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The main pattern of deglaciation across southern Sweden has been established but many details, both regarding chronology and ice-sheet dynamics, are less well known. Along the Swedish west coast the course of deglaciation can be followed by conspicuous ice-marginal zones consisting of moraines and deltas, which mark re-advances or halts during active retreat. On the east coast, the ice-margin retreat has been reconstructed by investigating varved clays. The south Swedish deglaciation chronology is to a large extent based on (marine) radiocarbon dates, clay-varve chronology and pollen stratigraphy and has some uncertainties.

Between the coastal areas is the South Swedish Upland, which is the highest area in southernmost Sweden (Fig. 1), and where information on the deglaciation is more scarce. The moraines on the west coast gradually disappear as they reach the higher terrain and their eastward continuations across the Upland are not yet identified. Large areas of hummocky moraine are found on parts of the South Swedish Upland, indicating widespread stagnation (dead ice) instead of active retreat in some areas.

In this study I have done sedimentological and geomorphological investigations at several sites in the northeastern part of the South Swedish Upland (Fig. 1). The aim has been to reconstruct the depositional environments in an upland area at the southern margin of the Scandinavian ice sheet and to better understand the deglacial ice-sheet dynamics. To emphasise the landforming processes of the landscape I have used the landsystem and sediment-landform association concepts.

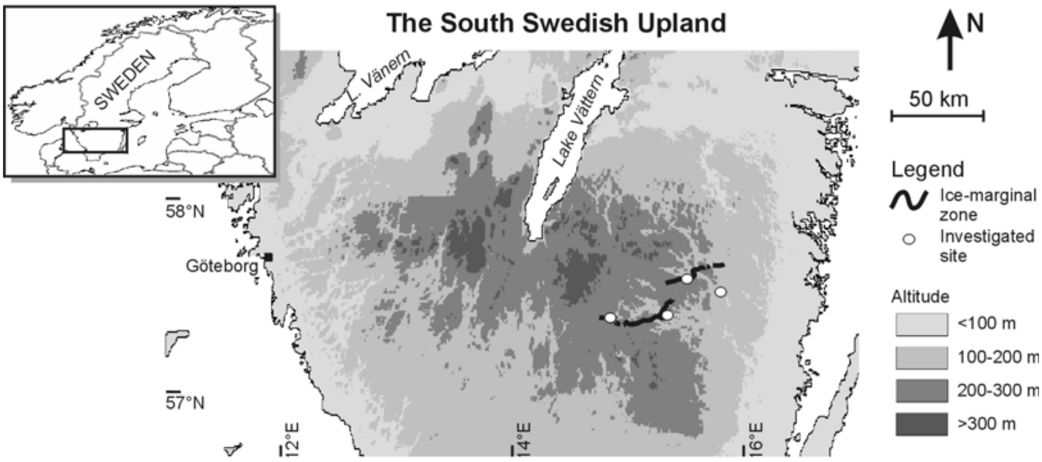

Figure 1. Map of the South Swedish Upland showing the location of the investigated sites.

A discontinuous ice-marginal zone, which reflects one or more still-stands or readvances during deglaciation, has been the focus of interest. The sediment-landform associations related to this zone are e.g. end moraines, ice-contact deltas and valley trains. The distribution of these associations seems to be controlled by topography and there are two major settings, valleys and higher, hilly terrain.

Glacifluvial or glacilacustrine deposits dominate the large valleys and indicate that the glacial drainage was concentrated to the topographically lowest areas. In some valleys sandur plains and valley trains extend to the highest coastline where they turn into deltas. In other valleys, ice-contact deltas were deposited in local glacial lakes that formed where the meltwater was dammed by bedrock or ice. Till-covered glacifluvial sediments show that the ice sheet readvanced but it did not deposit any moraines in the valleys. Kettle holes are found mainly behind the former ice margin, but also on the proximal parts of the deltas and valley trains.

The higher, hilly terrain between the valleys is dominated by cover moraine, with patches of hummocky moraine. Small discontinuous moraines and a marked difference in till thickness and continuity record the position of the ice margin. A few large drumlins, some of which contain more than one till, are also found, as well as minor glacifluvial deposits (kames, terraces).

I have dated the glacifluvial sediments with optically stimulated luminescence (OSL) at the Nordic Laboratory for Luminescence dating (Risø, Denmark). In general, the samples seem to give ages older than expected for deglacial deposits. For example, six sandur samples yield 21-25 ka. I am currently doing further analyses of the dates to check if this is due to incomplete bleaching (or other methodological errors), or if a reinterpretation of the Late Weichselian glacial history of southern Scandinavia is needed.

LITHOLOGY AND PALAEOMAGNETIC RECORD OF LATE WEICHSELIAN VARVED CLAYS FROM NW RUSSIA

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The lithology and palaeomagnetic investigation of Late Weichselian glaciolacustrine deposits from two ancient periglacial lakes was carried out in the valley of the Ust-Pjalka River (S-E Kola Peninsula, 66°20′ N, 39°40′ E) and Shuja River (South Karelia, 61°42′ N, 33°30′ E). The rhythm structure of varved clays was studied as rhythms of typical turbidities with essential differences for proximal and distal area of deposits accumulation. In proximal area the textural-structural properties of the sediments both in distal direction and partly in the lateral direction are described. The varves in proximal part are reduced while in the distal area they are represented by continuous sequence. The complete geochronology "record" could be fixed in distal area of periglacial basin and partially in distal part of proximal area. But in the last one clay-varve layering may not be complete. Specific conclusion about the duration of sedimentation in proximal area is not possible. Varved clays of distal area should be considered as suitable for varve chronology. The duration of accumulation of one couplet (DE rhythm, second order cycles) during one year is confirmed by palaeomagnetic data.

Structural and textural differences of deposits from proximal and distal areas are emphasized by the difference in their magnetic parameters and declination-inclination "records" in proximal and distal varves. The presence of mixture of magnetic minerals carrying of remanent magnetization do not significant affects the palaeosecular variation (PSV) record in lake-glacial varved clays. The important information about deposition processes could be distinguished by anisotropy of magnetic susceptibility measurements (AMS). The directions of water flows and succession transportation of clastic material from different delta are reflected in AMS directions. Moreover the undeformed (primary fabric) and deformed (secondary fabric) sediments could be easy selected according to AMS parameters.

The palaeomagnetic feature was analyzed for section to section together with lithological changes. The distal varved clays (which are represented by the DE rhythm) carry the palaeomagnetic records and first of all could be used for palaeosecular variation recover. In some cases the varved clays in proximal area far from glaciofluvial delta could be used for palaeomagnetic research also. But taking into account the erosion of underlying deposits by turbidity flows and inclination shallowing these sediments couldn't "record" PSV with enough precision. So only the distal varved clays are convenient both for geochronology and palaeosecular variations recover.

The palaeomagnetic features of declination and inclination records are presented with correlation of chrono- and magnetostratigraphy scheme of N-W Russia. The questions of "inclination error" and anisotropy of magnetic susceptibility research in glaciolacustrine sediments depending upon the lithology were discussed also.

THE PALAEORELIEF OF THE PLEISTOCENE AND THE SEDIMENTATION OF THE TILL IN SOUTHERN LITHUANIA

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Valuable experience of donation of sub-Quaternary surface, a more precisely defined hypsometrical picture of this paleorelief, identification of deposits, filling up palaeoincisions and overlying watersheds available have created premises for compilation of a new zonation scheme (Baltrūnas, Pukelytė, 1998). The scheme of palaeogeomorphological regionalization of sub-Quaternary surface in South Lithuania at a scale of 1:500,000 has been compiled. The following structural-palaeogeomorphological regions have been established:

– Sandy and clayey, in the western and south–western part carbonaceous, erosional-exarational **Great Lithuanian lowland,** with deep valleys and prevailing of Medininkai (Warta, Moskva) and in the eastern part – of Dainava (Elster 2, Oka) of the Middle Pleistocene age undulated and terraced watersheds, in the western part disintegrated by valleys of cuesta type.

– Sandy, clayey and carbonaceous, in the southern part only sandy denudated **East Aukštaičiai plateau** with shallow valleys and prevailing Dainava undulated and slightly hilly watersheds of the Middle Pleistocene.

– Sandy and clayey, here and there carbonaceous erosional–exarational **Šventoji slope**, declined south–westwards, with deep valleys and prevailing Medininkai watersheds and in the southern part – Dainava undulated and slightly hilly, terraced watersheds of the Middle Pleistocene, disintegrated by paleoincisions of cuesta type.

– Sandy, clayey and carbonaceous erosional-exarational **South Lithuania plain**, with deep valleys and prevailing of Medininkai watersheds and in the southern part – Dainava undulated and slightly hilly, terraced watersheds of the Middle Pleistocene, disintegrated by paleoincisions of cuesta type.

Different hypsometrical, often step–like position, different, from the standpoint of composition and age rocks forming paleosurface, conformity with geological and tectonical structures of the established paleogeomorphological regions testify the great influence of the endogenic factor (neotectonic deformations) upon formation of this paleosurface (Šliaupa, 1997; Šliaupa, 2004). Genesis, composition and age of rocks overlying paleowatersheds of paleogeomophological regions, evolution of scale of some exogenetic (exarational, erosional, etc.) processes, occurred during Quaternary period, show prevailing Middle–Upper Pleistocene age of paleowatershed morphosculpture of his surface and different significance of geological processes in separate regions. Palaeoincisions of sub-Quaternary surface testify by their hypsometry and filling upon old hydrographical system, which has underwent partial regenerations during different time of Quaternary period, particularly, during interglacials, has been heavily modified by neotectonic, exarational and erosional processes, but may reconstructed in general. The analysis of the thickness and palaeorelief of the surface of Dainava and Medininkai tills showed the wide variety of their relationships. In

Druskininkai region, in the zone of the valley of Nemunas River, Dainava till equalize the ancient relief. Medininkai till in the larger measure is eroded. North of Druskininkai (region of Birštonas) sub-Quaternary relief is equalized by Medininkai (md) till. Dainava (dn) till is extended only locally (Fig). In the region Daugai the tills mentioned above equalize the palaeorelief and they are not the base of the present Dzūkai highland (Baltrūnas and Gaigalas, 2004).

Analysis of the available literary and archives material and the compiled scheme of palaeogeomorphological regionalization allow us to draw the following conclusions. The structural and statistical analysis of Quaternary strata deposits in the areas studied in detail has enabled to distinguish some significant peculiarities. In palaeoincisions of sub-Quaternary surface the structure of deposits most often is of three kinds, according to the distribution of morainic and non-morainic deposits (Fig.).

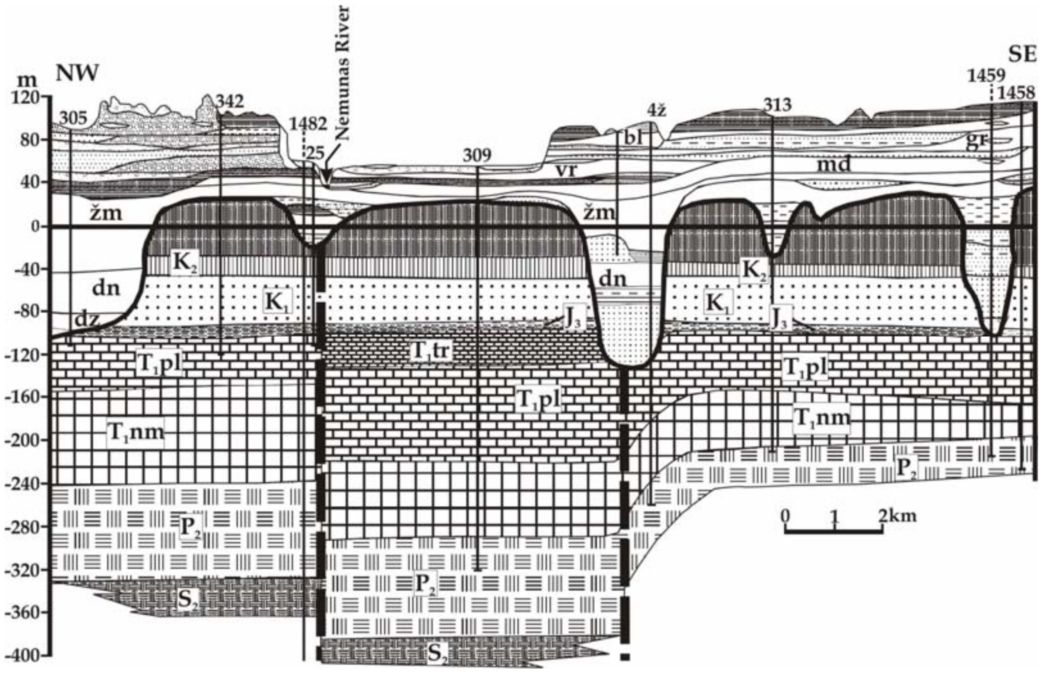

Fig. Geological cross-section of the Birštonas area. Pre-Quaternary deposits: S_2 – Upper Silurian, P_2 – Upper Permian, T_1 – Lower Triassic, J_3 – Upper Jurassic, K_1 and K_2 – Lower and Upper Cretaceous. Pleistocene tills: dz, dn, žm, md, vr, gr, bl.

These palaeoincisions, particularly in localities of inheritage in later interglacials and during the post-glacial, are the zones of separation among the strata of Quaternary deposits occurring on intervales (elevations) of sub-Quaternary surface. Often the strata of Quaternary deposits occurring above the sub-Quaternary intervales are characterised by a rather monotonous and areally persistent structure confirmed by data of relative entropy and determination of morainicity. A comparison of relative entropy and morainicity schemes of sub-Quaternary relief and present surface with maps of tectonic structure and neotectonic activity of territories has revealed a frequent coincidence of linear and areal geological and geomorphological objects.

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GLACIOTECTONIC MAP OF CENTRAL EUROPE IN SCALE 1:1 750 000

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During the period of 1996-1999 the Working Group on Geospatial Analysis of Glaciated Environments (GAGE) at the INQUA Commission on Glaciation has undertaken a preparation of the glaciotectonic mapping project, as a base of the Glaciotectonic Map of Central Europe, in which geospatial analysis (GIS) has been utilized for compilation of databases and map production.

The main goal of the Glaciotectonic Map of Central Europe project was to create the first European region–wide assesment of the types and distribution of glaciotectonic phenomena creating a unified GIS database for central Europe and a published map of the whole region. The national glaciotectonic maps have been completed for the region from Germany and Denmark, across Poland and Czech Republic to Belarus, the Ukraine, Russia (Kaliningradian District) and Eastern Baltic countries (Estonia, Latvia and Lithuania).

In project have been involved the following national map leaders and sometimes their authors: Hans-Jürgen Stephan (Germany), Peter R. Jakobsen (Denmark), Daniel Nyvlt (Czech Republic), Andrzej Ber (Poland), Vitalij Zagorodnikh (Russia), Andrei Matoshko (Ukraine), Aleksander Karabanov (Belarus), Albertas Bitinas (Lithuania), Vitalijs Zelcs (Latvia) and Volli Kalm (Estonia) under the direction of Andrzej Ber (Poland). In works participated also Maris Rattas (Estonia), Paulius Aleksa (Lithuania) and Janis Dzelzitis (Latvia). The computer work were under supervision and authorship of the Waldemar Gogołek and Jacek Kocyła (PGI, Poland).

The project was under science supervision of James S. Aber (USA) and Jan A. Piotrowski (Denmark). Besides national leaders in project have been involved actively also (as authors) tens specialists from national geological surveys, universities or academies of sciences.

In 2000 year units and symbols the legend for Glaciotectonic Map of Central Europe have been elaborated by: A. Ber, A. Bitinas, A. Matoshko and V. Zelcs.

Preliminary national maps of Poland, Belarus, Estonia and Lithuania have been presented at the XV INQUA Congress in 1999 (Durban, South Africa). Owing to support of the Commission on Glaciation INQUA most the national glaciotectonic maps to 2000 year were done. They were prepared on the common topographic base map.

Glaciotectonic features were digitized from 1:250 000 or 1:500 000 in scale base maps for compilation into Glaciotectonic Map of Central Europe. These features are classified in four main categories:

- glaciotectonic landforms expressed in recent relief;
- glaciotectonic buried landforms;
- glaciotectonic disturbed Quaternary sediments;

- glaciotectonic disturbed pre-Quaternary sediments (in situ and rafts).

Distribution of glaciotectonic features over central Europe is related primarily to the presence younger glaciations and the thickneses of the deformable substratum.

Preliminary the Glaciotectonic Map of Central Europe has been presented as poster at the XVI INQUA Congress in 2003 (Reno, USA). Presented version is nearly this same as has been presented on mentioned Congress. In meantime, from 2003 to today, modified and supplemented works under particular sheets of the national maps were conducted.

The final compilation and printing of the Glaciotectonic Map of Central Europe is anticipated on the first part of 2006.

DYNAMICS, MORPHOGENESIS AND DEGLACIATION OF THE SCANDINAVIAN ICE SHEET: ON THE WAY OF A NEW PARADIGM

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A relatively harmonious system of presumptions, theories, hypothesis, models, etc. explaining the dynamics, morphogenesis and deglaciation of the Scandinavian Ice Sheet (SIS) of the Last Glaciation were developed in the second half of the XX century in the peri-Baltic area, especially in its eastern flank – the Baltic countries. We think that the above-mentioned system of standpoints could be named as a paradigm – according to terminology of T. Kuhn (2003). Looking retrospectively, the science philosophy of the XX century could be defined as discussion about the ways of scientific cognition (Nekrašas, 2004). The main discussion was between two marginal conceptions: K. J. Poopers' critical rationalism and T. Kuhn's theory of scientific revolutions. Despite the attempts to develop some compromise theories (e.g. I. Lakatos, P. Feyerabend), this discussion seems not to be finished (Nekrašas, 2004). According to K. J. Popper's (2001) doctrine, the process of scientific cognition is going incessantly, while T. Kuhn propagates the theory of scientific revolutions, when stabile phases of science development are changed by periods of radical variances – changes of paradigm. The last sophisticated term could be described as fallows: paradigm – it is totality of scientific presumptions, theories, hypothesis, models, etc., whereby the particular part of scientific society is guiding during the particular historical period. According to our subjective opinion, the process of progress of science is better explained by T.Kuhn's doctrine of changes of paradigm. Thus, following the mentioned theory, it is possible to distinguish a few paradigms in the Quaternary glacial geology. One of them, involving dynamics, morphogenesis and deglaciation of the SIS (abbreviating it could be named as glaciodynamics-deglaciation paradigm) is an object of our studies.

The recent glaciodynamics-deglaciation paradigm of the SIS substantially explains many peculiarities of ice sheet dynamics, formation of number forms of glacial relief as well as deglaciation of territory. But there is a set of new factual data (as well as a few relatively old ones) that couldn't be explained by the existing paradigm. Why are the glacialacustrine plateau-like hills (or so called "zvontcy") common only for the relief of the Last Glaciation and are dislocated on the highest topography? How can the kame terraces be formed on the distal slopes of recessional marginal ridges? Why does the age of fresh groundwater in the Baltic countries (despite the geological age of aquifer) does not exceed 34-35 ka? Why is the distribution of palaeoincisions in the Eastern Baltic territory so uneven?

For a long time the existing paradigm of glaciodynamics-deglaciation didn't pay attention to the role of meltwater circulation beneath the glaciers (except explanation of process of regelation only). Recently the formation of paleoincisions or tunnel valleys (Boulton et al., 1993; Piotrowski, 1997), origin and distribution of drumlins (Ratas, Piotrowski, 2003), occurrence of different glaciotectonic forms, etc. are explained by this phenomenon. Regardless of this, an opinion that formation of paleoincisions and tunnel valleys could be explained by circulation by normal fluvial flush is still exist (Baltrūnas, 1997).

The most significant contradictions between the present glaciodynamics-deglaciation paradigm and some factual data are related to the explanation of the process of deglaciation of the SIS. According to the existing paradigm, the stadials and phasials, i.e. cold periods, when glacier sheet advanced, were interrupted by warm periods when the interstadial or interphasial sediments (organic, lacustrine) accumulated, i.e. large territories have been deglaciated completely during the latter periods. Such opinion is reflected in the number of published palaeogeographic reconstructions or resent stratigraphic schemes (Gaigalas, 2001). However, no geological section containing interstadial or interphasial sediments is known at the present time. According to the data of recent investigations, an interstadial or interphasial status of a few previously famous geological sections containing organic sediments (Ūla, Raunis, Antaviliai) haven't been confirmed. The other factual data do not confirm an existing concept of deglaciation either: formation of glaciolacustrine plateau-like hills or kame terraces on the distal slopes of marginal ridges could be imagined only between the lobes of active glacier and the blocks of dead ice (Bitinas et al., 2004). The results of cosmogenic dating (^{10}Be) of boulders of the eastern margin of SIS showed that glacier on the large territory from so called Middle Lithuanian Phase until the Gulf of Finland melted practically at the same time, i.e before 13,5-13 ka (Rinterknecht et al., 2003).

According to our opinion, the mentioned factual data serve as sufficient background for formation of a new glaciodinamics-deglaciation paradigm of SIS. It would be a few principal radical attitudes in the new paradigm in comparison with the old one:

– the meltwater played exclusively significant role for the SIS dynamics and sub-glacial morphogenesis: plenty of facts starting from structure of till until the formation of resources of fresh underground water could be explained by this phenomenon;

– there were no fluctuation of so called stadials-interstadials or phasials-interphasial during the deglaciation: the areal deglaciation of SIS significantly prevailed over to the frontal deglaciation;

– the so called stadial or phazial marginal recessional ridges occurred as result of surges: they were asynchronous along the SIS margin (maybe, except the Salpausselkä moraines only).

According to the new paradigm, a significant number of new factors should be considered in explaining the dynamics, morphogenesis and deglaciation of the SIS: new data about geological structure of Quaternary, sub-glacial morphology, last results of glaciological investigations of continental glaciers, physical-mechanical properties and hydro-geological parameters of sub-glacial strata, sub-glacial hydrodynamics, tectonics and neo-tectonics, glaciotectonics, palaeoclimatology, isotopic content and geochronology of groundwater, etc.

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WAS EEMIAN LAKELAND PRESENT OUTSIDE THE MAXIMUM EXTENT OF VISTULIAN GLACIATION IN CENTRAL-EASTERN PART OF POLAND

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During the mapping program for the Detailed Geological Map of Poland in scale 1 : 50 000 many new sites of fossil lake deposites were discovered.

Detailed palinological studies were conducted. During the research was found out that most of those lakes were created after the recession of the Wartanian Glaciation, they existed during the protocratic, mesocratic and telocratic phases of the Eemian Interglacial. In a few places acumulation continued within the Vistulian glaciation. One of the example are biogenic lake sediments at Porzewnica site. Silts and gyttja are covered by sand. Thickness of biogenic sediments is about 5 m there. In the Porzewnica pollen diagram are 7 L PAZ and 1 interzone without sporomorphes. That represent vegetation succession during the late Wartanian Glaciation , the protocratic, mesocratic and part of the telocratic phases of the Eemian Interglacial.

FOSSIL MOLLUSCS OF THE LITHUANIAN BALTIC COAST

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The paleontological investigations of the subfossil molluscs of the Lithuanian Baltic Coast are linked with state geological mapping at a scale of 1:50 000 and special geological mapping of coastal zone at a scale of 1:5 000. In the northen part of Lithuanian Baltic Coast well-preserved mollusc fauna has been discovered in the boreholes, in southen part – in the boreholes and two outcrops. The estimation of the isotopic composition of oxygen and carbon as well as radiocarbon (^{14}C) dating of mollusc shells in a few sections have been done also. The lithological composition of mollusc bearing sediments is very different and varies from gyttja to fine-grained or medium-grained sand and gravel. The amount of subfossil mollusc varies from a few fragments to big concentration (5-10% of volume of sediments).

Late-Glacial subfossil mollusc fauna presended by *Armiger crista* f. *cristatus, Gyraulus albus, G. laevis, Lymnaea peregra, L. stagnalis, Musculium lacustre, Pisidium* sp., *Sphaerium lacustre, S. rivicola, S. solidum,* etc. has been found only in the one outcrop – Ventės Ragas. Such composition of species of the mollusc fauna is characteristic for the nearshore of the freshwater shallow basin.

