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The Pleistocene stratigraphy of the south-eastern sector of the Scandinavian glaciation (Belarus and Lithuania): a review

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Abstract The paper summarises geological and palaeobotanical investigation data on Pleistocene of recent decades in Lithuania and Belarus. The main problems in Pleistocene stratigraphy and correlation of sections are discussed. As a result, the chronostratigraphical correlation chart of Pleistocene deposits is presented and some changes in local stratigraphic schemes are proposed. The main stratigraphical units are comparable and correlate well; however some unsolved stratigraphical problems still exist. The lack of the absolute chronology dates of the Pleistocene deposits of Belarus and the controversial dating results of some sections in Lithuania is still the main problem.

Keywords *• Pleistocene • stratigraphy • palaeobotany • correlation*

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INTRODUCTION

The areas of Lithuania and Belarus belong to the zone of the continental glaciations and have similar geology of the Quaternary cover varying from 10–30 m up to 300 m. Quaternary stratigraphy has been one of the high priority research objects in Lithuania and Belarus for many years. Pleistocene stratigraphic subdivision elaborated in the mid-nineties was mainly based on lithostratigraphy (petrography and mineralogy) and biostratigraphy (pollen, plant macroremains, diatoms, mammal and mollusc) data (Gaigalas, Satkūnas 1994; Baltrūnas 1995; Kondratienė 1996; Velichkevich *et al*. 1996, 1997). In 2004, the improvements proposed to the Quaternary stratigraphic subdivision of Lithuania (Guobytė, Satkūnas 2011), have not been accepted by the Lithuanian Stratigraphic Commission due to the controversial opinions. The new stratigraphic charts for the Precambrian and Phanerozoic of Belarus were accepted in 2010 (Kruchek 2010) except for the Quaternary because of the disagreements between the researchers.

MATERIAL AND METHODS

Within the last decades, when the drilling became rather limited, the possibilities to get new cross-sections have decreased. Therefore much attention was paid to use new methods, in particular for chronology dating. The promising results were obtained from various methods: U/Th datings (Satkūnas *et al.* 2003; Arslanov *et al.* 2005; Gaigalas *et al*. 2005; Baltrūnas *et al.* 2013); OSL (Molodkov *et al*. 2010; Satkūnas, Grigienė 2012); ESR (Gaigalas, Molodkov 2002) and palaeomagnetic investigations (Sanko, Moiseev 1996; Baltrūnas *et al.* 2013, 2014).

The stratigraphical subdivision presently used for the Quaternary of Lithuania and Belarus is based mostly on climatostratigraphy (Kondratienė 1996; Rylova 2006; Rylova, Savchenko 2006, 2011). According to the Lithuanian Stratigraphic Guide (Grigelis *et al.* 2002), in order to determine a rank of a unit, the amplitude of climate fluctuations and time duration are used. Following this rule the boundaries between the stratigraphic units are drawn by applying a climatostratigraphic criterion that is valid for interglacial periods. In opposite, for glacial periods the application of the climatostratigraphic criterion is limited, therefore a lithostratigraphical criterion is used. The naming of stratigraphic units for interglacials is based on section stratotypes, the areal stratotypes are used for the glaciations (tills). In Belarus, the stratigraphical subdivision is based on the Russian Stratigraphic Code (Zhamoida 2006), where the basic lithostratigraphic unit is named *horizon* (highlighted with asterisk* in Fig. 1).

Thus, the stratigraphical description of the Pleistocene presented in this paper, worked out within the bilateral project between Lithuania and Belarus, makes an attempt to review the existed data and to compile a new lithostratigraphic correlation chart. Principal lithostratigraphic unit-terms used below are: Formation, Subformation, Member, Bed(s) (Grigelis *et al.* 2002) (Fig. 1).

