEPT AND IMPLEMENTATION

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A concept of Lithuanian Stratigraphic Guide is based upon the requirements of the international stratigraphic rules (1, 2). The hierarchy of stratigraphic units is now under discussion by the Project Working Group and the Lithuanian Stratigraphic Commission. In the part of the principal unit-terms the main proposal has been considered as follows:

Stratigraphic Categories Stratigrafinės kategorijos	Principal Stratigraphic Unit-terms	Pagrindiniai stratigrafinių padalinių pavadinimai
Lithostratigraphic Litostratigrafiniai	Group Formation Member Bed Flow	Serija Svita Pluoštas Sluoksnis Srautas
Unconformity-bounded Sekvenciniai	Synthem	Sintema
Biostratigraphic Biostratigrafiniai	Biozones: Range zones Interval zones Lineage zones Assemblage zones Abundance zones Other kinds of biozones	Biozonos: Paplitimo zonos Intervalo zonos Filogenetinės zonos Bendrijų zonos Gausos zonos Kitos biozonų rūšys
Magnetostratigraphic polarity Magnetostratigrafinio poliariškumo	Polarity zone Poliariškumo zona	
Other (informal) stratigraphic categories Kitos (neformalios) stratigrafinės kategorijos	- zone (with appropriate prefix) - zona (su atitinkamu priešdėliu)	
Chronostratigraphic Chronostratigrafiniai	Eonothema Erathem System Series Stage Substage Chronozone	Eonotema Eratema Sistema Skyrius Aukštas Poaukštis Chronozona

Regarding regional unit-terms a Regional Stage (- Stage with appropriate local geographic name) has been approved instead of former widely used unit-term "Horizon".

The unit-terms for the Quaternary stratigraphy have been distinguished taking into account a wide experience of the stratigraphers of the Baltic States. The main principle in subdividing the Quaternary is based upon the climatostratigraphy concept. The hierarchy of climatostratigraphic unit-terms is still under discussion.

The Lithuanian Stratigraphic Guide is planned to be completed until the end of 1999 and published in 2000, on the occasion of the XXXI International Geological Congress in Rio de Janeiro, Brazil, August 2000. The Guide will be supplied by An Abridged Version of the International Stratigraphic Guide, and Glossary of Stratigraphic Terms.

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SCLERACTINIAN CORALS IN THE UPPER JURASSIC OF LITHUANIA

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Fossil corals are rather rare in the Upper Jurassic of Lithuania. Four coral taxa have been distinguished in the Oxfordian in the borehole Šaukliai-12 (drilled by LGS in 1998), within the white or dark-grey weathered limestone sequence from the depth of 82.5m up to 90.0 m. The following species have been determined: *Isastrea* cf. *crassa* (Goldfuss, 1826), *Fungiastraea arachnoides* (Parkinson, 1808), and *Thamnasteria concinna* (Goldfuss, 1826); one taxon remains undetermined and represents a probable montlivaltiid coral preserved exclusively in the form of cast. With the exception of a ramose montlivaltiid coral, other skeletons are lamellate.

In the lower part of the sequence (82.5 m-83.3 m), in a dark-grey rock with abundant bioclasts of a sand fraction, thin lamellate *T. concinna* and *F. arachnoides* may be observed in their growth position. Their skeletons preserved in aragonitic mineralogy are strongly weathered, the structural elements known as trabeculae being decomposed into isolated aragonitic fibres. As a result, extremely fragile skeletons may be completely dissolved by underground water, what ends with formation of natural casts of their surfaces. The whole assemblage of this part of the sequence contains *T. concinna, F. arachnoides, I.* cf. *crassa* and an indetermined montlivaltiid.

In the remaining part of the sequence, *I.* cf. *crassa* prevails, associated at the depth of 85.5 m only with F. *arachnoides*. The skeletons are solid, but the details of their microstructure are nearly completely obliterated by the calcitic recrystallization. The whole assemblage reminds this from the Middle Oxfordian of the margins of the Holy Cross Mts (Góry Swiętokrzyskie) in the central Poland. However, the corals considered here show rather large stratigraphic extent and may be found also in the Kimmeridgian.

Lamellate shapes of colonies shown by three taxa dominating the sequence are indicative of a low hydrodynamics of water in the environment where corals lived.

HALJALA STAGE – A NEW UNIT IN THE ORDOVICIAN CHRONOSTRATIGRAPHY OF BALTOSCANDIA

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The interval under discussion is well-known in the stratigraphical charts of the East Baltic as the Idavere and Jõhvi stages comprising the sequence from the upper boundary of the early

Caradoc Kukruse Stage up to the base of the thickest K-bentonite bed on the lower boundary of the Keila Stage. Jaanusson (1995) proposed to include these units as substages into a new Haljala Stage. The main motivation for the proposal was the difficulties with the recognition of the boundary between the Idavere and Jõhvi stages outside the Estonian confacies belt. The boundary interval of these units is represented by lithologically similar rocks in northern and central East Baltic (Kahula and Adze formations). The thickest and lithologically more differentiated Idavere–Jõhvi rocks occur in the NW part of Russia (Gryazno, Shundorovo and Khrevitsa formations) and also in southern East Baltic (Resheniya..., 1978).

The uniqueness of the Idavere–Jõhvi interval compared to the preceding and succeeding ones lies in relative stability or continuity of environmental changes in the conditions of sea level high stand. The rarity of discontinuity surfaces, lithological similarity of deposits and indistinct levels of faunal changes in the limits of one confacies belt and essential differences between the confacies belts complicate the determination of the boundary between the former Idavere and Jõhvi stages all over the Baltoscandia. The lower part of the Haljala Stage, including its lower boundary, is well characterized by chitinozoans (Nõlvak & Grahn, 1993), but the Idavere–Jõhvi boundary coincides neither with the boundary of zonal chitinozoans nor with that of conodonts which have an advantage over benthic shelly fauna in stratigraphic work.

The Figure shows the Idavere–Jõhvi interval in North Estonia, West Latvia and NW Russia. In all studied sections the lower boundary of the Idavere Substage is well defined by the appearance of zonal chitinozoans and in several sections by the disappearance of Kukruse graptolites. At that, the zonal chitinozoan *Lagenochitina dalbyensis* is distributed in the whole region, but the oldest Idavere chitinozoans (*Armoricochitina granulifera* and *Angochitina curvata*) and the corresponding strata occur mainly in the offshore facies. The N–S profile (Peetri – Kandava-25) shows a remarkable decrease in the thickness of the studied units. This is associated with the replacement of North Estonian type of shelly fauna by a specific one characterising the central part of the basin. The sections on the W–E profile (Savala – core No 111) demonstrate an eastward increase in thickness and the distribution of generally similar faunas. The identified fauna, including ostracodes and some other microfossils, together with the K-bentonite beds allow us to correlate the Estonian and Russian sections rather well. However, it appeared that in some sections the boundaries of identified units, stages and substages do not coincide with the boundaries of the lithostratigraphic units (Gryazno, Shundorovo and Khrevitsa formations) accepted in Russia. The units defined mainly by associations of macrofauna, seem also to have a shift in time determined by environmental changes. Comparison of the East Baltic data with those from Scandinavia and other parts of the East European Platform allows to conclude that the Haljala Stage could be accepted as a regional unit which is represented by sequence formed at the transition from dominantly transgressive to regressive conditions. This interval presents a distinct epoch in the evolution of the Baltoscandian basin.

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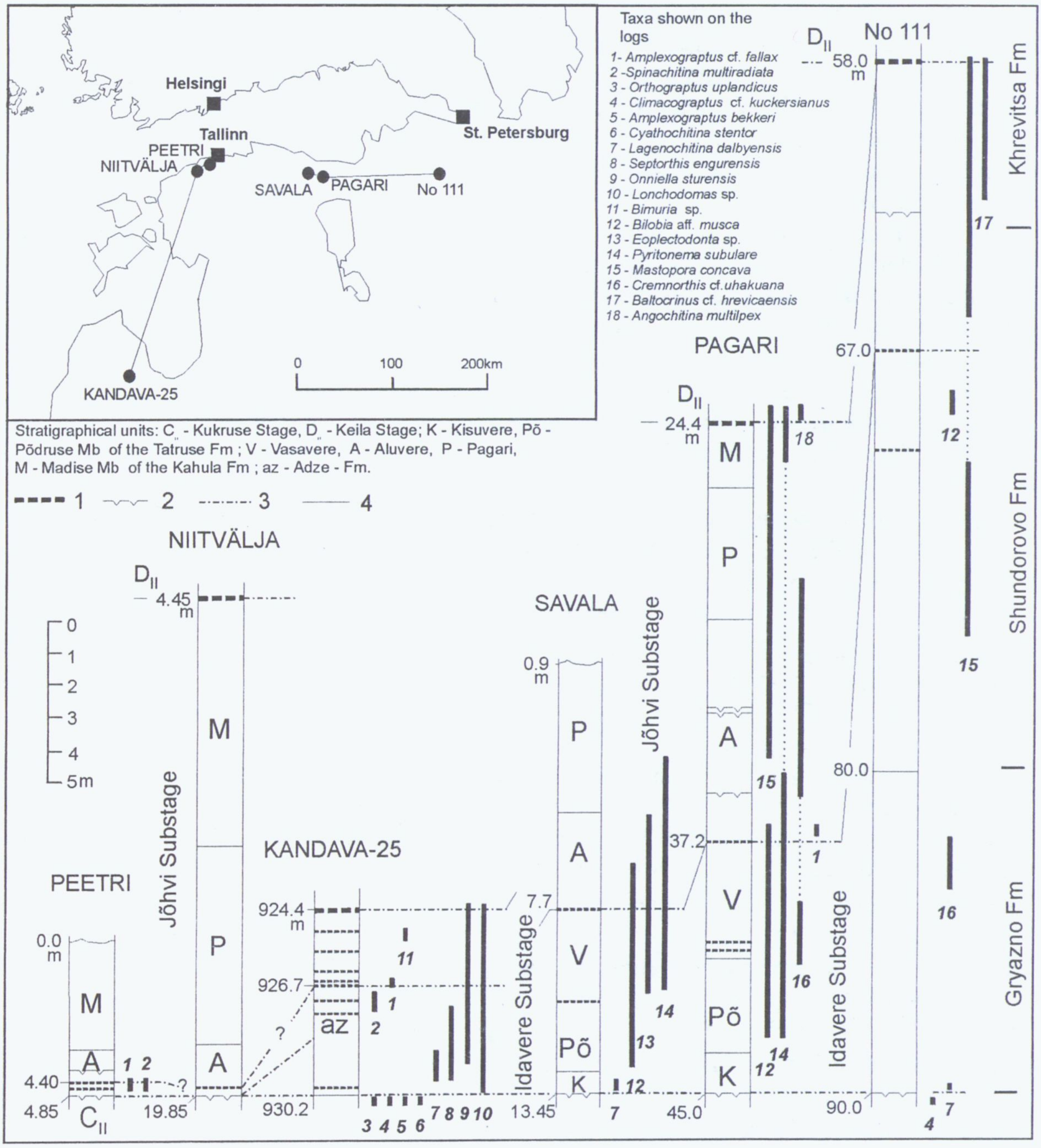

Figure. Correlation of sections and ranges of selected fossils (by Männil, 1976; Nõlvak & Grahn, 1993, Põlma *et al.*, 1988, and new data) in the Haljala Stage. 1, K-bentonite; 2, discontinuity surface; 3, boundary between stages and substages; 4, boundary between members.

PROPOSAL FOR THE BOUNDARY-STRATOTYPE OF THE KEILA REGIONAL STAGE (UPPER ORDOVICIAN)

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The Ordovician stratigraphy has a remarkably long history of studies in Estonia. This has resulted in a detailed chronostratigraphical scheme, which has served as the standard for a large area on the East European Platform, and in Scandinavia. In recent years the lower and upper boundaries of the Ordovician System have been approved and steps are being taken towards the global chronostratigraphic scheme of the Ordovician (Webby, 1998). Moreover, revision of the regional Ordovician stratigraphy has been started in several areas (e.g., Fortey *at al.*, 1995). In this connection there arises the need for the modernization of the concepts Estonian chronostratigraphic units are based on. Since the lower boundary-stratotypes are the only way for unambiguously defining chronostratigraphic units (see Salvador, 1994), it is essential to provide appropriate boundary-stratotypes for those units which so far are based on unit- rather than specifically designated boundary-stratotypes.

The Keila Stage, originally introduced as the "Kegelsche Schicht" by Schmidt (1881) on the basis of distinct macrofauna, has been rather uniformly understood. Since Jaanusson and Martna (1948) the lower boundary of the stage has been bound to the thickest K-bentonite (metabentonite) bed in Baltoscandia, and since Männil (1958) it has commonly been viewed as the base of this bed. This K-bentonite, recently named the Kinnekulle K-bentonite (Bergström *et al.*, 1995; previously known also as "bed XXII", "bed d", "main metabentonite" and "the Big Bentonite") enabled Männil (1966) to extend the name Keila to Scandinavia.

The original (denominative) type section of the stage is located in an old quarry near the town of Keila, North Estonia. In that section, limestones crop out in a thickness of approximately 2.0 m, but the Kinnekulle K-bentonite is about 10 m in subsurface, as revealed by drill core data (Põlma *et al.*, 1988).

The Munalaskme and Keila drill cores, which have been chosen as additional type sections, the hypostratotypes, of the Keila Stage (Rõõmusoks, 1970, Põlma *et al.*, 1988), contain the mentioned K-bentonite. However, these sections convey the concept of the content of the unit rather than the boundary, and neither of them was designated as the lower boundary-stratotype. This enables us to propose a specific boundary-stratotype without conflicting with earlier authors and without the need to change anything in practice, yet the concept of the Keila Stage would in this case agree with the recommendations of the International Stratigraphic Guide.

The type locality of the lower boundary of the Keila Stage proposed herein be at Pääsküla hillock, south of Tallinn, North Estonia, where the composite section of limestones of the Kahula Formation is more than 10 m thick. The Kinnekulle K-bentonite Bed crops out in subsurface tunnels, extending horizontally for about 900 m in an east–west and about 1100 m in a north–south direction. The exact stratotype section is located in the subsurface tunnel near the entrance to the shelter No. 4 (see Fig. 1 in Hints *et al.*, 1997); the approximate geographical co-ordinates of it are $59^0$20'30" N and $24^0$38'00" E. The lower boundary of the Keila Stage in this section is defined as the base of the approximately 30 cm thick Kinnekulle K-bentonite Bed.

The main advantages of the above locality and section can be summarised as follows. (1) In case of an outcrop, the material for study is not limited, as it would be in case of a drill core. (2) The section is rich in various well-preserved macro- and microfossils (including brachiopods, trilobites, graptolites, chitinozoans *etc.*), and rather extensively collected. (3) It provides the largest vertical and lateral extent of the Jõhvi and Keila stages among the outcrops in Estonia. It is the only permanent outcrop of the Kinnekulle K-bentonite in this area. (4) This outcrop has a remarkable spatial extension, which allows tracing possible lateral changes in the fauna and lithology. (5) The nature and extent of the outcrop provide good chances for its long-time preservation.

Correlation of the boundary of the Keila Stage is very precise within the distribution area of the Kinnekulle K-bentonite. That is due to the volcanic origin and correspondingly very rapid formation of the bed. The Kinnekulle K-bentonite can be distinguished from adjacent K-bentonites by its thickness and relative position, but geochemical and mineralogical criteria may also be helpful. It can confidently be traced in Scandinavia, Estonia, Latvia, parts of Denmark and Poland, and in the westernmost part of Leningrad District (Bergström *et al.*, 1995). The absolute age determinations, as well as the data on fossils, show that the Kinnekulle Bed is approximately coeval with the Millbrig K-bentonite widely distributed in northern America. This enables accurate correlation of the boundary horizon of the Keila Stage on two different continents, something, which could hardly be done in case of regional units.

Although volcanic ashfalls may cause mass mortalities in benthic communities, and thus some reorganisation of the fauna in connection with the Kinnekulle Bed might have occurred, no extinction event can be observed. Since there is also no gap, the boundary coincides with little or no biotic change. Most of the new fauna traditionally considered as typical of the Keila Stage appears somewhat above the Kinnekulle Bed. However, the short-ranging zonal chitinozoan *Angochitina multiplex* (Schallreuter) has been found in numerous localities in Estonia and Sweden just above the Kinnekulle K-bentonite (Nõlvak & Grahn, 1993), providing thus another good criterion for correlations. In addition, a rather short-ranging chitinozoan *Hercochitina* sp. may ensure correlation of the boundary of the Keila Stage. Both mentioned species can likely be traced east- and southwards from where the Kinnekulle K-bentonite extends.

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THE ESTONIAN EARLY CAMBRIAN MOLLUSCS

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During the last decades more and more Cambrian Mollusca have been discovered, particularly among the small shelly faunas of the Lower and Middle Cambrian. Many of these have led to considerable discussion about their systematics and the molluscan phylogeny at all. These early molluscs show such a radiation at the beginning of the Phanerozoic, which led to the diversification into recognised classes living today. Most shelled molluscs remained small until the end of Cambrian, and also generic and specific diversity remained low and relatively constant (Runnegar & Pojeta, 1985). Some of new body organisations evolved fairly quickly, in the Early Cambrian, whereas the development of the characters defining some of the classes, including complete torsion in gastropods apparently did not take place until the Late Cambrian. The development of new shell shapes, coiled and compressed, are plausibly explained as adaptive to new life habits (Morris, 1990).

The Cambrian molluscs from Estonia were first described by Schmidt (1888) as *Scenella* (?) *discinoides* and *S.* (?) *tuberculata*. As with many Cambrian molluscs, the systematic position of *Scenella* is the subject of debate in literature. Apart from chondrophorine interpretation (Yochelson & Gil Cid, 1984), *Scenella* has been interpreted as a gastropod (reviewed by Harper & Rollins, 1982), a helcionellacean monoplacophoran (Runnegar & Jell, 1976) and a possible tryblidiidan monoplacophoran (Geyer, 1986). The type species, *Scenella reticulata* Billings, occurs in the trilobite-bearing Lower Cambrian of several Avalonian regions. All available evidence indicates that the type species is best regarded as a helcionellacean mollusc (Landing, 1992).

The oldest known Estonian mollusc from the Lower Cambrian Lontova Stage was first described by Öpik (1926) as *Pleurotomaria* ? *kunda*. Subsequently, Rozanov (1973) assigned this species to the genus *Aldanella* Vostokova, 1962. A recent identification of *Anabarella* (Helcionelloida) by Mare Isakar from the Kestla Member of the Lontova Formation in the Vanamõisa F-149 core (Mens & Isakar, 1999) is significant addition to molluscs' distribution on East European Platform (Lendzion, 1977; Føyn & Glaessner, 1979). Up to now it was thought that *Aldanella* predominated in the eastern North America, northwestern Siberia and East European Platform (Poland, Norway, Estonia), while *Anabarella* was most abundant in eastern Siberia, Mongolia and South Australia, being rare in North America, South China and New Zealand (Bengtson *et al.*, 1990; MacKinnon, 1985; Gubanov, 1998). Now *Anabarella* is found from Estonian Lower Cambrian too (Figure).

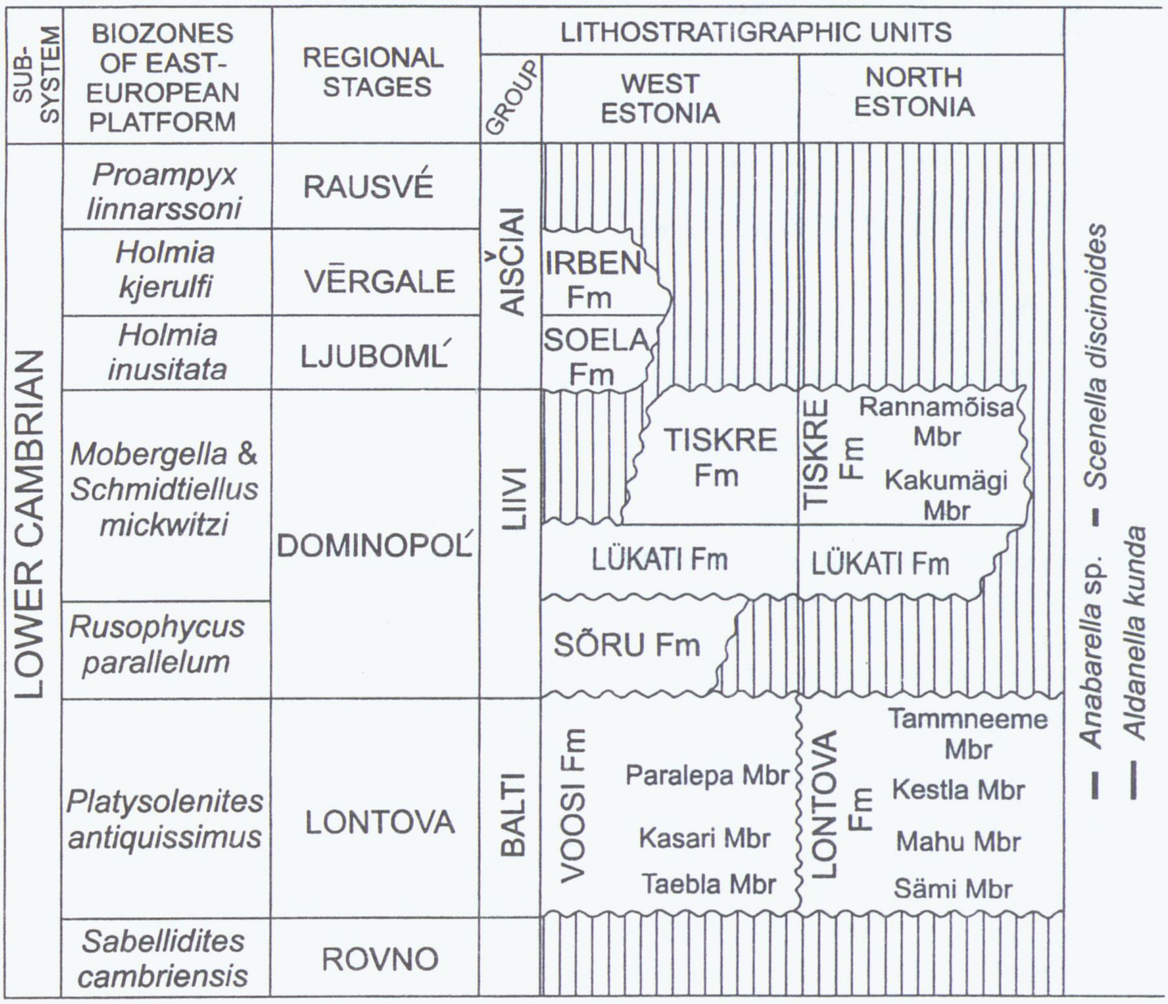

Figure. Molluscs distribution in Estonian Lower Cambrian

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GEOLOGICAL STRUCTURE OF THE TRANSITIONAL OIL POTENTIAL ZONE OF THE SILURIAN BALTIC BASIN

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A system of the marginal basins was established along the western edge of the Eastern European Craton during Latest Precambrian-Early Cambrian. As a part of it, the Baltic Depression depocentre originated initially as the passive margin basin, changing from passive margin to the convergent setting during Silurian (Šliaupa & Lazauskiene, 1997).

In the Silurian the Baltic Basin was a marginal platform depression with a sedimentary basin open to the to the south-west, to the Polish Trough. The main sources of the sedimentary influx to the basin were Fennoscandia-Sarmatia inland and adjacent Caledonian Orogen (Lapinskas, 1996). Silurian strata comprises 40-1200 m thick sedimentary succession, occurring at the depth of 100-1200 m. The most thick sequence of predominantly clayey facies (dark graptolite shales, grey carbonate clays) is deposited in the depressional part of the basin - in the Baltic Syneclise. From the east shaly normal marine lithofacies are edged by the elongated narrow Sutkai reef belt, extending from the south to the north across the Lithuania (Figure). Reefoid build-ups, consisting of stromatoporoid and crinoidean limestone, were formed during the Late Ludlow-Pridoli. The sedimentation of carbonate-shoal sediments (limestone, dolomite intercalating with marl) is recorded in the easternmost part of the basin. The transitional zone between clayey facies with graptolite fauna and carbonate facies with benthic fauna makes a bridge for correlation of stratigraphic units. The sophisticated depositional environments in the Baltic Basin and ambiguous relationships between clayey and carbonate facial zones make correlation rather complicated, therefore, lithofacial correlation principles being of primary importance.

Reefoid limestones and dolomites comprise transitional zone, which is currently regarded as highly prospective for oil. Thus, drilling activities started in 1976 to detect the distribution of barrier reef belt in the south-eastern slope of the Baltic Syneclise. Since then structural drilling was carried out along Sutkai, Ariogala, Vilkaviškis profiles crossing the southern and central part of the reefogenic zone, while the northernmost boundaries remained problematic. Some disagreements exists regarding the possible continuation of reefogenic zone to the north of Telšiai fault in Lithuania and adjacent region of Latvia (Stirpeika, 1998). Thus, three wells were drilled along the Kurtuvenai profile during 1993–1994 period to define the northern limits of the oil prospective reefogenic zone.

The West Sutkai zone of paleoflexures clearly distinguishes in the western part of the profile bounded by wells 102–162. Morphological discrimination of the East Sutkai paleoflexure along the profile was rather complicated: it has been marked only by facial peculiarities in the central part of the profile. The West Sutkai zone comprises two separate flexures: the western, bordered by wells 102–91, and the eastern one, restricted by wells 161–162 (Figure). Monoclinal bedding was recorded among these two flexures. Pagegiai palaeolagoon reefogenic bodies are related to the western flexure. Reefoid build-ups of regressive type (the upper part of Mituva Formation) comprising mainly crinoidean and detrital limestone, as well as barrier reefs of transgressive type (Ventspils Formation) consisting of detrital stromatoporoid limestone were recorded. Barrier reefs of the Šilale and Early Mituva time were determined in the eastern flexure (Figure).

Based on the Kurtuvenai profile drilling data, an individual barrier reef was predicted. Reefogenic build-ups of similar type were recorded in the Vilkaviškis (Kudirka reef), Ariogala (Pavasaris, S.Bliudžiai reefs) profiles; analogous reef was forecasted in the Sutkai profile. The positive structure of up to 100 m amplitude, confirmed by AH S_2pr horizon, tends to support a presence of a reef. Therefore, well data obtained did not allowed to define the northernmost extension of the East Sutkai paleoflexure along Kurtuvenai profile.

The most oil prospective area was referred to the quiet shelf zone between the western and eastern flexures in the West Sutkai zone. The eastern boundary of the Late Silurian oil prospective area was defined by the location of 162 well. The boundary of the Wenlock – Early Ludlow oil prospective area was complicated to determine.

Thus, reefogenic carbonate sediments of the transitional zone are currently regarded as a potential major producing sequences onshore Lithuania. So, all Silurian oil potential is concentrated in the middle Lithuania, the western part of the area being the most prospective. Reservoir rocks are represented by oil-bearing reefogenic bodies occurring at depths of 650-1150 m, cavernous beds of dolomite, oolitic and oncolitic limestone (Jacyna & Lazauskiene, in press). Up to now there are discovered 3 small oil-fields (Kudirka, S. Bliudžiai and Lapgiriai), Kudirka oil-field, therefore, containing 294 000 t of extractable oil resources. In general, more than 35 mln.t. extractable reserves are forecasted in this complex.

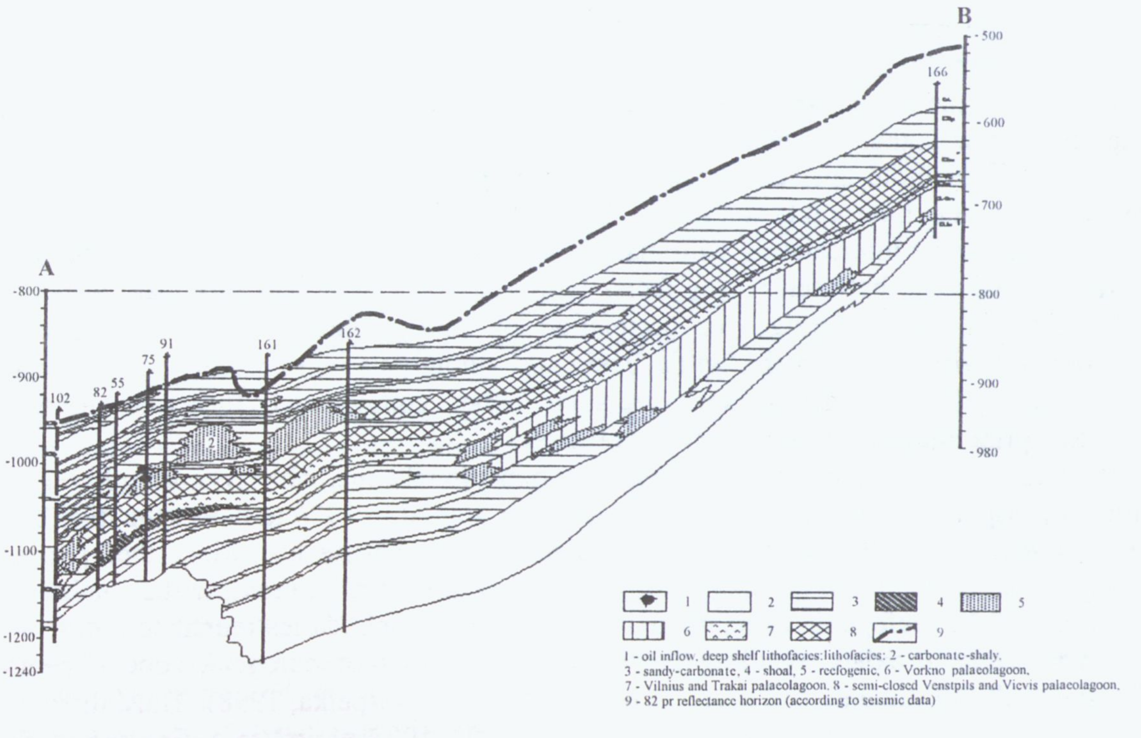

Figure. Lithofacial cross-section of the Upper Silurian strata

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THE PRECAMBRIAN-CAMBRIAN BOUNDARY PROBLEM IN THE EAST EUROPEAN PLATFORM

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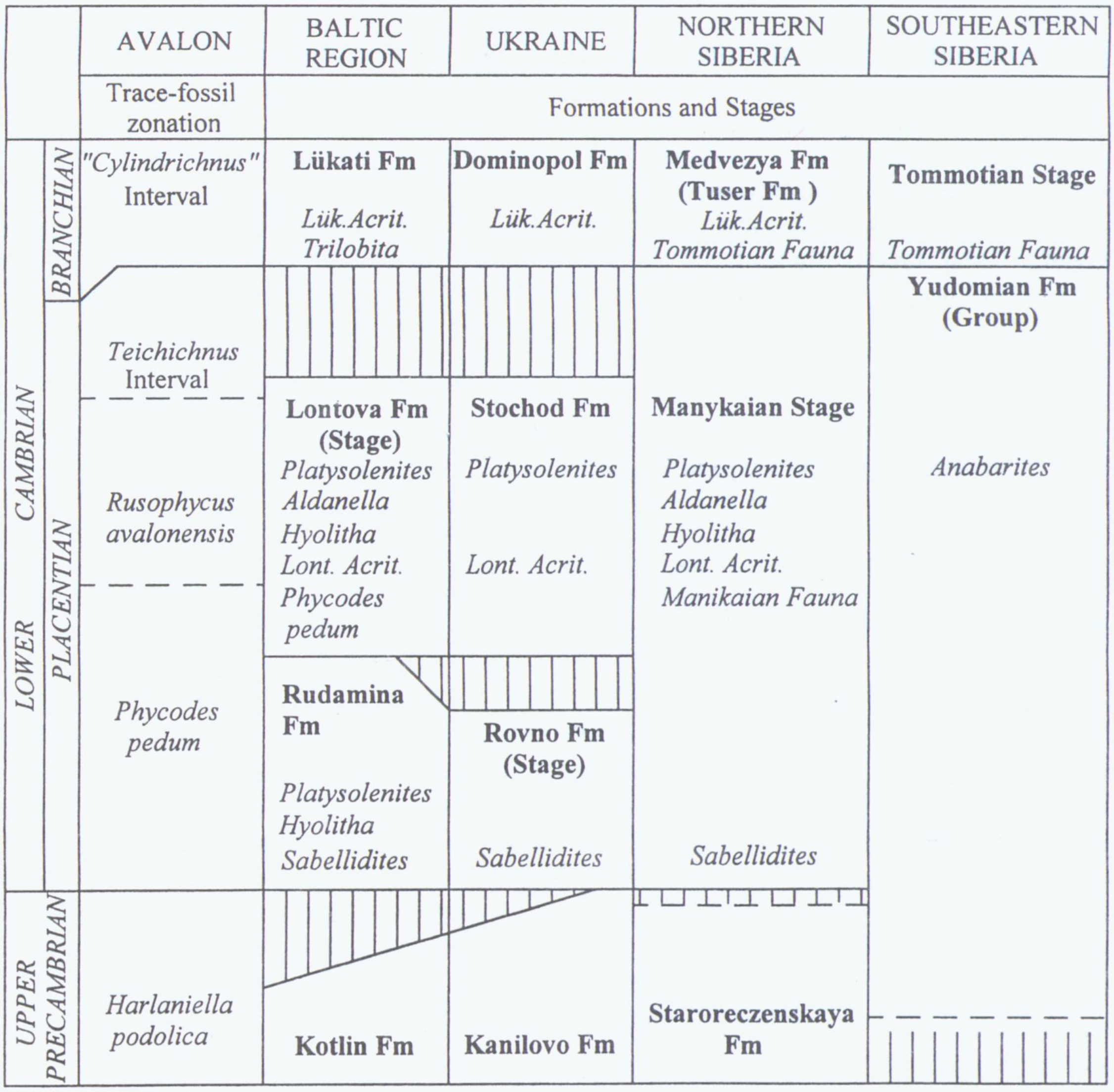
According to the global stratotype section in southeastern Newfoundland the position of the boundary occurs at the first appearance of trace-fossils *Phycodes pedum* or fossils with skeletons. In the stratigraphic succession of the East European Platform the ichnofossil *P. pedum* appears in the Lontova Regional Stage, whereas the oldest skeletal shelly fauna of *Platysolenites* occurs in the Rovno Regional Stage of Latvia and Lithuania.