Shoreline of the Joldia Sea and the Ancylus Lake were situated westwards from the present Baltic Sea coast: mollusc fauna of these basins have not been founded.

The biggest amount of the subfossil mollusc fauna have been found in the Litorina Sea deposits. In the northern part of the Lithuanian Baltic Coast well preserved *Cerastoderma glaucum, C. edule, C. crassum, Macoma balthica, M. calcarea, Mytilus edulis, Bithynia tentaculata, Hydrobia ulvae, Valvata piscinalis, V. pulchella,* as well a few peaces of *Littorina littorea, Theodoxus fluviatilis, Pisidium amnicum* have been found. A big size of mollusc shells, especially *Macoma balthica, M. calcarea, Cerastoderma glaucum* and *C. edule*, shows the prevailing of brackish water – the Litorina Sea. Content of this species is characteristic for littoral zone of brackish sea basin which salinity was 5-10‰ and depth don't exceeds 5-10 metres. The freshwater species such as *Valvata piscinalis, V. pulchella* and *Pisidium amnicum* are redeposited.

In the southern part of the Lithuanian Baltic Coast only the freshwater subfossil mollusc fauna have been found. The big concentration of *Bithynia tentaculata, Valvata naticina, V. piscinalis, V. piscinalis* f. *antiqua, V. pulchella, Viviparus fasciatus, V. fluviatilis, V. viviparus, Musculium lacustre, Sphaerium solidum, Pisidium amnicum, P. henslowanum, P. lilljeborgi, P. milium, P. moitessierianum, P. nitidum, P. pulchellum, P. supinum, Unio* sp. shows the prevailing of freshwater shallow basins, probably small lakes or lagoon.

The species composition of the mollusc fauna in the Litorina Sea deposits shows that the littoral zone of brackish sea basin existed in the northern part of the Baltic Coast, while in the southern part the freshwater shallow lagoon spreaded or a few small freshwater lakes exsisted. Such conclusion well corresponds with data of palynological and diatom analysis as well as with results of radiocarbon (^{14}C) and optically stimulated luminescence (OSL) dating and isotopic investigations of subfossil mollusc shells and mollusc bearing sediments.

SEDIMENTATION PATTERNS IN THE SELECTED VALLEYS WITHIN THE UPPER DNIEPER CATCHMENT: PALYNOLOGICAL EVIDENCE OF THE ENVIRONMENTAL CHANGE

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Lacustrine, lacustrine-alluvial, alluvial, bog, deluviual, proluvial and other sediments compose complex of Late Glacial and Holocene deposits of the territory of Belarus. These deposits are quite well studied. There are more than 300 sections investigated palynologically. The best studied sections represent lake, bog and lake-bog sediments, however, a detailed study of alluvial deposits (river-bed, floodplain and oxbow facies) is less developed but it is very important.

Late Glacial and Holocene alluvial deposits formed high and low floodplains of the rivers in the Dnieper, Pripyat, Neman, Bug, Zapadnaya Dvina basins, as well as two lower terraces of Neman and Zapadnaya Dvina. They usually reach a thickness about 10 m, to maximum of 15-20 m. River-bed facies consist of vari-grained sand often with streaks and lenses of sandy-gravel material. Muddy sandy silts and fine silts are prevailing within floodplain sequence. Oxbow accumulations presented by silty sand, sandy silt, silt, clay, sapropelite and peat. Due to sedimentological peculiarities of alluvial deposits (scattered organic matter, sporadic presence of microfossils, sedimentary breaks, washing-out), a palynological study of such deposits meets with certain challenges. We can view them on example of few sections located within the Upper Dnieper catchment.

The section near Zabolot'e village, Gomel region is located on the first terrace of Dnieper river, within the peat-bog massif. In terms of geomorphological setting, the massif is affiliated with Streshin glaciofluvial lowland, and is limited by isohypses of 135-140 m. The lowland stretches along the modern valley of Dnieper over more than 10 km from north to south. The study area is drained by Belitsa river. The section contains the following deposits: grayish sandy loam (0,00—0,18 m); brown peat, well-decomposed (0,18—0,39); brown peat, partly decomposed (0,39—0,95); black peat, well-decomposed (0,95—1,24); black peat, medium-decomposed (1,24—1,41); silty sandy loam (1,41—1,61); light-grayish, fine sand (1,61—1,75). In total, 70 samples were analyzed with use of palynological method. The results of spore- and pollen analysis are summarized in diagram, which reflects the evolution of vegetation and climate in different environments of the Late Glacial and Holocene by 34 palynocomplexes.

Kholosov and Liudkov sections are located within the Centra-Berezina glaciofluvial plain, and are limited by the isohypse 150 m. The study area is situated in between the rivers of Lakhva and Mokrianka. This area also represents the peaty ameliorated depression, streaching over 9 km from north to south. In its southern part the study area connects with the floodplain of Mokrianka river (tributary of Dnieper. The deposits of the depression were studied within the lowest topographic level of the study area, near the village of Kholstov, as well as within the medium level, -- near the village of Liudkov.

The following deposits are determined in the Kholstov section: peaty sandy loam (0,00—0,05m); black mineralized peat (0,05—0,20); gray-bluish glayey loam (0,20—0,30); light-gray medium-size sand (0,30—0,41); yellowish medium-size sand (0,41—0,54); yellowish coarse sand with gravel and pebble (0,54—0,85). The compiled palynological diagram includes 7 palynocomplexes, which reflect the accumulation of the studied thickness taking place from SB-2 to SA-3.

The deposits from Liudkov section include sandy loam (0,00—0,03 m); black mineralized peat (0,03—0,24); dark-grayish loam (0,24—0,48); dark-grayish vari-grained sand (0,48—0,74). 15 samples were analyzed in total. The resulting palynological diagram shows three palynocomplexes , reflecting the change in vegetation cover, which is recorded within the depth interval of 0,00-0,20. The deposits in this interval have accumulated from SA-1 to SA-3.

Thus, those palynologists, who use the spore-and pollen analysis for studying alluvial deposits, face a number of problems. Among them appear to be an occurrence of "dumb" thicknesses in course of ceaseless deposition pattern (the significant amounts of microfossils are attributed only to the strata with high content of organic matter); the special character of pollen curves; and high content of corroded pollen.

POPULARIZATION OF QUATERNARY GEOLOGY IN LITHUANIA

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During the period 1993-2005 Geological Survey of Lithuania implements the state programme "Geology for Society". One of the most important direction of this programme is to popularise the geology: to present geological information to young geologist, schoolchildren, tourists. For this purpose the Quaternary geologist closely collaborate with personnel of protected areas of Lithuania. Each national or regional park has number of attractive geological objects (river meanders with outcrops, springs, boulders), the part of them are as geological monuments.

According to the requirements of staff of protected areas a set of informative posters about the different geological objects, to attract attention of tourist, to incite people to be more interested in geological heritage and protection, were prepared. The geological objects have scientific, esthetical, cultural value. The geological information that have been collected during the large-scale geological mapping and others researches were used arranging the posters.

The geotopes inventory and the compilation of the database "Geotopes of Lithuania" is in progress since 1995. At present, the database contains information on 376 geologic, geomorphologic, hydrogeologic sites of Lithuania (Mikulėnas, 2004).

Four most attractive objects from different parts of Lithuania will be presented in the conference poster session.

The "Bobos daržas" spring and "Ūlos" outcrop are most interesting objects in the "Dzūkijos" national park. The Quaternary geological-geomorphological map and cross-section of the surroundings are compiled and shown in the poster of "Bobos daržas" spring. The sprig occurs in the thermokarstic depression, where is fountainhead of Skroblus river with very pure water. The sandy thickness formed by melt water of the Last Glaciation is exposed in the outcrop of the Ūla River outcrop. This section represents different geological structures formed by meandering and braided water flows.

"Vetygalos" (Јьventoji River) and "Šlavės" (Šlavė River) outcrops are most famous geological objects in the "Anykščiai" regional park. The Neogene – Prepleistocene boundary is present in the "Vetygalos" outcrop. The deposits of the oldest Interglacial (Šlavė Interglacial stratotype) are outcropping in the "Šlavės" exposure.

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Mikulėnas, V. 2004. The geotopes database support project. Geological Survey of Lithuania, Annual report 2003, 31.

ICE SHEET DYNAMICS ON KOLA PENINSULA DURING LGM ICE BUILD UP AND SUBSEQUENT DEGLACIATION - INTERPRETATIONS FROM THE GLACIAL GEOMORPHOLOGICAL RECORD

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During the Late Weichselian, Kola Peninsula was covered by the northeastern sector of the Fennoscandian ice sheet. One of the key elements in reconstructing the deglaciation of Kola Peninsula is the Keiva moraine system along the southern and eastern coast of the peninsula. This moraine system is traditionally interpreted to have formed during the last deglaciation (~16-12 ka); partly along the margin of an ice lobe filling the White Sea depression, and partly along the margin of a hypothesised Ponoy Ice Cap. In this project, we have conducted detailed geomorphological mapping of the whole Kola Peninsula region, using primarily aerial photographs and satellite images, combined with field work (see separate map presentation during this symposium). From the geomorphological data we conclude the following about the Keiva moraines: i/ The moraines display ice contact features (e.g., feeding eskers, collapsed ice contact slopes) on both the Kola side and the White Sea side along its whole length. ii/ There is widespread morphological evidence of warm based ice flow on the White Sea side of the moraines (eskers, drumlins, flutings), but the Kola side of the moraines is dominated by indicators of cold-based ice (lateral meltwater channels). iii/ The moraine is partly drumlinised and fragmented, indicating that it was overrun from the southwest by erosive White Sea based ice after formation. iv/ The moraine system is sloping along its length from ~100 m asl in the west (Varzuga R.) to ~250 m asl in the east (Ponoy R.). There is ubiquitous evidence of massive meltwater discharge eastwards, in the form of large drainage channels, all along the Kola lowland between the Keiva moraines and the coast. vi/ The Keiva ice marginal zone can be traced as far north as Lumbovka, at the northeastern tip of Kola Peninsula, which is substantially more northward than what has been identified earlier.

From these observations we conclude that the Keiva moraine system is not a synchronous feature formed along the lateral side of a White Sea based ice lobe. If it was, the moraines should have sloped in an eastward direction. Rather, we interpret it to be formed time transgressively at the junction between a warm-based ice lobe expanding from the southwest into the White Sea depression, and a more stable cold-based part of the Fennoscandian ice sheet over Kola Peninsula. As the ice lobe expanded, this junction and hence the moraine building, migrated towards the northeast. As the White Sea based lobe expanded, the ice margin dammed large lakes on southeastern Kola Peninsula, which drained successively to the east via large outlet channels. In contrast to earlier reconstructions, we find it unlikely that an ice expansion of this magnitude, with an ice lobe extending from the south well into southern Barents Sea, was a mere readvance during the deglaciation. Instead, we propose that the Keiva moraine system was formed during the expansion of the Fennoscandian Ice Sheet towards its LGM position. Hence, we propose that the Keiva moraines should be labeled "time-transgressive expansion moraines".

Based primarily on the morphology and position of the Keiva moraine system, it has earlier been suggested that an independent ice cap – the Ponoy Ice Cap – existed on eastern Kola Peninsula during the last deglaciation. However, in the glacial geomorphological record, we find no evidence for such a Ponoy Ice Cap. Rather, all deglaciation landforms (eskers, meltwater channels, ice dammed lake features) indicate that there was a coherent and steady retreat across the Kola Peninsula from east to west, with only local deviations. One example of an area with such deviations is the central part of the Kola Peninsula, including the Khibiny and Lovozero massifs, where extensive moraine systems and lateral meltwater channel series reveal a complicated interaction between regional ice sheet dynamics and local cirque glaciation. During Younger Dryas, the eastern ice margin of the Fennoscandian ice sheet was positioned north-south across the central Kola Peninsula, and end moraines were deposited fragmentarily on the lowlands surrounding the mountains. Within the central mountains themselves there is extensive evidence of ice marginal positions both from local mountain glaciation, such as regular end moraines at the mouths of cirques, and from continental glaciation, with inlet glaciers flowing up and into the valleys and cirques, depositing marginal moraines.

A GLACIAL GEOMORPHOLOGICAL MAP OF KOLA PENINSULA AND ADJACENT AREAS IN MURMANSK REGION, RUSSIA

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A map of the glacial geomorphology of Kola Peninsula and adjacent areas in Murmansk region, northwestern Russia, is presented. The primary data source for identification and classification of landforms has been Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite images, added by aerial photograph interpretation and field work in selected areas. The map, at the scale 1:900,000, consists of over 20,000 landforms pertaining to the Quaternary glacial activity, considerably improving existing knowledge of this area. The distribution of landforms shows large variations, indicating different glacial regimes in different areas. For example, the central part of the peninsula largely lack signs of subglacial activity, and only exhibits lateral meltwater channels, which occur in great numbers. This indicates cold-based conditions of the ice sheet throughout the last glaciation(s), and deglaciation through ice surface melting and runoff alone. In the western part of the area glacial lineations are the dominant landform type, and they indicate the presence of areas with fast warm-based ice flow. Such areas include south of Khibiny Mountains and in the southernmost area, where densely spaced drumlins with high elongation ratios possibly indicates the presence of a palaeo-ice stream. The largest coherent glacial landform system in the area is an ice marginal system running parallel to the southern and eastern coast of Kola Peninsula. This ice marginal system, the Keiva moraine complex, consists of end moraines, end moraine complexes, hummocky moraines, meltwater channels and outwash sediments. This moraine system has been known for over a hundred years, but no conclusive formation theory has been accepted. In this map, we show that parts of the moraine system have been overrun and drumlinised by ice flow from the southwest, particularly in its western and northeastern parts. The interpretation of glacial events from this geomorphological map is further presented in an oral presentation.

GLACIOHYDROLOGICAL INDICATORS OF DEGLACIATION ON THE PYHÄTUNTURI MOUNTAIN, FINNISH LAPLAND

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Pyhätunturi, a seven kilometres long mountain range consisting of quartzite and conglomerate, is a residual feature rising above the surrounding mires and hills (Mielikäinen 1979, Räsänen and Mäkelä 1988). Its highest tops reach an elevation of over 500 metres, dominating the landscape of Central Lapland for tens of kilometres. Deep gorges and channels incised in the mountain range are typical features formed by meltwaters from the continental ice sheet (Johansson 1995, Johansson and Kujansuu 2005).

During the deglaciation the hundreds of metres thick ice sheet still covered this mountain area, a subglacial meltwater stream under high pressure crossed it, eroding almost 50 metres deep subglacial gorge of Peurakuru. The meltwater transported debris from the gorge, accumulating it on the lower slope as a subglacial esker ridge known as Peuraharju.

Sarvikuru is genetically a typical overflow channel. It appears in the form of a sharp cut in the otherwise gently rounded mountains. During the nunatak phase, meltwater flowing on the ice gathered in depressions between the tops from where they discharged supraglacially across the mountain range, eroding gorges in the process (cf. Kujansuu 1967). Isokuru and Pikkukuru are the most significant gorges of Pyhätunturi. In addition, Isokuru is the deepest gorge (220 m) in Finland. The formation of gorges was influenced by weakness zones in the bedrock, where deep fracturing had occurred due to movements in the Earth's crust millions of years before the Ice Age (Hänninen 1994). Ice lobes also caused effective erosion and plucked blocks off the fractured bedrock. Finally meltwater streams cleaned the gorge floors, carrying away loose rock material and spreading it at their mouths as outwash fans. Kettle holes are found on their surfaces, tens of metres in diameter and several metres deep.

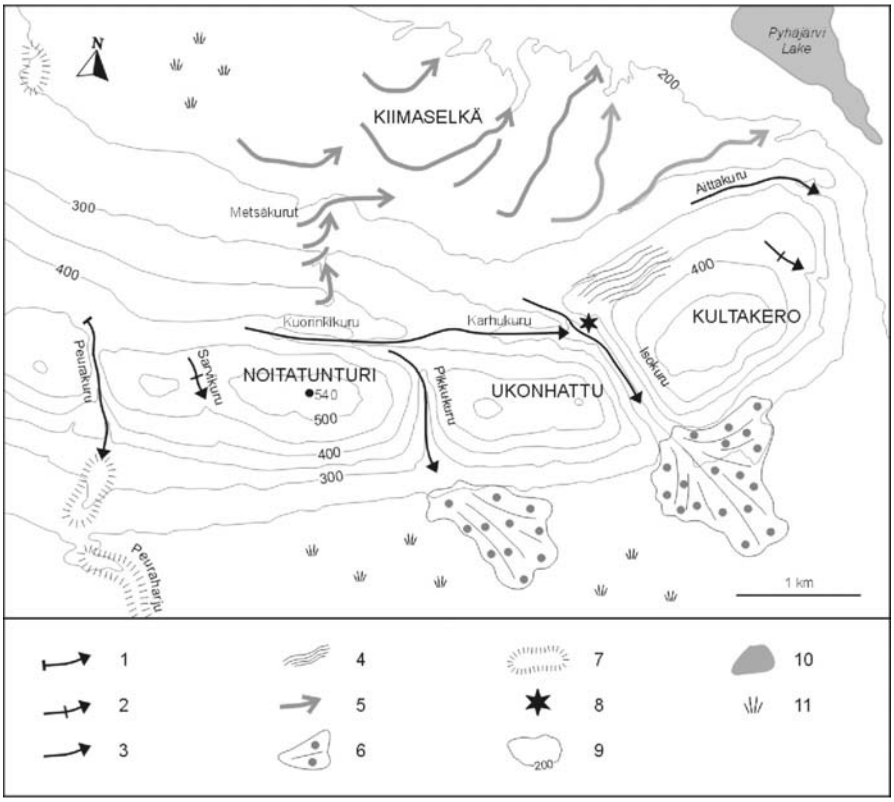

Figure: Glaciohydrography of the Pyhätunturi area, Finnish Lapland. 1 - subglacial gorge, 2 - overflow channel, 3 - marginal and proglacial meltwater channel, 4 - lateral drainage channels, 5 - extramarginal channel, 6 - outwash fan, 7 - esker, 8 - Pyhänkasteenlampi ('baptism pond') and Pyhänkasteenputous ('baptism rapids'), 9 - contour line, 10 - lake and 11 - mire.

About 30 – 40 m deep marginal channels such as Karhukuru and Kuorinkikuru were formed as the meltwater discharging from the tunnel mouth started flowing marginally, following the northern slope of the mountain range eastwards. Their steep walls and even floors reflect the long-term meltwater erosion, reaching deep into the broken rock. The water flowed first into Pikkukuru, later shifting into Isokuru. Pyhänkasteenlampi ('baptism pond') and Pyhänkasteenputous ('baptism rapids'), the most wellknown geological attractions in the area, were formed at the mouth of the Karhukuru gorge.

Lateral drainage channels are common on the till-covered northwestern side of Kultakero, the easternmost top of the Pyhätunturi mountain range. They are almost parallel and slope gently downward. Individual channels are from a few hundred metres to a kilometre long. They are 1 – 2 metres deep and open at both ends. They were formed by meltwater flowing from the ice sheet and eroding a channel in the slope parallel to the edge of the ice. When the ice became thinner, its surface sank a few metres. The next year a new channel was again formed below the preceding one. In this way a series of parallel channels was formed one below the other. The lateral drainage channels reflect the gradient of the ice surface and indirectly describe the annual thinning of the ice and the retreat of its margin towards the northwest about 10 400 years ago (Lunkka et al 2004, Johansson and Kujansuu 2005).

At the final stage of the deglaciation arcuate extramarginal channels were formed, sloping gently towards the northwest. These channels end around the 200 m level, reflecting the shoreline of the Ancylus Lake, part of the ancient Baltic basin that reached up the Kemijoki river valley to the foot of the Pyhätunturi Mountain.

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EARLY- AND MIDDLE-WEICHSELIAN DEPOSITS IN NORTHERN ESTONIA

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Although the occurrence of Eemian interglacial deposits is most valuable to distinguish the Late-Pleistocene and older deposits, the number of studied Eemian sites in northwestern Estonia is limited. In addition to the sedimentologically and micropalaeontologically studied sites (Fig. 1), it is assumed that organic-containing Eemian deposits occur on the islands of Mohni, Keri, Äksi and Vergi in the Gulf of Finland, where occurrences of natural gas have been recorded.

As determined in several studies, the termination of the Eemian was sudden and therefore the sediments deposited during the very last Eemian stage E9, distinguished at Juminda-2 site are sparse and thin. Data from Juminda-2 site suggest that a relatively cold freshwater environment characterises the end of Eemian. The remnants of mostly minerogenic marine sediments as well as freshwater organic sediments are usually deformed and eroded by the Weichselian ice or proglacial waters. These waters eroded sediments deposited earlier and therefore the Eemian pollen has been re-deposited into Weichselian strata.

According to some later studies in Scandinavia, the Early-Weichselian glacier did not reach Estonia, which is supported by latest investigations of northern Estonian sections where only one Weichselian till bed was found. Our investigations in northern Estonia (Juminda-2 and Põhja-Uhtju) indicate that only fine-grained periglacial deposits represent the Lower-Weichselian in the area. This supports the conclusion regarding periglacial conditions in northern Estonia during the Early-

Weichselian by which the ice margin was located north of northwestern Estonia. Therefore the stratigraphic position of till beds distinguished previously as Lower-Weichselian ones in Vääna-Jõesuu, Prangli and Juminda-1 sites is questionable.

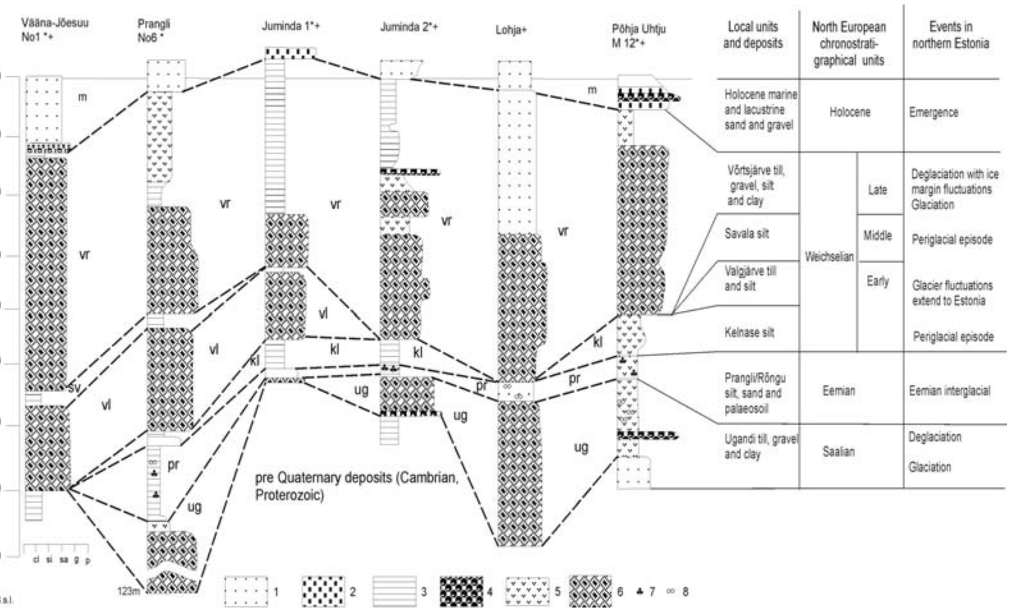

Figure 1. Pleistocene sections in Foreklint Lowland, northern Estonia and formal stratigraphy of Upper-Pleistocene deposits (Kadastik 2004; after Raukas 1978, Raukas and Kajak 1997b - Vääna-Jõesuu section; Raukas and Kajak 1997a - Prangli section; Raukas 1978 - Juminda-1 section). *- micropalaeontologically studied site; + - sedimentologically studied site; m - Holocene deposits; vr – Late-Weichselian deposits (Võrtsjärve Subformation); sv – Middle-Weichselian deposits (Savala Subformation); vl – Early Weichselian deposits (Valgjärve Subformation); kl – Early Weichselian deposits (Kelnase Subformation); pr – Eemian deposits (Prangli and Rõngu Formation); ug – Saalian deposits (Ugandi Formation). 1 - sand; 2 - gravel; 3 - clay; 4 - pebble and cobble; 5 - silt; 6 - till; 7 - plant remains; 8 - fragments of mollusks.

