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Andreas Börner, Heiko Hüneke, Sebastian Lorenz
(eds.)

Field Symposium of the INQUA PeriBaltic Working Group

"From Weichselian Ice-Sheet Dynamics to Holocene Land Use Development in Western Pomerania and Mecklenburg"

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"FROM WEICHSELIAN ICE-SHEET DYNAMICS TO HOLOCENE LAND USE DEVELOPMENT IN WESTERN POMERANIA AND MECKLENBURG"

Abstract Volume

Edited by
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State Authority for Environment Nature protection and Geology of Mecklenburg – Western Pomerania, Geological Survey, Güstrow

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Welcome note and introduction to the Field Symposium of the INQUA PeriBaltic Working Group 2019

"FROM WEICHSELIAN ICE-SHEET DYNAMICS TO HOLOCENE LAND USE DEVELOPMENT IN WESTERN POMERANIA AND MECKLENBURG"

We cordially welcome the Quaternary Peribaltic community and guests to the 2019 Field Symposium of the INQUA PeriBaltic Working Group at Greifswald University. We gather here to present new research findings and share them with the Peribaltic scientific community. In addition, the symposium also provides the opportunity to address challenges and directions of our future research and to discuss innovative approaches and methodologies to our research work. Results will be presented during a full day presentation session followed by the traditional 4-day field trip to present current research sites and findings from ongoing investigations on Quaternary themes and lake monitoring activities.

8th September 2019: Oral and poster presentation
9. –12th September 2019: Field trip from Rügen Island to the Mecklenburg Lake District

- Kinematics of the Jasmund Glacitectonic Complex on Rügen island (landform and structural analysis)
- Weichselian glaciation on Rügen (luminescence dating, sediment-facies analysis, micromorphology, till microfabrics, seismites)
- The River Tollense valley - From subglacial channel to Bronze age battle field (Quaternary and Holocene valley and river development, archaeology) and the Nature Discovery Center Müritzeum
- From Krakow am See to Lake Tiefer See (postglacial lake, river and soil development, limnic deposition, lake monitoring)

We thank all participants for their inspiring contributions and results summarized in this Abstract Volume and wish all of us fruitful discussions, fresh ideas, new collaborations, and an enjoyable time in the field among friends in Mecklenburg-Western Pomerania.

On behalf of the entire organization team

Andreas Börner, Heiko Hüneke, Achim Brauer and Sebastian Lorenz

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Differences between periglacially-, seismicity-related and glacitectonically-trigerred soft-sediment deformation structures, case study from Slinkis site (Central Lithuania)

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Soft-sediment deformation structures (SSDS), frequently occurring in Pleistocene unconsolidated clastic sediments in the Southern Peribalticum area, may originate from various deforming mechanisms, i.a. gravity-driven processes, glacitectonics, cryoturbations, seismicity-related liquefaction or bioturbations. Extraordinary variation of plastic and brittle deformations has been described from the 5 m-high and 6.5 m-wide Slinkis site in the central Lithuania. The study site, located in the Dubysa river valley (3 km from its confluence with Nemunas river), is assigned to the hummocky morainic Nevėžis Plain, which was deposited and afterwards deformed during the end of the Last Glaciation (Upper Weichselian) and the Holocene.

The sedimentary succession was divided into two sedimentary units. The lower one consists of 2.3 m thick planar- and cross-stratified sands with silt admixtures (lithofacies Sp, Sl, St and Sr), while the upper one consists of up to 0.64 m thick cross-laminated, massive and deformed more fine-grained deposits (silt, silty sand, sandy silt; sand; lithofacies Fr, Fw, FSr, Sr, Sp, Fm, FSd and Fd). The sediments in the lower unit represents compound bar, point bar and floodplain deposits of cold meandering river system (Pisarska-Jamroży et al., 2019*)*.

Three groups of deformation structures are observed within the whole succession in Slinkis. First of them are cryostructures represented by syngenetic/epigenetic ice-wedge casts, cutting the lower sedimentary unit. Wedges are relatively narrow (max. 10 cm) and widen in the uppermost parts. The second group are seismites represented by two layers with liquefaction-induced SSDS, interbedded with undeformed sediments. The SSDS, abundant along the whole lateral extent of the outcrop, contain water/sediment-escape pillars/channels, clastic diapirs, flame structures, pseudonodules and load casts accompanied by downwards and upwards injection structures. The shape and internal structure of load casts and injection structures as well as their relation to the host sediments clearly indicate the liquefaction of water-saturated sediments. Glacial isostatic earthquakes or glacial earthquakes are proposed as primary deformation trigger mechanisms. The third group of deformations are glacitectonic deformations represended by low angle dip-slip reverse faults occurred in both lower and upper units. They often cut load casts, water/sediment-escape structures as well as ice-wedge casts. An orientation and geometry of faults suggest its development in thrust regime, interpreted to be induced by compressive shortening during Last Glacial ice sheet advance from NNE-ENE direction.

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Co-existence of diverse deformation structures led to the conclusion that the fluvial sequence in Slinkis site were succesively exposed on periglacial conditions, affected by seismicity-induced liquefaction and glacitectonic processes during the Late Pleistocene.

Acknowledgements. The study has been financially supported by a grant for the GREBAL project (No. 2015/19/B/ST10/00661) from the National Science Centre Poland.

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The last Scandinavian Ice Sheet: areal vs. frontal paradigm of deglaciation

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A relatively harmonious system of presumptions, hypothesis and models explaining the dynamics, morphogenesis and deglaciation of the last glacial advance (i.e. related with MIS 2) of the Scandinavian Ice Sheet (SIS) was developed in the second half of the XXth century in the entire peri-Baltic area (Raukas et al., 1995; and many others). The mentioned system of standpoints could be named – according to terminology and approaches of T. Kuhn (2003) – as a paradigm, i.e. as a glaciodynamics-deglaciation paradigm. This paradigm, influenced by ideas of P. Woldstedt (1931), predicts that the last deglaciation of SIS has a pulsating nature: the colder periods, when the ice sheet advanced (i.e. cryostadials and cryophasials; in publications usually named as stages and phases) periodically were changed by warmer periods (i.e. thermostadials and thermophasials) when the ice margin retreated (in the ice-free territories the organic rich sediments began to accumulate). Thus, stratigraphic subdivision of sediments, as well as palaeogeographic reconstructions of the last glacial advance, were based on the climatostratigraphic criterion. This standpoint was very deeply developed in the Eastern Baltic region. For example, the detailed descriptions of above mentioned climatostratigraphic units (cryo- and thermostadials, cryo- and thermophasials) were included into the Lithuania Stratigraphic Guide (Grigelis et al., 2002). Moreover, the Guide guide requires that each stratigraphic unit should have a real stratotype (typical section) based on the data of corresponding investigations (palaeobotanic, geochronological, etc.). Others postulates of this paradigm, maybe the most important ones, are follows: 1) the frontal retreat of the ice margin prevailed during the last SIS deglaciation; 2) the ice margin pulsations (cryostadials, cryophasials) were synchronous according to entire perimeter on the ice sheet. As a result, a large amount of papers explaining different peculiarities of the last SIS deglaciation was published on the basis of this paradigm.

The problem of existing glaciodynamics-deglaciation paradigm is that the thermostadial or thermophasial status of all the previously famous geological sections (so-called stratotypes) with organic sediments (for example, sections of Ūla, Raunis, Antaviliai, Odra Bank) have not been confirmed after the more detailed investigations carried out during the last few decades. It was found that: 1) real age of the dated sediments is younger/older as previously estimated; 2) the sediments are laying not *in situ*; 3) the organic sediments were re-deposited from older interglacial layers (Bitinas, 2011). The existing concept of deglaciation cannot logically and convincingly explain the formation of such forms of glacial relief as glaciolacustrine plateau-like hills or kame terraces on the distal slopes of marginal ridges.

Due to existing contradictions of the existing glaciodynamics-deglaciation paradigm the idea of a new paradigm was suggested and developed (Bitinas, 2011, 2012). The new paradigm contains a few postulates linked with deglaciation of the last SIS:

– fluctuations of the so-called cryo- and thermostadials or cryo- and thermophasials were absent;
– the so-called stadial or phasial recessional marginal moraine ridges are result of glacial surges where meltwater beneath the ice sheet played the exclusively significant role: a majority of these ridges (probably except the Salpausselkä moraines only) are asynchronous along the SIS margin.

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– the areal deglaciation of the last SIS significantly prevails against the frontal one: the frontal ice retreat was more characteristic for the initial stage of deglaciation, whereas the areal ice melting prevailed during deglaciation of the biggest part of glaciated territory.

Moreover, the new paradigm could more reliably explain formation of above mentioned very specific forms of glacial relief as glaciolacustrine plateau-like hills or kame terraces on the distal slopes of marginal ridges: it could be imagined only between the lobes of active ice sheet and the blocks of dead ice (Bitinas et al., 2004, 2012). The results of cosmogenic dating of boulders as well as OSL data of surficial and inter-morainic sandy sediments collected in the eastern flank of SIS and published by different authors during the latest decades do not contradict with presented postulates of the new paradigm. Moreover, the oldest radiocarbon data of reindeer's antlers in the Eastern Baltic region maintain about synchronous expansion of reindeers into the biggest part of deglaciated territory (Ukkonen et al., 2006) – it also indirectly confirms the concept of areal deglaciation.

Any new evidences confirming the existing glaciodynamics-deglaciation paradigm and the prevailing concept about the frontal pattern of ice margin retreat (deglaciation) have not been found during geological investigations carried out in the few last decades. Nevertheless, this paradigm is still alive and widely applied in a number of present-day scientific publications.

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Mass movement deposits in the sediments of Lake Gościąż

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The subject of our research – Lake Gościąż, is located in the central part of the Płock Basin, which is a wide section of the Toruń - Eberswalde spillway. The lake fills the lowest part of a subglacial channel system, which formed during the last ice sheet transgression. The depth of subglacial channel incision, taking under consideration the depth of the lake and thickness of lake bottom sediments, reaches 50 metres. The slopes of subglacial channel under current water level reach up to 5 metres, and their angle up to 20 degrees. Along the southern slopes of subglacial channel with Lake Gościąż, there are numerous active spring niches and 3 well visible inactive fossil landslide niches.

Lake Gościąż is widely known in Earth Sciences because of annually laminated lake sediments, which occur in almost the entire sediment profile from the deepest part of the lake. During previous research a massive sand layer was discovered in the Late Glacial part of the sediment record about 70 years after the onset of the Younger Dryas (Ralska-Jasiewiczowa et al., 1998). However, it was concluded that its accumulation was caused by mass movements, which did not result in a large erosion.

Current investigations showed that this sand layer is only a component of a large mass movement deposit with different sedimentological expression within the lake basin. Generally, in the southern part of the central deep of the lake, these mass movement sediments reach a thickness of about 2 metres. From the bottom sediments upwards, we can distinguish the following units:

1. Slump folds composed of deformed laminated gyttja and a massive sand layer included in these deformations which we interpret as subaquatic landslide.
2. Mixed gyttja with numerous sharp-edged intraclasts of brecciated laminated gyttja. The number of intraclasts decrease upwards. We interpret this unit as a debrite.
3. Mixed gyttja - as a result of mudflow.
4. 2 mm thick layer of silty gyttja – deposited from suspension.

In the northern part of the central deep of the lake only units no. 3 and 4 have been deposited. Geomorphological observations in the shore zone of the Lake Gościąż basin allow for connecting subaquatic movements with an inactive landslide located in central - southern part of the basin. This landslide has a very well developed main scarp. The presence of minor scarps in the upper part of the landslide tongue indicate a rotation type of the landslide. Similar type of landslide niches also occur in the south – eastern part of the subglacial channel. 14C dating of gyttja covered by 6 metres of colluvium indicate their time of origin to be similar to the central landslide.

The analysed landslides occurred around the transition from Allerød to the Younger Dryas, three hundred years after the assumed final melting of the buried dead ice in the subglacial channel. At that time the lake basin has been already fully developed. This allows us to exclude dead ice melting processes as direct cause of the landslide activity. Possible causes of landslide activity include rapid changes of sediment moisture on the slopes of the lake basin as well as degradation

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of permafrost. However, taking into account the fact that central landslides were formed during the cold period of the Younger Dryas, the degradation of permafrost is unlikely. Instead, we suspect permafrost aggradation and related concentration of ground water outflow. In this case, the mass movement activity could be attributed to high - pressure local ground water outflow. However, the level of age similarity between central and southern - eastern landslides can also show an earthquake activity, caused by glacioisostatic rebound.

A key argument to support this hypothesis is the occurrence of numerous tectonic dislocations in Cretaceous and Paleogene and Neogene sediments. In close proximity to the studied area also numerous salt structures as salt domes occur. Both the tectonic dislocations and salt structures were highly susceptible to all kinds of movements connected with glacioisostatic rebound after deglaciation.

In the early Holocene, within annually laminated lake sediments, only small, several – centimetres thin layers of deformed sediments can be observed. They occur in the form of small folds and load cast structures. These structures indicate minor subaquatic slopes instability.

This study is a contribution to scientific project financed by the National Science Centre, Poland - No. UMO-2015/19/B/ST10/03039.

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The exploration of heavy minerals and Rare Earth Elements (REE) in marine sand deposits on the SW Baltic Sea floor – Scientific background and progress report of the SEEsand project

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The project name "SEEsand" derives from the German term for REE (**S**eltene **E**rden **E**lemente) and aims at assessing the potential for producing REE as a byproduct from ongoing off-shore aggregate extraction. The project consortium comprises an interdisciplinary team composed of geological state authorities, industry, academia, and raw material traders. Heavy mineral enriched deposits containing REE bearing Zircon are locally common within unconsilidated clastic deposits of the SW Baltic Sea floor. The most important source minerals in which REE occur are found in alkaline magmatic and metamorphic complexes and carbonatite rocks. Rocks of this type were eroded, transported and deposited by the advancing Scandinavian Ice Sheet during the Late Quaternary period and are associated with several glacial deposits in the Baltic Sea basin. The Baltic Sea transgression some 8,500 years ago caused intense marine reworking of glacial sediments e.g. tills and/or glaciofluvial deposits originating from southern Scandinavia, leading to mechanical and mineralogical differentiation resulting in heavy mineral enriched secondary sediments. Mineralogically, the heavy mineral fraction contains primarily almandite, ilmenite, magnetite, rutile and zircon with minor contents of monazite. First systematic investigations of the heavy mineral fraction within the marine sands of the SW Baltic Sea during the 1980s showed that the zircon fraction contains approximately 0.7% of REE, with 88% of these REE representing Heavy REE (HREE; Glombitza et al., 1988). Despite the relatively small amount of zircon-bound REE, a by-production of REE from aggregate mining seems economically viable considering the high volume of aggregate mining from the Baltic Sea shelf (c. 500 000 t annually), which are primarily used for purposes of coastal protection and construction.

During the first project phase the distribution and concentration of detrital heavy minerals in offshore areas of the southwestern Baltic Sea were determined, using archival drill core information from the exploration of near-surface clastic soft-sediments on the Baltic Sea shelf conducted by the Central Geological Institute (ZGI) of the former German Democratic Republic (Weinert and Stephan, 1983, 1985). A spatial examination of 21,526 heavy mineral measurements, obtained from 7,164 drilling and surface sampling locations (cf. Fig. 1) with 40,349 granulometric measurements show an aerially averaged (mineralogically undifferentiated) heavy mineral content between 0.12 and 0.93 % mass (derived from averaging the HMC from the <1.0 mm sand fraction of all available sediment cores).

For the subsequent recovery of zircon a combination of off- and onshore gravity, magnetic and electrostatic separation techniques will be applied. Further processing will separate the REE-bearing Zircon-fraction and extract the REE from the Zircon by means of environmentally friendly hydrochemical and biochemical leaching. Alternatively, various conventional chemical and as newly developed mechano-chemical leaching techniques will be tested. A quantified estimation of the total economic resource potential will be used to evaluate the different methodologies at market conditions.

The SEEsand research project is mainly financed by the research funding "r4 – Innovative Technologies for Resource Efficiency – Research for Supplying Strategic Economic Raw Materials" of Federal Ministry of Education and Research of Germany (BMBF grant No. 033R163A).

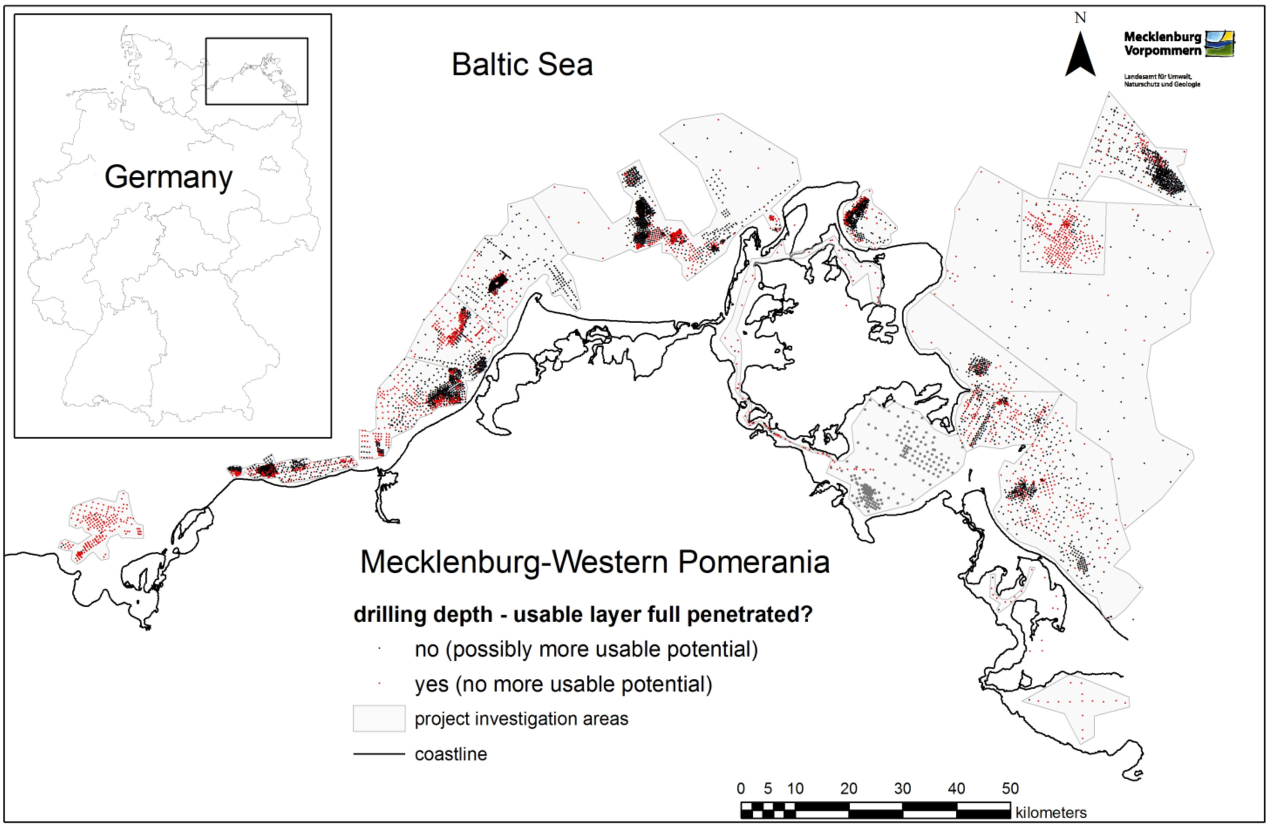

Fig. 1: Locations of exploration drill cores within Pleistocene marine sand and gravel deposits of the SW Baltic Sea (recovered during the period 1980 until 2017).

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The southwestern sector of the Weichselian Scandinavian Ice Sheet: Facts and knowledge gaps

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Some progress was made in dating of Weichselian sediments in the south-western sector of the Scandinavian Ice Sheet (SIS) in Sweden, Denmark and Germany. Most ages are based on luminescence dating of glaciofluvial and glaciolacustrine sediments, and cosmogenic nuclide exposure dating of glacial boulders. The increasing number of numerical data gives new insights into the timing of various glacigenic, glaciofluvial and glacilimnic processes (Hughes et al., 2015). In Germany, the traditional names of ice advances like Brandenburg, Frankfurt and Pomeranian advance pretend a synchronous formation of ice marginal positions over some distance, not taking into consideration the varying ice dynamics at the distal part of the SIS. In this study, we review existing data and present a revised model of Weichselian ice dynamics in the SW sector of the Baltic Sea.

During MIS 4 and/or the early MIS3, according to the present knowledge, the Ellund-Warnow advance marks the first expansion of glaciers during the Weichselian into the SW Baltic Sea area. But it is only lithostratigraphically documented in western Mecklenburg and in parts of northern Schleswig-Holstein. Morphological features are missing as well as geochronological data.

During late MIS 3, the ice attained the maximum extent within the Oder lobe (Brandenburg advance) and reached into western Denmark (Klintholm advance) (Hardt et al., 2016, Hardt, 2017). Nevertheless, there is no evidence that Bornholm, the Rønne Bank as well as Rügen were overridden by ice at that time; instead (glacio-)fluvial processes are documented and glaciolacustrine sediments were deposited in ice dammed lakes. The maximum ice advance of the Oder lobe is dated to 32-28 ka by samples from glaciofluvial material at the southernmost ice marginal position as well as in the hinterland. The results correspond with the morphological and sedimentological observations. The area is mainly characterized by meltwater sediments and erosional channels, which are in accordance with the assumption of a fast flowing ice of an outlet glacier. Distinct terminal moraines are missing, and the till is about 2 m thick. In western Mecklenburg as well as in Schleswig-Holstein no data are available so far.

The ice advance in correspondence with the global LGM at about 22-20ka, is named Pomeranian advance in NE Germany, (Lüthgens & Böse, 2011, Lüthgens et al., 2011). This phase was likely characterized by slower moving ice and a steady state situation at the ice margin, what can be deduced from the boulder-rich and distinct end moraines in northern Brandenburg. In western Mecklenburg, data of sediments of similar processes are missing, and the morphological situation is not so clear. The complex and overlapping ice advances in Schleswig-Holstein are not yet well dated. But isochronic ice cover is also documented in the Baltic Sea basin, at the German coastal cliffs in Mecklenburg-Vorpommern and in Denmark.

Thus, various sedimentary environments existed in close neighborhood in the southwestern Baltic Sea basin and the surrounding areas, shedding new light on ice dynamics. The cosmogenic nuclide data of boulders represent the down wasting of the ice cover and the stabilization of the landscape which can last until the melting of dead ice in the subsurface. Therefore these ages represent different processes.

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The configuration and dynamics of the SIS in its southwestern part were obviously very different during the MIS 3 and MIS 2 ice advances, influenced by climatic parameters, and the topography of the Baltic Sea basin and adjacent areas.

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The isotopic composition of groundwater in the Baltic–White Sea region as a reflection of geographical and climatic evolution in the Late Pleistocene-Holocene

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Significant change in the configuration and water levels of paleo water reservoirs which took place in the Late Pleistocene and Holocene are the distinctive features of the Baltic Sea – White Sea region. Groundwater can reflect the history of the territory development in the geological past, so they are a paleogeography archive (Kendall, McDonnell, 1998; Ferronsky, Polyakov, 2012). Groundwater formed during the last cold period under the influence of the Eemian Sea and the Baltic Ice Lake, and also cryogenic metamorphism was discovered.

The present paper is based on studies of deuterium (δ2H), oxygen-18 (δ18O), tritium (3H) and uranium (234U/238U) to uncover the conditions of the groundwater formation and assess the effect of climate changes on aquifers. Isotope tracers were applied for groundwater dating and to identify the processes of evaporation or freezing in past. Studies were carried out in 2005–2017 and included monitoring of atmospheric precipitations, analyses of GNIP IAEA database (the WISER tool on https://websso.iaea.org/), snow surveys and testing of surface water and groundwater. The research concerned the formation of unique groundwater composition in some sites including the southeastern part of the Baltic shield hydrogeological massif, east part of Baltic Artesian Basin (in the Leningrad region and the Karelia) and west part of the North Dvina artesian basins (Eemian Sea).

The iodine groundwater is formed in North Dvina River valley in the upper part of the Vendian sand- and siltstones (Vpd) under marine clay (mQIIImk) on the depth near 100 m. The highest iodine content is 40 mg/L), groundwater salinity varies from 15 to 25 g/l. The iodine water has a relatively heavy isotopic composition (from δ2H=−38‰ and δ18O=−5.2‰ to δ2H=−69‰ and δ18O=−10.1‰) which is shifted to right from GMWL (Global Meteoric Water Line) and the uranium-234 enrichment (234U/234U ratio from 4.3 to 6.8 by activity). The formation of the water iodine anomaly apparently included two consecutive stages: 1) burial of the saline and isotopically heavy waters together with the organic material containing bound iodine, within the clay complex of the Eemian Sea; 2) freezing of the geological strata, accompanied by the release of iodine from the organic matter and the displacement of residual water down to the clay basement as a result of the pore pressure increase during the underground ice formation.

The fresh ferruginous (highest iron content 147 mg/l) groundwater is formed in the oxidation zone of the schungite- and pyrite-bearing of the Lower Proterozoic crystalline rocks in the western part of the Onega structure (Karelia, spa "Marcial Waters Resort"). The isotope tracers (δ2H, δ18O, δ13C, 3He, 234U/238U, 3H) in groundwater have strongly changed over the past 30 years (Tokarev et al., 2015). Early data indicated the cryogenic metamorphism under partial water freezing in the last glacial period. Now we observe a rapid penetration of meteoric water and a gradual vanishing of the "old" component. At the same time, the major chemical composition of water did not change. This is possible only if the beneficial balneological agent (iron) comes with the young water component. In turn, this means rapid equilibration in the water-rock system due to the presence of iron in the easily soluble compounds. Most likely, these are the secondary sulfates formed during the glaciation period during oxidation of sulphides in the black shales. The most intense oxidation process proceeded during the Weichselian cooling, when the general decrease in the level of groundwater, the increase in oxygen content, and the decrease in the organic content in the frozen zone happened.

The Riphean and Vendian aquifers of Baltic artesian basin located south of the Baltic hydrogeological massif. On some sites the isotopic composition of groundwater are extremely depleted up to $\delta18O=-22‰$ and $\delta2H=-170‰$ at the Tallinn water intake (Raidla et al., 2009) and identified as the waters recharged in cool climate conditions at the end of the Pleistocene or at the beginning of the Holocene period .

The presented materials allow us to formulate a conceptual model of the influence of geographic and climatic variations in the Baltic Sea – White Sea region at the end of Pleistocene and in Holocene on the groundwater formation.

A) Eemian interglacial – sea level rising and intrusion of seawater in aquifers near shoreline;
B) Weichselian glaciation – freezing of the geological section in areas not occupied by ice, squeezing down of residual water (cryopegs) in the geological section with simultaneous cryogenic metamorphism of chemical and isotopic composition, penetration of fresh meltwater during thawing of ice at the sheet bottom, the appearance of oxidizing conditions;
C) The end of the glaciation – recharging of the aquifers in coastal zone with fresh water intrusion during the Baltic Ice Lake, the appearance of “regenerated waters” in case of permafrost thawing;
D) Holocene – discharge of groundwater into the modern water reservoirs.

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Did the Baltic Ice Stream exist during the Late Saalian? New data from the northern Wielkopolska and Eastern Pomerania regions, Poland

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The last Saalian ice advance took place approximately 155-135 ka BP (Penultimate Glacial Maximum – PGM). Vast areas of Central Europe were covered by an ice sheet which left thick series of glacial deposits. The question is: what was the direction of the ice inflow into the area of contemporary Poland in the late MIS-6? To find the answer, we investigated glacial deposits in the Northern Wielkopolska and Gdańsk Pomerania regions. One of the best exposures of the Late Saalian is located in the Wapienno quarry, northern Wielkopolska region. The till unit B1 (Sokołowski, 2007; Wysota et al., 2009) consists of brown sandy diamicton, up to 4 m thick, predominantly massive, with poorly visible lamination in the uppermost part. In the northern part of the Wapienno quarry, B1 till lies directly on the Upper Jurassic limestones exploited in the quarry, whereas in the southern part of quarry, it is underlain by the sandy Wapienno Formation. The lower part of unit B1 comprises a layer of boulder pavement with ploughing structures. Till facies formed as a result of subglacial deformation combined with ploughing, lodgement and melt-out processes. Striae orientation on the pebble surfaces and Jurassic bedrock and till fabric measurements indicate the west to south-east ice movement (azimuth: 110°) (Sokołowski and Czubla, 2016). The same directions of glacial striae and till-fabrics were detected in neighboring key sites in Barcin, Młodocin and Dębówko Nowe. Although this is only an indicator of the local direction of ice movement, the inflow of ice from the western part of Fennoscandia is confirmed by the petrographic analysis of the fine gravel fraction in which there is only a slight predominance of sedimentary rocks over crystalline rocks. Similar conclusions were also drawn from the analysis of erratics in the fraction over 20 mm, carried out in Barcin, Młodocin, Dębówko Nowe and Wapienno sites. The maps of the erratic source areas show the balanced participation of Dalarna, Uppland, Småland, the bottom of the Baltic Sea and the Åland Islands in supplying rock material to the ice sheet which deposited the analyzed till. Erratics from western Sweden, Blekinge and Bornholm are rather rare in the Late Saalian tills in the northern Wielkopolska region. No rocks from Norway nor from mainland Finland were found in these deposits. Thus, it can be concluded that the analyzed ice mass was moving along the western edge of the Baltic Sea depression. Probably its path led across eastern Sweden (perhaps along the Baltic coast) and left the Baltic Sea depression towards the south.

Theoretical boulder centers (TBC – for the method, see Lüttig, 1958; Meyer, 1983; Czubla, 2001, 2015) of the B1 till in both studied profiles are shifted towards the southwest (16.16ºE; 58.21ºN in the western part of the pit and 15.97ºE; 58.45ºN in the eastern part) compared to the same parameters calculated for the younger glacial levels in Wapienno (Sokołowski and Czubla, 2016).

The TBC indicators calculated for tills in other outcrops under study (Barcin, Młodocin, Dębówko Nowe) yielded similar results. Therefore, we decided to investigate the same features of Late Saalian glacial deposits far to the north from these sites in Łęczyce near Lębork, northern Poland. The Late Saalian till in Łęczyce contains significantly more erratics from Åland regions, but the ratios between groups of indicator erratics originating in other regions of Fennoscandia are close to those found (observed) in northern Wielkopolska. As a result of the higher number of Åland rocks, a shift of TBC to the north-east can be observed. Initially, the Late Saalian ice flowed to the south

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most probably along the present-day Swedish coast, but in the final stage it turned to the east. The movement of ice from NW Fennoscandia is confirmed by erratics incorporated in southern Sweden and Bornholm.

The Scandinavian stage of ice flow is rather typical, but it is very hard to explain and justify the return of ice toward the east, which probably occurred in the southern part of the Baltic Basin close to the modern shoreline. A possible (hypothetical) ice stream (the older equivalent of the Baltic Ice Stream, if such existed) should have blocked the ice mass route to the south, and forced outflow towards the west, into the Danish straits. Numerous rocks from Bornholm and southern Sweden found in tills in Pomerania contradict this hypothesis.

Perhaps, during the Late Saalian, the western part of the Fennoscandian ice sheet developed (increased its range) faster than the eastern one and, therefore, in lower latitudes, the direction of ice movement was changing to the east. We speculate that this could have been caused by climatic factors, i.e. bigger humidity and, consequently, more frequent and larger snowfall which decreases with increasing distance from the Atlantic Ocean. In the light of petrographic analyses, no equivalent of the Baltic ice stream (sensu Punkari, 1997) existed in PGM.

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The Late Pleistocene-Early Holocene palaeoenvironmental evolution in the SE Baltic region: a multi-proxy palaeolimnological approach based on the Kamyshovoe Lake record

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The Kamyshovoe Lake (54 22 605` N, 22 ° 42 790` E, 189 m a.s.l.) sedimentary record in the southeastern Baltic Sea Region was studied to reconstruct climatic fluctuations and abiotic responses to them during Late Glacial and Early Holocene time. New results of geochemical, chironomid, isotopic, and palaeomagnetic data analysis were correlated with earlier evidence for lithological and palynological changes in the Kamyshovoe Lake record (Kublitsky et al., subm.). The fragment of the record studied encompassed an interval between ca. 16 000 and 6 500 cal. a BP.

The results obtained have led the authors to the following conclusions:

1. Palaeoclimatic chironomid-inferred reconstruction reflects summer temperature fluctuations of approximately 5°C over the period of ca. 15 300 – 6 800 cal. a BP. Mean July temperature was shown to increase from ca. 15 300 to 14 370 cal. a BP with an exceptionally high reconstructed temperature (19.8°C). A decreasing trend for summer temperatures is observed between 14 370 and 12 000 cal. a BP, when a minimum temperature (11.5°C) was recorded. A steady but very smooth rising temperature trend with fluctuations between 12.5 and 14.0°C persisted until ca. 9 800 cal. a BP, when a warmer period (14.1 – 16.0°C) began.
2. The Kamyshovoe Lake sequence reflects clear environmental responses to short-term early Holocene climatic oscillations superimposed upon general warming: about 11 300 cal. a BP, 10 700 – 10 500 cal. a BP, and 10 000 – 9 800 cal. a BP. These cooling events are diagnosed by chironomid analysis and changes in the palynological spectrum, geochemical record and lithostratigraphy of the sediments.
3. Despite marked changes in the vegetation around Kamyshovoe Lake at the onset of the Holocene climatic warming dated at 11 700 cal. a BP, no clear sediment responses at that time have been detected. All available data, including recent geochemical, isotopic and palaeomagnetic evidence, prove that both the terrestrial and limnic environments remained unstable until ca. 11 500 cal. a BP, when the sedimentation environment began to transform markedly.

The detailed study of bottom sediments from Kamyshovoe Lake has considerably expanded our knowledge of the climate and changes in the lake systems in the southeastern Baltic Sea Region at the Pleistocene-Holocene boundary. The results obtained show the significance of local factors and conditions which, together with global processes, could be responsible for differences in the response of natural systems to global trends. The study of Kamyshovoe Lake shows that in this case differences were indicated by the non-simultaneous and unequally distinct pattern of the response of individual natural components to global changes in climate.