Recently the Precambrian-Cambrian boundary was established at the base of the Lontova Stage in the regional stratigraphical scheme of the East European Platform within the former USSR. This solution coincides with the presence of *P. pedum* in the Lontova deposits, however the finds of the shelly fauna with *Platysolenites* on the older Rovno Stage contradict this solution. It seems that the former view (of 50-70ties) on the position of Precambrian-Cambrian boundary at the base of the Rovno Stage may be more suitable (Figure).

The lower part of the Rovno Stage in the stratotype area in Ukraine contains ichnofossils *Bergaueria* and *Conichnus*, which are known in the lowermost Cambrian (*Phycodes pedum* zone) in the Precambrian-Cambrian boundary global stratotype, southeastern Newfoundland, and have never been found in the Precambrian strata. Ichnofossil *Tyreptichnus triplex* from the Rovno Stage of Ukraine is morphologically similar to the above-mentioned *Phycodes pedum.* The absence of the ichnofossil *P. pedum* in the Rovno stage may be explained by facies control.

The originally mineralised skeletal fossils (shelly fauna) *Platysoleniles* are found in the Rovno stratum of Lithuania: in boreholes Navikai-1 (depth 563.8 m), Šašakai-2 (550 m), Tverečius-336 (434.1 m, 434.3 m, 435 m, 441 m), Vilkiškiai-68 (347.3 m). Findings of these fossils prove the Cambrian age of the Rovno Stage.

The oldest shelly fossils *Platysolenites,* Cambrian-like ichnofossils *Bergaueria, Cochlichnus, Treptichnus* and microfossils *Teophipolia lacerata, Cerotyophycus vernicosum, Cochleatina rudaminica, Leiovalia striatella, Leiosphaeridia dehisca, L. simplex* indicate the Precambrian-Cambrian boundary in the East European Platform.



Lük. Acrit. - Lükati Acritarch Assemblage of the Baltic Region, established together with the oldest trilobites.

Lont. Acrit. - Lontova Acritarch Assemblage of the Baltic Region in the pre-trilobite strata.

Figure. Biostratigraphic correlation of the European and Siberian lowermost Cambrian deposits.

CURRENT STATE OF THE STRATIGRAPHICAL RESEARCH IN ESTONIA

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Putting it colloquially, stratigraphy has been a favoured field of research in Estonian geology during the last 40 years, even if the 1990s have shown some decline. The Ordovician and Silurian regional stratigraphical schemes and correlation charts published more than ten years ago (Kaljo, ed., 1987, the Ordovician part republished without principal changes in English by Männil & Meidla, 1994) represent the final accomplishment of the Baltic Regional

Stratigraphical Commission. Analogous summaries have appeared for the Cambrian (Reshenie..., 1986) and Devonian (Rzhonsnitskaya & Kulikova, 1990).

The most recent versions of the stratigraphy of all systems represented in Estonia are available in a monograph on the Estonian geology (Raukas & Teedumäe, eds., 1997). In details the schemes there do not differ much from the earlier ones (some items see below), but they highlight clearly the current trends in Estonian stratigraphical research.

Political changes in our area brought independence not only to our countries, but also to our stratigraphical services. The Republic of Estonia occupies only a very limited area, where regional stratigraphical framework, facies pattern and basin evolution are very difficult to understand fully, if at all. I see here a real need to initiate basin-wide research projects in co-operation with different Baltic a.o. institutions; if not today, then tomorrow for sure. Contacts are easiest on the project level, but certainly also the BSA can play a supporting role, if desired.

Some other developments, topical in Estonia nowadays, can be evaluated positively:

1. Further progress in high-resolution biostratigraphy and preparation of the corresponding detailed correlation charts. Here only a few examples could be mentioned, taken from fields closer to my own speciality (Ordovician and Silurian):

- conodont-based correlation of Silurian sequences of Saaremaa, Gotland and Britain, new detailed biozonations (R. Aldridge, L. Jeppsson, P. Männik, V. Viira),
- chitinozoan biozonations for Baltoscandian Ordovician and Silurian (V. Nestor, J. Nõlvak, Y. Grahn),
- distribution of ostracode associations in the Estonian late Ordovician (T. Meidla),
- detailed revision of graptolite succession in the Ohesaare core and correlation with conodont and chitinozoan biozonations (D. Loydell, D. Kaljo, P. Männik),
- contributions to elaboration of global conodont, chitinozoan and microvertebrate biozonal schemes (Baltic participants were respectively P. Männik, V. Nestor, T. Märss and V. Talimaa).

The progress can be easily apprehended when the above biozonations are compared with those I reviewed together with J. Paškevičius for the 2nd Baltic Stratigraphical Conference in Vilnius, 1993.

2. The last five years have shown rapid widening of use of carbon isotope data in Baltic stratigraphy. The first results were published in 1994 (Ordovician ones by P. Brenchley, L. Hints, T. Meidla *et al.*, Silurian ones by D. Kaljo, T. Kiipli and T. Martma); by now several interesting stratigraphical correlations and conclusions have been reached, e.g. age of the *Holorhynchus* Beds, correlation of the Keila and Porkuni sequences in North and South Estonia (Ärina and Kuldīga formations), position of the base of the Ludlow Series in Estonia, several gaps in the sections, besides promising environmental conclusions.

Continued refinements of the stratigraphy, partly connected with changes in the global stratigraphical standard (position of the Cambrian-Ordovician boundary and the subdivision of the Pakerort Stage, series boundaries of the Ordovician System), are going on, e.g. stage and formation classification and nomenclature of the Vendian, Cambrian and Devonian, different smaller-scale adjustments, *etc.* throughout the lower Palaeozoic. Proterozoic and Quaternary stratigraphy seem to be most elaborated and stable, at least corresponding working groups have not suggested any changes into the current schemes.

In the very beginning, the BSA tried to compile a Baltic stratigraphical code, but in 1993 it was decided to use the International Stratigraphical Guide (the second edition was published in 1994) as a base document. We still share the opinion that an Estonian code is not necessary, but some national rules for stratigraphical procedures seem to be useful as well as instructions for stratigraphical terminology and nomenclature in the Estonian language. The latter is our internal problem, but important for national culture.

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SILURIAN OCEANIC EPISODES AND CARBON ISOTOPE SHIFTS: A PRELIMINARY BALTIC COMPARISON

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Evolution of the environment is mostly a cyclic process. Jeppsson (1990) generalised this in his model of oceanic changes, where more humid, cooler primo (P) episodes alternate with drier and warmer secundo (S) episodes. This alternation was accompanied with a set of more or less severe events (extinctions of taxa, changes in the environmental conditions, *etc*.). The current succession of P and S episodes (Jeppsson, 1998) was established mainly on the basis of the sections of the Gotland and Oslo areas. Conodonts were used as the main guides for identifying the boundaries of the episodes.

Recent studies in carbon isotope cyclicity have revealed four $\delta^{13}C$ positive excursions (early Aeronian, early Sheinwoodian, late Homerian, middle Ludfordian) in the Baltic Silurian (Kaljo *et al*., 1998), more or less coinciding with different environmental changes and biotic events (sea level fluctuation, bottom oxygenation, glaciations, extinctions, etc.).

The idea behind this study was to check the degree of harmony between the oceanic episodes by Jeppsson and carbon isotope excursions if established in the same core sections. For this purpose, conodonts and carbon isotopes were studied in five sections (Kirikuküla, Ohesaare, Ruhnu, Ventspils and Viki).

The distribution of critical conodonts noted by Jeppsson (1998) allowed identification of intervals where certain episodes or events should occur. The early and middle Llandovery conodonts were too scarce and gaps in the sections made determination of event levels impossible. In the Telychian the *Pterospathodus eopennatus* Biozone marks the beginning of the Snipklint Primo Episode at the level of the upper part of the *turriculatus* Biozone or earlier. This level was identified in the uppermost Rumba Formation in the Kirikuküla and Viki cores and, with some doubt, in the Ruhnu core, in the Degole Formation at Ventspils. In all these sections $\delta^{13}C$ values began to rise after a low in the *sedgwickii* Biozone (Kaljo *et al*., 1998), and the lowermost Velise (Viki, Ruhnu) and Irlava (Ventspils) formations show a small (2‰) positive shift. Higher the curve turned down until a rise in the latest Telychian.

The lower boundary of the Ireviken Event is well dated by conodonts of the *Pterospathodus amorphognathoides amorphognathoides* and *Pseudooneotodus bicornis* biozones in the uppermost Velise (Ruhnu, Ohesaare, Viki) and Irlava (Ventspils) formations. The event interval occupies also the lowermost Jaani and Rīga formations. In terms of graptolite zonation, the event began in the Ohesaare core just before the undoubted Wenlock (above the *lapworthi* Biozone) and ended before the lower boundary of the *riccartonensis* Biozone. The $\delta^{13}C$ values were increasing through the whole event interval, but the peak was reached only in the *riccartonensis* Biozone. The early Wenlock carbon isotope excursion is wide, with $\delta^{13}C$ values remaining high well above the peak until the first occurrence of *Monograptus flexilis* (Ohesaare, Ventspils). After that the values decrease until a minimum (about -2‰) is reached in the lower Homerian (*lundgreni* Biozone). The described by Jeppsson (1998) two P and two S episodes and two events from this interval had no obvious influence on the carbon isotope curve. At least in two deeper water sections $\delta^{13}C$ values are steadily decreasing, in the shallower Viki core the curve is more variable, but dating of these shifts is not yet adequate.

The Mulde Event can be exactly placed just before a prominent $\delta^{13}C$ peak in the Ohesaare core and a much smaller one in the Ventspils core. The peak seems to occur in the *ludensis* Biozone (Ventspils), but the event at least partly in the *nassa* Biozone.

In the Ludlow, characteristic conodonts of the Linde Event were not found in the Ohesaare core and obviously the event interval corresponds to a gap. At Ventspils the exact position of the event is also doubtful, but the most probable interval of the carbon isotope curve does not show any remarkable changes. The upper boundary of the Lau Event could be identified much better thanks to the appearance of *Ozarkodina remscheidensis baccata* just above it. In the Ohesaare core there is another gap just below the FAD of the latter species, at Ventspils there occurs a large (5.0‰) positive shift of $\delta^{13}C$. If correctly interpreted, then the Lau Event interval and the carbon isotope excursion coincide, and do not follow each other as in the earlier cases.

Higher in the Silurian, no significant positive carbon isotope excursion was found in Baltic sections. The $\delta^{13}C$ curve remained close to 0‰ (mostly -1‰). All three events, established by Jeppsson (1998), seem to coincide with more or less clear negative shifts of the curve: most unambiguously the Klev Event just above the LADs of *Ozarkodina crispa* and *O. snajdri parasnajdri* in the lowermost Kaugatuma and Minija formations; the Mid-Pridoli and Klonk events with some contradictions in the studied cores. Against the background of very low $\delta^{13}C$ values (mainly -1...+0.5‰) during post-middle Ludfordian and Pridoli, a small (+1...1.4‰) positive excursion is well traceable at Ohesaare and Ventspils at the very end of the Ludlow. It probably marks the *spineus* extinction Event in graptolite evolution.

The above data could be summarised as follows:

1. There occur four different states of the carbon isotope curve: a stable or slightly changing interval (e.g. middle Wenlock); a small (<2‰) positive excursion (early Telychian, late Ludfordian); a large (3...7‰) positive shift (listed above); and a strong (>2‰) negative shift (late Rhuddanian, late Aeronian, close to the Wenlock/Ludlow junction, some doubtful ones in the upper Silurian).
2. Most of the oceanic events established in Baltic cores are in some way connected with the above states of the carbon isotope curve, e.g. the early Silurian ones are all followed by a positive $\delta^{13}C$ shift: the pre-Snipklint S-P Event is followed by a small, but the Ireviken P-S and Mulde S-S events are followed by major positive shifts. The late Silurian Lau P-S Event coincides with a major positive excursion, but events in the Pridoli are marked with negative excursions.
3. Several events (Boge and Valleviken in the Wenlock, Linde in the Ludlow) and "normal" S-P episode replacements do not have any reliable carbon isotope signature.

4. The items above show that there is no unambiguous relationship between changes of oceanic episodes and carbon isotope fractionation and storage in the Silurian seas. Case-by-case analysis is necessary; also facies situation and biostratigraphical adjustment of episode boundaries should be considered. Another aspect in need of explanation is that reported positive or negative shifts of the carbon isotope curve are in conflict with model characteristics (P or S) of some oceanic episodes.
5. The carbon isotope curve can be used for stratigraphical refinements, e.g. the Wenlock-Ludlow boundary etc.

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VERTEBRATE ASSEMBLAGES OF THE SILURIAN/DEVONIAN BOUNDARY BEDS AND THE SECTION COMPLETENESS IN THE BALTIC SYNECLISE

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The Upper Silurian sequence of the Baltic area has been formed within the gradually reducing palaeobasin. Sedimentation during the Latest Silurian (Rietavas Beds of the uppermost Jura Formation, uppermost Lapes Fm, Lūžņi Beds of the Targale Fm) has occurred only on the small axial areas of the Baltic Syneclise: Southern (Lithuania and north of the Kaliningrad District) and Northern (Kurzeme peninsula of Latvia). Distinct differences in the vertebrate assemblages permit to suppose not only different facial situation, but also lack of connections between them.

Vertebrates (thelodonts, heterostracans and acanthodians) and conodonts from the most complete boundary Silurian/Devonian series: Nida-44, Stoniškiai-1, Šešuvis-11, Sutkai-87, Kurtuvenai=162 (Southern area) and Lūžņi-4, Kolka-54 and Ventspils-D3 (Northern area) cores have been analysed.

The sequence of thelodont assemblages of the topmost Silurian and the earliest Devonian from the Baltic is of a great significance for correlation and allows conclusions on the completeness of geological series within the Old Red Sandstone Continent. The *Paralogania kummerovi, Katoporodus lithuanicus-K. timanicus* and *Turinia pagei* zonal succession reflects all links of taxonomical composition of thelodont associations.

In the Timan-Pechora region, similarly to the Baltic, the uppermost Pridoli defines itself by the lack of *Thelodus parvidens. Katoporodus timanicus* is distributed on the western, more terrigenous facial area (North Timan), whereas *Katoporodus lithuanicus* - on the eastern, more marine facial area (Varandei-Adzva structural area). In Baltic both species were also existed simultaneously: *K. timanicus* - in the Northern, whereas *K. lithuanicus* - in the Southern area (bay) of palaeobasin.

The most complete Late Silurian series has been conformably overlain in both areas by the Early Devonian Tilže Fm. Thelodont assemblage of the latter includes typical Devonian species making their first appearance (*Turinia pagei, Boreania minima etc.*) and still existing Late Silurian taxa. This member of geological succession has been always attributed to Devonian in the Southern area. In Latvia, however, this transitional member with mixed vertebrates has been partly placed in topmost Silurian and only its smaller part - in the Devonian. The Silurian/Devonian boundary thus was drawn distinctly higher the first occurrence of the zonal *Turinia pagei.*

Acanthodian assemblage of the Rietavas Beds (topmost Jura) is represented by dominating *Nostolepis* ex gr. *striata, Gomphonchus sandelensis, Cheiracanthoides planus* and scales of specific morphology, preliminary defined as *Nostolepis* sp. or *Cheiracanthoides* sp., and smaller numbers of *Nostolepis gracilis, Gomphonchus hoppei, Poracanthodes punctatus, P. subporosus etc.* Eastwards, the topmost Lapes Fm dated by conodonts as *Ozarkodina eosteinhornensis remscheidensis* Zone, contains the all mentioned taxa with additional *Gomphonchus hoppei* among the dominants and including new elements: *Nostolepis* sp. cf. *N. robusta, Endemolepis inconstans, Canadalepis linguiformis* and *Nostolepis athleta* type scales, and the new genus.

The Lūžņi Member is distinguished by acanthodian assemblage rather similar to that of the topmost Lapes Fm including the above-mentioned new genus and *Nostolepis alta* as characteristic taxon. The latter was recently first defined also from the Lithuanian core, but occurred distinctly below in the sequence (Kurtuvenai-162, depth of 1043 m), in the middle part of the *Ozarkodina e. eosteinhornensis* Zone.

Transitional Silurian/Devonian member in the Lūžņi-4 core (depth of 165-188 m) yields dominating the sequence *Nostolepis striata* (not typical *striata*, as figured by H. Pander or W. Gross, but distinctly elongated and flattened scales), *Nostolepis* sp. or *Cheiracanthoides* sp., *Gomphonchus sandelensis* and *Gomphonchus* sp. (some varieties) accompanied by smaller numbers of *Cheiracanthoides planus, Poracanthodes punctatus, Poracanthodes* sp. cf. *P. porosus, Poracanthodes subporosus, Nostolepis gracilis, Nostolepis* sp. cf. *N. robusta, N. athleta* and the above mentioned characteristic *Nostolepis alta* and scales of the new genus.

STRATIGRAPHY OF THE TRIASSIC SYSTEM APPLYING PALAEOMAGNETIC METHODS

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The Triassic variegated rock mass, as in the adjacent regions of its distribution (in Poland, Germany), is related with specific conditions of its formation: submerging wide continent with periodically repeating conditions of sedimentation, accumulation of deposits, and breaks in sedimentation, with activity of lakes and rivers in previous desert plains in arid climate, where representatives of organic world, which are important for correlation of deposits, were almost absent. These are the natural reasons why the palaeontological, lithological and geochemical studies are not sufficient for the reliable stratigraphic subdivision of accumulated deposits.

The stratification, subdivision into formations and groups and their attribution to stages, created on the basis of available material, is more conventional, logically concluded than proved.

So it was very important to find the application methods, which could connect the stratigraphic subdivision carried out by previously used methods with the Standard Global Scale or schemes of large regions which are significant for correlation, and in that way to compile unified stratigraphic schemes, which could be combined with the local detailed schemes, used for mapping (including the scheme of the Baltic region).

The palaeomagnetic investigations perspective for stratigraphy started rather long ago, however they became modern studies with perfection of equipment and methods of investigation. The methods of these investigations are based on the influence of the Earth's magnetic field on rocks during their formation. A direction and value of this field may be determined by laboratory studies. The method of thermal demagnetisation is widely used. Its point is that samples of rocks at first are heated, then their magnetic properties are measured, and the direction of previous magnetic field is established. Considering the history of the Earth may be subdivided into zones of direct and inverse polarity, one may correlate rocks of the same age from separate regions according to size and polarity of these zones. These investigations are most effective studying samples from outcrops, however, oriented samples of drill core are sufficiently informative. The palaeomagnetic sections of several geologic systems are compiled, thus it is possible to correlate the obtained results with these sections.

480 Bundsandstein samples were collected for palaeomagnetic investigations from 2 boreholes (Kernai-1, Zvelsenai-1) situated in Lithuania. The samples were oriented only upwards - downwards. The Bundsandstein rocks were also sampled in the outcrops located not far from the boreholes. The rocks under study are characterised by a very small thickness, which does favour investigation.

Several 2 cm long core specimens were prepared from each sample for examination. The natural remnant magnetisation (NRM) of specimens was measured by a JR-5 spinner magnetometer. Each specimen was subjected to stepwise demagnetisation in a non-magnetic camera with mimetal screens. Magnetic susceptibility was monitored using a KLY-2 susceptibility bridge. Demagnetisation and measurements were carried out on reducing the ambient field by about 95. A principal component analysis as presented by Kirshvink was used to calculate the components of NRM and their unblocking temperature spectra. The thermomagnetic analysis and analysis of isothermal remanence magnetisation (IRM) acquisition were used to determine the nature of magnetic carriers.

Late Permian - Early Triassic palaeomagnetic results from stable Europe give the reversed polarity direction for Lithuania, displaying the declination and inclination, the values of which usually are within the range of 190 - 210 and -30 to -40, respectively.

In the magnetic polarity scale from borehole Kernai -1: from 149.0 to 145.0 m - reversed polarity, from 145.0 to 90.0 m - normal polarity, and from 90.0 to 41.0 m - reversed polarity (Nawrocki & Katinas, 1999).

In the magnetic polarity scale from borehole Zvelsenai-1: from 265.0 to 251.0 m - reversed polarity, from 251.0 to 190.0 m - normal polarity, and from 190.0 to 149.0 m - reversed polarity.

The magnetic polarity scale for the Lower Triassic from the boreholes Kernai-1 and Zvelsenai-1 revealed a very good correlation with other boreholes from Lithuania and adjacent areas.

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CORRELATION OF TELYCHIAN (SILURIAN) METABENTONITES IN ESTONIA

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The Silurian was characterised by severe environmental perturbations recorded in lithological sequences as rapid facies changes, extensive gaps (particularly in shallow-water regions), extinctions of biota and isotopic variations. In order to study and understand the nature of ancient environmental changes, detailed correlation of sections is essential. Among other methods, correlations based on the studies of trace elements in metabentonites have proved perspectives.

An attempt at geochemical correlation of Telychian metabentonites in Estonia was made in Kiipli *et al.* (in press). Sixty-six samples (representing 55 metabentonite beds) from six drill cores from Saaremaa and Muhu islands, and from the south-western part of continental Estonia, spanning the Adavere Stage, were analysed by XRF and XRD. The concentrations of trace elements (Nb, Zr, Y, Ga, Rb, Sr, and Ti) were measured. Multivariate cluster analysis of element concentrations and their ratios divides the studied beds into 15 groups. However, it appeared that in several cases metabentonites from the same core, but clearly from different stratigraphical levels, fell into the same clusters.

In order to test the correlations based on the trace element characteristics of metabentonites, the results of geochemical correlations were plotted against biostratigraphical data. It became evident that ash from different eruptions could be characterised by similar chemical features and, therefore, cannot be distinguished on the basis of studied trace elements only. Biostratigraphical control is necessary to constrain the metabentonite correlation.

Comparison of the results of geochemical correlations with biostratigraphical data, based on the distribution of conodonts, revealed 27 separate volcanic eruptions. Twelve of them are represented by metabentonites, each of which was recognised only in one section. Forty-three metabentonites, representing the remaining fifteen eruptions, can be identified in 2 or more sections.

Although the metabentonites occur randomly throughout the studied interval, it is evident that during the *Pterospathodus eopennatus* and *P. amorphognathoides lithuanicus* times the volcanic activity in the Northern Iapetus region was considerably higher than in other times during the Telychian. Nineteen metabentonites out of a total of 27 come from these intervals.

Data from Norway and Gotland exhibited 2-3 times higher Rb and Y values than in Estonia. Possibly some fractionation of material during air transport or different diagenetic pathways occurred. Also, the trace elements in Estonian metabentonites confirm the conclusion of Batchelor *et al.* (1995) about two types of source magmas ("primitive" and "evolved"), and suggest at least two volcanic sources. Some preliminary correlation with metabentonites from Norway and Sweden is proposed, which assigns the main part of the Garntangen Member in Norway to the *P. a. lithuanicus* Zone.

Comparison of mean thicknesses of metabentonites revealed that the source of the "evolved" magma was probably equidistant from Garntangen and Estonia. The source of the "primitive" magma was evidently closer to Garntangen than to Estonia.

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BOUNDARIES OF SUBDIVISIONS OF THE NARVA REGIONAL STAGE AND THEIR CORRELATION IN THE BALTIC REGION

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The Narva Regional Stage is spread in whole Baltic area and has been relatively well correlated with units in the neighbouring areas (Rzhonsnitskaya, 1998). The left bank of the Narva River near Gorodenka, the banks of the Gorodenka Brook, and the Poruni River near the place where these watercourses flow into the Narva River in the northeastern Estonia, make up the stratotype area of this stage. In this area excellent Narva and Sirgala quarry sections lie, where the lower part of the stage exposes.

On the basis of palaeontological, lithological and mineralogical characteristics, the Narva Regional Stage has been divided into three substages traceable from stratotype area up to eastern Belarus (Valiukevičius *et al*, 1986; Kleesment *et al.*, 1987). These units, the Vadja, Leivu and Kernave substages, correspond to the acanthodian zones, established by J. Valiukevičius (1998): Vadja Substage - to the *Cheiracanthoides estonicus* Zone, Leivu Substage to *Ptychodictyon rimosum* Zone, and Kernave Substage to *Nostolepis kernavensis* Zone.

All units of the Narva Stage have been exposed in the above mentioned stratotype area. Deposits of the Vadja Substage exposures in the outcrop located on the left bank of Narva River, 300 m from mouth of the Gorodenka Brook, where the boundary of the Vadja and Leivu substages occur, and in the Narva and Sirgala quarry sections. These outcrops characterise whole Vadja section in the distribution area. Rocks of the Leivu Substage are exposed at lower reaches of the Poruni River, where only an insignificant part of the upper half of the section exposures. The lower part of the Leivu section thins out in the northeastern Estonia (Kleesment & Kurik, 1997). The deposits, corresponding to the upper, Kernave Substage, crop out at the banks of the Gorodenka Brook, where sandstones and siltstones occur, characterising this unit in Estonia and North Latvia. In southern regions, especially in Lithuania, the Kernave Substage is composed mostly of variegated clays with intercalations of variegated and grey dolomitic marls, sandy siltstones and conglomerates.

The lower boundary of the Narva Stage, corresponding to the lower boundary of the Vadja Substage, coincides with the base of a carbonate breccia or dolomitic marl, 0.2 to 10 m thick, which overlie sandy dolomite or sandstone of the Pärnu Stage. This is a good correlative level.

The lowermost bed of the Leivu Substage is commonly represented by grey dolomitic marl, containing remarkable amount of silty-sandy particles with diameter up to 1-3 mm. In western part of Latvia up to 19 m thick dolomite-cemented layer of sandstone and siltstone occur in this level. In other areas only very thin sandstone layer is discovered (2-10 cm). This level outlines a hiatus in sedimentation, overlying with unconformity the Leivu deposits with northward decreasing age (Kleesment & Kurik, 1997).

The lower boundary of the upper, Kernave Substage, is marked by the topmost part of the Leivu Substage, consisting of reddish-brown, purplish-grey and grey mottled massive argillaceous dolomitic marl, overlaid by silty sandstone of the Kernave Substage. The layer of mottled dolomitic marl is one of the most persistent correlative markers.

The upper boundary of the Kernave Substage, the boundary of the Narva and Aruküla Stages coincides, in general, with the lower surface of the first significant uncemented reddish-brown sandstone bed above the dolomitic siltstone or marl of the Narva Stage. The topmost part of the Narva Stage often shows a greenish-grey siltstone layer. The overlying Aruküla sandstone is mostly inequigranular. In some regions, especially in Võrtsjärv Depression, the boundary of Narva and Aruküla stages is often difficult to establish.

In spite of the fact that the above-observed units of the Narva Stage correspond to biozones, their boundaries are established on the basis of lithological criteria. Also they have distinct lithological criteria for determination. Two lower units are lithologically similar in the whole East Baltic area. They can be observed as Vadja and Leivu formations. The upper, Kernave Substage differs remarkably in North and South region. It can be distinguished in the territory of Estonia and North Latvia as the Gorodenka Formation, and in southern regions as the Kernave Formation.

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2D SEDIMENTARY MODELLING OF THE SILURIAN BALTIC BASIN

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The Baltic Basin, consisting of Peri-Tornquist sub-basin coupled with the Peri-Baltic sub-basin is a marginal basin situated on the western margin of EEC. In the initial stage BB was established as a passive margin basin during the Latest Precambrian-Early Cambrian. Based on 1D subsidence modelling results, a change from passive margin to convergent setting during Late Ordovician and Silurian, culminating in the foredeep stage of the basin development during Late Silurian was suggested relating to the overthrusting the Eastern Avalonia onto the south-western margin of Baltica (Sliaupa *et al.*, 1997). Relying on the isopach and lithofacies distribution, three distinct reconstructed Silurian sub-basins could be distinguished in the Baltic Basin: 1) the Peri-Tornquist high gradient sub-basin with palaeothickness ranging from 2 to 5 km within the area of 200-300 km; 2) the Peri-Baltic sub-basin (400 km wide) with the range of thickness of 0.5-2 km; 3) the Lithuanian-Estonian borderland where palaeothicknesses ranges from 0.5 to 0 km.

3D flexural modelling of the Silurian Baltic Basin, incorporating lateral variations of the lithospheric strength and complex distribution of the load was carried out. The flexural modelling results show that Silurian Baltic Basin can be interpreted as a foreland basin of Caledonian Orogen generated in response to superimposed moderate wave-length flexure resulted due to North German Polish Caledonian (NGPC) orogenic loading (Peri-Tornquist sub-basin) and subduction-induced long-wavelength dynamic flexure (Peri-Baltic sub-basin), caused by viscous mantle corner flow (Lazauskiene *et al.*, 1998).

Those implications are supported by characteristic trend of sedimentation. The thickness of the Silurian carbonate-shaly succession increases towards the south-west exceeding 4 km. Deep-marine graptolite shales predominate in the south-west grading to the shallow-water marls, limestones and dolomites to the east, indicating deepening of the basin towards NGPC. Accelerating subsidence was associated with no remarkable increase in sediment thickness during Early Silurian, that implies the starvation stage of the basin evolution (Kaljo *et al.*, 1991). The succeeding significant increase of the subsidence was accompanied by intense increase of sediment influx, gradual narrowing and shallowing of the basin during Late Silurian implying the compensated regime of the sedimentation. During Early Silurian the inflow of terrigenous sediments derived from the eastern sources prevailed. Since late Wenlock sediments were derived mostly from the active orogens in the west (Lapinskas, 1987).

Numerical modelling of the sedimentary infill of the Silurian Baltic Basin was carried out quantitatively to evaluate how tectonic processes deduced from geodynamic model can be explained by the certain patterns of sedimentation of the basin.

The quantitative sedimentary infill modelling of the Baltic Basin was carried out by means of 2D modelling technique SEDPAK 2.0 (Ch. Kendall, 1991), allowing to incorporate the influx of sediments to the basin from both sides, the combination of clastic sediments and *in situ* carbonate growth, eustatic sea level and tectonic subsidence changes.

Quantitative lithofacial models of clastic and carbonate sediments evolved throughout time were created for Baltic Basin to test the sensitivity and interaction of tectonics movements, eustasy and sediment accumulation, and their effect to basin architecture. The value of such quantitative models lies mostly in their ability to calculate the degree of filling to the flexural depression and gross basin geometry as a function of time neither than detail lithofacial distribution. Quantitative sedimentary models for the Silurian Baltic Basin show a consistent association of sedimentary pattern with main tectonic phases in the foreland system (Figure). The model results show Fennoscandia-Sarmatia inland and adjacent Caledonian Orogen being main provenances for the two-side sediment supply of the Silurian Baltic Basin (Lazauskiene *et al.*, 1999). Changes of the sedimentation regime in the Silurian Baltic Basin could be regarded as corresponding to the main phases of the foreland basin development.

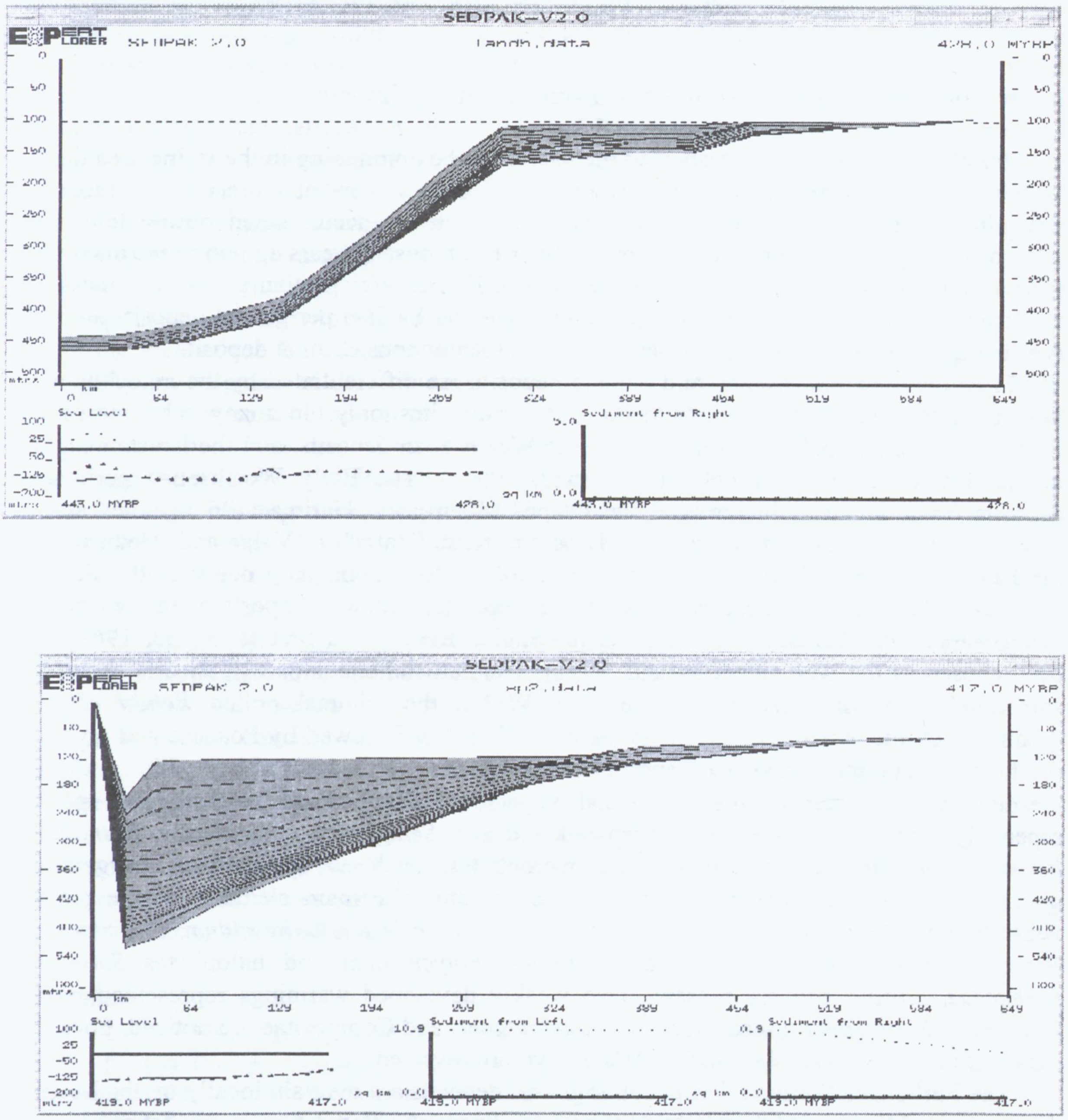

Figure. Quantitative lithofacial models of the main stages of Baltic Silurian Basin development: a) model of the underfilled stage; b) model of the infilling stage.