RESULTS AND DISCUSSION

Lower Pleistocene

The Lower Pleistocene has limited distribution, floral and faunal remnants are absent or very poor, high amount of re-deposited material is observed. The lower boundary of Pleistocene in Belarus is designated at 1.8 Ma (Kruchek 2010). Having in mind that International Commission of Stratigraphy redefined its position by placing at the base of Gelasian Stage, i.e. c. 2.558 Ma (Gibbard, Head 2010), the Dvorets Formation is placed in the Lower Pleistocene (see Fig. 1). The holostratotype section (the outcrop on Dnieper River and borehole No. 7; Fig. 2) of this formation correlates with the Tiglian sections in the Netherlands (Stuchlik 1994). In the western part of Belarus the Dvorets Formation is divided to Novogrudok and Olkhovka Members. According to the pollen composition, the Novogrudok Member has the same typical features as the Dvorets Formation occurring in the eastern part of the country. The older Olkhovka Member contains plant macrofossils typical for periglacial environments and pollen of tundra plants. Thus, the

Age (Ma)	Chron	System	Division	Subdivision	Belarus Formation/ subformation*		Lithuania Formation	West Europe	MIS
	Brunhes	Quaternary	Holocene						1
			Pleistocene	Upper		Poozerian	Nemunas	Weichselian	2-5a-d
						Muravian	Merkinė	Eemian	5e
0.13				Middle	Pripiatian	Sozh	Medininkai	Saalian complex	6
							Snaigupėlė		7-9
						Dnieper	Žemaitija		10
0.43						Alexandrian	Butėnai	Holsteinian	11
						Berezina	Dainava	Elsterian	12-14
					Belovezhian	Mogilev	Turgeliai	Cromerian complex	15-21
						Nizhninsky			
						Borky			
						Narev	Dzūkija		
							Vindžiūnai		
							Kalviai		
0.78	Matuyama			Lower		Brest	Daumantai	Bavelian	
						Gomel		Menapian Eburonian Walian	
						Dvorets	Anykščiai	Tiglian Praetiglian	
2.58	Gauss	Neogene	Pliocene	Upper		Kholmech	Neogene		

Fig. 1 Pleistocene chronostratigraphical correlation chart for Belarus and Lithuania in comparison with Western Europe standard scale and Marine isotope stages (MIS)