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Properties of the aeolian covers in extraglacial part of the last Vistulian ice sheet limit (Central Poland)

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Landscape of Central Poland is characterized by the common occurrence of aeolian deposits fashioned as coversands and inland dunes. They are located in valleys of different origin as well as on interfluves. Dune hillocks reach a maximum of 17-18 m in height. Aeolian covers occur either as accompanying dunes or as individual phenomena. It happens frequently that their small thickness causes that they are being skipped during geological and geomorphological mapping and excluded from palaeogeographical reconstructions. Also their age is not clearly recognized. In the classic approach of evolution of aeolian forms in the extraglacial area of Central Poland by Dylikowa (1967) and Manikowska (1985) these landforms started to develop as early as the Oldest Dryas, thus at the decline of the last glacial period. Within the current studies 2 profiles of aeolian covers were subjected to investigations: Ługi and Wolskie Bog (Fig. 1).

The Ługi site is situated in inactive part of the Warta river valley. Sandy cover of a thickness about 1.0 m rests on fluvial deposits of the river terrace of both sides of the valley. Mostly it creates the present-day surface, sometimes small dune hillocks of irregular shape, up to a few metres high, have developed on it. The series consists of medium grained sand. Sedimentary structures are obliterated due to weathering and soil processes. The OSL analysis gave the result 15.4±1.6 ka BP (GdTL-2963). The covering dunes are very young, and were built on the soil horizon ^{14}C dated at 0.98±0.03 ka BP (GdA-5747) (0.957–0.796 ka cal BP; 95.4% prob.), while the OSL date yielded for a sample of sandy dune material is 0.118±0.016 ka BP (GdTL-2964).

The Wolskie Bog area is situated in the marginal zone of the Warta Stadial of the Odranian Glaciation on the morainic plateau and end-moraines. The area is slightly undulated and relief features are hardly expressed. The surface of glacial origin is covered by thin and discontinuous sandy coat, which forms ramparts of a small height in relation to the width. It usually does not exceed 1.0 m high, and consists of medium and fine sand. As at the Ługi site, the sedimentary structure is destroyed. OSL datings were made in two profiles, in first of them the obtained age was 18.25±0.95 ka BP (GdTL-3138), in second one results of dating of the bottom part of the profile gave the age 17.40±0.89 ka BP (GdTL-3139) and the top part – 12.21±0.82 ka BP (GdTL-3143).

Results of palaeogeographical studies carried out in the study area locates the origin of the described aeolian covers in the Oldest Dryas cold period. As is shown in environmental reconstructions based on advanced statistical methods for the area of the Łódź Region in Central Poland, the Oldest Dryas could have lasted for about 3 millennia, between 17.2 and 14.2 ka cal BP (Dzieduszyńska, 2019). Intensification of aeolian processes in that time were reported from several localities of Central Poland. At the Kamion profile (the Vistula river valley) the sand unit, underlain by palaeosoil ^{14}C dated at 14.59±0.27 ka ^{14}C BP (18.4–17.1 ka cal BP) and overlain by palaeosoil dated at 12.23±0.26 ka ^{14}C BP (15.1–13.6 ka cal BP), originated in the aeolian environment under conditions favoring strong mechanical weathering and deflation processes (Manikowska, 1985; Cichosz-Kostecka et al., 1991). The cover created the basement of the Lateglacial dune. The study by Kalińska and Wyszomierski (2010) provided data on the aeolian origin of a flat plain of the southern Masovian Lakeland. Obtained OSL dates ranging between 16.3±0.8 ka and 14.81±0.78 ka

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also indicate the Oldest Dryas. However, an age of 12.27±0.63 ka for the top of the series indicates the formation during the Younger Dryas.

Conclusions:

- ✓ the analysed sandy covers occupy significant areas in valleys and interfluves, but because of a small thickness their occurrence is not reflected on the geological and geomorphological maps;
- ✓ interpretation of thin sandy covers is difficult because of their structureless character resulted from weathering and soil processes; the sandy covers usually create the present-day surface;
- ✓ the results of OSL datings from Ługi and Wolskie Bog sites and other few datings from Central Poland suggest that sandy covers were formed during the Oldest Dryas, and some of them were build up during the Younger Dryas; the latter are still very poorly known;
- ✓ the widespread Oldest Dryas aeolian cover around the Ługi site was possibly fixed by vegetation during the Younger Dryas; restrain of aeolian activity is recorded in small mineral admixture in the Younger Dryas organic succession of the basin of biogenic material.

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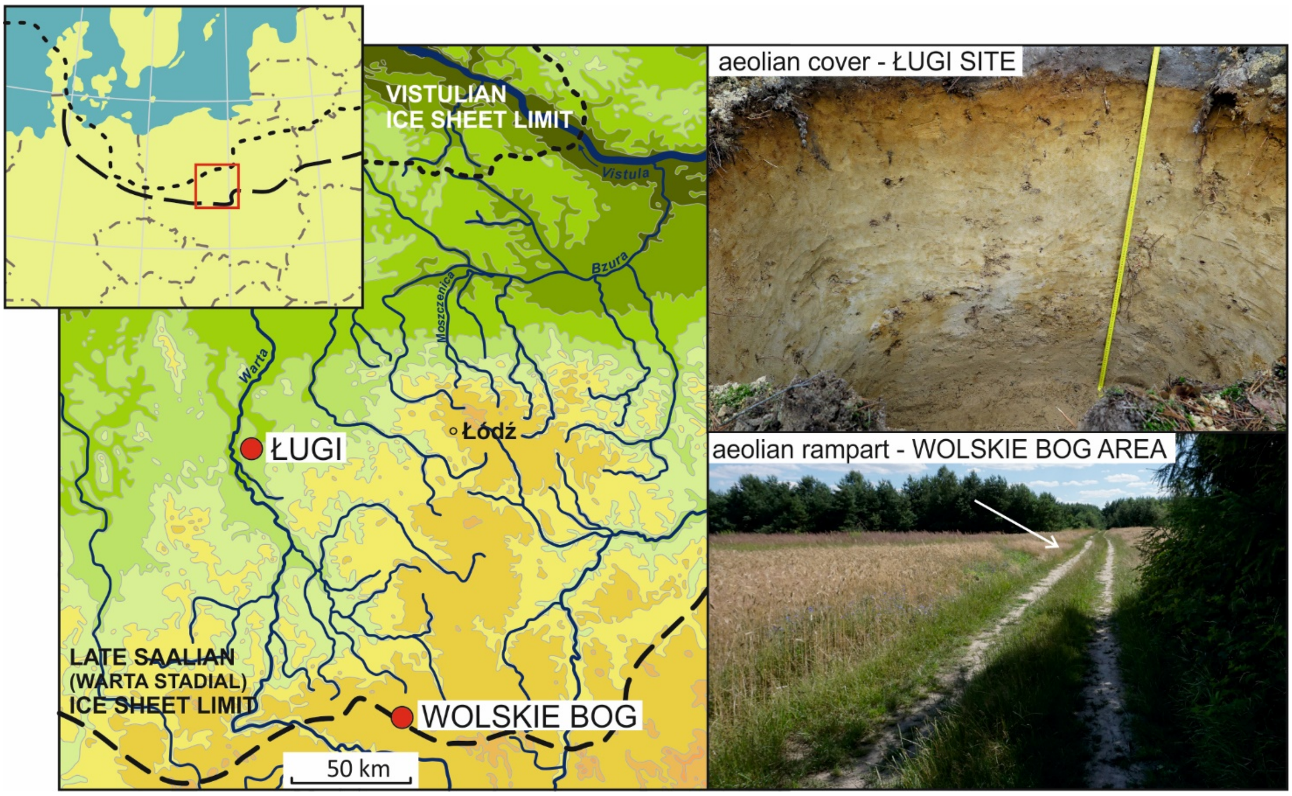

Fig. 1. Location of studied aeolian covers, example of aeolian cover deposits and its expression in the relief

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Relic pingo at Józefów in central Poland

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Closed depressions in Józefów are located in a morainic plateau of the Łódź Upland. This part of Central Poland was glaciated during the Warta Stadial (Saalian) for the last time, and many postglacial depressions have been documented in this area. Some of them contain infillings composed of lacustrine deposits or peat (among others Klatkowa, 1990; Roman, 2016; Majecka et al., 2019).

Geological inwestigation at Józefów were initiated in 1960s. Biogenic and mineral-biogenic deposits were examined in two depressions (Dylik, 1961, 1963, 1967; Klajnert, 1965). These depressions are dry at present and do not contain any biogenic sediments of Late Vistulian or Holocene age. In the depression B there are lacustrine deposits of the Eemian Interglacial, covered by sandy series and peat of the Early Vistulian; a sequence terminates with sand and sandy gravel of the Plenivistulian (Dylik, 1963; Sobolewska, 1966). According to Dylik (1963) the deposition was twice interrupted by development of pingo structures. The first phase followed deposition of peat layer, then the deformed deposits were covered by congelifluction deposits and sandy-silt deposits with injectional deformations caused by ice of the second pingo-formation phase (Dylik, 1963, 1969). The Józefów site was considered for a classical example of pingo remnants (e.g. De Gans, 1988; French, 2007), but there are also views questioning such origin and age of the studied structure (e.g. Klajnert, 1965; Flemal, 1976, Seppälä, 1988).

In 2018-2019 four new exposures were examined in the middle part of the site and in a marginal part of the depression B. They confirmed presence of a deformed peat series and many crack-structures with sandy infillings. The peat layer is bent in a marginal part of the depression. Above, there is a sandy-gravel series with deformations and stretched thin peat layers. The upper layer is composed of sandy-silt with post-depositional deformations. OSL dating of sediments indicates age 19 to 21 ka BP of the sandy fillings in cracks in the peat series. The sandy-gravel series is dated at 17-19 ka BP, and the upper sand 14-17 ka BP. Analysis the quartz grain surface processing proved predominance of aeolian grains formed in cracks infillings (about 50-55 % RM-type towards EL-type below 10%). In the upper series there are more shiny grains (EL-type), but in all samples participation of cracked and fresh grains is significant.

New palaeobotanical research confirms the Early Vistulian age of the peat. Cracks with sandy infilling and shift of the peat could originate in periglacial conditions. They are similar to dilatation cracks, observed in contemporary pingos (Mackay, 1998). Dating and analysis of the quartz grain surface suggest that cracks were formed during the Plenivistulian and are synchronous with LGM. If the peat layer was raised by the expanding ice body inside a pingo, sand may have been moved into dilatation cracks, because sand was commonly wind-transported at that time. After the pingo collapsed, the depression has been rejuvenated and sand with gravel from the surroundings could flow down by congelifluction.

Studies carried out in recent years confirm the pingo origin of the depression B at Józefów as proposed by Jan Dylik, but it was formed probably in a single cycle during the Upper Plenivistulian.

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The problem of analysing grain size distribution in fluvioglacial coarse-grained sediments

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Research into coarse sediments using quantitative analyses presents numerous problems which result from the lack of an appropriate method. In order to perform a possibly reliable reconstruction of the conditions of sediment transport and accumulation, the optimal choice is to perform a complete analysis of grain size distribution. For coarse sediments it is much more difficult and labour-intensive than for fine sediments. Most existing methods focus on a single group of sediments, analysing either coarse or fine sediments. Methods which allow for the entire spectrum of grain size distribution to be analysed are very time-consuming and labour-intensive, often involving the necessity to disturb large masses of sediments. Developing such a method was the aim of many authors (Rutkowski, 1995; Rubin, 2004; Graham et al., 2005; Buscombe, 2008; Pisarska-Jamroży et al., 2011). In well washed gravelly sediments of rivers, the problem of grain size distribution analysis has virtually been solved. The most traditional method is the clast size measurement according to Wolman, which is currently being replaced by software for Automated Grain Sizing (AGS) such as Digital Gravelometer (Graham et al., 2005) or BASEGRAIN (Detert and Weitbrecht, 2012). Unfortunately, the software does not offer the possibility to measure the content of sandy and finer fractions. Fluvioglacial coarse-grained sediments from former glaciations are analysed in walls of natural or artificial outcrops and they are mostly not well sorted. Due to this, many authors who analyse the sediments of sandurs, eskers, terminal moraines or other forms present data without taking into account the most coarse or fine fractions.

The authors believe that a new combination of Automated Grain Sizing and sieve analysis would offer the possibility to analyse the entire spectrum of sediment fractions. The authors expect a greater precision of the method than if AGS only is used, as the measurement error will be reduced for fine fractions. The research concept includes the experimental and verification stages. The analysis involves taking photographs of sediments at outcrops (Fig. 1A). Photographs will be taken for sediments with varied textural characteristics. The use of an infrared photography filter will be tested, which may have a positive influence on image precision. At the second stage, the images will be processed in Digital Gravelometer software (Graham et al., 2005). The analysis procedure involves using a morphological bottom-hat filter, double threshold and selecting an appropriate threshold value for the watershed segmentation algorithm. The final result is an image with isolated clasts, on the basis of which the grain size distribution report is created (Fig.1B). The large area of images poses a problem with the recognition of fine gravels by the software. This is why one of the main aims of the experimental stage is to determine the optimal cut-off border, beyond which the measurement becomes unreliable. For the finer fraction a sieve analysis will be performed. The results will be combined on the basis of the calculated area of the analysed photographs. The verification stage will involve a grain size distribution analysis using the method of direct measurements and sieve analysis of sediments at the photographed locations.

The results of preliminary research conducted at the Siedlątków site where sediments of glacial flood was documented (Frydrych and Rdzany, 2018) have revealed a great potential of the method.

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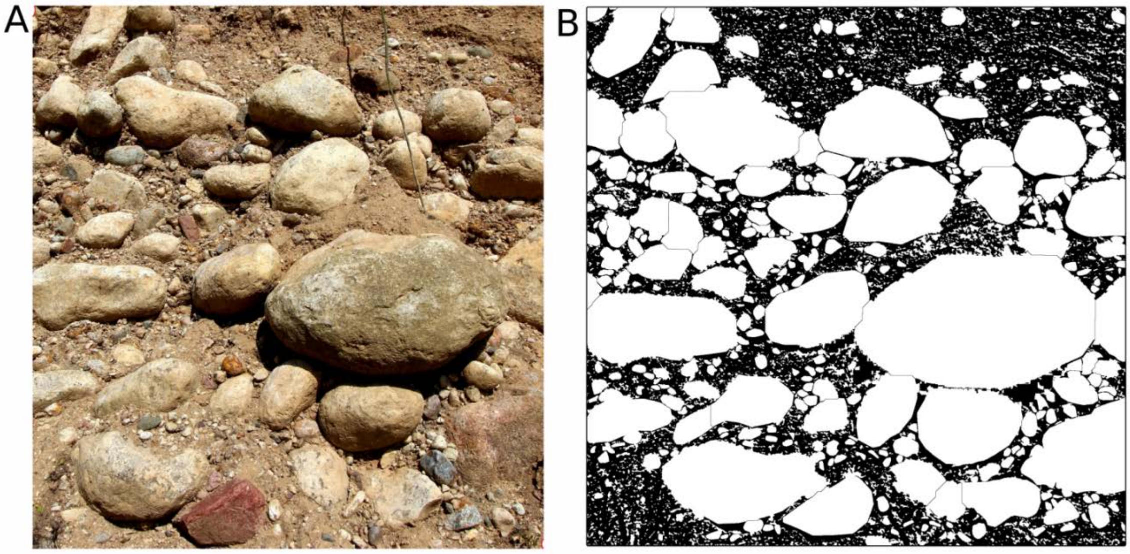

Fig.1. Automated Grain Sizing. A. The photograph of coarse-grained sediments of glacial flood at Siedlątków site; B. The image with isolated clasts from Digital Gravelometer software.

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Microbiomorphic analysis: possibilities, limits and information capacity for landscape reconstruction

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Microbiomorpic analysis refers to the combined study of phytoliths, spores, pollen, diatoms, sponge spicules, cuticle casts, detritus, and other microscopic biological parts (Golyeva, 2001). Most soils – including natural strata, plowed fields, pastures, and cultural layers – contain different and distinctive arrays of these microscopic remains. The primary purpose of microbiomorphic analysis in pedology and palaeopedology is the determination of evolutionary trends of soils and anthropogenic sediments and the determination of modern and past environmental conditions (Barczi et al., 2009; Golyeva and Andrič, 2014; Solís-Castillo et al., 2015; Sikora et al., 2019). For archaeological purposes, a combined microbiomorphical analysis increases the reliability of individual data and truthfulness of the reconstruction of a behavioral people activity (Engovatova and Golyeva, 2012; Sánchez-Pérez et al., 2013; Golyeva and Svirida, 2017; Golyeva et al., 2018).

Each method has its limitations when its informative capabilities are limited or even impossible at all. For example:
- severe erosion (water, wind) contributes to the distroy of the upper soil horizon and, accordingly, losses all components of biogenic nature;
- loess deposits of aeolian genesis do not contain microbiomorphs, since the separation of particles occurs during movement and dust particles settle earlier;
- mountain rocks are very porous so small particles migrate down the soil profile and along the slope;
- when ploughing, mixing (homogenization) of a significant part of the soil profile occurs, which makes it impossible to carry out a detailed reconstruction of the evolution of the landscape;
- the application of significant doses of organic fertilizers to the soil complicates the microbiomorphic complex and does not allow to determinate the initial components.

But all these limitations do not reduce the high information capability of the method. Often the opposite - the absence of certain microbiomorphs or their complete absence is also a diagnostic indicator.

Microbiomorphic analysis allows one to:

1. Identify past erosional and depositional events and estimate the thickness of resulting deposits

2. Identify buried soils

3. Determine the composition of past local and regional plant communities

4. Assess anthropogenic impacts on soils, even where there are no evident morphological traces of these impacts

5. Determine the parent material, especially of hydromorphic soils

6. Judge the degree and cause of soil hydromorphism.

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Hybrid event beds from the Tylmanowa site (Polish Outer Carpathians)

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The thick-bedded sandstone succession from the Polish Outer Carpathians was described at the Tylmanowa site. Studied succession consists of the Lower Eocene sediments dominated by massive, ripple-cross laminated, planar and trough cross-stratified, horizontally-laminated and deformed sandstones as well as massive and horizontally-laminated mudstones. Among them massive sandstones predominant. The origin of all these lithofacies is related to the deep-water gravity flows (low- and high-density turbidity currents, debris flows and grain flows) that prograde across the continental shelf and slope towards the widespread abyssal plain. Succession at the Tylmanowa site records the deposition from complex, internally-stratified gravity flows, whose behaviour were changing from plastic to fluid. It is manifested by the gradual transition from a decelerating, dense debris flow to a strongly diluted turbidity current.

Three recognised lithofacies association are related to the upper and middle parts of the submarine fan: (1) association of massive sandstones represents distributary channel fill deposits, (2) association of sandstones interbedded by mudstones refers to the middle fan channel-margin levees deposits or interchannel deposits, and (3) association of mudstones interbedded by sandstones exhibits the upper fan channel-margin levees deposits.

Succession at the Tylmanowa site may be considered as an example of the fluxoturbidites or high-density turbidites. However, its characteristic features of both, turbidity current and debris flow deposits point to the interpretation as the hybrid event beds (Górska, 2019).

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Merkinė (Eemian) deposits at the Kurkliai outcrop

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Kurkliai outcrop was documented during geological mapping of the Ukmergė area at a scale of 1:50 000. The Kurkliai outcrop is situated in Anykščiai district, 3 km southwest from Kurkliai settlement, on the right slope of ravine opening to Judinys River valley. The top of the outcrop is at a 120 m a.s.l. Till, sand, peat, lacustrine carbonate sediments are observed in the outcrop (cf. fig. 1). The Merkinė (Eemian) Interglacial deposits are composed of peat and lacustrine carbonate sediments that were accumulated in the lake of depression of the Saalian glaciolacustrine sandy terrain. The thickness of the interglacial deposits layer is more than 3,34 m.

Pollen and chemical analyses were carried out in the section. The lacustrine sediments contain $CaCO_3$ up to 84%. The pollen data show that accumulation of lacustrine carbonate sediments began in the early Eemian. The vegetation was dominated by mixed pine-birch forest. The accumulation continues in the first subzone of the climate optimum of Eemian Interglacial. The vegetation was characterized by spread of oak-elm forest. Peat accumulation started at the beginning of the second subzone of the climate optimum of the Eemian Interglacial. At that time the lime-trees appeared in the territory.

The upper part of interglacial lacustrine deposits was most likely eroded by Upper Nemunas (Weichselian) glacier and covered by till (Fig. 1).

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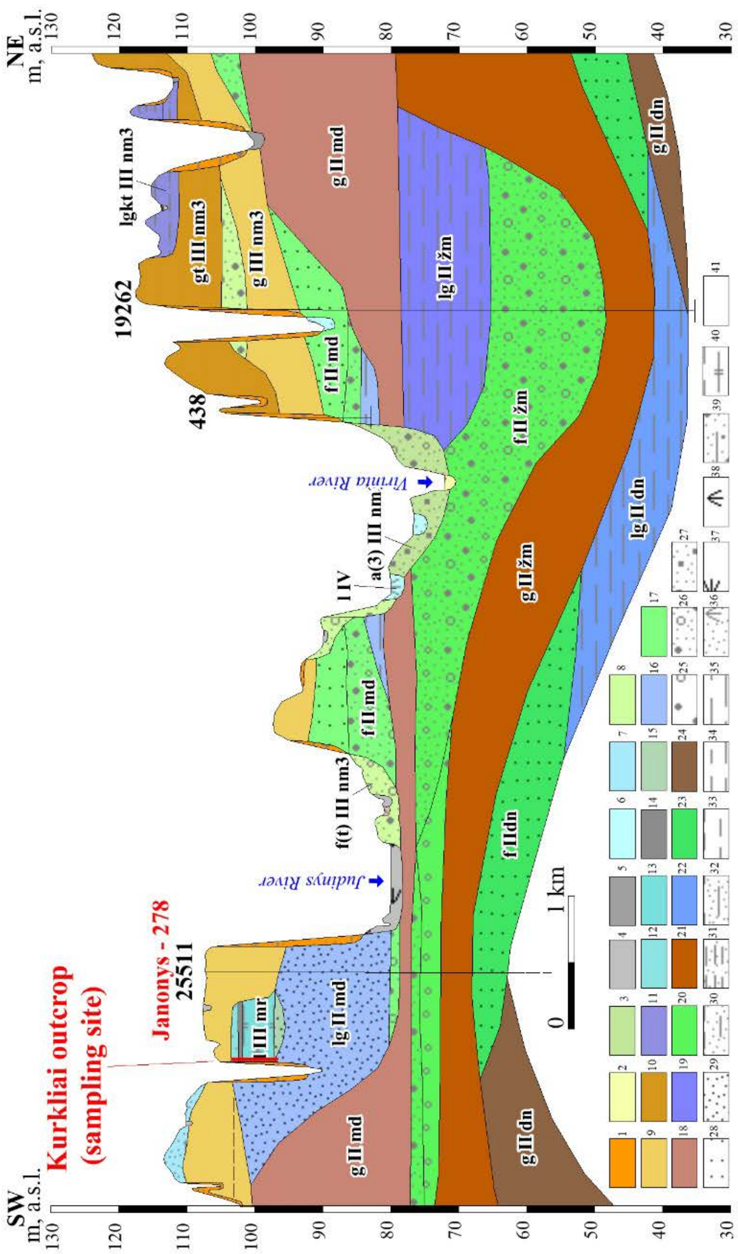

Fig.1. The geological cross-section. Legend: Late Glacial and Holocene – 1-deluvial deposits, 2-alluvial deposits, 3-3-rd terrace alluvial deposits, 4-peat (type not identified), 5-lowmoor bog peat, 6-lacustrine sediments; Upper Nemunas glacial – 7-glaciolacustrine sediments, 8-glaciofluvial deposits, 9-basal till, 10-marginal till, 11-sediments of kame terrace; Lower Nemunas – 12-lacustrine sediments; Merkinė Interglacial – 13-lacustrine sediments, 14-peat bog deposits, 15-alluvial deposits; Medininkai glacial – 16-glaciolacustrine sediments, 17-glaciofluvial deposits, 18-basal till; Žemaitija glacial – 19-glaciolacustrine sediments, 20-glaciofluvial deposits, 21-basal till; Dainava glacial – 22-glaciolacustrine sediments, 23-glaciofluvial deposits, 24-basal till. Lithology – 25-pebble and gravel, 26-sand with gravel, 27-various grained sand, 28-fine grained sand, 29-very fine grained sand, 30-silty sand, 31-sandy silt, 32-clayey sand, 33-silt, 34-silty clay, 35-clay, 36-sand with peat, 37-peat (type not identified), 38-low moor bog peat, 39-clayey sand with gravel, 40-carbonate sediments, 41-loam.

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Glacial varves of Onega Ice Lake, Russian Karelia

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Onega Ice Lake developed in front of the receding Late Weichselian Fennoscandian Ice Sheet margin in Russian Karelia. Glacial varves that formed in Onega Ice Lake have been earlier studied by means of varve counts, palaeomagnetism and 14C AMS dates from small lakes north of modern Lake Onego and from Lake Onega proper. Synchronous changes in magnetic parameters and similar stratigraphy of these varve records together with the existence of basin-wide marker interval of pink-coloured varves have been used for core-to-core correlation and palaeogeographic interpretations (Demidov, 1997; Saarnisto and Saarinen, 2001). Unfortunately, there are missing varve-to-varve correlations between these cores. We present a 1155 yr long local varve chronology based on 3 parallel overlapping cores from two small lakes in the Zaonezhsky Peninsula at the northern coast of Lake Onega. Interval of laminated clays covers 395 cm and 440 cm in Lake Polevskoe and Lake Keratskoe respectively. In both lakes lower contact of varved clay with underlying glaciofluvial sandy-gravel is very sharp and indicates that the whole of varved clay complex was penetrated during the coring. Correlation among the cores, made directly on sediment sequences, was not problematic due to regular appearance of distinctive varves or varve intervals. Varve counting between marker layers along the cores and matching of varves between the cores was done on digital images. Mean varve thickness graph based on composite varve graphs of two lakes comprises 1155 consecutive varve years and is considered as a local varve chronology for Onega Ice Lake (OIS).

Presented varve calculation errors are not systematic, varying in positive as well as negative directions. The difference in total varve number between all studied sections counted by two workers and compared to the final number of varves in presented chronology is ranging -1 – -13 %, replicated counts on one sequence with parallel cores by two workers gave the difference in total varve number -6 – -11 %. The interval of microlayered clay (clay unit E) is a main source of uncertainties in the presented chronology with the difference between all counts ranging up to -24.3% of the final number of varves within that interval. Further studies into microlayered varve interval on new sections are expected to reduce the uncertainty in true number of varves in OIL chronology.

Following the textural, structural, colour and thickness changes of varves within OIL varve series, six characteristic lithologic units were identified. These clay units reflect changing sedimentary conditions at the time of clay accumulation which in general can be interpreted as a progressively increasing distance to the source, the retreating ice margin. Variations in varve thickness superimposed on that overall trend, namely episodes of abrupt and consistent decrease in varve thickness (clay units B and E), do not correspond to known lake-level changes or shifts in outflow directions (Zobkov et al., 2019). AMS chronology for deglaciation of Lake Onega basin (Saarnisto and Saarinen, 2001) gives some evidences for correlation of above intervals of decreased varve thickness with the GI-1c2 and GI-1B cold events in NGRIP δ 18O event stratigraphy but further age estimations are needed to confirm these correlations.

Earlier described in many OIL clay sections an interval of reddish-brown varves – the 'pink horizon' – was recognized in all three sequences and according to varve correlation, at the same stratigraphical level which proves its basin wide synchronous appearance.

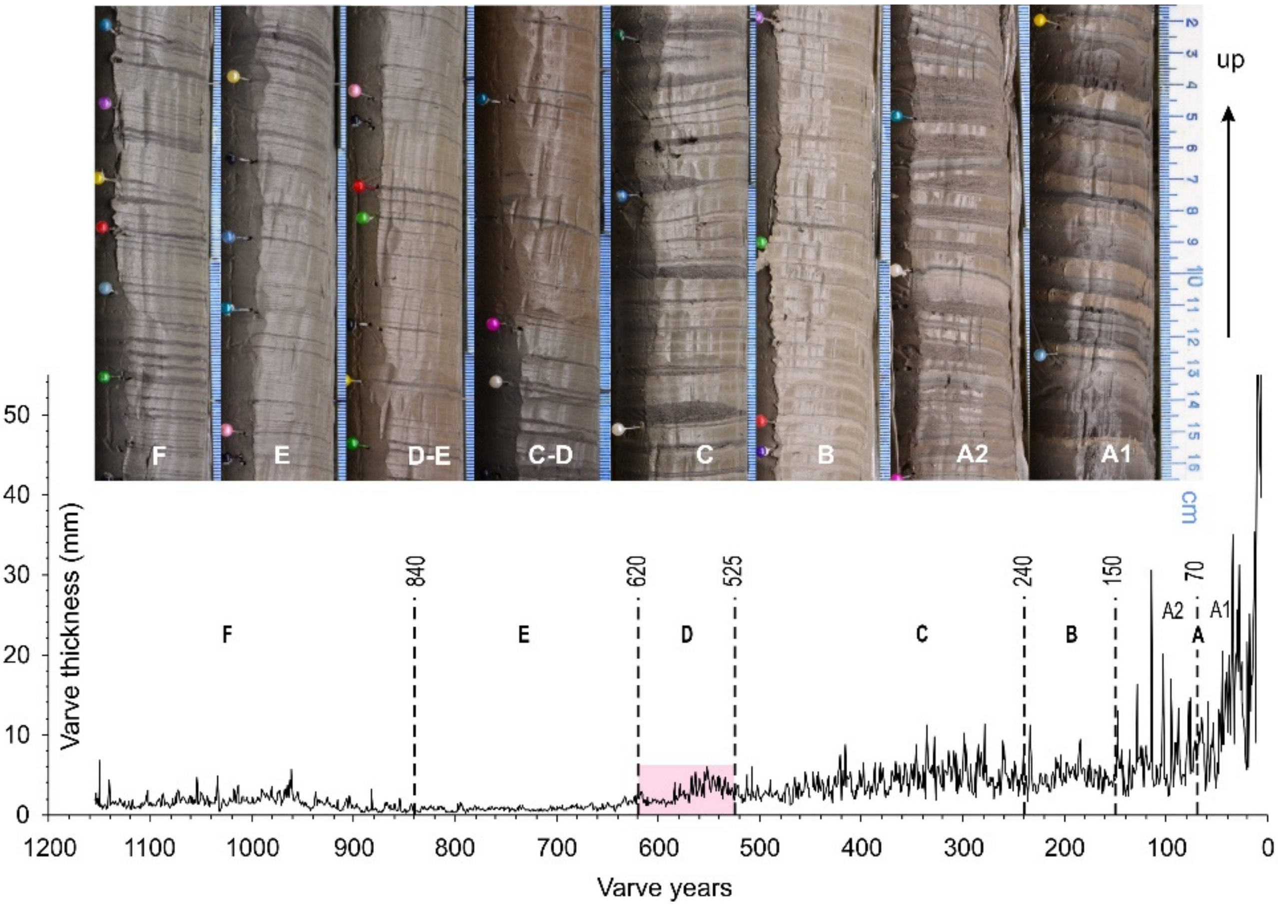

Fig. 1. Images and the position of the clay units (A-F) on the background of the mean Onega Ice Lake varve thickness graph. Varve numbers counted from the bottom and pointing to the unit boundaries are approximate due to gradual boundaries between the clay units; pink box points to the position of the 'pink horizon'.

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Late Pleistocene deglaciation and Scandinavian Ice Sheet dynamics in NE-Germany: new results from surface exposure dating in Mecklenburg-Vorpommern

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Recent international age compilations documenting the late Quaternary dynamics of the Scandinavian Ice Sheet (SIS; e.g. Hughes et al., 2015, Stroeven et al., 2016, Hardt and Böse, 2018) have highlighted that last glaciation advance and retreat timings varied significantly across different sectors of the SIS. Although this overall pattern is by now well established, there are still numerous areas with contradictory evidence and/or gaps in the record due to lack of absolute age information on glacial landforms and glacio-depositonal formations. Among the regions where significant chronological uncertainties persist is the North-German Plain, in spite of representing one of the classical landscapes for glacial research since the mid-19th century. As a consequence, there is ongoing debate around a series of SIS research questions which include (a) if and how far a potential mid-Weichselian ice advance (Warnow advance) extended into northern Germany; (b) whether or not the maximum of the Odra ice stream coincides, or alternatively significantly pre-dates the overall SIS maximum at ~21 ka; and (c) at what time the final LGM ice retreat commenced and how the deglaciation process of the German mainland was structured.

Here we present new information on the regional deglaciation history of the SIS based on a total of 38 CRN surface-exposure-ages (^{10}Be) from moraines between the Pomeranian ice margin and the Baltic Sea coast. Using the global ^{10}Be-production-rate by Heyman (2014), our ^{10}Be age data indicate that ice retreat from the Pomeranian moraine (W_2) commenced at around 16.5 ± 0.9 ka (n = 11). Ice positions further to the northeast (W_3), including the Rosenthal ice marginal zone (W_{3R}), yielded a mean age of 16.0 ± 0.9 ka (n = 12), while glacial boulders from the Islands of Rügen and Usedom, deposited just before the SIS retreated into the Baltic Sea Basin, returned a mean age of 14.9 ± 1.2 ka (n = 15).

Our record shows that the post-LGM deglaciation of NE-Germany, starting with ice recession from the Pomeranian moraine and ending with the deglaciation of the islands of Rügen and Usedom (retreat distance: 100-130 km) occurred over a time period of only 1 - 2 kyr between c. 16.5 – 15 ka ago. This indicates a relatively rapid SIS retreat from the North German Plain during the Last Glacial-Interglacial Transition, which was likely accelerated by the prevalent calving of the ice margin into large proglacial lakes. Contrary to the established glacial model for NE-Germany, which infers the W_3 ice positions to represent a last SIS re-advance out of the Baltic Sea Basin onto the mainland (*Mecklenburg-Phase*), our data indicate that it is more likely that the W_3 ice terminal positions formed as recessionals stillstand during the overall SIS retreat from NE-Germany.