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WEICHSELIAN PERIGLACIAL DEPOSITS AND TILL BEDS IN ESTONIA AND CORRELATIONS IN THE BALTIC AREA

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Periglacial conditions have showed themselves to be dominating in the Baltic area during Weichselian time. Continuous ice cover has lasted only somewhat more than 10 thousand years in the area. Periglacial deposits have thought to be accumulated during long time interval starting from the end of the Eemian about 120 thousand years ago up to the maximum spread of ice cover about 20 thousand years ago. Earlier Weichselian glacier advances are under discussion. Determination of the Weichselian and Saalian periglacial deposits and tills is also aggravated in cases of the absence of the autochthonous Eemian deposits.

In Estonia the Weichselian and Saalian deposits are differentiated by the autochthonous Eemian layers at the Prangli, Juminda and Peedu sites only. In many other cases the redeposited Eemian pollen, being found in the Weichselian deposits, and the Holsteinian one in the Saalian deposits, is helpful (Liivrand, 1990a). The Early Weichselian periglacial deposits occur in great thickness at the Otepää (40 m) and Harimäe (26 m) sites and in considerably less thickness at the other, Tõravere, Kitse (Valgjärv), Valga and Peedu sites in SE Estonia and on Kihnu Island in SW Estonia. In N Estonia they occur at the Prangli, Juminda, Püssi and Lüganuse sites. All these deposits contain redeposited Eemian pollen, being sometimes abundant. Harimäe 323 borehole, investigated first (Liivrand, 1969), has been chosen as the type site (Liivrand, 1991). The autochthonous part of spectra shows the spread of cryophilic periglacial vegetation. Within the arboreal pollen *Betula nana* is dominant. Of the herbs, Cyperaceae is the most abundant followed by Poaceae and a variety of herbs including *Artemisia* and Chenopodiaceae. This assemblage illustrates the mesophilous character of the periglacial vegetation. Tundra and north boreal species, especially *Betula nana,* became widespread, but also *Selaginella selaginoides, Botrychium boreale, Lycopodium alpinum* and mesoxerophytes, such as *Lycopodium pungens*, *L. appressum, Artemisia borealis, A. arctica* are present. The main elements of the pioneer vegetation are the mesophytes *Chenopodium album, C. rubrum, C. hybridum, C. viride* a. o. Some xerophytes, such as *Eurotia ceratoides, Polycnemum* and halophytes *Salicornia herbaceae, Salsola kali* are present. Two weakly developed warmings represented by the increase of *Pinus, Betula* sect. *Albae*, *Calluna vulgaris* and Compositae are noticed. Four TL-data within an age interval of 90 000-108 000 yr. are revealed.

The Early Weichselian (Harimäe) periglacial deposits are overlain locally by the Mägiste till (type site Mägiste 266 borehole) having a thickness of about 1-5 m in SE Estonia and 14 m at the Vääna-Jõesuu in the foreklint area in NW Estonia (Liivrand 1991).

The Middle Weichselian (Tõravere) periglacial deposits were investigated at Tõravere (borehole 16, type site, Liivrand, 1990b), Valguta and Kitse (Valgjärv) in SE, at Vääna-Jõesuu in NW and at Savala located within the Purtse buried valley in NE Estonia. They also contain redeposited Eemian pollen of different quantity. Periglacial vegetation is also cryophytic but of more xerophilous character. *Artemisia* is often prevailing. Group of the tundra and north boreal species is more developed, and the composition of the xerophilous pioneer flora is richer. *Eurotia ceratoides* and *Polycnemum* are more frequent and *Ephedra* is present. TL-data 62 400 and 66 500 were obtained from the Valguta sequence.

The Middle Weichselian (Tõravere) periglacial deposits are everywhere overlain by the Valgjärv till (type site Kitse 19-Valgjärv borehole) with a thickness up to 19 m in SE and 30 m at Vääna-Jõesuu in NW Estonia. In the Purtse buried valley in NE Estonia, tills occur deficiently (Liivrand, 1991).

The Late Glacial ice recession commenced with the Kammeri warming when periglacial shrub tundra was spread in SE Estonia (Liivrand, 1995). Alternation of short stadial coolings and interstadial warmings within a time interval 10 000- 13 500 yr. is characteristic to the Weichselian Late Glacial, named as the Võrtsjärv Subformation in Estonia (Pirrus & Raukas, 1996). In addition to the units represented in the official chart, a new Sõrve zone of warming has been distinguished between the Pandivere and Palivere zones of cooling. The Sõrve and Alleröd warmings are characterised by the periglacial shrub tundra, but the Pandivere, Palivere and Upper Dryas coolings show a spread of the periglacial herb tundra as have been proved the palynological investigations of the Ilumäe site in N Estonia. In western Estonia the deposits of the Sõrve warming occur between the Pandivere and Palivere tills (Liivrand, Kadastik & Kalm, manuscript). All the Late Glacial periglacial deposits contain redeposited Eemian pollen, but usually to a lesser extent than the Early and Middle Weichselian ones.

In the area of the Baltic states the Early Weichselian deposits are more complete and profoundly investigated at the Jonionys type site in S Lithuania (Satkunas *et al.,* 1998). Alternation of two zones of the interstadial forests and of zones of periglacial vegetation has been distinguished. The first of them J 1 (Brörup), being characterised by the coniferous forests, and the second J 2 (Odderade), representing the *Betula – Pinus* forests, are separated by Nm 2 zone of cooling. J 3 is represented by *Betula* – Cyperaceae zone and correlated with the Middle Weichselian Oerel interstadial from the Oerel type site in NW Germany. The latter shows an open treeless shrub tundra with a rich variety of herbs (Behre, 1989). Possible correlation of the Oerel and Tõravere interstadial deposits has also been supposed (Liivrand, 1991). The periglacial conditions existed between the J 2 and J 3 interstadial warmings in Lithuania. The Mägiste till could have accumulated in Estonia at that time.

The Middle Weichselian periglacial flora of the Lejasciems sequence, being dated 32 – 35 th yr. in Latvia, consists of *Betula, Betula nana, Pinus, Artemisia,* Cyperaceae, Poaceae and of abundant *Selaginella selaginoides,* locally (Meirons & Straume, 1979).

The beginning of the Late Glacial may be correlated with the Kammeri zone in SE Estonia and with the Raunis zone in N Latvia. Deposits of the Sõrve zone of warming, being widely spread between the Pandivere and Palivere till beds on Saaremaa and Hiiumaa Islands, may also be expected in the bottom sediments of the Gulf of Riga. The Gulf was presumably ice covered during the Pandivere zone yet.

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NEW DATA ON THE LATE GLACIAL STRATIGRAPHY IN ESTONIA

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Upper boundary of the Late Glacial has been biostratigraphically fixed by transition of the open periglacial to closed Holocene forests and chronostratigraphically by 10 000 yr. acknowledged in INQUA Congress in 1969. The lower boundary, however, is disputable in Estonia. At present it is based on the Raunis Interstadial dated about 13 500 yr. BP in N Latvia (Pirrus & Raukas, 1996). One cannot exclude possible evidences of that interstadial also in S Estonia. Regardless of very controversial radiocarbon data a certain intertill deposits with pollen spectra of bushy tundra have been observed between two different uppermost till beds in SE Estonia. The sediments were named as Kammeri interstadial deposits by its first investigator Orviku (1958) and correlated to the Raunis Interstadial in N Latvia. The Kammeri interstadial deposits are overlain by the till of the Haanja Stage (DR1) and the latter in turn by deposits of the proglacial lake where sedimentation has started about 2800 yr. ago according to the clay-varve chronology and magnetostratigraphic investigations of the Tamula site near Võru (Hang & Sandgren, 1996). Palynological investigations do not yet represent clearly the Bølling warming by the reason that great amount of the redeposited Eemian pollen is present in these deposits (Pirrus, 1969).

More profound modern lithological, clay-varve chronological and palynological investigations were carried out in northern and western Estonia. The Pandivere ice marginal zone has been dated 12 480 yr. and the Palivere one 11630 yr. (Pirrus & Raukas, 1996). The palynological studies of the Ilumäe site, located between the Pandivere and Palivere zones near Võsu in the middle part of N Estonia, have distinguished alternation of several warmings and coolings. The Pandivere/Palivere or Sõrve and Allerød warming episodes are characterised by increase of *Betula nana* pollen but also by increase of *Betula humilis, Pinus* and *Picea* pollen. Deposits of the Palivere and Upper Dryas cooling events are characterised by increase of herbs, mainly *Artemisia*, especially in DR3. The AL and DR3 zones are richest in primary pollen of the periglacial vegetation on account of which the amount of the redeposited Eemian pollen has decreased in these zones. There are no signs of coolings inside of the Allerød. Therefore, the placing of the Palivere Stadial inside it in the official local stratigraphic chart has not been enough grounded.

In the western Estonia, on Saaremaa and Hiiumaa islands, the Pandivere and Palivere stadials are represented by tills which in places (Sõrve, Mõntu and Kõpu) are separated by organic-containing deposits of the Sõrve warming event. Pollen spectra of Sõrve beds, being formed within a large water body, are presumably richer in long-transported pollen. *Pinus* pollen, being mainly long-transported, has often morphologically poorly developed features. In the Sõrve beds at Sõrve (type site) site only one pollen zone with three subzones and at Mõntu site one pollen zone, both consisting mainly of herbs, *Betula nana* and *Pinus* pollen, were possible to determine. In the Sõrve beds at the third and the northernmost of the three sites, at Kõpu on Hiiumaa Island, the pollen concentration in very low but of the same composition. Redeposited Cambrian, Ordovician and Silurian acritarchs, identified to the species at Sõrve, are common in the intertill deposits at all mentioned sites and also in the Palivere till, investigated at Mõntu. Lower part of the Pandivere till at Mõntu contains many redeposited Middle Devonian spores from Narva Formation.

Lithology of the tills refers to a different direction of ice movement during Pandivere and Palivere Stages. According to the widely accepted conclusion, the accumulation of tills during the Pandivere Stage was affected by southerly or south-westerly ice flow, while the flow during the Palivere Stage was to the south-east or even to the east near Saaremaa. The deposits of the Palivere stadial, in contrast to the Pandivere deposits, contain rapakivis from south-western Finland, granites and rapakivis from the Åland Islands, Baltic red quartz-porphyries from Satakunta, all of which are virtually absent on the areas of Pandivere till outcrops (Raukas, 1978, 1986) in Eastern Saaremaa. Data on mineralogical and chemical composition support the lithological differentiation of Pandivere and Palivere tills.

Glacier retreat during the Sõrve warming was significant reaching apparently the coastal area of Finland. There the Pikkala sands have accumulated between two uppermost tills, which are also deposited by ice flowing from different directions (Bouchard et al. 1990; Nenonen, 1995). Apparently the Gulf of Riga has became ice free not earlier than at the Sõrve warming episode.

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LITHOSTRATIGRAPHIC CORRELATION OF SELECTED SECTIONS OF THE QUATERNARY IN NORTHEASTERN POLAND AND SOUTHERN LITHUANIA

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Similar lithologic examination of tills has been applied for several dozen of years, both in Poland and Lithuania (Galgalas, 1979; Rzechowski, 1971, 1974). The results are fundamental for a lithostratigraphic correlation of the Pleistocene. Petrographic composition of clasts in tills was found the most applicable to lithostratigraphy.

A standard lithologic studies of the Pleistocene sediments, collected from drilling cores, has been applied in Poland for the *Detailed Geological Map of Poland* in scale 1:50,000. A petrographic analysis of gravel (5-10 mm in diameter, 100 grains per sample) from tills is based on contents of different groups of Scandinavian rocks (including the northern ones i.e. of the Palaeozoic and Precambrian, as well as of the Jurassic and Triassic ones which are very rare in Poland), and local rocks (of the Tertiary and Cretaceous). Then, petrographic coefficients O/K-K/W-A/B are calculated. They present relations between different

Scandinavian erratics in tills (totals of: O – sedimentary rocks, K – crystalline rocks and quartz, W – carbonate rocks, A – non-resistant, and B – resistant rocks).

Petrographic analysis of gravel (5-10 mm in diameter, about 300 grains per sample) from tills, applied in Lithuania, includes crystalline rocks, northern quartz, feldspars, and subordinately quartzites (equivalent roughly in the Polish method to a total of crystalline rocks and northern quartz i.e. - $Kr+Q_P$), Jothnian, Palaeozoic and Mesozoic sandstones and occasional siltstones (equivalent in the Polish method to the northern sandstones - P_P), mostly Devonian dolomites (equivalent in the Polish method to the northern dolomites - D_P), two groups of limestones: the organogenic ones of the Ordovician and Silurian, and of the Palaeozoic, Triassic and Jurassic (in the Polish method a total of northern limestones - W_P), predominant Cretaceous marls (in Polish method roughly equal to the local rocks – mostly, difficult to separate from one another, Cretaceous and Palaeocene limestones and marls - $W_L+P_L+M_L$). Gaigalas (1979) presents results of petrographic analysis with a use of histograms that indicate contents of gravel of different rocks in particular tills, in relation to average contents of these gravels as calculated for all the tills in many sections within the area. Such histogram was handed over to the Polish party in 1995. It presented results of the study in the Vištytis region in the Lithuanian-Russian borderland. The same method was applied to the boreholes in the Polish part of borderland.

Geological material was collected from 6 boreholes in the Polish-Lithuanian borderland near Wiżajny in the Suwałki Lakeland. On the Polish side five boreholes i.e. Żytkiejmy Forestry Headquarters, Żytkiejmy, Bolcie, Stankuny and Poszeszupie (*fide* S. Lisicki, 1998) were done for the *Detailed Geological Map of Poland*, scale 1:50,000 (sheets Żytkiejmy, Wiżajny and Poszeszupie). The sixth borehole (Norvydai) was done on the Lithuanian side and a joint Polish-Lithuanian team examined it. Sediments of eight glaciations were distinguished and their stratigraphic setting was defined in the analysed sections. They were correlated to lithostratigraphic schemes of the central Mazury Lakeland (Lisicki, 1996, 1997) and the Augustów Plain (*fide* S. Lisicki, 1998), and results of petrographic analyses in the sections Aukštakalnis and Lakštuciai. The central Mazury Lakeland is the area with sediments of the Mazovian (Holstenian) Interglacial, and the Augustów Plain – with sediments of Mazovian and Augustovian (Bavel Complex?) Interglacials (with palynologic examination).

The most probable is the following lithostratigraphic correlation of tills in northwestern Poland and southern Lithuania (Lisicki, 1998):

- tills of the Dzukija complex correspond to a till of the older stadial of the Nidanian Glaciation N_1 (Glacial C of Cromerian Complex?); tills of the Dainava complex correspond to a till of younger stadial of the Nidanian Glaciation N_2 (Glacial C, too?);
- tills of the Žemaitija complex with a characteristic maximum of dolomites (D_P) represent tills of the Wilgian G (Elsterian 2) and Liwiecian C (Fuhne) Glaciations, and presumably also tills of the Sanian Glaciation S_1 and S_2 (Elsterian 1);
- tills of the Medininkai complex do not represent tills of the Wartanian Glaciation W_1 and W_2 (Warthe), but correspond to tills of the Odranian Glaciation O_1 and O_2 (Saalian ss. – Drenthe);
- tills of the Grūda complex are in fact of the older (Świecie) stadial of the Vistulian Glaciation B_1 (middle Weichselian), and tills of the Baltija complex represent the younger (Leszno-Pomeranian) stadial of the same glaciation B_2 (late Weichselian).

In the present scheme there is no equivalent in Lithuania of the Narewian (Menapian), Sanian (Elsterian 1) and Wartanian (Warthe) Glaciations. According to A. I. Gaigalas (*fide* S. Lisicki, 1998), there is no lithostratigraphic equivalent of tills of the Narewian (Menapian) Glaciation, recognised in the borderland area, probably due to a lack of this complex in the Vištytis region of southern Lithuania. Tills of the Sanian (Elsterian 1) Glaciation, sporadically present in the Suwałki Lakeland, contain, however, a slightly increased content of crystalline rocks (Kr), their petrography is similar to the one of tills of the Žemaitija complex. This similarity could result in a misleading incorporation of tills of the Sanian Glaciation into a lithostratigraphic complex of Žemaitija, which corresponds presumably to tills of the Wilgian (Elsterian 2) and Liwiecian (Fuhne) Glaciations. Tills of the Wartanian (Warthe) Glaciation are several metre thick only, and predominantly occur within a thick sandy-gravely complex that separates tills of the Odranian (Saalian ss. – Drenthe) and Vistulian (Weichselian) Glaciations. Poor development of tills of the Wartanian Glaciation in the Polish-Lithuanian borderland resulted in their missing in petrographic and lithostratigraphic schemes of Lithuania. The fact that the Lithuanian geologists have included this entire sandy-gravel complex into the Vistulian (Nemunas) Glaciation seems groundless.

1. All tills in the borderland belong to eight glaciations: Narewian (Menapian) – A1, A2, Nidanian (Glacial C of the Cromerian Complex?) – N1, N2, Sanian (Elsterian 1) – S1, S2, Wilgian (Elsterian 2) – G, Liwiecian (Fuhne) – C, Odranian (Saalian ss. - Drenthe) – O1, O2, Wartanian (Warthe) – W1, W2 and Vistulian (Weichselian) – B1, B2.
2. All lithostratigraphic complexes of the Pleistocene in the Vištytis region distinguished by A. I. Gaigalas correspond to lithostratigraphic horizons in the Wiżajny area.
3. The South Lithuanian lithostratigraphic complex does not correspond to the assigned lithostratigraphic horizons in Poland.
4. The lithostratigraphic scheme by A. I. Gaigalas for southern Lithuania does not fit to the scheme of stages and stadials in Poland. Complexes of Dainava, Žemaitija and Medininkai do not correspond to the chronostratigraphic stages designated with the same names. Furthermore, the Žemaitija complex seems to be correlated with tills of the Liwiecian Glaciation C and/or the Wilgian Glaciation G, or ever the Sanian Glaciation S_1 and S_2. In northeastern Poland, tills of the Wilgian and the Liwiecian Glaciations separate sediments of the Mazovian Interglacial M defined by palynologic analysis. In southern Lithuania, no lithostratigraphic complexes were distinguished that could correspond to the Narewian, Sanian and Wartanian Glaciations.

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SUBDIVISION OF THE FAMENNIAN STAGE IN THE BALTIC AREA BY BIO- LITHO- CYCLOSTRATIGRAPHIC METHODS

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Most of the Famennian succession in the Baltic area consists of deposits of an open shallow water sea with normal salinity or closed marginal basin with brackish or sometimes hypersaline waters, and is represented by rhythmical alternation of chemical, biomorphic-biodetrital, biodetrital, biolithodetrital limestones, dolostone with the relict organogenous-detrital structure, sandstone, siltstone and clay.

The Famennian is subdivided into three substages in the stratigraphical chart of the Latvian Devonian, the Lower (including the Eleja, Joniškis, and Kursa formations), the Middle (the Akmene, Mūri, and Tērvete formations), and the Upper substage (Sniķere, Žagare, Ketleri, and Šķervelis formations).

The cyclicity of sedimentation and the succession of the main taxonomic groups of fauna and flora (chiefly brachiopods, fishes and miospores) allows to subdivide the Baltic Famennian into four large equal scaled sedimentological cycles, namely Bandava, Zemgale, Piemare, and Duvzare cycles, which correspond to substages.

The Lower Famennian (Bandava cycle) correlates with the succession of the Eleja, Joniškis and Kursa Formations. The last two formations correspond to the Zadonsk and Elets Regional Stages of Pripyat Depression and Central Devonian Field respectively. The deposits analogous to the Eleja Formation have been only partially developed or often washed out there, except the Kuzmichevo Beds of Pripyat Depression, currently included into the Zadonsk Regional Stage. The conodont fauna of the *triangularis* Zone has been found in the Eleja Formation.

The Zemgale cycle (Middle Famennian) unites the Akmene, Mūri and Tērvete Formations, which probably correspond to the *marginifera-velifer-styriacus* conodont zones. The Middle Famennian in the regional stratigraphic chart of the East European Platform corresponds to the quite larger interval (Rzhonsnitskaya & Kulikova, 1990), including the Lebedyan, Optukha (Mtsensk and Kiselevo-Nikolsk Beds), and Plavsk (Turgenevo and Kudeyarovo Beds) Regional Stages. The upper boundary of the Middle Famennian has been traced above the Kudeyarovo Beds corresponding to the Žagare Formations of the Baltic section.

The Upper Famennian in the stratigraphic chart of Latvia unites the sequence of two large-scale sedimentation cycles: Piemare and Duvzare. The deposits of the Piemare cycle are represented by the rocks of the Sniķere, Žagare Formations and Nīgrande Beds. This succession corresponds to the Turgenevo and Kudeyarovo Beds and the lower part of the Ozerki Beds of the CDF, and Streshin Regional Stage of Pripyat Depression. The Duvzare cycle units the deposits of the Pavāri and Varkaļi Beds of the Ketleri Formation and Šķervelis Formation. This succession corresponds to the Ozerki and Khovanschina Regional Stages of the East European Platform.

Keeping in mind that substages could be evaluated as an equal-scaled sedimentological cycles, we agree with the fourfold subdivision of the Famennian. The previous Upper Famennian in Baltic might be subdivided into Upper and Uppermost Famennian corresponding probably to the *costatus* conodont Zone. The boundaries between four Famennian substages coincide with the boundaries between large sedimentological cycles. The most important stratigraphic border in the Baltic sequence is the boundary between the Middle and Upper Famennian, dividing the deposits of two higher-scale sedimentological cycles, Sosnovsk and Megava cycles.

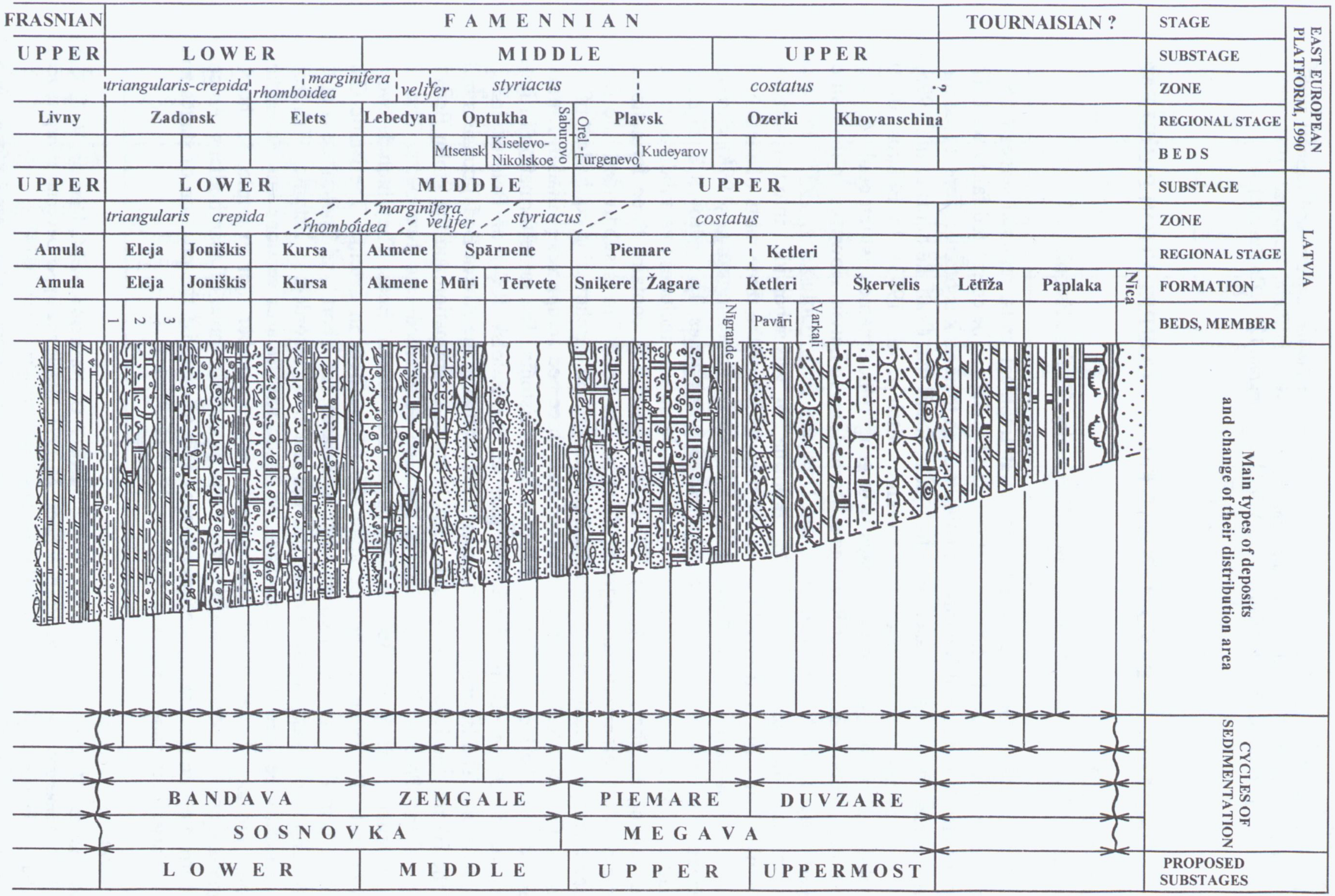

Figure. Cyclic structure of the Famennian in the Baltic area

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SOME MIDDLE DEVONIAN AND EMSIAN CORRELATION PROBLEMS

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Major Middle Devonian and Emsian stratigraphical units, regional stages (R.S.) and/or formations (Fm) of the Baltic area, Estonia and Latvia, can be correlated fairly well. The same applies also to the coeval Belarussian units, though their rank is often different (see the chart). The correlation is largely based on lithological, fossil fish (Valiukevičius *et al.*, 1995, Mark-Kurik in press) and miospore data (Avkhimovitch *et al.*, 1993). In Belarus, the Emsian Vitebsk R.S. includes three units, beds with geographical names, which could correspond to the Lower, Middle and Upper Rēzekne subformations in Latvia. However, in the Baltic region a gap corresponds to the lower unit, the Drevyaty Beds (Golubtsov, 1997). In Estonia, an equivalent of the Rēzekne R.S., the Mehikoorma Fm, was subdivided into two subformations (Valiukevičius, 1994); it should be established which of the three parts of the Rēzekne Fm known in Latvia is lacking here. It is of note that Rzhonsnitskaya (1998) correlated the Rēzekne Fm with the *inversus* and *serotinus* conodont zones. The Adrov R.S. in Belarus is a small unit, whereas the coeval Pärnu Fm in the Baltic area includes two subdivisions (the Tori and Tamme members in Estonia). The Baltic Narva R.S. contains three formations, which correspond to three regional stages in Belarus. The Leivu Fm is subdivided into four units, extending from Estonia to northern Belarus. The probable Belarussian equivalent of the Leivu Fm, the Gorodok R.S., has three subdivisions. Three bed complexes (Viljandi, Kureküla, and Tarvastu) can be identified in the Aruküla Fm in Estonia. The same formation in Latvia and the coeval Goryn' Beds (the lower part of the Polotsk R.S.) of Belarus include two subdivisions. The Burtnieki Fm "proper" (not including the Abava Beds) consists in Estonia of the Härma and Koorküla Beds. In Latvia, the same formation and the Stolin Beds (middle part of the Polotsk R.S.) in Belarus are also subdivided into two parts. The probable equivalents of the Abava Beds in Belarus are the Moroch' Beds. They include two units of lower rank. The same can be said about the Abava Beds in Estonia. The Baltic Gauja and Amata formations have their coeval units in Belarus, the Ubort' and Zhelon' beds of the Lan' R.S. The upper part of the Amata Fm has not been recorded in Estonia. Fish zones can successfully be used in the correlation of Baltic and Belarus sections but, depending on a group and an interval, zonal subdivisions vary in number. For example, in the Givetian agnathan and placoderm zones are more numerous than those of acanthodians. As conodont occurrences are rare, miospore assemblages help to establish the position of stages and their boundaries in the above regions.

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	CONODONT zones	AGNATHAN ZONES	Placoderm*& acanthodian zones		East European miospore zones	ESTONIA R.S., Fm	ESTONIA Beds, Member	LATVIA Formation	LATVIA Subf., Beds	BELARUS Regional Stage	BELARUS Beds
Frasnian	*falsiovalis#*		*B. cellulosa**		BI	Pļaviņas	Sn. Gora	Pļaviņas		Sargaevo	
			B.obrutschevi	*Devon-onchus*		Amata		Amata	Upper		Zhelon'
	disparilis		*B. prima**				Lower		Lower	Lan'	
	hermanni-	*Psammolepis paradoxa*	*Asterolepis ornata**	*concinnus*	IM	Gauja	Lode Sietiņi	Gauja	Lode Sietiņi		Ubort'
Givetian	*cristatus*	*Psammolepis abavica*	*Watsonosteus**				Abava upper lower		Abava		Moroch' mr$_2$ mr$_1$
	varcus	*Pycnosteus tuberculatus*	*Asterolepis dellei**	*Diplacanthus gravis*	EX	Burtnieki	Koorküla Härma	Burtnieki	Upper B. Lower B.	Polotsk	Stolin sl$_2$ sl$_1$
		Pycnosteus pauli				Aruküla	Tarvastu Kureküla	Aruküla	Upper		Goryn' gn$_2$
	hemiansatus	*P. palaeformis*					Viljandi		Lower		gn$_1$
Eifelian	*kockelianus#*	*S. striatus*	*C.cuspidatus**| *N.kernav.*		RL	Nar-va R.S.	Gorodenka	Narva	Kernave	Kastyukovichi	ks$_{1-3}$
	australis		*Ptychodictyon rimosum*				Leivu Mbs $_{1-4}$		Leivu	Gorodok	gr$_{1-3}$
	costatus		*Cheiracanth. estonicus*		DR		Vadja		Vadja	Osveya	os$_{1-3}$
	partitus	*Schizosteus heterolepis*	*Laliacanthus*		PT	Pärnu	Tamme Tori	Pärnu	Upper Lower	Adrov	
Emsian	*patulus*	*Skamolepis fragilis*	*singularis*		DI	Rēzekne R.S./Mehi-Koorma Fm	Upper Lower	Rēzekne	Upper Middle	Vitebsk	Lepel' Obol'
	serotinus				RC				Lower		Drevyaty

Correlation chart of Baltic and Belarussian Middle Devonian and Emsian stratigraphical units and biozones including standard conodont zones (# shows zones known in Baltic), based on Golubtsov 1997 and Mark-Kurik in press. *B., Bothriolepis; C., Coccosteus; Cheiracanth., Cheiracanthoides; N. kernav., Nostolepis kernavensis; P., Pycnosteus; S., Schizosteus*; B., Burtnieki; Fm, Formation; Mbs, Members; R.S., Regional Stage; Sn., Snetnaya; DR, *Dibolisporites radiatus* Zone after Vaitiekuniene in Narbutas *et al*, 1993; abbreviations of the other miospore zones after Avkhimovitch et al., 1993.

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RIVER NETWORK OF THE HOLSTEINIAN INTERGLACIAL IN MID-EASTERN POLAND AND WESTERN BELARUS

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Geological setting and regional peculiarities of the Holsteinian Interglacial sediments within adjacent areas of Belarus and Poland are of special significance for the understanding of the Baltic Sea drainage pattern development. While the stratigraphic position of the Holsteinian sediments is fairly undoubted, so far only limited palaeogeographical aspects of their distribution and structure have been examined in this part of Europe. Most publications dealing with the mid-Pleistocene geologic history of the area have been based on palaeobotanical data from a few key sites, and generally they have focused on the past climatic aspects. Few papers concerning reconstruction of the drainage pattern confirm the inherited development of the Holsteinian rivers. The latter is the aim of the authors' investigations which have been based on an analysis of structure and geological position of profiles, containing interglacial deposits, coupled with examination of their relationship with the underlying and the overlying deposits.

Within the Belarussian part of the area (Neman region), the Holsteinian is mostly predominated by lake sediments which are set at the very varying altitudes (from -5 b.s.l. to 112 m a.s.l.). Alluvial sediments occur in the Neman Lowland, mainly at 70-80 m a.s.l. but their altitude decreases gradually to 55-60 m a.s.l. near the Polish-Belarussian border (Lososna and Svisloch basins). River sediments are usually underlain by a thick glaciolacustrine sequence, but in some profiles there is a till beneath the alluvia. The latter are underlain commonly by a gravel-pebble bed, 1-3 m thick and filling the incisions, associated presumably with a catastrophic runoff of ice-dammed lakes at the termination of the Elsterian Glaciation (cf. Marks & Pavlovskaya, 1998). River sediments are composed of fine-grained sands, underlain by varigrained well-sorted sands of channel facies, and their thickness does not exceed 10 m as a rule. Aggrading fluvial and oxbow lake facies prevail within the areas of the Elsterian glacial lakes where the interglacial sequence is up to 30 m thick. In several profiles, there are alternate alluvial and lacustrine deposits, with gradual and indistinct transition between the layers of different origin. Such structural peculiarities reflect a stagnant hydrodynamic regime of the Holsteinian drainage pattern in the Neman Lowland. Most probably, during the initial part of the interglacial there were overflow lakes, connected by channels.

Near Grodno, the Holsteinian sediments occur at 95-110 m a.s.l. but in some cases they are at 2 m a.s.l. and at -5 m b.s.l. Such a variability might be due to glaciotectonic deformations during the following glaciations when the interglacial and the underlying deposits, and their thickness were disturbed significantly right up to the Quaternary bedrock. Taking into account the lacustrine origin of the Holsteinian sediments in this area and also a regular drop of an alluvial bed altitude within the another part of the Neman region, it may be assumed that there was no river valley similar to the present one downstream from Grodno.

Fluvial pattern of the Holsteinian (Mazovian) Interglacial in Poland has been many times incorrectly assumed to the depressions in the Quaternary substrate. Lack of reliable dating methods makes the assumed water level of the Holstein sea to be the most important index for a reconstruction of a buried fluvial pattern. In the Lower Vistula valley, bottom parts of tills of the Middle Polish Glaciations (Saalian) contain glacial rafts of marine sediments. They are mainly sands and silts with pieces of *Cardium* sp., *C. echinatum*, *C. edule*, as well as foraminifers of the Holstein sea that undoubtedly occurred in the southern Baltic Basin. According to the studies in the Kaliningrad District (Russia) and in the Hamburg region (Germany), this postulated sea level seems to be close to the present level of the Baltic Sea. Therefore in Central Europe, outside the areas with undoubted glaciotectonic deformations and neotectonic movements, the buried river valleys of the Holsteinian Interglacial occurred at similar altitudes as the contemporary rivers.