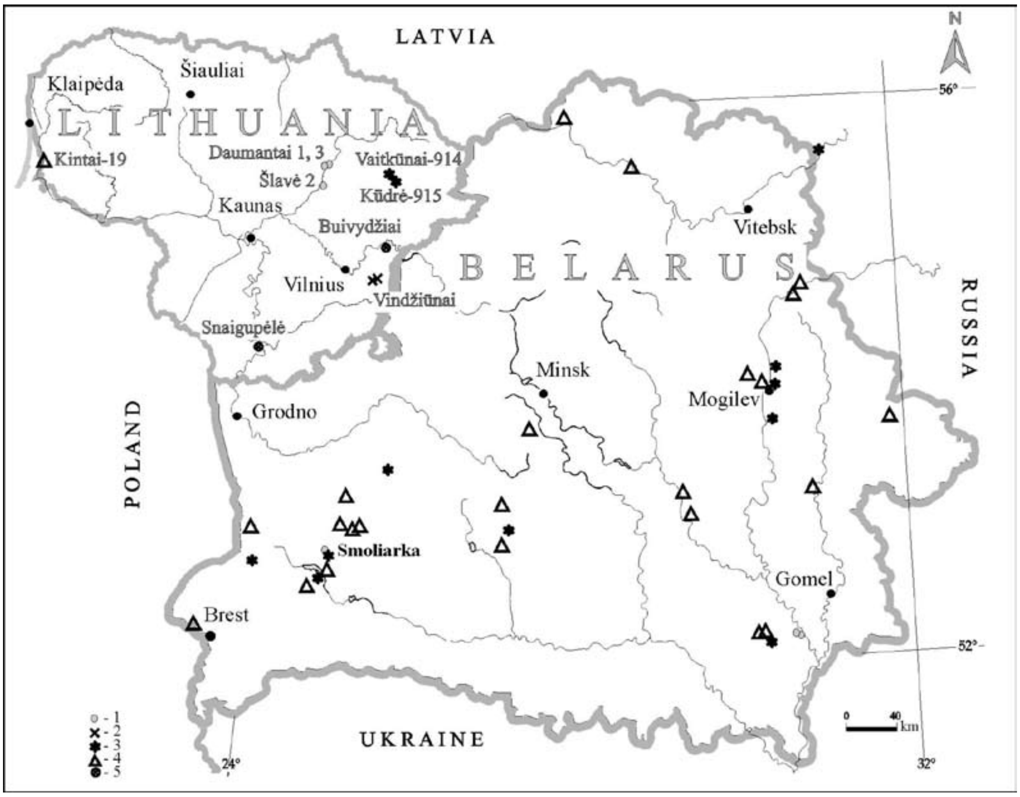

Fig. 2 Location of the sites discussed in the paper. 1 – Sites with Brunhes/Matuyama Boundary detected; 2 – Vindžiūnai Interglacial sites; 3 – Mogilev/Turgeliai Interglacial sites; 4 – Borky Interglacial /Kintai-19 sites; 5 – Snaigupėlė Interglacial sites

Olkhovka Member may correlate with the Praetiglian deposits in Western Europe (Kruchek 2010). The Dvorets Formation overlies the Kholmech Formation which denotes the top of the Neogene system.

In Lithuania, the lowermost Lower Pleistocene is presented by the Anykščiai Formation likely analogous to the Dvorets Formation in Belarus. The lower boundary of the Anykščiai Formation holds in the pure quartz sand sequence gradually changing to Neogene according to palaeobotany data (Kondratienė 1996). The upper boundary of this formation could be stated by the presence of hornblende and black ilmenite, high contents of feldspars and garnets (Klimašauskas, Prakapaitė 1971).

The Dvorets Formation is overlain by the Brest Formation mainly occurring in western and southern Belarus. The formation is composed of lacustrine, lacustrine-alluvial and alluvial deposits, reaching the thickness of 20–35 m. A lithological composition is rather similar to that of the Neogene (high content of quartz and low content of feldspars). However, the higher content of feldspars and carbonates in the upper part of the formation allows to attribute it to the Pleistocene ones. In the stratigraphic chart of Belarus (Kruchek 2010), the Brest Formation is subdivided into two subformations and four members. Nevertheless, present investigations do not provide evidences for such subdivision. Therefore the authors leave the presence of single Brest Formation, as it was described previously (Golubtsov 1983). The Brest Formation could be correlated with the Daumantai Formation in Lithuania.

The Daumantai Formation is distributed in the eastern Lithuania, Anykščiai and Vilnius regions, where they overlie the pre-Quaternary sedimentary rocks. The formation is represented by 10–20 m thick lacustrine sandy-silt sediments. The recent palaeomagnetic studies have detected a Brunhes/Matuyama boundary in the two outcrops: Daumantai-1 and Daumantai-3. Additionally, a Jaramillo subchron was detected in the Daumantai-3 and Šlavė-2 outcrops (Baltrūnas *et al.* 2013; 2014). These findings enabled to justify the stratigraphical position of the deposits studied.

The Brunhes/Matuyama boundary was fixed in the Brest Formation as well, in the section Smoliarka-3 in south-western Brest region (Sanko, Moiseev 1996). An inversion was obtained in the layers of grey sandy loam, black clay and dark grey sandy loam with mollusc shells. This sequence lies on the Miocene deposits (sandy coal).

Palaeobotanical investigations of the Brest and Daumantai formations point out similar characteristics implying their simultaneous sedimentation environments. Pollen and plant macrofossils composition reflects the cold, but ice free climatic conditions (Yakubovskaya, Rylova 1992; Kondratienė 1996).

Rhythmic vegetation changes stated from the pollen diagrams indicate climate changes representative for stadial and interstadial climatic periods. Frequent sedimentation breaks are apparent in the sections. The numerous ancient extinct pollen species are decreasing upwards, toward the younger time period.

Middle Pleistocene

The oldest glacial deposits of the Middle Pleistocene in Belarus are those of the Narev Glacial. The Narev ice sheet covered the greater part of Belarus, however deposits of this glaciation have been mostly eroded and disturbed during the subsequent ice advances. As a result, today the Narev tills are not exposed anywhere and are found mainly in palaeoincisions or depressions. The thickness of the Narev till varies from 0.2–0.5 m up to 40–70 m. The limit of the maximum ice advance is debatable (Matveyev 2002). The distinctive feature of the glacial deposits of this formation is a very high content of clayey particles as compared with the younger formations and low contents of crystalline rocks. The tills are composed of sandy loam, clay loam or clay of high density and contain a great admixture of gravel and pebbles (Yarcev *et al*. 2002). In the stratigraphic chart (Kruchek, 2010) the Narev Formation is subdivided into three subformations: Novogrudok, Korchevo and Yaselda.