Middle-Weichselian interstadial deposits containing pollen assemblages indicative of cold and dry periglacial conditions have been encountered at few sites (Vääna-Jõesuu, Prangli and Savala). Dating of fine-grained sand underlain by glaciofluvial gravel from the Pehka site in northern Estonia resulted in an age of 26 800□3500 OSL years (Kadastik 2004). Correlation of this deposit to the north European scheme suggests deposition during the Middle-Weichselian Denekamp interstadial warming. This is supported by the dating of mammoth remains from Estonia and Finland, most of which date about 31 000–22 000 radiocarbon years (Lepiksaar 1992; Lõugas *et al.* 2002). This evidence supports the conclusion that northern Estonia was not ice-covered during the Middle-Weichselian.

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THE RESPONSE OF FLUVIAL AND LACUSTRINE SYSTEMS TO CLIMATE CHANGE/HUMAN IMPACT IN THE HOLOCENE: CASE STUDY IN DRUT RIVER BASIN, BELARUS

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The response of fluvial and lacustrine systems to the environmental change in the Holocene has been studied in two river valleys of the upper Dnieper basin (Belarus). They are Drut river valley (1st order tributary of Dnieper) near Belanichi and Neroplia river valley (1st order tributary of Drut river). The both studied rivers are underfit.

The Drut valley includes backswamp zone and meandering belt. The first zone is older and wider (about s of the valley cross-section). A change form braided to meandering river pattern occurred there in the Late Glacial because peaty silts and peats had deposited on channel sediments since 11 085±85 BP at the most remote from the modern channel area. The near-bottom layers of organic sediments of the backswamp zone are younger towards the present-day river. They were dated at 8610±70 years BP in the middle part and at 5840±65 years BP in the limit of this zone. The meandering belt consists of different bodies of the Holocene alluvia, in which cut offs (at before 8010 and before 7660 BP) and changes of sedimentation pattern in the palaeomeander fills (at 7235, 5910 and 5720 BP) and on river flood plain (at 1150 BP and recently) recorded.

Neroplia river meandering in the wide valley with several depression formerly occupied with lakes and now filled with lacustrine deposits. One of these depressions is still occupied by the present-day shallow Neroplia Lake and filled with almost 9-m thick lacustrine deposits. Although the first human settlements in the studied valleys were established during the Mesolithic-Neolithic, and pollen records in Neropla Lake evidence presence of agricultural activities in nearby areas since 4100 BP, distinct anthropogenic changes are observed only since historical times, when fertile loess soils began to be intensively cultivated. About 2000-year delay occurred between appearance of pollen of anthropogenic indicators and sedimentation changes in the Neroplia valley. A spread of peat bogs in the bottom of Neroplia valley were dated at 2020 BP and there were buried by colluvium and levee at 570 and 510 BP, respectively.

Fluvial deposits in the Drut valley contain records on the regional-scale natural environmental changes (~ 8.6-8.0, 7.6-7.2, 5.9-5.7, 5.5-5.0, 3.4-3.1, 2.1, 1.0-ka BP, last centuries), which mark major episodes of stabilization/destabilization of the hydrological regime during the Holocene. Changes in the sequence and composition of fluvial deposits due to human impact are pronounced clearly only in recent (last millenium) deposits, although are seen in pollen spectra, minor changes in grain size characteristics and chemical content of the sediments. Fluvial deposits in the valley of Neroplia river contain records of river evolution only since the Neoholocene (2.0 ka BP, last centuries). At the same time the lacustrine deposits in this valley contain the records of environmental changes in the entire Holocene. Changes in the sequence and composition of fluvial deposits due to human impact occurred almost 2000 years later, as compared with pollen data. They are pronounced clearly since ~500 years BP and are supported by the simultaneous episodes of colluviation.

DIRECTIONAL AND STRUCTURAL ANALYSIS OF DIAPIR-LIKE STRUCTURES AT ULMALE SITE, WESTERN LATVIA

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The Ulmale Site is part of 10-18 m high bluffs of the Baltic Sea coast in W Latvia between the city Ventspils and the town of Pāvilosta. It was part of field excursion of Periblatic Group field symposium in September, 2004 in Western Latvia (A.Kalvāns *et all* 2004). Diapirs of dark grey clay or clayey silt are observed here overlain by fine sand and grey till. The height of diapirs exceeds 15 m, as their base is not exposed but tops are often eroded. The spacing between toppings of diapirs varies from 100 to 250 m. The intervals between diapirs commonly are filled with glaciolacustrine fine-grained sand sediments and lens-like bodies of the upper till. Bodies of the upper till are up to 100 m long and in places more than 10 m thick.

According to several biostratigraphical investigations in different places I.Danilans (1973) correlated these sediments with Holsteinian interglacial, however contrary results are gained later. Biostratigraphical investigations at the Ulmale site suggest late Eemian or even Early Weichselian age (Kalniņa, 2001). OSL dates of fine sand sediments lying between dark grey silt and upper till suggest middle Weichselina age (Dreimanis, *et all* 2004).

Several of diapirs are complicated with small scale overthrusts and dike structures. The simple diapirs usually have layered inner structure and consist of up 10mm large angular darker silt fragments resting in a lighter, coarser matrix. Evidences of shearing are observed in the inter layers of these diapirs that are repeating curvature of diapir surface. In contrast the silt in diapirs that are complicated with dikes is massive with no visible inner structure. Micromorfological structure of these sediments has been investigated in thin-sections.

The formation of diapirs seems to be last stage of deformation. No shearing-off of the diapir tops is observed in the Ulmale site. After formation of diapirs no significant deformation of glacial sole due to glacial drag and erosion occurred. The measurements of structural elements reveal that most of the diapir structures are elongated. The long axes are similar for the most of the structures ranging from 293˚-316˚ to 113˚-136˚. During retreat phase of Weichselian glaciation Ulmale site was positioned in south-west margin of Apriķi ice tongue (V.Zelčs, A.Markots 2003). The orientation of elongated structures is close to ice movement direction in the Apriķi ice tongue. Asymmetry of some structures suggests that stress direction was from north-east to south-west. These facts indicate that the formation of diapirs can be correlated with slowdown and ceasing of ice flow in Apriķi ice tongue.

This study is cofinanced by European Social Fund.

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INVESTIGATION POSSIBILITIES OF EOLIAN DEPOSITS AND PROCESSES ON THE TERRITORY OF LITHUANIA USING LARGE SCALE AERIAL PHOTOGRAPHY

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The interpretative signs of eolian deposits within the boundaries of the region of continental glaciation are established on the standard area located in the Southeast Lithuania.

The tone and pattern of a photographic record, types and forms of relief, topsoil and vegetation cover, indications of economic assimilation of a territory are the main signs for deciphering eolian deposits and processes as well as their character and intensity.

The tone of an aerial photographic picture of eolian sands varies from white to dark-grey. The plots of eolian sands absolutely devoid of vegetation cover have a dazzling-white photo tone on aerial photographs because of a uniform lithologic composition, deeper occurrence of groundwater level and high reflecting ability. In places covered by herbaceous vegetation the tone of aerial picture is grey. The pattern of sand is even, and in plots covered with trees it is dotted.

Morphological expressiveness is one of the main distinctive peculiarities of eolian deposits for their deciphering. Dunes and hillocks are distinguished by characteristic forms of relief distinctly observed with a stereoscope both on open plots and those covered with wood. On aerial photographs it is possible to trace a whole complex of eolian relief: deflation plane, hillocky eolian relief, weakly developed dunes and hillocky-depression surface of sand deflation.

In woodlands, the elementary forms of eolian relief are identified by a characteristic density of trees.

Alongside relief forms, the major sign for deciphering and simultaneously the sign indicating the intensity of eolian processes is vegetation. The role of vegetation consists not only in its ability to consolidate the superficial part of sand mass by roots and to prevent the development of deflation processes, but also in decreasing the wind velocity at Earth's surface and in contributing to a partial discharge of wind-driven sand flow. According to the degree of vegetation development, eolian sands are usually subdivided into unconsolidated, weakly consolidated, semi-consolidated and consolidated. On unconsolidated and weakly consolidated sands wood vegetation is usually absent or is found in solitary forms. As the vegetation cover develops, the sands are enriched in humus which in its turn contributes an increase of vegetation cover. As a result, on semi-consolidated and consolidated sands a considerable number of different herbaceous plants, bushes and trees which are distinctly fixed on aerial photos begin to grow. Trees and bushes form a dotted pattern on aerial photos, and their density may be evaluated rather from aerial photographs. Herbaceous plants do not form a dotted pattern, however, they have an influence on the tone of aerial photo picture (the denser the herbaceous cover, the darker the tone of an aerial photo). Thus, by the tone and pattern of aerial photo it is possible to judge almost with certainty about the degree of sand consolidation. Unconsolidated sands are presented on aerial photographs by almost white tone, a dotted pattern is absent; weakly consolidated sands are depicted by a grey, dark-grey tone, the dotted pattern is expressed very weakly; semi-consolidated sands form a dotted pattern and consolidated sands give a dark-grey tone; the dotted pattern is practically absent.

The main characteristics of eolian sands are their weak consolidation by vegetation and looseness. These features bead to the formation of eroded parts in forest roads, distinctly visible on aerial photos. Sand is very good reflector, thus on vertical aerial photographs the intervals of eroded roads are surrounded by a peculiar dazzling-white halo; a road-bed stretching across the deflated sands (across the halo) is hardly seen. The other, no less important indication of the roads crossing the eolian deposits is their decreased linearity compared with roads built on a firmer ground. These roads are meandering, they twist, pass round the unconsolidated plots. The absence of arable land is characteristic of the areas of eolian sand development.

All the enumerated features allow a rather reliably determination and mapping of eolian deposits and processes by aerial photographs. From the orientation of eolian relief forms on vertical aerial photos, it is possible to judge about the direction of prevailing winds. The direction and velocity of sand displacement are determined most precisely by comparative deciphering of materials of repeated aerial photographs.

The analysis of repeated aerial photography after a long span of time allows to determine the tendencies in the development of eolian processes.

AGE OF THE NEMUNAS RIVER TERRACES IN THE ENVIRONS OF KAUNAS ACCORDING TO THE DATA OF GEOCHRONOLOGICAL INVESTIGATIONS

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The morphological and geological structure of the Nemunas and the Neris valleys became an object of interest already at the end of the 19th century. Yet more detailed studies were carried out only in 1955 by A. Basalykas. In spite of the following comprehensive studies about morphology, an evolution of valleys and terrace alluvium the issue about the time of terrace formation remained unsolved. The thickness of alluvial sediments in the areas where they overlie sandy intermorainic formations (especially when they have no basal horizon) is unknown.

The reconstruction of Nemunas River evolution was one of the aims of mapping of Kaunas city and environs. A detailed geological map of Quaternary was compiled at a scale of 1:10 000. Dating of alluvial sediments was carried out using the method of optically stimulated luminescence (OSL). The absolute age of bog deposits in the Nemunas valley was determined by radiocarbon method (^{14}C). The relative altitudes and width of terraces, their morphological features, height of alluvial socle and specific features of structures and textures in the outcrops were determined during field works.

The Nemunas and Neris valleys have been inherited. A few sectors of valleys (at Eiguliai, Pažaislis and Kaniūkai) coincide with paleoincisions. The deepest paleoincisions reach up to 55 m. They are filled with fluvioglacial deposits of Ћemaitija (Saalian) Formation.

VI-th, V-th, VI-th, III-rd, II-nd and I-st flood plain terraces as well as overbank were distinguished. Relative altitudes of terraces are: VI-th – 40–48 m, V-th – 30–35 m, IV-th – 20–28 m, III-rd – 12–15 m, II-nd – 7–11 m, I-st – 4–6 m, overbank – 2–3 m. The greater part of the study area is included in the territory of Kaunas city. The city was established at the confluence of the Nemunas and the Neris rivers. The large-scale earthworks, digging and piling, considerably transformed the surface of terraces. Eolian processes also affected the height of terraces (especially of terrace II-nd).

I-st and II-nd terraces are very important: terrace II-nd occupies almost the whole valleys of the Nemunas and the Neris. It was first attempted to determine the age of deposits of terraces I-st and II-nd by dating the alluvial sediments instead of valley peat. Three samples for OSL dating were taken from the outcrop of terrace I-st in the Panemunė meander at a depth of 1.7–1.8 m, 2.9–3.1 m and 3.7–3.8 m. The age of the all three samples is comparable, from 2640±200, 2930±2100 to 3570±2500 years BP, implying that the deposits were accumulated in Sub-Atlantic (SA) and Sub-Boreal (SB).

Three samples for OSL dating were also taken from borehole on the terrace II-nd of the Panemunė meander. The obtained results are the following: at a depth of 1.4–1.5 m the age of deposits is 11900±700, 2.4–2.5 m – 19400±1900 and 4.4–4.5 m – 21300±2500 years BP. These results allow assuming that only the upper part of deposits belongs to alluvium and was accumulated during the Older Dryas (OD) – Allerцd (AL). The lower layered fine- and medium-grained sand is older and can be attributed to the socle of terrace (or it can be insufficiently "zeroed" alluvium also). According to the radiocarbon (^{14}C) dating the peat layer at a depth of 6.9–7.0 m in terrace II-nd was deposited 4370±130 ^{14}C years BP in Sub-Boreal (SB) whereas the upper part of the peat layer was deposited 2530±110 ^{14}C years BP in Sub-Atlantic (SA), i. e. these data do not contradict to the results of OSL dating. Obtained data of the age of the II-nd flood plain terrace (Late Glacial) well corresponds with the old results (1989) of single termoluminescence dating (TL) of II-nd flood plain terrace of the Neris River close to Pundħonys outcrop – 11000 years BP.

INTERTILLS SANDY DEPOSITS IN THE CHEŁMNO LAKELAND (POLAND)

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The study area is situated in the central part of the Chełmno Lakeland between the towns of Chełmża and Brodnica (north-central Poland). Quaternary deposits attain a thickness of 30 to 190 m in this region. 9 moraine till horizons and 8 intervening sand-gravelly horizons have been identified within the Quaternary section. The investigations focused on deposits representing the Augustovian, (Cromerian I), Great (Holsteinian) and Eemian Interglacials, as well as on glaciofluvial sediments separating Wartanian tills. These deposits were encountered in 8 boreholes in the area. Their lithostratigraphic and genetic interpretation was based on granulometric analyses, heavy mineral contents (0.25-0.1 mm), mineral-petrographic composition (1.0-0.5 mm) and quartz grain roundness analyses (1.0-0.5 mm). The Eemian and Holsteinian age of the deposits was confirmed by a palynological analysis.

The investigations were aimed both at showing similarities and/or differences between stratigraphically and genetically diversified sand deposits and at determination of the lithodynamics of sedimentary environment.

Augustovian alluvial deposits attain a thickness of up to 60 m. They are represented by grey and grey-brownish fine- and medium-grained sands with gravel admixture. They are variably sorted ranging from very poor to moderate. The roundness coefficient of quartz grains is variable, but there is always a small content of angular grains. Mineral-petrographic composition indicates dominant contribution of quartz and small content of crystalline rocks and northern limestones.

Alluvial deposits of the Great Interglacial reach a thickness of up to 76 m. They are represented by well, moderately or poorly sorted fine- and medium-grained sands, grey in colour. Quartz grains are commonly well-rounded. The sands are composed almost exclusively of quartz grains, occasionally with a small contribution of crystalline rocks and northern limestones. The heavy fraction contains mainly garnets.

Glaciofluvial deposits are represented by fine- and medium-grained sands with gravel admixture, up to 28 m thick. They are variably sorted (ranging from poor to moderate). The roundness coefficient of quartz grains is also variable. Besides quartz grains, the sand fraction also contains much feldspar, crystalline rocks and northern limestones. This sediment was deposited by flowing water of a changing hydrological regime.

Eemian deposits, up to 28 m thick, fill a well developed system of ancient river beds. These are light-grey fine- and medium-grained sands with gravel admixture at the base. They are moderately and poorly sorted. The grains were transported over a long distance that resulted in a good selection of sand material. The degree of selection increases to the south in the study area. This is evidenced from the roundness of quartz grains, increasing in the same direction. The dominance of quartz grains and a small content of crystalline rocks, with the almost absence of northern limestones, also suggest a long transport distance.

ENVIRONMENTAL RESPONSE TO THE JUNCTION OF THE BARENTS SEA AND KARA SEA ICE SHEETS IN NORTHERN RUSSIA

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In-depth knowledge on palaeo-glaciological conditions related to multiple ice dispersal centres and ice flow towards the same termination on mainland Russia requires both spatial and temporal information on the interaction between the Kara Sea, Barents Sea and Scandinavian ice sheets. It is established that the Scandinavian and Barents Sea ice sheets merged during Late Weichselian, offshore the present Norwegian-north Russian coast, while only ice from Scandinavian reached the terrestrial part of northwest Russia. The nature and glaciodynamic behaviour behind the zone of confluence related to this ice sheet junction is unknown. The Middle Weichselian scenario associated with the junction between the Barents and Kara Sea ice sheets is even less understood and recent literature has ceased to distinguish between the two ice sheets. Either way the confluence or possible separation between the Barents and Kara Sea ice sheets must be addressed before the climate sensibility of palaeo-ice shelves is evaluated or used as analogous for modern conditions in West Antarctica. In the Early Weichselian, the challenge is to understand the influence of the Barents and Kara Sea ice sheets on damming the northbound rivers from the Pechora and Arkangelsk-White Sea regions.

The Kanin Peninsula in northern Russia holds a strategic position facing the Barents Sea, north of the ice sheet terminations. Thus, sediment successions from the Weichselian record the marginal behaviour of all major ice sheets and their mutual interaction i.e. between the Scandinavian, Barents Sea and Kara Sea ice sheets. New evidence from Kanin and adjacent areas identified the widespread occurrence of marine tidal sediments deposited at c. 60 ka BP up to 40-50 m above present. The deposition of the tidal unit is corresponding to rapid eustatic sea level rise and inundation of the sea. We consider this tidal succession an important stratigraphical marker as it divides Barents Sea dominated glaciation, and subsequent Kara Sea dominated glaciations during MIS 3. The Barents Sea glaciation is associated with regional ice flow from NW and the Kara Sea glaciation with ice flow from NE. Both directions are recognized in southward positioned ice marginal moraine system and we suggest that this Markhida moraine and its western continuation are composite in nature over a longer time span. As tidal sediments contain no signal of ice proximity and considering the marginal position of Arkhangelsk relative to open marine conditions, we speculate that the fast eustatic sea level rise – c. 20 metre pr. 1000 years, triggered a rapid ice shelf collapse.

Numerical modelling of the Eurasian ice sheets throughout the last – Weichselian glacial cycle predicts four major phases of glaciation, which become progressively larger from MIS 5 to MIS 2 with maxima at c. 110 ka, 90 ka, 60 ka and 20 ka. Geological information from marine cores in the Arctic Ocean, sedimentary successions and geomorphological mapping on mainland Russia and Siberia largely confirm these reconstructions. Also, it seems from the sedimentary record that ice sheet activity is most pronounced in the Kara Sea during the MIS 5, shifting stepwise towards the Barents Sea and Scandinavia during the MIS 4-3 and MIS 2. This pattern is balanced by warm Atlantic moisture reaching far to the east during the Weichselian initiation - progressively moving to the source of precipitation as warmer water fronts shifted southwards during ice build-up over the Barents Sea shelf. However, now we are able to distinguish between the two marine-based ice sheets and, the glaciation dynamic of northern Eurasia seems to be more intriguing with a less straight correlation to isolation minima. Also the simple east-to-west migration of precipitation during Weichselian must be more complex than previously thought.

MORPHOTECTONIC STRUCTURE AND TENSION DISTRIBUTION IN THE KHIBINY MOUNTAIN MASSIF, KOLA PENINSULA, NW RUSSIA

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The regional analysis of the structural heterogeneity, resulted in the morphological state of the surface relief, is an important theoretical task of the investigation. To solve it the morphotectonic blocks of the earth surface and of different ranks were distinguished within the Khibiny mountain massif as the most active structure in the Kola region. The morphometric methods were applied (Simonov, 1999) using the remote sensing images and the medium- and high-scale topographic maps. Boundaries of the structures and their ranks were outlined on the rivers' valleys in couple with the tectonic faults (gorges, ledges).

It is established that the erosion systems within the Khibiny mountain massif are represented by the valleys of five orders. On this basis the morphotectonic structures of the five ranks can be distinguished. The boundaries of the 1st rank blocks, represented by more or less extended zones, were determined on the erosion valleys of the highest fifth order (fig. 1). Following the same technique, the boundaries of the 2nd, 3rd and 4th rank structures were outlined. It was empirically established, that the formal way applying the morphometric methods to distinguish the smallest blocks (5th rank in our case) is not efficient at the low reliability of the results.

The theoretic background of the method is based on the assumption that the rivers valleys through the selective erosion were formed along the tectonic faults and as the valley order is higher the valley was formed along the more active and deeper tectonic zone. Respectively, as the erosion valley rank is higher the outlining of corresponding lineaments (block boundaries) is more reliable. The established regularities of tension distribution in conditions of the rugged relief confirm theoretical background of the method.

Vertical section, crossing the structure in north-east direction was analyzed at modeling of the tension state of the rocks in massif. Method of the borderline elements in two-dimensional statement of the first task of the theory of elasticity with use of a principle independence action of forces has been applied. It is suggested that the morphostructure consists of homogeneous isotropic rocks with mechanical properties similar to most abundant rocks in the area. Through the mathematical modeling the horizontal (σ_x) and vertical (σ_y) tensions were determined.

The great influence of the relief on the tension distribution resulted from the interaction of the lithospheric plates is established. In terms of the action of the horizontal tectonic and uniformly distributed on the depth compressing tensions (- 40 MPa, (Seismicity…, 2002)) on the infinity, the value of the horizontal tension concentration (σ_x) depends on the radius of the surface curvature.

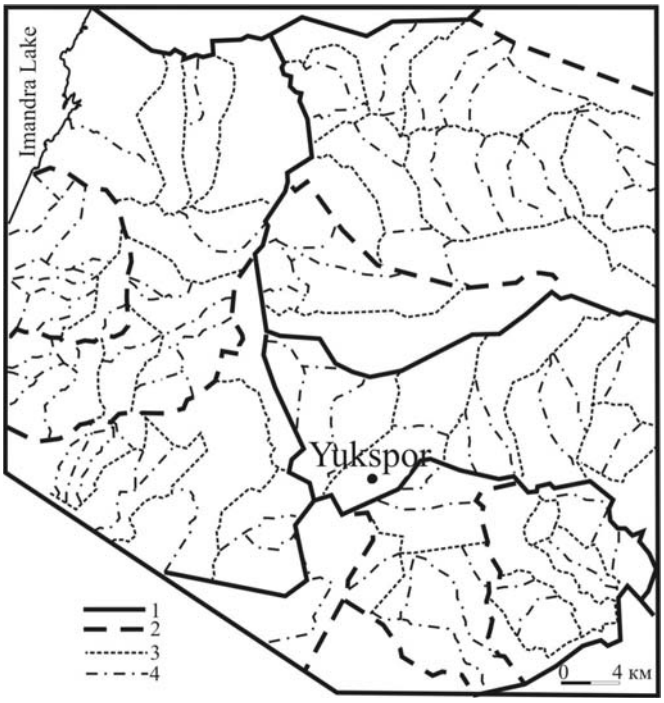

Fig. Scheme of morphotectonic structures of Khibiny mountain massif
(According to morphometric data)

Structures bundary: 1 - the first rank; 2-second rank; 3-third rank; 4-fourth rank.

Closed to surface the horizontal tensions beneath the valleys are more than applied forces (-40 MPa), and less in the upland areas. The elevated concentration σ_x is indicated also beneath the local erosion valleys throughout the whole studied morphological structure.

The influence of the tectonic forces, related to the movement of the lithospheric plates, on the vertical tensions (σ_y) is negligible and comprises ±5 MPa. Their distribution is characterized by the phenomena that the σ_y is compressing beneath the valleys and stretching in the upland areas. In the last case they spread to the greater depth (up to the twice and more altitude of the relief).