At present, a bed of alluvia of the Holsteinian Interglacial is located at about 110 m a.s.l. in the Sandomierz Basin in southern Poland, and 104-88 m a.s.l. in the Vistula gap in the South Polish Uplands. Further to the north, this ancient valley occurs within the present Vistula valley, with its bed at Dęblin at 86 m a.s.l., two fluvial series with their bottom at 75 m near Kozienice, and at 63-70 m a.s.l. at Magnuszew. This buried valley corresponds with the tributary river valleys of the pre-Kamienna, pre-Wieprz (bed at 95 m a.s.l.), pre-Radomka (90-110 m) and pre-Pilica (130-140 m, at its mouth at 74 m a.s.l.). To the north, there are two river palaeochannels in Warsaw (bottom of alluvia at 52-54 m a.s.l.): one of them coincides roughly with the present valley, the other runs northwards to a palaeovalley of the pre-Bug River and then turns westwards. A bed of the Holsteinian river network in the Lower Bug River valley is located at 50-59 m, and in the Lower Narew River below 70 m a.s.l. The pre-Bug was supplied with the tributaries of the pre-Liwiec and the pre-Cetynia. A base level of erosion of the Holsteinian Lower Wkra River is located at 35 m a.s.l. In the western Warsaw Basin the main river got a tributary of the pre-Bzura (bed at 54-76 m a.s.l.) and another river near Kutno (at 49 m a.s.l.). The pre-Vistula bed drops gradually from 36 m in the northern Warsaw Basin to 30 m a.s.l. in the Płock Basin.

Quite a lot of research drillings in Central Poland permits to establish a more detailed geologic setting of river sediments of the Holsteinian Interglacial. In the Warsaw Basin they are either to over 30 m thick when underlain by a several dozen metre thick ice-dam and glaciofluvial sediments in the Elsterian glacial tunnel valleys, or they are considerably thinner (several metres only) when underlain and overlain by tills of the same age (in this case, a top of a fluvial sequence has been presumably subjected to a glacial erosion). In the northeastern Mazovia fluvial sediments of the Holsteinian Interglacial are commonly underlain by a thick ice-dam series and locally, by glaciofluvial deposits in deep glacial tunnel valleys. Especially interesting is the occurrence of a dozen metre thick series of interglacial lake sediments just beneath fluvial sediments (e.g. Nowa Wieś, Ruskołęka, Żabikowo and Chmielew) or between the two there is a till, several metres thick. In the Podlasie Region, alluvia of the Holsteinian Interglacial are commonly about a dozen metres thick. They are usually underlain and overlain by ice-dam sediments, but in a single research drilling (Derewiczna) there are the interglacial lake sediments beneath. This very area is distinctly poorer in ancient glacial tunnel valleys.

A comparison of a geologic setting, thickness and structure of the Holsteinian deposits suggests that the main watercourse of the Holsteinian fluvial pattern was quite different from the present one in the Polish-Belarussian cross-border area. The Holsteinian Neman flew westwards to the Narew River valley through a passage between the Late Elsterian glacial lakes of western Belarus and mid-eastern Poland. The Warsaw Basin was a principal hydrographical junction of the Holsteinian Vistula, Bug and Narew rivers. The main watershed between the Baltic and the central Poland rivers occurred in the southwestern Mazury Lakeland in northern Poland.

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AN INTEGRATED PALYNOSTRATIGRAPHY AND LITHOSTRATIGRAPHY OF THE MIDDLE DEVONIAN LACUSTRINE SEDIMENTS OF THE ORCADIAN BASIN, SCOTLAND AND THEIR CORRELATION WITH THE BALTIC AREA

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It has long been known that the fish faunas of the Orcadian Basin and the Baltic are in many respects closely similar. Such comparisons have been generally produced in the form of correlation tables listing the fossil fish characteristic of groups of strata, which are then placed in general equivalence. Although this emphasis the similarities and produces broad correlations it will not allow a more precise correlation. In part, this is due to the nature of the two successions. The Orcadian succession being relatively thick, fault-dislocated and lithostratigraphically monotonous. In contrast, the Baltic succession is relatively thin, almost certainly contains many gaps and, like Orkney, does not have fish fossils throughout the succession.

Recently there has been much new work on the Orkney succession of the Orcadian Basin. This has, for the first time, established a directly logged, internally correlated lithostratigraphy. Significantly this lithostratigraphy can be defined using the lacustrine cycles. These cycles represent periodic orbitally forced changes between playa lake and permanent lake condition. These lacustrine cycles can also be bundled into groups, which represent periods when the climate tended to aridity interspersed with wetter episodes.

In parallel with this new lithostratigraphy there has been a linked programme of palynological sampling to devise a palynostratigraphy for the basin. Rather than defining assemblages, this has defined spore ranges against the lithostratigraphy. This gives a series of palynological inceptions and extinction events placed against a cycle-based lithostratigraphy and thus has an in-built time base.

Within the Baltic and Orcadian successions there are a number of horizons, which can be closely correlated. These are the Kernave Beds and the Sandwick Fish Bed which both contain the distinctive Achanarras fish fauna. Above this level, a further distinctive fish assemblage links the Abava Beds with the Eday Flags. In addition, there are also a number of palynological tie points. Significant is the incoming of *Geminospora lemurata* which also defines palynologically the base of the Givetian stage. There are also a number of other palynological inceptions, which although not defined in the Baltic, can be picked through correlation across the East-European Platform. These palaeontological tie-points allow the two successions to be compared lithostratigraphically in a more direct way. In doing this, a number of similarities in the cyclicity become apparent. If these similarities can be substantiated they may well show a more direct linkage of Orcadian Basin lacustrine cycles and Baltic transgressive-regressive cycles. A possible mechanism, which causes synchronous changes within quite distinct sedimentary systems, is the changing balance of water between the sea and lakes/groundwater in an orbitally forced system.

SUBGLACIAL EROSION AND PRECIPITATION: THE SICHELWANNEN CASE

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Sickle-shaped depressions - sichelwannen - on bedrock surfaces are reported from different environments. We will discuss sichelwannen forms in granite areas of Bohuslän, SW Sweden.

Sichelwannen (descriptions in Ljungner, 1930; *cf.* Shaw, 1988) are shallow pots with two horns pointing in the ice-movement direction, occurring alone or in clusters. They vary in size from cm to 3-4 m in width, from cm to dm in depth; in length the development of their horns is decisive. They occur even on vertically rock precipices. In some instances they are eroded into neighbouring rocks constituting furrows with overhanging "half-tunnel" parts.

Subglacial forming of sichelwannen: some hypotheses

Ljungner (1923, 1930) concluded that sichelwannen were created by subglacial sheet-flood water-erosion. Hjulström (1935) proposed cavitation-erosion (rock-failure by implosion) due to high-speed subglacial water, and Johnsson (1956) erosion by an ice-water paste. From other areas, sichelwannen are reported, e.g., by Gjessing (1965; erosion by soaked ground moraine), Dahl (1965), Bernard (1971-1972), Shaw (1988; referring to Allen [1971, 1982], and proposing a relation to catastrophic subglacial flooding events), Eyles and Boyce (1998; referring to Gjessing, 1965 and proposing abrasion by wet, deforming debris below the ice).

Bedrock morphology and Quaternary deposits of Bohuslän

An outline of the *bedrock morphology* of Bohuslän shows a central high-level area of rugged plateaus, descending in E to the Lake-Vänern basin, and in W to the Skagerrak depression. Valleys, ridges and hills are strewn with roches moutonnées and other small forms.

A prominent landscape feature is the *scarcity of Quaternary deposits in Bohuslän*, with vast areas of naked rocks, and an extreme development of sichelwannen rock-sculpture. Southwards, in the district of Halland, this situation is drastically changed, with tills and other Quaternary deposits, but without sichelwannen where the bedrock surface can be studied.

The reason for the lack of tills *etc.* has been discussed, e.g. by Lundquist (1958), who concluded that marine abrasion could not be the full explanation as the sediment-covered areas of Halland had experienced the same wave exposition as Bohuslän.

Sichelwannen, shield-boss rocks and features of quarrying

Sheet jointing and sets of vertical joints divide the granite into parallelepipeds or polygonal blocks. Quarrying has occurred during the sichelwannen event. Next to the abrupt rock rise is a zone of small cm-sized sichelwannen and (dominating) elongated spoon-forms; further away is another zone with dm-sized forms, and still further the "normal" pattern with m-sized sichelwannen. The two areas with cm- and dm-sized forms can be coupled to the two-step removal of granite blocks illustrating gradual stages of sichelwannen development.

There are many other indications of plucking ice-erosion during and/or after the sichelwannen event, and chiselling of the proximal steep-dipping part of sichelwannen, shaping rock facets of the *split-fracture* type (fläk) or the mussel-*shell* type. Such a facet has a rough rock surface without striae, or it is glacially smoothed and thinly striated, a striation distinctly different from both the sichelwannen polish and the crude striae of the roche moutonnée.

Weathering and precipitates

The roches moutonnées with rough long striae and small transversal fractures show a rugged, weathered surface, often covered with a thin mat of lichens. The sichelwannen lack both such vegetation and ice-erosion fractures - the erosion has been of a "soft-wearing" type.

Many sichelwannen, some facets, and sometimes striated lee-sides and walls of open joints, are covered by a very thin (sub-millimetre) iron-type precipitate of red-brownish colour (*cf.*, e.g., Andersen & Sollid, 1971). Carbonate crusts containing scattered granules of quartz, feldspar and rock debris also occur. Calcite has been deposited during fluctuating accumulation/erosion conditions: a first thin calcite layer has been deposited, then scratched by ice striae but not completely destroyed; on top of it a new calcite layer has been deposited and scratched from a somewhat new direction, and so on.

Origin and genesis of sichelwannen sculpture

1) Sichelwannen are incised in (and in between) roches moutonnées. In exceptional cases, the sichelwannen-sculpture encircles a roche moutonneé creating a shield-boss rock. This form is, therefore, a "round" central part of an old roche moutonneé standing up above a later developed sichelwannen-sculptured rock-floor. During the sichelwannen event, quarrying may initiate the development of new generation(s) of sichelwannen.

2) The very thin striation present, if any, differs from the striae on neighbouring rocks, and shows a soft cast-like habitus resembling the aeolian polishing-striation on strongly wind-eroded rock-surfaces. The smooth, polished surface of the sichelwannen contradicts the hypothesis of cavitation (implosion erosion) presented by Hjulström (1935). The smooth, polished surface also contradicts a forming by normal grinding-striating ice-erosion. Erosion by wet debris - deforming-sediment theory - is an interesting approach, but little is known about the bedrock eroding capacity, and no deforming sediments are preserved in this granite area.

3) Sichelwannen forms, in patterns and as individuals, have been well documented in controlled experiments. The erosional effect of water below a glacier is influenced by pressure-temperature, flow characteristics, sediment load, and bed qualities. Most hypotheses presented are related to "fluvial" processes or erosion by water-soaked debris.

4) The ferruginous and calcareous coatings indicate precipitation during a phase of little or no erosion. The thin calcareous layers gradually deposited and faintly scratched by moving ice may indicate a situation below thin ice or in association with shelf-ice conditions.

5) The water postulated for sichelwannen formation may come from catastrophic draining of (subglacial) lakes. The Lake-Vänern basin offers a topographical prerequisite of ponding volumes of subglacial water, but signs of exceptional flooding-events have been interpreted as results from the draining of the Baltic Ice Lake. Another possibility is the supply of

supraglacial melt-water to the ice bed. A flat-lying ice-surface may offer a large area of melting, and also an ice-surface configuration of "confluent" dipping during the downwasting.

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CHANGES IN SCALE MORPHOLOGY – A BASIS FOR HIGH RESOLUTION THELODONT BIOSTRATIGRAPHY

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Species of *Thelodus*, *Paralogania* and *Katoporodus* were studied to find out the intraspecific morphological changes of scales in sequences; the parallel, ecological lineages of loganiid thelodonts are discussed.

Thelodont scales from bore cores of the Baltic Sea area and some examples from South Sweden and the Severnaya Zemlya Archipelago were examined. Morphological varieties (morphs) of the scales of *Thelodus sculptilis* Gross, *T. admirabilis* Märss and *T. trilobatus* Hoppe come from the Kuressaare and Ohesaare stages, Ludlow and Pridoli, correspondingly, of the Tahula, Sakla, Kuressaare, Kaugatuma, Kaavi-568, Ohesaare, Sõrve-514 and Ruhnu-500 bore cores of western Estonia, and from the Öved Ramsåsa Beds, Ludlow of Skåne, South Sweden. Changes in scale characteristics of *Paralogania martinssoni* (Gross) are demonstrated on the example of the material from the Rootsiküla and Paadla stages, Wenlock and Ludlow, respectively, from Saaremaa Island, Estonia, and Ludlow of Pioneer Island, Severnaya Zemlya Archipelago. *Katoporodus tricavus* (Gross) and *K. timanicus* (Karatajūtė-Talimaa) scales from the Ohesaare Stage of the Kaavi-568 (Estonia) and Ventspils (Latvia) bore cores are considered.

Morphological changes of the scales of *Thelodus admirabilis* Märss in time are shortly described in Märss (1982). Basing on the scale features, Karatajūtė-Talimaa (1997) divided the genus *Loganellia* into two genera - *Loganellia* and *Paralogania.* The morphology of thelodont scales has changed during existence of the species. In the beginning, each species had relatively small and simple scales. With the development of the species the scales became bigger and more complicated, the number of ribs, grooves, protuberances or spines on the crown grew. Some levels of changes in scale morphology can be followed vertically in core sections and also geographically. These features are not sufficient for establishing new taxa, but they can be used for regional biostratigraphical correlations.

The dependence of the scale sculpture on the environment is not firmly established. There is some evidence that certain features of thelodont scale morphology were caused by the environment. Fredholm (1992) studied *Thelodus schmidti* (Pander) from Möllbos locality, Gotland Island, and concluded that spiny scales occur on vertebrates that lived in muddy habitats, represented by calcareous mudstones and argillaceous limestones; non-spiny scales are common in vertebrates whose remains were found in pure crinoidal limestones (*ibid.*). Another example of the *Thelodus* lineage comes from western Estonia. A sample of argillaceous domerite from the Ruhnu bore core, depth 163.2 m, contains *Thelodus parvidens* Agassiz scales which have conspicuous spiny crowns.

Most of the thelodont species that lived on the northern hemisphere at the time of Late Llandovery sea level high-stand belong to the *Loganellia* lineage [*Loganellia scotica* (Traquair), *L. sibirica* (Karatajūtė-Talimaa), *L. asiatica* (Karatajūtė-Talimaa)] that had certain scale features of well stream-lined longitudinal ridges of the crown. In the Late Wenlock - Early Ludlow, *Loganellia* sp. 3 and *L.* sp. 5 Märss *et al.*, 1998 continued the lineage in Canadian Arctic and *L. cuneata* (Gross) in the Pridoli in Europe. The start of sea level lowering in the latest Llandovery and Early Wenlock gave rise to the *Shielia* lineage in Scotland and Canadian Arctic. The species have scales with 3-7 posteriorly pointed crown apices. The species of the *Paralogania* lineage occupied shelves (carbonate platforms) during the Late Wenlock, whole Late Silurian in Eurasia and occurred also in the Early Devonian in the Canadian Arctic. Their scales have spines and ribs postero-laterally of the crown. The *Shielia* lineage preceded *Paralogania*. Species of the lineage including *Loganellia grossi* Fredholm, *L. tuvaensis* (Karatajūtė-Talimaa), *Loganellia* sp. 2 and *L.* sp. 4 Märss *et al.*, 1998 appeared in the late Early Wenlock and continued higher in the Early Ludlow in Europe and Canadian Arctic, and in the Pridoli in Tuva. Their scales exhibit a flat crown surface and one or two short ridgelets postero-laterally of the crown. Judging from above, we may conclude that at least *Loganellia* and *Paralogania* are ecologically parallel lineages of species with certain scale features; the third, yet unnamed lineage used, perhaps, similar ecological niches to *Loganellia,* and *Shielia* inhabited those similar to *Paralogania.* The scale sculpture of all species in studied lineages developed in course of time.

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THE VOLKHOV STAGE IN EAST BALTIC: DETAILED STRATIGRAPHY AND FACIES ZONATION

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For the Volkhov Stage, two independent sets of names for similar rock units are used in northern East Baltic, in the Baltic-Ladoga Klint area. In North Estonia, five members of the Toila Formation (Saka, Telinõmme, Künnapõhja, Kalvi and Lahepera) constitute a successive three-fold subdivision of the interval, and this subdivision is thought to be consistent with the set of eastern Baltic substadial units (from the base: Saka, Vääna and Langevoja substages) (Orviku, 1960; Männil & Meidla, 1994). In the vicinity of St. Petersburg, the term "Volkhov Formation" is applied, whereas its three-fold subdivision by Lamansky (1905) was originally based on the trilobite zonation.

Due to extensive use of Volkhovian limestone in the buildings of St. Petersburg and the vicinity, a detailed subdivision for the same stratigraphical interval, based on traditional quarrymen' beds, formed about three centuries ago in the area. This subdivision has recently been reviewed in papers by Dronov *et al.* (1998). It consists of 29 individual named beds or bedsets and is established for all principal sections along the Russian part of the Baltic-Ladoga Klint.

For developing a uniform detailed chronostratigraphical framework for the Baltic-Ladoga Klint area an attempt was made to extend detailed bed-by-bed correlation into the Estonian area (Figure). It has been approved in course of field investigations that the bed system is applicable for the lower and middle part of the Volkhovian sequence in northeastern Estonia, in the Toila-Narva interval. Further to the west, several beds loose their individuality and only the most characteristic key horizons can be traced at Saka.

The consistency of the informal units needs to be proved biostratigraphically. For the time being the available ostracode data can be used (Meidla *et al.*, 1998). The epibole zone of *B. palmata* in the succession of informal beds maintains its stratigraphical position at Saka, Toila and Päite. Position of the *B. palmata* epibole zone can also be recognised in a number of sections where the detailed bed nomenclature is inapplicable, and it allows to trace this particular level in more on- and offshore parts of the facies profile.

Tracing of the beds of informal nomenclature along the Baltic-Ladoga Klint demonstrates that the three-fold subdivision of the Volkhov Stage used in Estonia and Russia is consistent in general, although some differences in details occur.

The boundary of two principal Volkhovian lithofacies zones (the North Estonian grey wackestones or packstones with coarse glauconite and the Swedish-Latvian red-coloured wackestones) can be traced in South Estonia, in subsurface (Meidla, 1997). The rocks in the St. Petersburg area, mudstones to packstones with occasional red beds, resemble the transitional lithofacies south of the Estonian outcrop area, reported already by Põlma (1982) and Mägi (1970; 1987). On the basis of general stability of the Ordovician facies zonation in Post-Tremadoc, we assume that the transitional lithofacies zone is continued in the near-cliff area in the St.Petersburg Region. This zone apparently represented a relatively deeper part of the palaeobasin than the area of northwestern Estonia. The extension of the principal zonation of the palaeobasin further to the east adds new aspect to the Volkhovian palaeogeography in this area.

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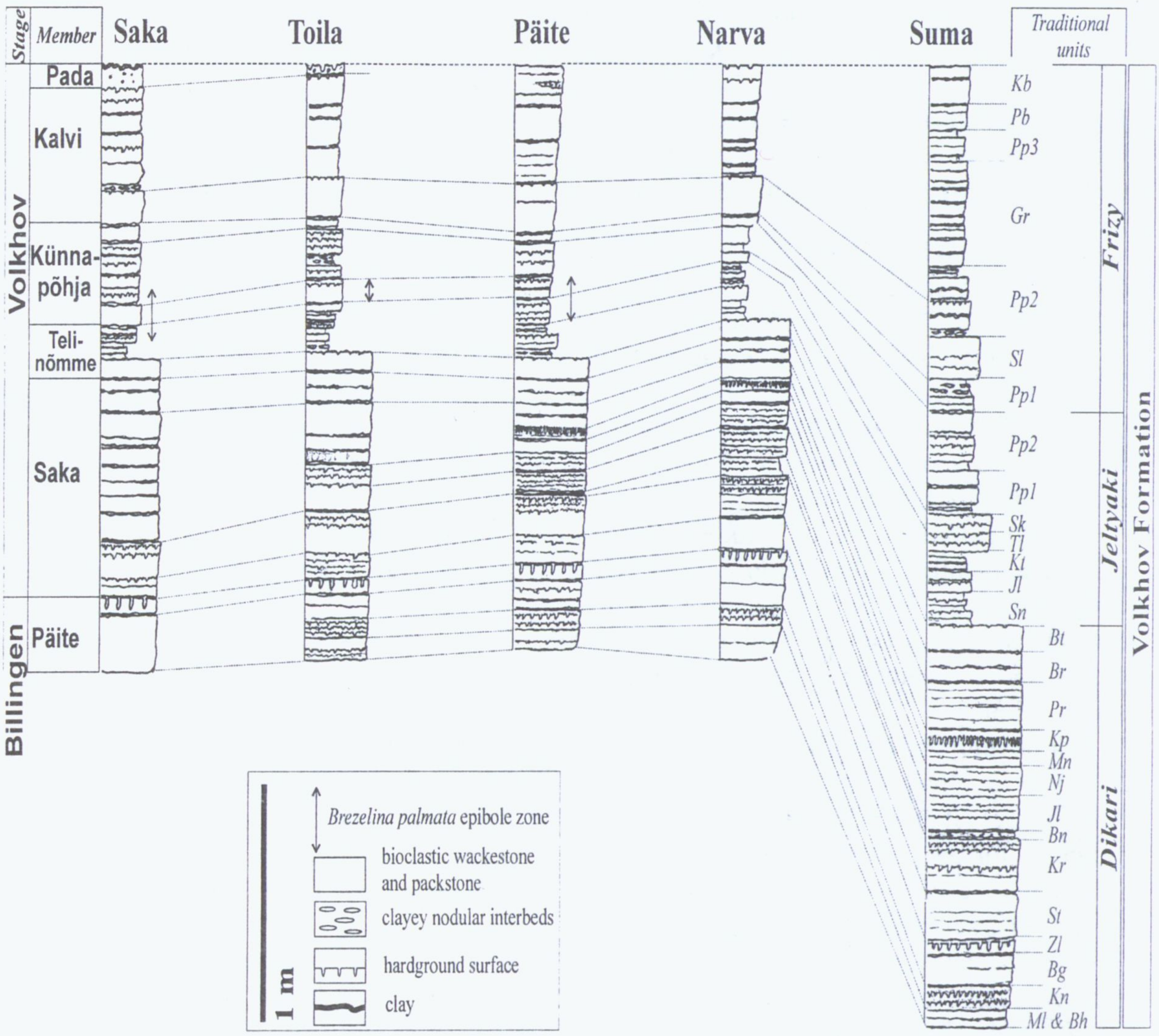

Figure. Bed-by-bed correlation of the upper Billingenian and Volkhovian strata along the Baltic-Ladoga Klint between Saka and Narva, North-East Estonia. F. – Formation, S. - Sillaoru Fm. Bed indices (under traditional units) from Dronov *et al.* 1998.

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SOME PROBLEMS OF THE UPPER PLEISTOCENE OF LATVIA

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Upper Pleistocene deposits are distributed in a whole territory of Latvia. Their thickness in highlands attains even 100-200 m, but in lowlands up to 20-30 m. Stratigraphically these deposits are subdivided in Felicianova and Latvia formations. Lacustrine and alluvial deposits of the Felicianova Formation were found in 8 sites. Their correlation with Eemian interglaciation in Western Europe and Mikulino interglaciation in Eastern Europe does not make difficulties.

Some problems arise in separation of Latvia Formation's sediments into stratigraphic units. This is connected to opposite opinions on numbers of glacial advances and their distribution boundaries in Late Pleistocene. Determination of stratigraphic position of till beds and organic deposits between them in the cover of Upper Pleistocene in different parts of Latvia, particularly in lowlands, is difficult due to disturbances by glaciotectonic processes. Thus, consequently the problems arise in compilation of geological maps.

Recent data obtained from large-scale geological mapping and detailed investigations of several type areas concludes on possibility to subdivide the Latvia Formation. For example, at the base of strata of the Upper Pleistocene in several sections alluvial and lacustrine sediments were found which overlie the Felicianova deposits and are named Rogaļi Beds (Meirons, 1992). They were formed in interstadial conditions.

In the part of territory of Latvia situated distally from the Linkuva marginal formations the Latvia Formation is represented by two till beds. The lower one is named Augšzeme Till, but the upper one - Vidzeme Till. Their thickness fluctuates from few meters up to 40-50 m. In the lower till the pebbles composed of the Silurian and Ordovician limestones were found, transferred by glacier from the bottom of Baltic Sea. Also crystalline rocks from Middle Sweden are present here. Therefore the lower till was deposited by glacier, which advanced from north-west. During creation of the upper till the glacier was moving towards south. The tracing of two till beds is easier due to fact that in wide area these are separated by aqueoglacial deposits. For instance, between Talsi and Kandava towns, in area of 20 km, two intertill glaciofluvial deposit beds reach thickness up to 50-80 m. Above them, but below the upper till bed the glaciolacustrine clays with organic admixture were found. Below upper till bed in some places the grey till of Kurzeme Formation is determined. Intertill organic sediments were found also in other regions of Latvia. As follows from the data of pollen and palaeocarpological analyses, organic rich sediments were formed in the tundra or park tundra zone and in the boreal forest zone, too. Above-mentioned facts allow to conclude that in the Late Pleistocene two glacial advances, separated by interstadial, covered the territory.

In the part of Middle Latvia lowland situated proximally to the Linkuva moraine, in the deposits of Latvia Formation a few till beds were found. The distribution boundary of the upper bed is marked by Linkuva marginal zone. Nevertheless, in the Middle Latvia lowland the glaciotectonic deformation structures are widely distributed (Zelčs, 1993). They are mainly composed of interbedded basal till and aqueoglacial sediments, as well as mixture of the above-mentioned sediments. In eight sites below upper till bed alluvial and lacustrine deposits with plant remains were constituted, which indicates subarctic climate. Their pollen diagrams may be divided into three types indicating asynchronous deposition of intertill sediments. There were obtained several radiocarbon data ranging from about 12 000 to 14 000 yr B.P.

Study of the Upper Pleistocene deposits and their stratigraphical subdivision is not possible without detailed investigations on Quaternary cover structure at type sections and areas, observations of glaciotectonic phenomena, as well as improvement of geochronological and biostratigraphical investigation methods.

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SPECIFYING THE CORRELATION OF THE FRASNIAN REGIONAL STAGES IN THE TIMAN-PECHORA PROVINCE WITH THE CONODONT AND AMMONOID ZONATION

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The Frasnian deposits of the Timan-Pechora Province contain rich zonal assemblages of miospores, conodonts, and ammonoids. Using the miospore zonation, the local units of the Southern Timan type sections were correlated with the regional stages of the Timan-Pechora Province and the entire East European Craton. Within the INTAS and RFFR projects, the composition and succession of conodont assemblages from the Sargaevoan, Domanikian, Sirachoyan, Evlanovoan, and Livnyan regional stages of the Frasnian were supplemented and added details for the Southern Timan sections; for the interval from the mid-Sargaevoan to the lowermost Evlanovoan regional stage (the Ust'-Yarega, Domanik, Lyaiol formations), the succession of local ammonoid assemblages was specified. The Montagne Noire (MN) Zonation of G. Klapper appeared most appropriate for correlation with the international conodont zonations. The succession of MN zones 3--13 is distinguished in Southern Timan and in the adjacent regions. The difficulties of correlation with the actual standard conodont zonation are due to the low frequency of *P. hassi, P. rhenana, P. jamieae*.

The local succession of ammonoid assemblages was correlated with the I-B - I-J interval of the international Frasnian ammonoid zonation. Should additional investigation of the Polar Urals sections be carried out, the detailed conodont and ammonoid characteristics of the lowermost and uppermost Frasnian Stage could be obtained. The new correlation chart of the Frasnian regional stages, miospore, conodont, and ammonoid zonation of the Timan-Pechora Province will probably be important for the comparative analysis of the development history of the Late Devonian basins of the East European Craton and other regions all over the world.

CRETACEOUS CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF LITHUANIA

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Cretaceous system in Lithuania is represented by Lower and Upper Cretaceous deposits. The Lower Cretaceous (Albian) consists of non-carbonate glauconite and quartz sands and siltstones. Nannoplankton is not found there. The Upper Cretaceous (Cenomanian-Maastrichtian) is represented by various carbonate rocks. Nannoplankton found in those deposits was investigated. Several nannoplankton zones distinguished by author in 1993 and 1997 are determined more exactly.

The lower boundary of each zone is marked by the first appearance of the index-species. Sizes of individual zones differ. The determination of nannoplankton zones is based upon the existing foraminifer zones.

Nannoplankton in the Lower-Middle Cenomanian is rare and badly preserved. No nannoplankton zone is distinguished there.

Ten nannoplankton zones were distinguished in the remaining Upper Cretaceous deposits:

Gartnerago obliquum - Microrhabdulus decoratus Zone

Definition: Interval from the first occurrence of *Gartnerago obliquum* (Str.) or *Microrhabdulus decoratus* Defl. to the first occurrence of *Quadrum pyramidum* (Gard.).

Age: Late Cenomanian - earliest Turonian.

Quadrum pyramidum Zone

Definition: Interval from the first occurrence of *Quadrum pyramidum* (Gard.) to the first occurrence of *Lucianorhabdus maleformis* Rein.

Age: Early Turonian.

Lucianorhabdus maleformis Zone

Definition: Interval from the first occurrence of *Lucianorhabdus maleformis* Rein. to the first occurrence of *Micula staurophora* (Gard.).

Age: Late Turonian - the middle of late Coniacian.

Micula staurophora Zone

Definition: Interval from the first occurrence of *Micula staurophora* (Gard.) to the first occurrence of *Lucianorhabdus cayeuxi* Defl.

Age: Latest Coniacian - the middle of early Santonian.

Lucianorhabdus cayeuxi Zone

Definition: Interval from the first occurrence of *Lucianorhabdus cayeuxi* Defl. to the first occurrence of *Broinsonia parca* (Str.).

Age: End of early Santonian - late Santonian.

Broinsonia parca Zone

Definition: Interval from the first occurrence of *Broinsonia parca* (Str.) to the first occurrence of *Ceratolitoides aculeus* Str.

Age: Beginning of early Campanian.

Ceratolitoides aculeus Zone

Definition: Interval from the first occurrence of *Ceratolitoides aculeus* Str. to the first occurrence of *Quadrum trifidum* Str.

Age: End of early Campanian - beginning of late Campanian.

Quadrum trifidum Zone

Definition: Interval from the first occurrence of *Quadrum trifidum* Str. to the first occurrence of *Lithraphidites quadratus* Braml. et Mart.

Age: Latest Campanian - beginning of early Maastrichtian.

Lithraphidites quadratus Zone

Definition: Interval from the first occurrence of *Lithraphidites quadratus* Braml. et Mart. to the first occurrence of *Nephrolithus frequens* Gorka.

Age: Early Maastrichtian - beginning of late Maastrichtian.

Nephrolithus frequens Zone

Definition: Interval from the first occurrence of *Nephrolithus frequens* Gorka to the top of Cretaceous deposits.

Age: Late Maastrichtian.

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SILURIAN SMOOTH BRACHIOPODS OF LITHUANIA AND THEIR PALAEOBIOGEOGRAPHIC SIGNIFICANCE

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Silurian strata revealed in the Lithuania boreholes contain different benthic fauna among which brachiopods are most common. Their communities and relationships with various facial zones were investigated and published in many papers (Musteikis, Karveliene & Yacyna, 1987; Musteikis, 1989, 1991; Brazauskas & Musteikis, 1991; Musteikis & Kaminskas, 1996). But detailed morphological studies of brachiopod and their descriptions are still absent, although a few parts of key collection have been described previously, in particular enteletids and athyridids (Paskevičius, 1962; Musteikis & Puura, 1983; Modzalevskaya, 1985; Bassett & Musteikis in press). Smooth brachiopods are chosen now for studies because of their characteristic convergent features, which are due to the common life strategy. Most of their evolution appears to strong pedicle attachment, hinge mechanism and absence of macrosculpture on the shell surface. They inhabited mainly shallow water off-shore zone and were typical to BA 2-3 (benthic associations).

The collection of smooth brachiopods comes from 20 boreholes of two facial profiles. One is stretched from the west to the east of Lithuania (Taurege-11, Geluva-99, Krekenava-7, and Svedesai-252), and the other - from the north to the south (Krekenava-7, Sutkai-87, and Virbalis-5). Brachiopod fauna occurs in several Silurian stratigraphic levels and horizons. It contains atrypids (*Glassia, Septatrypa, Atrypoidea, Cryptatrypa*), athyridids (*Meristina, Collarothyris, Pseudoprotathyris, Nucleospira*), and rhynchonellids (*Plagiorhyncha*). The latter is the exception in this set of genera as far as spire-bearing brachiopods are concerned for the most part. But *Plagiorhyncha* is variable externally (from smooth to plicate) as well as *Glassia* (from rounded to elongated in outline, with or without sulcus and fold on both valves). Their communities contrary to the remaining shallow water communities of smooth brachiopods lived under quiet water dysaerobic environment of BA4 (Sutkai Beds, Paprieniai Fm).

Smooth brachiopods are indicators of an accurate Wenlockian-Ludlowian and Pridolian ages. Most of their genera (*Cryptatrypa, Septatrypa Glassia, Meristina,* and *Nucleospira*) occur in many places in lower-upper Silurian of Baltic, Belarus, Wales, Gotland, and Podolia. Such a wide distribution of smooth brachiopods also supposes that all these basins were connected at that time. The presence of such genera as *Atrypoidea, Collarothyris,* and *Pseudoprotathyris* in Pridolian indicates close faunal relations between Lithuania and Podolia. The latter is the same which is known from the western slope of the Urals, Russian Arctic Islands (Greben Regional Stage) and Northeast of Russia (Mirny Reg. St.). The main interest of the Lithuania fauna lies on species identified with *Atrypoidea* and *Collarothyris.* Moreover, *Atrypoidea* fauna is also typical of Canadian Arctic Archipelagos (Reed Bay Fm).

Thus the Baltic basin was open in the south and through the Podolia there were connections with the Uralian and Arctic basin during late Silurian (Pridolian).