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Earth, water, air, fire – human-environment relationships in the multi-proxy palaeoecological study at Serteya in Western Russia

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The Serteya site is situated in Western Dvina Lakeland (called also Vitebsk Lakeland), Western Russia. It is located within the recently glaciated area of the Valdai Ice Sheet and the land relief was formed from the Late Weichselian. The Serteyka River Valley, the left-bank tributary of the Western Dvina River, creates the main axis of the micro-region. The present-day valley was developed during the Holocene within a tunnel channel that was earlier occupied by few lake basins and later successively drained by the Serteyka River (Kalicki et al., 2015). The environmental conditions of the area were attractive for the Mesolithic as well as for the Neolithic communities, due to a high level of geo- and biodiversity of the landscape. It seems that settlement strongly depended on climate and vegetation changes, which influenced the availability of natural resources.

Numerous post-lake basins filled with biogenic deposits existed in the lower section of the Serteyka River valley floor. The largest one is the Great Serteya Palaeolake Basin. The discovered camp-sites and/or settlements were situated on the palaeolake shore and pile-dwellings also in the deep-water part of the basin. The Serteya II site is one of the most interesting archaeological sites in the area, situated within the Great Serteya Palaeolake Basin (Kittel et al., 2018). The remains of examined pile-dwelling constructions are dated from 4.9 to 3.8 ka BP, the main occupation phase existed however almost 140 years between 4.2-3.8 ka BP. The pile-dwelling settlement developed in the period of a domination of hunter-gatherer economy and beginning of agriculture (Mazurkevich et al., 2012).

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In the recent years, archaeological relicts dated from 8th to 3rd mill. BC found at the site area. They document an existence of multi-layered archaeological complex preserved both within organic deposits of the post-lake basin as well as on the sandy surface of the surrounding kame (Kittel et al., 2018). The Mesolithic and Neolithic settlement at Serteya II functioned in a period when palaeolakes existed and were affected by changes of the water table. The archaeological context suggests the presence of short-term episodes of lake water table decrease (ex. ca. 4,2 ka BP), allowing the pile-dwelling settlement's development on a post-lake plain (Mazurkevich et al., 2017). The geological study at the site area demonstrates as well an increase of water table in the Middle Holocene, ca. 6 ka BP (Kittel et al., 2018).

The palaeoenvironmental reconstruction based on multi-proxy palaeoecological analyses were undertaken at the site for better understanding of: i/ natural environment components' changes in the Holocene, ii/ environmental conditions of ancient communities' existence, iii/ natural resources of ancient communities, iv/ human-environment relationships in the Neolithic. The research is based on palaeoecological analyses: pollen, plant macrofossils, charcoal, diatoms, fish remains, mollusc, Cladocera, Chironomidae, geochemistry, sedimentology. A few AMS radiocarbon dating was made for elaboration of absolute chronology of the profiles and for correlation with archaeological chronology of the site. Two cores of organic deposits from the Serteya II site area are studied: I/ the ST IIa core collected with the use of Instorf sampler from the central part of the site - covers 7.8 m of sediments with approx. 4.5 m of organic deposits; II/ the STII M25 core from the archaeological trench wall excavated in the palaeolake shore zone - 1.4 m organic deposits.

The pollen diagram shows a strongly forested landscape (AP 98-99%). The fluctuations of aquatic plants are visible with a decrease together with NAP increase during the main settlement phase. The plant macrofossil analysis shows a few horizons with potential gathered plant remains and other ecofacts (charcoal, fish bones, shells), recognised as cultural layers. The site was situated in shallow freshwater conditions in the close vicinity to the shoreline as demonstrated by still occurrence of terrestrial botanical remains. Nevertheless, the results revealed some changes within the macrophyte assemblages demonstrating water table fluctuations: the distinct increase ca. 6.2 ka BP and later a decrease between ca. 4.6-4.3 ka BP and again increase phase ca. 4.2 ka BP. The phases of water table lowering were connected with a main settlement activity period. Analysis based on malacological finds indicated fluctuations in water level and evolution of the water basin. Molluscs appeared in larger numbers in the studied profile along with lowering the water level. Typical are molluscs living in sublittoral zone associated with rooted aquatic vegetation, in rush and reed beds, characteristic for permanent water bodies such as lakes and ponds. The ichthyofaunal spectrum is composed of Perch, Pike and undetermined cyprinids. These species populate water bodies filled with rich aquatic vegetation, which is used by fish for habitat and spawning. While a small amount of fish deposits probably results from natural death in most of the studied sequence, the vast majority of ichthyofaunal remains are associated with Neolithic pile-dwelling settlement layers, and likely illustrate the importance of fishing activities among these communities.

The results of the charcoal analysis show a close relationship between the human activity and the settlement with local fires period around study site. Two phases with a significant number of charcoal particles connected with local fires were defined; the 1st between 6.2 – 4.0 ka BP and the 2nd in the Middle Ages. The local fires reconstruction registered for the Neolithic notices high content of charcoal particles (max. 350).

Whereas the size of pile-dwelling settlement still remain unrecognized it is difficult to prove that local human settlement influenced significantly water quality in the lake. It should be rather assumed that climate (mostly summer air temperature and the continentality) was the main driver of lake's ecosystem and human society. Chironomidae-inferred July palaeotemperatures are relatively high

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proving favourable conditions for local Mesolithic and Neolithic populations, however changeable concentration of midge subfossils indicate long-time fluctuations of the water level in the lake and thus precipitation. As water table existence is crucial for midge larvae development, at least 4-6 week inundation of the studied site during warm season (spring to summer) was needed for development of abundant Chironomidae populations. Non-biting midge communities prove that during the Holocene the lake was shallow, overgrown and eutrophic water body. Reconstruction based on palaeozoological proxies shows the changes of content of organic matter in the water of the palaeolake basin and water level fluctuations, and it confirms, similar as plant records, the distinct lake water increase in the Middle Holocene (ca. 6.2 ka BP) and again, in the onset of the Late Holocene (ca. 4.2 ka BP).

The organic matter from STII M25 core mainly came from terrestrial sources and the PCA for sedimentological analysis showed that the positive correlation coefficient with all three PC axis has very fine sand (3-4 phi) and clay (fraction > 9 phi). Terrigenous and biogenic silica, organic matter and carbonates ($CaCO_3$) are the main chemical components of deposits.

The results of undertaken multi-proxy palaeoecological reconstructions allows for better understanding of the relationships of Neolithic communities and local environmental changes controlled both by global climate fluctuations and human impact. The study of Serteya region is significant due to the importance the area in the Neolithization of Eastern Europe, as well as to the strong impact of landscape geo- and biodiversity and also climate and hydrologic fluctuations on local settlement and economy in the Neolithic (Mazurkevich et al., 2009, 2012; Kulkova et al., 2015).

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Imandra Lake depression in the Late Glacial and Holocene (Kola Peninsula, NW Russia)

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The Imandra Lake (127 m above sea level (a.s.l.)) is the largest in the eastern part of the Fennoscandian crystalline Shield. Its eastern coast relates to the Kola Peninsula, and the western coastal areas are situated in the mainland part of Fennoscandia. At the present time, the lake consists of three parts (reaches). In the north, the reach of Bolshaya (Khibinian) Imandra Lake extends in the meridional direction; its depression has tectonic origin and mainly lies within range of the early Proterozoic Imandra-Varzuga Greenstone Belt. In the south, through the narrow Ekostrovsky Strait, the Bolshaya Imandra reach connects with the Ekostrovskaya Imandra and Babinskaya Imandra reaches (Fig. 1), which are separated by the Shirokaya Salma Strait. Situated within the Archaean Belomorian Domein in a single zone of Paleozoic tectonic labializing, this both southern reaches are oriented in a sublatitudinal direction according to trend of the intratelluric strike-slip fault (Astafiev et al., 2012). As well as the Bolshaya Imandra reach, the depressions of the Ekostrovskaya Imandra and Babinskaya Imandra reaches are tectonically predetermined, but they were substantially transformed by the Belomorian (White Sea) Ice Stream of Late Valdaian (Late Weichselian) Fennoscandian Ice Sheet (FIS), which expanded here from west to south-east. Bolshaya Imandra depression was mainly located in the marginal areas of the Barentsevomorian (Barents Sea) Ice Stream and within the ice-divided zone of the Belomorian and Barentsevomorian Ice Streams of the FIS.

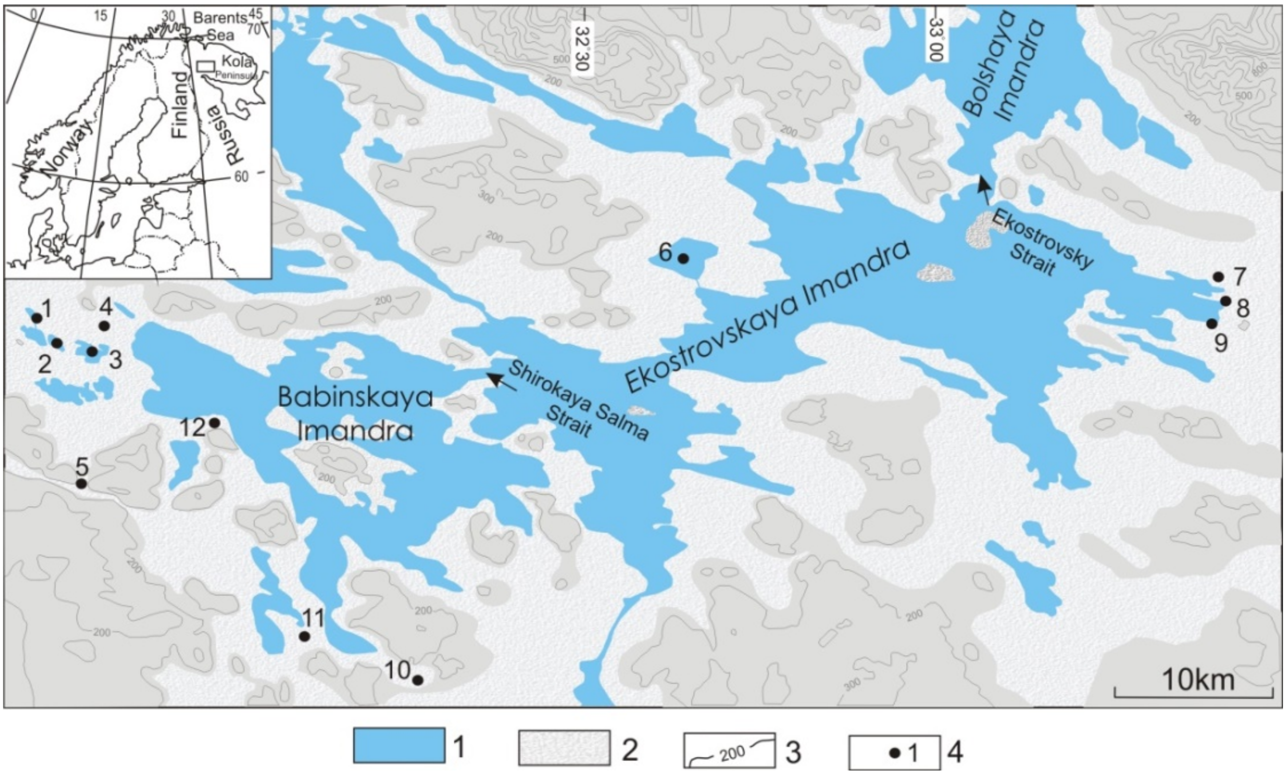

Fig 1. Location map of the study area: 1 – present-day Imandra Lake, 2 – coastal areas of the Imandra Lake, inundated by the water in the Late Glacial and Holocene; 3 – elevation (100 m contour interval), 4 – studied localities.

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Data and methods. Studied the coastal topography and bottom sediments from the small lake basins on coastal areas of the Imandra Lake (localities 1–6 in Fig. 1), we aimed the paleoenvironment reconstructions pra-Imandra at the Late Glacial and Holocene. The lithological, diatoms, spore and pollen, and radiocarbon dating data were obtained from the studies of sedimentological successions cored in the coastal small lake basins, which were isolated from the pra-Imandra Lake; coastal and glacial landforms were also observed. Same geomorphological and diatoms data derived from earlier studies (Armand et al., 1964, 1969; Armand and Samsonova, 1969) (localities 7–12 in Fig. 1) and same results of paleoseismological and paleolimnological research (Nikolaeva et al., 2015; Tolstobrova et al., 2016) (localities 2, 3, 6 in Fig. 1) were also taken into account. The currently available evidence suggests the reconstructions in the coastal areas of the Ekostrovskaya Imandra and Babinskaya Imandra (Fig. 1).

Findings. (1) According to topography of the highest lacustrine terraces, height lacustrine limit is variable and seated at the altitudes from c. 143–145 m a.s.l. to c. 173–177 m a.s.l., bounding the coastal areas of the Imandra Lake (Fig. 1). (2) In the Allerød, an extensive periglacial freshwater lake existed in the present-day Kandalakshsky Bay and adjacent areas included the Imandra Lake depression. Saline water started to inundate into this basin in the late Allerød during the Late Glacial marine transgression. (3) In the Younger Dryas, the ice margin was located in the Imandra Lake depression, with glacier covered western Babinskaya Imandra and south-eastwards shifted on the coastal Kandalakshsky Bay; as before, the freshwater periglacial lake existed in the Ekostrovskaya Imandra depression. (4) Brackish water and scarce marine diatoms were identified in the lower part of sedimentological sequences in the outcrops on the coastal Ekostrovskaya Imandra and southern Babinskaya Imandra reaches and in the cores from Osinovoe Lake (Fig. 1, locality 7–11 and 6, respectively). According to spore and pollen data and radiocarbon dating, this sediments seem to be the late Younger Dryas – early Preboreal in age. We suggest that periglacial pre-Imandra Lake water body was connected to the marine reservoir for a short time. Height marine limit were identified here at the altitudes of 136–138 m a.s.l. Only fresh water diatoms were founded in the sequences from the western Babinskaya Imandra coastal areas, which seem to be covered by glacier ice during Late Glacial marine ingression. (5) In the Preboreal, significant westward retreat of the ice margin took place on the western Imandra Lake depression and adjacent areas; extensive freshwater pra-Imandra Lake basin already formed here at the end of Preboreal. During the Holocene, its coastline configuration was changing, the water square reducing, and isolated small lakes occurred on the coast. (6) A segment of a large seismotectonic zone, where violent earthquakes occurred repeatedly at the end of the Late Glacial and in the Holocene, is known in the study area.

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Mid Weichselian paleoenvironments in the N-E Fennoscandian Shield (N-W Russia)

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Reconstructions of the Mid Weichselian paleoenvironments in the N-E Fennoscandian Shield, included the Kola Peninsula and adjacent continental part of the East European Plain, are hampered because of the fragmentary sedimentary record and poor chronological control. Located in the areas with limited erosion during Late Weichselian glaciation, several sites provide here with the Middle Weichselian depositional successions (Fig. 1).

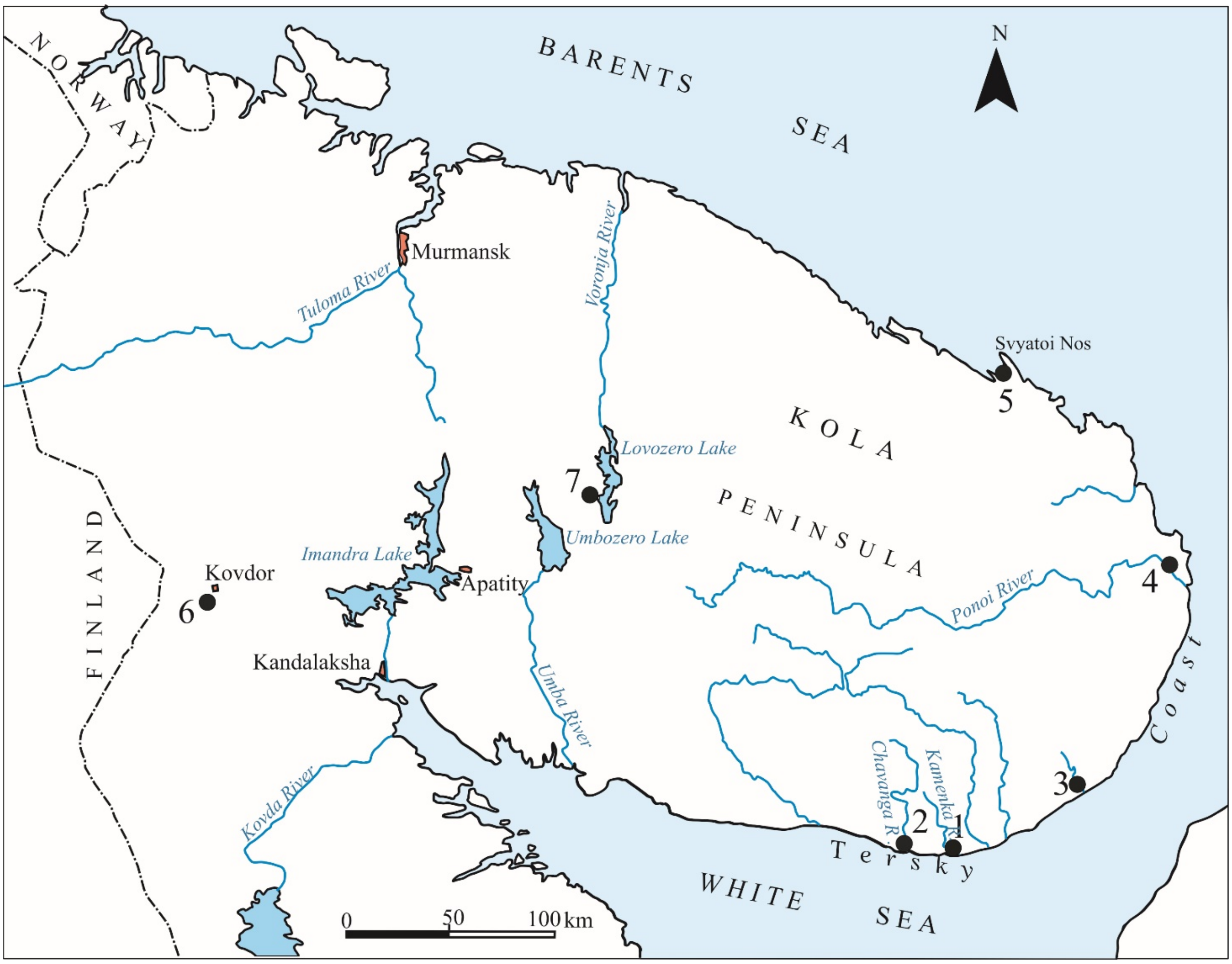

Fig. 1 Location of the sites provided with Middle Weichselian sequences in the study area

Data. The lithological, spore-and-pollen, diatoms and single IR-OSL, ESR, and radiocarbon dating data were obtained from the investigation of natural outcrops on coastal Kola Peninsula and derived from earlier studies (Grave et al., 1964; Armand, 1969; Gudina and Yevzerov, 1973; Yevzerov and Koshechkin, 1980; Korsakova et al., 2004).

Findings. (1) Early Middle Weichselian (MIS 4) glacial deposits are known from the central, north-western, western, and southern parts of the Kola region. Drilled on the western Kola

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Peninsula, glacial till seems to be the early Middle Weichselian, according to the stratigraphic position in the sequence between Last Interglacial lacustrine sandy loams and interstadial lacustrine and fluvial laminated sands, sandy loams, loams. Natural outcrops with the early Middle Weichselian glaciomarine, glaciofluvial or glaciolacustrine sands and sandy loams have been found on the Tersky Coast of the White Sea; the glaciolacustrine sands here has been IR-OSL dated to 63.6±8.0 ka (Korsakova et al., 2004). (2) The glacial deposits, overlapping the last Interglacial marine sediments in the coastal Kola Peninsula, are probably associated with the Kara-Barents ice sheet (Korsakova et al, 2007), as suggested on evidence from region adjacent to the Kola Peninsula. According to Helmens et al. (2000), the Early and Mid Weichselian Scandinavian Ice Sheet has not reached the Kola Peninsula in its expansion.

Indirect evidence of the Kara-Barents ice sheet invasion into Kola region can be the finding of pebbles of exotic rocks unknown in the bedrock of the Kola Peninsula. On the White Sea coastal areas and in the marine bottom sediment, debris of thinly laminated carbonate rocks, as well as the pebbles of organogenic-clastic carbonate rocks included abundant fauna of brachiopods, bryozoans, and echinoderms were found (Korsakova et al., 2007). In the bedrock, such rocks are common in the Carboniferous and Permian deposits on the northwestern part of the Russian Platform (southern and eastern White Sea coasts, Pechora River basin). (3) The early Mid Weichselian Kara-Barents ice sheet degradation caused the glacioeustatic marine transgression on coastal Kola Peninsula. According to the geochronological data and spore-pollen-proxy (Korsakova et al., 2004), marine deposits in the sequences (1–3 in Fig 1) correlate here to early MIS 3. Dominating marine molluscs of arctic-boreal and arctic species suggest that shallow water temperatures in the White Sea were only slightly cooler than today.(4) Stratigraphic position and spore-and-pollen proxy of the interstadial peat, lacustrine, and fluvial deposits from the sites 6 and 7 (Fig. 1) (Grave et al., 1964; Yevzerov and Koshechkin, 1980; Korsakova, 2019) suggest that terrestrial area was mostly dominated by forest-tundra with *Betula, Salix, Pinus*, as well as a rich herb flora and Bryales (*Betula-Pinus* sparse growth of trees) and tundra with a local presence of tree *Betula* during Mid Weichselian (MIS 3). Arboreal pollen dominates the spore-and-pollen spectra from MIS 3 deposits, even in the western Kola region, which is close to centre of the Scandinavian Ice Sheet glaciation. Spore and pollen data suggest that the environment conditions were more severe than nowadays in the Kola region. (5) ESR and ^{14}C dating of mollusc shells and humus has been used to get the ages of the Middle Weichselian (MIS 3) sediments, which are about 31, 43.5, 44.4, 52 and 59 ka (Korsakova, 2019).

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Palaeolimnological approach for the reconstruction of environmental changes in the Serteya region (Western Russia) – preliminary results

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The paper presents the results of the field work (July 2017) and laboratory studies (2018-2019) on the bottom sediments of the kettle hole in the vicinity of the lower Serteyka River valley, Smolensk region, Russia. The Serteya region of the Upper Dvina Basin was settled periodically from the Late Palaeolithic to the Modern Time (Mazurkevich et al., 2012). For the better understanding of settlement pattern, extent of human impact on environment and also feature of human life in the different stages of its existence, it is necessary to find out markers of human societies' activities in the natural archives (Subetto, 2009). One of the most reliable nature archives is bottom sediment of the lakes and peat-bogs, because it contains an unique organic material that allows one to reconstruct with a high degree of reliability the paleoenvironmental conditions, vegetation cover and human impact in the catchment area of the basin with annual to centennial time resolution (Subetto, 2009).

Fieldwork took place in the North of the Smolensk region, (Velizh district) in kettle hole peatland in 1 km from the Serteya village. The research area is located on the southern periphery of the Valdai glaciation, so the study of lake and marsh sediments formed at the beginning of organic sedimentation will allow reconstruct the natural conditions of the Late Pleistocene and the Holocene. Through the central part of the peat bog, the paleolimnological transect was carried out that includes a series of borehole processed by Russian peat (Instorf) corer. The sediments were sampled at the point with their maximum capacity (13.5 m), that mean that sedimentation rate in this basin was extremely high.

For each core of bottom sediments the lithological description including color, structural features, the presence of inclusions was executed. Laboratory studies of LOI were conducted at the Limnological Institute of RAS and Herzen State Pedagogical University of Russia. The studied in detail core of deposits is represented by: sand, basal peat, clayey gyttja, gyttja, and peat (from bottom to top). The results of the analysis of the loss on ignition (LOI) allow estimating the content of organic matter in the bottom sediments of different types and, accordingly, changes in the conditions of sedimentation and bioproductivity of the reservoir. Based on the preliminary interpretation of

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changes in the lithological composition and dynamics of the organic matter in the bottom sediments, a hypothetical picture of the transformation of sedimentation conditions was made. The lower part of the column is represented by sand with a low content of organic matter. On the sands lies a horizon of peat (peaty gyttja), presumably formed on melting dead ice is characterized by a high content of organic matter. With the increase the depth of the reservoir there was a change in the type of sedimentation on the lake, the formation of clayey gyttja. The content of organic matter is sharply reduced. With overlying organogenic gyttja associated increase in LOI. When crossing the border of gyttja-peat, the LOI parameter is stabilized at the high level of 90 %. The study is scheduled to run: geochemical, pollen, plant macrofossils, Chironomidae, Cladocera analyses, as well as radiocarbon datings for a detailed reconstruction of environmental changes, determine extent of human impact and get a new knowledge about feature of ancient human life.

Eastern Europe is the area whose palaeoecology is still poorly explored. The high-resolution palaeoenvironmental data combined with archaeological and historical research results provide to distinguish the natural and human impact on the lake and peat bog ecosystem development. The obtained results of detailed multi-proxy palaeoecological analysis of the long core of organic deposits will allow contributing to the discussion on local, regional and also global climate change.

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Bipartite Sediments within the Moscow (Saalian) Glacial Limits of the Russian Plain: Mineralogy, Micromorphology and Soil Formation Framework

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Macro- and micromorphological characteristics, as well as textural and mineralogical properties of soils on a reddish brown Saalian basal tills of Moscow (Late Saalian / Warthe / MIS 6) deposits, covered only with a thin veneer of sands, sandy and silty loams - the cover layer, are discussed.

Basal till and the cover layer forms bipartite sediments - an important component of landscapes in northern Europe, including the centre of the Russian Plain. Our numerous laboratory studies allow to confirm that the formation of the cover layer took place close in time to the deposition of the basal till, and the cover layer resulted from rewashing of the till surface by temporary streams with local aeolian input. This was established by spatial field studies - similar lithological features of the cover layer and the basal till; laboratory analyses - similar coarse fragments, uniform distribution of geochemical indexes may – all these indicate such type of deposition of the cover layer (Makeev et al. 2019). Numerous OSL datings of the cover layer which vary from late Moscow (Saalian) to Early Valday (Weiselian) time also support, that such bipartite sediments are among the oldest soil parent materials subjected to pedogenesis starting from the time of their deposition (MIS 6) till now.

Transformation degree of basal till and cover layer under the influence of pedogenesis have been studied in four key sites of following regions of the Russian Plain: Moscow, Yaroslav, Tver and Archangelsk. It was estimated using a set of morphological methods: X-ray high-resolution microtomography on Skyscan 1172 (Bruker) for visualization and morphometric analysis of the internal microstructure in non-disturbed natural samples of peds; micromorphology on the polarizing microscope BX51 (Olympus) and photo scanner 9000 MarkII (Canon); submicromorphology on SEM GSM 6060a (Jeol) and set of analytical methods including clay mineralogy.

Many lithological features show high stability under the pedogenetic impact. Such features look similar for the lower soil horizons (BC and C) formed in the basal till at a depth of approx. 2m and for horizons subjected to intensive pedogenesis (Bt1 and Bt2 horizons at a depth of approx. 60 cm). These morphological key features include: high weathering through the whole strata; bright reddish-brown color (up to 5YR 6/6 by Munsell soil color chart) inherited from sediments mobilized by the glacier; overconsolidated matrix-supported fabric with low porosity as a result of big pressure under the glacier; till architecture including sand lenses, shearing features, folding, thrusting and rotational structures, tension fractures and other evidences of emplacement of matrix within the mobile sediment.

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Clay mineralogy in the bulk samples also shows several key features: a) uniform composition of the basal tills part in the all studied key sites; b) difference between cover layer and basal till part; c) uniform changes in the clay mineral composition with increasing depth (from 2Bt1 horizon to 2BC) and its correlation with geographical position of the key site; d) local and profile differences between clay mineral composition of the cover layer.

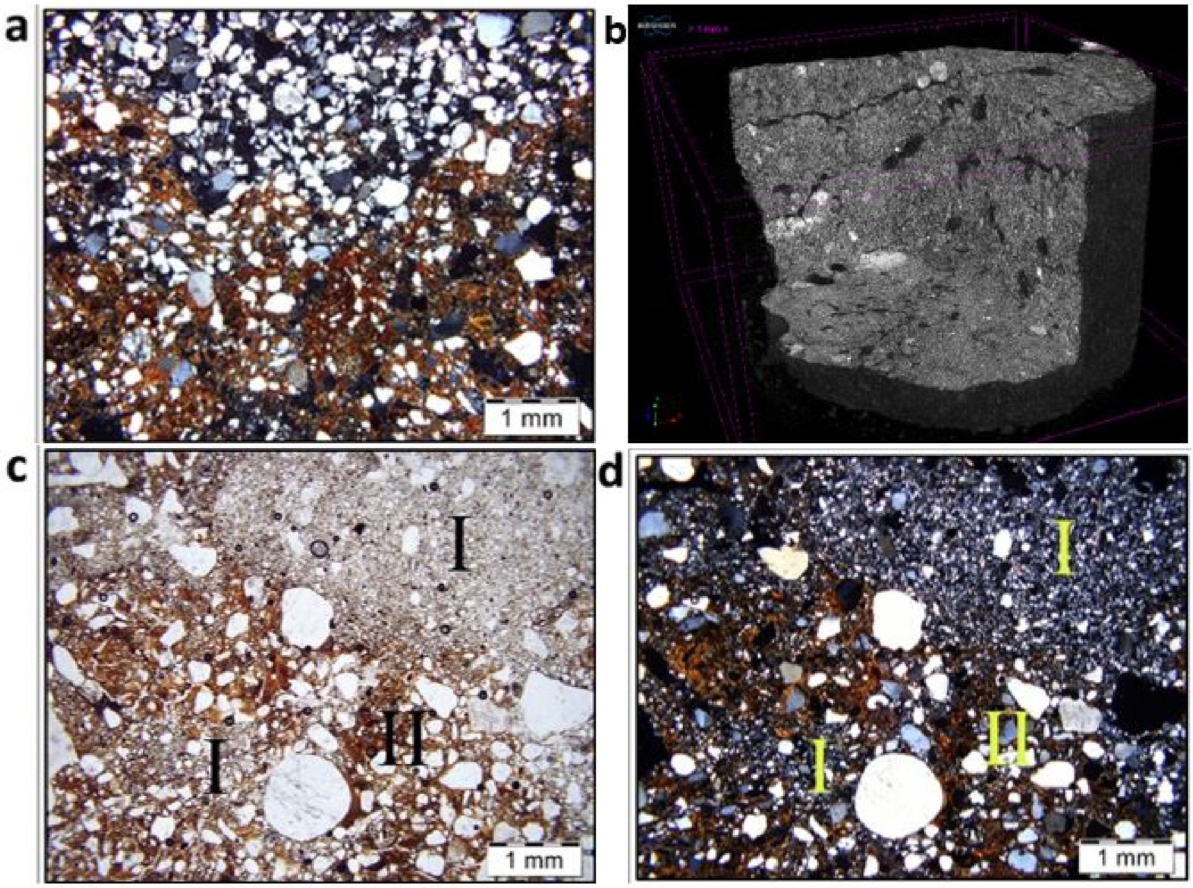

Figure 1. Stability of lithological features. a: lithological discontinuity, a clear border between the cover layer and basal till part; b: 3D structure of E horizon (cover layer) with fragments of the 2Bt horizon (basal till part); c, d: shearing zone on the top of basal till part. I – cover layer fragments, II – basal till fragment (NII – left, NX – right)

Studying these soils as pedosedimentary sequences allowed to identify the following set of features: pre-depositional, syndepositional, pedogenic (of different developmental stages). The abundance of relic pedogenic features allows regarding such sequences as surface paleosols.

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Organic sedimentation in Lake Ladoga during the Holocene

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Ten new cores from different parts of Lake Ladoga were retrieved during 2018-2019 and analyzed for organic matter content. The sampling was performed by gravity corer (1.5 m long) from the depths 30-182 m.

The sediments are generally represented by gyttja clay/silt and clayey/silty gyttja. The retrieved sediment thickness ranges from 0.67 to 1.65 m. Sometimes in the lower clay horizons, a thin lamination is observed. Fine sediments prevail, but sometimes pebbles and gravel are occasionally found in the bottom part of the sequences. In most of the cores black bands of hydrotroilite and inclusions of vivianite are marked. The lower part is gray, in the upper part color changes to brown or greenish-brown. All boundaries are gradual, without sharp contacts. In some cores Fe crusts are marked in the upper horizons.

The organic matter (OM) content was estimated by loss on ignition (LOI). The LOI values are in the range of 1.9-12%. The amplitude of the oscillations within one sediment sequence is much smaller and is not more than 4.2%, except for two sections from the central part of the lake, where the range of values reaches 9.3 and 8.5%. There is a direct relationship between the LOI mean value in the core and the depth of the lake at the sampling point and the distance from the mainland shore.

By the dynamics of organic sedimentation five similar periods are distinguished in most of the cores which have the significant similarity despite the big distance between the sampling points.

- Period A – the stable low OM content. LOI values do not exceed 3%, which is typical for late Pleistocene and early Holocene homogeneous clays lying in the deep parts of lake Ladoga.
- Period B – steady growth of the OM content.
- Period C – the OM content rise stopped and stabilized at high values. This period is attributed to the climatic Holocene optimum.
- Period D – rapid drop of OM content. In some sections there was a marked rise of OM in the middle part of the period.
- Period E – rapid or moderate growth of OM content to maximum values. Sometimes at the top of the section there are 2 peaks, separated by a sharp fall.

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Catastrophic coastal flooding events along the southern Baltic Sea coast during the Late Holocene

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Catastrophic coastal flooding is one of the main forcing agents of short-term coastal system changes and represent a major threat to human activities concentrated along the coasts worldwide. In order to better understand the frequency and character of catastrophic marine inundation events as well as predict their future trend the knowledge on the long-time records of Holocene coastal flooding chronologies is necessary. There have been no systematic research on frequency and character of palaeo-storms undertaken in the Baltic Sea area.