In the case of the joint action of the tectonic forces and relief, the σ_y beneath the valleys is more than the established value (proportional to rock density and to the depth from the surface), and significantly less in the upland areas. The results of the vertical tensions decreasing in the upland areas and increasing beneath the valleys (both depending on gravitational and tectonic forces) are added. In the temporal aspect the joint action of the gravitational and horizontal tectonic forces causes to interrelated ascending and descending of the blocks. In that case the valley areas descend and the top areas ascend relatively to the overall up-rising orogenic processes of the crust, inherent for the Khibiny mountain massif.

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GIS-TECHNOLOGIES IN STRUCTURAL-GEOMORPHOLOGICAL ANALYSIS OF THE BELARUSIAN POOZERYE AREA

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INTRODUCTION

Geographical informational systems (GIS) are getting a special significance in the current development of geology and geomorphology. GIS-technologies allow to visualize landforms and geological information, as well as to carry out different kinds of geomorphological analysis (structural-geomorphological and morphometric mapping, profiling) and modelling (three-dimensional models of landforms and other structural surfaces, evaluation and prognosis of endogenic and man-caused processes).

METHODOLOGY

Structural-geomorphological analysis of the Belarusian Poozerye area has been realized according to the morphometric method of tectonic features recognition (after Filosofov 1975). These traditional methods have been supplemented by an application of GIS (fig. 1). Together with geomorphological data geological and geophysical information has been used in order to improve the reliability of morphometric investigations and to carry out the correlation of the recognized active neotectonic structures with the present neotectonic pattern.

RESULTS

Structural-geomorphological analysis of the area has been realized in the software environment of the geographical informational system ArcGis 9.0 (ESRI, USA). GIS-project “Landforms of the Belarusian Poozerye” has been originated (Kurlovich, Karabanov 2004). This project consists of following vectorial layers: topography (rivers, lakes, settlements, limits of the Poozerye), digital relief model (isoline, three-dimensional model of landforms – fig. 2), morphometric data (order of valleys, basic surfaces and their differences, top surfaces, residual landforms), structural surfaces (basement surface, surface of pre-Quaternary sediments, underlying surfaces of the morainic and intermorainic beds), active neotectonic structures.

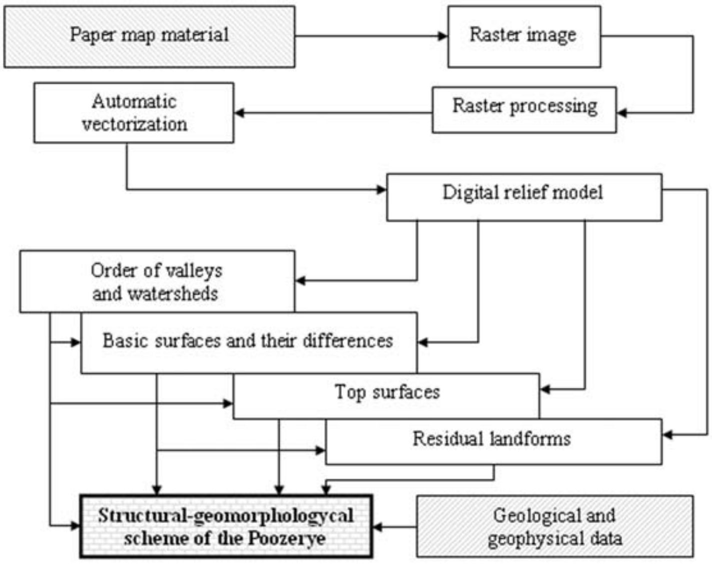

Fig. 1. Process of the structural-geomorphological analysis

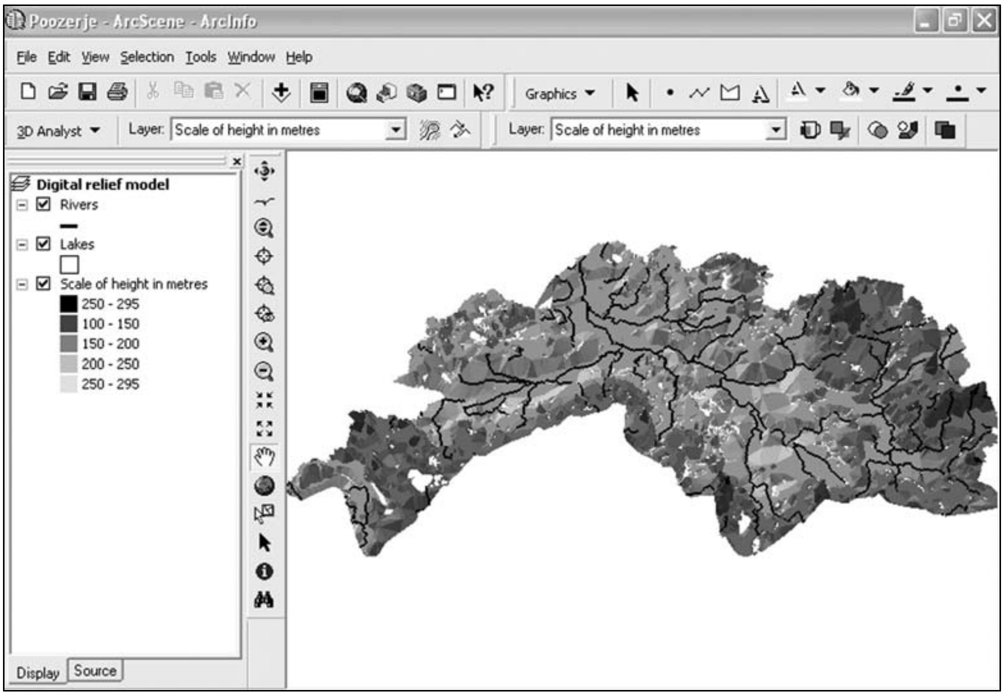

Fig. 2. Three-dimensional model of landforms of Belarusian Poozerye

As a result of GIS-analysis of the landforms, structural-geomorphological scheme of the Belarusian Poozerye has been developed.

CONCLUSIONS

Application of the modern GIS-technologies in study of geology and geomorphology of the Poozerye area allowed to solve several questionable problems related to structural-geomorphological peculiarities of the area. Obtained structural-geomorphological results within the Poozerye could serve as a base for geological and geomorphological mapping as well as for a human impact assessment and prevention of natural hazards. This study allowed to reveal active neotectonic features and to evaluate general seismotectonic situation.

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STORM EFFECTS ON THE OPEN BALTIC EXPOSED COASTAL RELIEF OF LATVIA

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Erosion of the Baltic Sea coast, including the coast of present-day Latvia, has been occurring, in accordance with on climatic trends and long-term fluctuations in sea level, already in times when people were completely helpless in the face of natural phenomena. However, changes in coastal processes have been observed during the 20th century, as a result of human economic activities, and possibly also in connection with global climate change. In connection with land prices, recreational opportunities, the threat to private and public assets, as well as restrictions on economic activities, the present state of the coast has become a subject of interest among researchers, the press and thus also the general public.

In the second half of the 20th century, several studies of a high standard, but very restricted in scope, have been undertaken on processes in the coastal zone. Most significantly, before 1992, no long-term, comparable monitoring studies were undertaken on major stretches of the open Baltic coast. Accordingly, the present study only makes use of the methodologically sound instrumental data for the period 1992–2004. During this period changes in the exposed coastal relief and in the distribution of coastal surface sediments have been affected by four especially powerful storms: in January 1993, December 1999 "Anatoly", November 2001 and January 2005.

The erosion vulnerability of Latvia's open Baltic coast is very varied. Thus, the natural protective barrier in front of the coast (beach + active aeolian relief) varies from less than 5 m^3/m to more than 150 m^3/m of sediment above sea level (Eberhards, 2003).

The volume of sediment eroded in storms has been calculated using the data obtained within the frame of the Latvian Coastal Geological Monitoring Programme. This consists of two datasets: levelling measurements using an optical level on an annual basis (63 profiles) and ordinary measuring lines (1190 lines) located in 58 model stations. The total length of coastline covered by monitoring is 65 km (the total coastline length from the border with Lithuania to Cape Ovīši being 188 km). The levelling profiles and measuring lines are located in those stretches of coastline subject to the greatest change. The levelling profiles are placed where wide beaches and foredunes are present, while the simpler "distance to bluff" model stations have been placed in the stretches with a coastal bluff. For those stretches of the coast where a measurement network has not been established, the volume of eroded material is assessed by comparison with adjacent stretches, and by analysing beach parameters.

After processing of the field data, the following conclusions may be drawn:

- despite of extreme power of the storm of January 2005 (max wind speed reached 38-40 metres per second), volume of sediment eroded in this event was not greater than the volume eroded in the previous three storms (Table);
- the greatest erosion occurs in the coastal sub-cells of Nidasciems, Cape Bernāti, north of Liepāja, in the stretch from Pāvilosta to Jūrkalne, at Cape Melnrags and in the stretch from Ventspils to Liepene;
- the total length of coastline subject to major storm erosion is increasing, and this is occurring at the expense of coastal sub-cells that were previously depositional, as well as those that were stable.

This study was supported by European Social Foundation.

Table. Volume of sediment eroded from the exposed part of the coast during storms and the loss of land area.

	Storm of Jan. 1993	Storm of Dec. 1999	Storm of Nov. 2001	Storm of Jan. 2005
Volume of erosion of exposed relief, million m^3	3.0 – 4.0	2.0 – 2.5	1.0 – 1.1	2.0 – 3.0
Total area of eroded coast, ha (approx.)	15.0	10.0	1.0	12.0
Mean/maximum width of eroded coast, m	4.0/18.0	5.0/23.0	0.8/2.5	3.5/12.0
Areas with maximum damage on the open Baltic coast of Latvia	all coastline	southern part of coastline	northern part of coastline	northern part of coastline

Reference:

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PLEISTOCENE ICE SHEET LOBES AND PALAEO-ICE STREAMS IN CENTRAL EUROPE

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Jotunheimen in Norway is the place, where the continental ice sheets were born in Pleistocene.

Presently only small field glaciers and smaller cirques appear in this place. An example of present dome-shaped ice are Iceland ice sheetc. The Antarctica glacier is the biggest contemporary ice sheet, where the thickness of ice obtain to 4 300 m. The Greenland ice sheet smaller than Antarctica has a thickness exceeding 3 000 m and its surface is comparable with the surface of the Pleistocene Scandinavian ice sheets. The thickness ice sheet of the youngest glaciation exceeded 2 500 m.

Present glaciers and ice sheets are characterized by warm and cold regimen. Ice mass moves faster in warm regimen than in cold one. Sediment deformation is often subjected to movement in the warm regimen. The movement of ice is a result of plastic flow and glides of ice mass along shear planes. Velocity distribution in ice resembles such distribution in liquid between two stiff discs. The ice mass consists of ice crystals and films of water, so this is a diphasic system – non-Newton liquid. The colder ice are more similar in physical parameters are to Newton liquids. Cold ice is characterized by inclusion of big fragments of frozen bottom sediments (glacier rafts) into ice body, while ice moving processes. Warm ice mainly causes detraction, breakage and exaration of the bottom.

The flow speeds of the continental ice sheets and glaciers are very different. The minimal speed of the ice streams movement range to 0,2 km a year. Present glaciers can move up to 7 km per year. Probably, the Pleistocene ice sheet moved during the maximum range of the Vistulian Glaciation with the average speed of 0,5 m per year.

Modeling physical parameters of polar and mid-latitude ice streams present in a different way. These differences are connected with a different pace of ablation, what is mean reason of the different speed of ice's movement (Christoffersen, Tulaczyk, 2003). It also is reason an arrangement of temperature and forces (effective stress and shear strength) in the sediment deformation. Differences in speed of ice mass flow are main reason into formation of ice-streams and ice-sheet lobes. Ice streams show a direction of ice flow and ice sheet lobes present morphologic image of ice edge, as a result of flow.

Present-ice tongues and ice sheet lobes (e.g. of dome-shaped ice sheet in Finland – Vatnajökull) resemble the ones from the Pleistocene, e.g. ice sheet of the Vistulian glaciation in western part of the Baltic Sea.

An influence of morphology of rocks of direct glacier's and ice streem's basement is a very important issue concerning directions of ice flow. This morphology imposes on formation of present-ice tongues (e.g. in Norway) or ice sheet lobes (e.g. in Iceland). Elevations of deeper basement had an influence on ice sheet advance directions in the Pleistocene, e.g. of ice sheet of the Vistulian glaciation (Ber, 2000). Big rivers basin areas, such as: the Vistula, the Oder and the Elbe, also influenced formation of ice sheet lobes and non-synchronous amount of ice sheet advances on its areas (Lindner, Marks, 1994). Formation of palaeo-ice streams and ice sheet lobes had an asynchronous character during the Vistulian Glaciation (Christoffersen, Tulaczyk, 2003; Marks, 2002). Ice-sheet lobes were formed as a result of older flows of ice sheets to south. However, younger palaeo-ice streams moved ice masses towards west (e.g. Young Baltic Ice Streams – BIS). Configuration of subglacial channels in the south Baltic area confirms such directions. Direction of ice streams are marked in direction of glacitectonic structures, e.g. NE Germany region, of glacial strations, e.g. in Finland or directions of drumlins, e.g. in Estonia (Rattas, Piotrowski, 2003) and in Denmark (Jørgesen, Piotrowski, 2003). The direction of ice streams also can be showed on the basis of spatial reconstructing of crevasses configuration in the ice sheet (Morawski, 2003).

Directions of palaeo-ice streams during the last glaciation were reconstructed as following:

- for the palaeo-ice stream in the range of the Vistula ice sheet lobe – on the base of studies of the till structure, direction of glacial strations and glaciotectonic deformations;
- for the main palaeo-ice stream (Norwegian Channel Ice Stream – NCIS) and other Norwegian streams on the area of the North Sea – on the base of the morphology of sea bottom (Sejrup at al, 2003; Ottesen at al, 2001).

Directions of ice sheet palaeo-streams of the Saale and Elstera glaciations were reconstructed, for NE Germany during their late phases, on the base of appearance of the red clayey tills (Ehlers, 1992).

Such directions were reproduced on the basic results under erratics studies in the area of Lithuania, Latvia and Estonia (of coarse gravelly fraction – Gaigalas, 1995) for all ice sheet advances. They were reproduced for the youngest glaciation on the base of similar studies (Smed, 1993) in the area of Sweden and Denmark. Directions of palaeo-ice streams for the Cracov-Częstochowa Highland in Poland were also fixed on local rocks.

Outlines of the Mazurian and Lithuanian ice sheet lobes of the Vistulian Glaciation in the Suwałki Lakeland in Poland were defined on the ground configuration of the subglacial channels, during the Pomeranian phase (Ber, 2000). Limits between the same lobes of older ice sheets (San 2 = Elster 2 and Liwiec 2 = Fuhne) were defined on the basis of the petrographic studies of tills (of gravelly fraction 5–10 mm in diameter). Tills of these glaciations, within the Lithuanian ice sheet lobe are rich into Palaeozoic dolomites, and within the Mazurian ice sheet lobe are poor into of these rocks. Shifts of these borders towards east appear from older to younger glaciations. It can suggest movement of the glaciation center from west to east during the Pleistocene.

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SUITABILITY OF PRIMARY AND SECONDARY COLOUR METHODS IN MORAINE STRATIGRAPHY

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The geological investigation is performing to the sediments colour to descried first, and this, near sediments composition, is a differential and original characteristic indication – easy recognisable, but inconstant and unknown descend, therefore in this investigation are adverted to the moraine colours different, to stability, to reason of heterogeneous, to characteristic and that signification, as well as possibility's and limitations of the practicability in the colour stratigraphy.

In Latvia, little information is available in the literature concerning moraines genesis and its stratigraphic significance. In Latvia, A.Stinkule [5] has given the most significant contribution in this field. Origin of colour in Devonian classical rocks has been studied by V.Kuršs [1, 4]. V.Seglins [3], D.Ozols [2] and other researchers also have contributed to moraines colour.

The research goal was analysing the use of moraines colour in stratigraphic correlation, estimation and preparation of methodical instructions for colour identification and the necessary investigations to be conducted on colour use in stratigraphic correlation.

Research on genesis and role of moraines colour in stratigraphic correlation was conducted using different methods and their interpretations.

In stratigraphic correlation, moraine colour could be partly used when determining geo-chemical conditions of glacigenic deposits formation.

Colour used as additional component in glacigenic deposits stratigraphy should be identified both by Munsell colour chart and analytical analysis. In that way these methods might be inter-correlated and credible results could be obtained. Such an approach might be helpful in determining material of moraine origin and influence of geo-chemical processes on moraine deposits. Comprehension of these criteria and analysis of primary and secondary origin of colour in material allow rather wide discussion regarding genesis of glacigenic deposits being the most significant criteria for colour partial use in stratigraphy.

When identifying distribution and genesis of colour, research is recommended in the following succession: moraine samples taken in field conditions should be placed in tightly sealed polyethylene bags to preserve natural moisture level. In the laboratory, material from common sample is taken for dry sample colour identification using Munsell colour chart and for analysing in scannering electronic microscope. The rest of the sample is recommended to be stored in temperature similar to that at the moment of sampling thus maintaining its initial state. Material used for colour diagnostics and analysis in scannering electronic microscope should be dried in natural air-moist conditions. Chemical-quantitative amounts of elements were determined colorimetrically. Prior to analytical analysis chemical vessels and reagents should be prepared, and moisture content in moraine samples should be determined. Samples should be numbered in a definite succession, and after moisture determination quantitative analysis was completed. Obtained results were summarized and inter-correlated with colour codes for naturally dry samples. Morphology was analysed and microanalysis was done separately in scannering electronic microscope. Obtained results should be considered in distribution of colour definable elements in samples of moraine deposits. Results were graphically delineated in a colour pyramid or in colour profile considering changes both in geological plan and geological section where colour shades of moraine layers of different age would sooner get covered, as distribution of colour was not connected with the age of deposits but with geo-chemical conditions.

There is possible only a partly use of moraine colour in stratigraphic correlations, i.e. indirectly (see above) using it parallel to other stratigraphic methods.

Strictly defined criteria for moraine colour use are necessary in stratigraphic correlations.

A partly use of colour is recommended in stratigraphy applying it in reconstructions and interpretations of geo-chemical conditions, which would limit tactless use of colour in stratigraphy when considering particular colour layers as geological values of different age.

Colour is a significant geo-chemical value, which could be used when analysing conditions and environment of glacigenic deposits transfer.

Colour of glacigenic deposits is closely connected with geo-chemical processes going on in moraine material. Colour is an indicator of geo-chemical conditions.

Iron compounds are like cohesive substance of crystalline matter as amounts of clay minerals in moraine are comparatively small – up to 15 %.

Moraine colour is better distinguished in geological plan rather than in geological section, it is dynamic and inconsistent value.

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A NEW LATE PLEISTOCENE SITE IN NORTH-EASTERN ESTONIA: PRELIMINARY PALYNO- AND CHRONOSTRATIGRAPHICAL RESULTS FROM THE VOKA SECTION

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The first chronostratigraphic and palaeoclimatic data on Late Pleistocene palaeoenvironmental changes in North-Eastern Estonia were received in the course of the pilot study of a new Late Pleistocene section at the Voka site.

The section of the site that was visited in 2003 during the second day of the field symposium in Estonia (Human impact... 2003) is situated on the North-Estonian Klint (a steep cliff along the northern coast of Estonia). The Klint at this site is interrupted and forms an about 2-km-wide Klint bay, which is filled with Quaternary deposits (Fig. 1). The deposits studied are exposed in two neighbouring outcrops situated approximately 25 metres apart coastwise separated by a ravine (Fig. 2). The deposits of the outcrops are easily correlated thanks to a gravelly marker layer in the base of the upper fine-sediment bed about 4 (V1) and 12 (V3) m in height for the eastern and western parts of the section, respectively.

It is established that this section does not display the assumed lateglacial and the subsequent Early Holocene deposits, but it covers most of the Late Pleistocene period. The upper part of the section consists of deposits spanning the time period from about 40 to 30 ka, and the lower part – from about 110 to 70 (V1) and from about 115 to 90 (V3) ka. This proves that interglacial (Prangli/Eemian) deposits correlating at least with the oxygen isotope substages 5d to 5a occur here. The presence of older deposits is expected in the deeper part of the section currently not available due to thick talus at the base of the outcrops.

On the basis of the pollen data a conclusion is made that the sands of the lower part of the V1 section dated by optically stimulated luminescence (OSL) at about 110 ka were deposited during the last interglacial.

Sedimentation of the deposits in the middle part of the V3 section occurred in an aqueous environment, probably, in a glaciolacustrine basin under severe climate conditions of the Järva/Weichselian time. In the lower part of these deposits at a depth of 10.7 and 8.8–9.2 m two

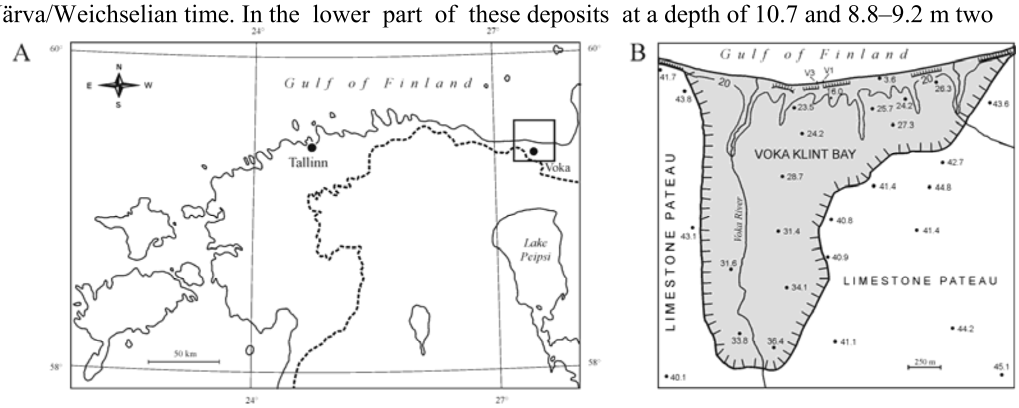

Fig. 1. A – location of the study area and the distribution of the Baltic Ice Lake about 11000 years ago (dotted); B – location of the Voka Klint Bay and the studied section.

interstadial intervals were recognised. The pollen spectra of these intervals are characterised by an increase of the forest component contribution.

The spore and pollen data have shown that the deposits underlying the Holosene soil accumulated in a fresh-water basin. It is clearly indicated by the abundance of algae (*Pediastrum* sp.), and also by the constant presence of the pollen of littoral aquatic plants occupying fresh-water basins today. In some samples investigated typical species of freshwater diatoms were also encountered (V.S. Gunova, pers. comm.).

The climate-chronostratigraphic data obtained from the Voka section were correlated with the results from the neighbouring and remote regions where on the basis of the palynological and electron spin resonance (ESR) studies an interglacial and 6 interstadials ESR-dated at about 145-140 to 70, 65, 56, 44, 32, 26 and 17 ka, respectively, were identified within the Late Pleistocene period.

Thus, the data already obtained during the present study show unambiguously that in contrast with the expectations to find and to study the Lateglacial-Early Holocene deposits (see e.g., Human impact... 2003) the greater part of the Late Pleistocene sequences correlating with oxygen isotope stages 4 to 2 (ca 70 to 25 ka, Bassinot et al., 1994) are to be found in the Voka section. At that, the upper part (A) of the section (Fig. 2) represents the last ca 10-ka time interval predating the Late

Weichselian glacier advance. It offers a unique opportunity to study this time period in the greatest detail.

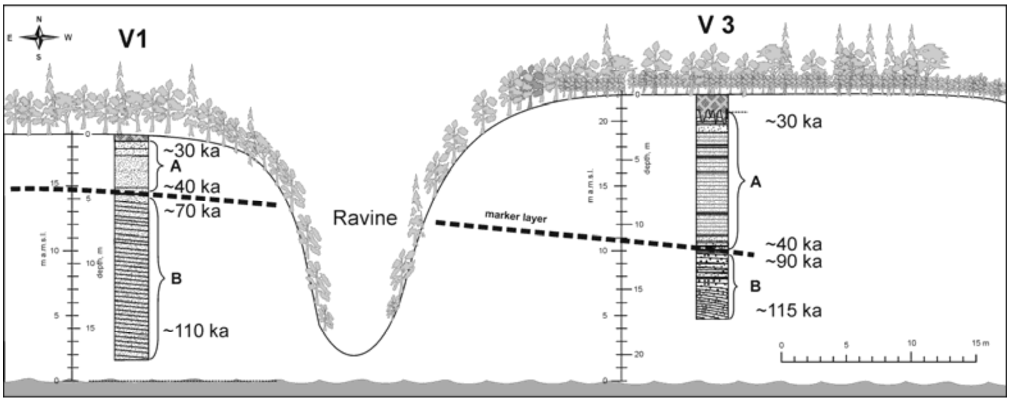

Fig. 2. The Voka outcrop. Subdivision into lithological complexes and age constrains according to OSL-analyses.