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COMMUNITY PATTERN AND SUCCESSION OF BALTOSCANDIAN EARLY PALAEOZOIC STROMATOPOROIDS

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Due to very complete and continuous carbonate sequences, rich in various benthic fossils, and detailed taxonomical research of stromatoporoids, the Baltic-Scandinavian region offers the best possibilities for elaboration of the biostratigraphical standard which takes into account both the stratigraphical succession and lateral community pattern of the late Ordovician and Silurian stromatoporoids. Twenty-eight stromatoporoid communities have been established spreading in the upper Ordovician and Silurian deposits of Estonia, Sweden

(Gotland) and Norway (Oslo Region) (Nestor, 1999). The communities are bound to the facies model of the Palaeobaltic Basin after Nestor & Einasto (1977) and to the Standard Benthic Assemblages (BA) after Boucot (1975).

The ecological niche of stromatoporoids was roughly restricted to the euphotic zone of the normal-marine carbonate shelf (platform) (Nestor, 1984). The richest and the most diverse stromatoporoid association was connected with the sediments of the high-energy, shoal (middle shelf) facies belt, represented in fossil record by coral-stromatoporoid boundstones, skeletal and coquinoid grainstones and rudstones, corresponding to the benthic assemblage BA2. Stromatoporoids were also rather numerous, but less diverse in the moderate- to low-energy open shelf environment which is represented by nodular skeletal pack- to wackestones and roughly corresponds to the benthic assemblages BA3 (above storm-wave base) and BA4 (below storm-wave base). Rare stromatoporoids occurred in the inner, restricted shelf (semilagoonal) sediments which correspond to the transition of the benthic assemblages BA1/2 and are represented in geological record by argillaceous wackestones interbedding with different primary dolostones. An impoverished taxonomical content is also characteristic of the communities distributed in marlstones, formed at the outer edge of the carbonate shelf, corresponding to the transition between the benthic assemblages BA4/5.

The lateral communities of stromatoporoids are rather indistinctly delimited and partly overlapping. The diverse reef communities, corresponding to the benthic assemblage BA2, usually contain the most common elements of the coeval open shelf (BA3-4) communities, but in addition they include some specific taxa which also have a shorter stratigraphical range and enable more detailed biozonation of the sections of the shoal facies belt in comparison with the open shelf deposits. The stromatoporoid communities in BA3 and BA4 position do not show principal differences except certain decrease of variability in the latter. The marginal, BA1/2 and BA4/5 communities stand out with very few and long-range species among which there prevail representatives of the finest-structure, microreticulate stromatoporoids (*Densastroma, Desmostroma, Araneosustroma, Actinostromella*).

First stromatoporoids appeared in the Baltic-Scandinavian region in the middle/late Caradoc (Oandu Stage in Estonia, Mjøsa Limestone in Norway), due to the drift of the Baltica continent from the moderate to subtropical/tropical zone. Up to the late Ashgill (Porkuni Age) stromatoporoids had scattered distribution and very poor communities. Therefore it has been impossible to distinguish coeval lateral communities in the Ordovician stromatoporoid faunas of Baltoscandia. During the Silurian a gradual diversification and enrichment of communities took place reaching maximum values in the open shelf environments by the early Telychian, Adavere Age (*Clathrodictyon variolare* Community), and in the shoal environments by the early Ludfordian, late Paadla time (*Simplexodictyon podolicum* Community). The characteristic elements of these two communities have also the widest geographical distribution in other regions of the world. It is remarkable that the lateral differentiation of the stromatoporoid faunas also increased in time, and in the Ludlow even four lateral communities have been distinguished.

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LITHOLOGICAL CORRELATION FEATURES OF THE LATVIAN LOWER PALAEOZOIC DEPOSITS BASED ON WELL LOG DATA

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In Latvia, the Lower Palaeozoic is represented by the Cambrian, Ordovician and Silurian deposits, characterised by a varying stratigraphic completeness of sections and different lithological and facial features. As a result of the core studies, 72 formations, 13 layers and 38 members were singled out in the L. Palaeozoic (Brangulis 1989, 1985, Gailite 1987, Ulst 1982).

The Cambrian deposits are represented by sandstone, siltstone, clay and, to a lesser extent, by gravelstone and oolitic ironstone (Fig. 1). In the Ordovician section, limestone, marl and clay prevail, while dolomite and sandstone are of a secondary importance (Fig. 2). The Silurian deposits are represented, predominantly, by carbonate clay, marl, clayey limestone. Organogenous-detrital and bioherm limestone, clayey dolomite and dolomite marl are present in the Silurian section to a lesser extent (Fig. 3).

The above-mentioned principal types of rocks, in some intervals of the L. Palaeozoic section, contain organic remains, glauconite grains, members of dark bituminous clay and metabentonite interlayers. They display heightened radiation levels and are characterised by anomalous values in the log diagrams (Fig. 1,2,3).

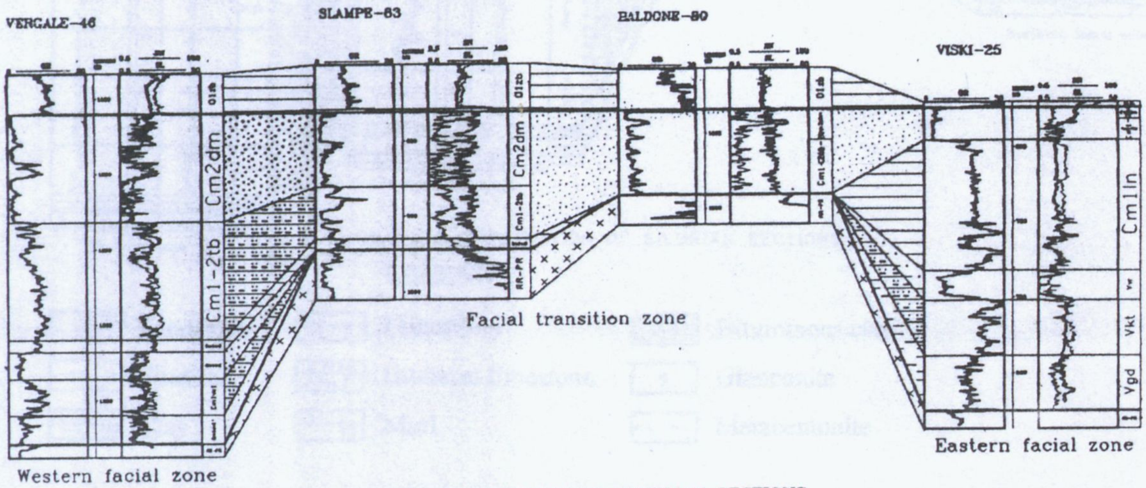


Figure1. CORRELATION OF CAMBRIAN SECTIONS

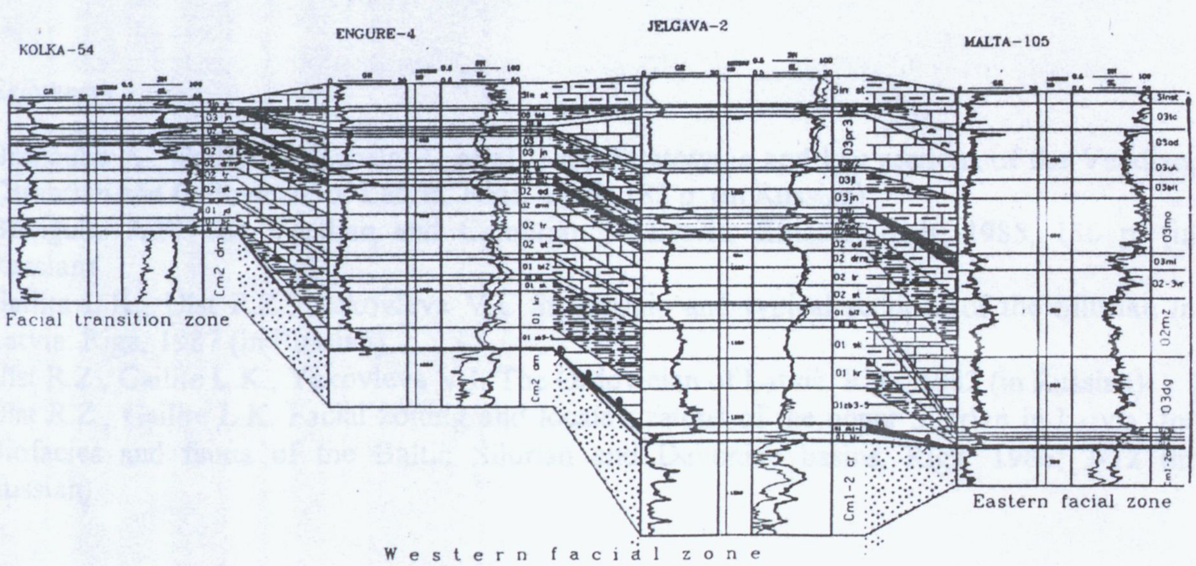


Figure2. CORRELATION OF ORDOVICIAN SECTIONS

Based on detailed comparisons of the lithological features of the L. Palaeozoic sections and logs from 200 wells, key layers with a uniform lithofacial composition were singled out, well sections with gradual and abrupt facial changes in the Cambrian, Ordovician and Silurian structure were identified, the boundaries of lithostratigraphic units were determined, those of the facial zones were defined more accurately (Fig. 1,2,3).

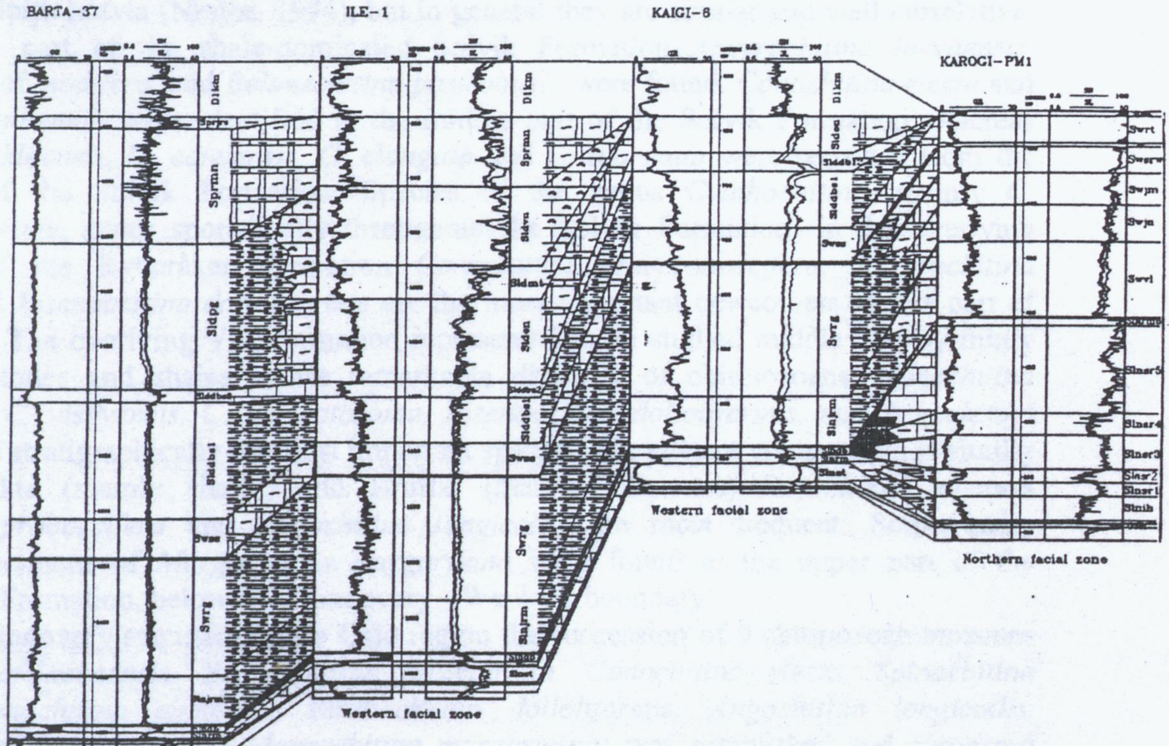
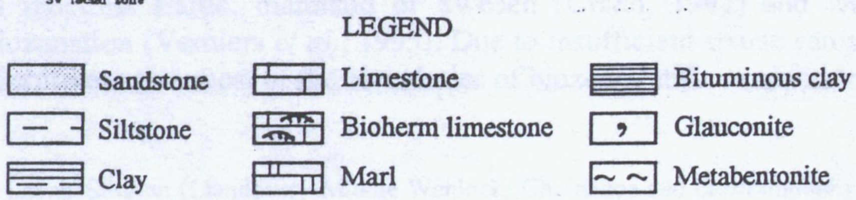


Figure 3. CORRELATION OF SILURIAN SECTIONS



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CHITINOZOANS IN THE LLANDOVERY OF THE OSLO REGION

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Ninety-five chitinozoan samples were studied and 34 species were identified from the 11 Llandovery localities of the Oslo Region. The chitinozoan assemblages of the Oslo region are less diverse and less numerous than those from the corresponding subsurface sections of Estonia and North Latvia (Nestor, 1994), but in general they are similar and well correlative. In the lower part of the shale-dominated Solvik Formation *Ancyrochitina laevaensis, Plectochitina* cf. *nodifera,* and *Belonechitina postrobusta* were found. *Conochitina electa* and *Spinachitina maennili* were identified in the middle part of the Solvik Formation, whereas *Conochitina iklaensis*, *C. edjelensis*, *C. elongata* and *C. alargada* were recorded from the upper part of the Solvik Formation. Species of the genus *Cyathochitina*, mainly *C. campanulaeformis*, occur sporadically throughout the Solvik Formation. In the overlying limestones of the Rytteråker Formation *Conochitina praeproboscifera, Ancyrochitina primitiva,* and *Eisenackitina dolioliformis* are the most important newcomers in this part of the sequence. The overlying Vik Formation represented in its studied middle part by thinly bedded limestones and shales shows remarkable diversity of chitinozoans. *Conochitina proboscifera, C. visbyensis, C.* cf. *leptosoma, Eisenackitina dolioliformis,* and *Angochitina longicollis* are stratigraphically the most important species. The species composition is similar in Skinnerbukta (mainly shales) and Bruflat (mainly siltstones) formations, whereas *Conochitina proboscifera* and *Angochitina longicollis* are most frequent. Some badly preserved specimens of *Margachitina margaritana* were found in the upper part of the Skinnerbukta Formation, below the Llandovery - Wenlock boundary.

In the Llandovery sequence of the Oslo region the succession of 9 chitinozoan biozones (*Ancyrochitina laevaensis, Belonechitina postrobusta. Conochitina electa, Spinachitina maennili, Conochitina alargada, Eisenackitina dolioliformis, Angochitina longicollis, Conochitina proboscifera,* and *Margachitina margaritana*) was established and compared with those of the East Baltic, mainland of Sweden (Grahn, 1998) and with the global chitinozoan biozonation (Verniers *et al*., 1995). Due to insufficient sparse sampling and poor assemblage of chitinozoans, most of the boundaries of biozones still remain indefinite.

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ORGANIC-WALLED MICROFOSSILS AND GLAUCONITE MINERALOGY OF THE VARANGU FORMATION IN ITS STRATOTYPE

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The Lower Ordovician Varangu Formation is an up to 3.5 m thick unit of compact, mostly greenish-grey silty clays with intercalations of glauconite sandstone. This unit, distributed in a limited area in northern Estonia, was first recognised as "the strata of glauconitic clay" by Luha (1946) and named by Männil (in Aaloe *et al*,. 1958) as the Varangu Member, after the Varangu section on the left bank of the Selja River 8 km NE of the Haljala village. The conodont studies (Viira, 1970 and Viira *et al*., 1970) established that the Varangu Member was of the Upper Tremadocian age, and it was assigned to the *Ceratopyge* Regional Stage. Later, the rank of formation was given to the Varangu Member. The *Ceratopyge* Stage was renamed as the Varangu Stage with stratotype section in Varangu (e.g., Männil, 1990).

In 1994, the overgrown stratotype section was reopened and studied for organic-walled microfossils and for morphological-structural characteristics of glauconite. All the micropalaeontological samples (28 from the Varangu Fm and 2 from both under- and overlying beds) yielded well-preserved acritarchs. Chitinozoans were found from the top 30 cm of the Varangu Fm and in the Leetse Fm. Four organic-walled microfossil assemblages were established. Nine mineralogical samples were studied by means of XRD and light microscopy. The generalised description of the stratotype section, from the base to the top follows (Figure).

Regional Stage	Formation	Bed, thickness (m)	Assamblage of organic-walled microfossils	Conodont zones
Hunne-berg	Leetse	Bed 5 +0.55	3	*Parois-todus proteus*
Varangu	Varangu	Bed 4 0.25	2b	*Paltodus deltifer deltifer*
		Bed 3 1.20	2a	
		Bed 2 1.35	1	*Paltodus deltifer pristinus*
	Türi-salu	Bed 1 +0.15		?

Figure. Assemblages of organisms and bed thickness in the stratotype section of Varangu Formation.

Türisalu Formation, Toolse Member. Bed 1. Exposed thickness 0.15 m. Dark-brown kerogenous argillite. The low-diversity organic-walled microfossil **Assemblage 1** distinguished by *Prisco-theca tremadocea* includes mainly stelliferidium-type acritarchs accompanied with *Leiosphaeridia tenuissima*.

Varangu Formation. **Bed 2**. Thickness 1.35 m. Grey clay with thin lenses and laminae of silt-sized quartz and glauconite grains, partly bioturbated. This interval yielded the acritarch **Assemblage 1**, identical to that in upper part of the Türisalu Formation.

Bed 3. Thickness 1.2 m. Grey silty clay and siltstone with sand-sized glauconite and quartz grains, intensely bioturbated, with pyritized burrows. The lower boundary marked by coarsening of grain size. This bed has yielded a highly diverse acritarch **Assemblage 2a**, including the genera *Acantho-diacrodium*, *Actinotodissus*, *Cymatiogalea* and *Stelliferidium*. This assemblage yields first acritarchs belonging to the genera *Aryballomorpha*, *Athabascaella* and *Baltisphaeridium*.

Bed 4. Thickness 0.25 m. Light-grey clay, containing grains of glauconite and pyrite. The lower boundary marked by a discontinuity surface. This interval yields **Assemblage 2b**, including the same acritarchs as in Bed 3, but differing by the first appearance of a chitinozoan, tentatively assigned to *Lagenochitina* sp.

Leetse Formation. Bed 5. Exposed thickness 0.55 m. Green glauconitic clay, containing reddish-brown phosphatic nodules. Lower boundary marked by discontinuity surface, with burrows. This interval yields **Assemblage 3**, containing mostly acritarchs that are not represented in lower beds. The typical acritarchs, *Cymatiogalea messaoudii* and *C. deunffii* are accompanied with the representatives of the genera *Rhopaliophora* and *Peteinosphaeridium*.

Morphological features of the glauconitic grains were studied. Three main types of grains were distinguished: 1) reniform grains, 2) rounded grains, and 3) irregular (including broken) grains. Rounded grains represent a highly evolved state of glauconite (Odin & Fullagar, 1988). In the Bed 2 reniform grains prevail, with some other grain types present. The Bed 3 is characterised by a mixture of different morphological types of glauconite containing mainly reniform and rounded grains, with low content of irregular grains. The Bed 4 contains mainly rounded grains, and less irregular grains. In the Bed 5, the grains are rounded, clearly reniform grains are lacking, and rare irregular ones are present.

Nine samples of the 0.1-1.0 mm fraction of glauconite were studied by means of XRD. Because of a well-established correlation, the glauconite lattice parameters can be used for evaluating the K_2O content, related to the maturity of glauconite (Odin, 1988). Amorosi (1993, 1995) has demonstrated the potential of using the maturity of glauconite for correlation of lithological units and sequence stratigraphy.

In all the studied beds (2-5) of the Varangu and Leetse formations, the glauconite grains were evolved to highly evolved. The trend of slight upward increase of the XRD-estimated K_2O-content was observed in Beds 2 and 3, with an upward jump at the boundary of these beds. In the Bed 4, the K_2O content is lower, close to the values at the base of the Bed 2. Glauconite grains from the Bed 5 have considerably higher K_2O content than those from any lower beds.

The morphological features are in good correlation with the structure of glauconite. In samples from beds with prevailing reniform grains comparing samples with rounded grains not so evolved structure was measured (Bed 2). Samples with rounded grains are characterised by the evolved structure of glauconite established by the XRD.

A good correlation is found between the biostratigraphical boundaries based on the distribution of organic-walled microfossils and morphological-structural characteristics of glauconite. Clearly identified boundaries are within the Varangu Formation between beds 2 and 3, also between beds 3 and 4, and between the Varangu and Leetse formations. Combining the micropalaeontological and mineralogical methods allows us to tie the biostratigraphic intervals to consecutive phases of sedimentation.

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COMPARISON OF MIRE PALYNOSTRATIGRAPHY WITH THE LOCAL AND PRESENT VEGETATION

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Palynostratigraphy is very important tool in the determination of the age, development stages of the palaeobasins and mires, and the reconstruction of the dynamics of the palaeovegetation. Origin and development of Latvian vegetation is closely connected with the climatic changes and soil conditions during the Holocene. There are some plant species that are rare and protected nowadays, but have been widely distributed during first part of the Holocene. What is the reason of their decrease or disappearance? Is it only climate and soil conditions? Why are some plant species found in a few sites? How is this revealed in the pollen diagrams? When the vegetation became stable and was very little influenced by the climatic changes? One of the most stable vegetation types are mires.

Mires develop in two ways - by lake terrestrialization and land paludification. However, within the different regions of Latvia, combination of different factors resulted in a considerable variation in mire formation and peat accumulation. Peat development, number and area of mires has increased since the Pre-Boreal time (Table). At the beginning of the Holocene, fens dominated. Fens are minerotrophic mires being fed by ground-waters rich in nutrients. During this time in the mires several plant communities grew that can be found in the fens also nowadays, for example, communities formed by *Pragmites australis* and *Scirpus lacustris*.

Czech scientist Rybnicek (1973) has found that the fossil *Pragmites-Scirpus* community was characterised by *Equisetum, Carex, Galium, Nymphaea, Myriophyllum spicatum, Lycopus, Sparganium, Typha, Pragmites australis, Scirpus lacustris, Lysimachia vulgaris, Carex pseudocyperus, Carex rostrata, C. diandra,* Polypodiaceae, *Filipendula ulmaria, Cirsium, Alnus glutinosa, Comarum palustre, Calliergon giganteum, C. trifarium, Drepanocladus revolvens, D. sendtnerii, D. fluitans.* With low frequency occurred also *Alisma-plantago aquatica, Scutellaria galericulata, Parnassia palustris, Drepanocladus intermedius, Utricularia, Sphagnum palustre.* According to pollen and macrofossil data the same plant composition characterises the fen communities of Latvia, both in the Boreal time, also Subboreal and the Subatlantic time.

Most widely mires and particularly raised bogs developed during the Atlantic time when the climate became warmer and more favourable for mire development. The raised bogs developed obtaining nutrients only from the precipitation. The fossil communities from the raised bog are, for example, *Sphagnum* cf. *cuspidatum-Drepanocladus fluitans* (characteristic for raised bog pools) and *Rhynchosphora alba-Spagnum* cf. *cuspidatum*, that in addition is formed by *Scheuchzeria palustris, Eriophorum vaginatum, Andromeda polifolia.* This species composition is closely analogous to the present community described as *Rhynchosporetum albae.*

Table. Comparison of the sediments and pollen content from the Late Glacial and Holocene from the Teiči Mire and Ķemeri-Smārde Mire

	Climatic period	Index	**Teiči Mire** pollen zones	**Teiči Mire** sediments	**Ķemeru-Smārdes Tīrelis Mire** pollen zones	**Ķemeru-Smārdes Tīrelis Mire** sediments
Holocene	Subatlantic	SA3	*Pinus, Betula*, herbs	*Sphagnum fuscum* peat	*Pinus, Betula, Ericales*	*Sphagnum magelanicum* p.
		SA2	*Picea, Pinus*		*Picea*	*Sphagnum fuscum* peat
		SA1	*Betula, Pinus, Alnus*		*Pinus, Betula,*	
	Subboreal	SB3	*Picea, Carpinus*	*Sphagnum* peat	*Picea*	wood peat
		SB2	*Betula, Alnus*		*Pinus, Betula, Alnus*	*Scheuchzeria-Sphagnum* peat wood peat
		SB1	*Picea, Pinus*	*Scheuchzeria-Sphagnum* peat	*Pinus, Alnus*	*Sphagnum fuscum* peat *Sphagnum angustifolium-Scheuchzeria* peat
	Atlantic	AT3	*Ulmus, Quercus, Corylus*	*Eriophorum-Sphagnum* peat	*Ulmus, Quercus, Carpinus*	
		AT2	*Alnus, Betula*		*Picea, Betula, Tilia, Ericales*	*Carex-Eriophorum* peat *Sphagnum fuscum* peat
		AT1	*Ulmus, Tilia, Quercus, Alnus, Corylus, Picea*		*Ulmus, Tilia, Corylus*	*Eriophorium-Sphagnum* peat
	Boreal	BO 2-2	*Pinus, Betula, Alnus*	transitional mire peat	*Betula Pinus, Alnus*	wood-grass peat
		BO 2-1	*Betula, Pinus*		*Pinus*	
		BO 1	*Pinus*	*Carex-hypnum* peat		wood-sedge peat with admixture of sand
	Preboreal	PB	*Betula, Pinus, Cyperaceae*		few pollen of *Pinus, Betula* nana and herb	sand
Pleistocene	Younger Dryas	DR 3	*Betula, B. nana, Artemisia*	clayey gyttja		
	Allerød	AL	*Pinus*			
	Older Dryas	DR 2	*Betula nana, Artemisia, Dryas*	clay, silt		

Climatic conditions in Latvia are influenced by the Atlantic Ocean and the location near the Baltic Sea. There are differences in vegetation between the coastal part and the continental parts of Latvia and can be observed in the vegetation development in general and on mires as well. In the pollen diagrams from the western Latvia in the intervals corresponding to the Atlantic time *Hedera helix, Taxus baccata, Erica tetralix* appear that are still present in this region, but are not found in the eastern Latvia. These are rare and protected species in Latvia found only in the Coastal Lowland.

The end of the Atlantic time was drier, and the terrestrialization of the shallowest lagoon lakes, for example, in the Sārnate area, started. Conditions were favourable for the growth in the lakes of the water chestnut (*Trapa natans*), and the pollen of this plant are found in several samples and in the numerous cores.

Special interest can be paid to the distribution of the pioneer plant like *Betula nana* that was widely distributed during the Younger Dryas. In several areas of Latvia the species has maintained through the whole Holocene up to nowadays (for example, in the Teiči Nature Reserve).

These are only some examples of the similarity of plant communities and rare plants from separate periods in the Holocene and nowadays. Comparison of the pollen data and macrofossil data allows to state that the mire plant communities became stable already in the Atlantic time and are not significantly influenced by the climatic changes. This study allows to state that the pollen data indicate regional changes in the vegetation and climate as well, while plant remains reflect only local changes. It can be considered that in the second part of the Holocene the mire vegetation was more dependent on the microclimate. These events are similar for the whole area of Latvia that can be demonstrated comparing the data from the Ķemeri-Smārde Mire from the coastal Latvia and the Teiči Mire from the eastern Latvia (see Table).

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SEQUENCE AND PALAEOGEOGRAPHICAL AFFINITIES OF ACRITARCH ASSEMBLAGES FROM THE ARENIGIAN OF SOUTH-EASTERN BALTIC

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The present palynological study of the Arenigian (Lower Ordovician) deposits is based on the material sampled from deep boreholes located in different structural-facial zones of Lithuania and north-western Belarus. Samples, coming from borings located in Kaliningrad district of Russia, yield no phytoplankton. Quantity and taxonomic diversity of acritarchs differs at several stratigraphic levels as well as in different facial zones.

The sequence of four acritarch assemblages stratigraphically replacing each other has been established within Arenigian of the Livonian facial zone (the Jelgava Depression) and three - of the Lithuanian facial zone. The early Latorp association from the Jelgava Depression includes *Athabascaella playfordii, Rhopaliophora pilata, R. palmata, Peteinosphaeridium breviradiatum, Stelliferidium simplex* and other acritarchs. Species of the genera *Baltisphaeridium (B. castaneiforme, B. flexuosum, B. ingerae, etc.)* and

Lophosphaeridium (L. disparipelliculum, L. papillatum, L. spp.) predominate in the late Latorp assemblage. The early Volkhov assemblage characterises by a greatly impoverished systematic composition of phytoplankton. Single *Leiosphaeridia* spp. and/or *Tasmanites* sp., accompanied by small amount of *Baltisphaeridium* and *Multiplicisphaeridium,* are found here. Rare finds of *Costatilobus?* sp. aff. *C. bulbosus* are significant for biostratigraphical problems. The impoverishment of specific composition, distribution of sphaeromorphic unornamented acritarchs together with prevalence of red-coloured deposits, are seemingly caused by unordinary conditions of the sedimentary facial situation. Poorly represented lower Volkhov acritarch assemblage is replaced in the sequence by a rich and diverse assemblage of the upper Volkhov. *Peteinosphaeridium velatum, P. hymenoferum, Ampullula suetica, Costatilobus? balticum, Dasydorus cirritus, Lilliosphaeridium kaljoi, L. hypertrophicum* and others are characteristic taxa of this assemblage.

Taxonomic composition of acritarchs coming from the Latorp Regional Stage in the Lithuanian facial zone is scarce and less informative. There are a single specimens of *Baltisphaeridium flexuosum, Veryhachium* sp. *Leiosphaeridia* spp. and *Multiplicisphaeridium* sp. aff. *M. acaciaense* defined here. More diversified microphytoplankton is obtained from the Medeikiai Formation. *Costatilobus? balticum, C.?* sp. aff. *C. bulbosus, Ordovicidium* sp. aff. *O. elegantulum, Veryhachium trisulcum, V. trispinosum, V. rhomboidium* and species of the genera *Baltisphaeridium, Lophosphaeridium* and *Goniosphaeridium,* are indentified here. Acritarch assemblage from the Gaide Formation includes plenty of common taxa with the upper Volkhovian phytoplankton from the Livonian facial zone. This Late Arenigian renewal level of acritarch flora is traced through the entire Baltic region.

From a palaeogeographic point of view the studied Arenigian phytoplankton is typical for the Baltic palaeoprovince. However, the assemblages from Lithuania and Belarus include acritarchs found in other provinces. Some species of *Athabascaella, Dasydorus, Pirea, Rhopaliophora* and *Lophosphaeridium* are the same as in the Equator (or Australia) palaeoprovince, and those of *Caldariola, Stelliferidium, Cymatiogalea* and *Veryhachium* - as in Perigondwana. The Upper Arenigian acritarchs of the Baltic province show a great similarity with the flora from the Daping section of Southern China, which belongs to the Perigondwana palaeoprovince. But the Baltic assemblages contain no characteristic Perigondwanan taxa *Striatotheca, Coryphidium* and *Arbusculidium.*

PALYNOSTRATIGRAPHY OF THE LOWER AND MIDDLE DEVONIAN OF EASTERN PART OF SAYANO-ALTAI REGION

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Red continental Devonian strata of southern Siberia (Siberian Old Red Sandstone) are widely spread in the Minusa and Rybinsk troughs. They were rather poorly studied since the large-scale geological survey (1:50000) has been started at 70ies till 90ies. The spores were extremely poorly studied. We have studied the spores from our own collection, as well as from the collections of geologists from Tuva and Krasnoyarsk Region. The palynological data provide a significant support for better ageing of the studied deposits, recognition of new stratigraphic units and their broad correlation. The oldest spore assemblage has been found in the Karymov Formation of the Rybinsk trough and the Kendian Formation of Western Tuva. It contains a few species of uni-layered small spores of simple structure. This assemblage is related to the Ziegen – lower Emsian complex from Ukraine, and they both correspond to *Retusotriletes clandestinus* zone.

The second spore assemblage has been observed in the Northern Minusa trough, from the new stratigraphic units of Ust'-Parninskaya and Elovskaya beds. It is similar to the Vanyashkin and Vyazovski assemblages from the upper Emsian of western Bashkiria, and corresponds to *Diaphanospora inassueta* zone. Both geological and palynological data allow estimating the age of Byskarski volcaniclastics, which are widely spread within the Minusa trough, as Lower Devonian, rather than Lower-Middle Devonian as assumed previously. Simultaneously these data show an absence of the regional break in the basement of the Toltakovski Formation and allow correlating it and its analogues to the Byskarski complex.

The third spore assemblage have been found in sediments of the Ilemorovski Formation of Minusa and Pavlovsky Formation of the Rybinsk trough. It is similar in age to the assemblages from the Eifelian *Periplecotriletes tortus* zone. These data show that the deep transformation of palaeoecological system occurred not in the pre-Givetian, but in the pre-Eifelian. These data are approved by the remnants of weathering crust of the same age.

The fourth spore assemblage was noticed in deposits of the Beyskaya Formation from northern Minusa, containing a rich fauna of the upper Givetian. It corresponds to the *Geminospora extensa* spore zone. A good correlation of the Lower-Middle Devonian spore assemblages from Southern Siberia with the spore complexes of the same age from the other regions of the world proves obviously an absence of the sharp botanical and geographical zonality in that time.

ORDOVICIAN MICROFACIES IN THE POLISH PART OF THE BALTIC MARINE PLATFORM

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In this paper lithological and paleontological features based on microscopic observation are used as the criteria for microfacial definition and thus environmental suggestions. The cycle of carbonate deposition starts at the top of glauconitite in the Arenigian stage (Bednarczyk, 1998; Modliński & Szymański, 1997). The Ordovician strata in the Polish part of the Baltic marine platform show high content of carbonate sediments. Those are grey to yellowish-brown organodetrital limestones, mostly calcarenites, that become more and more marly in the upper part.

Arenigian

The lower Arenigian glauconitite is overlaid by glauconitic limestone that begins a cycle of carbonate deposition. These rocks are micrites or biomicrites with variable share of allochems of various composition. The organic remains are frequently impregnated with glauconite, pyrite, or are dolomitised. The matrix is micritic or sparitic. Several types of microfacies have been distinguished (Szymański, 1984). These are, from the oldest one: 1, brachiopod clayey biomicrites; 2, sparites, and 3, trilobite-brachiopod biosparites.