The main aim of the presented research is to reconstruct the chronology and intensity of catastrophic coastal flooding on the southern Baltic Sea coast in Poland and Germany during the late Holocene (last few thousand years) embedded in relative sea-level history. The research focuses on deposits associated with catastrophic marine inundation events of various origins (i.e. storm, infragravity wave, tsunami) archived within back-barrier marsh/coastal mire environments.

The specific research objectives of the study are: 1) to analyse sediments for sea-level and coastal flooding proxies; 2) to reconstruct the chronology and intensity of coastal flooding along the southern Baltic Sea coast during the late-Holocene; 3) to evaluate representativeness and lateral variability of coastal flooding markers.

The southern coast of the Baltic Sea is regionally, as well as globally important study area because (1) the neglectible tidal forcing does not bias the elevated water table of marine water surge event, so the true coastal flooding signal is preserved in the sedimentary record; and (2) the southern Baltic coast is exposed to both, (north) westerly and (north) easterly storms and corresponding seiche effects (Hippensteel, 2010). Moreover, as demonstrated in a recent study by Piotrowski et al. (2017) in the area of Polish coast the low lying marsh areas behind coastal dunes or at river mouth are the most promising sedimentary environments to provide with record of catastrophic coastal flooding.

During the INQUA PeriBaltic Working Group Meeting the preliminary results of the extensive fieldwork on the Polish Baltic Sea coast will be presented. The key test areas where deposits representing catastrophic marine inundation events were found will be characterised and the results of the fieldwork, including ground penetrating radar survey and drilling will be presented. The laboratory techniques employed within this research will be discussed and the major challenges

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in the process of differentiating of marine inundation origin deposits from other types of sediments will be highlighted.

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Diatom-inferred Lake Ladoga preglacial paleoenvironments and its possible connection to the Baltic

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Lake Ladoga is the largest lake in Europe (18 330 km^2, maximum depth 230 m) with a very large catchment area of ~258 600 km^2. It is located in northwestern Russia, close to the city of St. Petersburg and the Baltic Sea, and within the limits of Scandinavian ice-sheets. While the Late Glacial and Holocene sediments are widespread at the bottom of Lake Ladoga, the preglacial sediments are overlain by till which makes them inaccessible for the routinely used coring equipment. The only preglacial record existed till recently was obtained by deep geological drilling in 1930s and uncovered marine sediments below the Weichselian till. Consequently, preglacial environments in Lake Ladoga are very poorly investigated compared to postglacial ones. The ideas on the environmental conditions in Lake Ladoga prior to the Last Glacial Maximum were primarily built upon the studies of terrestrial boreholes and outcrops. They suggested that in the Last Interglacial the Ladoga basin became a part of the Baltic-White Sea connection during the Eemian marine transgression (Lavrova, 1961), and turned fresh when the Eemian Sea regressed by the onset of the Weichselian glacial epoch (Malakhovskiy and Markov, 1968). However, these records, often incomplete and poorly dated, leave major uncertainties on the environment established in Lake Ladoga after the Eemian Sea regression and its evolution throughout the Weichselian.

Here we discuss the results of the diatom study of the first dated Late Eemian – Early Weichselian sediment core retrieved from Lake Ladoga within the frame of the Russian-German research project PLOT (Melles et al., 2019). The specific question to be addressed is whether Lake Ladoga could remain under marine influence after the termination of the Eemian marine transgression, i.e. throughout the Late Eemian – Early Weichselian. The composition of marine taxa prevailing in our diatom record is similar to that from the marine Eemian sediments in NW Russia (e.g. Cheremisinova, 1957, 1959). Since the ratio of marine to freshwater species in our record does not demonstrate any distinct trend, no signal of the marine-freshwater transition can be revealed. Thus marine environments could have been immediately suggested for the entire study period (ca. ~38 ka). However, according to the recent studies (Miettinen et al., 2002, 2014), Atlantic waters entering the pre-Baltic steadily decreased in the Late Eemian, and the eastern Baltic already turned slightly brackish to almost fresh ~118 ka, i.e. when our record formed. Besides, no connection with the White Sea existed by that time (Funder et al., 2002). It is therefore not clear how marine conditions could have still persisted in the Lake Ladoga basin during the study period, taken that the global sea level never reached its Eemian levels during the Early Weichselian (Wohlfarth, 2013).

The freshwater species, also abundant in our record, are, in turn, similar to those having thrived in Lake Ladoga during the Late Glacial and the Holocene. This co-occurrence of ecologically incompatible species (marine and freshwater) suggests an allochthonous origin of one of these groups. Low diatom and other siliceous microfossils concentrations and selective preservation provide an alternative interpretation for our record as a result of reworking of the previously accumulated marine sediments and re-deposition of marine diatoms, rather than the direct marine influence. Such mixed diatom-poor assemblages are characteristic for the Early Weichselian deposits uncovered in the boreholes in the Ladoga region (Malakhovskiy and Markov, 1968). Thus, Lake Ladoga is believed to remain fresh during the Latest Eemian and Early Weichselian time, and unstable high-energy environments are thought to prevail at the coring site. Lowered siliceous

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microfossils concentrations are probably related to the cooling phases (e.g. Kurgolovo cooling, corresponding to MIS 5d), while their increased values are likely attributed to the climate amelioration (e.g., Upper-Volga warming corresponding to MIS 5c).

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New botanical records from the fossil closed depressions in the central Poland

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Central Poland is rich in fossil closed depressions, in refugia of which the Eemian Interglacial and Early Vistulian flora has been documented. Both the nature of deposits and the scope of documented succession can contribute to a more complete diagnosis of morphoclimatic conditions prevailing since the last ice sheet in this area. As part of the project funded by the National Science Center (Decision no. DEC-2014/15/B/ST10/03809), research was restarted in several closed depressions located in the Łódź Upland, including Józefów site, which since the 1960s was the first with the documented Amersfoort succession, locally called the Józefów Interstadial (Sobolewska, 1966; Dylik, 1968, Mojski, 2005) and now recognized as Brörup Interstadial (Zagwijn, 1996b), corresponding to MIS 5c. The Józefów site is also interesting in terms of the genesis of the depression because current research allows to recognize it as relict pingo (in this materials). From Józefów site a sediment core with an intact structure with a total length of 7.20m was removed from the tubes with a length of 1.20m (Geoprobe). Currently, the analyzed profile includes sediments from the depth range of 6.32-5.0m. It is mainly made of gyttia, peat and peaty silt. Glacial deposits, lithologically recognized as steel-gray silt with clay were documented below. Biogenic sediments mainly peat and biogenic silt were also recognized above the analyzed section but their analysis is still incomplete. The palynological and plant macroremains analysis from the Józefów profile probably cover the succession from the end of the Warta Stadial, the Eemian Interglacial and the beginning of the Early Vistulian Glaciation. The diagram allow to distinguish 8 local pollen assemblage zones and plant macroremains. The lowest -1 level (6.32-6.10m) due to the presence of *Betula nana* indicates cold climatic conditions and belonging to the end of the Warta Stadial of the Odra Glaciation (Saalian), which has not been confirmed in previous studies. The occurrence of *Isoetes lacustris* in level 8 (5.04-5.00m), both in pollen and plant macroremains, indicates the strongly oligotrophic character of the lake at the beginning of Early Vistulian. The high share of this plant in the aquatic communities of this period is characteristic for many sites, including the nearest Zgierz-Rudunki (Jastrzębska-Mamelka, 1985) and Żabieniec Południowy (Majecka, 2014).

In the Łódź Upland a new site named Pieńki Bielańskie was also recognized, in which the core of biogenic sediments with a thickness of 2.10 m was collected. So far, the pollen analysis of sediments, mainly peat and peaty silt deposited below mineral sediments of 1.65 m thickness, indicate their deposition in the Eemian Interglacial. Palaeobotanical research was also carried out at the Rogóźno site near Lake Okręt, located in the Warsaw-Berlin ice-marginal valley, where in the 1960s the occurrence of the Eemian Interglacial were documented (Klajnert and Piechocki, 1972). The purpose of present research in this site is to obtain a more precise and wider spatial recognition of the floristic and climatic changes in Central Poland, especially in the final phase of the Eemian Interglacial and Early Vistulian in relation to the Łódź Upland. From the lake sediments, mainly limestone gyttia, a core has been taken with an intact structure. Currently under the depth of 14.60-10.70 m is subjected to paleoenvironmental analysis (pollen, malacological, geochemical and

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isotopic). As yet obtained results of pollen analysis in the Rogóźno site indicate the numerous taxa of thermophilic flora, which may confirm the presence of the Eemian Interglacial.

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Landscape response to the Late Holocene climatic cycles at the southern frontier of the forest belt of the Russian Plain.

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The Russian plain in the second half of the Holocene seems to be an arena of complex interactions of different civilizations. Ethnic shifts were largely determined by the climatic rhythms recorded in the buried soils of archaeological sites. In this regard, paleolandscape reconstructions are important for understanding the causes of ethnic shifts and migration waves. Landscape evolution was studied based on detailed morphological, analytical and microbiomorphic research of the soil chronosequence that included surface soils and soils buried under burial mounds of the Bronze Age (Tokhmeyevo kurgan cemetery, Chuvashia Republic, Mihailov et al., 2014).

Soils are formed on similar surfaces in similar loess parent material at the same elevation under the broadleaved forest. Both buried and surface soils meet the criteria for Glossic, Folic, Albic, Dystric Retisol and show similar morphology and key analytical features (Fig. 1a, 2a, b, c, d) indicating close similarity of the landscapes in the study area that existed from the Bronze Age to nowadays. The burial mound is composed of mud blocks with central parts made of material of the E horizons and covered by the material of Bt horizons enriched in fluvial sand grains (Fig. 1b, c, d, e). The use of these materials in the burial mound construction is an independent proof of the presence of E and Bt horizons in the soil of the Bronze Age.

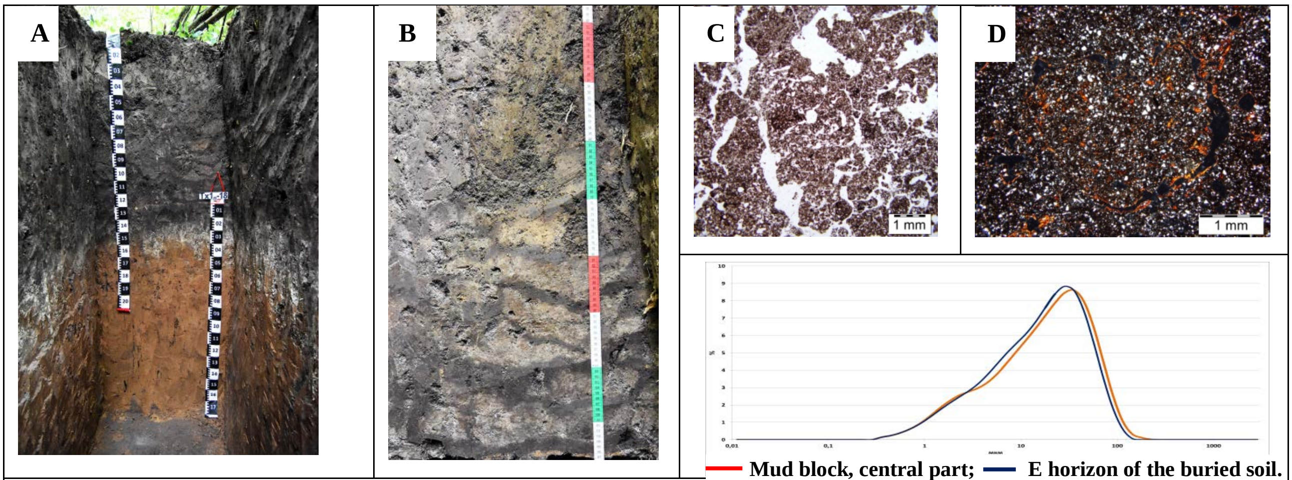

Fig. 1 A - Buried soil. Note mud blocks in the construction of the earth mound; B. mud blocks; C – microstructure of the material from the central part of the mud block is typical for E horizons of Retisols; D – microstructure of the cover layer of mud blocks. Note the signs of kneading of material (disrupted clay cutans, rotational structure and grains of fluvial sand added to the material of Bt horizons); E - grain size pattern of material from the central part of the mud block, laser diffraction method. Note the similarity with grain size pattern of E horizon.

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Microbiomorphic assemblages (Golyeva, 2001) support this conclusion, showing a bit more humid climate during the Bronze Age comparing to the present (Fig. 2e, f). The presence of black humus cutans on top of brown clay cutans in the Bt horizons of the buried soils also correlates with more wet soil moisture regime (Fig. 2g, h). Bt horizons of the surface soils have only brown clay cutans. These conclusions are also supported by earlier published data on soil chronosequence that included surface soils and soils buried under fortification earth wall of the Early Iron Age: Glossic, Folic, Albic, Dystric Retisols of Sareevo Settlement are formed in similar environment of the broadleaved forest, in mantle loams and close to Tokhmeyevo kurgan cemetery (Makeev et al., 2019).

The study of the soil chronosequence in the Tokhmeyevo kurgan cemetery is also complemented by the previous study Taushkasy kurgan cemetery of the Bronze Age where the surface and buried soils were formed in the derivatives of the Permian sandstones (Folic Eutric Cambisols, Aseyeva et al., 2019). Soils of the three archaeological monuments could be combined in one chronosequence that includes soils of the Early Iron Age and the Bronze Age formed in parent rocks that differ in their response to environmental impact (different features of soil memory, Targulian and Goryachkin, 2008). This chronosequence displays the stability of forest environment at the southern boundary of the forest belt from the Bronze Age to the present. Landscape stability in the studied area makes it possible to establish the northern limit of the wide belt, which stretches out from the dry steppe to the northern forest-steppe, where landscape shifts influenced by the Late Holocene climatic cycles resulted in a combination of polygenetic features of forest and steppe pedogenesis in the surface soils. Fortification walls of the Early Iron Age and burial mounds of the Bronze Age are not only indicators of landscape dynamics, but also the unique cultural heritage of the East European Plain. Further studies will link the critical stages of landscape evolution with the migration waves of the ancient tribes.

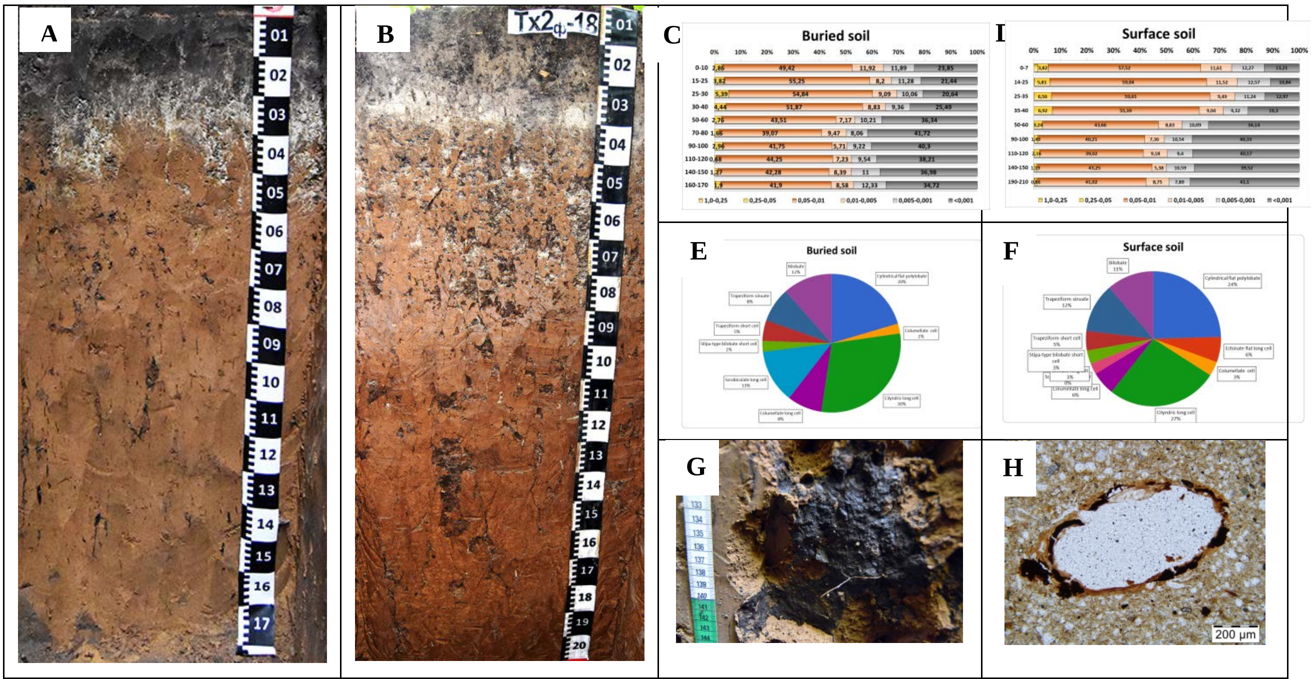

Fig. 2 A - buried soil; B - surface soil. Note the similarity of profile composition; C, D – grain size distribution in the buried and surface (D) soils; E, F - phytolith spectrum of the upper horizons of the buried (E) and surface (D) soils; G - black humus cutan in Bt horizon of the buried soil; H - black humus cutan on top of the brown clay cutan in the buried soil, PPL.

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Sedimentological record of glaciofluvial flood (distal part of Gwda sandur, W Poland)

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The study succession is located in the distal part of Gwda sandur near Stobno (W Poland). This large, 110 km long sandur was formed during Pomeranian phase of Weichselian glaciation. The succession at Stobno site, consists of two lithofacies associations separated from each other by sharp and erosional boundary.

The lower lithofacies association *Sr, Sh, (Fm)* is 4 m thick, and consists of ripple cross-laminated or climbing ripple cross-laminated fine-grained sands (*Sr, Src*), horizontally-laminated fine-grained sands (*Sh*), massive fines, i.e. silt+clay (*Fm*) and wavy-laminated fines with sands (*FSw*). The thickness of each lithofacies is various, and ranges between 10 cm (e.g. *Fm* lithofacies) and 80 cm (e.g. *Sh* lithofacies). The boundaries of lithofacies within this association are depositional. Furthermore, some lithofacies are arranged in rhythms, e.g. *Sr→Sr* and *Sh→Sr*. The climbing ripple cross-laminated sands are inclined towards the south and south west. The sediments of the lower association were deposited in a typical, distal, low-energy sandur environment. The *Sr→Sr* or *Sh→Sr* rhythms suggest that deposition took place under variable (decreasing or increasing) flow conditions. The hydraulic flow periods were separated by periods of stagnation during which fines from suspension were deposited, i.e. lithofacies *FSw* and *Fm* were deposited. Probably, the lower lithofacies association *Sr, Sh, (Fm)* is a record of secondary, external, periodically dying channels of the fluvial system in the distal part of Gwda's sandur.

The upper lithofacies association *SGp, SGt* is 3.5 m thick, and consists of planar cross-stratified gravelly-sand (*SGp*) and trough cross-stratified gravelly-sand and sand (*SGt, St*). The total extent of *SGp* lithofacies is 70 m. The thickness of this lithofacies varies from 50 cm to 100 cm, however the thickness increases towards the southern part of the exposure. This lithofacies contains the most coarse grains in the succession at Stobno site, i.e. the MPS parameter is 102.4 mm. Upper-laying lithofacies *SGt* is at least 2.5 m thick, and is inclined towards the west and south west.

The upper lithofacies association *SGp, SGt* was deposited in much higher (than the lower one) energy conditions. The *SGp* lithofacies represents the prograded transverse bar located in the middle part of the braided river channel. The flow velocity reached at least 2.5-3.0 m/s. Whereas, *SGt* lithofacies represents megaripples, which were deposited by relatively intense and deep flow.

An abrupt change in deposition conditions from very low energy, sometimes dying flows to very high energy flows is enigmatic. Such high energy currents are not typical for the distal part of sandurs. It's possible that in Stobno site there is a sedimentological record of glacial floods that were e.g. documented in the proximal part of Gwda sandur by Szafraniec (2008).

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Sedimentary record of storm surge deposits along SE Baltic coast formed under indundation and overwash regimes

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Sedimentary record of extreme storm deposits depends on coastal geomorphology, weather, and marine conditions (height of dunes, wind direction, water level, etc.). Relationships between those factors may be bound together in classification of storm surge regimes, including: swash, collision, overwash and inundation regimes (Goslin and Clemmensen, 2017). Despite of the progress in the field of extreme storm surges research, proper identification of particular regime may be misinterpreted due to insufficient data of contemporary sedimentary records.

Accumulation parts of South-Eastern Baltic coasts consist sandy barriers and wetlands, which contain sedimentary record of palaeostorms and are prone to contemporary extreme storm surge events. Two coastal types with different geomorphological features were examined to show how local conditions may influence the record of storm surges. The first one was characterized by wide, low inclined sandy beach, high sediment supply, and presence of up to 5 m high dunes. In contrast, the second type of coast was characterized by short, high-inclined sandy to gravelly beach, low sediment supply and almost lack of dunes. As the result of storm surges, analysed deposits showed different sedimentological features related to specific regime (overwash or inundation). Detail investigation of sedimentological features included lithofacial, grain size, and heavy mineral analyses.

Deposits formed under overwash regime showed wide range of sedimentary structures, including horizontal and planar cross-stratification or ripple lamination. Grain size distributions indicated that sediments were composed with medium, well sorted sand. Heavy minerals content was 1% on average, with outliers of 10%. Their composition revealed wide spectra of minerals (including e.g. garnets, amphiboles, pyroxenes, tourmalines, staurolites, epidotes, and many more), however garnets and amphiboles dominated in most of samples, with average content of 60 % and 15 % respectively.

Deposits formed under inundation regime were built with medium to coarse, well sorted sand. Bottom boundary of storm layer was erosional. Within the layer, rip-up clasts, molluscs shells, and gravel particles were observed. Sedimentary structures were absent. Heavy minerals content was 10% on average. Their composition was dominated by high dense minerals (over 4.35 g/cm^3), like garnets or zircons, with their average content of up to 80%.

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Provided results showed that sedimentary record of extreme storm surges may be distinct under different conditions. In the case of coasts characterized by wide, low inclined, sandy beach, high sediment supply, and presence of up to 5 m high dunes, storm surge triggered overwash process, which lead to formation of washover fans built with wide range of sedimentary features. The coast characterized by short, high-inclined sandy to gravelly beach, low sediment supply and almost lack of dunes allowed long-distance marine inflows and formation of massive sand layers under inundation regime.

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New insights on ice dynamics from analysis of terrain of Latvia

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During deglaciation ice bed topography is playing an increasingly important role in ice dynamics. Rises in the ice bed are becoming obstacles causing splitting of ice flow into separate lobes. Bed topography constrained ice flow can be quite fast, sometimes even surge like, thus leading to formation of new landforms that are specific to ice flow properties of their formation time. If new ice flow direction persists for long enough time, all morphological evidence of previous ice regime can be erased. Availability of new LiDAR based high-resolution digital terrain models allows to start to search for landforms that preserves information on ice flow properties before its separation into lobate structure – characteristic for glacial retreat time. The bed of Last Weichselian glaciation in territory of Latvia mainly consisted of soft sediments accumulated during previous glaciations and in the front of advancing ice (Zelčs et al., 2011). Such sediments are prone to glacial erosion and thus fast erasure of any pre-existing landforms. Thus small linear landforms characteristic of fast ice flow could be preserved only in areas afterwards covered with stagnant ice, or in cases when ice flow direction did not change with the onset of deglaciation.

Preliminary analysis of new high-resolution terrain model of Latvia has revealed presence of linear landforms underlying landforms of deglaciation time. In the basal elevation of Northern and – more prominently – Eastern Kursa Upland large number of narrow linear landforms are present. Their width is from 20 to 300 m, height – 0.5 to 10 m, with less than 5 m being most common. Length of such lineaments can exceed 10 km, although tracing for more than 5 – 8 km is complicated due to erosion by or cover of younger landforms (fig. 1C). In some places on the eastern side of the upland they are traceable as negative landforms, although most likely it is more related to mode of preservation than being indicative of their genesis. Morphological properties of those landforms match description of Mega-scale glacial lineations (MSGLs) as given by Stokes et al. (2013).

The age of these MSGLs can be determined only tentatively – they are (barely) traceable below landforms of Gulbene Ice Marginal Zone (IMZ) – the first step of deglaciation of Eastern Kursa Upland (Zelčs et al., 2011) –, and thus predate it. Orientation of MSGLs indicates on a fast flow from the direction of Baltic Ice Stream (fig. 1B), but there is no large moraine present that one could expect in case of its collision with the fast flowing Zemgale Ice Lobe (Lamsters and Zelčs, 2015) of Rīga Ice Stream (B_5 after Boulton et al., 2001). This indicates complete reorientation of major ice flow direction in the region during the Late Weichelian glaciation with Baltic Ice Stream being the dominant one before onset of deglaciation.

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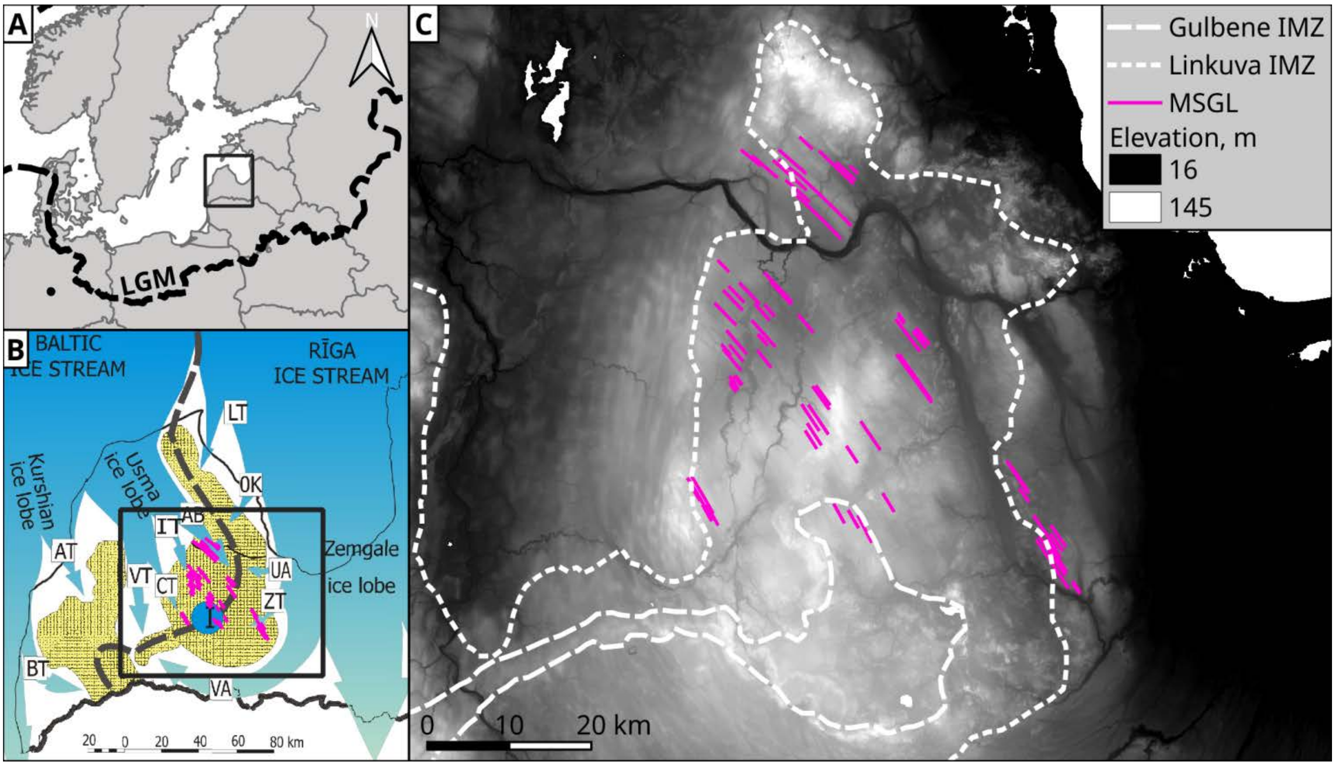

Figure 1: A – location of study area. Area of B shown with a square; B – major ice flow directions after Zelčs and Markots (2004). Area of C shown with a square; C – location of selected MSGLs from Northern and Eastern Kursa Uplands. IMZs after Zelčs et al. (2011). Elevation data – Latvian Geospatial Information Agency (2018).

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Climate change, environmental history and Human impact during the Late Holocene inferred from palynological, diatomological and geochemical data from selected lakes in the north-eastern Poland

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The following article concerns the research on lake sediments accompanied by archaeological objects from the late Holocene which was conducted in north-eastern Poland, in the area of the Iławskie Lake District. The main goal of the research was to find traces of human activity recorded in the gathered sediments. In order to find and analyze the activity, the sediments were taken by means of drilling, and then the archaeological team carried out excavations on the objects. The archaeologists identified historical periods in which human activity took place on the objects and determined the following periods: early iron age (around 2300 BP and earlier), Roman period - Wielbark culture (100 BC years - 300 years AD), early periods Middle Ages (700-1000 years AD) and Middle Ages (1000 years AD).

The studies of lake sediments confirmed human activity during that time, which was manifested by the presence of synanthropic plants, changes in the depth of the lakes or changes in the sediment geochemistry.

The surroundings of the Młynek Lake were favourable for several phases of prehistoric settlement. Along the 3.5 m long core, covering about 2300 years of sedimentation, there was found human activity from the Roman, early Middle Ages and Middle Ages periods as well as the contemporary one. The record of the period between 300 and 1000 years AD seems especially interesting as it corresponds to the time of peoples' migration, in which, according to diatomological studies, a clear deepening of the lake takes place. The people's migration was spurred on by climate change, and in northern Poland, these changes consisted in an increased humidity, probably due to precipitation. The Middle Ages period is marked by the development of agriculture, in which the cultivation of cannabis had its dominant share. The cannabis share in the pollen diagram amounts to over 20%.

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Impact of pre-historic settlement and natural processes on development of the land surface. The Redecz Krukowy archaeological site (Kuyavia, Central Poland)

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The archaeological site Redecz Krukowy 20 is located in Central Poland, in the eastern part of the Kuyavian Lakeland. Archaeological excavations at the site were carried out in the years 2006–2010 by the Museum of Archaeology and Ethnography in Łodź (Papiernik and Płaza, 2018). During the five years of archaeological excavations, they examined 7469 m^2 area and a large number of archaeological artefacts were unearthed and classified to many cultural cycles – from the Mesolithic to modern times. Among them the most numerous (including 118 thousand fragments of vessels, 16,000 flint products) and the most interesting are the remains of the oldest phase of the Funnel Beaker culture settlement, consisting of at least 6 homesteads. A series of 55 radiocarbon datings, including 24 using AMS, were made for the purposes of the archaeological sources and stratigraphy of the site. An important element of field work was excavation by hand with equipment the so-called mechanical layers (a thickness of 10 cm) with systematic sieving of total material, including the modern arable layer. At the same time spatial distribution plan was made with the numbering of all artefacts unearthed *in situ,* and photographic and drawing documentation. Observation of excavation profiles was carried out, allowing for the correlation of discovered monuments with the geological and soil layout of the site.

The area of the site and its vicinity was formed during the Poznań Phase of the last Scandinavian Glacial Period (Vistulian/Weichselian), which took place ca. 18 000 – 18 800 years ago (Wysota and Molewski, 2011). This was the time of the deposition of glacial till and glaciofluvial sands. In the next recessive phases of the Weichselian Glacial Period (Pomeranian, Gardno phases), the terminus of the ice-sheet did not have a direct impact on the Kuyavian area. However, the periglacial conditions caused intensive transformation of the recently shaped landforms.

The harsh climate of that period, finished with the decline of the Younger Dryas, caused a severe reduction of vegetation cover, so the whole European Lowland belt was affected by aeolian, denudational and slope processes (Kaiser et al., 2009). It can be assumed that the bottom part of aeolian sediments at Redecz Krukowy could have been deposited that time. In the older and the middle part of the Holocene, in the conditions of well-developed vegetation (Ralska-Jasiewiczowa et al., 2004), the activity of morphological processes was limited. Thick vegetation prevented aeolian processes and mechanical denudation. For the area of today's Poland, it is the time of undisturbed, natural ecosystems functioning, with domination of forest complexes. Abundant assemblage of Mesolithic artefacts has been unearthed at the Redecz Krukowy site, however the interference of man into the vegetation composition and distribution was so insignificant that it did not cause any visible changes in land surface or deposition of mineral sediment. This was the time of soil-forming processes, deposition of lake sediments and the growth of peat cover in wetlands and in the vicinity of lakes.

The estimated time of the first settled humans (the Danubian culture) communities presence at the Redecz Krukowy site is ca. one thousand years. It occurred in the middle of the Atlantic period that was the Holocene climatic optimum. Archaeological traces indicate a possibility of cultivating

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hydromorphous mucky soils (Gleysols Arenic, Humic) and black earths (Gleyic Phaeozems) spread at the site and in its vicinity. This must have been connected with partial deforestation, the triggering of mechanical denudation and the disturbance of natural soil processes. Relics of mucky soils and black earths directly at the archaeological site indicate higher than the present day level of ground water and probably presence of a big lake in the neighbouring land depression. Only the settlers of the Funnel Beaker culture (FBC) brought about significant changes in land surface, as a result of very intensive exploitation of the site and its vicinity. They triggered aeolian deflation processes at some places of the site, which resulted in the erosion of the topsoil humus horizon (A) and sometimes even the sandy layers underneath. It also started accumulation processes, which involved the formation of sandy covers, up to several dozen centimeters thick, and a partial covering of mucky soils, together with some older archaeological artifacts. Significant increase in levelling of the area of the site and its close vicinity was an effect of aeolian cover formation. The phase of intensive FBC exploitation of the area in the Sub-Boreal Period was followed by a partial regeneration of the plant cover around the site that is recorded in soil horizons formation. However, the late Neolithic communities and the Bronze Age groups (including the Lusatian culture) left multiple traces of activity at the site, visible in areas used as arable lands, free of vegetation cover. This led to a further re-deposition of thin sandy layers. Further flattening of the surface was a result of aeolian deposition and also of faster accumulation of biogenic sediments in small closed basins, surrounding the site. The older part of the Subatlantic period was characterized by land surface stability, resulting from a not intensive use of the area by the Iron Age cultures and probable break in settlement during the Peoples Migration Period. Until the Middle Ages, the area of the site did not undergo major change, allowing forest vegetation and the soils to regenerate. The soil cover of that period was represented by rusty soils (Brunic Arenosols), typical of fresh deciduous forest (*Carpinion betuli*). Significant changes only occurred in wetland areas, where a considerable part of a former lake was covered by peat. This, however, resulted probably from regional climatic changes. Visible transformation of landform resulted from agriculture and settlement during late Middle Ages, and the modern period.