The Narev glaciation was interrupted by the warm Korchevo interglacial. Recent geological and palaeobotanical data from numerous sections allow to conclude that the Korchevo Subformation occurred in the intertill interval of the Narev/Berezina glaciations. They are supposed to be formed during the Belovezhian period (Yarcev *et al*. 2002; Rylova 2006; Mamakova, Rylova 2007; Karabanov *et al.* 2011).

In general, the Narev Formation can be correlated with the Dzūkija Formation in Lithuania. The Dzūkija glacial deposits are widespread within their representative site in the south-eastern Lithuania. An average thickness is 7–10 m. The Dzūkija Formation is composed by sandy loam and loam, glaciofluvial sand, sandy gravel, glaciolacustrine sand, silt and clay. The Dzūkija till is of a grey, greenish grey and greyish brown colour and is predominated by gravel and pebbles of crystalline rocks presumably transported from southern Sweden (Gaigalas 1979). The high content of SiO_2, TiO_2, Ti, Zr and Yb as compared with other tills of the Middle and Upper Pleistocene and the low content of CO_2, MgO and FeO are characteristic for the Dzūkija till (Guobytė, Satkūnas 2011).

However, the Dzūkija Formation does not represent the oldest Middle Pleistocene glacial deposits discovered in Lithuania. One likely older till formation is described near Anykščiai, in several outcrops on the Šventoji River (Gaigalas 1987). The similar till was found in 11 boreholes of the Kalviai locality near Vilnius, and named as Kalviai Formation (Satkūnas 1993; Gaigalas, Satkūnas 1994). The till thickness reaches 2–3 m and it is a greenish grey loamy sand with pebbles (3–8%). The Kalviai till is carbonate-free and contains small amounts of dolostone and marl gravel. These features separate it from the younger tills. No analogous glacial deposits were discovered in Belarus so far.

The Kalviai Formation is overlain by the Vindžiūnai interglacial deposits (Kondratienė 1996; Guobytė, Satkūnas 2011) that have been discovered in the same Kalviai representative site and encountered in five sections (see Fig. 2). The pollen composition from the Vindžiūnai interglacial sections indicates that the vegetation does not represent a complete warm (interglacial) climatic cycle but the fragmented sequence can be attributed to the first part of an interglacial period (Kondratienė 1996). The vegetation is represented by mixed coniferous-deciduous forests with a high presence of *Quercus* (up to 34%) and some admixture of pollen of broad-leaved trees (*Quercus, Tilia, Alnus).* Single grains of exotic taxa such as *Tsuga, Pterocarya* and *Pinus haploxylon* are also present. According to O. Kondratienė (1996), these remains are most probably re-deposited. However, the absence of full vegetation successions and a specific character of vegetation composition, i.e. high number of herbs (up to 30–40%), domination of Poaceae, *Artemisia*, Cyperaceae, overall presence of Caryophyllaceae, Apiaceae, Ranunculaceae (including *Thalictrum*) and of spores *Botrychium*, *Selaginella selaginoides*, makes difficult the interpretation of these sediments as deposited during the interglacial as well as their correlation.

The Narev Formation in Belarus is overlain by the Belovezhian Formation that is composed of two Borky and Mogilev interglacial subformations separated by the periglacial Nizhninsky Subformation with presence of Arctic-boreal fauna and flora. The Belovezhian Formation is represented by lacustrine, bog and alluvial formations and reaches up to 10–15 m in the Poozerye region, 15–25 m in the Central Belarus Highland and up to 36 m in the Dnieper and Pripyat River basins.