The lower part (B) of the V1 section seems to hold the border marking the transition between the palaeoenvironmental conditions of the Last Interglacial *s. lato* (OIS 5) and those of the Last Ice Age (OIS 4). This is extremely important in the context of large-scale chronostratigraphical correlation and palaeoenvironmental reconstruction, especially because such kind of key deposits are known to be very rare in the Baltic region.

The study is supported by Grants No. 5440 and 6112 from the Estonian Science Foundation.

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HOLOCENE PALEOENVIRONMENTS OF THE CENTRAL KOLA PENINSULA, RUSSIA, AS INFERRED FROM RADIOCARBON, DIATOM AND PALINOLOGICAL DATA

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The European Arctic of Russia underwent drastic changes since the last glaciation when Kola Peninsula and the west coast of the White Sea were covered by the thick Fennoscandian continental ice sheet, and represent an area of intensive glacial erosion and isostatic uplift. Not much is still known about Holocene climate-driven evolution of landscapes and environments in the Central Kola Peninsula. This study based on radiocarbon-dated sediment cores, which were obtained from the boggy and lake sediments in onshore zone of the Lake Umbozero (Figure 1), and detail diatom and palynological investigations of sediments provides the first insight into the short-term temporal variability in environments of this area during the postglacial time.

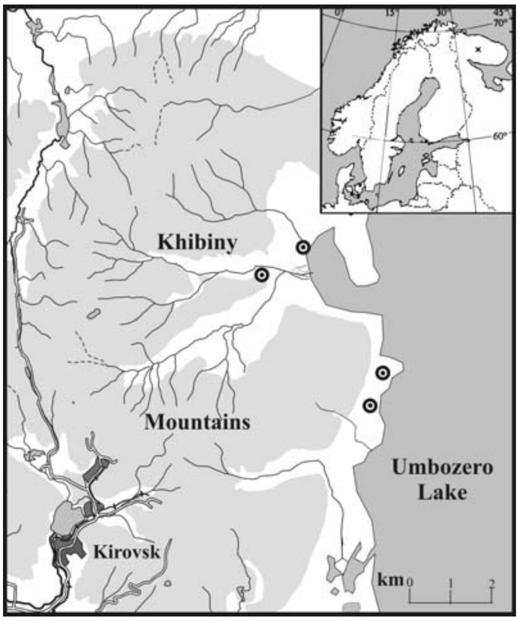

Figure 1. The sketch map of the area studied by expeditions of Geographical faculty of Lomonosov Moscow State University in summer 1999-2003. The location of peat cores examined by diatom and palynological analyses.

Large depressions occupied by lakes (Imandra Lake, Umbozero Lake, Lovozero Lake) and mountains (Chuna-tundra, Khibiny Tundra, Lovozery Tundra) are usual for the Central Kola Peninsula. The Umbozero Lake coast is one of the poorly investigated areas in Khibiny Mountains. This area is located in the northern part of the boreal forest belt. Spruce forests with birch and grass, mosses and sphagnum dominate the area. Pine forests and bogs are found in some locations.

Geological structure and relief of this area were studied by expedition of Moscow State University carried out in Central Kola Peninsula in summer 1999-2003 (Romanenko et al., 2004).

The sedimentary sequence of 20 peatbogs was investigated. Herbaceous-sphagnum string bogs and lichen-moss-shrubs bogs with peat mounds are very common for Umbozero Lake area. The thickness of peat changes from 0.5 up to 3 m. According to detail radiocarbon age chronology sediment cores used in this study encompasses the last ~ 9,5 ka. The beginning of peat accumulation corresponds to the Late Boreal and Early Atlantic (7500-8000 years BP). The most intensive lateral growth of bogs took place at Late Atlantic (4500-6000 years BP). The interruptions in peat accumulation are connected with dry climate of Early Atlantic and Late Subboreal.

Four sediment cores were taken for diatom analysis and one core was investigated by palynological analysis (Figure 1). Diatom and pollen-and-spore assemblages are abundant and taxonomically diverse from all studied cores. The distribution parrens of different ecological groups of diatoms are characterized by a high variability throughout the cores sections, reflecting changes in hydrology and environmental conditions at the study area under postglacial warming and climatic fluctuations.

The following major events were established in the development of paleoenvironments during Holocene:

1) End of Late Dryas and Preboreal was characterized by deglaciation and lake formation within depressions under cold-climate conditions. The characteristic features of this time were permafrost processes and active slope erosion. According to palynological records landscapes at the study area of Khibiny Mountains were represented by tundra and forest-tundra with willow-shrubs, mosses and sedge assemblages.

2) Boreal time was marked out by regressions of lakes (e.g., Lake Umbozero) under warm and relatively dry conditions. Pine forest gradually dominated in landscapes, and tundra vegetation was partly reduced.

3) Late Boreal and Early Atlantic was characterized by overgrowing of small lakes and starting of peat accumulation. Dry climatic conditions of the Early Atlantic caused the interruption of peat accumulation in many peatbogs between 7,0 and 5,0 ka BP.

4) Climate of the Middle and Late Atlantic was warm and moisture. Mixed forests with spruce, pine, birch and boreal broad-leaves flora were dominant. This time was characterized by increase in peat accumulation and rapid lateral growth of bogs.

5) During Subboreal climate was getting more continental, both colder and drier. Permafrost formed on peatbogs. Shrubs and hypoarctic assemblages appeared in vegetation associations. A small intensity and the alternations in peat accumulation are usual in Late Subboreal.

6) Subatlantic time was marked out by increase in moisture. Partial degradation of permafrost on peatbogs was typical for the second part of Subatlantic. Spruce and birch forests with ahrubs hypoarctic assemblages and grass, mosses and sphagnum bogs dominanted in landscapes under relatively warm conditions.

This work was supported by Russian Foundation for Basic Research (Project 05-05-64872).

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SEDIMENTS AND LANDFORMS OF NORTH VIDZEME – EVIDENCE OF GLACIAL SURGES

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The territory of the study includes lowlands and elevations of the North Latvia.

Sediments. On the lowlands there are typical laminated structures within gentle hills (drumlins etc.), that has been made of alternating layers of sand, gravel and pebbly deposits with thin diamicted lenses of silty and clayey material, almost without thrust slices. On the top of sections, as a rule, lies sandy loam with admixture of gravel and pebble, the deposit, traditionally considered as basal till.

Distinct grain size differences of layers testify of short distance of deformation.

Bad sorting of sediments, absence of cross-laminated and perluvium (lag) layers, massive composition of some parts of sections indicate the high saturation of sediment flow beneath the glacier (as far as regimes of floating earth and turbidites).

Little thickness and very different composition of layers testify of short terms of its origination. Lack of the thrust slices and uniform deformation testifies of very high pressure of meltwater beneath the glacier.

On the uplands the sand and gravel quarries are situated within the dome like hills. There sand deposits dominate. Greater part of the sands have massive texture that testifies of floating earth conditions of generation.

Landforms. The maps obtained from the analyze of the topographic maps 1:10 000 exhibit the set of landforms formed at the subglacial conditions. Strong evidence of action of subglacial currents is the pattern of medium scale erosion landforms.

Gentle forms (**valleylike depressions, drumlins**) are older; oriented according the glacier movement. Smaller **transverse valleylike depressions** are younger; oriented in different direction. Youngest, more articulate and better preserved forms are **subglacial valleys (channel valleys – "senlejas"), eskers, kames, dome like hills**.

Glacial surges. The theory of glacial surges is best explaining the features that we observe. It is hard to establish how to consider surge sediments and landforms – as glacigenic or glacifluvial and erosion or accumulative because both sides of the processes are involved.

Surges were alternate with longer periods of glacier stagnation. Those processes in the territory of North Latvia were part of normal evolution - not the events of catastrophic character.

Beginning. Meltwater at the base of glacier couldn't find free leakage. Due to the pressure of overlying ice sheet subglacial water was under very high pressure (10-100 atm) and made overlying glacier **buoyant**. That led to disappearing of friction between glacier and underlying sediments. In the situation of underlying soft sediments, the glacier it was becoming buoyant together with the appended frozen in sediment sheet. The surge was beginning.

Active stage. Erosion persisted within thin layer of meltwater that separated the glacier from underlying substratum. Within the North Latvia lowland erosion formed the divergent-type network of gentle channels. Elongated hills arose between channels as erosion remains with some involvement of accumulation on the top of the forms.

Within the Middle Latvia lowland flat erosion lowered subglacial surface and made gentle - wide and shallow depressions.

The buoyant part of glacial lobe and tongue, moved in the direction of glacier margin. Highly variable regimes of hydrodynamics and pressures persisted. Water streams had very high saturation of drift; sometimes in the regime of floating earth and turbidites. Clastic material had been carried in the direction of ice-divides and ice margin.

Ending. Cinematic wave approached ice margin and subglacial water got free outflow from the glacier. That led to decreasing of pressure of subglacial water and the base of glacier tongue came to closer contact with underlying substratum.

Pressure and movement of the glacier diamicted the upper part of the sequence and involved into the movement. Part of the moving material was changed into the semi liquid mud. The mud mass had been pressed into the emptiness (holes and fractures) amongst the glacier and underlying sediments. Then it gradually loosed water content and mobility and got orientated or massive textures and orientation of particles. The later material traditionally has been considered as basal till deposited by lodgment processes. Hills that arose during the previous stages were deformed by moving glacier and got characteristic features of drumlins (on the lowlands) and dome like hills (on the uplands).

Post surge stage. Movement of the glacier gradually stopped. Pressure of water column was falling and the network of subglacial channels was reformed to converging pattern – with the main meltwater streams lying in deeper subglacial valleys. As a rule one subglacial meltwater river lay in the axial part of the glacier tongue. The final stoppage of the glacier marked the end of the surge cycle and the transition to the next surge cycle. Subglacial valleys, eskers, small kames and outwash plains were formed.

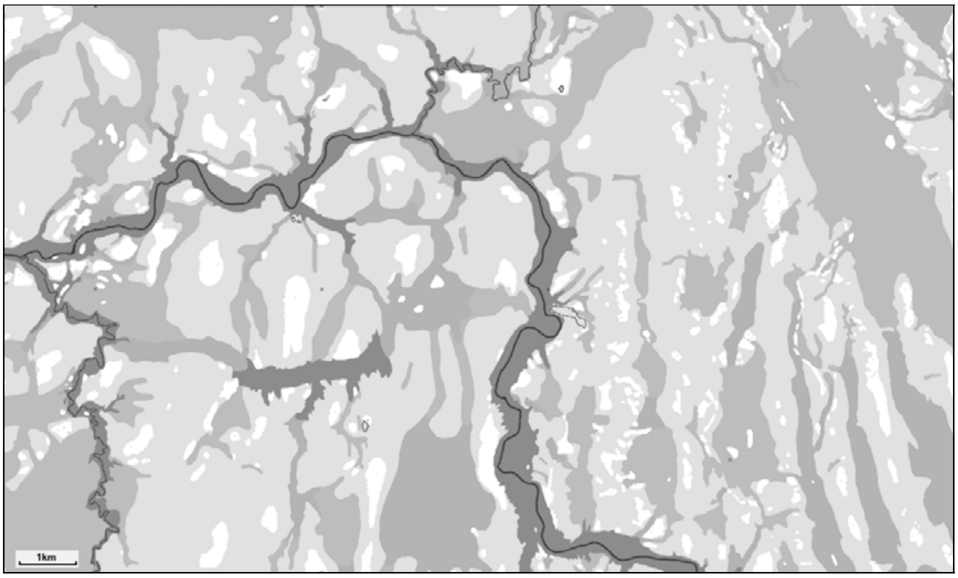

Fig.1. Pattern of the landforms to the north from Mazsalaca.
In white – positive landforms (drumlins etc.), grey – valleylike depressions;
darkest - subglacial valleys.

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LATE PLEISTOCENE SEDIMENTARY SUCCESSIONS AND EVOLUTION OF THE MIDDLE NEMAN FLUVIAL SYSTEM

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Geosites in the Belarusian part of the Middle Neman area contain a rich information on sedimentary environments and a development of hydrographical network within the drainage basin of Neman – one of the largest rivers of Central Europe. The Middle Neman region can be considered as a key area for studying of fluvial sequences and river system evolution influenced by Pleistocene glaciations. Generally, the Quaternary sequence of the area represents a quite consistent repetition of glaciolacustrine and glaciofluvial beds and tills. The Quaternary thickness varies from 80 to 140 m, with its maximum in the deepest part of the Neman bedrock depression, convincingly decreasing towards the peripheries of the depression. The remarkable feature of the Quaternary structure is a wide occurrence of thick glaciolacustrine series of the Middle and Late Pleistocene Glaciations. These series form several vari-level beds. The largest glaciolacustrine basin, Skidel periglacial ice-dammed lake, existed during the last glaciation. Its sediments formed the present surface of the Neman Lowland. These deposits are exposed in the Neman river banks (Bogatyrevichi, Dubna, Lunna, Mosty and many other sites). Their stratigraphical position is clearly defined due to presence of numerous sections with organogenic sediments of the Eemian Interglacial and the Weichselian Interstadials studied in this area. However, a study of sediment succession as a whole, as well as lithofacies analysis has been less developed. Last years, such a study was done for the best stratigraphically defined sites with fluvial and glaciolacustrine deposits in order to reveal sedimentological records of the Late Pleistocene river evolution. Studied successions of lithosomes and lithofacies were the base for correlation of sections, as well as for reconstruction of changes of sedimentary environment both in space and time.

Numerous profiles with Eemian deposits represent accumulations of isolated sedimentary basins existed throughout the Interglacial. According to available sedimentary records, there is no sign both in exposed and buried sections which could be interpreted as fluvial sediments of a large river valley like Neman. A development of Neman as a fluvial system began during the last glaciation. It was connected with existence and consecutive lowering of water level of the Skidel extraglacial ice-dammed lake that was a part of the Neman glacial lake system. As recorded in sediment successions, there were several 'fluvial' and 'lake' episodes due to periodical damming of periglacial streams and the Skidel lake runoff.

Lithofacies arrangement and their correlation allow to recognize typical lithosomes reflecting the Weichselian geological history of the area. The oldest lithosome represents fluvial sediments deposited by a stream with unstable hydrodynamic regime. In general, change of lithofacies upward this lithosome indicates decreasing in stream energy. Presence of horizontally laminated well-sorted sands within cross-laminated sequence allows to suppose that the stream was dammed periodically most probably due to ice sheet advance. Most likely this fluvial sequence was formed in a braided river with prevalence of aggradation processes in periglacial conditions. That might have been caused by change of threshold just before the maximum advance of the last ice sheet. Fluvial sedimentation was changed by glaciolacustrine one during the ice sheet maximum advance and retreat. Glacial lake deposition is represented by several rhythmite successions which have been correlated site by site. The lower succession consists of sediments corresponding to initial phases of basin sedimentation where a water discharge and amount of clastic material were relatively high. It changes upwards in the 'clay' rhythmite succession of the high level phase of the Skidel lake, 'clay-sand' sequence and 'sand' sequence of level drop phases. Successions are subdivided by drainage layers of five episodes of lake level drops. The Neman present watercourse within the area was formed during the final phases of the last glaciation and the Late Glacial.

THE DEVELOPMENT OF QUATERNARY DEPOSITS IN THE TYRNÄVÄ REGION OF NORTHERN FINLAND

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The continental ice sheet receded from the Tyrnävä region about 9,800 years ago. Towards the end of glaciation, till, moraine and glaciofluvial landforms were formed here by an ice sheet flowing from NW to SE. The ice finally receded during the Ancylus Lake Stage. Reddish-grey varved clays were deposited in this vast ancient lake, but were later covered by younger sediments. The Litorina Sea stage of the Baltic began around 7,500 years ago, when the water became more eutrophic and biological productivity increased rapidly, due to a combination of the warmer climate and inflows of saltier water. Sediments laid down in the Litorina Sea therefore typically consist of gyttja rich in organic material. As the land slowly rose out of the sea the coastline receded, leaving behind raised beaches. Until about 2,700 years ago the River Oulujoki flowed much further south than its present course, depositing a lot of material around Tyrnävä. The most recent process affecting the area's soils has been paludification, which in most cases has been primary – with mire vegetation occupying the land as soon as it emerges from the water.

The moraine features of Tyrnävä are mainly basal tills, which have generally been covered by younger sediments, although they are found on the surface in places. Fluvial deposits form a considerable proportion of the area's soils. The fine sands, sandy silts and some of the sandy deposits shown on the maps (Fig. 1) were laid down in the ancient delta of the River Oulujoki, and later reshaped by the wind and waves. The mainly silty marine sediments were deposited during the Litorina Sea Stage. The silts shown on the map are typically blackish, due to the presence of iron sulphides. Clear signs of wave action include raised storm beaches, which largely consist of sand, and are 1-3 metres high and range in length from about 0.5 km to 2 km. The peat deposits found around Tyrnävä are very thin, which is typical of coastal regions. The peat is largely made up of decayed sedges, although more nutrient-poor sphagnum bogs can also be found.

The soil stratigraphy has been surveyed in detail at two sites. The Lassila research site NW of Tyrnävä is representative of the Oulujoki deltaic areas, where there are few topographic variations. Research at the other research site, at Rahkasuo east of Tyrnävä (Fig. 1), has focussed on peat deposits laid down after the subglacial and subaquatic stages. These deposits illustrate how mires can still reshape the soil morphology, especially in lowlands.

The soil profile examined at Lassila was 12 metres deep, and consisted throughout of fine sands intermixed with varying amounts of silt and clay. Depositional conditions were assessed by analysing the sediments' siliceous algae content as well as through grain size analysis. Changes in the occurrence of siliceous algae associated with different biotypes suggest that materials have been redeposited; and increases in the occurrence of aerophilic and freshwater siliceous algae towards the surface also indicate that materials have partly been transported by rivers.

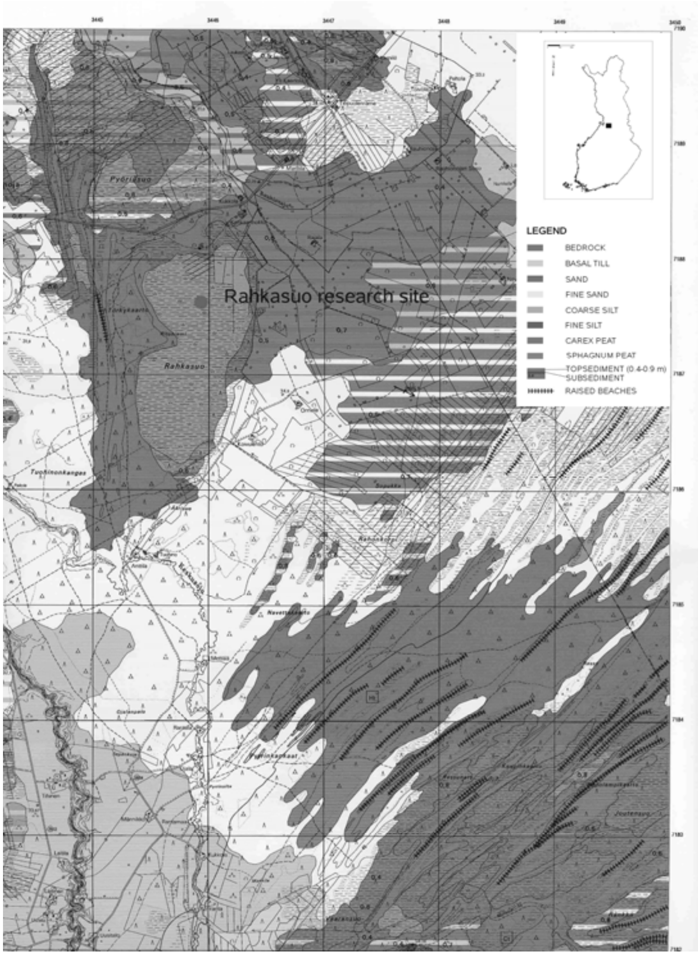

Figure 1. Map of Quaternary deposits around the Rahkasuo research site. Note the raised beaches in the SE. Base map © National Land Survey of Finland, permission No. 13/MYY/05.

The peat deposits at Rahkasuo were 1.95 metres deep, overlaying fine sands. Peat stratigraphy and pollen analyses indicate that the area was paludified primarily as soon as it emerged from beneath the waters of the ancient sea. The mire gradually evolved over time, becoming less rich in nutrients as sedges and grasses were replaced by the sphagnum mosses that still grow on the surface today. According the pollen analyses birches were the dominant trees at first, but later pines became more common.

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DEEP BURIED VALLEYS IN THE NORTH SEA: A SPECTACULAR PRODUCT OF SUBGLACIAL MELTWATER EROSION?

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New high-resolution 3D seismic data from the Danish sector of the North Sea reveal abundant, spectacular valleys of Quaternary age. In two areas studied in detail, buried valleys occur at various depths throughout the Quaternary succession. In the Sirinor-96 area, 15 valleys were mapped with lengths up to 31 km, maximum depth of 350 m, maximum flank angle of 32° and longitudinal profile gradient of up to 13°. In the Agip area, 22 valleys were mapped with a maximum length of 34 km and depth up to 240 m (e.g. Fig. 1).

Valleys in both areas are characterised by highly undulating bottom profiles with frequent overdeepenings and sills, they either have one principal channel of bifurcate, and they often begin and end abruptly without obvious continuation. No catchment areas of the valleys can be delineated and no clear directional preference was noticed, but the biggest valleys seem to follow a NE-SW trend. They are filled with loose, sorted sediments possibly including tills and often intersect at different levels. At least 11 valley generations, often intersecting, were mapped in the Agip area. Due to the lack of stratigraphic control, the age of the valleys cannot be better constrained at present.

Based on the morphological, geometrical and partly geological characteristics it is suggested that the valleys are relict subglacial meltwater channels (tunnel valleys) possibly formed during multiple glaciations. This study, in accord with numerous investigations from on-shore central and northern Europe, stresses the importance of erosion by pressurised meltwater under past ice sheets as a geomorphic agent. In terms of palaeoglaciological conditions, such incisions indicate a surplus of meltwater at the ice-bed interface in relation to the drainage capacity of the substratum and thus suggest a temporarily unstable behaviour of the ice sheets.

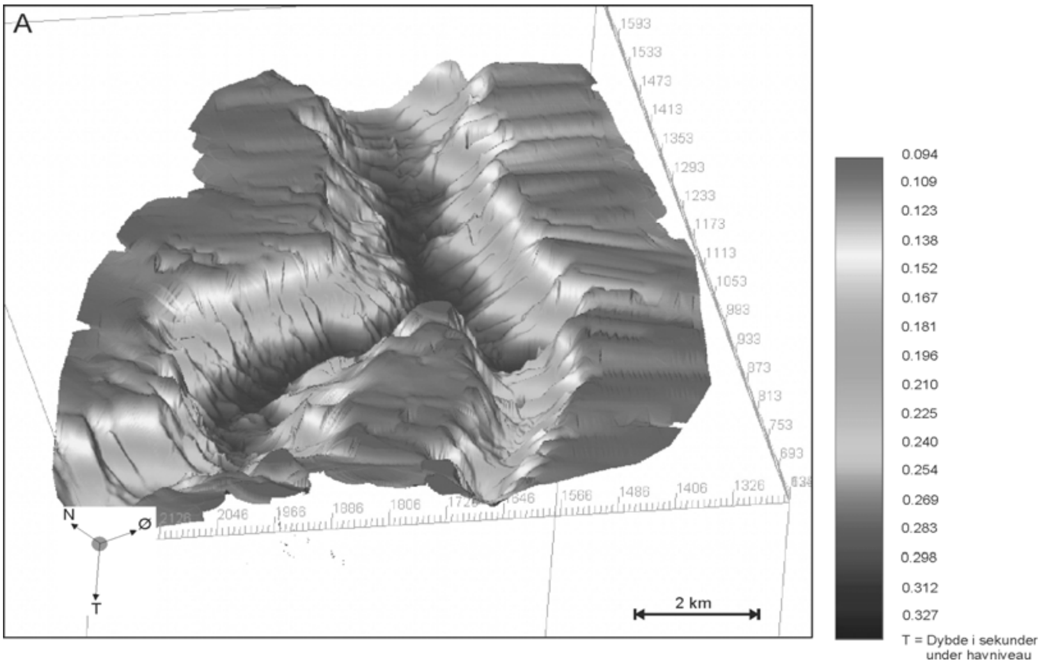

Fig. 1. A buried valley from the Agip area, North Sea, interpreted from a 3D high-resolution seismic volume. Relief given in seconds TWT under sea level.