Archaeological documentation and the abundant movable material, obtained as a result of sieving the total material building cultural layers, and precise levelling measurements, made it possible to evaluate the scale of landform change, with reference to thickness and spatial distribution of particular sediment series. If this is compared with the sequence of cultural layers, we can clearly indicate phases of intensive land surface changes, degradation of soil horizons and re-deposition of mineral sediments at the site and in its vicinity. We can also point out phases of stability and regeneration of vegetation and the soil cover. However, local character of these processes should be indicated, resulted from “individual” history of settlement at the Redecz Krukowy site, regularities of natural processes and human activity interaction can be accepted as representative for analogous landscapes widely spread in Poland and the entire Central European Lowland.

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The Late Vistulian record in deposits of the Moszczenica River valley at the Swędów site (Central Poland)

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The Moszczenica River is a small lowland river with a length of ca. 55 km. It is situated in central part of the Vistula River drainage basin, and is the tributary of the Bzura (Fig. 1). The Moszczenica drains northwards the area of the Łódź Plateau; its source is located at 210 m a.s.l. and enters the Bzura at 94 m a.s.l.

In the middle reach, the valley of Moszczenica is about 1500 m wide and 20-25 m deep. The valley is incised into Quaternary deposits which there are about 40-60 m thick. Near the Swędów site the valley is ESE-WNW oriented. Its morphology is characterized by strong asymmetry – north-exposed left slope is 2-3 times longer and higher than south-exposed right slope. The valley is occupied by one terrace level (5-6 m above the present riverbed) and a narrow floodplain 50-150 m wide. The slope exemplifies a long denudational form transformed under periglacial conditions (Dylik, 1969), which gently passes into the narrow terrace surface. The relief is diversified by a belt of small irregular dunes (up to 5-6 m high) and aeolian covers, extending across the valley over a length of about 1800 m.

At the Swędów site, on 14.5 km of the river's course at ca. 145 m a.s.l., in a natural undercut of the meander, Kamiński (1989) discovered a thin organic series covered with fluvial sediments and then with aeolian ones at the top.

In 2018 a survey was undertaken in the mentioned undercut (profile B, 4.3 m deep; Fig. 1) as well as in another undercut of the river located about 500 m up the valley (profile A, 5.0 m deep). The lower unit in both profiles is composed of sand and gravel with silt admixture, with different grain size, is very poor sorting, and was deposited in fluvial sedimentary environment. The OSL date yielded for a sample from the B profile is 19.8±1.3 ka BP (GdTL-3137); for the profile A similar ages were obtained from two samples: 20.9±1.2 ka BP (GdTL-3141) and 18.9±1.2 ka BP (GdTL-3140). The middle unit was only recorded in the profile B. It is consisted of organic-mineral silt series of ca. 70 cm thick, with variable content of organic matter but sufficient for palaeobotanical analysis. The radiocarbon dates of this depositional seqeunce (from the bottom to the top) are as follow: 11.39±0.1 ka BP (GdS-3963) (13.43–13.07 ka cal BP; 95.4% prob.), 11.41±0.065 ka BP (GdS-3970) (13.4–13.11 ka cal BP; 95.4% prob.) and 8.98±0.095 ka BP (GdS-3983) (10.3–9.74 ka cal BP; 94.8% prob.). The time period represented by these dates covers the Allerød to the early Holocene. The results obtained by Kamiński (1989) allow to locate its formation during the Younger Dryas and early Holocene. It should be mentioned that the top part of the organic-rich series in the described geological situations is contaminated by present-day root systems, which may influence radiocarbon estimations. The upper unit is composed of medium and fine well sorted sand, of a thickness of ca. 3.2 m in the profile B and OSL ages ranging between 7.98±0.42 ka BP (GdTL-3136) and 13.78±0.77 ka BP (GdTL-3135). In the profile B the deposit is characterized by a greater diversity of grain size indices. The beginning of the accumulation of the upper unit sediments can probably

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be associated with fluvial sedimentary environment, and their topmost part likely with aeolian conditions.

There are similarities between the position of the organic deposits at the Swędów site and the previously investigated organic series containing remains of fossil forest of the Younger Dryas age (site Koźmin Las, Dzieduszyńska et al., 2014). This site is situated in the extensive valley of a relatively large lowland river of Warta. The similarities concern exceptional extent of the series, moreover both the alluvial origin of the sediments and their lithological features (grain size of organic series and of under- and overlying alluvial sediments). The main difference is the scale of the river valleys of Moszczenica and Warta as well as the complicity of aeolian processes in the formation of sediments covering the organic series at Swędów. The collected data may indicate a large similarity of the Late Vistulian record, despite the significant differentiation of the scale of river valleys, and thus the subordinate role of local factors.

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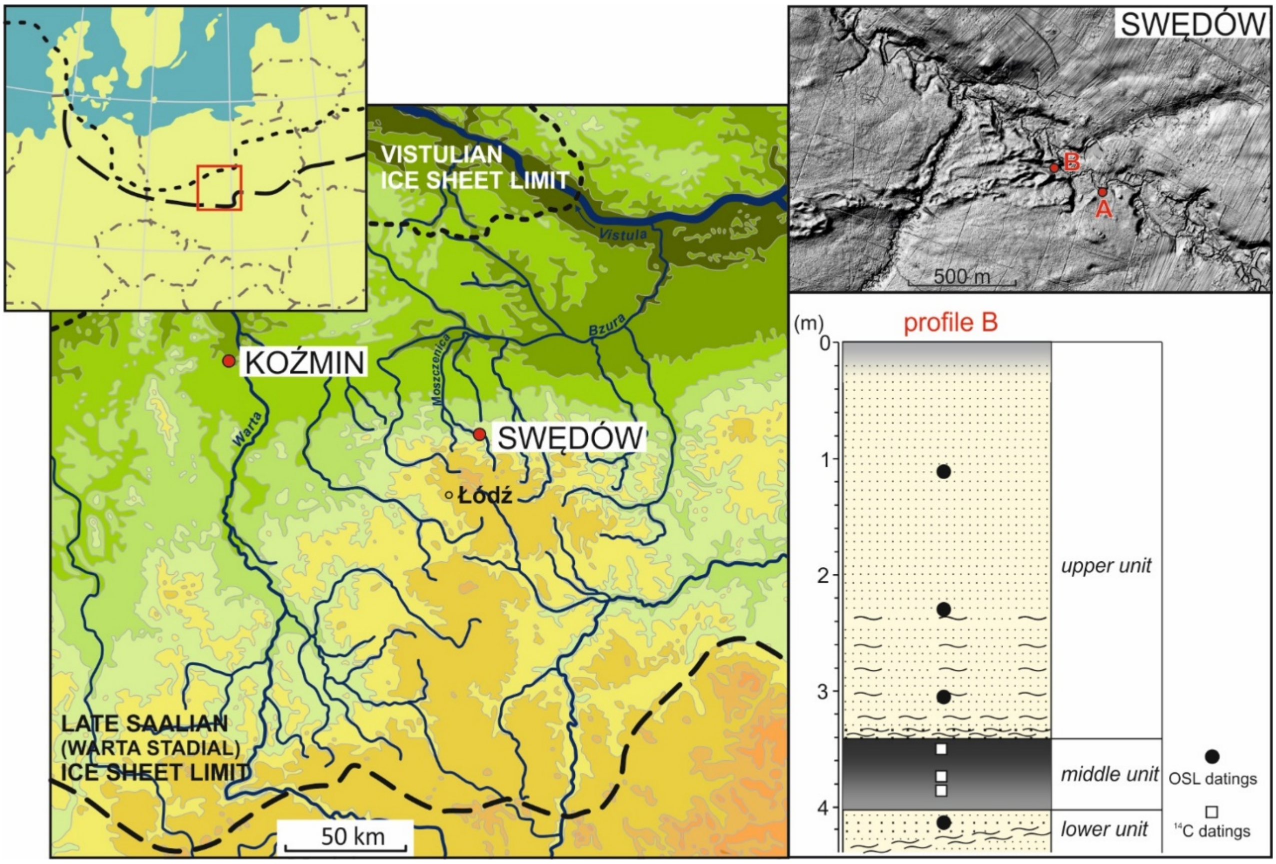

Fig. 1. Location of the Swędów site and properties of the profile B

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Geological effects of a catastrophical flood of salt water - inundation - tsunami in Kolobrzeg in 1497 in the light of chronicler's records, N Poland

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Introduction. Among the many storms that have been recorded in the last thousand years in Kolobrzeg, the event of 17 September 1497 is noteworthy. The storm occurred all along the coast of the southern Baltic Sea, from Königsberg (Kaliningrad) to Lübeck. Among the many storms that have been recorded in the last thousand years in Kolobrzeg, the event of 17 September 1497 is noteworthy. The storm occurred all along the coast of the southern Baltic Sea, from Königsberg to Lübeck. The effects of this extreme wave phenomenon of similar strength were also recorded in Rogowo 8 km to the east and Darłowo about 70 km to the east.

Methods. The subject of the analysis were chronicler's records, which were verified by field research, drilling, detailed analysis of the relief, height relations of individual places mentioned in the Chronicle. Archaeological excavations carried out in recent years have also been the subject of analysis. The research was carried out within the framework of the National Science Centre project No. 2011/01/B/ST10/07220.Z of the National Science Centre. The historical description of the consequences of the catastrophic wave for the city of Kolobrzeg and its surroundings is presented in the town chronicle (Riemann, 1873) and the calendar of the city (Kroczyński, 2000).

Results. From the chronicle record you can read indirect information about the height of the wave, and above all about the extent of the accumulation of sand that this wave caused. Wave height can be estimated at a minimum of 3.5 to 4 m and even up to 5 m. The range of sand defined along the river bed is 1,600 m and directly from the sea shore is 1,200 m. The height of the wave can be estimated at a minimum of 3.5 to 4 m or even up to 5 m. The range of sand defined along the river bed is 1,600 m and 1,200 m directly from the sea shore. The distant sea range of accumulation of sediments and their displacement by dragging and transporting in suspension is one of the criteria for qualifying the phenomenon of a catastrophic sea lagoon as a tsunami event. Both distances indicate the uniqueness of the extreme wave phenomenon - tsunami in 1497 in Kolobrzeg.

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Bolder stone Tryglaw in Tychowo, Pomeranian North Poland

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Introduction. Tryglaw boulder is one of the largest erratics ever found on European lowlands. Tryglaw boulder is located in Tychowo Wielkie 40 km from Koszalin. It is located in the center of the village within the cemetery.

Methods. The analysis of the boulder's location, its morphology and location in the geological profile was carried out. The transport route was reconstructed. In order to achieve this goal, boreholes were drilled and a new research approach was applied using the unmanned aerial vehicle.

Results. The boulder is smoothed and scratched in the proximal part. However, there are no scratches and smoothings on the almost vertical distal, southern wall. The boulder was deposited during the Pomeranian baltic glaciation phase within a dike clay, which is 8 m thick. The ordinate of the area is currently 20 m above sea level. The distance to the edge of the ice sheet was 20 km. We can assume that its settlement took place in the final part of the ice sheet standstill which lasted about 400 years; it was a stage of the formation of efflorescences and scratches on the Tryglaw boulder mutation. During the ice sheet receding, the ceiling part of glacial sediments in its surroundings (clayey sands, sandy clay) was accumulated. Petrographic analysis indicates that the boulder belongs to a group of rocks not marked with respect to its source. The estimated source areas of the boulder are in central Sweden and western Finland. The figure below shows the Tryglaw boulder.

Fig. 1 Tryglaw Boulder

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Stronghold Santok in the light of UAS Photogrammetry

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Introduction. The aim of the study was to reconstruct the natural conditions in Santok geoarcheological site. Santok stronghold is located between branches of the Warta and Noteć rivers, which belongs to the Odra drainage basin, in the northwestern Poland. The research area is 250 km from the sea. These are examination-physical and complementary to earlier examinations carried out at this position and in its vicinity. So far, the following have been carried out: drilling, geophysical surveys, archaeological trenches.

The research was funded by the National Science Centre, Poland (project Sonata Bis No.2015/18/E/HS3/00425).

Methods. Short-range photogrammetry is a multispectral imaging of the terrain surface using unmanned aerial vehicle systems (drone). In the Stronghold area an air raid was carried out with the use of Phantom 3 system by DJI. The air raid was made at a height of 100 m. Spatial resolution was 6.47 cm per pixel. The longitudinal coverage of the photographs was 90 percent. 71 photos were taken. Then, in the AgisoftPhotoscan software, the autocorrelation of images was made, finding the means of projection of individual images. A dense point cloud was generated and then a Digital Surface Model was created to show the surface of the stronghold. The final stage was to generate an orthophotomap of strongold and its surroundings. This made it possible to read the details of the terrain relief and the changes that have occurred in it over the last few hundred years.

Results. The landform features have been finally shaped in the last 8 thousand years at the most as an anastomosing system of river beds. Each of the two rivers, Noteć and Warta, flowed along three or four riverbeds. The final connection of the rivers was located directly to the west of the hill of the stronghold. Orthophotomap and Digital Surface Model confirm this fact. In the last 300 years, the valley floor surface has been transformed by natural processes and human activity. A major flood in the 18th century caused the main riverbed of the Warta River to be moved to the Noteć riverbed east of stronghold. In the 19th century, the regulation of the riverbed of the Warta and the Noteć rivers stabilized the system of the main streams of these rivers. The effect of the adjustment is the imposed sand cover masking the original fossils arms-rivers system of the Noteć and Warta rivers. The Stronghold area was transformed as a result of the creation of rural buildings within its boundaries. In the north-western part of stronghold, the stronghold embankment was destroyed. Archaeological research conducted before the World War II resulted in large amounts of cultural sediments from the stronghold area being deposited in the area directly adjacent to stronghold. The above mentioned natural and artificial processes also led to the blurring of traces of the historical road leading from the old Polichno to the city and from the city to the north of the bridge and then to the land road. It was an important communication artery from south to north from the Great Poland to Pomerania (Fig.1).

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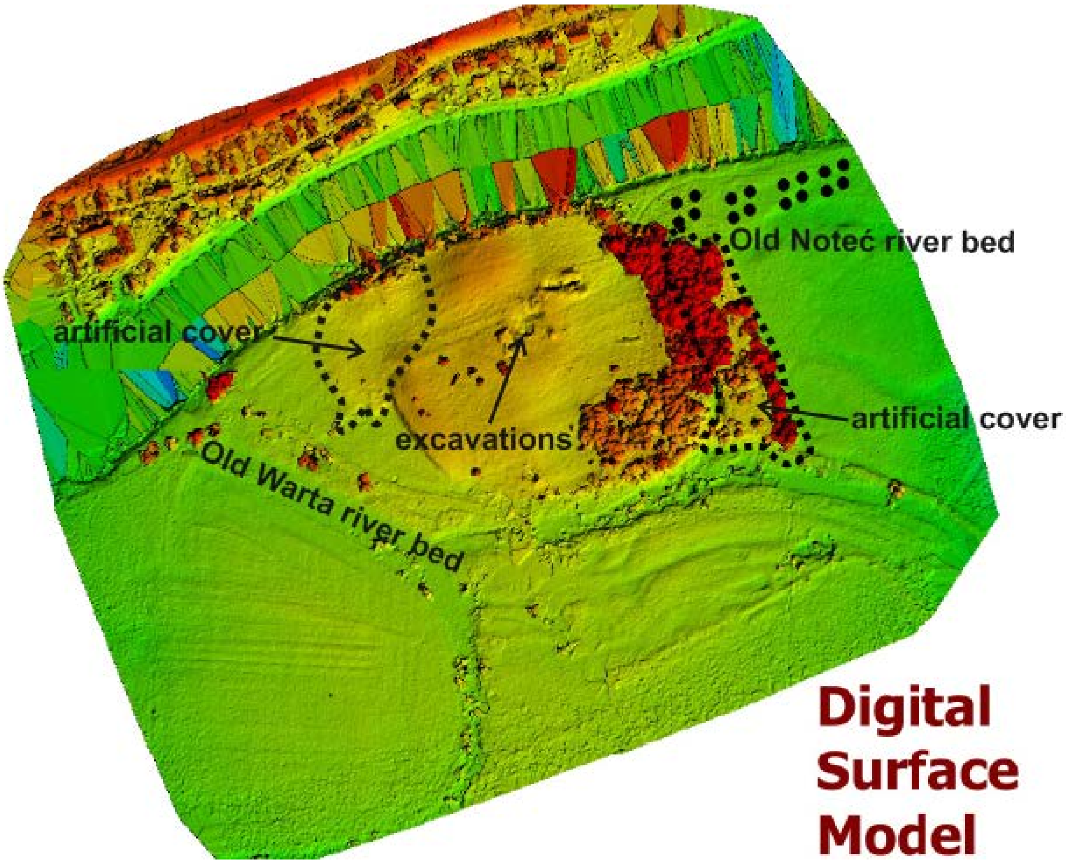

Fig.1. Santok stronghold of digital surface model

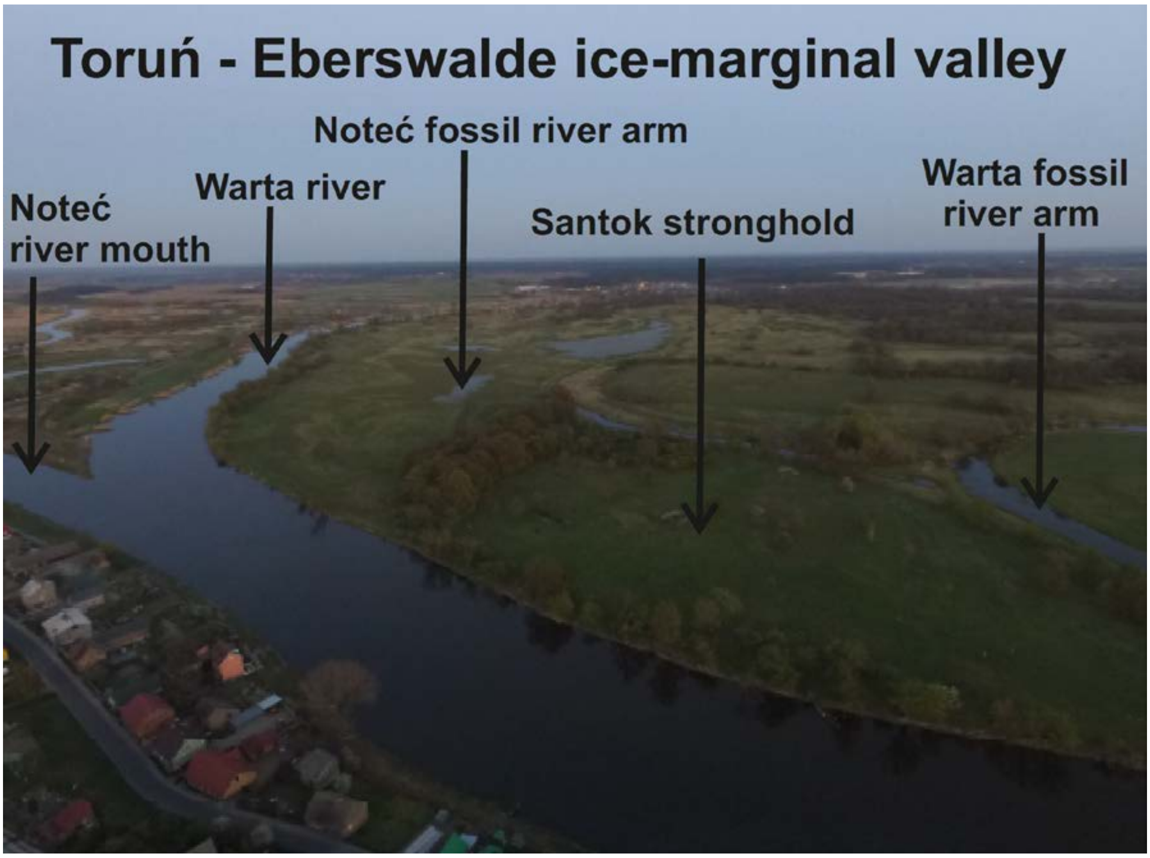

Fig.2. View from the northwest to the Santok Stronghold

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Load casts and pseudonodules as indicative soft-sediment deformation structures of glaciolimnic kames

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In six fine-grained glaciolacustrine kames located in eastern Poland and southern Lithuania and formed during MIS6 and MIS2 are analysed soft-sediment deformation structures. These kame sediments consist of a distinctive suite of sediment grain sizes, being in constitution an admixture of clay, a full range of silt fractions, and fine-grained sand. A characteristic feature of all of the analysed kames is their extraordinarily rich scale of soft-sediment deformation structures like large-scale load casts, pseudonodules and injection structures observed in the kames. Furthermore, the large-scale load casts and pseudonodules contain a few generations of smaller soft-sediment deformation structures, i.e. the largest load casts or pseudonodules can enclose two, three, four or even five generations of smaller deformations. This complexity derived probably from multiple-stages of kame-sediment deformation. The trigger mechanism of this complexity was linked to a very specific water regime presents during kame formation and to slight differences in their grain-size distribution.

We suggest that all these fine-grained kames were most likely formed during the initial stages of deglaciation, occurring in isolated depressions within the ice with bottoms located above the sediment-rich subglacial zones.

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Clay illuviation in loamy soils of north-western Eurasia - evidence of early Holocene warm stage?

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Clay illuviation is an important pedogenetic process. The mobilization and redistribution of clay particles is most typical for the soils of the temperate humid forest ecosystems where Luvisols and Retisols are common. Towards the northern margins of forest zone the intensity of this process decreases; the dominant soil types Podzols on sandy parent materials and gleyic and stagnic soils on clayey substrates. However we encountered soils with clear morphological features of clay illuviation in Karelia (North-Western Russia) and in Western Siberia near to Nadum city. Both regions have cold climate and represents taiga close to sounthern bourder of tundra zone. Which factors and processes promoted formation well developed texture differentiated soils in such climatic conditions? To answer this question, we studied two soil profiles, located in mentioned areas.

The soil profile of Karelia site is located n the southern part of Karelia, where areas of loamy soils with *argic* horizon are found among podzols. The area is characterized by Ustic soil moisture and Cryic temperature regimes. The parent material for soil formation is moraine of Luga stage of Valday glaciation (approximately 13 ka). The West Siberian profile is located more to the north, under even colder climatic conditions with patchy permafrost. Earlier this area was thought to be covered with permafrost, however recently the extent of Pleistocene ice sheets was revised. Dominant parent material is alluvial sediments of multiple terrace levels.

To investigate the formation of both soil profiles, following analises were curried on: a detailed morphological description and classification, texture analisis and micromorphological observations. The Karelian soil was classified as an Albic Fragic Retisol (Cutanic) (IUSS Working Group WRB, 2015) (Fig. 1a). As it was reflected in taxonomy of the soil, the texture differentiation is an important characteristic of this profile because of the albeluvic tonguing and accumulation of illuviated clay in the lower part of the soil profile. The Siberian soil was defined in the field as Stagnic Luvisol (Fig.1b)

Both soils have features of potent illuviation that is hardly could take place under modern climate. We suppose a milder and warmer climate and another vegetation cover for the formation of such soil types. Both soils were formed during the Holocene, which has warmer and colder periods. As it was noticed in lake and peat sediments, during the Atlantic period the boundary of the taiga regione was moved to the north and studied regione has broad-leaf forests (Yelina and Filimonova, 2007), so it had more favourable climatic conditions for the strong texture diffentiation. The same tendency we notice for the Holocene climate for the Siberian region. According to the peat chronology during the Atlantic period there was a warmer climat as well, that should be convenient for the strong clay illuviation.

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Fig. 1 The investigated soil profiles: a) Karelian Albic Fragic Retisol (Cutanic); b) Siberian Stagnic Luvisol.

We conclude that for both regions, located in North-Western Eurasia, the most probable explanation of those formation is the texture differentiation in warmer climate during the Atlantic period for the Karelia site for the Nadum site in Siberia.

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Holocene paleoenvironment of the Central Baltic Sea based on benthic foraminifera record from the Gotland Basin

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The establishment of water exchange with the North Atlantic (via the North Sea) during the shift from the Ancylus Lake to the Littorina Sea stage had a key impact on the formation of the environment of the modern Baltic Sea. The present Baltic Sea is semi-enclosed brackish basin with limited water exchange (Hermelin, 1987; Kabel et al., 2012). Due to positive freshwater budget, the water column is permanently stratified (Kabel et al., 2012). The hydrological and hydrochemical regimes of isolated deep layer are strongly dependent on the frequency of irregular inflows of dense, saline and oxygenated North Sea water through the narrow Danish Straits. The Baltic Sea basin is subdivided into several sub-basins connected by shallow and narrow channels and sills. The salinity decreases northward as inflow waters become successively diluted while moving across sub-basins (Hermelin, 1987).

During 44th cruise of the R/V Akademik Boris Petrov (October 2018), sediment core ABP-44035 was taken in the Western Gotland Basin. The core was recovered from the water depth of 117 m by gravity corer. The core is 396 cm long; however, upper 4 cm of the sediments were lost. Complex sediment analysis was performed to reconstruct the Baltic Sea paleoenvironment including the changes in frequency of saline water inflows. Aboard the ship, the lithological description of the core was made, after which the core was sampled with 1 cm interval. The core is mainly composed of olive gray and dark gray silt and silty clay. Benthic foraminifera were wet counted and identified in the >63 µm size fraction and shells concentration was calculated as number per gram of wet sediments. Total organic carbon (TOC) content was determined using carbon analyzer AN-7529M. Loss on ignition (LOI) was determined by drying the samples at 100 °C and subsequently ashing them at 550 °C for 3 hours and calculating the resulting mass difference. To construct an age model the radiocarbon dating of bulk sediment was performed at the Poznan Radiocarbon Laboratory (Poland). AMS ^{14}C dates have been calibrated using Calib7.1 ("Marine 13.14c" calibration curve, Stuiver and Reimer, 1993). The calendar age (before present; BP = AD 1950) is represented as an average value within the 1σ confidence interval. The core represents Littorina and post-Littorina stages of the Baltic Sea back to 8036 (392 cm) years BP. The sediment core consists mostly of fine sediment fraction (<63 µm) with less than 10% of sand fraction. Foraminiferal assemblages had low diversity. Agglutinated foraminifera were found only in the upper 100 cm of the core and were represented by three species (*Reophax nana, Reophax regularis* and *Reophax dentaliniformis*). Higher concentrations of agglutinated tests in the core were recorded at 1845 – 2324 years BP. Two species*, Cribroelphidium (Elphidium) excavatum* and *Cribroelphidium (Elphidium) incertum*, were dominant among calcareous species. Calcareous tests were extremely rare in the studied core and showed two distinct peaks in the record: 941 and 8011 years BP. The presence of *Elphidium sp.* implies bottom water salinity values higher than 12 psu at the time of deposition. LOI values vary in a range of 10–17%; TOC content in sediments changes from 2 to 4.5%. LOI showed increased values at 1473–1953 years BP interval; at the same time, an increase in TOC content was observed. Another peak of high TOC content was found at 4771–6502 years BP.

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Based on complex sediment analysis data paleoenvironmental conditions of the Gotland Basin over the last 8036 years were reconstructed. The presence of *Elphidium sp.* in the very bottom of the core indicates the onset of the Littorina Sea stage at the Western Gotland Basin as early as 8011 years BP. High TOC content at 4771–6502 years BP indicates enhanced primary production and water column stratification which led to widespread hypoxic condition during the Holocene Thermal Maximum (Binczewska et al., 2017; Hausler et al., 2017). An increase in agglutinated foraminiferal content during 1845–2324 years BP interval indicates existence of dynamic hydrological conditions in the bottom water layer caused by inflows activity. However, higher LOI values at 1473–1953 years BP imply hypoxic conditions during that time due to increase in primary production and water column stratification caused by climate warming during the Roman Warm Period. Most likely, at that time, inflows activity only temporarily improved bottom water oxygen conditions but was insufficient to entirely oxygenate bottom waters. Second peak in calcareous tests content at 941 years BP shows the intensification of water exchange between the Baltic Sea and the North Sea during the Medieval Climate Anomaly caused by positive North Atlantic Oscillation and consequently strong westerlies (Binczewska et al., 2017). Presented reconstruction is preliminary and requires further clarification by increasing the time resolution and additional geochemical investigation.

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Glacial outburst floods in the old glacial landscape zone of the Polish Lowlands

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Extreme flooding events, which occurred both in the ice marginal zones of contemporary glaciers and in the foreland of the youngest Pleistocene ice-sheets (Weichselian, Wisconsian), have been extensively documented in literature. They have been well examined as regards both sedimentological and morphological evidence. As far as ice-sheets of the older glaciations (Saalian, Elsterian) are concerned, there are much fewer studies of this kind. Among the analysed glacial floods from Saalian in continental Europe, examples of well recognised events include GLOF (glacier lake outburst flood) events near Hannover (Central Germany), from the extent of the Early Saalian Drenthe ice-sheet. They resulted in releases of proglacial lakes, e.g. of Weser and Münsterland in North Rhine-Westphalia (NW Germany, Lang et al., 2018). In Poland, in the old glacial belt of the Lowlands, shaped during Saalian, more than 10 sites have been identified with geological traces of such events. The vast majority of better documented sites are related to younger deglaciation stages of the Late Saalian ice-sheet (Fig. 1).

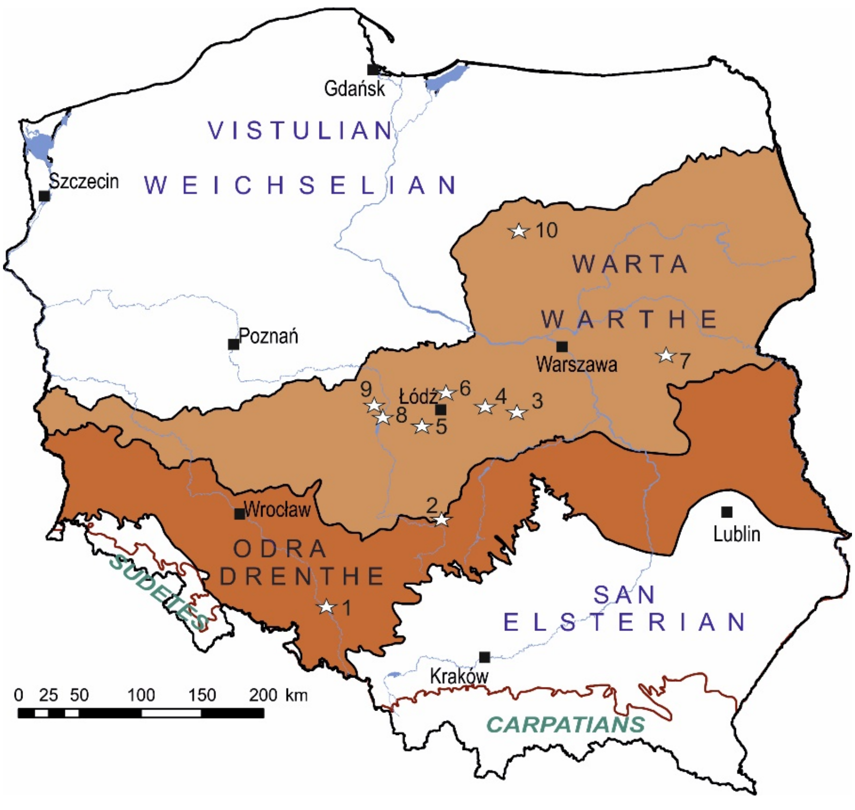

Fig. 1. Occurrence of traces of glacial floods in Poland against the background of Saalian glaciation extents according to Rdzany and Frydrych (2018), simplified. Example sites are based on works by various authors: 1 – Gogolin (Salamon, 2009); 2 – Adamów near Radomsko (Fig. 2B), 3 – fields of glaciolacustrine kames of the Rawka river basin (e.g. Rdzany, 1997); 4 – Rylsk esker (Jaksa and Rdzany, 2002); 5 – Zygry (Jaksa, 2006), 6 – Leonardów (Jaksa, 2006); 7 – Łuniew near Siedlce (Godlewska, 2014); 8 – Siedlątków (Frydrych and Rdzany, 2018); 9 – Rzymsko (Frydrych, 2016); 10 – Uniszki near Mława (Fard and Gruszka, 2007).

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The authors' research allows to conclude that glacial floods occurred more commonly than it has been believed so far. However, they were mostly local floods, which left behind mostly sedimentological evidence, whereas their influence on the relief was relatively small.

The analysed cases of flood were reflected in the marginal zones of ice-sheets (Fig. 2A), in the proximal zones of sandars (Fig. 2B) and near the outlets of subglacial tunnels. The thoroughly studied instance of flood at the Siedlątków site in Central Poland (Frydrych and Rdzany, 2018, Fig. 2A) allows for it to be compared with a minor jökulhlaup in the ice-contact zones of Icelandic glaciers. The occurrence of jökulhlaup resulted in cutting erosional channels and filling them with glaciofluvial sediments. Their characteristic features include: erosional and deformational contact with substratum formations, a high content of very coarse and poorly sorted sediments, normal and inverse grading, dominance of massive structures, the presence of rip-up clasts, similarity of clast features to clasts in till and other facies of sediments from the late Saalian glaciation.