Llanvirnian

Llanvirnian sediments lie unconformably on uneven surface of the Arenigian glauconitic-carbonate complex (Bednarczyk, 1998; Modliński & Szymański, 1997). The presence of allochems of various type mineralised with goethite is characteristic feature of the Llanvirnian sediments. These carbonates are biomicrites, oobiomicrites, and oobiopelmicrites. The problems of the goethitic mineralisation as well as analysis of the biogenic structures are dealt with in earlier papers (Podhalańska, 1984, 1992, 1995). Three microfacies are distinguished. These are (from bottom to top):

1, trilobite-ostracode mf. Majority of pseudoooids present is the ostracode carapaces infilled with goethite. Matrix is micritic, sparite is secondary;

2, trilobite mf. which is dominated by fragments of trilobite carapaces coated with goethite. Some of them were subjected to action of endoliths (Podhalańska, 1984, 1992);

3, echinoderm mf. It is characteristic that the quantity of echinoderm particles increases considerably toward the top of the Llanvirnian. It points to gradual shallowing of the basin. In Llanvirnian the local sedimentary discontinuities are extremely frequent. In the Podlasie Depression stromatolites were stated.

Llandeilian

The typical characters of the Llandeilian sediments are:

- almost complete disappearance of ferruginous mineralisation, ooids, pseudoooids and microborings particular in the Podlasie Depression (except the lowermost part);
- extremely large content of grainy particles, often grain-supported structure;
- lack of sediment selection and non-oriented texture.

Two microfacies have been distinguished:

1, echinoderm mf. in the lower part;

2, trilobite-echinoderm mf. which passes upward into the Caradocian stage.

Caradocian

The trilobite-echinoderm biomicrite is overlaid by grey biomicrite containing bryozoans (Trepostomata). Layers rich in organic remains show current orientation of the particles. The following microfacies types are distinguished:

- trilobite-echinoderm mf. (its upper part);
- bryozoan mf.;
- marly micrite mf. with remnants of trilobites and echinoderms. This member terminates organodetrital deposition of the Ordovician.

Presence of bryozoans as sessile organisms is interesting from the point of palaeoecological view, pointing to aerobic conditions within bottom zone with abundance of nutrients. Alternation of layers of wackestone with packstone and even grainstone may point to variable hydrodynamic conditions within the marine basin. Wave and current action could have a considerable influence onto the carbonate deposition at that time. Topward the Caradocian sediment becomes less and less organodetrital and shows large admixture of marl.

Ashgillian

The Ashgillian deposition differs from that of the older Ordovician stages with the exception of the upper part of the Caradocian, which makes a continuation. The production of the organic material was lower and organodetrital deposition was of episodic character. There is mainly grey or greenish marly mudstone with quartz grains interbedded with wackestone containing biogenic allochems. In a few boreholes in the Podlasie Depression at the top of the Ashgillian rich marly wackestone and sedimentary unconformity was to be found. In several boreholes in the Peribaltic Depression the marly mudstones and wackestones are of nodular texture.

Environmental remarks and conclusion

1. Ten microfacies have been distinguished in the calcareous deposits of the Ordovician.
2. Facial and microfacial analysis has evidenced that the area belonged to rather broad, flat and mostly low-energy platform with episodes of high-energy regime. The Podlasie Depression can be interpreted as a region of higher energy of near-shore zone. The Peribaltic Depression appears as a region where different facies existed, onshore facies in the east, shallow and deep-neritic facies from the central part to the west.
3. The change from the trilobite- through trilobite-ostracode to echinoderm microfacies in the Llanvirnian indicates shallowing of the sea.
4. Rich biomicrites and especially bryozoan grainstone and floatstone in Caradocian of the Podlasie Depression may suggest rather shallow and moderate-energy environment.

5. The presence of the terrigenous material in Ashgillian was connected with a regressive event in the upper Ordovician.
6. It is assumed that the main facial changes were connected with eustatic changes of the sea-level, whereas the sequence of microfacies is connected rather with a local factors such as overproduction of organic matter, energetic regime or endolithic activity of microorganisms.

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THE ROLE OF THE BIOSTRATIGRAPHIC METHOD IN THE DEVONIAN STRATIGRAPHY OF THE WEST-SIBERIAN PLAIN

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Palaeozoic deposits of the West-Siberian plain are with an angular disconformity overlapped by thick Mesozoic and Cainozoic sedimentary cover. Their compound block-folded structure had been revealed by scientific investigations.

Monotonous carbonate-clayey rocks yielding abundant fauna and rare spore-pollen assemblages dominate the section. Practically full absence of lithological markers is the other characteristic peculiarity of Palaeozoic deposits. Therefore it was very complicated to work out the chart of local lithostratigraphic units. Many stratigraphic problems concerning the development of Palaeozoic formations in the West-Siberian plain were managed to solve only on the basis of the biostratigraphic method. The results of such investigations were summarised in the regional stratigraphic chart accepted by the Siberian Regional Joint Stratigraphic Committee in November 1998. Nyurolskaya structural-facial area has been defined as the stratotype locality. It is characterised by the high density of boreholes from first dozens meters to three kilometres deep. Various points of view on the Devonian stratigraphy in the south-eastern part of the West-Siberian plain have been published (Dubatolov, Krasnov, Bogush *et al.*, 1990; Krasnov, Isaev, Astashkina *et al.*, 1993). The existing disagreements were stipulated first of all by the insufficient regard to peculiarities of the Devonian sedimentation: the availability of polyfacies along the horizon and the availability of monofacies along the vertical section. Devonian facial-lithological complex was formed during two stages. The first stage corresponds to the Early Devonian – Ichkalinsk group. The second one coincides to the Middle-Late Devonian – Tcharymovsk and Tartassk formations (Figure). The distribution of facies was controlled by the block structure of the basement formed at the end of Early Palaeozoic. The inherited structural plan of the basin bottom was characteristic for the whole Devonian period that had led to the formation of two types of sedimentation areas: carbonate platforms and depression zones.

The formation of organogenic-detrital limestone (Kyshtovsk, Armitchevsk, Solonovsk, Nadezhdinsk, Gerasimov and Luginets formations) (Figure) took place in the Devonian within rises, expressed geomorphologically by carbonate banks, and at their slopes. Their age was designated on the basis of foraminifers, stromatoporats, corals, ostracodes, brachiopods, dacryokonarides, conodonts (Dubatolov, Krasnov, Bogush *et al.*, 1990).

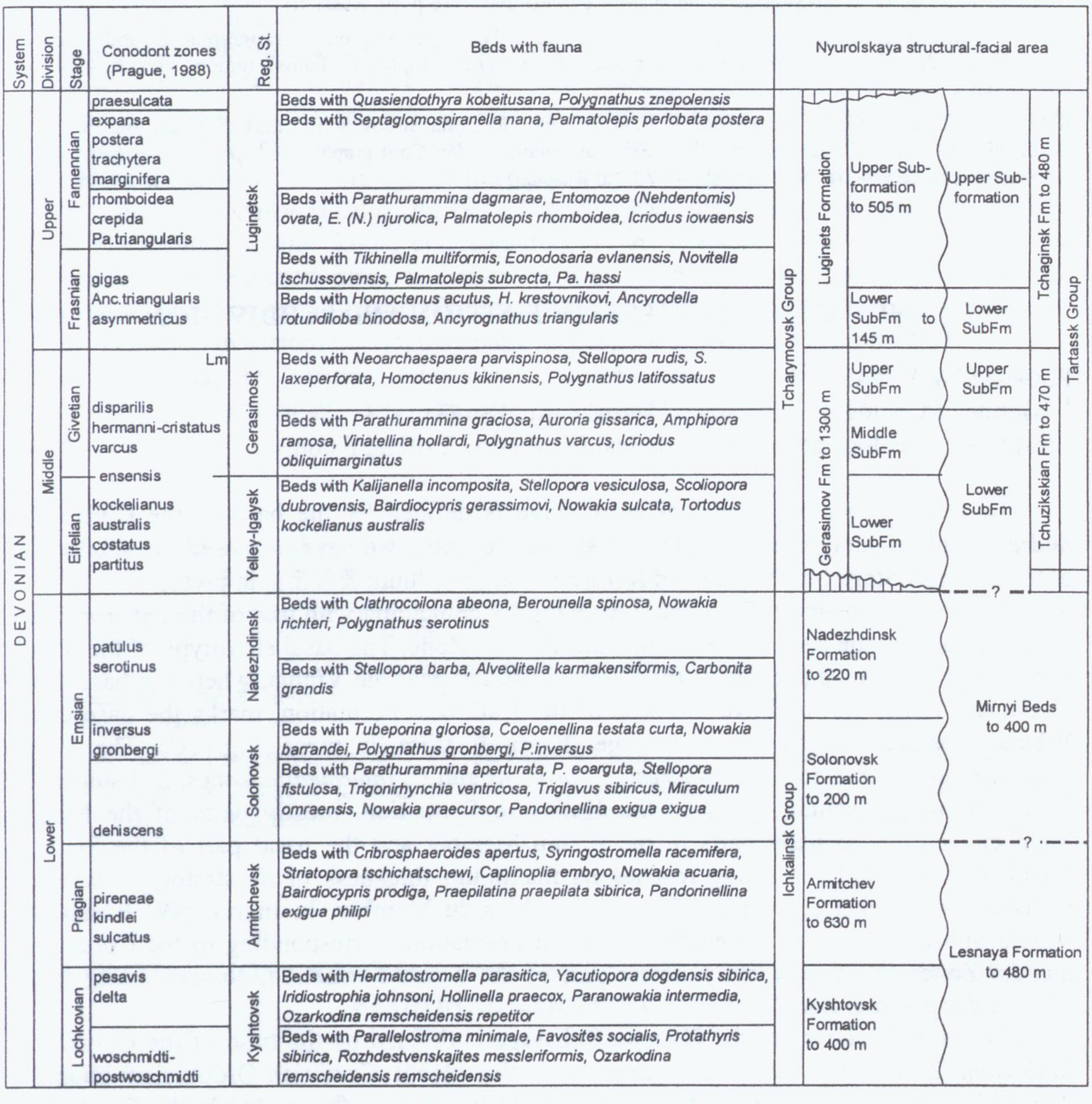

Figure. Regional chart of the Devonian deposits of West Siberian plain (fragment)

Clayey-siliceous-carbonate deposits (Lesnaya Formation, Mirnyi Beds, Tchuzik and Tchaginsk formations) were accumulated at the same time in the troughs, dividing carbonate banks. Dacryokonarides, conodonts and radiolarians are the most significant for the biostratigraphic investigations.

On the basis of the whole of studied organism assemblages 15 layers with fauna and 7 regional stratigraphic units in the range of regional stages (Figure) have been established in the Devonian of the West-Siberian plain. These regional stratigraphic subdivisions were traced in the majority of structural-facial areas in this territory and compared with deposits of the same age in extensive territories and type sections of West Europe (Isaev, Saev, Savina & Makarenko, 1995).

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THE PAKERORT STAGE: DEFINITION AND SUBDIVISION

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The lower boundary of the Pakerort Stage is defined by the base of the *Cordylodus andresi* Zone in the type area, northern Estonia. Recently, we have proposed the subdivision of the Pakerort Stage into Vihula and Karepa substages (Puura & Viira, in press).

The lower boundary of the **Vihula Substage** is coinciding with that of the Pakerort Stage and is defined by the base of the *Cordylodus andresi* Zone. The basal stratotype of the Vihula Substage is the Vihula section, at the Mustoja Rivulet near the Vihula, where the base of the *C. andresi* Zone, 0.6 m above the base of the Kallavere Formation, marks the base of the Vihula Substage and the Pakerort Stage (Puura & Viira, in press, Fig. 1C). The Vihula Substage corresponds to the *C. andresi*, *C. proavus* and *C. intermedius* zones. In Estonia, the Vihula Substage includes parts of the Kallavere Formation, mostly parts of the Maardu Member, and occasionally parts of the Rannu Member and the basal part of the Suurjõgi Member. The Vihula Substage reaches its maximum thickness in its stratotype, where it includes the upper 5.2 m of the 5.8 m thick Maardu Member. In Ingria, NW Russia, the Vihula Substage includes the entire Lomashka Formation, corresponding to the *Cordylodus andresi* Zone, and, occasionally, lower part of the Tosna Formation, corresponding to the *Cordylodus proavus* Zone.

The lower boundary of the **Karepa Substage** is defined by the base of the *Cordylodus lindstromi* Zone. This level approximates to the global Cambrian-Ordovician boundary defined by the first appearance of the conodont *Iapetognathus fluctivagus* in the Green Point Section in Newfoundland (Cooper, 1998).

The basal stratotype of the Karepa Stage is the Toolse section, 5 km SE of the Karepa village, where the base of the *C. lindstromi* Zone, 3.6 m above the base of the Kallavere Formation, marks the base of the Karepa Substage (Puura & Viira, in press, Fig. 1B). The substage corresponds to the *C. lindstromi* and *C. angulatus* zones. Its upper boundary coincides with the lower boundary of the Varangu Stage at the base of the *Paroistodus deltifer pristinus* Zone.

In Estonia, the Karepa Substage includes parts of the Kallavere and Türisalu formations. In Ingria, NW Russia, the Karepa Substage includes parts of the Tosna and Koporye formations.

In Latvia, the lower part of the obolid-bearing sandstones previously assigned to the Pakerort Stage (the Ülgase Member of Gailīte & Ulst, 1976) have been found to represent an older part of the Upper Cambrian, equivalent to the Petseri Formation (Volkova *et al.*, 1981). In eastern Latvia, the overlying beds beginning with the obolid coquina assigned by Gailīte and Ulst (1976) to the Maardu and Orasoja members are likely the equivalents of the Kallavere Formation in southern Estonia. These beds are likely of the Upper Cambrian age, but their precise position and the question whether their age is older or younger than the *Cordylodus andresi* Zone, remains open because of lacking biostratigraphic data.

In some other cases, the sandstones assigned to the Kallavere Formation are younger than the Pakerort Stage. For instance, the Kallavere Formation in the Sturi-8 core (depth 1166.5 m) has yielded a conodont assemblage including *Cordylodus angulatus*, *Oneotodus variabilis* and *"Acodus" tetrahedron* (Ulst *et al.*, 1982, Fig. 24). The latter two species are characteristic of the *Paroistidus deltifer* Zone, corresponding to the Varangu Stage. Thus, as yet, the occurrence of the Pakerort Stage in Latvia, is not confirmed by biostratigraphic evidence. However, it cannot be excluded, that further biostratigraphic data from the beds overlying the Petseri Formation in eastern Latvia, may confirm the presence of the Pakerort Stage.

In Lithuania, the "Obolus" sandstones of the Salantai Formation yielding *Ungula* cf. *convexa* (e.g. Lashkov *et al.* 1993) are most likely older than the *C. andresi* Zone and the Pakerort Stage.

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INVESTIGATION OF IMPACT AND EXTRATERRESTRIAL SPHERULES IN REGIONAL STRATIGRAPHY

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As the 4th Baltic Stratigraphical Conference will focuse on the problems and methods of modern regional stratigraphy, I should like to describe here the first, rather promising results obtained in studying impact and extraterrestrial spherules for the purposes of precise stratigraphy. During the last one hundred years, microscopic glassy and ferroic spheroids of different origin have often been found in various geological formations, both in the bedrock and Quaternary cover. The oldest palaeometeoritic matter known in the Baltic States so far was discovered by H. Viiding (1965) in the Lower Cambrian sandstones in the Viru-Roela borehole. He established the cyclicity in the meteoritic activity in the Early Palaeozoic in Estonia's territory. During the history of the Earth, the global occurrence of spherules seems to have had altogether five abundance peaks: in the Late Devonian, at the Permian - Triassic boundary, at the most well-known K/T boundary, in the Late Eocene and in the Quaternary.

The autor's main interest has centered on the Estonian Holocene craters. In and around the Kaali craters in the SE part of Saaremaa Island, the soil contains a large number of micrometeorites and pulverized impactite matter. The mighty explosion with accompanying high temperature led to the formation of glassy silicate spherules which distributed over a large area in Saaremaa and Hiiumaa, allowing to estimate the age of the impact at about 7500 years BP and correlate rather far-lying sediments.

In the summer of 1996, we found glassy spherules at a depth of 5.70 m in the Meenikunno Bog, 6 km SW of the Ilumetsa craters. This enabled us to establish not only the meteoritic origin of the craters, but also the age of the impact (about 6600 years BP).

Glassy spherules were selected under a binocular microscope from the ash left after the burning of peat. The spherules were determined one by one by means of electron microprobe analysis. The chemical composition of glassy microimpactites is diverse. In the Kaali crater field, some spherules consist mainly of silica and calcium with a small admixture of iron, others are prevailed by calcium and iron, while the third ones consist of silica with a small quantity of calcium, iron and nickel. Some sperules are extremely rich in nickel, containing at the same time Co and Ti as well.

It is obvious that the new method will give excellent results in the regional stratigraphy and global correlations. This work is coordinated by the IGCP Project 384 "Impact and Extraterrestrial Spherules: New Tools for Global Correlation", launched by the IGCP Board in 1996 for five years (1996-2000).

MAIN OUTLINES OF THE ESTONIAN QUATERNARY STRATIGRAPHY

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Several local and regional stratigraphical schemes have been compiled for Estonia. These were mainly correlative parts of the schemes of the European part of the former Soviet Union or the Baltic States and Belarus. On May 6, 1993, a new official stratigraphical scheme of Quaternary deposits of Estonia was accepted by the Estonian Stratigraphical Commission (Raukas & Kajak, 1995). The scheme was approved as a correlative part of the stratigraphical chart of the Baltic States at the II Stratigraphic Conference in Vilnius (May 9-14, 1993), and there is no need to change it.

The deposits of the Prangli (Eemian, Mikulinan) interglacial, both continental (Rongu) and marine (Prangli), serve as key sediments in stratigraphic subdivision and correlation of the Pleistocene cover. Late-glacial deposits are divided into Arctic (Oldest Dryas, Bölling, Older Dryas) and Subarctic (Alleröd, Younger Dryas) chronozones (Pirrus & Raukas, 1996). Traditionally, the Late-glacial interval in Estonia starts from the accumulation of Rauna interstadial deposits in Central Latvia dated in several laboratories as 13,200-13,400 y BP. The newest dates in Tallinn Laboratory, however showed Pre-Boreal age (9200-9300 y BP) of those deposits, what hampers the correlation.

The stratigraphical scheme of the Holocene deposits (Raukas *et al.*, 1995) is mainly based on the continental deposits, because marine offshore and nearshore deposits are characterised by numerous unconformities and rapid facies changes, and in many sequences gaps cover longer time spans than the preserved strata. The evidence of four major phases in the postglacial history of the Baltic Sea (the Preboreal Yoldia Sea, the Ancylus Lake, the Litorina Sea and the Limnea Sea) is recognised.

Based on the above, we can say that in Estonia we have all necessary stratigraphical schemes of Quaternary deposits needed for large-scale geological mapping and for different applied works. Compared with Latvia and Lithuania the stratigraphical scheme of the Quaternary deposits in Estonia is simpler, because the most unclear part of the section - the Lower Pleistocene, is absent here.

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CURRENT RESEARCH ON PLEISTOCENE STRATIGRAPHY IN SWEDEN

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Research on Pleistocene biostratigraphy in Sweden has revealed the existence of interglacial lacustrine sediments correlated with the Holsteinian Interglacial (Miller, 1977, Garcia Ambrosiani *et al.*, 1998, Garcia Ambrosiani & Robertsson, 1998). The sediments found at three sites in southern Sweden are, however, partly reworked and the vegetational succession is not complete. According to analyses of microfossils (pollen, diatoms) and macrofossils laminated diatom-rich sediments at Snickarekullen were deposited during different part of the interglacial. An open *Pinus – Betula* forest was replaced by a closed coniferous forest of *Pinus, Picea* and *Larix,* mixed with *Alnus* and some *Carpinus*. Water depth, pH and trophic state were reconstructed by means of the fossil diatom flora. At Hyby in Skåne the vegetational succession was partly different since broad-leaved and thermophilous trees appeared more frequently, and the results can be compared with sites in the Baltic States.

The vegetation history during the Eemian Interglacial is so far best known from northernmost Sweden, but comparison and correlation with other parts of NW Europe is hampered by the large distances between the sites. Sediments tentatively interpreted as deposited during the Eemian Interglacial have been found in central Sweden. Correlation with Finland is discussed (Robertsson, 1997, Robertsson *et al.*, 1997, Robertsson in press).

Organic bearing fine-grained sediments accumulated during two separate (Early) Weichselian interstadials have been identified at many sites in northernmost Sweden. The interstadials have been correlated with Brörup and Odderade and/or a Middle Weichselian interstadial (Lagerbäck & Robertsson, 1988, Garcia Ambrosiani, 1991). Several sites are under investigation and within the current project "Correlation of Weichselian stratigraphy between northern Sweden and the Baltic States" the composition of the interstadial vegetation is compared with the early Holocene and recent pollen flora in the same areas. New results from sites in Härjedalen, central Sweden, are shown (Granoszewski & Robertsson in press).

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CLITAMBONITIDINES (BRACHIOPODA) DATABASE

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A database is a set of data connected to each other in some way. There must be somebody who gathers, improves and uses the data. The *Treatise on Invertebrate Paleontology* (its first and second editions), for instance, its brachiopod part (Moore, 1965) is also a kind of highly specific database with well-known goals.

Technologically, the two first operations (to gather and save) in the existing *Treatises* are carried out only once. Because of that, it is attractive to comprise the next *Treatise* electronically, as a real database, which would be more dynamic and voluminous than the existing ones in the form of books. Nevertheless, as yet, there is only an agreement on the electronic version of all text and illustrations of the third edition of the *Treatise* (see Fossil Record, 1998). But, "Second, PaleoBank, an electronic relational database, is being prepared as a tool for *Treatise* authors, other palaeontologists, and PI staff members" (*ibid.*)

Besides systematics, the *Treatise* gives a diagnosis, as well as stratigraphic and geographic distributions for each genus, to use them for identifications of the described genera, without using proper identification procedures like special keys. It would be rational to extend the PaleoBank to species level. Some kind of keys of the included taxa could be introduced in the limits of such a PaleoBank even today.

As usual, the PaleoBank for the future palaeontologists should be realised by a number of specialists, using common tools (terms, concepts, and algorithms). However, the descriptions of species, as well as their automated keys would be based on much more specific (group-oriented) morphologic terms and literature than those at the generic level. The suborder Clitambonitidina, especially its superfamily Clitambonitoidea, serves as an example on diversity and distribution of brachiopods related mostly to the Ordovician of Baltica. And such a database for suborder Clitambonitidina is in a good progress.

The PaleoBank proposed by the Kansas group (see *http://www.cc.ukans.edu/~paleo*) is a relational database consisting of the following layers: (1) taxonomic concepts, (2) publication-illustration, (3) ecology, (4) plate tectonics, (5) morphology, and (6) stratigraphy-geography. Each of these layers has a specified structure and is mutually tied with others. Not all layers are equally elaborated up to now. From these layers, the layers 1,2,3,4 and 6 will be included to our database structure.

The morphology layer (5), not finally developed by the Kansas group, must include keys of genera and species, based on the descriptions. For compilation of the morphological base (character list), character-based unified descriptions of taxa, and on-line identification (key) for the taxa, including drawings and photos, we have used the DELTA software by Dallwitz et al. (1997). DELTA has proven to be a very useful tool for character-based descriptions and has been used by us for the development of the morphology layer (5) of our database. It can be recommended for this task in similar databases, like PaleoBank.

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ESTABLISHMENT OF *ALNUS* AND *PICEA* IN ESTONIA

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The immigration and expansion of *Alnus* and *Picea* is of interest in stratigraphic respect, as both of them have been used in the compilation of the Estonian Holocene stratigraphic chart (Raukas *et al.*, 1995). *Alnus* appeared into Holocene pollen spectra at the end of the Pre-Boreal and soon reached the maximum frequencies at the northern sites. At the south-eastern sites alder maximum occurs considerably later. Explanation for this could be the difference in climatic conditions of northern coastal and south-eastern more continental regions and a series of local events, as the topography, hydrology and seedling conditions.

Alder empirical limit lies between 9200-7600 BP and shows spatial and temporal variations even between sites in the same region. The patchy character of alder population makes it difficult to detect any certain trend in its spread and expansion. The habitat of alder is patchy primarily already due to its edaphic demands (nutrient-rich wet soils) and relatively mild climate making its spread and establishment highly dependent on the seed dispersal to a new favourable habitat (Bennett & Birk, 1990). Reaching the suitable site, the alder is highly competitive and can expand extremely quickly. Finds of *Alnus* macrofossils confirm the establishment of alder in Estonia since the Boreal. Before the Boreal, alder was present locally in the coastal regions.

On much pollen diagrams the alder curve starts with a sharp rise. The reason for that is not quite clear, but one can argue on some possibilities. When *Alnus* reached a site it usually surrounded the wet habitat with a rim and its pollen became dominant very fast. Furthermore, overgrowth of the coastal shallow lakes took place in the Boreal providing suitable habitats for alder to colonise.

The uneven spread of alder is in contrast to time-transgressive spread of spruce in Estonia. Quite obvious south-east–north-west immigration route for spruce has been confirmed. During the Younger Dryas and in the Boreal, spruce was established only in the extreme south-east and its population was sparse. Spruce forest boundary probably reached the Sakala Upland and Võrtsjärv basin between 7000-6500 BP and the Pärnu-Narva line at about 6000 BP. By 5000 BP, spruce forest was common in mainland Estonia, except the north-western part.

Some confusion has arisen in connection with the macrofossil find of spruce dated 1000-2000 years older than the regional spread of spruce. The same phenomenon was mentioned by Tallantire (1972) in Fennoscandia, where the macrofossil finds were at least 1000 years older than of spruce regional spread on the basis of pollen data. The most recent discovery of *Quercetum mixtum* and spruce macroremains in central Sweden shows that spruce grew there 8000 BP, or about 5000 radiocarbon years before the pollen record (Kullman, 1996, 1998). It shows that the small scattered spruce populations could grew locally a thousands of years before spruce forest reached the area, being in some places, delayed due to unfavourable ecological or soil conditions.

The low rate range of spruce in Estonia, about 100 m yr^{-1} was mostly determined by the rather warm climate and dense forest canopy formed by broad-leaved trees. This explains why spruce was subdued in the Atlantic, with maximum occurrences in the Sub-Boreal, when the climate became more continental and caused the broad-leaved trees to cease and established favourable habitats for spruce.

The spruce first maximum is intermittent between 4000–2800 BP, the second maximum at 2000–1000 BP. Spruce prefers relatively continental climate, plentiful snow cover to protect seedlings, and smoothly rising spring temperature without sharp fluctuations (Tallantire, 1972). The seedlings are also sensitive to drought, overheating, direct insolation (Kostler, 1956) and grow best at constant low temperature (9° C; Junttila & Skaret, 1990). Human activities and forest clearances certainly accelerated spruce expansion and in some places could have been the major agent, but climate seems to be the primary factor controlling spruce regional expansion, at least in Estonia.

Comparison of alder and spruce spread and expansion manifests their different response to climate, with *Alnus* being most broadly distributed between 7500-5500, and *Picea* at 5000-1000 BP. *Alnus* became abundant first in northern coastal areas with maritime climate and later in more continental south-eastern Estonia, just opposite to spruce.

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TENTICOSPIRIFER TIEN 1938, AN IMPORTANT BUT POORLY DEFINED AND MISUNDERSTOOD MIDDLE FRASNIAN CYRTOSPIRIFERID GENUS FROM THE MAIN DEVONIAN FIELD

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Tenticospirifer was established as a subgenus of *Spirifer* Sowerby, J., 1816 by Tien (1938), who included in it eight species and one variety from China, one species from the central Ural Mountains, and one from the Main Devonian Field. The latter, *S. tenticulum* de Verneuil 1845, was designated as the type species.

T. tenticulum is a species of small size found near the village of Buregi on Ilmen Lake - Tien (1938) erroneously indicated the Ural Mountains as the type area - at the base of the Buregi beds [*Spirifer buregi* Nal. mentioned under this name by Hecker (1935) is a junior synonym of *S. tenticulum*]. These beds were correlated by Zhuravlev, Evdokimova & Sokiran (1996) with the top beds of the middle Frasnian Semiluki horizon of the Central Devonian Field. What Tien described as *Spirifer (Tenticospirifer) tenticulum* occurs in the middle Famennian *Nayunnella* beds of central Hunan, with the exception of a single young specimen of Frasnian age.

The pyramidal shape (tent-shaped, hence the name of the species) seems to have overshadowed other essential features mentioned in the original description of the species by de Verneuil, such as a "small shell", a "slightly pronounced fold", a "small number (6 to 8) of rarely dichotomised costae in the sulcus", *etc.* These features were forgotten or played down by Tien, with the result that the Chinese form has very little in common with the type species.

Is *Tenticospirifer* a subgenus or a distinct genus? Is it a synonym of one or all of the following genera: *Cyrtospirifer* Frederiks 1924, *Hunanospirifer* Tien 1938, and *Sinospirifer* Grabau 1931? These questions have been debated at length in the literature, mostly in vain, because the arguments brought forward were based on external and internal characters of taxa assigned erroneously to *Tenticospirifer*. Therefore, today the only sound basis for discussion still remains the original description of *T. tenticulum* and that by Nalivkin (1941), but, although the latter author illustrates specimens from the Buregi beds cropping out on the southwestern bank of Ilmen Lake, his description includes specimens from both the Ilmen and Semiluki beds. Unfortunately, both descriptions lack any reference to internal structures. Beznosova (1959) tried to fill this gap by making serial transverse sections in a specimen of the species; she figured two sections through a specimen collected in undifferentiated Upper Devonian beds from Chudovo. Unfortunately, the location of this village 120 km NE of the type locality of the species and the vague stratigraphical position do not guarantee that we are dealing with the type species.

In reviewing the literature of the last ten years, one is bound to note that many species, including forms erroneously identified as *T. tenticulum*, are assigned continually to *Tenticospirifer*. The particular shape, combined with the orthocline ventral interarea, has been a conclusive argument for the assignment to *Tenticospirifer*, at one time or another, of some 70 species, and as many forms again left in open nomenclature, ranging from the early Givetian to the early Carboniferous, and "discovered" in the five continents.

Confronted with this confusion, the author decided to examine in detail the internal structures of *Tenticospirifer*, and finally to give it a definition combining internal and external characters. This definition will allow reevaluation of the various species assigned to the genus.

LATE PLEISTOCENE STRATIGRAPHY AT THE MEDININKAI SITE (EASTERN LITHUANIA) AND ITS IMPLICATION FOR INTER-REGIONAL CORRELATIONS

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Eemian - Weichselian sequences, located outside the maximum limit of the Late Weichselian ice sheet, provide excellent possibilities to find continuous sedimentary records encompassing the whole Last Interglacial/Glacial cycle. One of the most complete sequences has been found in eastern Lithuania at the Medininkai site (30 km east of Vilnius). The site is a small palaeolacustrine kettlehole filled by sediments.

Methods and material. The borehole at the Medininkai displays 15 metres of peat, gyttja and silt, lying on top of a Saalian till. This section has been investigated using palynology, lithology, palaeocarpology, physical (U/Th) datings and mineral magnetic methods. 19 lithostratigraphic units have been established according to micro- and macrofossil content, colour, lithological composition, structure and texture.

Pollen and spores have been analysed in 152 samples by A. Grigiene. The sequence has been subdivided into 13 local PAZ. Palaeocarpological analyses were performed by F. Velichkevich on 51 samples each 20-25 cm thick and taken continuously in the core. 80 taxa of trees, shrubs and herbs have been identified in the section.

Mineral magnetic parameters have been analysed by P. Sandgren in 89 samples, and good correlation of both concentration of magnetic minerals and magnetic mineralogy to stadial and interstadial periods have been demonstrated. Warmer periods display lower concentrations and relatively higher S-ratios. Colder periods show higher concentrations and relatively lower S-ratios. During colder periods more minerogenic material has been washed into the basin and during warmer periods dissolution of magnetite particles have occurred which explains the higher S-ratios during these periods.

Stratigraphic interpretation. Taking into consideration all data, the Merkine (Eemian) Interglacial and two Early Weichselian interstadial: Jonionys 1 (Brörup) and Jonionys 2 (Odderade), separated by cryomers, have been identified in the Medininkai section. In the upper part of the section intervals interpreted as analogous to the Denekamp and Hengelo interstadials were established according to the composition of the pollen flora. The section ends up with the Late-Glacial silts and Holocene peat. The most important palynological and palaeocarpological results of study of the section Medininkai are given below.

Merkine (Eemian) Interglacial (depth 15.0-11.1m, gyttja) is represented by a forest succession from coniferous to broad-leaved and back to coniferous. At the beginning of the interglacial *Betula* and *Pinus* were the pioneer trees (AP). Then broad-leaved trees arrived during the climatic optimum. The order was: *Quercus*, *Ulmus*, *Corylus* and *Tilia*. *Alnus* grew along the lakeshores. *Carpinus* immigrated during the later part of the interglacial. After the climatic optimum the vegetation changed from a deciduous to a coniferous forest, at first *Picea* spread, then *Pinus* and herbs (NAP) increased. The sediments represent the Merkine (Eemian) interglacial since macrofossils of *Caulinia flexilis* and *Pilea lithuanica* were identified. Among herbaceous plants also macrofossils of *Salvinia natans, Sparganium microspermus, Nymphaea alba* and *Nuphar lutea* were noted.

During the first early Weichselian stadial (cryomer) - **the Nemunas 1a** (11.0-10.0m, gyttja) the *Pinus* forest was replaced by a sparse *Betula* forest with ericaceous shrubs and various herb communities (Cyperaceae and *Artemisia*). The end of this cryomer is traced by a decrease in NAP and increase of AP in the local vegetation cover. Palaeocarpological remains of *Larix, Betula nana, Selaginella selaginoides, S. tetraedra, Potamogeton alpinus, P. dorofeevii, P. filiformis,* Characeae, *Batrachium* and *Iso□tes lacustris* are typical for this interval.

The **Jonionys 1 (Brörup) interstadial** (10.0-8.7m, gyttja and peat) represents a climatic amelioration and expansion of dense coniferous forests, when *Betula* (first appearance of *Betula humilis* is noted) was replaced by *Pinus* and some *Picea.* According to macrofossils, *Larix* was dominating. Macrofossils *of Comarum palustre, Scheuchzeria palustris, Menyanthes trifoliata, Carex* and *Potamogeton* (6 species*)* have been identified. During the later part of this interstadial, the opposite succession took place indicating a decrease of the arboreal vegetation.

The second stadial - **Nemunas 1b** (8.7-7.5m, gyttja) is characterised by a decrease of AP, significant increase of NAP (dominance of Cyperaceae), replacement of *Pinus* by *Betula (B. humilis)*, appearance of *Selaginella selaginoides* and *Potamogeton filiformis.* Single remains of *Larix* were noted. The opposite change of vegetation is reflected during the second part of this stadial.