The Borky Subformation is widely spread in southern and eastern parts of Belarus. The complete pollen investigations enabled to distinguish eight pollen zones (Rylova 1998; Rylova, Savchenko 2006). The characteristic features of vegetation development are maximal distribution of *Larix* during the beginning of interglacial as compared with the rest of it; the spread of broad-leaved trees in the subsequent order, i.e. *Quercus* and *Ulmus* the first and *Tilia* and *Corylus* the second; predominance of *Quercus* and *Ulmus* during the climatic optimum; and wide presence of *Ulmus* and absence of *Carpinus*.

The data of pollen diagrams of the Borky Subformation could be correlated with the diagrams of the Muchkap Interglacial of Russian Lowland (Pisareva 1997), the lower warm interval of the Zidini Interglacial in Latvia (Kondratienė *et al.* 1985) and the Ferdinandov Interglacial in Poland (Janczyk-Kopikowa *et al*. 1981; Pidek 2003). They are also similar to the Hunteburg Interglacial in Germany (Hahne 1996) and the Westerhoven section in the Netherlands (Cromer II; Zagwijn 1996). No sections analogous to the Borky Subformation were found in Lithuania. The most similar vegetation succession to that of the Borky Interglacial is present in the Kintai-19 section located in western Lithuania (see Fig. 2; Kondratienė *et al.* 2003).

The Nizhninsky Subformation is presented by a succession of periglacial deposits of greenish-grey sandy loam and loam with admixture of sand and gravel and loamy clay with peat and gyttja interlayers. The thickness of the deposits reaches up to 3.5 m. As to palaeogeography, the Nizhninsky time could be interpreted as a Little Glacial but not reaching northern Belarus where the periglacial deposits predominatead (Vaznyachuk 1985; Kondratienė, Sanko 1985; Makhnach, Rylova 1986; Velichkevich *et al*. 1996).

The Nizhninsky Subformation correlates with periglacial beds dividing the Glazov and Konachov formations of the Roslav stratotype region in Russia (Biriukov *et al*. 1992) and glacial deposits of the Cromer B-complex (Zagwijn 1996). The vegetation history is analogous to that from the Zidini section in Latvia (Kondratienė *et al.* 1985) and the Ferdinandov, Zdany and other sections in Poland (Janczyk-Kopikowa *et al*. 1981; Pidek 2003). Notably, no analogous deposit sections are found in Lithuania.

The Mogilev Formation is mainly distributed in southern and eastern Belarus (see Fig. 2). The thickness reaches up to 1.8–5.0 m. The Mogilev Interglacial could be correlated with the Turgeliai Interglacial in Lithuania. Five vegetation development phases were distinguished during this period (Rylova, Savchenko 2006; Kondratienė 1996). According to the palynological data, the composition and succession of vegetation are comparable in both countries: the broad-leaved trees (*Quercus, Ulmus, Tilia*) appeared and spread in the forests simultaneously except for *Carpinus* which appeared a bit later; *Alnus* appeared at the same time as the broad-leaved trees; the presence of *Abies* was inconsiderable; such thermophilous plants as *Taxus*, *Ilex*, *Buxus* and *Ligustrum* were registered. Turgeliai Interglacial is represented by lacustrine, bog and fluvial deposits. They are found in the north-eastern Lithuania, near the Utena town and are not widely spread. The thickness of the formation reaches up to 5–6 m.

The Belovezhian Formation is underlain by the Berezina Formation glacial deposits. The Berezina ice sheet covered almost all Belarus area except its southernmost part. In general, the Berezina glacial deposits are of 10–15 m thick in the north, 15–25 m in the south and 50–70 m in the central part of the country. Abundance of associated glaciolacustrine sediments, especially widespread in the western and eastern Belarus is characteristic for the Berezina Formation. Tills predominate consisting mainly of sandy loam with lenses of sand-gravel and various sands.

The Dainava Formation in Lithuania correlates with the Berezina Formation. The Dainava glacial deposits are widely distributed with a stratotypical area in the southern Lithuania. The formation is presented by sandy loam, loam, glaciolacustrine sand, silt, clay, glaciofluvial sand and sandy gravel. The till is of 8–12 m thick, grey, greenish grey and greenish brown. Gravels and pebbles consist of crystalline rocks (presumably from central Sweden), Devonian dolostones and Mesozoic sedimentary rocks. The high contents of Al_2O_3, SiO_2, Y, Yb, Pb, Zr, Cu and low CO_2 characterize the Dainava till (Guobytė, Satkūnas 2011).