A

B

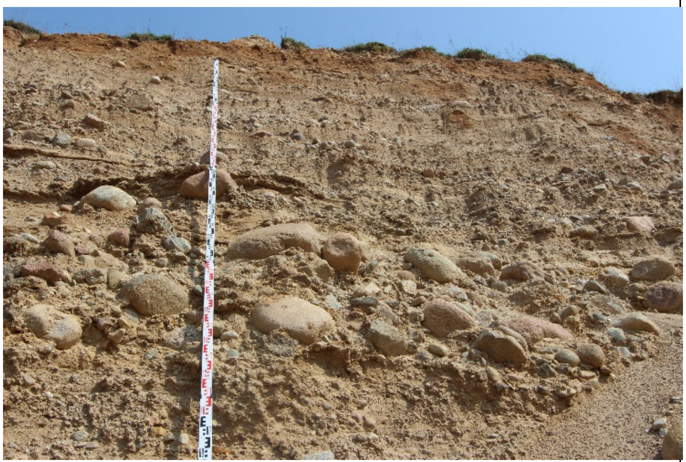

Fig. 2. Examples of coarse-clastic sediments of glacial floods: A – Siedlątków site, B – Adamów site. measure length: 4 m.

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Holocene relative shore level changes in the Gulf of Riga – new data from the Pärnu Bay area

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Gulf of Riga is located on periphery of the Fennoscandian postglacial land uplift region with present-day apparent land uplift rates at about 2 mm per annum in the northern part and at about 0 mm per annum in the southern part of the gulf. Our previous relative shore-level (RSL) reconstructions in the northern (Saarse et al., 2009), eastern (Rosentau et al., 2011; Habicht et al., 2017) and central part (Muru et al., 2018) of the gulf have shown complex RSL change with shifting coastlines and burial of the terrestrial landscapes and prehistoric settlements. This study focuses on RSL changes and Stone Age paleogeography of the Pärnu Bay area in the north-easterrn Gulf of Riga by using sedimentological and archaeological proxies and GIS-based landscape modelling. We discovered and studied buried palaeochannel sediments on the coastal lowland and in the shallow offshore of the Pärnu Bay and interpreted this data together with previously published shore displacement evidence.

The reconstructed relative shore-level (RSL) curve is based on 78 radiocarbon dates from sediment sequences and archaeological sites in the Pärnu Bay area and reported here using the HOLSEA sea level database format. The new RSL curve displays regressive water levels at –5.5 m and –4 m a.s.l. before the Ancylus Lake and Litorina Sea transgressions, respectively. According to the curve, the total water level rise during the Ancylus Lake transgression (10.7–10.2 cal. ka BP) was around 18 m, with the average rate of rise about 35 mm per annum, whilst during the Litorina Sea transgression (8.5–7.3 cal. ka BP) the water level rose around 14 m, with average rate of 12 mm per annum. The RSL increase rate around 7.8–7.6 cal. ka BP clearly exceeded the concurrent rate of the eustatic sea level rise similarly to slowly uplifting areas in Samso (Denmark), Blekinge (Sweden) and Narva-Luga (NE Estonia). The palaeogeographic reconstructions show the settlement patterns of the coastal landscape since the Mesolithic and provide new perspective for looking Mesolithic hunter-fisher-gatherer settlement sites on the banks of the submerged ca. 9000 years old river channel in the bottom of the present-day Pärnu Bay.

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Buried soils under stone mounds in the Eastern part of the Leningrad region, Russia (the monument Zabel'e 1): Genesis and paleoenvironmental inferences

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In 2016 during the archaeological protective excavations in the forest landscape near the village of Zabel'e (Boksitogorsk district, Leningrad region) some areas with unusual and unique stone mounds were discovered (fig. 1). These objects are restricted to the flat top of the moraine hills (a.s.l. ~160 m) of the last Late Pleistocene glaciation (MIS2). This study area belongs to the end-moraine landscapes of the Valdai Upland.

Fig. 1: The stone mounds in the Eastern part of the Leningrad region, Russia (the monument Zabel'e 1).

We have to stress that the complex of archaeological methods did not give an unambiguous answer to the questions about the genesis and time of creation and functionality of these stone mounds, or embankments. During the excavation at the sites, neither objects of material culture nor traces of burial were found. This fact allowed specialists to assume that the stone mounds were not cultural, but had an economic purpose. So, stone mounds could have arisen during the cleaning of agricultural lands from stones or as a result of the collection of stones as raw material for construction needs.

Soil studies were carried out on two excavation sites during fieldwork in the summer 2017. The profiles of buried and surface soils (during excavation works the original vegetation was cut) located in close proximity to one another (2-3 m) were described and classified. An additional soil

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profile was in the forest nearby. Our studies have shown that soils under a bulk material, whose thickness does not exceed three dozen cm, have a good profile safety with an undisturbed sequence of genetic horizons. The buried and surface soils are formed on bipartite sediments: water-glacial sandy deposits, underlain by carbonate moraine loams. The depth of change of parent material in the studied sections varies from 33 to 75 cm. The all soils of both chronosequences are preliminarily classified as Entic Podzols (Arenic) (IUSS Working Group WRB, 2015), which supports the fact that a relatively short time has passed since the construction of the embankments. The both buried and surface soils have a set of genetic horizons: Ah-Bf(1)-(Bf2)-Dca.

The main goal of this research is to study the soils of the chronosequence "buried soil - surface soil" in order to reconstruct the soil and landscape conditions that existed before the construction of the stone embankments. To study the detected soil profiles, a complex of various natural-scientific methods will be used, including paleopedological ones. In particular, radiocarbon dating of humic acids of buried soils will allow estimating the time of creation of these stone mounds. Based on the formulated aim, the following objectives were set: 1) morphological and genetic analysis of the soil structure and identification of the properties of surface and buried soils to establish the degree of preservation of the latter one; 2) study of phytolithic and spore-pollen spectra of soil chronesequence to define the degree of anthropogenic change in the landscape; 3) establishment of an evolutionary trend for the formation of soils on dated surfaces.

The results of radiocarbon dating of humus horizons of buried soils for two embankments (non-calibrated data) were obtained: 5537±70 yr. BP (SPb-2491), and 5541±70 yr BP (SPb-2492), although a relatively recent burial period of the studied soils of the chronosequence was originally assumed (hundreds of years, the first thousand), based on the similarity of the morphological investigations of the soil profiles. Based on data obtained, this means that the burial of the soil, and therefore the construction of these stone embankments, dates back to the Atlantic period and suggests the construction of these studied embankments corresponds to the building of the bronze mounds of the steppe and forest-steppe zones. The recognition of such ancient radiocarbon datings from an archaeological point of view requires further study by specialists.

The conducted studies allow us to judge about a slight change in the morphological structure of the soil profiles of chronoseguences and about the absence of noticeable trends in the evolutionary development of the Entic Podzols of the southern taiga subzone. Changes in the properties of the soil have only qualitative character, in particular, a decrease in the actual acidity in the surface soils in comparison with the buried analogues. These granulometric composition of the soils of the chronosequences do not allow us to talk about a change in the degree of differentiation of the soil profile; almost the same trends are observed when comparing non-silicate (free) iron. Diagenetic soil changes are noticeable in the reduction of humus content in the profiles of buried soils.

The results of phytolithic analysis of humus horizons indicate transformation processes of vegetation from the original open meadow communities (with motley grass-grasses associations) with an admixture of trees to communities with more close forest stand and meadow vegetation in a ground cover. The samples of stone mound material contain no or minimal amounts of microbiomorphs. Moreover, the data obtained on three soil pits demonstrate that bottoms of the Ah-horizons (at a depth of 10 cm), perhaps, used to be the surface ones. The presence of cuticular casts in the lower parts of humus horizons or the inverse distribution of phytoliths in profile is evidence in favor of this assumption.

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A spore-pollen analysis was made for samples from one excavation. Based on the data, it could be said that the territory was dominated by secondary pine and birch forests with an admixture of meadow cereals and motley grasses, particularly herbs of the *Onagraceae* family. These communities evolved during restorative post-pyrogenic successions that could have both natural and anthropogenic character.

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LiDAR-based mapping of the variable subglacial geomorphology in the central part of SIS

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An airborne LiDAR (Light Detection And Ranging) based glaciomorphological mapping has revealed new data for the morphological interpretation in the central part of the last glaciated terrain of the Scandinavian Ice Sheet (SIS). The on-going mapping project of the Geolocical Survey of Finland supported by the work done in the universities in Finland can be used in an examination of landscape development and glaciodynamic themes in the glaciated terrain. The mapping process combines the main geological unit (deposit) and new, landsystems-based glacial geomorphological feature information (Putkinen et al., 2017). So far, the interpretation has been focused in the areas of active ice lobes in central and northern Finland. In those areas previously detected large mega-scale glacial features, such as mega flutings, drumlins, end moraine complexes and glacial melt water systems show up in LiDAR-based digital elevation models (DEM) in greater detail than ever before. This has lead to a new definition of the landform categories for supporting the mapping and creating the database (Putkinen et al., 2017).

Here we present new LiDAR-based mapping results (of the project funded by the K.H. Renlund’s Foundation) close to the Late Weichselian ice-divide zone, in the central part of the Scandinavian Ice Sheet (SIS) in Finnish Lapland. The area is mostly dominated by the passive-ice, basal till cover without an indication of significant ice movement. However, on both sides of the ice divide zone, there are some narrow areas having well-formed drumlin fields and onset areas for active ice lobes; Salla Ice lobe towards SE and Inari Ice Lobe towards NE. Further on south, the glacial morphology is composed mainly of moraine morphologies such as the glacial streamlined lineations of the Kuusamo drumlin field in the eastern part and different hummocky and ribbed moraines in the western part, i.e. at the core of the Kuusamo Ice Lobe. The drumlin field was formed under surging type glacial movement during the Younger Dryas while the core part of the glacier remained cold-based. Glaciofluvial deposits (eskers and delta formations) occur in places representing the last melting phase of SIS. Particularly, the ribbed moraines represent the depositional formations formed under subglacial conditions at the transitional zone between the warm- and cold-based glacier. However, new LiDAR-based mapping showed that large areas in eastern Finnish Lapland are rich in Pulju moraine type ring-ridges and hummocks, overlapping the drumlin ridges. In addition, small end moraine ridges occur in close connection to the ring-ridges, which indicate the formation of this moraine association in the marginal zone of glacier during the late phase of last deglaciation. Presence of deep pre-glacial weathered crust and tor formation are the evidence of repeated, prevailed passive and cold-based subglacial condition through the Quaternary.

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Springs in Quaternary landscape – source of information on climate change and anthropopression

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Springs are attractive and dynamic element of natural landscape, first of all as factors creating particular landforms such as suffosion cirques, erosional ravines, holes etc thus contributing to geodiversity. A springs is a link connecting the underground and the surface parts of the water circulation system. Their distribution is determined by a number of natural factors – the most important factor being geological structure (Chelmicki et al., 2011). Some springs arise due to neotectonical active zones, palaeoincisions. Therefore presence of springs could be an important factor for structural studies. In addition, it was noted the research of springs forming in Quaternary glacial deposits is lacking (Szczucinska, 2016).

Spring are valuable sites for monitoring as water chemistry and the ecological state of springs may be a fine indicator of environmental changes (Chelmicki et al., 2011.). For example the long period of observations in Poland has revealed changes of spring properties due to natural and anthropogenic factors. Only 38% of investigated springs maintained their natural character. The majority were completely devastated and overwhelmed (Siwek and Pociask- Karteczka 2017).

Research of all most known or newly detected springs of Lithuania was carried out by Lithuanian Geological Survey in 2012–2015 and resulted in publication of the catalogue of springs in 2017 (Kadūnas et al., 2017). This study presented data of investigations of the 220 springs and contains measurements of chemical and physical properties of springs, as well as conditions of their occurence, environment and regime. Almost all springs in Lithuania are related with Quaternary aquifers and mainly are outflows of shallow groundwater. It was determined that water qaulity of 72.4% of investigated springs was excellent, 17.7% of springs was good quality. This means that 90% of springs are without signs of anthropogenic contamination.

After the study in Lithuania 35 springs were selected for monitoring as part of state groundwater monitoring system and measurements of hydrochemistry and hydrodynamic were carried out in 2016, 2017 and 2018. Results of monitoring were interpreted looking for indicators of increasing anthropopression.

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The Boundary of the First Late Pleistocene Glaciation of The European Russia

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In frame of works on Geological map 1:1 000 000 scale (third map generation) we outlined the boundary of first Late Pleistocene Glaciation (LPG) at European Russia with account on new evidences found. The stratotype of glacial deposits of first LPG (site Podporozhskiy, fig. 1) is located near Podporozhye town. The boundary of the first stage of LPG is not as remarkable in the relief of the territory as the boundary of the second stage, so this borderline is being under discussion. We distinguished this line with two methods. First, we assumed geomorphological evidences of the glacier fringe, radiocarbon and OSL dates of its deposits, and we investigated cores where Pleistocene optimum (MIS 5) deposits were not covered with glacial sediments. Secondly, we analyzed periglacial lakes deposits and their dates.

Inside the boundary of the first LPG we studied Yakhroma-2 site (Zastrozhnova, 2015). We described slightly lithified peat deposits covered with moraine. The peat is dated 105 – 96 ka (U-J), thus, glacial deposits correspond to Late Pleistocene.

Large periglacial lakes were formed in Pechenga, Severnaya Dvina with its inflows Vychegda and Vaga valleys. In estuary of Vychegda river (Gorodishna site, 3, fig.1) high terrace deposits (95 – 100 m) are OSL-dated 47, 5±3,6 ka (RLOG 2516), 54,2±4,0 ka (RLOG 2457-117), 57,1±4,3 ka (RLOG 2517-078), 98,2±7,2 ka (RLOG 2456-087), which corresponds to the first stage of Late Pleistocene Glaciation. In Pechora river valley, the glacier-dammed “Lake Komi-1” were found. Its inner margin is 100-110 m height (Nikolskaya, 2006). The lake existed during first LPG, which is confirmed by the deposits of Garevo site (4, fig.1), dated OSL from 82 to 99 ka.

At Severnaya Dvina and Pechora river valleys Periglacial Lake deposits comprise periglacial lake sediments of second LPG. They form large lowlands and wide terraces. Its inner margins are 70 – 80 m height for Severnaya Dvina and 60 – 70 m for Pechora. Thus, we suppose that freshwater supply during first stage of Late Pleistocene Glaciation was more, probably, due to increased climate moisture.

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Fig. 1. Boundary of the First Late Pleistocene Glaciation of The European Russia

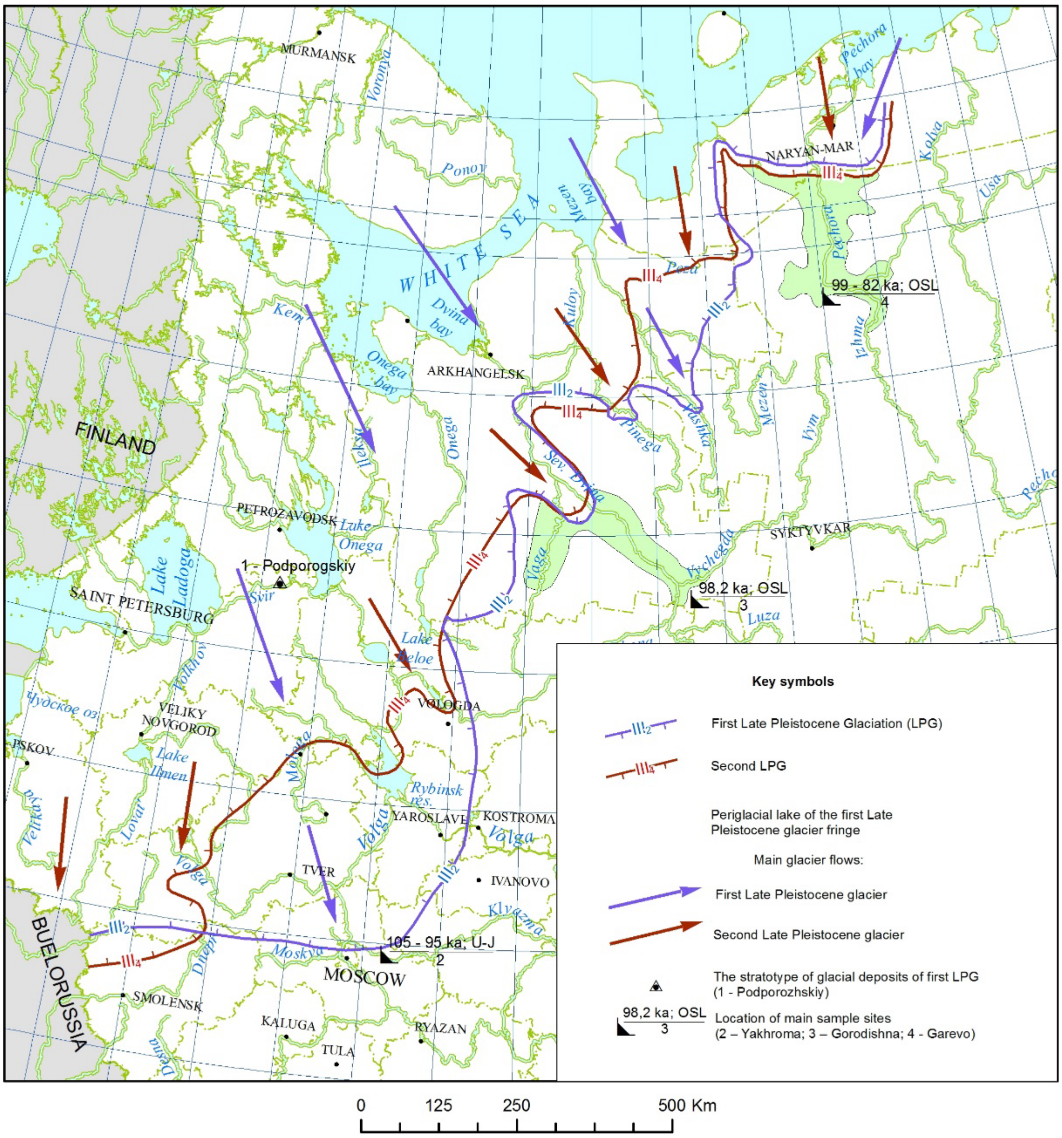

Fig.1 Boundary of the First Late Pleistocene Glaciation of The European Russia

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Study of the Holocene sea-level changes of the Baltic Sea on the territory of the Karelian Isthmus

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In recent decades, the development of the Baltic region has been the main subject of international conferences, symposia and meetings. The question of changes in the levels of the Baltic sea during the Late Pleistocene and Holocene is studied by scientists from many European countries. There are still discussions about the number of the Holocene transgressions, their spatial and temporal limits, as well as the evolution of the Baltic-Ladoga connection. The North-Western part of the Karelian Isthmus (NW Russia) is insufficiently studied from the point of view of paleolimnology. This is the area of the greatest interest for the establishment of transgressive-regressive cycles of the Eastern Gulf of Finland in the Holocene (Shatalova et.al, 2018).

According to the studies of lake sediments in the Eastern part of the Gulf of Finland, the Litorina transgression began at about 8.45 cal. years ago (Miettinen, 2004). The maximum level of the transgression was observed between 7.6 - 6.5 cal. years ago (Miettinen, 2004). Some authors also identify from two to six transgressive phases (Sandgren et.al, 2004), (Rosentau et.al, 2013). The salinity of the coastal waters in the Gulf of Finland was estimated as 6-8‰, which is about twice as higher as today. The highest estimated levels of Litorina transgressions in the Eastern part of the Gulf of Finland vary from 10 to 20 m due to uneven isostatic land uplift (Miettinen et.al, 2007).

With the aim of reconstruction of the dynamics of transgressive-regressive cycles of the Baltic sea and the changes of the environmental conditions of the North-Western part of the Karelian Isthmus, 3 lakes was selected at different hypsometric levels: Goluboye (11 ASL), Mozhevelnoye (14 ASL) and Trigorskoye (16 ASL). Sampling was carried out in October 2017 from the raft, using a Russian peat corer. In the field, the area around the lakes was studied in detail, bathymetry was measured and more than 30 sediment cores of precipitation were described. Then the cores were packed and transported to the laboratory. Analytical studies include geochemical, diatom, pollen, chironomid analyses and radiocarbon (AMS-dating). The obtained data will show physic-chemical features, bioproductivity of the lakes, the duration of sediment formation, vegetation change, average temperatures in July (Shatalova et.al, 2018).

At the moment, the results of the geochemical and diatom analyses for lake Goluboye are completed. Based on the results of geochemistry, we have identified levels for sampling for AMS-dating, where the increase in salinity is significant. Most likely this is due to the flooding of the territory by marine waters, resulted from the Litorina transgression of the Baltic Sea.

The composition of diatom assemblages allows to distinguish 5 local diatom zones (DZ) corresponding to the main stages of the evolution of Lake Goluboye. In DZ- 1 the species typical of the Early Holocene Ancylus Lake stage in the Baltic are abundant *(Aulacoseira islandica, Opephora martyi, Navicula jentzschii, Ellerbeckia arenaria, Diploneis domblittensis, D. maulleri)* (Krammer et.al, 1991). The diatom assemblages of DZ-2 are characteristic of a small lake, however, a sudden peak in halophilous taxa might indicate the earlier phase of the Litorina transgression. In DZ- 3 high abundances of halophilous diatoms (up to ~18%) apparently correspond to the next phase of the Litorina transgression. However, as the lake still remained fresh, the Litorina Sea level is only thought to have reached or slightly exceeded the lake's threshold (~11 m). The rapid decrease of the

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halophilous taxa in DZ-4 reflects the termination of the Litorina transgression. The diatom assemblages composition of DZ-4 and DZ-5 suggests small isolated-lake environment.

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Karelia's ice-divide accumulation uplands

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Karelia's glacial morphosculpture has been shaped by the last Upper Valdai (Ostashkovo) glaciation. Major glacial landforms, indicative of ice sheet degradation, occur as end-moraine belts, radial ridges, glacial depressions and ice divide (insular) uplands. The glacial morphosculpture displays a distinctive radial-concentric structure inherited from the structure of the last ice sheet and affected by the evolution pattern of marginal glacial zones and radial ridges (Ekman and Ilyin, 1991). There are six belts of marginal formations in Karelia and adjacent areas. They illustrate several stages in the degradation of the last Scandinavian ice sheet: Vepsovian, Krestets, Luga, Neva, Rugozero (Salpausselkä I) and Kalevala (Salpausselkä II). Twelve interlobate uplands, varying in size, were identified in all the marginal zones. The biggest uplands are Sumozerian, Volozerian, Vodlozerian (ice divide of the White Sea and Onega ice flows), Vokhtozerian-Veshkelitsa and Vedlozerian-Urokian (ice divide of the Onega and Ladoga ice flows). Similar but thinner formations are common in the Salpausselkä marginal ridge areas near Rugozero Town and Lake Nyuk. In Karelia, where the ice was moving mainly along the Precambrian bedrock, the amount of material required for the formation of big uplands, similar to macroforms in the northwestern Russian Plain, was insufficient. However, Karelia's ice divide accumulation uplands are the biggest structurally complex glacial sequences, except for glacial depressions. They vary in size from tens to thousands of square kilometers. Moraines and glaciofluvial deposits are part of the uplands formed at the contacts of inequidirectional ice flows, lobes and festoons during several stages and probably glaciations. The above uplands display some common features: 1) they are confined to interlobate zones that coincide with morphological watersheds; 2) they are confined to crystalline basement scarps; 3) their Quaternary sediments are at least 60-80 m thick; 4) they display a stratified structure; 5) they occupy the highest hypsometric position in the relief relative to other accumulation landforms.

The main morphosculptural feature of the interlobate uplands is their stratified relief, which reflects the formation stages of these macroforms. The lower levels are dominated by morainic ridges; the middle levels by ring and domal diapirs and the upper levels by primary scaly massifs and "zvontsy".

The Vepsovian (Kenozerian) - Krestets (Andomian) marginal belt is dated at 17 000-15 000 years ago. It is clearly correlated with Belozerian-Kirillovian marginal sequences that formed about 18 000-16 000 years ago.

These marginal sequences display fairly gentle outlines because they are confined to a Carboniferous scarp. Occurring there are the small Andomian, Undozerian and Kozhozerian ice divide uplands.

In the back-frontal zone of Luga marginal moraine (14 000-13 000 years ago) in Southern and Eastern Karelia, three insular uplands: Vodlozerian, Solotozerian and Onega, are distinguished at the contact of the Onega and White Sea ice flows. The Vodlozerian Upland displays the most complex structure. At the Neva (Sämozerian) stage and during the Bölling and Alleröd Interstadials (13 000-11 800 years ago), when the ice margin was on the Onega-Ladoga and Onega-White Sea isthmuses, it retreated to Central and Western Karelia (Ekman and Ilyin, 1995). The ice festoons occupied the Ladoga, Vedlozero, Shotozero and Sämozero lake basins and the northern Onega Lake basin. A

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frontal type of deglaciation predominated there, while in the large Onega, Ladoga and White Sea periglacial basins, a cross-cutting type prevailed (Demidov, 1998).

Six ice divide accumulation uplands varying in size, such as Solovets, Solotozerian, Volozerian, Vokhtozerian and Veshkelitsa, are the most distinctive topographic complexes of Neva stage marginal landforms. The Sumozerian and Vokhtozerian uplands display the most complex structure and some distinctive features of their own (Lukashov and Ekman, 1980).

As a result of rapid ice thawing during the warm Alleröd Interstadial, the ice was totally restructured: its festooned-lobate structure gave way to the more subdued outlines of the ice margin. The active ice sheet and the highly dissected topography of hard Precambrian rocks contributed to the predominance of the linear pattern of glaciofluvial accumulation: eskers, glaciofluvial debris cones and deltas were forming actively.

Rugozerian-Kalevala marginal complexes (Salpausselkä I: 11 200-10 900 years ago; Salpausselkä II: 10 800-10 200 years ago) terminated the Upper Valdai stage of glaciations in Karelia (Ekman and Ilyin, 1991; 1995; Demidov, 1998). The ice margin was on the Belomorsk – Rugozero Town – Motko line. The ice was moving mainly along the Precambrian bedrock. Therefore, Salpausselkä marginal belts are thinner than similar but older rock sequences and display a simple structure and more gentle outlines in plans view. They are seldom wider than hundreds of meters. 5-8 m high, 50-100 m wide push end morainic ridges occur in the frontal zone. However, in the areas where they extend across crystalline basement scarps (in the upper reaches of the Chirka-Kem River) large 30-40 m high, 5-6 km wide push-infill ridges are part of marginal complexes. Confined to these areas are accumulation sequences with all signs of ice divide uplands (Borovoy-Yushkozero area and Tiksha Town), a stratified structure, small-sized domal and ring landforms at low levels and the abundance of scaly massifs in which moraine scales are alternated with sand-gravel sequences.

Thus, Karelia's interlobate accumulation uplands are similar to and different from identical sequences in the northwestern Russian Plate.

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Seismites in the pre- and postglacial sediments of the Karelian Isthmus (Eastern Fennoscandia)

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The Karelian Isthmus is a part of Russian Karelia located between the Lake Ladoga and the coast of the Gulf of Finland of the Baltic Sea. The geological and tectonic structure of this region is determined by the location of the territory on the Eastern slope of the Fennoscandian Shield with outcrops of Proterozoic granite-metamorphic rocks dissected by faults of the Ladoga-Bothnian zone. Denudational-and-accumulative relief of the territory was formed under the impact of the Scandinavian Ice Sheet during the repeated glacier oscillations as a result of glacial erosion during advance stage (structural-denudation ridges) and accumulation during degradation stage (fluvio- and limnoglacial deposits formed during the occurence of dead ice and periglacial lake basins (Baltic Ice Lake). The outcrops of the crystalline basement rocks forming low ridges mainly of the north-western strike are interfaced with a thin cover of loose Quaternary deposits, common in the hollows.

The traces of post-glacial earthquakes, manifested in numerous seismic-gravitational displacements (Nikonov et al., 2009) and deformations of water-ice deposits (Nikonov et al., 2001) were found here earlier. The earthquake epicenter associated with activated Vuoksa fault zone were discovered here some years ago (Nikonov et al., 2014). The zone is characterized by a complex of kinematically coupled seismic deformations in rocks and loose deposits (Shvarev et al., 2018) and traces of catastrophic events which influenced the landscape and hydrographic network in the Holocene (Subetto et al., 2018). Seismic deformations were found in fluvioglacial, limnoglacial and lacustrine-alluvial deposits, traditionally attributed to the last glacial period and early Holocene. These textures includes traces of liquefaction, squeezing, faults with vertical and horizontal offsets, etc. were discovered in different parts of the Isthmus.

The area close to neotectonic activated Vuoksa Proterozoic fault zone (Afanasov, 1999) is characterized by maximum variety of types and duration of seismogenic deformations. Traces of six seismic events were discovered in sediments of four terrace levels (9-10 m (I level (H. a.s.l.)); 12-13 m (II); 15-17 m (III); 23-24 m (IV) in the valley of the modern Vuoksa river.

The earthquakes synchronous to the beginning of the early Weichselian glaciation are most ancient and reflexed in the glaciofluvial and limnoglacial sediments of the Podporozhsky age. Their traces are represented by two liquefaction horizons 89.0±7.3 (RLQG 2505-058) and 85.2±6.6 k.y.BP (RLQG 2504-058) (III level), corresponding to events 1 and 2 (figure); clastic dyke (IV level) with age 69.0±5.4 k.y.BP (RLQG 2502-058) and normal fault with age >72.7±5.7 k.y.BP (RLQG 2503-058) (II level), combined to event 3.

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Holocene seismic activity is reflected by the fragmentation and plastic deformation of the varved clays close to the surface of the III level with age about 8.3 k.y. BP (GIN-15444) (event 4); by the tectonic tilting of the sands crossbedded by sandy loams and peat exposed in the III and II levels, formed during the middle Holocene and deformed after 6.5-6.6 k.y.BP (GIN-15639) (event 5); by the fragmentation of varved clays and the mixing of rock debris and loose precipitation that formed accumulative II terrace level, as a result of catastrophic debris flow of 2.1± 0.2 k.y.BP (RLQG 2499-058), and synchronous with the fragmentation of varved clays mixed with plant detritus in the deposits of I terrace level about 1.9 k.y. BP (GIN-15442) (event 6).

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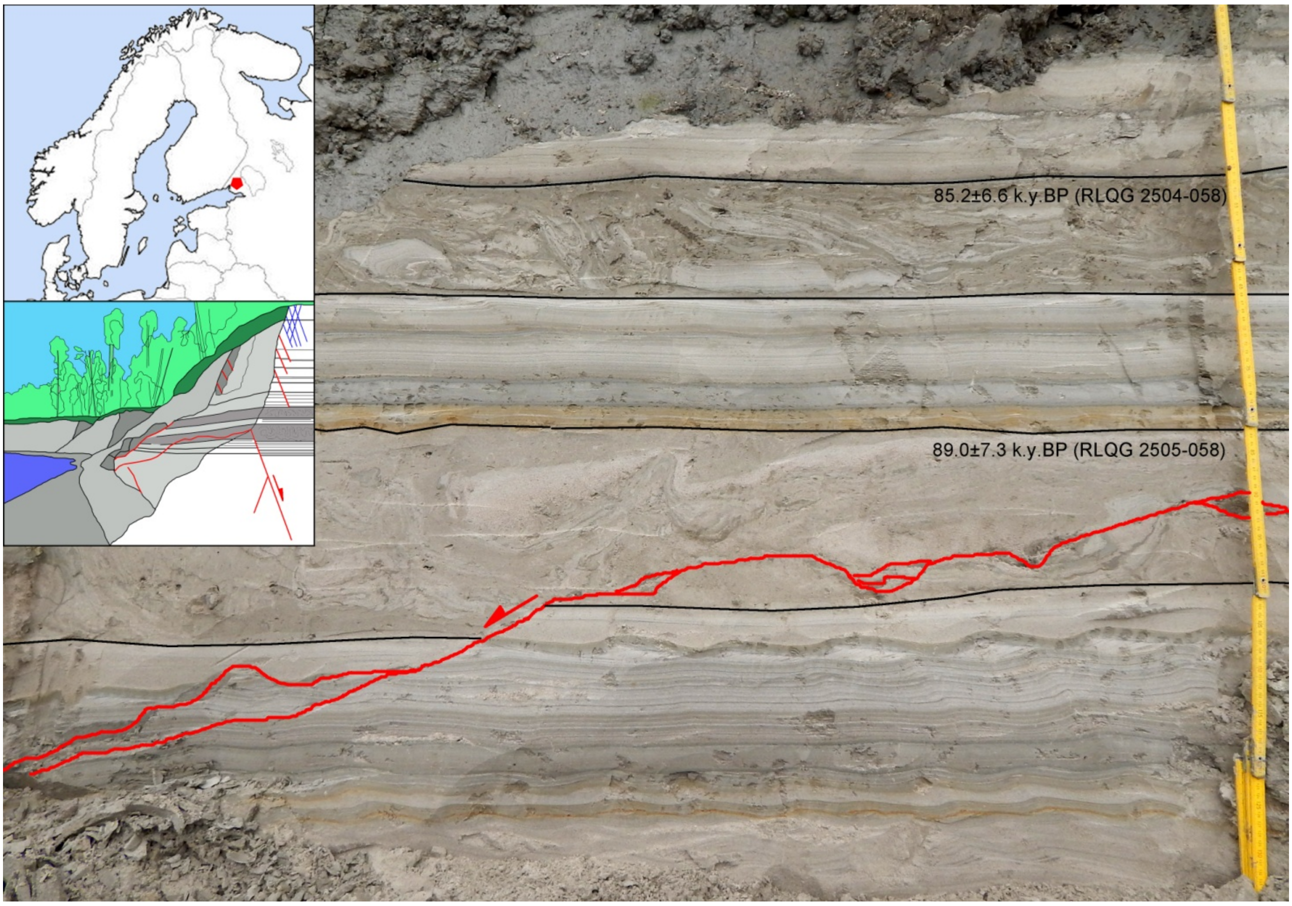

Fig.1 Two horizons of liquefaction associated with strong earthquakes of Early Weichselian glaciations (89,0 and 85,2 k.y.BP) and normal fault dissected all layers. Location of the area and the general scheme of the cross-section (right bank of the Vuoksa River near the town of Kamennogorsk) on the left.