DATING WEICHSELIAN ICE ADVANCES IN POLAND: IS THERE EVIDENCE OF A WIDESPREAD ISOTOPE STAGE 4 GLACIATION?

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Large continental ice sheets are known to have repeatedly expanded during the Weichselian glaciation, but their timing and extent remains contentious both in Eurasia (Mangerud et al. 2002; Larsen et al. 1999) and North America (Clark & Mix 2002). There is a broad consensus that major advances occurred during marine isotope stages 5d, 4 and 2, however the delineation of particular ice limits, synchronicity of ice advances in different areas and their response to orbital forcing remain uncertain despite concentrated efforts in recent years (e.g. Ehlers & Gibbard 2003), and models synthesizing ice sheet evolution (e.g. Boulton et al. 2001) still have relatively coarse resolution.

Problems with constraining glacial events of the Scandinavian Ice Sheet during the Weichselian glaciation are perplexing also in the type area of this glaciation, along the Vistula (Weichsel) River in central Poland (Mojski 1995; Marks 2002; Wysota et al. 2000). Dating control of the age of ice advances and retreats is all but lacking. Located south of the Baltic Sea at the major ice advance axis of the SIS, this is a key area to study the ice sheet fluctuations and evaluate its response to external climatic forcing.

In the last two decades the views on the Weichselian stratigraphy and ice sheet dynamics in the Polish Lowland have been polarised in two conflicting hypotheses (Wysota 2002):

1. The first model, based mainly on studies in the lower Vistula River considers three ice advances, i.e. the Torun advance in the Early Weichselian (MIS 5d), the Swiecie advance in the Middle Weichselian (MIS 4) and the Main advance in the Late Weichselian (MIS 2) (Drozdowski & Fedorowicz, 1987; Galon 1982; Makowska 1992, 1994; Mojski 1982), separated by ice-free interstadials. This model was subsequently adapted for the whole central and eastern part of northern Poland (Marks 1988, 2002; Lindner & Marks 1995).

2. The competing model that assumes just one advance of the SIS, during the Late Weichselian (MIS 2), up to the maximum extent position in western Poland (Leszno phase), followed by ice retreat with several local re-advances. This scenario builds upon studies in the Great Poland Lowland (Kozarski 1980, 1988) and in the Konin area (Stankowski 2000).

This paper presents first results of an on-going project in which Weichselian sediments in central and northern Poland are dated with the OSL method supported by radiocarbon datings in order to shed new light on the controversial MIS 4 glaciation in this area. In 2004, a total of 53 OSL samples and 6 radiocarbon samples were dated from sites spread along a N-S transect covering the area of the Weichselian glaciation from its maximum extent to the vicinity of the Baltic Sea coast. Wherever possible, sand samples bracketing till units were dated. Despite a wide geographic spread, the ages obtained thus far do not yield any unequivocal evidence of possible MIS 4 glacial sediments, which seems to support the second model as above. More sampling is foreseen for 2005 before concluding remarks can be formulated.

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SUBGLACIAL DRAINAGE SYSTEM UNDER AN EAST-BALTIC WEICHSELIAN ICE STREAM: DISTRIBUTION OF ESKERS AND TUNNEL VALLEYS IN ESTONIA

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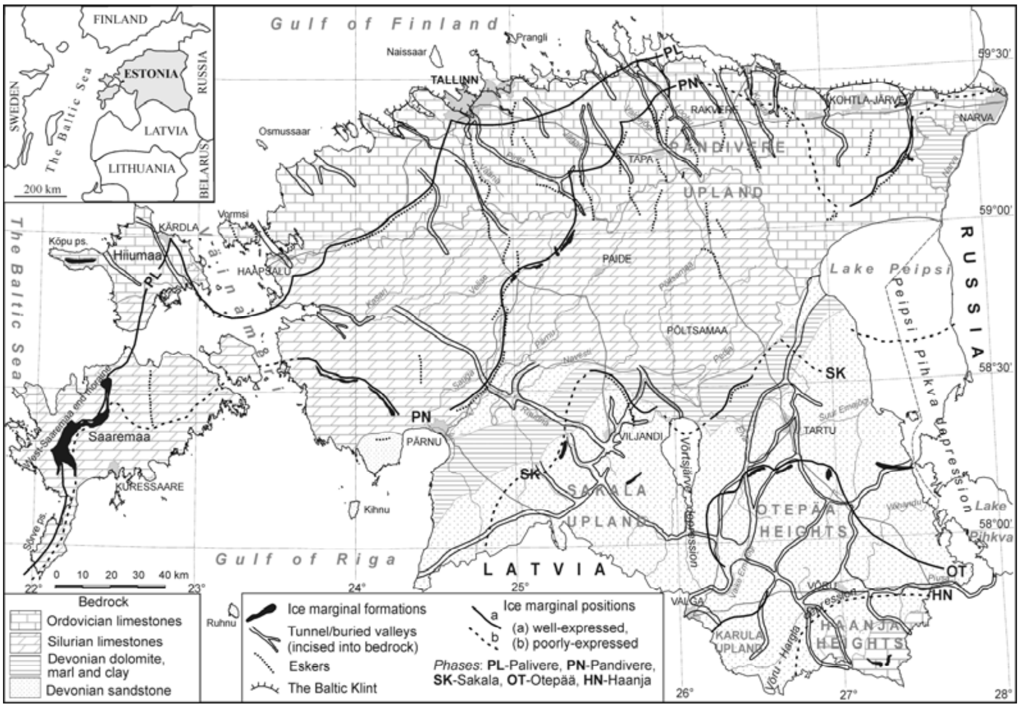
The melting of ice sheet produces large volume of meltwater which exerts a profound influence on dynamic behaviour of the ice body and glacial landform genesis. The bulk of meltwater concentrates at the glacier bed, creating and maintaining subglacial drainage systems. Subglacial meltwater flow can occur in channels and tunnel valleys, or in more dispersed ways such as pore water flow as groundwater flow, thin films or braided canal network (Benn & Evans, 1998). Channelized drainage develops when not all basal meltwater can be evacuated as groundwater flow through the substratum. Water will be confined to channels or conduits forming efficient drainage pathways capable to discharge large water volumes in a short time. As a result tunnel valleys or different channel fills (such as eskers) are formed. The timing and style of meltwater release are based on morpho-sedimentary observations of these bedforms.

In Estonia the bedrock is strongly dissected by deep ancient valleys (Fig. 1), mainly filled with aqueoglacial deposits, or stratified with one or more till beds (Tavast & Raukas, 1982).



A number of them are inherited from the pre-Quaternary river drainage, others developed during the glaciation cycles. The valleys are found either at the present land surface as elongated steep-sided incisions or are buried under younger sediments. Most of them drained subglacial or proglacial meltwater of variable energy and probably high velocity during the retreat of one or more ice-sheet. Distribution and morphology of the valleys are well known, validated by borehole and geophysical data. However, very little is known about the nature of meltwater sediments filling the tunnel valleys because of few direct sedimentological observations. Following the bedrock lithology, two different valley systems were evolved in Estonia; in the carbonaceous bedrock area the valleys are distributed by aside and arranged mostly from NW to SE; in the Devonian sandstone area they have more uneven distribution making up a complicate jointed drainage network.

Eskers in Estonia are located mostly in the northern part of the territory and are associated with the Ordovician and Silurian carbonaceous bedrock. Only few small eskers can be found in the Devonian sandstone area. Two general types of esker systems have been observed; eskers formed subglacially in tunnels, and eskers formed ice-marginally in deltic or fan environments. Detailed morphology and sedimentology of eskers in Estonia was investigated already in the 1960s (Raukas *et al.*, 1971). The structure and stratification of esker deposits indicate non-uniform sedimentation leading by fast changes in meltwater volume, energy and velocity. For determination of geomorphic and sedimentary continuity and the nature of meltwater channels, more detailed observations are needed, especially about contact zone between the sediments in channels and the surrounding sediments or bedrock.

Both valleys and eskers in northern Estonia are arranged in a subparallel pattern, mostly from NW to SE, i.e. subparallel to paleo-ice streams reflecting former meltwater flow towards the ice margin (Fig. 1). Several esker systems are formed in relation with tunnel valleys, occurring within their limits, superimposed on valley infill, or nearby. Some eskers and valleys were probably developed as a successive formation by a number of meltwater flow episodes. In southern Estonia, where the typical eskers are rare, the bulk of meltwater was probably drained through the tunnel valleys. It is very unlikely that all the meltwater was drained through the permeable substratum as groundwater. Futher detailed studies are needed which incorporate both morpho-sedimentological data and hydraulic properties of substratum to infer a model describing subglacial meltwater drainage systems in different substratum conditions in northern and southern Estonia.

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LAKE SEDIMENT COMPOSITION CHANGES DURING THE LAST 700 YEARS

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With the aim to find laminated lake sediments in Estonia, the model proposed by Larsen *et al.* (1998), which relates the lake's surface area and maximum depth to the presence or absence of laminated sediments was used and the most prospective lakes were selected and cored at the end of the 1990s. The basins containing laminated lake sediment are deepwater thermally stratified lakes in the hummocky terrain of South-East Estonia with steep slopes and river/stream inflow. Three lakes (Lasva, Verijдrv and Txugjдrv) with annually laminated sediment sequences from SE Estonia were selected out of more than 65 studied lakes for comprehensive investigation. In the early spring of 2001 and 2002 four parallel sediment cores were extracted from the central deepest part of lakes with a crust-freeze corer from the uppermost water-saturated sediment and two overlapping sediment cores from the rest of the sequences by Belarus peat sampler. Sediment was photographed after coring for later digital image processing. The varves were counted directly from the sediment surface and from the digital images. As profiles contain possible slumping, accelerator mass spectrometry (AMS) ^{14}C and ^{210}Pb dating were also included, to secure a reliable chronology. To study the organic and mineral matter and carbonate content loss-on-ignition (LOI) method was applied.

The sediment profiles of Lasva, Verijдrv and Txugjдrv have been divided into three statistically significant lithological units on the basis of LOI results, which illustrate a specific pattern, characterised by several reductions in the content of organic and mineral matter during the last 600–700 years. Carbonate content is low and stable in Verijдrv and Lasva profiles, higher in Txugjдrv where it fluctuates between 14–29%.

Unit I, which lasted up to AD 1650-1760, is characterized by the highest content of organic matter. Mineral matter input in this unit was considerably diminished, carbonate content stayed low. The 11-year and 30-year moving average graphs of Verijдrv display sharp reduction in the organic matter between AD 1250–1300 and only moderate decrease around AD 1250 in the other profiles. The beginning of slow and long-lasting decrease in organic matter was not simultaneous in different lakes: at AD 1350 in Rxuge, 1550 in Lasva, and 1650 in Verijдrv. It ended about 1850 years ago in all lakes. Climate reconstruction based on local proxies displays low temperature and severe winters around AD 1600 (Tarand, Nordli, 2001) and decreased temperature trend in Fennoscandia obtained from tree ring data (Mann, 2002); this coincides well with diminishing trend of organic matter in the studied sediment cores. According to the reconstruction, climate ameliorated for a short time at AD 1560, which is traceable in the 11-years moving average curve of all profiles. Influx of terrigeneous compounds, which mainly depends on the external factors, including lake level fluctuation, soil erosion and agrarian activities on the lake catchment, increases since AD 1550 in Txugjдrv and Lasva. It is in good agreement with the rise in the frequencies of cereal pollen in Txugjдrv diagram (Veski *et al*., 2005).

The second unit (II), represented by laminated silty gyttja, is thickest in Lasva profile (115 cm), in contrast to 77 cm in Verijдrv and 60 cm in Txugjдrv. Its formation lasted 190–320 years, which places the unit's upper limit at ca AD 1940-1970. This unit differs from the others by reduced organic (less than 30%) and increased mineral matter content (up to 86%). Carbonate content is low, around 5% and rather stable throughout the entire unit. One 10–15 cm thick slump and thick clayey varves are intercalated into the studied sediment sequences and interrupt the regular lamination of this unit. As slumps in lakes Txugjдrv and Verijдrv were formed at the same time, the same reason could be expected – heavy rain or water level regulation. Sedimentation and accumulation rate increased mostly on the account of inwash of mineral matter into lakes, due to more extensive erosion. The rapid rise of mineral matter in Verijдrv at ca AD 1725 is in good accordance with the pollen record, which shows a sharp increase in cereal pollen and, thus, enlarged crop cultivation as well as a drastic demographic expansion.

The climate reconstruction shows severe winters in Estonia at the end of Little Ice Age and large temperature variations between AD 1780–1820 with anomalous cold winters at AD 1780, 1800, 1803 and 1809 interrupted by temporary warming at AD 1730–1760 (Tarand, Nordli, 2001). The organic matter curves of Lasva and Verijдrv display a moderate increase during the above mentioned immediate climate amelioration at about AD 1750 and Verijдrv curve records also a sharp decrease in the content of organic matter during the following anomalous cold winters (AD 1780–1820). Besides climate factors, there are several local factors, which, beyond doubt, influenced the mineral matter inflow: bioproduction, and hydrology of the lakes, for example, are reasons because of which could be the thick (1–5 cm) clayey varves present in all sequences. As the timing of clayey varves in laminated sequences differs, they are interpreted as erosional events related to human induced changes in the catchment. The pollen diagram from Verijдrv shows extensive arable farming between AD 1700–1930, when rye cultivation spread widely. Slash and burn agriculture was one of the main agricultural practises, as could be conclude from the drastically increased content of charcoal particles (from 5% to 40%). It coincides well with the demographic data from the Kasaritsa manor, where the number of inhabitants between AD 1721 and 1850 increased 3 times and the number of farms doubled. Sharply increased mineral matter influx refers to the increased soil erosion in combination with agricultural activities and water level changes of lake.

The upper unit (III) is represented by silty gyttja, which is slightly calcareous in Txugjдrv and covers the time span of 32-63 years. Its thickness is quite stable in all lakes (30–35 cm). Specific to this unit is an upward growth of varve thickness and increase in organic matter content from 10–20% to 30% accompanied by a rise of carbonates in L. Txugjдrv profile. Mineral matter content diminishes from 70–80% to 60% caused by decreasing arable farming and closing up the landscape, concluded from the photos of the 1930s, increased AP and decreased NAP pollen and charcoal frequencies. Such a decline in land-use was a result of agrarian policy and usage of larger fields on more gentle topography, where heavy modern machinery was easier to manage and land more effectively used. The small open spots on the hillocks, once tilled, were overgrown with shrubs and trees, especially during the last 15 years. The marked rise in the content of organic matter during the last 50 years reflects a rapid increase in the organic production in the lakes caused by intensive fertilising of fields, which brought along eutrophication and higher nutrient load into the lakes. Higher organic production in the lakes also refers to climate warming which is instrumentally shown.

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THE MIDDLE WEICHSELIAN INTERSTADIAL: NEW OSL DATES FROM SOUTHWESTERN FINNISH LAPLAND

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While studying Quaternary geomorphology, sedimentology and stratigraphy in southern Finnish Lapland many till-covered, stratified sand deposits were observed. Many of them were northwest southeast oriented esker formations, obviously from the Early or Middle Weichselian. Some deposits were interpreted to be glaciolacustric delta or shore deposits, which were supposed to be suitable for dating purposes. For estimating the age of those sediments, samples were collected and analyzed in the Dating Laboratory of the University of Helsinki using OSL method. Study areas lie in southwestern Lapland: Liakka, Sihtuuna and Sompujärvi (Fig. 1).

The glacial morphology of the Liakka area is mainly composed of a northwest southeast oriented drumlin field, which is a relict of the earlier glacial phase of the Weichselian glaciation. The Late Weichselian ice sheet has covered the area only slightly smoothing the ground. Because the cold-based centre of the glacier situated over the area during the Late Weichselian maximum, the glacial erosion was only modest preserving older morphology. During the latest phase of deglaciation, thin till sheet, about 1-2 metres thick, was deposited over the pre-existing till sheets. Over five metres thick sand deposit with planar bedding was observed under 1.5-2 metres thick till sheet from the old sand/gravel pit. Preliminary estimations give the age of about 30,000 years for the sand.

In the Sihtuuna area, there is the field of minor ribbed moraines, which is called the area of Sihtuuna moraines. The field is consisted of ridges, which are in north-south direction, perpendicular to the latest glacial flow direction with intervening mires. The ridges have the dimensions of 100-500 metres in length, 10-50 metres in width and 3-5 metres in height (Aario et al., 1997, Sarala, 2003). The ridge morphology was formed during the early stage of deglaciation, in the boundary between the cold- and thawed-bed glacier. The stratified sand deposits with planar bedding, large-scale cross bedding and small-scale ripple-drift cross-lamination were observed as an inter-till layer in several sections dug by a tractor excavator. The thickness of sands is about 1.5-2.5 metres. The variation of ages in three dating samples taken from the two test pits was great: one is about 35,000 and the others substantially older.

The Sompujärvi area is situated on the boundary between the Peräpohja Schist Belt and the Pudasjärvi Granite Gneiss Complex. It is dominantly hilly area with a great topographic fluctuation. In a depression, till-covered sand deposit with gravelly interlayers was preserved. Planar bedding with some cross bedding indicates the deposition as a deltaic or fluvial environment. Age estimation for the sand deposit is about 39,000 years, although some older ages were also determined.

In spite of the great age range and the need of additional determinations, many age estimations younger than 40,000 years prove that the area of southern Finnish Lapland has been ice-free during the later stage of Middle Weichselian, in oxygen isotope stage 3. This interpretation is also supported by the TL ages clustering around 37,000 +/- 500 – 55,000 and OSL ages clustering around 41,000 +/- 2,000 – 66,000 +/- 5,000, which were done of the samples taken earlier from Kauvonkangas in Tervola and the area surrounding the towns of Kemi and Tornio (Hütt et al., 1984, Mäkinen, 1999 and 2005). Furthermore, the new age estimations presented here correlate well with the age determination of mammoth and reindeer bones (22,500-34,000) done, for example, from the basins of Iijoki River and Tornionjoki River in southwest Lapland (Ukkonen et al. 1999, Lunkka et al. 2001).

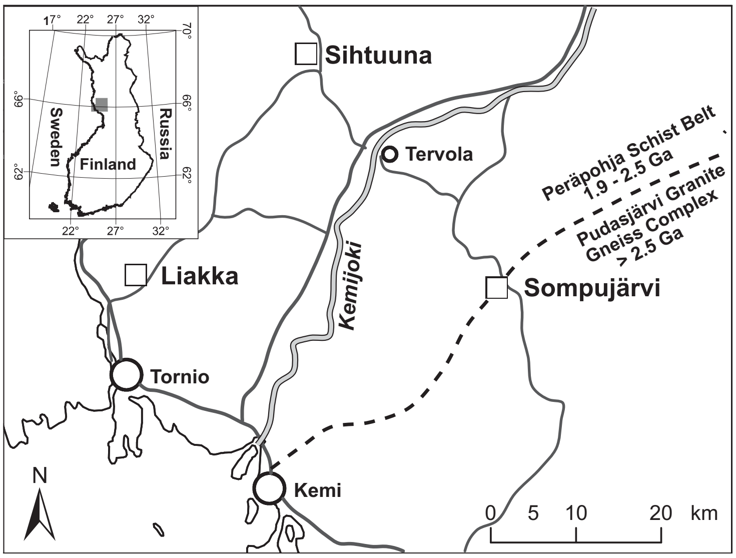

Fig. 1. The location of the test sites (smaller boxes) of Liakka, Sihtuuna and Sompujärvi in southwest Lapland.

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INTERPRETATION OF QUARTERNARY GEOLOGY PROCESSES IN THE NEW EXPOSITION OF NATURAL HISTORY MUSEUM OF LATVIA

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Department of Geology is one of the departments of Natural History Museum of Latvia that has 160 years long history. The exhibition acquaints the visitors with the general geology (historic geology, rocks and minerals), the structure of the Earth crust (mainly bedrocks) and natural resources of Latvia. The exhibition was created more than 30 years ago, therefore it is necessary to reconstruct it. It is determined by the following factors:

1. In recent years the geological collections have been enriched significantly that permits to cover various geological spheres;
2. The scientific approach has changed in specific geological branches;
3. Since the previous exhibition was formed, the museology has emerged as a separate science;
4. The new targets for the human life have been set: the society that is eager to learn have appeared;
5. The application of modern materials has enhanced the new trends and opportunities of visual design;
6. The application of advanced technologies has created new ways of presenting informative and visual material.

The above mentioned together with the experience and information obtained from the communication between the museum staff and visitors have produced the desire and need for the new exhibition.

The main aim of the new updated exhibition is to draw visitors' attention to the rocks that form the earth crust, encourage the learning of the conditions and processes of their formation. It is important to raise awareness about nature: what can we gain, why a sensitive attitude towards nature is necessary, what should be done to achieve it. The exhibition is expected to attract visitors of different ages and backgrounds, but the main target audience will be schoolchildren.

As regards the old exhibition, only one diagram and one show-case of specimens were devoted for Quarternary deposits. In the new exhibition one half of the hall is planned for the bedrocks of Latvia, the other half will house Quarternary deposits and processes. The hall is divided into separate sections by stylized show stratigraphie section.. This hall will not include fossils since they will be placed in the exhibition of palaeontology.

The new exhibition will present the following:

1. The extension and retreat of the ice cover in Latvia. Computer information. Absolute datings.
2. Real section of glaciotectonically deformed Quaternary deposits. Digital photo. One wall of the hall.
3. Relief landforms caused by the glacier and its melting water; the structure, a brief description, a particular photo of the place – installed in the plain-table.
4. Various tills in Latvia. Screen monoliths.
5. Deposits formed by the glacier and its melting water, interglacier deposits, mineral deposits. Specimens. The application of mineral resources, shown by several samples. Products.
6. Stratigraphic scheme of Pleistocene deposits. Information in the computer.
7. Division of the last glacial and Holocene, and characteristic features in Latvia. Information in the computer.
8. Spread of swamps and bogs in Latvia. The map in the computer. Spore pollen diagram of deposits from Kemeri mire.The diagram of Kemeri moor pollen pores.
9. Holocene deposits. Mineral deposits. Samples.
10. The development of the Baltic Sea. The recent coastal processes. Information in the computer.
11. The negative examples of deposit exploitation, and positive examples of recultivation. Information in the computer.
12. Geological and geomorphological natural monuments in Latvia. Map. Division. Description and pictures of each monument. Information in the computer.

In addition, the computer contains movies or their fragments on the theme. It is available for both an individual visitor in the form of the information in the computer screen and for the guided tours when a guide can project the information on the wall. A part of specimens will be accessible for visitors to touch or observe them in microscope. Schoolchildren will get task-sheets according to their school programs.

ENVIRONMENTAL CHANGES AND EUTROPHICATION FROM SEDIMENT RECORDS IN TWO LAKES OF SOUTH LITHUANIA.

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Varenis and Glebas lakes (south Lithuania) were studied by means of diatom, pigments, pollen, isotopes, and chemical analysis to test the environmental changes. These studies were a part of the project “Lake sediments – the chronicle of natural and antrophogenic changes”, supported by Lithuanian Science and Studies Foundation.

Varenis lake sediments were investigated in 10,9 m core. A total of 129 diatom taxa were identified from the bottom sediments. Plankton, alkaliphilous diatom species prevail throughout the section. Species composition indicates that sedimentation took place in mesotrophic-eutrophic palaeobasin with high water level. In the upper part of the section (during the Late Atlantic and Subboreal) number of plankton species decreased, indicating the decreasing of water level. Here the species diversity and the number of species indicators of eutrophication increased.