The **Jonionys 2 (Odderade) interstadial** (7.5-6.1m, peat and gyttja) shows an expansion of coniferous forests, when *Betula* was replaced by *Pinus*, *Picea* and *Larix*, indicating a considerable amelioration of climate during the optimum of this thermomer. *Selaginella selaginoides,* however, was still present. Macrofossils of thermophilous plants typical for interglacial conditions were identified e.g. *Ceratophyllum demersum, Eleocharis ovata, Rubus idaeus, Rorippa palustris, Lycopus europeaus* and *Potamogeton* (10 species). The end of the interstadial is marked by a sharp decrease in pollen of *Pinus* and *Picea.*

The interval 6.1-5.3 m (gyttja) displays a gradual decrease of AP and an increase of NAP (*Artemisia*, Ranunculaceae, *Ericales*, *and Thalictrum*). The composition of the pollen flora is interpreted as representing the **Nemunas 2a stadial.** A minor climatic amelioration can be distinguished within this interval at 5.3-4.7m (gyttja) where an increase of AP is traced. AP reaches 50-58% of the total sum and is represented mainly by *Betula*. An U/Th date of this gyttja, at 5 m depth, shows an age of 42 170 years B.P. (determined by S-E Lauritzen, Bergen University). According to the chronostratigraphy for north-western Europe, the gyttja was deposited during the Middle Weichselian **Hengelo interstadial.**

The interval 4.7-4.2 m comprises silt with some admixture of organic matter. The pollen flora shows a very significant decrease of AP and an increase of NAP e.g. *Artemisia*, Chenopodiaceae and spores of *Sphagnum*, reflecting a strong climatic deterioration (cryomer). This period is interpreted as the **Nemunas 2d stadial** following the Hengelo interstadial.

The next interstadial (4.2-2.7 m, silt) is reflected by an increase of AP pollen (*Pinus* and *Betula*). The pollen frequency in this interval is, however, low indicating very unfavourable climatic conditions and the presence of a sparse vegetation cover. The interval is tentatively correlated with the **Denekamp interstadial.**

The results from the Medininkai section show alternating periglacial and interstadial palaeoenvironments in Lithuania during the Early and Middle Weichselian. The results of the investigation of the Medininkai section as well as from other key sections will be used within a correlation project to compare Weichselian stratigraphy in the Baltic States and the central area of glaciation in northernmost Sweden.

LITHOSTRATIGRAPHICAL IDENTIFICATION OF TILLS IN WESTERN LATVIA

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The western Kurzeme occupies the large area in the space from the Venta River to recent shore of the Baltic Sea and is the unique stratotype region of Fennoscandian glaciations province in general. Tills of the Weichselian, Saalian, and Elsterian are widely spread here, and probably Menapian till occurs also. According to the Latvian Stratigraphic Scheme these tills correspond to Latvija, Kurzeme, Lētīža, and Latgale glaciations. A. Dreimanis began to study lithological differences of moraines here and in the other areas of Latvia in the 30ties and applied for it the petrographical composition in grain size 1,0-0,5 mm. First he established differences between the Upper (Latvija) and Lower (Kurzeme) tills (Dreimanis, 1936, 1939), and later in Rucava site discovered and identified the third - Elsterian (Lētīža) till also (Dreimanis, 1944). V. Pērkons continued similar investigations and regarded differences in composition of tills as the ground for stratigraphical subdivision of Pleistocene (1957; Spriņģis & Pērkons, 1961; Spriņģis, 1961). The group of well-known sites of the Quaternary with four tills is located in the southeastern part of the Western Kurzeme Upland in the valley of the Lētīža River (Figure). It is only one area in Western, Northern and Eastern Europe, where the tills of three glaciations could be clearly seen at once in several outcrops, and the fourth till lies below being found by core. Vecvagari outcrop is most typical here. The valley of the Lētīža River is favourable place for a detailed investigation of the tills and for field guide also. The great desert in the foundation and study of the Quaternary structure and the moraines, also in the valley of the Lētīža River, belong to V. Pērkons. The Kurzeme till and upper part of the marine Ulmale Formation crop out in the cliff of Baltic Sea (Ulmale, Jūrkalne, *etc.*). The results of investigation of a till composition in the Lētīža section were discussed by Spriņģis, Konshin and author (1964). Some results of studies of differences in composition of tills in the sections at Dēseles-Lejnieki and Pulvernieki, where Pulvernieki (Holsteinian) intertill interglacial sediments spread, are regarded by Danilāns, Dzilna and Stelle (1964, 1969). These investigations show that the indices of the composition of tills are not fortuity and chaotic values. On the one hand, they fluctuate in the sections of tills a little, and, on the other hand, allow distinguishing the moraines of different age. The data on composition allow to determine the contact zones between moraines and to mark zones of the influence of bedrock too. Lithological differences among tills are observed in all areas of their distribution in Western Kurzeme (Table). They are clearly marked for the Latvija, Kurzeme and Lētīža tills in boreholes of the southwestern part of Kurzeme (Spriņģis, Savvaitov & Straume, 1965), and in other regions of the western Kurzeme as well (Konshin, 1964, 1965; Savvaitov, 1966). Great attention to the composition of tills was paid at the time of mapping (Straume, Juškevičs, Meirons, Mūrniece, Segliņš), and later during special investigations (Danilāns, 1973; Segliņš, 1987; Meirons & Mūrniece, 1982; Mūrniece, 1996). The regional indices of composition of each till are demonstrated and discussed. Lithological distinctions between tills connected with influence of the composition of bedrock and Quaternary deposits, which were crossed and exarated by an active glacier, have been established. The Kurzeme till has most distinct lithological features and is distinguished by the highest predominance of the limestones over the dolostones, lowest content of the sandstones, highest prevalence of the amphiboles over the ore minerals, and highest content of rounded hornblende grains. This till in the southern and middle part of Western Kurzeme is characterised by the highest content of clayey and silty size grains also. The local bedrocks spread in Western Kurzeme had a little influence on the composition of this till. The bedrock surface, as a rule, was covered either by the Ulmale marine sediments (Holsteinian and Early

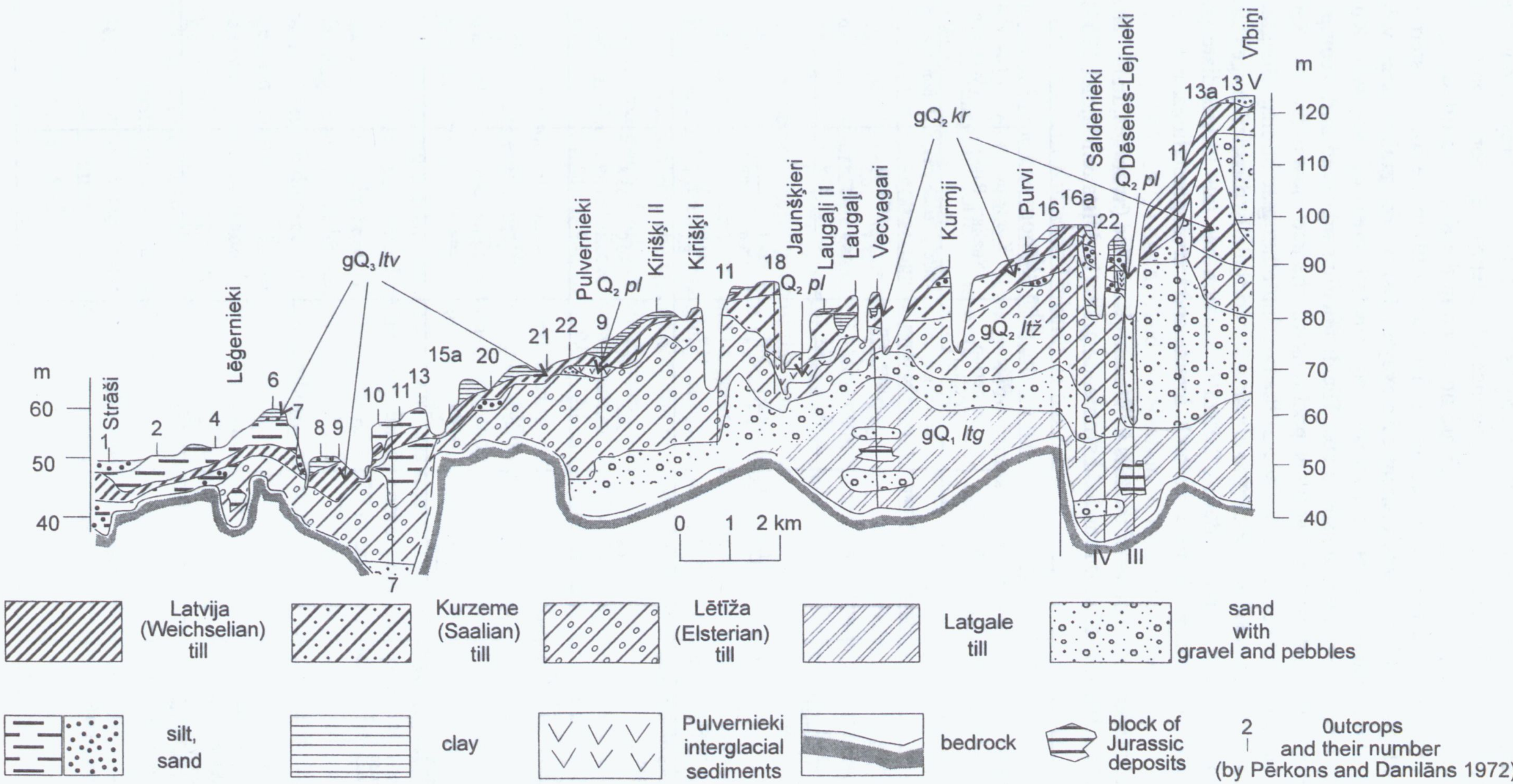

Figure. General section of Quaternary in valley of the Lētīža River (data of author, as well as of Pērkons 1957-1961, Danilāns, Dzilna *et al*., 1963, 1964, 1969, Danilāns 1973, Meirons, Mūrniece 1982).

Kurzeme) or Lētīža till, which preserved the bedrocks from exaration. Grey colour, the high content of silty and clayey size grains, the presence of redeposited spores, pollen, marine fossils, high content of organic matter, which are observed in the Kurzeme till, are connected with exaration of the Ulmale Formation sediments. The Latvia till in the southwestern part of Kurzeme is distinguished by a large content of clayey and silty size grains, large values of predominance of limestones over dolostones, and in all area of Western Kurzeme distinguished by a highest content of sandstones. The distinctions observed in the composition of different tills are interpreted by various positions of the ice flows. During Kurzeme Glaciation the glacier advanced more westwards than during other glaciations. The glacier of the Latvia Glaciation advanced to the east and was submeridionally directed in general. The general direction of ice movements during Lētīža Glaciation has the intermediate position between directions of glacier movement during Kurzeme and Latvia glaciations.

Table. Regional lithological indices of the tills in Western Kurzeme (averages, in %, data for debris by Konshin, 1964, 1965; for rounded hornblende grains by Ulsts & Majore, 1964)

Indices	The tills					
	Latgale (Menapian)	Lētīža (Elsterian, Mindel)		Kurzeme (Saalian, Riss)		Latvija (Weichselian, Würm)
Colour	dark-grey, grey, greyish brown	brown, greyish brown red-brown		blue, greenish grey, grey		brown, red-brown
Grain size:		Upper part		Upper part		
2,0-0,1 mm	30,1	38,6	32,7	28,4	36,3	29,6
0,1-0,01 mm	38,3	32,3	35,0	38,4	37,8	35,6
<0,01 mm	31,6	29,1	32,3	33,2	25,9	34,8
The petrographic composition in the grain size 1,0-0,5 mm:						
limestones	22,2	24,8	20,5	29,4	25.2	24,5
dolostones	7,6	6,7	4,4	3,6	4,9	10,4
sandstones	2,9	2,2	2,3	1,5	1,1	5,8
Total quantity of carb. rocks	29,8	31,5	24,9	33,0	30,1	34,9
Limestone/dolostone ratio	2,9	3,7	4,7	8,2	5,1	2,3
The mineral composition in the grain size 0,1-0,05 mm:						
amphiboles	34,8	38,2	44,6	40,0	45,8	32,7
ore minerals	21,5	23,3	14,7	20,3	10,8	28,0
Amphibole/ore mineral ratio	1,6	1,6	3,0	2,0	4,2	1,2
The petrographic composition in the grain size 3-5 mm:						
limestones	37,4	38,8		53,4		45,1
dolostones	7,7	15,5		6,7		10,9
sandstones	4,2	7,6		3,1		14,0
cryst. rocks	50,7	38,1		36,8		30,0
Limestone/dolostone ratio	4,9	2,6		7,9		4,1
The petrographic composition in the grain size 10-100 mm:						
Ordovician and Silurian						
limestones		51,7		70,7		54,0
dolostones		4,7		4,1		6,0
Devonian						
dolostones		12,7		5,2		18,6
sandstones		3,4		0,9		5,8
Cryst. rocks		27,5		19,1		15,6
Total quantity of the carb. rocks		69,1		80,0		78,6
Ord.-Sil. limestone/dolostone ratio		11,0		17,2		9,0
Limestone/dolostone ratio		3,0		7,6		2,2
The quantity of the rounded hornblende grains in the fraction 0,25-0,1 mm:						
The Western Kurzeme of Latvia	16	15		31		16
The Latvian part of the Baltic Sea - borehole 37		10		34		21
The Lithuanian part of the Baltic Sea - boreholes 54, 55, 58, 60, 61, 70, 71		11		31		15

LINKUVA STAGE OF THE LAST GLACIATION IN LATVIA

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The Linkuva Stage is one of well-known regional advancements of the last ice sheet during the Late Glacial time. The stage is termed Linkuva as the name of classical end moraine near Linkuva (Doss, 1910). Main part of the Linkuva end moraine is situated in Lithuania, but the northwestern and northeastern outlying parts - in Latvia. The North Lithuanian Stage in Lithuania, the Haanja Stage in Estonia, the Luga Stage in Russia are the equivalents of the Linkuva Stage of the Last (Weichselian) glaciation in Latvia. The boundary of maximum distribution of the glacier during this stage stretched across all area of Latvia from southeastern Estonia to northwestern Lithuania and well appears in topography (Figure). I. Veinbergs (1968, 1972) has marked the position of ice margin during the Linkuva Stage in Kurzeme. Here marginal belt is represented by such forms as: 1) northwestern part of the Linkuva end moraine proper; 2) the marginal slopes in southeastern, eastern and northwestern parts of the Eastern-Kurzeme Upland; 3) the Rauda-Lamiņi end hilly ridge; 4) the Lauciene end moraine; 5) the end moraine ramparts on the area of Venta Lowland and the Ēdole-Padure end hilly ridge; 6) the Tadaiķi flank moraine rampart, *etc*. On the rest large area of Latvia the Linkuva ice marginal formations were studied in details by O. Āboltiņš (1968, 1970, 1998; Āboltiņš, Straume & Juškevičs, 1975). These relief forms are: 1) end and flank moraine ramparts between rivers Daugava and Mēmele (Valle ridge by Zelčs, 1998) and between Lielvārde and Jūdaži (Lielvārde-Jūdaži ridge by Zelčs, 1998); 2) Raiskums-Dauguļi or Augstroze hilly interlobate massif; 3) Veselava, Rauna, and Branti hilly ridges along northern slope of Vidzeme Upland; 4) serial Aumeistere rampart-like forms and probably also ridge-like forms on the peripheral parts of the Middle Gauja Lowland. The distance of retreat of the ice margin is not less than 55 km (Āboltiņš, 1963). Underlying Raunis interstadial intertill sediments with plant remains and organics occur in Līdumnieki, Raunis and probably Krikmaņi sites on the area of marginal zone, that allows to determine the age of this regional ice margin advancement. The age of both the marginal formations and the beginning of retreat of the glacier margin of Linkuva Stage from its maximum spread border is about 13,000 years BP (Punning, Raukas, Stelle & Serebryannyi, 1968). Besides Raunis interstadial sediments under Linkuva till there is preserved also glaciolacustrine clay, silt and sand, which probably formed at the time of glacier retreat during older Pampāļi-Ranka Stage (Mēmele time by Stelle, 1976). Several lobes and tongues (Middle Gauja tongue, Northern Vidzeme tongue, Rīga lobe, Baltic lobe with Venta-Usma tongue, Apriķi and Bārta small tongues) were distinguished according to the dynamical structure of the Linkuva Stage glacier. The thickness of the glacier during the Linkuva Stage was less than at the earlier events of the deglaciation and probably reached some hundred meters in more proximal parts of the sheet, but in marginal parts was only from 80-100 m to 150-170 m and even less. The glacier during the Linkuva Stage was characterised by great activity. The definite position of ice margin during the Linkuva Stage indicated by geomorphological data, numerous glacial deformations in the structure of marginal formations of this stage and in older formations being under the ice, as well as wide distribution of the radial subglacial forms in proximal areas and local composition of till all together well reflect the activity of ice both during its advance and retreat at this time. The glacier was characterised by short oscillatory movements as well. These movements probably caused formation of the small-scale ramparts on the surface of the end forms, as well as the rogen and ribbed moraines, which are observed in characteristic interrupted rows in inner zone near Linkuva end moraine and Valle ridge (Zelčs, 1993, 1999; Dreimanis & Zelčs, 1998).

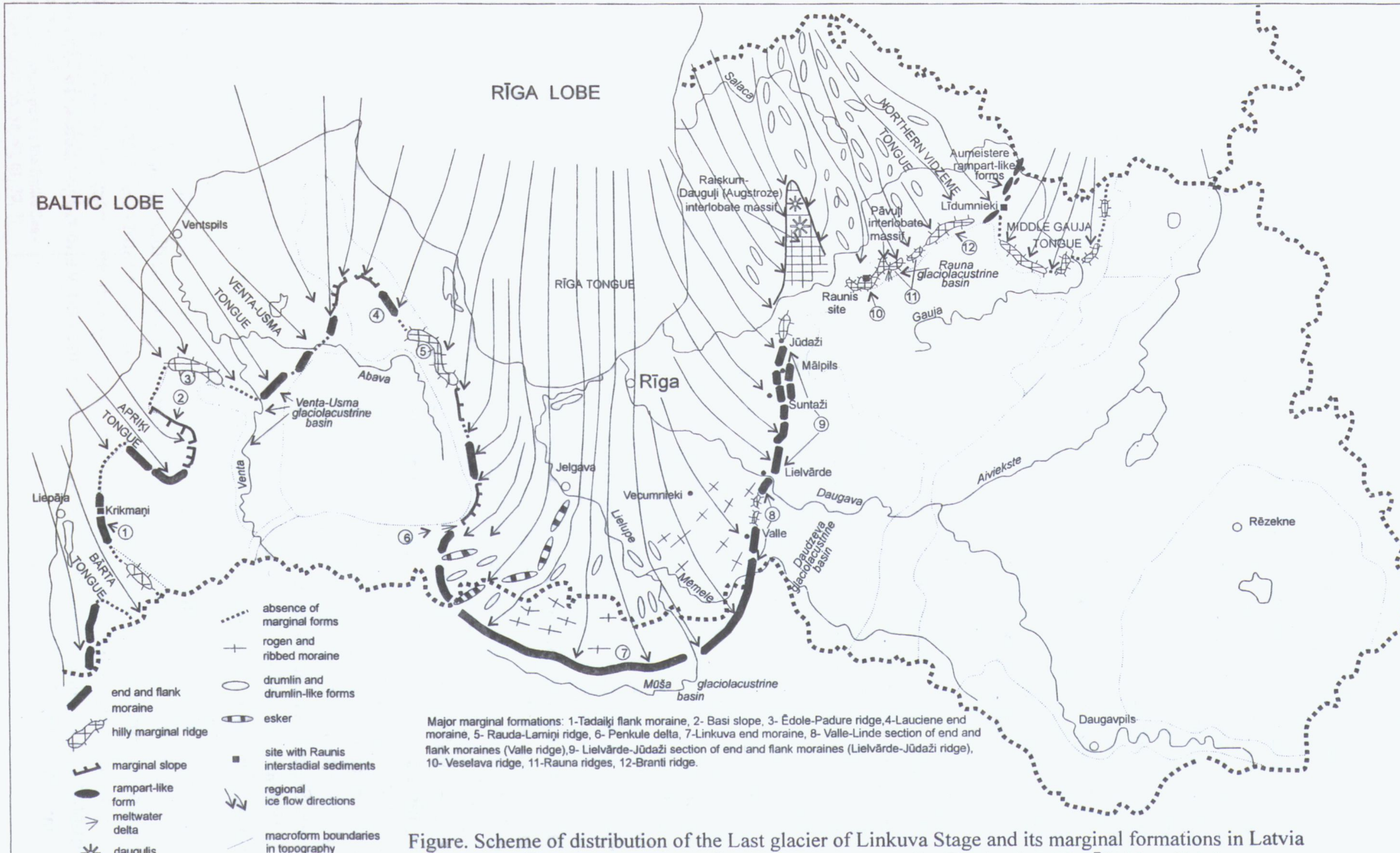

Figure. Scheme of distribution of the Last glacier of Linkuva Stage and its marginal formations in Latvia (after Āboltiņš 1970, 1998; Āboltiņš,Veinbergs, Stelle, Eberhards 1972; Āboltiņš, Veinbergs, Eberhards 1974. The data of Zelčs 1993, 1998, 1999 and Dreimanis, Zelčs 1998 are also taken into account)

HOLOCENE STRATIGRAPHY IN LATVIA AND REGIONAL DIMENSIONS

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Stratigraphic studies of the Holocene were introduced in Latvia from early century, but in principle were speeded up from twenties by the research of Prof. P. Galenieks and M. Galenieks-Liniņa. Most of them are based on traditional spore and pollen investigations added from sixties by radiocarbon dating.

Today there are the results of spore and pollen analysis in diagram from more than 500 investigated sites available for general studies. Less than 10% of those diagrams have been published and, unfortunately, the main part of observation notes and data have been lost.

With the 70 years retrospective, with highest respect and gratitude to 42 known palynologists who were worked in Latvia, one should notice that the interpretation and zoning of spore and pollen have been changed significantly. However the principles of zoning - correlation with Blytt-Sernander climatic periods and L. von Post pollen zones - have been preserved. There are some reasons for that. To a certain extent these are traditions and conservatism. At the same time the results obtained in Scandinavia (particularly in Eastern Sweden and Gotland) concerning composition of pollen spectra from classical studies are so close and identical with the results of similar investigations in Latvia, that it is not practical necessity to compile the pollen spectra of local stratification scale for regional and inter-regional correlation.

As basics the 11 spore and pollen zones (palynozones) and fixed content subzones prevailed over interpretation in Latvian case. The new proposals base on the interpretation of the Atlantic medium (AT2) and Post-Dryas (PB1) palynozone content and interpretation based on comprehensive studies of the above mentioned large number of data from whole Latvia and surroundings.

For that substantial assistance were founded at average pollen diagrams from different parts over the country. These diagrams are demonstrating the most general and disposition changes of spores and pollen spectra during the time. M. Galenieks (Linina) prepared the first diagrams of this type for Latvia in 1935, K. Bambergs (1962) prepared 4 regional average pollen diagrams, but in 1970 V. Stelle and I. Danilāns prepare a new Holocene deposit average pollen diagram, which was banded with the first radiocarbon dating based geochronological constructions.

Now all preceding constructions and, on a basis of collected pollen diagrams, series of regional pollen diagrams for the Holocene deposits from 21 areas of Latvia are renovated for discussions. For more general constructions the number of regions can be reduced to 4 (Kurzeme, Zemgale, Vidzeme and Latgale) in order demonstrate the main features of palynozones. The regional as well as typical or standard description with particular characters of pollen spectra of major palynozones presented with special attention to geographical features.

These palynozones are easy to correlate with corresponding ones in Estonia (S. Veski, T. Koff, R. Pirrus, K. Kajak), Sweden (J. Mangerud, S. T. Andersen, B. E. Berglund, T. Nilsson) and the Baltic Sea studies, but very complicate with Lithuanian and Belarussian.

It is easy to recognise common particular characters and some specific as well, in the vegetation development trends, but comparison and correlation is easy and verification is high even if the episodes (significant events in the vegetation history) are shifting in the time. In fact more differences can be recognised between Latvian Kurzeme and Latgale average diagrams, than between Latvian and Estonian or the Baltic open proper types (if the timing of events is not taken in account). Correlation in this respect very much assisted by chrono-stratigraphical substance of Blytt-Sernander`s zoning system.

Complications with applications of the Lithuanian Holocene stratigraphical construction to the neighbouring areas are well known and have number of reasons. The concept of 4 major parts of the Holocene (including Alleröd), direct L. von Post zonation system application from T. Nilson study on Ageröds mosse as a basic reference site, direct application of local particular radiocarbon data to general zonation system, and role of individual opinions should be mentioned as most substantial. During the last years the Lithuanian scheme is under revisions and be more open for discussions, however, newly published studies of M. Stancikaite demonstrate well comparable Holocene pollen spectra with corresponding found in Latvia.

It is proposed not to use L. von Post's system base for Latvian Holocene pollen data interpretation and more concentrate on local particularities, local indicators of stratification supported by radiocarbon dating tests. From late eighties a number of the results of successful studies in Nordic countries were copied and directly applied to local findings, mostly for pollen data interpretation or dating of particular events. These data should be fundamentally revised and re-interpreted.

As a role, the local and country features prevail during the last decade studies of the Holocene in Baltic. We do not propose to work out the unified Holocene stratigraphic scheme for the Baltic area, however, there are recognised needs for common accepted principles and attitude to speed up modern Holocene studies in the area.

FISH FAUNA AND ORIGIN OF A GESCHIEBE OF THE OLD RED SANDSTONE

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In North Germany erratics of the Devonian sandstones are rare. However in some areas they are slightly more common, and it is easy to collect them. The so-called Ball Sandstone is poor in fossil remains, but so-called Old Red Sandstone geschiebe contain apatitic fish remains in many cases. There maybe exist more than hundred geschiebe of that type with fish microremains in collections. It is conspicuous, that the geschiebe show highly different kinds of fish scales and also unknown scales are not rare. It will be necessary to examine this material in the future to complete our knowledge about Devonian fish fauna by geschiebe.

In continuation of the examination of a geschiebe (Bartholomäus *et al.*, 1997), it has been studied with respect to scales and teeth of Devonian fishes. Due to advanced disarticulation of the squamiferous dermal skeletons and the high amount of isolated scales, a determination at the generic or specific level was not always possible. Remains of representatives of Psammosteiformes are predominant. The scale *Corollaspis walteri* gen. et sp. nov. is supposed to occur in the lower Middle Devonian of SW Estonia (pers. comm. M. Otto, Berlin). New scales of unknown agnathans are described from geschiebe. Furthermore, scales of acanthodians are present in large numbers. Porolepiform sarcopterygians are represented mainly by marginal teeth. The scale of sarcopterygian *Porolepis posnaniensis* (Kade) points to the Middle Devonian age.

The fish fauna gives evidence of lowermost Middle Devonian age. This is confirmed by lithological characteristics. The geschiebe probably originated from submarine outcrops in the eastern part of the Baltic Sea.

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PALYNOLOGICAL CRITERIA FOR STRATIGRAPHICAL SUBDIVISION OF THE LATE GLACIAL DEPOSITS IN LATVIA

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The first areas in Latvia (Eastern Uplands) began freed from the continental ice probably 15,500-15,000 years ago. However the reliable biostratigraphical data about this deglaciation period are currently absent.

More clear and rich palaeobotanical data about retreat of the ice sheet from Latvia and development of vegetation on this area are known from the interstadial sediments of Raunis I, Raunis II and Līdumnieki sites. These sediments accumulated 13,500-13,000 years ago in periglacial conditions, showing tundra and shrubs tundra composition. This vegetation contains arctic, arctic-boreal and steppe species (elements): *Dryas octopetala, Salix polaris, S. reticulata, Alnaster fruticosus, Ephedra* spp., *Eurotia ceratoides, Betula nana, Lycopodium alpinum, Selaginella selaginoides, etc*. The spores and pollen composition indicates the cyclic development and changes of both climate and vegetation. Three pollen assemblage zones (*Betula, Pinus, Betula*) are distinguishable here with difficulties. The middle of them (*Pinus*) corresponds to the climatic optimum of Raunis interstadial time.

The sediments of the Oldest Dryas ascertained at Raunis II site and represented there by till, as well as clayey and sandy sediments. The clayey and sandy deposits contain the remains of periglacial plants. The content of *Artemisia* pollen is relatively high. The pollen of trees in the Oldest Dryas sediments is represented mainly by *Betula* and *Pinus* and their ratio is variable.

The Bølling sediments lie above in this site too. Two pollen zones characterise their spores and pollen composition: *Betula* zone and *Pinus* zone. Similar pollen assemblage zones are distinguished in lacustrine deposits in Eastern Latvian Lowlands (Zilāņi, Varakļāni sites) and Middle Latvian Lowland (Ozolnieki, Spartaks sites *etc*.).

The pollen composition of the Older Dryas deposits is determined at Ozolnieki site and Lielauce (southern part of Eastern Kurzeme Upland) site. These deposits are characterised by high herb pollen percentages, especially *Artemisia*, along with *Betula nana*.

The palynological study of the site with Allerød sediments allows considering that three pollen zones are observed inside the Allerød Chronozone - *Pinus, Pinus-Betula* and *Pinus*. The middle *Pinus-Betula* zone reflects the cooling. The age of appropriate deposits in Lielauce site by ^{14}C dating is 11,300±300 years B.P. (Rī-2). The sediments in Pamjerkes site in Lithuania have the similar age (11,500±400, Mo-341).

The pollen composition of Younger Dryas Chronozone (Dr3) is characterised by remarkably high ratio of herb pollen (*Artemisia* is dominant), as well as *Betula* and *Betula nana* among the tree's pollen. The Younger Dryas sediments are observed in many sites of Latvia.

THE BOUNDARY BETWEEN DEVONIAN RĒZEKNE AND PÄRNU FORMATIONS IN EASTERN LATVIA: SEDIMENTOLOGICAL ASPECTS

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The Rēzekne and Pärnu formations correspond to the Lower and Middle Devonian boundary beds. Each formation comprises one sedimentary cycle (Figure). However, it is

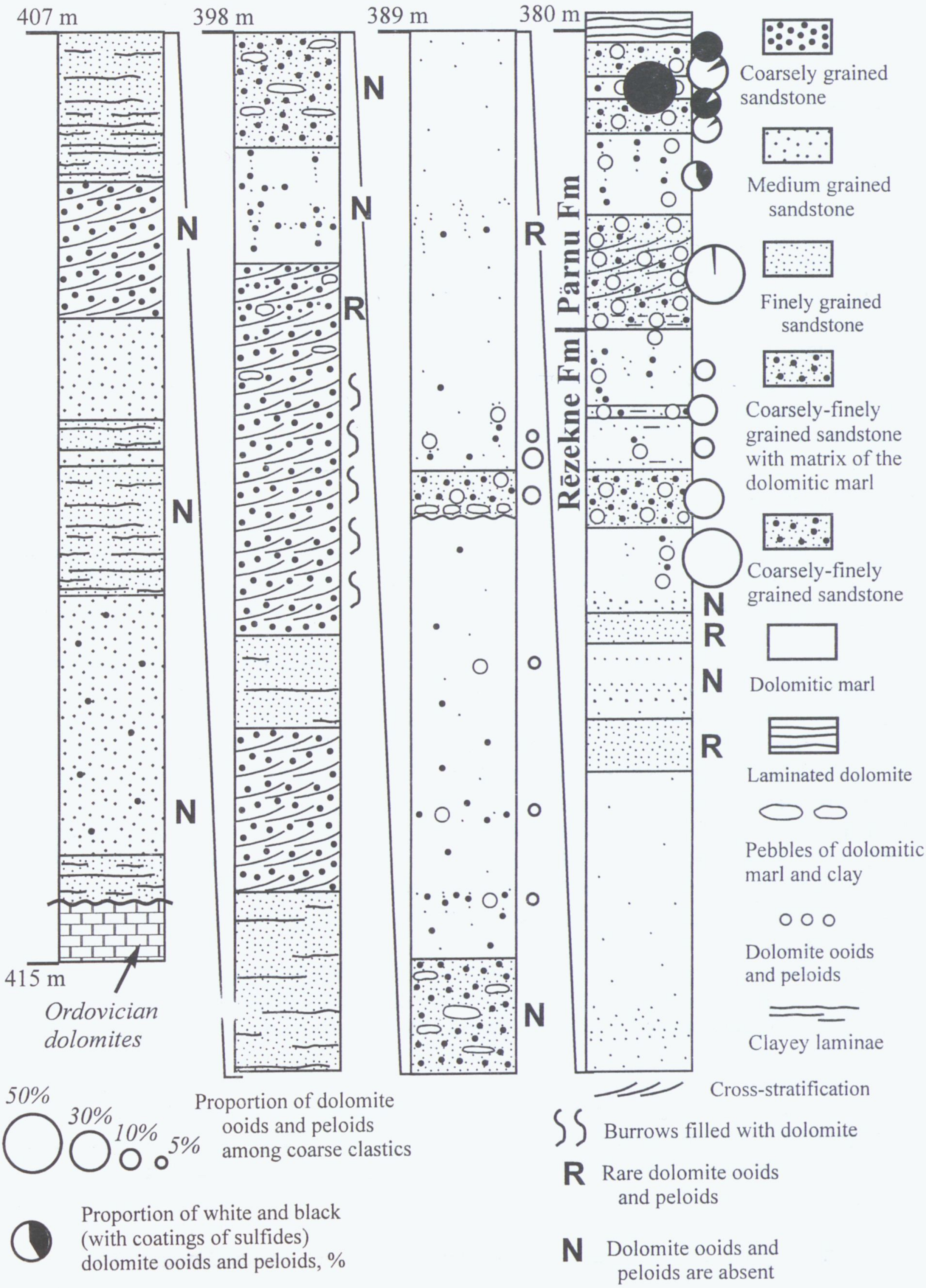

Figure. Detailed geological section of borehole 103. Šķaune through the deposits of Rēzekne-Pärnu Formations: carbonate ooids and peloids difficult to distinguish these two sedimentary cycles in western and central parts of Baltic, because during Rēzekne and Pärnu times rather uniform siliciclastic deposits have been accumulated there in shallow epeiric sea. Such sedimentary regime was regulated by strong inflow of river water from the north, which lowered the salinity of seawater and carried in it a large amount of sand and clay.

Along the eastern part of basin there developed the peneplained land composed of Ordovician and Silurian carbonate rocks, which supplied minor clastic material. Moreover, the currents, which transported clastic material across the central part of epeiric sea, in the eastern part of basin was largely hindered by the meridional barrier - Viļaka arch. Therefore during the Rēzekne-Pärnu times carbonate sediments accumulated there together with clay and sand. The cyclicity of sedimentary processes is clearly seen in this mixed-composition sequence.