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Osłonino Cliff section, northern Poland - an insight into palaeoclimate conditions during the end of Marine Isotope Stage 8

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The key site Osłonino Cliff is located on the western coast of the Gulf of Gdańsk, in the southern sector of the Baltic Sea. The series of Pleistocene age was first described by Skompski (1997). Pleistocene deposits are exposed along the length of about 400 m. Three main sedimentary units have been distinguished there: till from the last glaciation (U3 unit), glaciolacustrine sediments (the Rzucewo clays, U2 unit) and sandy sediments (the Błądzikowo Formation, U1 unit). Skompski interpreted the latter as fluvial sediments and included them in the Eemian Interglacial. U1 unit was the subject of interdisciplinary studies, including sedimentary, palynological and optically stimulated luminesce (OSL) age analyses.

In the light of the latest research, the following questions arose: under what conditions did the deposition of the U1 unit occur, and when did it take place? The fluvial series was studied in detail in 4 profiles. Its thickness ranges from 6 m to 15 m. Based on a sedimentary analysis, two main subunits were divided: lower, U1a and upper, U1b.

The lower subunit resembles the fluvial series at the Mrzezino site located nearby (Sokołowski et al., 2019). U1a is interpreted as a fluvial series deposited in a sand-bed braided to meandering river. The quartz grains and heavy minerals analyses suggest that these were redeposited sediments of glacial origin with short transport and without an influence of aeolian processes.

The U1b subunit represents different palaeoenvironmental conditions. Lithofacial analysis suggests the conditions of a sand-bed meandering river with a well-preserved floodplain. Also numerous syndepositional periglacial structures were observed. The presence of continuous peat layers made it possible to reconstruct the plant cover. As a result, it can be stated that steppe-tundra predominated in the severe periglacial climate. This interpretation is confirmed by analyses of quartz grains and heavy minerals. Their results reveal multiple redepositions of the sediments and a strong influence of aeolian processes on the deposition.

Three samples were collected from OS-I profile for OSL dating. The two lower layers are of the same age, 293 ka (+/- 16 ka). The dating of the uppermost sand layer above the peat layer showed a younger age 194 +/- 12 ka. Based on this, the deposition of the U1b subunit deposition can be interpreted to have occurred at the end of the Marine Isotope Stage 8. The uppermost layer was deposited later, maybe at the beginning of the formation of the Rzucewo clays.

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Modelling of glacially-induced stress changes in Latvia, Lithuania and the Kaliningrad District of Russia

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We model the change of Coulomb Failure Stress (δCFS) during the Weichselian glaciation up until today at 12 locations in Latvia, Lithuania and Russia that are characterised by soft-sediment deformation structures (SSDS). If interpreted as seismites, these SSDS may point to glacially-induced fault reactivation. The δCFS suggests a high potential of such reactivation when it reaches the instability zone. We show that δCFS at all 12 locations reached this zone several times in the last 120 000 years. Most notably, all locations exhibit the possibility of reactivation after ca. 15 ka BP until today. Another time of possible activity likely happened after the Saalian glaciation until ca. 96 ka BP. In addition, some models suggest unstable states after 96 ka BP until ca. 28 ka BP at selected locations but with much lower positive δCFS values than during the other two periods. For the Valmiera and Rakuti seismites in Latvia, we can suggest a glacially-induced origin, whereas we cannot exactly match the timing at Rakuti. Given the (preliminary) dating of SSDS at some locations, at Dyburiai and Ryadino our modelling supports the interpretation of glacially-induced fault reactivation, while at Slinkis, Kumečiai and Liciškėnai they likely exclude such a source. Overall, the mutual benefit of geological and modelling investigations is demonstrated. This helps in identifying glacially-induced fault reactivation at the south-eastern edge of the Weichselian glaciation and in improving models of glacial isostatic adjustment.

This study is submitted for publication in Baltica (Steffen et al. submitted).

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On models of glacially induced fault reactivation and how to constrain them

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Flexural stresses induced in the lithosphere during glaciation can be released near the end of deglaciation as earthquakes along pre-existing faults (e.g., Lagerbäck and Sundh, 2008). These faults are meanwhile termed glacially-induced faults (GIF). While the physics behind this process can be well explained (e.g. Johnston, 1987), its modelling is challenging. We will review how a commercial finite element software, which is mainly used for engineering investigations but has been shown to be a powerful tool in glacial isostatic adjustment (GIA) modelling, can be used for solving this geoscientific problem. We follow the detailed descriptions in Wu (2004) and Steffen et al. (2014a) for a model without and with a fault structure in the model geometry, respectively. The latter involves thereby the development of three models using the finite-element method.

Applying a compressional stress regime, which can be assumed in GIA-affected areas where GIFs have been found, the results show stable conditions along the fault during glaciation and deglaciation. After the end of the deglaciation period, the fault starts to move, and fault offsets of several tens of metres can be obtained depending on fault location w.r.t. the ice sheet (centre), its orientation etc. (Steffen et al., 2014b,c). In the following time, seismic activity along the whole fault but also only in the lower part can be observed. We will show such examples.

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Sedimentary environments in Lake Onega: from Late Glacial to modern conditions

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Lake Onega (LO) is the second largest freshwater reservoir in Europe, located in SE part of the contact zone of the Baltic Crystalline Shield and the Russian Plate. The depression of LO is of tectonic origin. Its catchment area lays on Precambrian crystalline rocks and Vendian to Phanerozoic sedimentary rocks, which are resistant to glacial abrasion and partly covered by Quaternary deposits. Oligotrophic waters of Lake Onega are characterised by low mineralization (35–46 mg/l). The area of the water surface is 9 720 km^2. The maximum depth is 127 m being as an average ca 30 m, the length (the longest distance from south to north) is 248 km, and the width is 83 km.

Time-space variations in the sedimentogenesis and diagenesis of Lake Onega sediments at all stages of its evolution from the last deglaciation ca.15 000 years ago to the present is reconstructed for the first time using digital elevation model (Zobkov et al., 2019). Recently 1-3 m long sediment cores from different parts of LO were collected from research vessels during the several field campaigns, while sampling sites were chosed following the seismoacoustic profiling data. For the first time in March 2019 from the water-depth 30-35 m in the Petrozavodsk Bay of LO several 10-11 m long sediement cores were sampled using the UWITEC-tripod coring equipment from the ice surface (Fig. 1). The most of collected LO sediment sequences are represented by Holocene greeinsh-gray silty-clay gyttja and homogeneous gray gyttja clay, and Late Pleistocene gray varved clays with the interval of pink coloured varves - the ''pink horizon''(see abstract Hang et al. in this volume) and reddish sand or till at the bottom (Fig. 1). Current sedimentation processes in LO are assessed for the first time by the integrated study of suspended substances in the water and chemical, mineral and particle-size compositions, physicochemical properties and structural and textural characteristics of bottom sediments using up-to-date mineralogical and geochemical methods.

The water-sediment interface is characterized by ochre-coloured colloidal gelatinous silty mud up to 1 cm thick. Below this transitional layer gray-green lacustrine silty-clay mud, gradually hardening and then being replaced downwards by homogeneous gray clay and varved clay. Black (due to the presence of complex oxides and hydroxides of Mn, Fe), green (containing vivianite), and cream-colored (containing rhodochrosite and siderite) microlayers are observed in the gray-green

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mud. The number of microlayers and their distribution in different cores vary (see Hang et al. in this abstract volume). The reduction-oxidation barrier zone in the upper parts of the sediment sequences in the areas with increased gas concentration coincides with the sediment-water boundary (a slightly oxidized layer that is less than 1 cm thick). The underlying horizons usually contain the same sediments, but withincreased number ofthin layers composed of manganese oxides and hydrous oxides and hydrotroilite concretions, forming banded diagenetic textures. The sediments also change their consistency and become more viscous, soft and highly plastic. The seismograms show background noise in the form of bubble clusters that are usually located in areas of thick bottom sediments and do not entirely block the recording completely. A clearer picture of gas accumulations has been observed in the seismic profiles, where entire sections at the seismic profiles are characterized by low image resolution. The seismic lines also reveal distinctive structures of gas fluids emission from the sediment deposits, the so-called pock-marks. Authigenic minerals are opal, chalcedony of the diatoms skeletons, Fe-illite and Fe-chlorite. The natural mineral phases of Fe and Mn represented by amorphous and crystalline goethite, birnessite, pyrochroite, pyrolusite, vivianite, rhodochrosite, and siderite. It is remarkable that the concentration of rhodochrosite, siderite and vivianite increases in the areas of gas-saturated silts. The formation of these minerals is possible only under reduction circumstances, i.e. this is an extra proof of the release of methane in reduction (Strakhovenko et al., 2018).

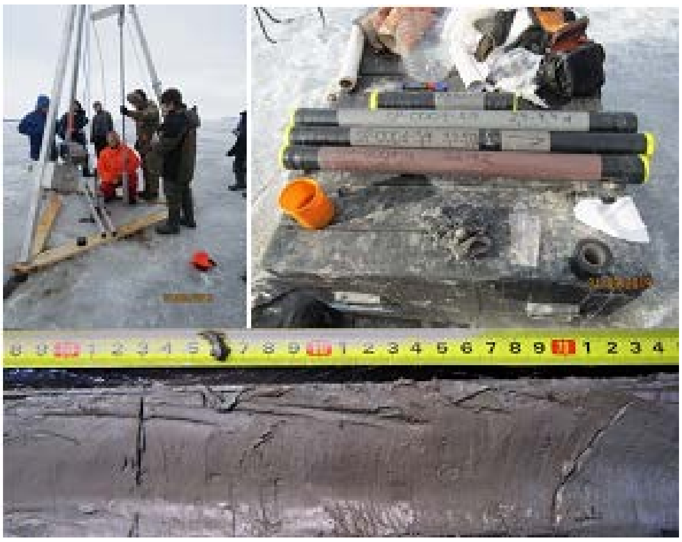

Fig. 1. Photos from the coring campaign in Lake Onega, March 2019.At the lower partis presented a fragment of Onega Ice Lake varved clays with the 'pink horizon'.

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Role of catastrophic events in the forming of hydrographic networks in the eastern part of the Baltic Sea

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One of the important scientific subject it is the reconstruction of the dynamics of the Baltic Sea level in the late Pleistocene and Holocene and identification of the role of natural disasters (sudden transformation of the hydrographic network, impact, earthquakes, tsunami). In the frame of a new project on the base of the conducted analysis, identification of the most poorly studied areas and carrying out new field works. As a result of implementation of the project will create a database of information on catastrophic processes in Russian regions of the Baltic Sea (Leningrad and Kaliningrad districts) during the late Pleistocene and Holocene. The database will be supplemented by new materials on lithology, dynamics of organic matter, geochemistry, micropaleontology and dating of peat and lake sediments. An analysis of the database will allow for an assessment of the relationship between climate change, Baltic Sea level fluctuations and natural disasters and the identification of their environmental impacts. It was established leading role of seismotectonic processes in forming and in sharp transformations of hydrographic network on the southeast periphery of the Baltic crystalline shield in Late Glacial and Post Glacial time.

The most essential catastrophic events which defined significant changes in hydrographic network and the further water regime of the main water basins are revealed. It was established the catastrophic descent of water of Lake Onega to via the valley of the River Svir. Seismogene deformations in friable deposits and rocky ledges along the southeast coast of Lake Onega to the north of the outflow of the River Svir, have been dated 4.4 cal. kyr BP. It is proved that transportation and redeposition of detrital material of different grain sizes and also objects of neolithic culture on tens of kilometers downstream (on the site from a source of the River Svir to “Lake Ivinsky”) about 4.5 cal. kyr BP are connected with emergence of a powerful tsunami as a result of an earthquake on Lake Onega (Nikonov, 2017). The break of waters of Lake Ladoga and formation of the River Neva around 3.2 cal. kyr BP were happened due to an earthquake (Nikonov, 2017).

The seismogenice deformations in a roof of deposits of the Ladoga transgression fixing change of the mode of sedimentation and demonstrating simultaneity of a strong earthquake and completion of the Ladoga transgression are observed. It served an arena of periodic significant restructuring of the hydrographic network associated with the filling and discharge of large late-glacial and Holocene basins during the degradation of the Scandinavian ice sheet and in postglacial time. One such restructuring is a sudden change of the Lake Saimaa direction of flow in the middle Holocene from the West to the South to the Lake Ladoga basin via the drainage hollow, inherited by modern River Vuoksi valley. Origin of the River Vuoksi is associated with the catastrophic water breakthrough of Lake Saimaa across the marginal moraine ridge Salpausselkä-1 of 5.7 cal. kyr BP.

According with adopted concepts this event connects with water accumulation and overflow due to non-uniform post-glacial uplift. The authors propose a great earthquake as the initial cause of the break of Lake Saimaa waters. This assumption is basing on the study of specific deformations of the rocky riverbed in the area of breakthrough and of the loose deposits in the banks of the River Vuoksi valley downstream. Open cracks and horizontally displaced rock blocks have been discovered in the area of the former rapids near the Imatra town (Finland). Their systematic displacements on the both sides of the rocky gorge indicate the shear kinematics of fault zone. Different types of deformations had occurred in loose sediments of the low terraces (3 – 4 m) in the River Vuoksi valley 20 – 30 km below the headwaters. In three studied stratigraphic sequences the three cardinal quite differenced types of deformations were discovered: 1) normal fault with vertical displacements; 2) tectonic inclination; 3) traces of catastrophic mudflow. The age diapason of the terrace forming (and of the corresponding deformations) is determined of 8.3 to 1.8 cal. kyr BP (by the ages of adjacent terrace levels), which corresponds to the origination time of the River Vuoksi. The earthquake, which presumably was a trigger for the formation of the River Vuoksi, had been generated by the activation of ancient fault zone, manifested in the crystalline foundation.

Periodic post-glacial tectonic activity of this zone is revealed in traces of strong seismic events both in the bedrock (initial emergence of the gorge, its renewal during the breakthrough), and in loose deposits (deformations in different levels of terraces) (Poleschuk et al., 2018; Shvarev et al., 2018; Subetto et al., 2018). New data on the deep paleovalley along modern valleys of the River Oshta (modern inflow of Lake Onega), the River Tuksha and the River Oyat (inflow of Lake Ladoga) is obtained. In this paleovalley there was a drain from Lake Paleo-Onega (at water level of 110 m and above) about 14 cal. kyr BP, so long before appearance of the River Svir.

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Degradation of soil covers the mining territory of the Leningrad region

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The Leningrad region is the large agro-industrial region, characterized by a large variety of soil cover (SC) and different types of soil cover structure (SCS). Anthropogenic activity in the region is one of the leading factors of differentiation of SC and has both direct and indirect impact. Direct influence leads to three types of transformation of SC – change, destruction and "construction".

The updated digital soil map of the Leningrad region at the scale of 1:200 000 was completed in 2018. The analysis of map showed that, virtually in all terrains, there are significant areas with anthropogenically transformed SC, components of which, along with natural ones, are man-influenced soils, man-changed soils, man-made soils and non-soil formations (Sukhacheva and Aparin, 2019). The natural SC is always a continuous formation. Anthropogenically disturbed territory characterized by not only the formation of new anthropogenically transformed and anthropogenic soils but also characterized by fragility and discontinuity of soil cover.

16 different groups of anthropogenically transformed and anthropogenic SCS were identified. They are forest logging, reclamation forest, fire prevention forest, recreational forest, post-war, agro-forest, agrogenic, recreation-park, agro-reclamation, postagrogenic, magistral, urbanized, agrourbanized structures of the soil cover and soil cover structures of forest nurseries, of highways and railways, of mining quarries.

The complete destruction of SC and the formation of new anthropogenic soils cover structure associated with mining, road construction, and urbanization. Soil covers near the quarries are radically different from the natural landscapes (Aparin and Sukachev, 2014).

The influence of the mining industry leads to a change in the structure of SC. These changes are manifesting in the territory of the quarry in the complete destruction of soil and soil cover and the creation of fundamentally new forms of organization of soil space that have no analogues in the natural environment. These changes are characterized by a rapid abrupt transition of soil combinations from the equilibrium climax state in which they were for a long time, in an unbalanced, often extremely unstable. More than 80 minerals deposits are exploited in the region: sand, granite, limestone, phosphates, bauxite, clay, shale, peat.

Despite the fact that quarries occupy relatively small areas in the region (about 1% of the entire region). It should be taken into account for further measures on reclamation of disturbed lands and state accounting. The territory of quarries and soil cover near strongly disturbed in connection with the laying of roads, construction of industrial sites and warehouses. Such areas are the most environmentally disadvantaged with the most disturbed functions of the soil cover.

A specific feature of most mining quarries is the presence of areas with overburden and abandoned development, and which are gradually overgrown with forest. In addition, such areas are often flooded.

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The combination of soils in adjacent areas to mining quarries represented by the concentric combination of man-made soils and non-soil formations, Technosols, Lithic Leptosol (O-M), Arenosols (O-C) (World soil resource reference 2014). Natural soils occupy small areas in anthropogenic SCS.

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Trends of development of karstic landscape due to climate factors - case of Lithuania

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The karstic sinkholes are unusual geomorphological phenomena in glaciated areas (e.g. Peribaltic region). Their presence indicate thin cover (up to 10 m) of glacial formations, occurence of dissolvable rocks under the Quaternary cover, favourable conditions of infiltration of precipitation. The karstic sinkholes including those that occurred several decades ago to the recent ones, forming each year, could be regarded as youngest and most rapidly developing landforms in post glacial landscape. The North Lithuania karstic region occupies over 1100 km² and its territory is evidently expanding.

Karstic phenomena there are related with dissolution of sulphatic (mainly gypsum) interlayers of Upper Devonian formations, taht occur under the 1-10 metres thick Quaternary cover. Due to quick dissolution of gypsum the sulphatic karst is developing much more rapidly comparing with carbonatic karst. Development of the karstic landscape is characterised by formation of new sinkholes, ground fissures, cavities, closed depressions and other phenomena. Besides geological conditions, intensity of the karst process is dependent on hydroclimatic factors: air temperature, duration of period seasonal frost, amount of precipitation and its intensity of infiltration, saturation and fluctuations of groundwater that facilitates dissolution of sulphatic rocks (Satkūnas et al., 2007

The monitoring of the karstic landscape is carried out by measuring of intensity of karstic gypsum chemical denudation and inventory (parametrisation) of karstic sinkholes. There are counted over 8000 sinkholes of different age and size. During the year 2018 it were inventoried 30 new sinkholes of different size. All information on karstic phenomena is stored in Subsystem of Geological processes and phenomena of the Lithuanian Geological Survey. The monitoring of the karstic chemical denudation is based on measurements of chemical composition of surface and groundwater, thus enabling to determine amount of gypsum, dissolved and removed annualy from the karstic region (the pattern river basin). The amount of dissoved gypsum is expressed via calculation as a space of cavities formed underground and measured as number of cubic metres of space formed during one year per one square kilometer of the karstic area. The monitoring of the karstic chemical denudation is carried out in North Lithuania since 1963 (with some gaps however). Mean annual amount of dissolved gypsum in the patern basin of Tatula river was 142 m ³/km² during the period of measurements untill 2018 (cf. fig. 1).

It is noted that intensity denudation increased by 30% during the period 1990-2000 and this period is characterised in general by climate amelioration (Satkūnas et al.,2006). Increase of gypsum chemical denudation, generally is followed by more intensive occurence of sinkholes, however direct correlation is still not established due to presence of number of other playing factors. For instance, in 2017, which was exceptionally wet, it was recorded highest rate of denudation during entire period of monitoring – even 284 m³/km²/ (54% higher comparing with mean value of the period 1963–1979). However in the year 2018 it was not recorded increase of number of new sinkholes.

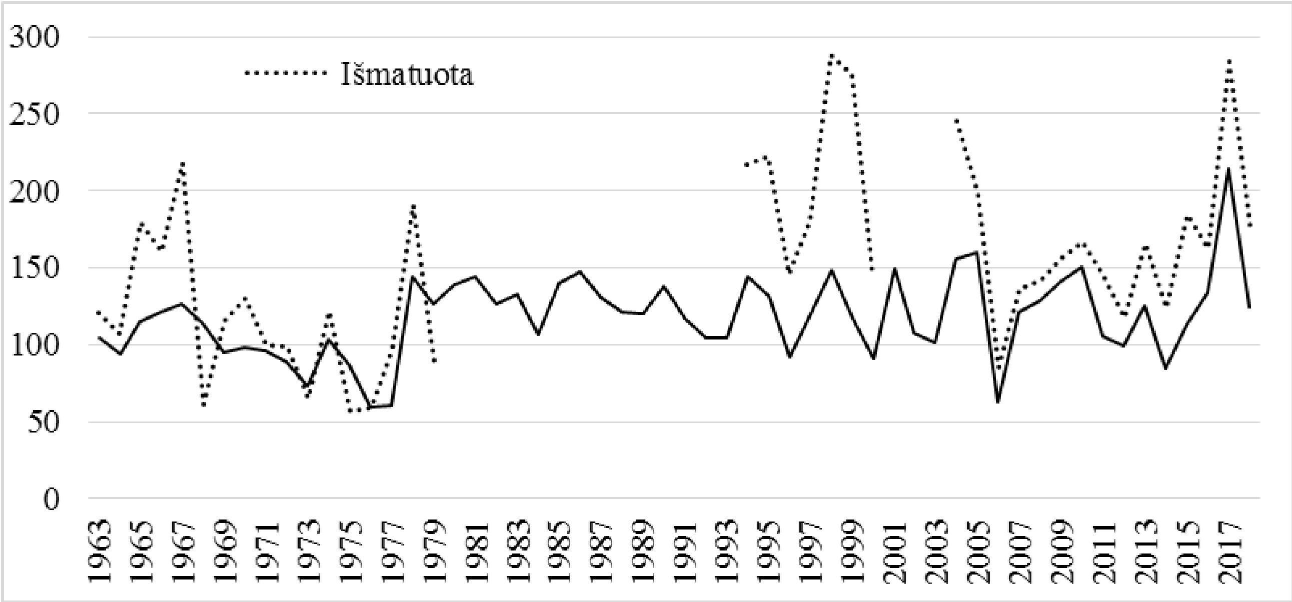

Fig.1 Fluctuation of gypsum chemical denudation in Tatula River basin in 1963–2018, m^3/km^2 per year.

Despite the year 2018 was very dry, the gypsum denudation remained rather high (177 m^3/km^2) and close to the mean value 179 m^3/km^2 of the period 1994–2018 (Fig. 1) (Mikulėnas et al., 2019). We assume, the high ground water level in the karstic cavities was keeping the cover of cavities stably and therefore conditions of forming new sinkholes were not favourable. Nevertheless, during the dry period, when the groundwater level droped, it was not observed more active forming of sinkholes. It means that very complex factors are playing and determining colapse of sinkholes. It is proposed that rapid climate changes (wet or dry years, like 2017 and 2018) do not determine rapid increase of forming of new sinkholes. Gradual amelioration of climate, however, determines, increase of gypsum chemical denudation.

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Reconstruction of environment and stages of human activity in the Bug river valley in the Holocene in Belarus

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For the aim of reconstruction of environment and stages of human activity in the Bug river valley the paleomeander sediments (52°13'17.8"N, 23°19'50.4"E) situated near the village Ogorodniki in Belarus were investigated. Two wells (profile 1 and 2) and a pit (profile 3, Fig. 1) were made within the paleomeander. Samples for palynological (89 samples), geochemical (33 samples) and radiocarbon (7 samples) analyzes were taken from the exposed sediments. Six phases in the history of the development of the natural environment were identified for the vicinity of the study area (Fig. 2).

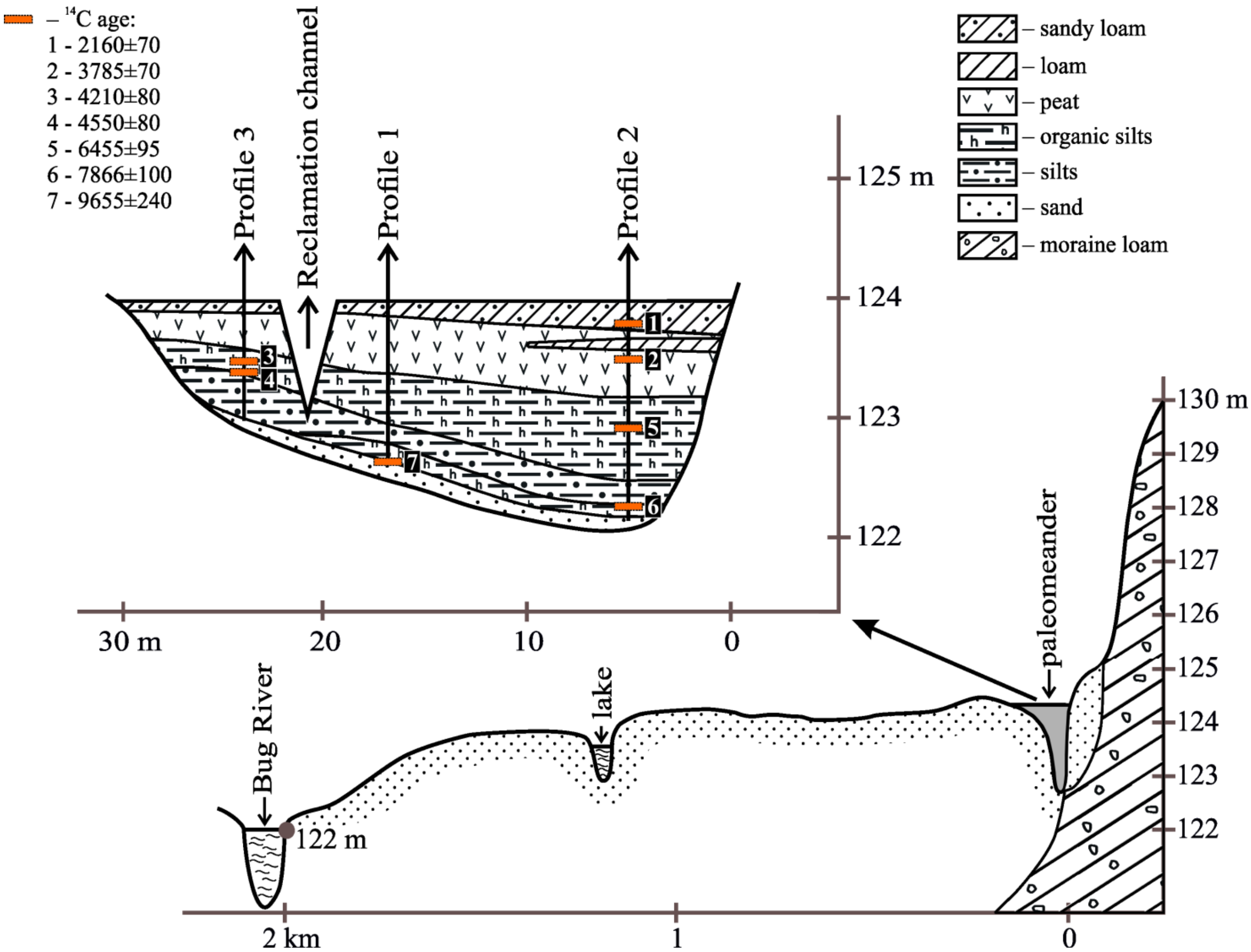

Fig. 1. Profile of the Bug river valley near the village Ogorodniki

Phase I (Early Holocene). The most ancient sediments filling the paleobed of river were dated in the range of 11 720-10 320 cal. yrs BP in the profile 1. In contrast, the age of the sediments from the deepest part of the paleomeander (profile 2) was Early Atlantic, which was identified on the basis of radiocarbon dating and pollen analysis. Probably, Early Holocene sediments from profile 1

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were formed during the existence of the active river bed at the studied site. *Phase II (Early Atlantic)*. Straightening of the meandering channel of the Bug River (cutting off a bend) and the formation of a meander lake occurred at the beginning of the Atlantic stage of the Holocene. This conclusion is confirmed by the data of the palynological (maximum of *Ulmus*) and radiocarbon analyzes (7 866 ± 100 ^{14}C yrs BP) of the deepest sediments of the paleomeander (profile 2) covering the bed alluvial sand. *Phase III (~5 600-5 200 cal. yrs BP)*. The high-ash silts with a low concentration of calcium (Ca) began to accumulate over the Early Holocene and Early Atlantic sediments. That sort of geochemical characteristic may indicate a flowage of the meander lake (Kuznetsov, 1973). The age of these accumulations is estimated according to radiocarbon dating obtained from the overlying layer of organic silts (profile 3, 5 203 ± 129 cal. yrs BP) and the composition of the pollen spectra. Presumably, the formation of the described sediments took place in the range of ~5 600-5 200 cal. yrs BP, which corresponds to the stage of increased fluvial activity in the river basins of Eastern Europe (Kalicki, 2006; Starkel, 2013). Strengthening of flowage of the meander lake contributed to erosion, which led to the loss of part of the Early and Middle Holocene sediments, in place of which the formations of the Subboreal period were deposited.

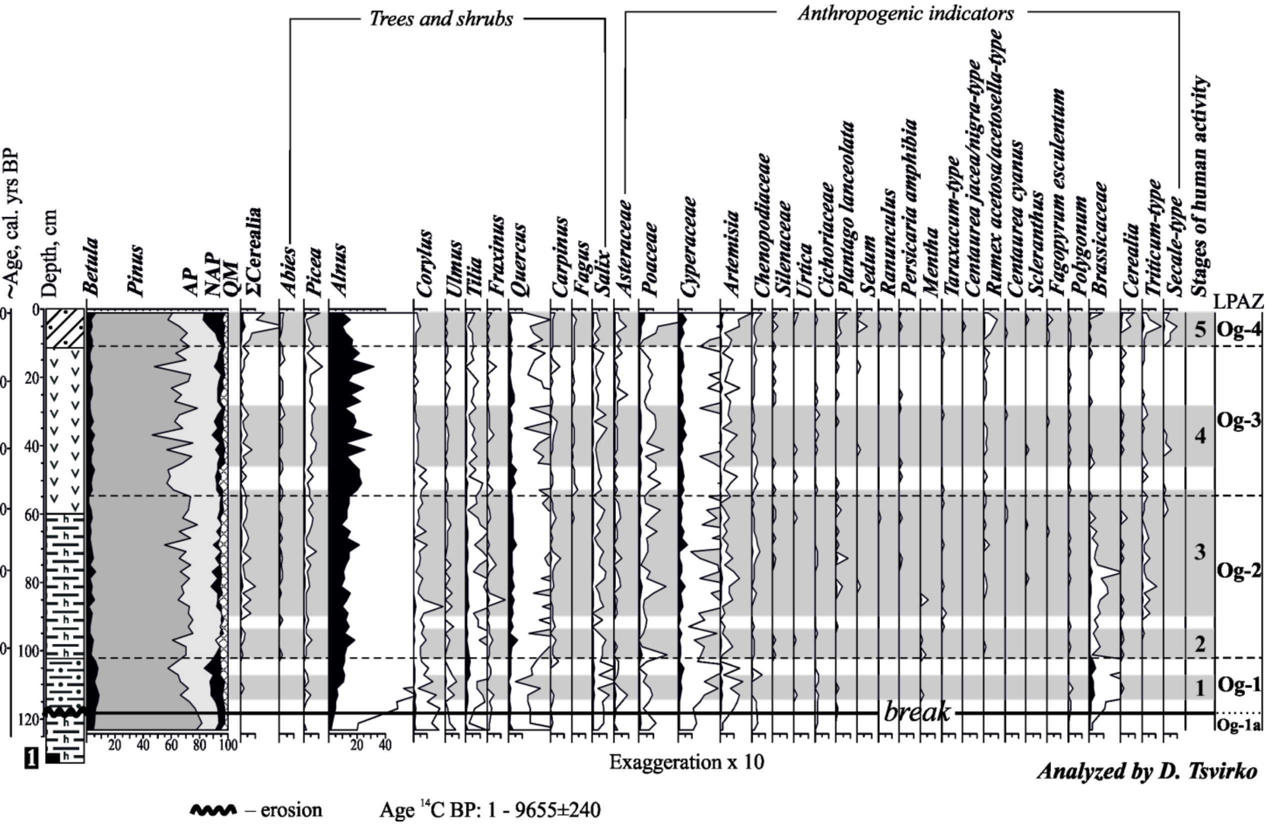

Fig. 2. Pollen diagram of sediments of the paleomeander Ogorodniki (profile 1)

Phase IV (~5 200-2 800 cal. yrs BP). During this phase, which may correspond to the Subboreal stage of the Holocene, organic silts accumulated in the meander lake, in which the ash-content falls, and the Ca content increases. The presented data indicate a decrease in flowage. The age of this phase was determined on the basis of pollen data and radiocarbon dating from profile 2 (3 785 ± 70 ^{14}C yrs BP), which indicates the post-optimal age of accumulations. The beginning of the bogging process and accumulation of peat in the reservoir (profile 2) dates from the second half of the Subboreal. *Phase V (~2 800-500 (800) cal. yrs BP)*. During this time interval, which is compared with the Subatlantic period (profile 2 – 2 160 ± 70 ^{14}C yrs BP), peat accumulated at the place of meander lake (profile 1), in which the growth of Ca, Mn, Cu, Pb, Cr, Ni, Cd and Fe (biogeochemical barrier) is

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traced. *Phase VI (from 500 (800) cal. yrs BP)*. This phase corresponds to the upper layer of sandy loams. In the sediments (profile 1) a sharp decrease in the concentration of Ca was noted, the values of Cu, Cr, Ni, Cd, Fe decreased, while the concentrations of Mg, Mn, Zn, Pb increased. The ash-content reaches 80 % (in profile 2).

Five stages associated with increase in anthropogenic activity in the vicinity of Ogorodniki were identified. Stages 1 and 2 establish the presence of an ancient man in the studied region, at the same time, the impact of human activity on the environment was insignificant. Stage 5 – the stage of large-scale transformation of landscapes.