Trends in diatom assemblage composition from the surface sediments suggest that Varenis lake has undergone substantial changes in hydrologic budget and trophic status during the period studied. 170 diatom species, including several varieties, were identified. The total abundance of them varied markedly from 70 thousands to 112 million g^{-1}. Relative abundance of plankton diatoms changed from

58% to 37% upwards. Taxa tolerant to water pollution, particularly *Cyclotella meneghiniana, Stephanodiscus hantzschii, S. minutulus*, reached their maximum, indicating the poorest water quality in the lake during the entire period study. Chlorophyll a and carotene concentrations increased slightly but remain higher values recorded in the upper layers. The C/N ratio (11,3-14,3 m depth) reflects allochtonous origin of organic matter in the lake sediments. In the upper part the concentration of phosphorus (0,1%) and nitrogen (>1%) were rather constant, N/P ratio values were about 11.

Large quantity of rheophilous species, such as *Meridion circulare, Gomphonema parvulum, Rhoicosphenia curvata* and etc. were present throughout all the section indicating material inflow.

Glebas lake sediments were investigated in 7 m core. A total of 135 diatom taxa were identified from the bottom sediments. Epiphytic, alkaliphilous species (mainly *Fragilaria* spp.) prevail through the section (up to 95%). Species composition indicates that sedimentation took place in quite shallow mesotrophic-eutrophic palaeobasin.

In the surface sediments significant increasing of diatoms abundance from 2 to 116 millions g^{-1} upwards recorded. 95 diatom species were identified. The great shift in composition of the diatom flora occurred. Total number of plankton diatoms (dominated *Aulacoseira granulata, A. italica, Cyclostephanus dubius, Cyclotella meneghiniana*) decreased from 20,3 % to 6,7 % of the assemblage. Benthic diatoms, mainly representatives of *Fragilaria* and *Achanthes* genus increased with sediments depth.

In the lower part of the core pigment concentrations do not show significant changes through time, a sharp increase of their content found from 23 cm upwards. Phosphorus and nitrogen concentrations differently slowly but steadily increase upward, thus causing the ratio N/P to decrease. The C/N ratio (10,5-12,8) is predominantly allochtonous.

Diatom and pigment investigations indicates the increasing eutrophication and productivity in both lakes studied.

The complex isotope studies allowed ascertaining the sedimentation parameters: sedimentation modulus (g/cm^2/years) and linear accumulation rate (mm/years). The modulus of the recent sedimentation according to ^{210}Pb and ^{137}Cs studies in Varėnis lake is –>0,5 g/cm^2/year and in Glebas lake 0,05 g/cm^2/year. Other sedimentation parameters – linear rates are changing subject to density and moisture of a material. According to ^{14}C method the mean accumulation rate of sediment thickness in Varenis lake is 0,8 mm/year and in Glebas lake - 1,6 mm/year.

Pollen studies of Varėnis lake sediments identified 9 local pollen assemblage zones, which can be correlated with North-west Europe chronozones (Mangerud *et al*., 1974) and indicates sedimentation from Early Dryas to Subboreal. Seven pollen zones were singled in Glebas lake pollen diagram and correlated with Late Dryas - Early Subatlantic chronozones.

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THE PALEOGLACIOLOGIC MAPPING (KOLA PENINSULA)

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The paleoglaciologic map of the last Pleistocene glaciation had being compiled in northwestern the Kola Peninsula in 2001-2002. Paleoglaciologic map construction includes 5 stages. The first stage is collection of information about the glacial deposits obtaining from geologic mapping early. The second stage is aerial photograph interpretation. The third stage is composition of the preliminary Quaternary deposits map. The fourth stage is survey (field routes, digging a hole and describing the sections).

The internal geological structures are studied in the sections (macro textures and micro textures in micro sections, granulometric and mineralogical analysis). Besides, boulder and rubble specimens were taken for determination of the petrografic content, roundness and unequal of the axes. On the fifth stage the results of the field work are plotted on the mentioned map, the geologic borders and the glacial facies are defined more exactly.

Usually 3 stages of glaciation form the typical groups of the deposits and relief's forms, therefore 3 schemes are constructed for the stationary phase, beginning regressive phase and final deglaciation phase.

Paleoglacial conditions of the stationary phase are show on the first scheme. The basal cover till in general was formed on the areas with debris, which was distributed evenly. The hummocky moraine was formed on the areas with heightened keeping of debris, which is distributed unevenly. Spreading areas of numerous lakes, which are situated very near to each other. It was stretched in accordance with general direction of ice movement, and form belts, which are transverse to ice movement. On these areas have gone maximum exaration. It could make only in conditions of melting bed.

The second scheme shows situation for the beginning regressive phase of glaciation. Power of the ice became to be less, speeds of ice's stream become to differentiate, variety and combination of relief's form increased. Borders of these lobes are fixed by hummocky ablation moraine, which was formed in the phase of the final deglaciation.

The third scheme shows environments in the final deglaciation phase. In this time is the most distinctly displayed. Plots of the jointing ice and depressions, which is filled by heightened power ice, are fixed by ablation moraine. Plots of slow melting ice in the big hummocky and mountain regions, in the non-pressure conditions are designated by annular and semicircular-formed moraine.

At last three schemes are combain. Each of phase's elements-indicators is showed on the scheme by definite color: the stationary phase – blue, the beginning regressive phase – green, the phase of final deglaciation – red. Drawing of elements is made from the late phases to early.

INTERGLACIAL SEDIMENTATION, VEGETATION AND CLIMATE IN LITHUANIA

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Interglacial climate conditions had determined the patterns of both sedimentation and vegetation. Interglacial climate being reflected in sediments and composition of plant microfossils provides a possibility of its simulation. Interglacial sediments usually occur in between the till beds, however the origin of the major part of intertill deposits is related to glacial ice melting during the climate shift from glacial to interglacial. In contrast the interglacial sediments of nonglacial sedimentation form only a minor part within these intertill sequences, however its significance for the palaeoclimatic reconstruction is evident.

Patterns of interglacially controlled sedimentation were established on a base of spatial model of Quaternary sequence built on lithological parameters and core descriptions of about 3000 boreholes and near half a hundred of outcrops studied sedimentologically and palaeobotanically. A distribution of intertill sediments related to ice meltwater stream, proglacial basin and nonglacial sedimentation was interpreted after borehole log correlation.

Two types of criteria were used to recognise indications of interglacially related terrigenous sedimentation. The first one consists of a sedimentological pattern of deposition deduced from a visual characteristic, peculiarities of grain-size frequency distribution and composition of sediments. Features of occurrence and bed topography derived from lithostratigraphy and proved under palaeogeomorphological interpretations served as the criteria of the second type. A statistical canonical ordination to analyse data was used as well (Fig.).

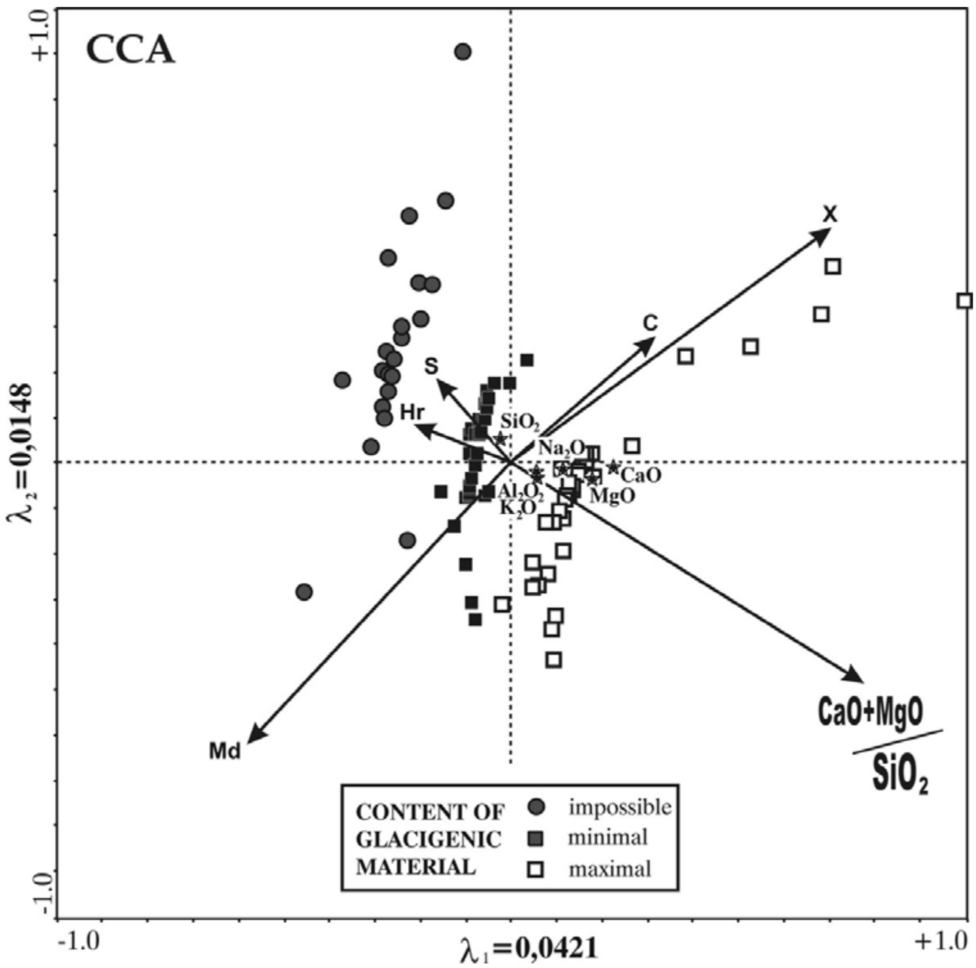

Fig. Diagram of canonical correspondence analysis of deposit chemical composition in respect of grain size parameters and content of glacigenic material.

While dealing with outcrop sediment sequences deposit bedding structures and texture contributed to visual identification of sedimentation conditions. However dealing with core material only a degree of sediment maturity was considered as a distinguishing feature of sedimentation pattern. A low content of non-resistant to weathering minerals and a high quantity of quartz is a characteristic of interglacial terrigenous sediments. It brings the light yellow or even white colour to deposits. This is clearly reflected in geochemical composition of sediments repeatedly redeposited and weathered in interglacial sedimentary environments. Results of statistical analysis display a very good positive correlation between the CaO, MgO, Al_2O_3, K_2O and Na_2O, high amount of that is a characteristic of deposits formed in glacial environment. On the contrary the quantity of these components decreases notably in terrigenous interglacial deposits of nonglacial sedimentation.

The maps of sedimentation environments of intertill deposits related to glacial ice melting during glacial climate shift to Butenai (Holstein) and Merkine (Eem) Interglacials were compiled. The interglacial sediments rich in organic matter provided the palaeogeographical evidence on climate conditions of sedimentation and trends of vegetation cover change. Fluctuation of mean year, January and July temperatures and annual precipitation during interglacials was inferred from a palaeobotanical data. Two methods were used to estimate the range of the climate variations: one is based on theory of probability evaluating the pollen composition and gradation of the trees according to their distribution and other one is of the climate indicating species.

During the interglacial periods of warm and wet climate, which usually corresponds to the interglacial climate optimums a land surface was sheltered by vegetation, that prevented the soil erosion. In this case organic sedimentation was predominant. In contrary the dry and severe climate was the reason of soil erosion and widespread intensive terrigenous sedimentation that caused a poor content of organic matter in sediments. Such climate conditions took place during the initial and final stages of interglacials. The period of general deterioration of climate at the end of Butenai (Holstein) Interglacial was especially long (Kondratiene, Seiriene, 2003). During it the soil erosion in treeless areas was able to supply a lot of terrigenous material into some sedimentary basins. On the whole, the interglacial sediments are linked to the surface topography and reflect the main features of hydrographical network, which in Lithuanian territory tend to be inherited throughout the Quaternary.

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STRATIGRAPHY AND SEDIMENTOLOGY OF PLEISTOCENE DEPOSITS AT THE WAPIENNO QUARRY, NW POLAND

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The Upper Jurassic limestone quarry in Wapienno near Inowrocław is located in NW Poland, approximately 50km to the south of Bydgoszcz (Fig. 1).

The Upper Jurassic deposits make up the south wing of the tectonic structure. It is of a brachyanticline character, and is referred to as the Zalesie structure. Its axis is NW-SE oriented. It consists of the Middle Jurassic siltstones and marls in the central part, and the Upper Jurassic limestones on the wings which pass on to sandstones and siltstones of the Lower Cretaceous (Matyja et al., 1985). The Tertiary deposits can only be found in the sinks on the structure itself. These are clayey sandy and carbonate deposits.

In the overburden of limestones there are Pleistocene deposits whose thickness reaches up to 30 m. The conducted investigations resulted in defining two formal lithostratigraphic units: the Wapenno formation and the Barcin formation.The lower unit (**the Wapenno formation**) is composed of 15-metre thick sandy deposits (Sokołowski 2004). Its lower part is dominated by the ***SGt**, **St*** lithofacies of an average and big scale. The ***Sh*** and ***Sr*** lithofacies can also be found. In its upper part the ***Sp*** lithofacies of an average and big scale, as well as ***Sr*** and ***Fm*** are predominant. The paleocurrents are characterized by considerable homogeneity and indicate paleotransport directions towards W and NW. The grain analysis implies average sediment sorting of the ***SGt*** and ***St*** lithofacies, and smaller sediment sorting of the remaining lithofacies. The quartz grains are typified by a high degree of eolization reaching 75-80%.

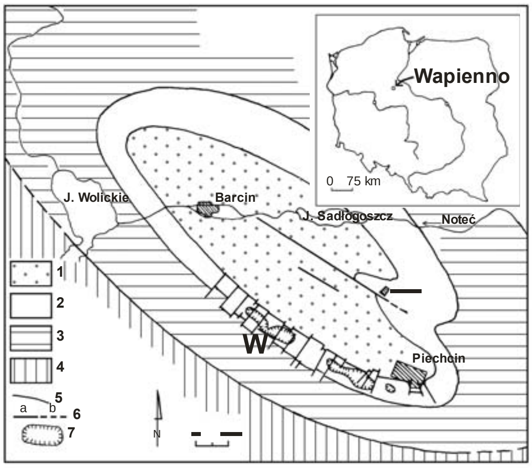

Fig. 1. Location of the Wapienno quarry and the geological map of the Zalesie structure (after Matyja et al., 1985, modified). 1- Lower and Upper Jurassic, 2- Oxfordian, 3- Kimmerigdian and Tithonian, 4- Cretaceous, 5-stratigraphic boundaries, 6- faults (a-stated, b-presumable), 7-quarries, W- the Wapienno quarry.

The deposit sedimentation of the Wapienno formation occurred in a **sandbed braided river**. It was of a changeable flow which may have resulted from periodic variability. Big dullness of grains as well as the observed syngenetic ice-wedges and frost-clefts (**the lower cryostratigraphic level**) indicate that the deposit sedimentation took place in the peryglacial climate with a multi-year developed permafrost.

The upper unit (the **Barcin formation**) comprises four members (Sokołowski 2004). The first member (**B1**) consists of sandy diamicton of mean thickness reaching 1.5 m, and locally up to 4.5 m. At its bottom a well developed zone of glaciodynamic deformations and deformation till can be observed. The measurements of longer axes of boulders indicate NE direction of ice-mass advance. The B1 member was formed under subglacial conditions.

Next member (**B2**) is the 1-1.5-metre thick comprises sands and gravels of poor sorting. The ***St*** and ***Sh*** lithofacies dominate in the sandy layer. The gravel layer contains mainly the ***Gm*** lithofacies of a disperse grain skeleton and the ***Gh*** lithofacies. The lithofacial structure of these deposits suggests their fluvioglacial genesis.

The third member (**B3**) is composed of sandy diamicton, locally clayey at the bottom, whose thickness reaches up to 9 m.

The longer axes orientation of the boulders is similar to the results obtained in the B1 member. It shows slight northwards deviation. In the upper part of this member there are sandy laminas and relatively small subglacial channels. The genesis of this unit is the same like in B1 member.

The last member (**B4**) is non-continuous layer deposited in small channels usually on the top of unit B3. The thickness is up to 2 m. There are gravels and sands formed during deglaciation of last ice-sheet in glaciofluvial conditions.

The **upper cryohorizon** can be found below the B3 member. It is developed in the form of wedges with primeval sandy filler of a high eolization degree and irregular pockets with sandy-gravely filling. These structures are up to 1.2 m long and their polygon grid has a 3 – 5 m diameter. They had developed before ice sheet transgression which left the b3 member behind in the conditions of severe peryglacial climate and permafrost agradation.

The sandy deposits from Wapienno, fluvioglacial deposits and sandy fillers of the ice-wedges from the upper cryostratigraphic level provided 12 samples for OSL dating. Their results should lead to a more certain correlation and placing the differentiated formations in the chronostratigraphic division. First results suggest, that the Barcin formation was deposited during the Last Maximum Glaciation (18-25 ka). Description of age of the Wapienno formation is more difficult. The estimated age is between 114 and 274 ka. Thus, it needs further studies.

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FORMATION AND DEVELOPMENT OF MORPHOLOGICAL FORMS IN BALTIC SEA COASTLINE

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Seashore is a dynamic and floating environment. It has quick, dynamic and a relatively easy observed fluctuations. In the seashore the processes are sharp and rolled down. It attracted my attention.

In order to understand formation conditions of morphological forms in Litorina Sea coast it is necessary to obtain information about modern seashore.

Hydrodynamic conditions, for example, wave undulation, wind direction; alongshore stream was studied properly in the present paper. The modern preserved relief forms developed as a result of defined geological processes reflect events carried out in the past.

In the Baltic Sea coast area the modern hydro- and litho dynamic conditions and processes are most intensive in comparison with the same processes in the Riga gulf seashore. The Baltic Sea cost zone is under influence of more intensive and strong coast erosion in comparison with the Riga gulf coast zone, i.e., leaching and accumulation. Therefore it is possible to get more information concerning the noted processes exactly in the Baltic Sea coast area.

In the studied region the modern landforms, for example, beach, fore dunes, modern dunes and litorina period relief forms (old lagoons, accumulative terraces of seashore, sand dunes and coastal ribs) were identified.

The present paper deals with the study of sediment accumulation sites, waves, wave undulation flow, wind regime and alongshore streams in the Baltic Sea coast area.

THE EEMIAN AND EARLY VISTULIAN EVOLUTION OF PALEOENVIRONMENTS IN SEA SITES AREA –IMPLICATION FROM PALYNOLOGICAL AND GEOLOGICAL STUDIES

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Sediments of the Eemian Interglacial (MIS 5e, Last Interglacial) and the Early Vistulian Glaciation (Last Glaciation) are described from a great number of coring boreholes situated in the Lower Vistula Region and the Elbląg Elevation. Makowska (1986, 2001) distinguished the Late Pleistocene complex that consists of deposits of Eemian Interglacial (*sensu lato*) and the post-Eemian within which there are two layers of tills called the Lower Vistula formation. The Lower Vistula formation has characteristic eemian marine sequences recorded in numerous boreholes drilled for needs Detailed Geological Map of Poland on the scale 1 : 50 000. Fine-grained sand to sandy silt, clay, and silt with mollusc shells, ostracods and foraminifera form these sequences.

In several profiles: Nowiny, Pagórki, Licze and Obrzynowo (Janczyk-Kopikowa 1991; Head & all, 2005; Makowska, 1986, Makowska 2001) the sediments of the Eemian Interglacial have been studied by pollen analysis. These studies show the characteristic feature of pollen successions: high percentage of *Quercus* as well as very high percentage of *Corylus* pollen. The successions recorded in the profiles mentioned above have documented the same spreading of trees and hazel in the following order *Betula-Pinus, Ulmus, Quercus, Fraxinus, Corylus, Alnus, Taxus, Tilia, Carpinus, Picea-Abies*, and *Pinus* what indicates that it could be the Eemian Interglacial. Nevertheless the distinctive feature of the these eemian pollen successions is their discontinuity connected with the presence of marine sediments recorded in the sections situated in the Lower Vistula Region and the Elbląg Elevation.

Detailed pollen analysis of the sediments from the Rzecino (Lobeska Upland – West Pomerania) (Dobracka, Winter 2003) section confirm data concerning the pollen succession of the Eemian Interglacial in the sea sites area, but provided new data on the Eemian/ Early Vistulian transition in this region of Poland.

The boundary between the Eemian Interglacial and the Early Vistulian in diagrams from Poland is marked by the rise of the pollen of herbs (Poaceae and *Artemisia*) and by great diversity of them. Moreover *Betula nana* is a characteristic taxon of the first zone of the Early Vistulian (Mamakowa, 1988, 1989). In the eemian pollen succession from the profile situated in the Lower Vistula Region and the Elbląg Elevation this boundary was established in the same criteria.

In western Europe the criteria applied for establishing the Eemian/ Early Vistulian transition are the rising proportions of Ericales and herbs as well as *Juniperus* (Behre 1989). The same characteristic features were used to mark it in the pollen diagram from Rzecino. This sequence of the pollen assemblage with high values of *Calluna vulgaris* and Ericaceae representing the Early Vistulian has been found in Poland only from Rzecino.

SUBGLACIAL PROCESSES AND THE LAST SCANDINAVIAN ICE SHEET DYNAMICS AS INTERPRETED FROM BASAL TILLS IN THE LOWER VISTULA (WEICHSEL) VALLEY, N POLAND

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The Lower Vistula (Weichsel) valley area is of significant importance for the reconstruction of the glacial palaeogeography during the Weichselian glaciation in northern Poland. This is due to the thick and undisturbed sedimentary succession formed during this glaciation overlying marine and terrestrial deposits of the Eemian interglacial (Makowska, 1976, 1980).

The Weichselian complex in the southern part of this area has recently been studied by the present author (Wysota, 2002; Wysota et al., 2002). In the upper, exposed part of the sedimentary succession, two major glacial units have been distinguished: the lower one is the Łążyn till and the upper one is the Starogród Zamek till. These units are separated by glaciolacustrine clays and silts (the Kiełp clays). The Łążyn till representing the first advance of the Scandinavian Ice Sheet during the Late Weichselian (Leszno advance), while the Starogród Zamek till representing the ice re-advance (Poznań advance).

Three basal till facies (A, B and C) were distinguished and examined in the Łażyn till. The lowest till facies A consists of a sandy diamicton 0.5–2.5 m thick. Its contact with the underlying deposits varies, commonly showing a gradual transition. Interfingering of till and the underlying material can also often be found in the contact zone, but a sharp contact is rare. The unconsolidated, usually fluvial sands beneath the diamicton commonly show soft-sediment deformations in the form of small recumbent folds and shear planes. The occurrence of deformed inclusions of the sandy substratum forming detached and attenuated folds and boudins in the lower part of the diamicton is characteristic. These structures are progressively less common towards the top of this facies, where the diamicton becomes homogeneous.

Facies B consists of a bedded diamicton 20-70 cm thick that either overlies facies A or rests upon a substratum of fluvial sands or silts and glaciolacustrine clays. The contact between till facies B and A is most commonly sharp and conformable. Facies B consists of several structureless or laminated diamicton layers of diverse lithology (from sandy to clayey diamicton) and various colours. The thickness of the individual diamicton layers ranges from 2 to 20 cm. The diamicton layers show thin (1-15 mm) interbeddings of sorted deposits that consist predominantly of medium and fine-grained sand, clay and silt. The alternation of diamicton and sorted layers is undisturbed and generally subhorizontal, although locally it is slightly undulating. Less common structures include coatings of diamicton and sorted sediment layers over boulders, and down-warping underneath boulders. The bedded diamicton is covered by a discontinuous layer of locally horizontally laminated and locally structureless clay of 20 cm up to 2.2 m thick. It contains local intercalations of structureless and horizontally bedded sands. Isolated stones were infrequently present in the clays.

The uppermost facies C is the best developed and most common facies of the Łażyn till. Generally, it covers till facies B, but locally it overlies till facies A or fluvial sands of the underlying substratum. The basal contact of the diamicton is conformable and no deformations have been observed. The facies consists of a brown diamicton 0.5-6.5 m thick (3.2 m on average). Although the diamicton is generally structureless, local thin layers or lenses of sorted sediments (mainly sand and silt) are found at the base. In places, coatings of clay laminae were found over boulders.