The Butėnai (Lithuania) and Alexandrian (Belarus) interglacials are characteristic the Middle Pleistocene formations because of their wide distribution and well exploration. The Alexandrian Interglacial is known from more than 200 sections in Belarus. The thickness varies from 20–30 m up to 40 m on the Pleistocene ridges. According to the palynological data the five regional pollen zones are distinguished (Rylova 1998; Rylova, Savchenko 2011). The main characteristic features of the vegetation development are wide spread of *Picea* and *Alnus* during the beginning of the interglacial; dominance of coniferous trees during all the interglacial; the simultaneous spread of broad-leaved trees; the later and simultaneous spread of *Abies* and *Carpinus*; insignificant role of broad-leaved trees during the climate optimum; inconsiderable presence of *Corylus*; presence of exotic species during all the interglacial (*Taxus baccata, Pterocarya*, *Fagus, Buxus, Vitis, Ligustrum* etc.).

The vegetation development during the Alexandrian Interglacial can be correlated with those of the Butėnai Interglacial in Lithuania, the Likhvin in Russia (Grichuk 1989; Pisareva 1997), the Mazovian in Poland (Krupiński 1995; Pidek 2003), the Holsteinian in Latvia (Kalnina 2001) and Germany (Erd 1978) and with the Marine Isotope Stage (MIS) 11 covering a time interval of 405–305 ka BP (Berger 1989; Loutre 2003).

Lacustrine sediments of the Butėnai Interglacial are well established and correlated palynologically. They occur throughout Lithuania except the central part of the country and are established in more than 40 sections. Most of the sections have been examined in the north-eastern Utena region regarded as a stratotypical areal. The seven local pollen zones were distinguished (Kondratienė 1996). The vegetation development is comparable with the described for the Alexandrian Interglacial in Belarus: coniferous forests flourished with the predominance of *Abies alba* and *Picea*; broad-leaved trees were not widely spread and *Quercus* with *Carpinus* dominated among them. It seems likely that there was no permanent snow cover in winter times. Climatic conditions were favourable for such thermophilous plants as *Abies alba, Taxus baccata, Picea omorica, Buxus sempervirens, Ilex aquifolium, Hedera helix, Pterocarya, Vitis, Osmunda cinnamomea* and *O. claytoniana* (Kondratienė 1996).

The Alexandrian Formation is covered by the Pripiatian Formation that deposits are widespread in all the Belarus. In the Belarusian Poozerye they form the land surface. Sediment thickness varies from several up to 100 m. The Pripiatian Formation is subdivided into Dnieper and Sozh subformations, representing two large glacial stages. The areal stratotype of the Pripiatian Formation is designated in the Pripyat River valley. This formation is subdivided into the Dnieper and Sozh subformations but the interglacial sediments are absent in between these two bodies.

A Pripiatian glacial ice sheet stretches southwards from the Belarus border and reaches the northern Ukraine. The Dnieper Formation is represented by till, glaciofluvial, glaciolacustrine and periglacial deposits. The Dnieper till occurs on the surface and forms marginal ridges in the southern Belarus. The average thickness is 10–18 m in the south and 2–10 m in the east, varying in the central part from 30–40 m up to 80–92 m. The Dnieper Formation could be correlated with the Žemaitija Formation in Lithuania.

The Žemaitija Formation is deposited by the Middle Pleistocene glaciation. The Žemaitija till is in average about 23 m thick, but reaches over 100 m in some deeply incised sections. It is represented by loam and sandy loam with high value of Fe_2O_3, MgO, Ca, Cr, Co and Ni. The maximum value of a SiO_2/Al_2O_3 ratio is recorded comparing with the other tills (Satkūnas, Bitinas 1995). The gravel component consists mostly of crystalline rocks (derived from southern Finland), dolostones and limestones. The dark brown colour and high hardness are the characteristic properties of the Žemaitija till. The stratotype areal of this unit is recognised in the north-eastern Lithuania.