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Sedimentary record of fluvial processes during MIS 4 in central-western Poland

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Poster presents the results of sedimentological and geochronological studies of Pleistocene sandy sediments exposed at Brześnica site in central-western Poland. The outcrop is located on the edge of moraine plateau, close to the maximum extent of the last Scandinavian Ice Sheet in the Wielkopolska region. Sedimentological methods included analyses of lithofacies, grain-size, quartz morphology, and heavy minerals. The geochronological studies included OSL dating of analysed sequence.

The analysed sedimentary sequence is 6 meters thick. Its lower part (subunit U1a) consists of medium and fine sand of horizontal stratification (Sh) or ripple cross lamination (Sr). In this part of the profile sedimentary cycles Sh → Sr were identified. The middle part of the profile (subunit U1b) consists of coarser lithofacies such as through cross stratified coarse sands and gravels (SGt, St), followed by fine and medium sands with horizontal stratification (Sh) or ripple cross lamination (Sr). The sedimentary cycle SGt, St → Sh → Sr was recognised. A distinct erosive boundary occurs between subunits U1a and U1b. The upper part of the profile consists of horizontally stratified, fine to coarse sand (Sh; subunit U1c) and massive diamicton (unit U2). Locally, the diamicton laterally changes to gravel.

The analysed sandy sequence was formed in fluvial environment as a result of following processes: 1) shallow, high-energy flow alternating to low-energy flow (lithofacies Sh → Sr); 2) the filling of erosional channels with fluvial sediments during the flood events and changing conditions from supercritical to subcritical flows (SGt, St → Sh → Sr); 3) shallow sheetflows (Sh). These processes are common within sandy braided rivers associated with cold climate conditions. OSL dating showed that the analysed fluvial sequence was deposited during MIS 4, what corresponds to the evolution of the regional palaeofluvial systems in the Late Pleistocene.

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Bayesian age modelling of the last deglaciation in the southern sector of the Scandinavian Ice Sheet

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Bayesian modelling offers a methodology for integrating various types of numerical dating and constructing consistent chronologies of geological sequences. Although it is routinely used for modelling radiocarbon chronology of lake sediments or archaeological deposits, it has been much less widely applied to model chronologies of palaeo-ice sheet retreat based on spatially distributed sites and multiple methods of numerical dating. Here, we present a Bayesian approach to model the timing of the last deglaciation of the southern sector of the Scandinavian Ice Sheet (SIS) in NW Poland and NE Germany. The study area covers two ice stream corridors crucial for the spatial configuration of the last SIS` southern margin: the Vistula ice stream (VIS) and the Odra ice stream (OIS) (Fig. 1).

We used published cosmogenic nuclide, luminescence (OSL) and radiocarbon ages relevant to the last SIS retreat after the local Last Maximum Glaciation within the VIS and the OIS regions. Our modelling is based on: 71 ^{10}Be surface exposure ages of erratic boulders resting on glacial landforms; 43 OSL ages of sand deposits; and 35 radiocarbon ages of organic and calcareous deposits intercalating tills left by the last SIS. The dating sites are distributed along the ice sheet limits that correspond to the glacial phases of the Late Weichselian as identified in continental Europe (Fig. 1). The relative age of the ice margin fluctuations during the ice streams retreat was inferred from the morphostratigraphy of glacial landforms and the lithostratigraphy of glacial tills. These produced the relative order models used as prior information, which constrained the independent probability distribution of each age in a sequence. Based on this distribution, we modelled ages for the VIS region and the OIS region, and obtained two sequences of the ice margin retreat. This allows to construct a consistent chronologies of the ice sheet retreat within two main ice stream corridors of the last SIS` southern sector, and model the rate of ice front recession along two longitudinal transects.

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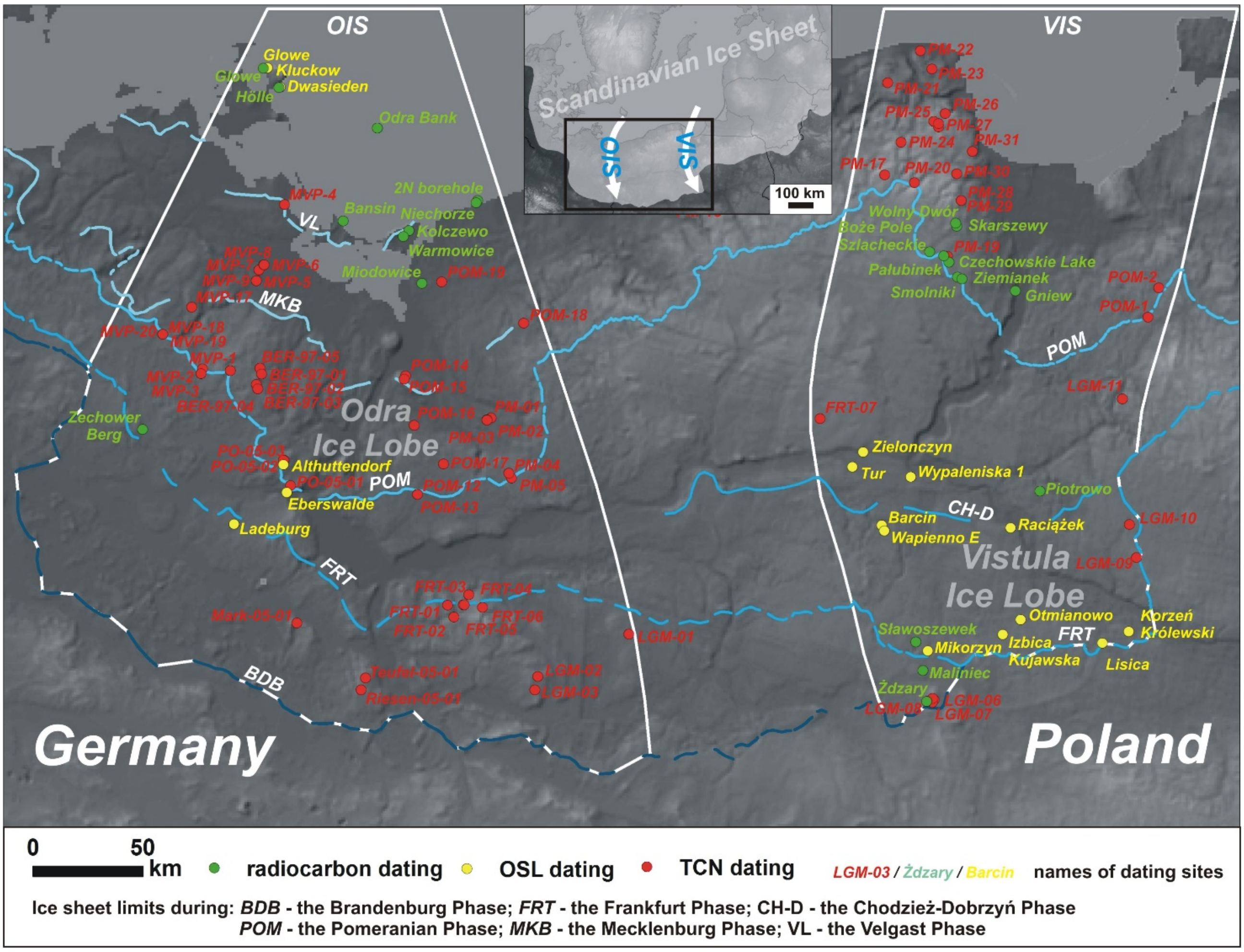

Fig. 1. Study area with the Late Weichselian ice sheet limits and sites of numerical dating used in the Bayesian modelling

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Geological investigations of postglacial environment in the Southeastern Baltic Sea area (Lithuanian zone)

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Geological investigations of the Lithuanian marine area (SE Baltic Sea) have been carried out since the 1960s. At the very beginning the studies were not very detailed due to limited possibilities of scientific equipment, but later the research conditions and technique were developed and a significant amount of geological data were collected. The marine geological mapping became one of the most important components of the mentioned investigations. The Lithuanian Geological Survey implemented marine geological mapping at a scale of 1:200 000 in 1986–1989 and, based on the collected geological material, compiled a set of thematic maps (bathymetric, sea bottom lithological, Quaternary geological, geomorphological, etc.). Later, in 1993–1996, a group of scientists of the former Institute of Geology carried out geological mapping at a scale of 1:50 000 in the northern part of Lithuanian nearshore. Geological mapping at a scale of 1:50 000 have been renewed in 2017 by the Lithuanian Geological Survey in the southern part of the Lithuanian waters (Preila project). A new research vessel MINTIS, acquired by Klaipėda University in 2014, provided a good opportunity to carry out a detailed marine geological mapping according to the highest standards. Researchers form the Lithuanian Geological Survey, Klaipėda and Vilnius Universities, Nature Research Centre and JSC "Geobaltic" have been involved in the implementation of the mentioned project. Up to recent time the fieldwork (hydrographic, geophysical and geological surveys) was completely finished; laboratory analyses and data interpretation are in the processing stage.

Reviewing the former geological information and the first data of the recent investigations, the main features as well as the detailed events of the postglacial environmental conditions in the Lithuanian marine and coastal area have been determined. Sediments of the Baltic Ice Lake, Litorina and Postlitorina Seas are reliably detected and investigated in the entire Lithuanian Maritime Region. However, distribution of the Ancylus Lake and the Yoldia Sea sediments, determination of coastlines of these palaeobasins are still problematic. A new geological information received during the recent stage of marine geological mapping, as well as the latest results of underwater archaeological investigations, supplement scientific information and contribute to better understanding of the SE Baltic Sea development during postglacial time. The influence of glacioisostatic adjustment into the results of reconstruction of sea level changes in the SE Baltic was estimated. The newest results of pollen and diatom analyses, data of geochronological investigations of palaeolakes and peatlands discovered on the present-day bottom of the Lithuanian marine areas are presented.

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Multiple deformed layers in Weichselian lacustrine sediments at Baltmuiža, western Latvia

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The Baltmuiža site is located at the Baltic Sea bluff in the western Latvia, 6 km to NE from Pāvilosta town. Close to the site two faults in Lower Palaeozoic sediments are recognised, the closer one is deep-seated in the crystalline bedrock (Ņikuļins, 2017). The Quaternary sediments cover lies directly on Devonian rocks and has 70 m total thickness (Kalniņa et al., 2000). During the Late Weichselian the study area was completely covered by the ice sheet. At the end of glaciation, due to an additional, local ice-advance of so called Apriki glacial tongue, older sediments have underwent a heavy diapirization (Saks et al., 2012b). Late Weichselian deposits are underlain by sands and silty sands of the Jurkalne 3 Member with thickness up to 40 m (Kalniņa et al., 2000), which were deposited at the margin of an extensive freshwater basin (cf. Kalniņa et al., 2000 and Saks et al., 2012a), in MIS 3 according to OSL dating results (Saks et al., 2012a). These sediments are visible along a prominent part of the western Latvia coast. Layers with 'trapped', internal soft-sediment deformation structures (SSDS) occur in them at Baltmuiža (Belzyt et al., 2018). Five layers with SSDS, sandwiched in generally not deformed sediments, were recognized there. The deformed layers are commonly rich in load casts and pseudonodules, injection structures and fluid-escape structures. Almost all layers with SSDS have an eroded top boundary.

The recognised layers with SSDS seem not to be directly connected with commonly observed in the vicinity of the Baltmuiža site glaciotectonic deformations (large-scale diapirs, folds, reverse faults; e.g. Saks et al., 2012a, b). What is more, due to the basal ice sliding of Apriki glacial tongue (Saks et al., 2012b), small-scale Late Weichselian subglacial deformations are limited to a thin layer of the topmost part of the studied sediments. The SSDS developed metadepositionally, in multiple stages, most probably just after the deposition of lacustrine sediments during MIS 3. Furthermore, Late Weichselian glaciotectonic processes caused that the layers with SSDS are deflected from the original horizontal position. The most probable trigger mechanisms responsible for the origin of the studied layers with SSDS include: (1) the glacioisostatic rebound affecting the crustal faults instability, (2) a local, seismic event (tremor) of moderate magnitude, caused e.g. by glaciotectonic processes. Moreover, as a trigger that induced Late Weichselian modifications of previously developed SSDS cannot be excluded: (1) an ice loading at the final stage of glaciation, and (2) a local seismic event (tremor) of moderate magnitude caused e.g. by ice-blocks fall/collapse.

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The evolution of lithic clast morphology in a debris flow – evidences from subaquatic debrites (Rzucewo, northern Poland)

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Debris-flow diamictons (debrites) were recognised in Puck Bay bluff at Rzucewo (northern Poland). They occur in the glaciolacustrine sedimentary succession as an effect of cohesive debris-flows on the subaqueous fan, most probably during the Middle Weichselian (Woźniak and Pisarska-Jamroży, 2018). The analysed debrites are rich in lithic clasts, what has enabled palaeo-flow direction reconstruction (Woźniak et al., 2018). Here we concern on these clasts morphology: their shape (relative shape of a particle) and roundness (the overall smoothness of particle outline). The main goal of our work was to recognise: 1) possible clast sorting and reshaping during flowage and 2) influence of clast lithology on their susceptibility to reshaping in a debris flow.

Analyses were performed in 2 debrites along longitudinal profile of the fan (in their proximal, medial and distal part respectively) for the following groups of clast lithology: 1) Proterozoic plutonic rocks, 2) Proterozoic volcanic rocks, 3) Proterozoic metamorphic rocks, 4) Proterozoic and Palaeozoic clastic sedimentary rocks, 5) Palaeozoic carbonate sedimentary rocks. All of these groups are far-transport (Fennoscandian) rocks. Rocs of local provenance (Mesozoic and Cainozoic sedimentary rocks) were excluded due to their low frequency in the analysed debrites. The influence of post-depositional weathering on the petrographic composition of debrites was excluded according to the results of analysis of carbonate content in debrites matrix.

Obtained results show no or minimal clast sorting during the flowage process (except single oversized clasts). Clasts were transported en-masse and were buoyant in a debris-flow material due to the cohesive nature of debris flow (Woźniak and Pisarska-Jamroży, 2018). The same reason with a relatively short transport distance (ca. 100–150 m) caused that clear clast-shape change is not observed. In contrary, despite the short transport distance, but due to that clasts were rotated during flowage (what is evidenced from debrites fabric, see Woźniak et al., 2018) the surface of clasts was smoothed. The clear change of clast roundness along the fan is recognised. It is mainly manifested in the diminishing of very angular and angular clasts percentage. The rise of roundness occurs in all analysed groups of rocks, despite their diverse susceptibility to reshaping. Observed some irregularity in the described tendency is explained by debrites redeposition, what is evidenced from lithofacies properties (Woźniak and Pisarska-Jamroży, 2018; Pisarska-Jamroży and Woźniak, 2019) and debrites fabric (Woźniak et al., 2018).

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Late Glacial in the European North-East: new data and pattern

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The history of the last Scandinavian ice sheet (SIS) degradation (17–11.7 ka) can be reconstructed not only by the marginal formations of the retreating glacier, but also by synchronous events occurring in the extra-glacial zone. In the European North-East, we consider the Vychegda river valley (the largest right tributary of Severnaya Dvina, Fig. 1A) as a key area for understanding the chronology and pattern of the Late Glacial. Locating outside the LGM limits, the valley of Vychegda was under the influence of its southeastern periphery.

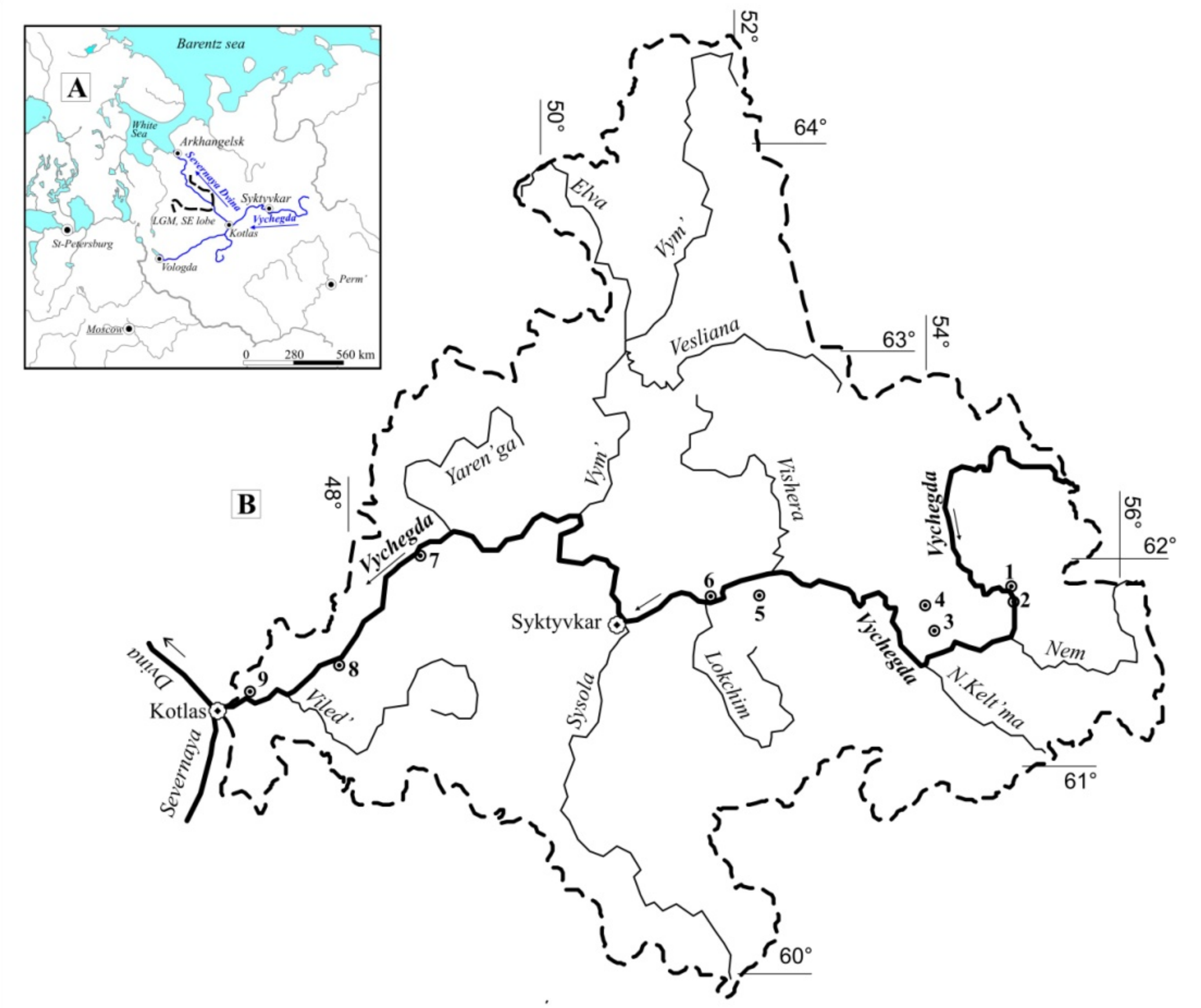

Figure 1. A – Northeastern Europe with the Vychegda - Severnaya Dvina fluvial system and SE limit of LGM. B – Vychegda River basin with the 1st terrace sections. Upper and middle reaches (Zaretskaya et al., 2014): 1 - Ust'-Timsher; 2 - Myjoldino; 3 - Kadam lake; 4 - Don-ty lake; 5 - Liokvozh'jol'; 6 - Biostation. Lower reach: 7 - Sherdyn'; 8 - Kiver; 9 - Solvychegodsk (Zaretskaya et al., 2018).

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The Late Glacial deposits are well seen in the outcrops of the 1st Vychegda terrace. Its mean height is 5-8 m above the low water stage, but often the aeolian dunes raise its level up to 12-13 m. The sandy alluvial sequence of the bottom part of the terrace is often interbedded with organic-bearing lenses. The lithology and bedding structure indicate the alternation of running water (channel alluvium) and slowly cooling or even standing water (overbank or oxbow lake alluvium). Earlier we studied terrace outcrops in the upper and middle reaches of Vychegda (# 1-6, Fig. 1B); three cooling episodes (16.5-15.7, 14.6-13.4 и 12.8-11.5 cal kyr BP) and three warming phases (17.1-16.5, 15.7-14.6 и 13.4-12.8 cal kyr BP) had been identified for the Late Glacial period based upon the results of ^{14}C dating and pollen analysis (Zaretskaya et al., 2014).

The new data had been obtained in the lower reach of Vychegda, where we studied the following terrace sections: Sherdyn' (7), Kiver (8) and Solvychegodsk (or Gusiha, 9), the latest is located near the Vychegda – Severnaya Dvina confluence. We provided the lithostratigraphic analysis in the field, and the OSL- and ^{14}C dating together with pollen analysis afterwards. The Sherdyn' section (left bank of Vychegda, 4.5 m above the low water stage) contains the organic-bearing lenses in the bottom part of the alluvial section, which were ^{14}C dated as 12 780±50 (15.2-15.3 cal kyr BP, GIN-15696, 3.4 m) and 13 300±100 (15.8-16.1 cal kyr BP, GIN-15697, 3.5 m). The overlying sands were dated by OSL as 11.8±0.7 ka (RISØ-176149, 2.1 m) and show a good agreement with ^{14}C; the underlying sands were dates as 13.8±1.2 ka (RISØ-176148, 4.1 m) that probably is an outlier.

The Kiver section (left bank of Vychegda, 7.8-8.0 m above the low water stage) represents alluvial sands covered by gyttja and peat which is therefore covered by aeolian sand OSL-dated as 9.3±0.5 ka (RISØ-176159, 0.75 m). The bottom layer of gyttja with ^{14}C date 9940±40 (11.3-11.4 cal kyr BP, GIN-15701A, 1.3 m) is filling disconformities of the underlying loamy clay, caused by cryoturbations, probably related to YD cooling episode. This strata is underlain by alluvial sands dated back by OSL as 13.4-12.1 ka, and the bottom layer of the section (7.8 m) is OSL-dated as 16.9±1.0 ka (RISØ-176155, 7.8 m) that fits well with calibrated dates from the Sherdyn' section bottom.

The Solvychegodsk (or Gusikha) section (right bank of Vychegda, 5.7 m above the low water stage) is composed of alluvial horizontally, cross- and oblique-bedded sands overlain by peat interbedded with aeolian sands. The bottom part of the peat filling the ice-wedge cracks was ^{14}C dated at 10050±40 BP (11.4–11.7 cal kyr BP, GIN-15704, 1.1 m) (Zaretskaya et al., 2018). Apparently, the ice wedges cracks are related to the YD sharp cooling episode. The results of palynological analysis indicate the dominance of forest-tundra vegetation. A twig from the underlying bed of alluvium was dated at 11 290±70 (13.1-13.2 cal kyr BP, GIN-15706, 4.1 m) (Zaretskaya et al., 2018), and the OSL-date from the bottom sands of this terrace is 14.6±1.2 ka (RISØ-176165, 5.2 m) confirming its Late Glacial age.

The surface of the 1st Vychegda terrace is often capped by dunes – rather small in the middle reach and large in the upper. One of these dunes is 7 m high above the surrounding surface, stretching along the bank of former river channel for more than 10 km. The OSL-age of aeolian sands is 12.5-12.2 ka, and the underlying alluvium is dated back at 15.9±1.1 ka (RISØ-176154).

Thus, after the degradation of the eastern flank of the SIS, fluvial sedimentation pattern predominated in the Vychegda valley during the Late Glacial; six short and abrupt warming and cooling climatic episodes are fixed during the Late Pleistocene – Holocene transition. Traces of the YD sharp cooling (as cryoturbations and ice wedge casts) are found only in the lowermost part of the river valley (Kiver and Solvychegodsk sections). Starting from the Sherdyn' section and further upstream we did not find such traces. This may be explained either by a closer location to the LGM limits, or by some local conditions. Strong aeolian processes followed the Late Glacial cooling episodes.

Studies of terrace stratigraphy, including OSL dating, was supported by Russian Science Foundation (project 17-17-01289); radiocarbon and pollen analyses were sponsored by the Russian Foundation for Basic researches (grant 17-05-00706), following the plan of the scientific research of the Institute of Geography of RAS (0127-2019-0008) and the Geological Institute of RAS.

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Palaeoseismic traces in the Late Pleistocene deposits of Southern Kola peninsula

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The Eastern Fennoscandia was tectonically and seismically active in the recent and remote past. The studies of palaeoseismic activity of the Kola peninsula as part of this region has been provided by (Nikolaeva et al., 2016, 2017 and others), and it was shown that strong earthquakes took place from deglaciation to middle Holocene at least. On the other side, the palaeoseismic history of this region cannot be reconstructed without the geological record, especially in the Late Pleistocene, when we can use instrumental methods for timing the succession of sediments formation and palaeoenvironmental processes and events.

In 2018, we performed the interdisciplinary studies of a series of Quaternary sections located along the Tersky coast of the White Sea, or southern shore of the Kola Peninsula (Fig. 1), for the detailed timing of stratigraphic sequences of the Late Pleistocene (MIS5e – MIS2), revealed in natural outcrops in the river valleys. We revisited three sections, which had been studied earlier (Korsakova et al., 2004; Korsakova, 2009).

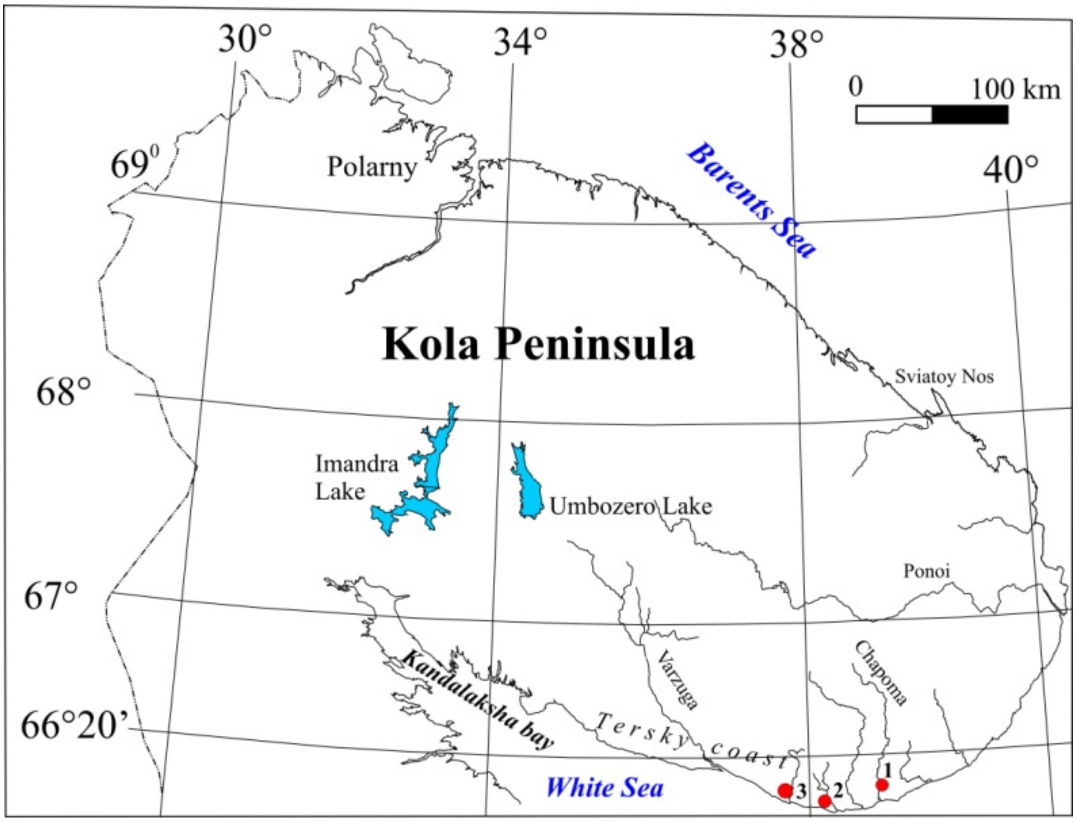

Figure 1. Location of the studied sections (southern Kola peninsula): 1 – Chapoma; 2 – Kamenka; 3 – Chavan'ga.

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The objectives of the research included: lithostratigraphic studies; detailed sampling of sandy horizons for IR-OSL, and mollusks for ^{230}Th/U dating, analysis of the Tersky coast morphostructure and search of traces of the Late Pleistocene activity of tectonic structures both in bedrock and loose sediments. Here we present the preliminary results obtained on three sections (fig. 1): Chapoma (#1), Kamenka (#2) and Chavan'ga (#3).

The Late Pleistocene record of the Chapoma section (18 m) starts from the MIS5e (Mikulino) deposits of the boreal transgression of the White Sea – dark clays with large malacofauna, which was dated back by ESR as 128.7±7.5 (Korsakova, 2009), and by ^{230}Th/U as 136±15/13 (LU-479b). This layer is overlain by tough marine sands and sandy loams with gravel and small shell fragments, dated back by ^{230}Th/U at 85.5±3.2 and 86.0±3.9 (LU-464B) and related to MIS 5a–c (Korsakova, 2009). Marine sediments grade to basin varve-like clayey loams (~5 m), probably related to MIS4 proglacial lake, which again grade to fine-grained sands with shell fragments (MIS 3?). These layers are strongly modified by palaeoseismic processes (Fig. 2). The LGM till lies at the top of the section.

At the Kamenka section (13.5 m), a sandy layer of marine MIS 3 sediments, dated back by ESR at 58.7±4.4 (Tln 344-073) and by IR-OSL at 52.0 ±4.3 (RLQG 416-119), lies between two tills (MIS 4 and MIS 2) (Korsakova, 2009). Both sandy layer and upper till have traces of palaeoseismic affecting.

The Chavan'ga section (7 m) is a completely sandy terrace outcrop with solid gravel layer at the bottom, strongly modified by palaeoseismic processes, which was earlier dated back by IR-OSL at 63.6±8.0 (Tln 1518-103) (Korsakova, 2009).

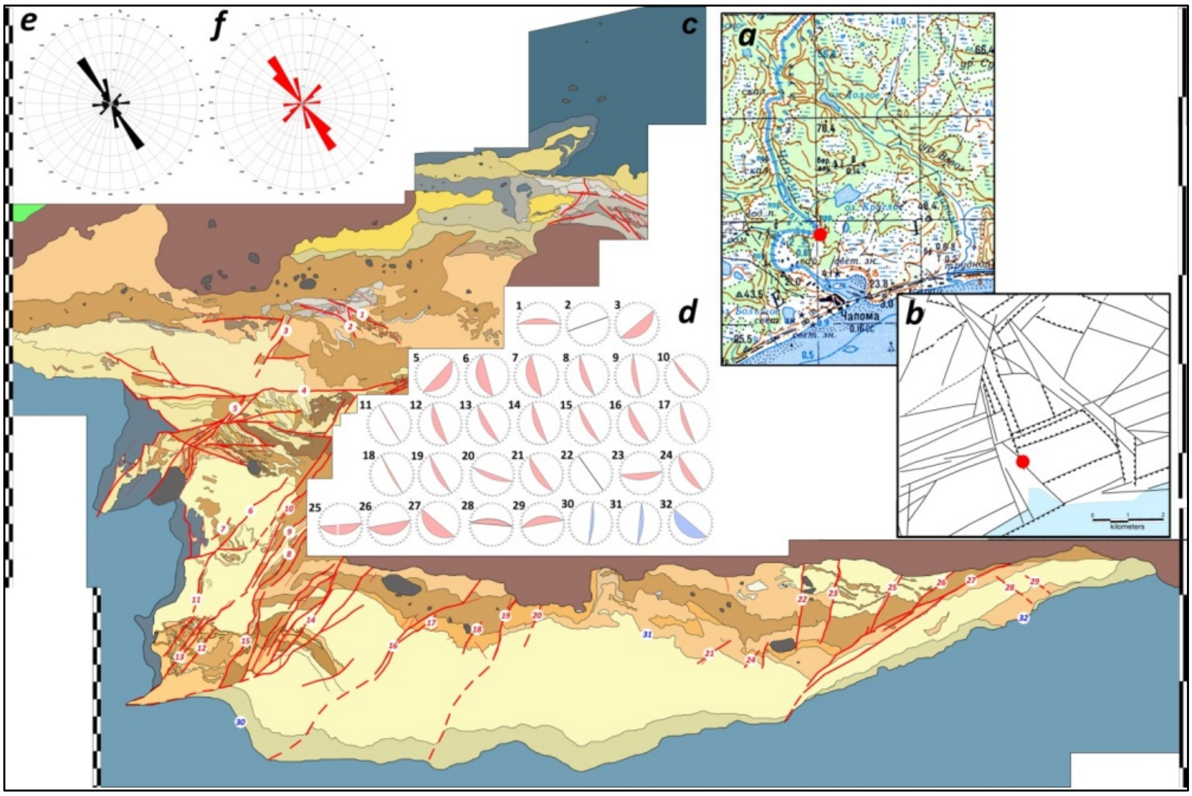

Figure 2. Palaeoseismic pattern of the Chapoma section: a – location; b – main structural elements of relief; c – cross-section of the middle part of the Chapoma river cliff; d - diagrams of parameters (dip azimuth and dip angle) of individual faults (1-29) and layers of deformed sediments (30-32); rose-diagrams of strike azimuth: e – the number of ruptures; f – the total amplitude of displacement on the wings.

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All studied sections are characterized by significant post-sedimentation deformation of sediments. In particular, there are folds of different amplitudes. In some cases, faults are associated with folds, in others – imposed on the folds, characterizing synchronous and successive deformations. Landslide displacement, boulders "floating" in the sands ("dropstones"), clastic dikes, horizontal breaks and extrusion are also observed.

The most of deformations are concentrated in the marine sand layers lying under the LGM till that allows us to propose their MIS 3 age. Deformations are associated with strong seismic events, as there are a number of signs indicating their relationship with the tectonic structure. Orientation of faults in loose sediments corresponds to tectonic faults of the crystalline basement, determining the main forms of topography. Deformations often constitute the dynamic pair showing the sequence of compressions (thrust-faults) and stretching (normal faults). On the other hand, in cases where deformations are similar to traces of glacial, permafrost, gravitational processes, there are signs contradicting these agents.

Results of IR-OSL dating will be presented at the conference.

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