The three till facies must have been formed by complex subglacial sedimentary processes during the first Scandinavian Ice Sheet advance during the Late Weichselian (Wysota, 2002, 2005). The lowest till facies (A) is interpreted as a deformation till, and was accumulated during the initial stage of the ice advance. The sedimentary data suggests that the deforming bed was rather not a continuous layer under the advancing ice. Deformation probably occurred in local areas separated by areas of no or very little deformation, where basal sliding rather than pervasive deformation was a more important mechanism of ice movement (Piotrowski et al., 2001; van der Meer et al., 2003; Piotrowski et al., 2004). The middle facies (B) represents a stagnation from the initial ice advance, and was deposited during recurrent periods of subglacial melt-out followed by meltwater sedimentation. The subhorizontal thin layers of sorted deposits record washing, transport and subsequent deposition of sand and silt by small-scale meltwater sheet flows during a periodical basal decoupling of ice from its bed (Piotrowski and Tulaczyk, 1999; Munro-Stasiuk, 2000; Piotrowski et al., 2005). The upper till facies (C) was laid down by direct subglacial melt-out during a stage of stagnant ice.

It is suggested that bed deformation and temporarily enhanced basal sliding may have been caused by ice streaming at the time of the ice sheet advance and just before its stagnation (Wysota, 2002, 2005). The petrographic composition of far-travelled pebbles indicates that an ice stream was fed by a Baltic ice stream that operates along the Baltic Sea basin. The second-rank, soft-bedded and land-based ice stream moved along the Vistula valley towards the ice sheet margin, where it formed the broad Vistula ice lobe (Marks, 2002; Wysota, 2002). Stagnation of the palaeo-ice stream may have been triggered by basal freezing (Tulaczyk et al., 2000; Christoffersen and Tulaczyk, 2003) and followed by rapid ice retreat/wastage (Wysota, 2002).

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DEGLACIATION OF KOLA REGION DURING THE LAST PLEISTOCENE AND HOLOCENE

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The Kola region includes the Kola Peninsula and adjacent shelves of the Barents and White seas. Deglaciation of this region corresponds to three terminal interstadial-stadial cycles of the Late Pleistocene and the beginning of warming in the Holocene. The degradation stages of the ice sheet in the Kola region have been correlated to climatic cycles by means of palaeomagnetic analysis of glaciolacustrine and lake deposits and by 14C dating of the initial stage of organic accumulation in lakes. During interstadial warmings extensive peripheral covers were cut off from the main ice mass and thick glaciofluvial deposits accumulated in periglacial basins near the edge of the active ice. Probably the deglaciation of the Barents Sea shelf was completed by the interstadial warming before the Older Dryas about 12,000-13,000 yr BP (Polyak et al., 1995; Polyak, Mikhailov, 1996), whereas deglaciation of the Belomorian depression was completed by the end of the warming in the Allerød (about 11,200 yr BP). The glacier, advancing during phases of stadial coolings, deformed interstadial deposits and built mainly push moraine ridges. Thus, a marginal belt was formed during each interstadial-stadial cycle at the edge of active ice. It consists of two bands of marginal ridges: an inner band - a dump moraine (marginal esker), and an outer band - a push moraine. The ice sheet was dissected by extended marine gulfs during the warming which followed after significant expansion of the glacier during the Younger Dryas. In these gulfs glaciomarine sediments were superseded by marine deposits, probably in connection with final melting of the ice about 9,000 yr BP.

CORRELATION OF THE PLEISTOCENE NATURE EVENTS BY CONTINENTAL AND JCEANIC SEDIMENTS OF THE NORTH HEMISPHERE

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The Pleistocene stratygraphical scheme of Belarus of the writer is based on the palynological materials of the stady of the old-limnetic deposits (Yelovicheva, 2001), includes the rhythmic sequence of the 8 interglaciations and 8 glaciations and responds to 18 isotopic-oxygen circles of the Pleistocene geochronological scale of the Northern hemisphere basing on the data of the absolute age of the oceanic sedimentations. The analysis of more ten isotopic-oxygen and insolacional curves has shown the convergence of the number of Pleistocene events not only within the limits of circles, but also inside them. In this connection these variations on during of the interglaciation and glaciation quite will definitely be agreeed quantity of the climatic optimum and interoptimum cooling-downs of interglaciations (macrosuccession series) and number of the stages and interstages of the glaciations. The age ratio of the Pleistocene interglaciations is provided with the difference in a structure of phytocenosises and and correspond to the consecutive series of the palynofloras, keeping lesser and smaller the number of exotic elements of flora from Neogen to a Holocene. The correlation of the isotopic-oxygen oceanic stages and successions of green by the continental deposits in the area region looks like this:

$\delta^{18}O$ is.st.	Horizonts		Structure of horizonts
1	Holocene interglaciation, there are up to 100 datings		one optimum with complete macrosuccession series
2	Poozerje glaciation — megastage III — Orsha; is present about 30 datings;		Usvyachi preglacial suite and Orsha maximum megastage;
3	Poozerje glaciation — megainterstage II; there are up to 11 datings;		Tur, Shapurovo and Borisov interstages, divided by Rogachevo and Michalinovo stages;
4	Poozerje glaciation — 4a-megastage II — Mezin; 4b-megainterstage I, 4c-megastage I; is present about 5 datings;		megastage I integrates Cherikov, Suraz and Polotsk interstages, disjointed by Mirogitshi and Sloboda stages; megastage I includes West-Dvina-1 and 2 megastages and sectioning them Black-shore interstage;

5	Murava interglaciation — 5a,b,c,d,e; is present 4 datings: 102600±11900 LU-5210U years (Murava, Carpinus and Picea phase), 104000±8000 TLM-363 years (Orlyaki), 105000±10000 TLM-437 years (Murava), 111000±5000 TLM-379 years (Milovidy)		two climatic optimum (Cherikov and Komotovo) with complete macrosuccession series, disjointed by Borchov intermediate cold snap, the third optimum only is occasionally submitted) in a rang of a warmer of a climate;
6	Shoz glaciation		6a – Mogilev stage, 6b – Gorki interstage, 6c – Slavgorod stage;
7	Shklov interglaciation — 7a,b,c,d,e; is present date 162000±15000 KTL-2M/85 years for Ugly intermediate cold snap;		three climatic optimum (Lubanj, Lysaya Gora and Chernitca) and sectioning them Ugly and Rzavtcy intermediate cold snap; first optimum with uncomplete, second and third are with complete macrosuccession series;
8	Dniepr glaciation — 8a,b,c; it is final date 216000±18000 KTL-1M/85 years		8a – Mozyrj stage with Lotvin interstage, 8b – Uzda interstage, 8c – Stolin main stage;
9	Smolensk interglaciation — 9a,b,c;		two climatic optimum with complete macrosuccession series, disjointed by intermediate cold snap;
10	Glaciation-5;		Main phase with Belichi interstage;
11	Alexandria interglaciation — 11a,b,c;		two climatic optimum (Malaya Alexandria and Prinemahj) with comlete macrosuccession series, disjointed by Kopysj intermediate cold snap;
12	Glaciation-4;		one main phase
13	Ishkoldj interglaciation — 13a,b,c,d,e;		three climatic optimum (Pushkari, middle and late) with complete macrosuccession series, disjointed by intermediate cold snap;
14	Beresina glaciation;		main phase with interstage;
15	Byelovezha interglaciation — 15a,b,c;		two climatic optimum — early (Borki) with uncomplete, late (Krasnaya Dubrova) with complete macrosuccession series, disjointed by Yaglevichi intermediate cold snap;
16	Servech glaciation;		one main phase;
17	Korchevo interglaciation;		one climatic optimum with complete macrosuccession series;
18	Narev glaciation;		main phase with Elizarov interstage;
19	Upper part of the Eopleistocene (Brest interval)		

Introduced above separately from each the other data under the contents of the isotopes of oxygen in the oceanic deposits of the Northern hemisphere and palynological date from the continental deposits of pools of Belarus in an equal measure confirm a synchronism and periodicity of the development glaciations and interglacial vegetation, that allows adequately at a qualitative level to conduct an inter-regional correlation of the Pleistocene natural events. Already more than 10 years the given version of the Pleistocene stratigraphical scheme correspond to in the greatest measure results of the spent geological-taking activities in the teritory Беларуси. Characteristicly, that in this version Alexandrya (Holstein, Lichvin) interglaciation responds 11 isotope stage, as it and was offered on the 14 Congress INQUA in 2003 in Rino (stat Nevada, America).

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THE VISTULIAN SEDIMENTS IN THE MAZOVIAN LOWLAND AND THE CZĘSTOCHOWA, POLAND

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The Vistulian ice sheets covered only the North Poland. The Mazovian Lowland and Częstochowa Upland were located out of maximum Vistulian ice sheets range. The first study area is situated on the South Mazovian Lowland, over 100 km to the south from Warsaw. The Częstochowa Upland is about 240 km south-west of Warsaw. The Vistulian period is divided by three glaciation stages: Torunian – 100 000 BP - Early Vistulian, Świecie – 60 000 BP - Middle Vistulian, Main Stadial – 20 000 BP - Upper Vistulian. The Vistulian fluvial deposites were accumulated in the Vistula Valley. These sediments consist of 4 fluvial units. The oldest one built the highest overbank terrace 6 in Upper Vistulian. The overbank terrace 5 was created in Oldest Dryas. The overbank terrace 4 was formed in Older Dryas and overbank terrace 3 in Younger Dryas. The upper 2 and lower 1 flood plains were created in the Holocene. Dunes and eolian sands on the overbank terraces were accumulated in these cold periods. Soils were created in Bölling and Allröd – warm periods. Sands were dated by TL method, organic material by C14 method. The Vistulian loesses near Kazimierz Dolny were accumulated in the Świecie Stadial and the Main Stadial. The thickness of loesses is 18 m in Bochotnica profile. The loesses were dated by TL method. The lake Vistulian deposits were investigated in Kontrowers profile. These sediments consist of peats and silts and cover Eemian deposites. These sediments were documented by palynological analysis. Vistulian series were dated by C14 method.

The sediments in Komarowa Cave (Częstochowa Upland) consist of weathering loams, silts, residual clays and sands. Deposites were investigated by geological, palaeontological and archaeological methods. These sediments were accumulated during Vistulian period and represented warm and cold periods: stadials and interstadials. The sediments accumulated out of Vistulian ice sheet range are very important for stratigraphy.

GLACIOTECTONIC DATABASE AND MAP OF LATVIA

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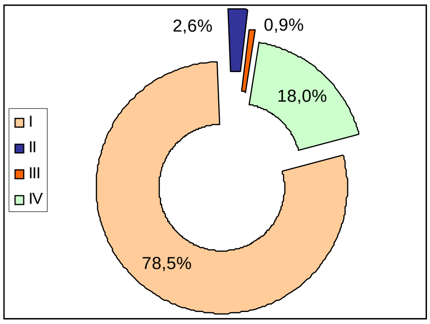
The glaciotectonic map of Latvia is an integral part of the INQUA GAGE Working Group project *Glaciotectonic GIS Database and Map of Central Europe.* The map and database were constructed using the ArcInfo system during the period 1997-2003. Twenty nine individuals have contributed information or assisted in preparation of the database. The database includes 4929 glaciotectonic features that are classified in four main categories (Table 1). Glaciotectonic features were digitized from 1:25,000 and 1:50,000 (or 1:75,000) topographic maps and derived from interpretation of aerial photographs, papers, unpublished reports and personal communications. The glaciotectonic map is supported by a supplementary map of a lobate structure of the Scandinavian ice sheet in Latvia, and visualizations of the pre-Quaternary surface and modern topography of Latvia.

T a b l e 1

Classification and estimated number of glaciotectonic phenomena in Latvia

Glaciotectonic features	Occurrence	
	Number	%
DISTURBED PLEISTOCENE SEDIMENTS EXPRESSED MORPHOLOGICALLY	**3871**	**78,5**
Glaciotectonic hills	182	
Glaciotectonic hills capped by glaciolacustrine sediments	227	
Glaciotectonic ridges parallel to ice movement direction	2216	
Glaciotectonic ridges transverse to ice movement direction	863	
Glaciotectonic composite ridges and massifs	254	
Point samples of disturbed pleistocene sediments	125	
Point samples of disturbed pre-Quaternary bedrock	4	
II. CONCEALED DISTURBED PLEISTOCENE SEDIMENTS	**127**	**2,6**
In exposures	56	
Boreholes	68	
In single borings	3	
III. LARGE RAFTS OF PRE-QUATERNARY BEDROCK	**42**	**0,9**
Expressed in recent relief	7	
Not expressed in recent relief	35	
IV. SOURCE BASINS	**889**	**18,0**
Glaciotectonic depressions expressed morphologically	741	
Buried glaciotectonic depressions	138	
Points samples	10	
Total:	**4929**	**100**



L e g e n d:

I = disturbed Pleistocene sediments expressed morphologically;

II = concealed disturbed Pleistocene sediments;

III = large rafts of pre-Quaternary bedrock;

IV = source basins.

Most of glaciotectonic features have been formed during the Late Weichselian. Considering that Latvia was located at outer part of the zone of predominate glacial erosion and at the inner part of the marginal zone, the subglacial as well as the proglacial glaciotectonic processes were responsible for the formation of the glaciotectonic features. As a result of deglaciation and subsequent geologic processes these structures and land systems were altered to some extent, and younger spatially diverse glaciotectonic, other glacial and non-glacial features were superimposed.

The glaciotectonic ridges with crests parallel to the ice movement direction occur mostly in glacial lowlands and undulated plains of uplands of northern and western Latvia, while the composite hills and ridges as well as the individual isometric glaciotectonic hills are dominant feature in the interlobate ridges and uplands of the eastern part of Latvia. The glaciotectonic ridges with crests transverse to the ice movement direction are the most common at the periphery of glacial uplands, and in the lowland areas with hard or alternating of hard and soft pre-Quaternary sedimentary rock overlaid by a thin cover (less than 5-8 m) of Pleistocene deposits. Large rafts of the pre-Quaternary bedrock tend to be located at the transitional zone between lowlands and uplands or on ice contact slopes. Buried deformed Pleistocene sediments and bedrock appear occasionally but glaciotectonic hills capped by glaciolacustrine silt and clay occur in the central portion of the largest interlobate uplands.

The map displays the spatial image of megascopic redistribution of the original thicknesses of glacial, interstadial and interglacial deposits and disruptions in the continuous cover of till

GLACIOTECTONIC DEFORMATION AND MORPHOLOGICAL SETTING IN CENTRAL KURSA, LATVIA, WITH EMPHASIS ON DE GEER MORAINES

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Geomorphologically the study area belongs to the Vārme Plain that forms the transitional zone between the Central Kursa Lowland and the Eastern Kursa Upland. The gently inclined surface of the plain is commonly undulated by up to 8-15 m high, 500-750 m wide and 4-6 km long, almost N-S trending ridges that, according to Zelčs (1993) and Strautnieks (1998), are superimposed by an assemblage of transverse low and narrow ridges. After prolongation about 6 km to the W in the adjacent area of the Central Kursa Lowland, both distinctly oriented systems of the glacial landforms gradually disappear because their of becoming covered with an up to 10 m thick sequence of glaciolacutrine sand and/or clay, that was deposited distantly from the Venta ice tongue at the outset of the Late glacial interstadial.

The transverse ridges occur in a 40 km long and 5-10 km wide area, known as the Vārme-Zirņi De Geer moraine area (Strautnieks, 1998). This area is comprised of approx. 1500 ridges grouped into subparallel, in places morphologically interrupted, belts. These belts are rather unevenly spaced and form wedge-shaped transverse arcs to the upslope of the Vārme Plain that are convex downglacier. The interbelts spacing considerably exceeds the width of ridges. Generally the interval between crests of ridges increases upglacier, ranging from 120-400 m up to about 1,000 m. Supposedly the glacier ice retreated from this area at a minimum rate of 120 m per year. The length of distinct ridges varies from 150-300 up to 600-1,200 m, the width – from some tens m up to 300 m, the relative height is dominantly 2-8 m.

The thickness of the Pleistocene deposits is ca. 10 m (Juškevičs et. al., 1997). The bedrock surface lies at 60-70 m a.s.l. It is composed of Upper Devonian rubbish grey and reddish brown dolomite, aleurolite and clay, which are replaced northerly by older greenish grey or bluish grey sandstone, aleurolite and clay.

According to our investigations of the internal structure of both glacial landsystems in the several nearby located large gravel pits (Braņķi W, Braņķi E, Ziķi, and Pakuļi), they mainly consist of heavily deformed outwash interbedded by basin sediments, banded diamicton lenses or lamina of particoloured local till. Occasionally ridges are also comprised of floes, imbricate thrusts or intercalations of Upper Devonian sedimentary rock altered to some extent as a result of successive deformation. Rafted blocks and bands are mainly of greenish grey or bluish grey sandstone, aleurolite and clay. According to local geological structure these bedrock erratic blocks are displaced in a distance 0.8-2.6 km.

All of the sequence described above is covered by variable coloured (from normal and dark brown up to rubbish red) clayey till. Glaciolacustrine clay and sand commonly occur in the interridge depressions, and most likely conceal all features of preceding subglacial topography at the lower hypsometric level of the tilted plain. The ridges resembling De Geer moraine are built from tightly contorted folds or imbricate thrusts with superimposed overthrusts on the upglacier slope. Higher parts of transverse ridges contain elongated injective folds of cores of the N-S trending ridges of drumlins altered by subsequent deformation.

The lineation of bedding measured in the sections located in the gravel pits suggests a compressive stress that subsequently changes from WSW to NNW, NW or ENE to NNE, NE. Commonly the pebble longitudinal axes maxima are parallel to the crest of the ridge but almost perpendicular to the lineation of bedding that reveal a local compressive stress direction out of the adjacent depression.

Consequently, the following succession of depositional and deformational events may be considered: (1) proglacial deposition of outwash and ice marginal sedimentation of diamicton, and their earliest proglacial deformation; (2) subglacial deposition of till and folding of formerly deposited and deformed strata resulting in the formation of anticline that morphologically is reflected as NNW-SSE trending ridge; (3) final overtrusting of flanks and lateral compression of anticline by the compressive stress from adjacent depressions and formation of transverse ridges; (4) development of a proglacial ice-dammed lake at the lower levels of glacial terrain and accumulation of glaciolacustrine sediments.

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QUATERNARY PROCESSES, PROMOTING THE DIAMOND PLACER FORMATION IN THE KOLA SHELF OF THE WHITE AND BARENTS SEAS

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The set of the several conditions is necessary for the diamond placer formation on the shelf. The most important are the diamond source' presence and intensive removal of the diamondiferous material from the continent, the active near-bottom hydrodynamics, psephytic composition of the bottom sediments (the predominance of the sandy-gravel-pebble sediments), the favorable structural and geomorphological forms of the bottom as the rugged relief and the presence of enclosed negative forms.

As the results of studies of the White Sea shelf the areas where the all conditions are fulfilled were revealed within the White Sea Throat and in the south part of the White Sea Funnel.

The sources of diamonds are the kimberlite pipes of the established and inferred fields of the Kola Peninsula (Ermakovsky, Pyalitzky, Pulongsky) and of the exposed fields of the Arkhangelsk province (Zolotitzky, Kepinsky). The primary and secondary collectors of diamonds (the sediments of the Paleogene weathering crust, the Quaternary fluvioglacial, limnoglacial and glacial sediments of the Kola Peninsula) could be regarded also as the possible sources of diamonds.

The lithological analysis of the bottom sediments in the White Sea Throat was done based on spatial distribution of the granulometric groups and the lithofacial scheme of the area studied has been prepared (Gavrilenko et al., 2000). In contrast to previous studies (Nevessky et al., 1977), it was established the larger area for the coarse-grained sediments (gravel and pebble material), favorable for accumulation of the diamonds. The main ways of the transporting of the detrital material are the coastal abrasion, continental drainage and the glacial removal. The abundant occurrence of the abrasion terraces along the Tersky Coast points in favor of the first way of transporting, supported also by petrographic composition of the pebble and boulder material and represented mostly by the gneisses, granites, amphibolites and arkosic psammites from the Tersky bedrock. Continental drainage is also of importance for the formation of detrital rocks, that is confirmed by the presence of the numerous submarine alluvial fans. Supply of sediment is resulted from disintegration and following transportation both of the Archean-Proterozoic-Paleozoic bedrocks and of the Quaternary glacial rocks of the Kola Peninsula. The poor gradeness and roundness of debris indicate on short distance from the source rock. The glacial transportation occurred as the result of exaration of the bedrock and the transporting of the diamond-bearing debris into the depression of the White Sea by the Late Valdaian Scandinavian (in eastern direction) and the Early-Middle Valdaian Kara-Novayazemlya (in western direction) ice-sheets (Zozulya et al., 2003). It is suggested that the psephitic material found far from the coast (up to 20 km) was transported by the Scandinavian ice-sheet.

The suggestion that in the end of the Early Valdaian and during the Middle Valdaian the ice-sheet invaded to the White Sea depression and to the coast of Kola Peninsula is enhanced by the newest geochronological and geological data (Korsakova et al., 2004). From the studies of Lauritzen (1995) the ice-free environment is established in the immediate vicinity of the centre of Scandinavian ice-sheet from 150 to 71 ka BP. Based on computer modeling data of Näslund et al. (2003) the eastern part of the Kola Peninsula was free form Scandinavian ice-sheet till 70 ka BP. The presence in bottom sediments of the White Sea Throat of the carbonate pebbles and boulders with the Paleozoic invertebrates indicates on the source of the debris to the east from White Sea and transporting by Kara-Novayazemlya ice-sheets (Zozulya et al., 2003). The suggestion is of importance as this debris could contain the diamonds from the Arkhangelsk kimberlitic diamond-rich province.

The facial distribution of sediments within White Sea Throat indicates on the intensive near-bottom hydrodynamics, which is determined by the tidal and permanent sea currents. The last one is of importance for the water exchange in the White Sea and for the sublittoral sedimentation.

From the geophysical studies (echo sounding of sea bottom, low- and high-frequency seismic profiling and others) it was established that there are land forms in the bottom of the White Sea Throat, favorable for placer formation. The depressions in the bottom are of erosion origin and represented by the river paleovalleys. Somewhere the enclosed depressions of neotectonic genesis are revealed. The thickness of sediments in the buried valleys reaches 80 m (normally, the thickness in the studied area does not exceed 20-30 m). The buried paleovalleys, filled with psephitic material, represent the most prospecting structural forms for accumulation of diamonds.

Based on the initial sampling of the bottom sediments of the White Sea Throat two most promising target areas were contoured: 1st one – at the traverse of the Pyalitsa and Pulonga mouths and the 2nd one – at the traverse of the Babya and Snezhnitsa mouths. During the next prospecting step the modified sampling was applied. As the results were the finds in the bottom sediments of a few diamonds and numerous kimberlitic indicator minerals: pyrope, chrome-diopside, olivine, chrome-spinel.

Diamond placer potential of the Kola shelf of the Barents Sea is defined by removal of the Mezozoic weathering crust from the Kola Peninsula to the Barents Sea that is supported by the presence of kaolin in bottom sediments (Evzerov et al., 1993) and by finds of diamonds in Jurassic terrigenous deposits of its basin. During the late processes the diamondiferous material could be redeposited and conserved in the Qauternary sediments. The next transporting way could be the removal by Late Valdaian ice-sheet in the northern direction. In such way the inferred kimberlitic fields of Northern Finland (Korovkin et al., 2003) and Sweden can be regarded as the sources of the diamonds. The diamond prospecting of the Barents shelf was done in its southern part and in the Murmansk Coast, where the coastal-marine sediments of different age were sampled. The pyropes, chrome-diopsides and kimberlitic chrome-spinels were found in bottom sediments of the Teriberka bay and in the littoral sediments of the Western Murmansk Coast. Of promising are the marine sandy-gravel-pebble deposits of the Pleistocene age, widely spread in the area.

The studies performed show the promise of the Kola shelf of the White and Barents seas for the occurrence of diamond placers and outline the necessity of extension of prospecting.

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