The boundary between Rēzekne and Pärnu formations in eastern Latvia has been drawn in different ways - according to differences of fish assemblages, mineral composition and types of deposits, as well as basing on geophysical logs. Generally this boundary is situated between the greenish-grey and grey dolomitic marls (upper part of Rēzekne cycle) and grey sandstones (lower part of Pärnu cycle). However, changeable composition of Lower-Middle Devonian transitional beds often does not allow tracing this boundary unequivocally between two certain beds.

Detailed sedimentological and mineralogical studies of Lower-Middle Devonian transitional sequence in eastern Latvia (boreholes 103-Šķaune, 15-Ludza, 25-Višķi and 9-Atašiene) allowed to define the boundary between Rēzekne and Pärnu formations more exactly. This boundary corresponds to lithological changes, which are related to development of sedimentary basin: in eastern Latvia the basal part of Pärnu Formation consists of varigrained sandstones, which by increased content of ooids and peloids radically differs from underlying Rēzekne Formation (see Figure). In direction to central part of Latvia, where total carbonate content sharply decreases, the layer with maximum carbonate content and rare peloids (which are not found in other beds) is accepted as the basal part of Pärnu Formation. Thus the boundary corresponds to cyclicity of sedimentary processes - Pärnu Formation starts a new transgression of the sea.

CONODONT-BEARING BEDS IN DEPOSITS OF THE FAMENNIAN STAGE OF THE PRIPYAT TROUGH (BELARUS)

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The analysis of the species composition and distribution pattern of conodonts from the Lower Famennian deposits (intersalt strata) within the Pripyat Trough (Kruchek & Strelchenko, 1998) has revealed some local biostratigraphic subdivisions - beds containing conodont remains, that permits the improvement of the Regional Stratigraphic Scheme of Devonian deposits of Belarus (Golubtsov *et al.*, 1983). The beds were named after one or two most typical species discovered in them.

Icriodus iowaensis **beds**. The assemblage of this biostratigraphic unit contains *Icriodus iowaensis iowaensis, I. iowaensis ancylus, I. alternatus, I. deformatus, I.* aff. *cornutus, I.* aff. *vitabilis*. *Polygnathus* often occurs together with them and is mainly represented by a new (endemic) species. *Polygnathus brevilaminus, P. izhmensis, Neopolygnathus vorontzovae, N. communis* are also present. The composition of the assemblage is supplemented by single specimens of *Palmatolepis triangularis, P. quadrantinodosalobata, P. werneri, P.* aff. *tenuipunctata, P.* aff. *subperlobata.* Beds containing *I. iowaensis* correspond to deposits of the Kuzmichi and lower Igrayev beds of the Zadonsk Regional Stage (R.S.) in the Pripyat Trough (Golubtsov *et. al*., 1983).

***Palmatolepis wolskae - P. circularis* beds.** The association from these beds is substantially different from that described above. It is characterised by the increased amount of representatives of the genus *Palmatolepis: P.* aff. *crepida, P. circularis, P. wolskae, P. termini, P. subperlobata, P. tenuipunctata, P. quadrantinodosalobata, P. minuta minuta, P. minuta loba, P. minuta wolskae, P. gracilis. Polygnathus glaber glaber, Polynodosus ovatus, Ancyrognathus sinelamina, Neopolygnathus* aff. *vorontzovae*, *Polylophodonta* aff. *confluens* and others are also present. These beds correspond to deposits of the most part of the Zadonsk R.S. (upper Igrayev and Visha beds). The bottom deposits of the Yelets horizon should be probably also referred to these beds.

***Palmatolepis klapperi - Polygnathus semicostatus* beds**. The conodont assemblage of this subdivision represents for the first time *Palmatolepis rhomboidea, P. glabra prima, P. glabra glabra, P. glabra pectinata, P. klapperi, P. poolei, P. perlobata schindewolfi, P. lobicornis. Polylophodonta confluens, Polygnathus semicostatus, Polynodosus fallax, P.* aff. *ovatus, Neopolygnathus mutabilis* and others also occur there. These beds are identical with the Turov beds of the Yelets R.S. of the Regional Scheme.

***Icriodus divergentus* beds.** The conodont assemblage of this stratigraphic unit is similar in composition to *P. klapperi - Po. semicostatus* beds. However, *I. divergentus* occurs there in abundance. This subdivision corresponds to the Drozdy beds of the Yelets R.S.

***Palmatolepis subperlobata helmsi* beds.** In this assemblage the representatives of the genus *Palmatolepis* are dominant in quantity: *P. rhomboidea, P. subperlobata helmsi, P. glabra lepta, P. glabra acuta, P. regularis. Polygnathus magidis, P. nodocastatus, P.* ex gr. *nodocastatus*, as well as *Vjaloviodus tardus,* are also abundant. Beds containing *P. subperlobata helmsi* conform to deposits of the Petrikov R.S. of the Famennian stage of the Regional Scheme.

The correlation of the biostratigraphic units subdivided in the Lower Famennian deposits of the Pripyat Trough with the Standard Conodont Scale of the Upper Devonian (Ziegler & Sandberg, 1997), as well as with units distinguished in neighbouring regions of the East European Platform (Aristov, 1988; Kononova & Ovnatanova, 1995) permits the conclusions as follows:

1. Deposits of the Zadonsk R.S. of the Regional Scheme of the Devonian of Belarus correspond to two conodont zones: *Middle - Upper triangularis* (*I. iowaensis* beds) and *crepida* (*P. wolskae - P. circularis* beds). According to Ziegler and Sandberg (1997), these deposits should be attributed to the Lower Famennian.

2. Formations of the Yelets and Petrikov R.S. contain the zonal species of *P. rhomboidea,* which together with the other conodont species definitively indicate these deposits correspond to the *rhomboidea* zone. In our opinion, the Yelets R.S. (beds containing *P. klapperi - Po. semicostatus* and *I. divergenthus*) corresponds to the *Lower rhomboidea*, and the Petrikov R.S. (beds containing *P. subperlobata helmsi*) to the *Upper rhomboidea* of the Standard Conodont Scale. According to Streel *et al*. (1998), the *rhomboidea* zone should be probably of the Middle Famennian age.

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LITHO- AND CHEMOSTRATIGRAPHY AND DEPOSITIONAL PALAEOENVIRONMENTS OF LOWER TRIASSIC SEDIMENTS IN SOUTH-WESTERN LITHUANIA

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Lower Triassic sediments in Lithuania exceed 200 m in thickness. Due to a lack of indicative paleontological evidences, stratigraphy of Triassic deposits in Lithuania is based on lithological criteria. Facies change from marginal to intrabasinal environments towards the south-west. Due to the post-depositional denudation, actually no near-shore sediments were preserved in Lithuania. The present-day distribution of deposits shows the regressive trend. The only place where stratigraphically rather complete succession of near shore lithofacies is preserved has been reported from the south-western Lithuania. Lithological features of this area reflect changes from typical intrabasinal depositional environments in the north within the Baltic Syneclise to near-shore environments in the south on the northern slope of the Mazury-Belarus Anteclise. This transition occurs within only 30-40 km wide zone what enables correct stratigraphic correlation of these two extremes (Fig. 1). Consequently, the south-western corner of Lithuania is regarded as a key area for studying the basin evolution trends. Profile presented in Fig. 1 evidences transgressive trend of Lower Triassic succession by contrast to the post-depositional regressive trend reported elsewhere in Lithuania. The section starts from the basal Nemunas Formation, which shows a trend of claystones passing into sandstones southward, i.e. towards the anteclise. They are overlain by the Palanga Formation, which is composed of reddish brown claystones and marlstones in the north, and near-shore grey sandstones in the south. In the transition lithofacies belt the oolitic limestones are abundant. The Palanga Formation is subdivided into the lower and upper sub-formations, the upper one showing a broader extent to the south than the lower sub-formation, thus pointing to progressing transgression of the basin. The Taurage Formation marks abrupt changes in the sedimentation environment. It represents a single sedimentation cycle composed of grey sandstones in the basal and upper parts separated by oolitic limestones. In the north sandstones are replaced by grey marlstones. The near-shore lithofacies consist of grey sandstones and conglomerates. The Lower Triassic succession is crowned by the Sarkuva Formation composed of alternating marlstones, claystones and clayey siltstones. Sandstones are abundant in the south.

Trace element geochemistry of Lower Triassic claystones has been studied in order to define the main evolutionary trends, also trying to correct the stratigraphic subdivision that was primarily based on lithological criteria. As it is seen in Fig. 2, the Nemunas Formation,

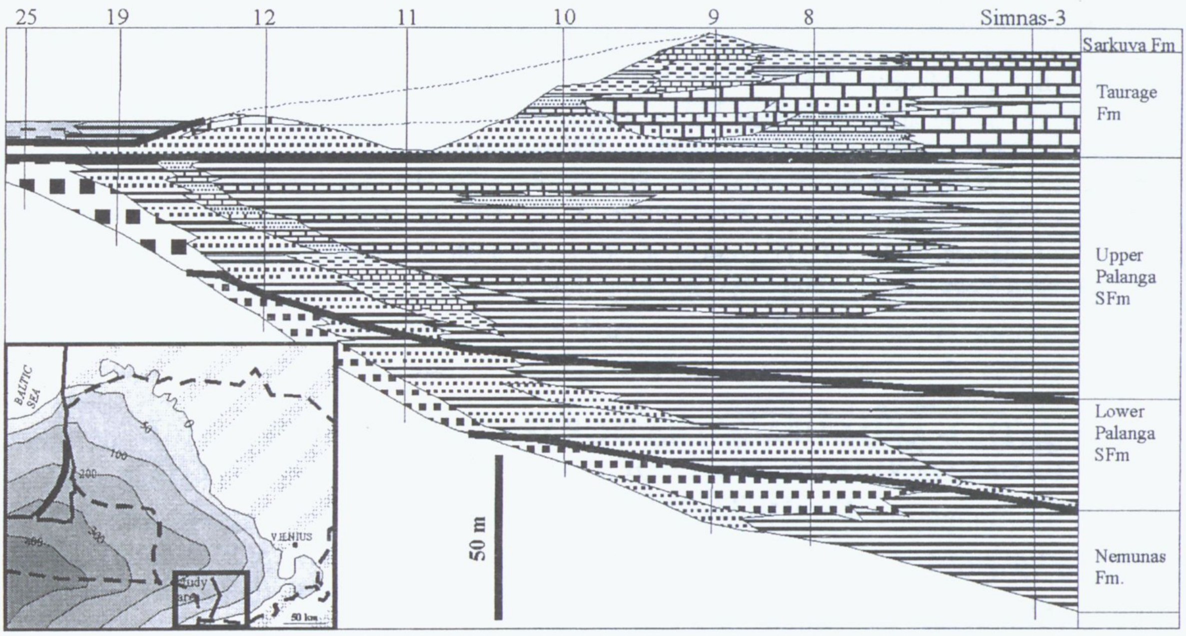

Fig.1. Lower Triassic cross section south-north, SW Lithuania

1 - conglomerate; 2 - feldspar-quartzous sandstone; 3 - quartzous sandstone; 4 - sandstone alternating with claystone; 5 - sandstone, oolitic limestone; 6 - siltstone, oolitic limestone; 7 -siltstone; 8 - claystone; 9 - claystone with interlayers of oolitic limestone; 10 - sandy oolitic limestone; 11 - oolitic limestone

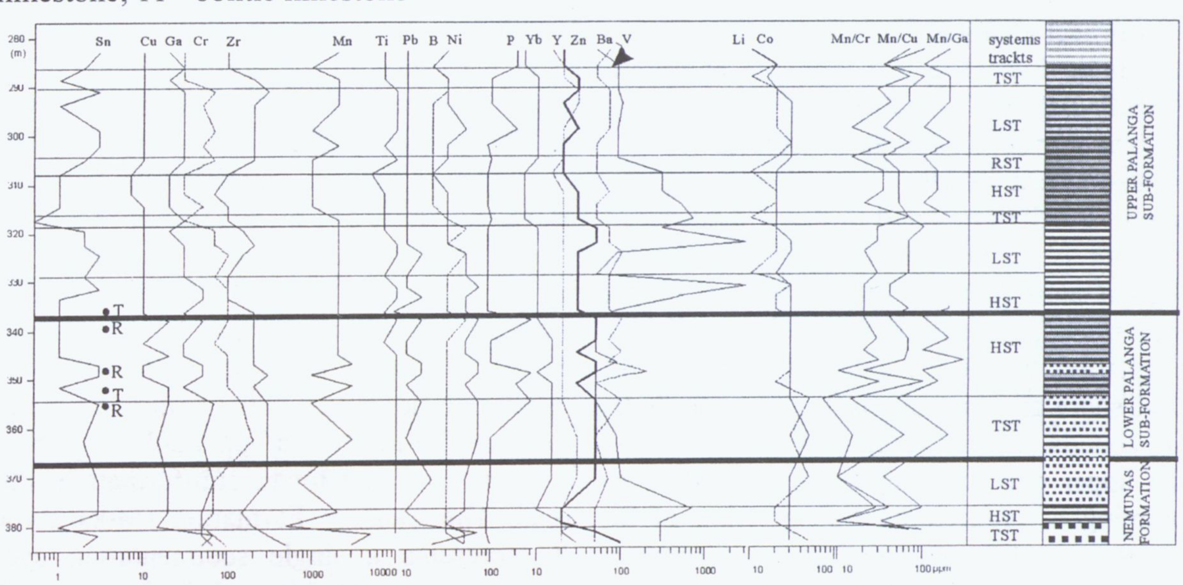

Fig.2. Trace elements patterns in red coloured claystones in well Dzukija-1, SW Lithuania

Lower and Upper Palanga subformations are well reflected in the trace elements patterns, the geochemical boundaries confined to the stratigraphic boundaries. The geochemical boundary between the Lower and Upper Palanga subformations is even more pronounced despite the less distinct lithological boundary than that between the Nemunas and Palanga formations. Actually all the trace elements show sharply decreased contents while passing upward the lithostratigraphic boundaries. The upward trend of decreasing of rare elements is likely related to stepwise distancing of the shoreline with respect to studied wells from the Nemunas to Taurage time. This is in agreement to stated southward migration of the limit of the Lower Triassic sediments recognised from lithostratigraphic data. Some variations in trace elements abundances are recognised inside the formations, which makes a hint to some cyclicity (Fig.2). Following the geochemical features, chemical weathering prevailed in the provenance over the mechanic denudation during Early Triassic. Also, they show low mineralisation of the basin water which likely was a transitional between the lacustrine and marine.

NEW DATA ON MACROFAUNA OF THE IDAVERE STAGE (LOWER CARADOC) IN THE ST. PETERSBURG REGION

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New data on the distribution and taxonomic composition of macrofauna in the Idavere Stage of St. Petersburg region, northwest Russia, allow a succession of four macrofauna associations to be distinguished.

1. A low diversity association in the boundary beds between the Idavere and Kukruse stages is represented mainly by linguliform brachiopods (*Siphonotreta intermedia* Gorjansky, *Lingulasma* sp.) and rare trilobites (*Asaphus* (*Neoasaphus*) *nieszkowskii* Schmidt). The association occurs within a 4 m thick limestone sequence in the Alekseevka and Klyasino quarries.

2. A diverse macrofauna association comprising at least 113 taxa can be documented in the carbonate clays and marls of the upper part of the Gryazno Formation that corresponds to the lower Ojamaa Substage of the Idavere Stage (Resheniya..., 1987). Ten species of brachiopods and seven species of trilobites have been found in the Idavere Stage for the first time. These species are well known from the Kukruse or Jõhvi stages in North Estonia. The most characteristic and frequently occurring species of the association are: *Platystrophia dentata lata* Alichova and *Bilobia* aff. *B. musca* Öpik among the brachiopods, and *Scopelochasmops wrangeli* (Schmidt) and *Calyptaulax* sp. among the trilobites.

3. A third association occurring in the dolomitic argillaceous limestone of the lower part of the Schundorovo Formation (corresponding to the Schundorovo Substage) is dominated by various representatives of echinoderms. These fossils are represented mainly by disarticulated skeletal elements of crinoids that occur as columnals of *Babanicrinus*- and *Baltocrinus* - type.

4. A specific association of shelly fauna characterises the argillaceous dolomite of the upper part of the Schundorovo Formation. Contrast to the older three associations, the late Schundorovo association is comprised mainly of sponges, bryozoans and receptaculites.

The macrofaunal associations in rocks of the first and third levels of the St.Petersburg region are similar to those known in North Estonia. The second level (upper part of Ojamaa Substage) is characterised by greater taxonomical diversity than found in North Estonia. The fourth level differs from that in North Estonia by the taxonomical composition of the sponges.

SEM RE-EXAMINATION OF CYATHOCHITINA PRIMITIVA TYPE MATERIAL AND ITS BIOSTRATIGRAPHIC SIGNIFICANCE

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It is obvious for chitinozoan workers that precise description and good illustration is very important for proper identification of species which are crucial in biostratigraphic application. This is especially given that chitinozoan phylogeny is poorly known, and their lineages can not be confidently used in biostratigraphy. The type material of *Cyathochitina primitiva* Szaniawski 1974 from the Lower Ordovician conglomerates at Międzygórz in Holy Cross Mountains, Poland (Chlebowski & Szaniawski, 1974) re-examined in scanning electron microscope revealed lack of carina, which is diagnostic feature for the genus. Moreover, the same is true for the new Estonian specimens from Leetse and lower Toila formations in Sukrumägi section (Nõlvak & Grahn, 1993, Nõlvak, 1999) used to designate the new type interval and locality for *C. primitiva*. The chitinozoan assemblage associated with *C. primitiva* contains *Lagenochitina esthonica* Eisenack 1955 or *L.* cf. *esthonica* and *Desmochitina minor* Eisenack 1931, and is analogous to Early Arenigian chitinozoan assemblage with *Conochitina symmetrica* Taugourdeau and Jekhowsky 1960 and *Amphorachitina conifundis* Poumot 1968 recorded in lowermost part of the Klabava Formation in the Prague Basin, Czech Republic (Fatka, 1993). This requires a reassessment of all previously reported occurrences of *Cyathochitina primitiva* assemblage beyond Baltoscandia and *Conochitina symmetrica* assemblage in the Gondwanan domain.

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PRINCIPLES OF STRATIGRAPHICAL SUBDIVISION OF THE HOLOCENE OF BELARUS

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The stratigraphical subdivision of the Holocene deposits in the territory of Belarus, palynologically investigated in more than 200 sections, is based on the analysis of changes of general, regional and local peculiarities of the environment in time and space for last 10300 years. Distribution of the main forest trees in a section reflects the **general** regularities of changes of the main environment components under influence of the global reasons, mainly climate. The climate was progressively becoming warmer during the Preboreal and Boreal periods, reaching the maximum during Atlantic times (the excess of temperature in January by 1-2 degrees, July - by 1-2 degrees, and of precipitation - by 50 mm in comparison with present time), and turning cooler after optimum. The climate effected character of palynoflora, vegetation, structure of the palaeophytocoenoses, migration of the forests, zonation, change of water regime, sedimentation, and development of the palaeobasins and bogs. The character of palynoflora reflects the distribution of boreal elements at the beginning, which were changed by the thermophilic light-demanding and nemoral plants, and subsequently again by boreal flora. The pine massifs were replaced by the pine-spruce forests, and subsequently by the birch forests, which gave place to the mixed and broad-leaved forests. During the next stage the pine and pine-birch, then the spruce coenoses have come, which subsequently as a result of the destruction of the forests were replaced by the pine, spruce and again pine forests alongside with the increasing areas of herb communities. The influence of climate on the structure of palaeophytocoenoses is reflected in the Holocene macrosuccessional series (uncompleted yet by a birch), which is expressed in the region by a series of the maximums of *Pinus* —> *Picea* —> *Betula* —> *Ulmus* —> *Tilia* —> *Quercus* —> *Pinus* —> *Picea* —> *Pinus*+NAP —> *Picea*+NAP —> *Pinus*+NAP —>...). Concerning the migration of the forests, the north-western, north-eastern, western and eastern flows of the light- and dark-coniferous trees, later *Betula*-coenoelement, were replaced by the migration of the southern quercetal flora in the first half of a climatic optimum, and the nemoral flora - in the second half, subsequently substituted by the waves of light- and dark-coniferous trees flows. The vegetation zones changed from the coniferous to the mixed and broad-leaved forest zone, and then again to the mixed and the coniferous forest zone. The climate effected also a water regime, causing the general increase of water level during Atlantic. The sedimentation changed from the accumulation of sand, sandy till, clay, till, peat underlying gyttja, and calcareous, mixed, coarse-detrital, fine-detrital, siliceous gyttja in the early Holocene to the maximum accumulation of the mixed, calcareous and coarse-detrital gyttja in Atlantic, and the intensive accumulation of the fine-detrital and siliceous gyttja in Subboreal and Subatlantic. The climate changes influenced the development of the palaeobasins and bogs, the independent lake and bog regimes, as well as the transition of the lakes in the bogs.

The **regional** features of the vegetation changes on the territory of Belarus regarding time aspect are evidenced by the variations of the forest trees, shrub and herb communities. They are characterised by the peaks of spores (mainly Polypodiaceae) in the early Holocene, *Picea* - in PB-2, *Betula* - in BO-1, *Ulmus* and *Tilia* - in AT-1, *Quercus* - in AT-3, by increasing of herb pollen starting with SA-1, and by the absence of the exotic floral elements.

The spatial changes of the regional factors are expressed by features of the palynological diagrams, which depend on a relief of the territory characterised by the pollen spectra. They are represented by the three types: Polesje (dominance of pine -30-90 % at the low value of spruce - 4-5 %, thermophilic trees - 20 %, birch - 10-30 %); Central Belarus (the increase of a role of spruce - 15 % and broad-leaved trees - 30 %, the homogeneity of the rational curve of alder, hazel, thermophilic elements); Poozerje (the best expressed maxima of the trees, the appearance in different time of the rational curve of the thermo- and mezophilic trees, the early rational curve of the spruce - during AT-1-2, the increase of its quantity - up to 50 % at the end of AT-3, the increase of the broad-leaved trees - up to 50 %, hazel - 30 %). They integrate the seven subtypes, dated for various physiogeographic provinces. It predetermined the existence of two or one natural zone with the subzones in the region during Holocene. The anthropogenic factor is stated in Polesje already from the Boreal, everywhere were spread in Atlantic and its activation is noted since Subatlantic period (decrease of forested territories and increase of a role of the open landscape associations, reduction of the geographic ranges of *Picea abies, Betula humilis, Abies alba*, appearance of the weeds originated from the steppe and desert plants. Rhythm of the sedimentation has changed: the supply of the mineral substance in the reservoirs increased, and the sedimentation of the fine-detrital and siliceous gyttja was replaced by the calcareous, mixed, clayey silt and sand).

The **local** episodes and events in the development of nature (vegetation on variably exposed slopes, valleys and watersheds, lakes and mires, inside the same basin, fires, erosion, change of water regime of the basins *etc.*) are reflected in the successions of the subforest, herbs, the poor preservation of pollen grains and combination of the ecologically incompatible flora.

The large quantity of palynological data allow to justify a principle of subdivision of deposits in details according to structure of the spectra, and already today to have the most difficult version of the Holocene stratigraphical scheme of Belarus. Besides the periods (PB, BO, AT, SB, SA - the general features of the development of natural environment) the stages (PB-1, PB-2, BO-1, BO-2, BO-3, AT-1, AT-2, AT-3, SB-1, SB-2, SA-1, SA-2, SA-3 - as a regional features), the phases and subphases (a, b, c...; a ", a ", b ", b ", c "...- as a local features) of the development of vegetation are established. Four phases are characteristic of PB-1, three - PB-2, four - BO-1, two - BO-2, one - BO-3, four - AT-1, two - AT-2, six - AT-3, three - SB-1, three - SB-2, three - SA-1, four - SA-2, and four - SA-3. Comprehensive subdivision of the palynological diagrams, which have been demonstrated here, promotes a certain correlation of the natural events for various territories not only during one period, but also in more short intervals of time. Mostly it indicates the regional features of the vegetational changes and events comparing distant areas, as well as the local events. In accordance with the above described the palynological method allows to reconstruct the successions of the vegetation for the minimum short term of every 75-100 years. That, combined with available geochronological data of the radiocarbon analysis from the lake, soil and bog deposits, provides possibilities to restore with the greatest reliability a history of the development of vegetative cover in the various environments of any section.

STRATIGRAPHY OF THE LATE-GLACIAL AND HOLOCENE OF BELARUS

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The stratigraphic scheme is based on palynological database POLBEL (100 of 200 available sections were used), new pollen materials and 82 radiocarbon dates. 25 sections of lacustrine and bog deposits were investigated by the author using very detailed sampling. An analysis of pollen diagrams together with determination of temporal levels made it possible to define the regional peculiarities of diagrams. The differences between the North-Eastern and South-Western regions are the most obvious ones. An approximate border between the regions lays to the north of Oshmiany, to the south of Minsk and then from those sites to the north of Gomel. The differences in pollen data collected within the certain temporal levels may be explained by an influence of different migration centers, by the plant migration rates, as well as by the edaphic conditions and background of climate change.

The deposits within North-Eastern region are identified based on the following pollen-assemblage zones (paz): 1, before 12700 BP, *NAP - Betula* (*B. nana* L., *B. humilis* Schrank., *Alnaster*); 2, 12700 - 11800 BP, *Betula - Pinus - NAP* (with *B. pubescens* Ehrh., *B.verrucosa* Ehrh.); 3, 11800 - 11300 BP, *Pinus* (with *Ephedra, Juniperus*); 4, 11300 - 10900 BP, *Pinus - Picea - Betula* (with *Picea abies* (L.) Karst., *P. obovata* Leded., *Salix*); 5, 10900 - 10200 BP, *Picea* (20-40%) - *NAP* - (*Pinus - Betula - Salix*); 6, 10200 - 9800 BP, *Pinus* - (*Picea*) - *Betula - NAP*; 7, 9800 - 9000 BP, *Betula* - (*Pinus*); 8, 9000 - 8600 BP, *Pinus* = *Betula - Corylus* - (*Ulmus*); 9, 8600 - 8400 BP, *Pinus - Corylus - Ulmus* - (*Tilia - Quercus*); 10, 7800 - 8400 BP, *Pinus - Corylus - Q.m* - (*Picea - Betula*); 11, 7800 - 6600 BP, *Ulmus - Corylus - Tilia -*

Quercus - Alnus; 12, 6600 - 6000 BP - *Ulmus - Tilia -Quercus - Corylus - Alnus* - (*Picea - Betula*); 13, 6000 - 5000 BP, *Quercus - Ulmus -Tilia - Alnus - Corylus*; 14, 5000 - 4200 BP, *Picea - Quercus* - (*Corylus - Carpinus*); 15, 4200 - 3200 BP, *Pinus - Picea - Quercus* - (*Carpinus*); 16, 3200 - 2700 BP, *Picea - Pinus - Betula* - (*Quercus - Carpinus – Fagus*< 1%); 17, 2700 - 2000 BP, *Pinus - Picea - Quercus* - (*Carpinus - Fagus - Alnus*); 18, 2000 - 1000 BP, *Pinus - Betula - Quercus - Carpinus* - (*Picea - Corylus*) - *NAP*; 19, 1000 - 500 BP, *Picea - Pinus - Betula* - (*Quercus - Alnus*) - *NAP*; 20, 500 - 0 BP, *Pinus - Betula - Picea* - (*Alnus*) - *NAP*.

The deposits within South-Western region are identified based on the following pollen-assemblage zones (paz): 1, before 11800 BP, *NAP - Betula - Pinus* (with *Picea abies*,1-2%); 2, 11800 - 10900 BP, *Pinus* (*Ephedra, Juniperus, Betula, Picea*); 3, 10900 - 10200 BP, *Pinus - Betula - Salix- NAP* (*Picea abies*,1-5%); 4, 10200 - 9800 BP, *Pinus - Betula* - (*Ulmus*); 5, 9800 - 9000 BP, *Betula - Ulmus* - (*Pinus*); 6, 9000 - 8600 BP, *Pinus* - (*Betula*) - *Ulmus - Corylus*; 7, 8600 - 8400 BP, *Pinus - Corylus - Ulmus* - (*Quercus - Alnus*); 8, 7800 - 8400 BP, *Pinus - Corylus - Ulmus* - (*Quercus - Alnus - Tilia*); 9, 7800 - 6600 BP, *Ulmus - Corylus - Tilia - Quercus - Alnus* - (*Fraxinus*); 10, 6600 - 6000 BP - *Ulmus - Corylus - Alnus - Quercus - Tilia*; 11, 6000 - 5000 BP, *Quercus - Ulmus -Tilia - Alnus - Corylus* - (*Carpinus - Fraxinus*); 12, 5000 - 4200 BP, *Pinus - Quercus* - (*Carpinus – Fagus* < 1%); 13, 4200 - 3200 BP, *Pinus - Quercus - Carpinus*; 14, 3200 - 2700 BP, *Pinus - Betula - Quercus* - (*Carpinus - Picea* < 5% - *Fagus* < 1%); 15, 2700 - 2000 BP, *Pinus - Quercus* - (*Carpinus - Alnus*) - *NAP*; 16, 2000 - 1000 BP, *Pinus - Quercus - Carpinus* - (*Corylus – Fagus* < 1%) - *NAP*; 17, 1000 - 0 BP, *Pinus - Betula - Quercus - Alnus*- (*Carpinus* < 1% - *Picea* ~ 5-6%) - *NAP*.

LOWER-MIDDLE FRASNIAN BIOSTRATIGRAPHY OF MIDDLE PART OF THE MAIN DEVONIAN FIELD

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Middle part of the Main Devonian Field occupies basins of the Velikaya, Shelon`, and Volkhov rivers in the Pskov and Novgorod districts. This region shows numerous outcrops of the Frasnian (Upper Devonian) carbonate and siliciclastic shallow-water deposits. The deposits were studied by authors in respect of biostratigraphy and palaeontology in 1995-1998 in course of stratigraphic investigations organised by the Russian State Geological Survey.

Rather abundant ostracode, brachiopod and conodont associations obtained allow us to establish local biozonations (Figure). Ostracode and brachiopod zones are range-zones in nature, but conodont zones are phyletic ones.

It is notable, that the sharpest boundary lies at the base of the Semiluki Regional Stage. This boundary is traceable in all the zonal sequences. It coincides with proposed boundary of the Lower and Middle Frasnian, and corresponds to Middlesex eustatic (transgressive) event.

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Stage	Regional Stages	Regional Substages	Formations	Local conodont zones		Local brachiopod zones	Local ostracode zones
Frasnian	Rechitskii	Snezha	Snezha	?		?	?
	Semiluki			*Polygnathus efimovae*			*Mylanovskya bicristata*
		Buregi	Buregi			*Cyrtospirifer tenticulum*	
		Il`men	Rdeisk	*Polygnathus pollocki*	*Polygnathus drucei*	*Cyrtospirifer shelonicus* gr.	*Acantonodella lutkevichi*
		Svinord			*Polygnathus pollocki* M2		*Neodreparella tricornis*
		Porkhov					
	Sargaevo	Dubnik		*Polygnathus decorosus*		*Rypidiorhynchus livonicus* gr.	*Cavellina batalinae*
		Chudovo	Staryi Izborsk				
		Pskov					
		Snetnaya Gora	Snetnaya Gora	?			*Cavellina subparallela*
						?	?

Figure. Local biozones of the Lower-Middle Frasnian in middle part of the Main Devonian Field.

THE IDAVERE STAGE: CURRENT STUDIES IN THE ST. PETERSBURG REGION

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The correlation of the Idavere sequence between northern Estonian and northwestern Russian sections creates a number of stratigraphical problems to be solved (Alikhova, 1960; Männil, 1963). The aim of the current study is to characterise faunas and facies of the Idavere Stage of the five sections in the western part of the St. Petersburg region. It is also attempted to determine the lower boundary of the Idavere Stage in northwestern Russia.

According to the regional stratigraphic scheme of the Stratigraphic Committee of the former USSR (Resheniya..., 1987), the Idavere Stage subdivides into the Ojamaa ($C_{III}\alpha$) and Shundorovo ($C_{III}\beta$) substages. Jaanusson (1995) proposed to include the Idavere and Jõhvi stages into the single Haljala Stage, lowering the rank of the first two units from stage to substage. Although this has already been accepted by some authors (Webby, 1998), the Idavere Stage is viewed in its traditional context (Resheniya..., 1987) in the present study, and the question whether application of the Haljala Stage might be useful for the St. Petersburg region is addressed for further study.

The lower part of the studied stratigraphical interval, the Ojamaa Substage represented by the Gryazno Formation, is well exposed in Klyasino quarry in the western part of the St. Petersburg region. In this section, dolomitic argillaceous limestone, dolomitic marl and clays crop out in a total thickness of about 6 m.

Preliminary data on organic-walled microfossils in this section were obtained from 14 samples. The assemblages of microfossils, including chitinozoans, scolecodonts, acritarchs, foraminifers, melanoscleritoids and hydroids show great similarity to those of the Kukruse and Idavere stages of northern Estonia. A notable increase in abundance of the acritarch *Leiosphaeridia* sp. and occurrence of zonal chitinozoans *Eisenackitina rhenana* and *Lagenochitina dalbyensis* indicate that the boundary between the Kukruse and Idavere stages is exposed in the Klyasino section. However, more detailed study of the boundary interval is possible after further cleaning of the section.

The comparison of the Idaverean rocks from Klyasino with those from the stratotype area in northern Estonia shows that the Ojamaa Substage is more argillaceous and more dolomitic in northwestern Russia. The layers of clay, which in a thickness of up to 0.6 m occur in Klyasino, are unknown in northern Estonia.

The Shundorovo Substage in the western part of the St. Petersburg region, represented by the Shundorovo Formation, is well exposed in Kaskovo quarry, where argillaceous dolomites crop out in a thickness of about 7 m. The comparison of this section with corresponding strata in North Estonia reveals that the rocks are more dolomitic in Kaskovo quarry.

In consequence, the deposits of the Idavere Stage in its outcrop area in the western part of the St. Petersburg region differ from those in northern Estonia. This is expressed particularly in lithology – rocks tend to be more argillaceous and dolomitic in the east. However, such dissimilarities in lithology are not abrupt in space, indicating rather continuous change of the palaeoenvironmental conditions. On the other hand, differences in the post-Idaverean geological conditions, resulting in widespread dolomitization, also account for the mentioned lithological contrasts.

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