The Sozh till is present in a considerable part of Belarus, but irregularly distributed. Deposits of the Sozh Subformation are in average 10–25 m thick, reaching 135 m in the highland areas. In the northern part of Belarus, it has been almost completely eroded. Some patches of the original till cover have been preserved within the largest glacial basin, i.e. the Polotsk glacial depression. During this time the highlands (Grodnenskaya, Volkovyskaya, Slonimskaya, Novogrudskaya, Minskaya) and ridges (Oshmianskaya and Kopylskaya) have been formed. The Sozh Subformation could be correlated with the Medininkai Formation in Lithuania.

The Medininkai till is represented by loam and sandy loam and texturally and structurally is quite similar to that of the Žemaitija. It is of yellowish brown colour and of smaller average thickness (~ 15 m). The gravel component consists mostly of crystalline rocks derived from northern Sweden and contains large amounts of dolostones as compared with the Žemaitija till (Gaigalas 1979). The areal stratotype of the Medininkai Formation is the Medininkai Heights in the Nalšia (Ašmena) Upland, the south-eastern Lithuania.

The Žemaitija and Medininkai formations in Lithuania are separated by the Snaigupėlė interglacial sediments that are discovered in the eastern part of Lithuania (see Fig. 2). They are subdivided into seven pollen zones (Kondratienė 1996). The succession of flora is most similar to that of the Merkinė Interglacial and differs from the latter by some distinctive features: *Alnus* appeared and spread simultaneously with broad-leaved trees much earlier than *Corylus*; the maximum spread of *Tilia* occurred before *Corylus* and was less prominent; *Quercus* culminated twice, i.e. at the beginning of the climate optimum and at the beginning of *Carpinus* expansion.

No analogous interglacial sediments to the Snaigupėlė Formation were observed in Belarus, Latvia and Estonia. Their correlation with similar sediments in other European countries is still under discussion (Kondratienė 1996; Gaigalas *et al*. 2005). Recently, the discussion points out that the two sections attributed to the Snaigupėlė Interglacial are of different age: Snaigupėlė section should be correlated with the MIS 9 and Buivydžiai section with the MIS 7 (Kondratienė 2011).

Upper Pleistocene

The Upper Pleistocene base marker formations are the Merkinė Interglacial in Lithuania and the Muravian Interglacial in Belarus unquestionably corresponding with the Eemian Interglacial in Poland (Mamakowa 1989; Granoszewski *et al.* 2003), Germany (Behre 1989), Latvia (Kalnina 2001) and Estonia (Liivrand 1991) and the Mikulinski Interglacial in Russia (Grichuk 1989). These interglacial sediments are covered by the Nemunas Formation in Lithuania and Poozerian Formation in Belarus.

The Merkinė Formation is mainly distributed in the eastern part of Lithuania and reaches up to 10 m in thickness. Five phases of the vegetation succession have been identified during this interglacial (Kondratienė 1996). Broad-leaved trees dominated (up to 80%) during the thermal optimum, firstly appeared and spread *Quercus* and *Ulmus,* later *Tilia*. In the southern Lithuania, *Tilia* was probably dominating and constituted ca. 70 % of vegetation. *Carpinus* appeared only in the second part of the interglacial. The maximum spread of *Corylus* occurred in between the *Quercus* and *Tilia* culminations.

The Muravian Formation is widely spread in Belarus and reaches from several metres up to 20 m. The palynological studies of more than 300 sections allow to subdivide the vegetation succession into nine regional zones (Rylova *et al.* 2008). The Muravian Interglacial is overlain by the Poozerian Formation which is subdivided into four subformations: Kulakovsky, Lovatsky, Dvinsky and Narochansky (Kruchek 2010). The stratotype area of this formation is chosen in the Belarusian Poozerye where its thickness varies from 20–30 m up to 60–70 m. The Poozerian Formation is composed by till, glaciofluvial, glaciolacustrine and diluvial-solifluction deposits. The till is represented by sandy loam with boulders and clayey loam of red-brown colour with interlayers of various sands with gravel, and is in average 10–15 m thick (Geology of Belarus 2001). The Early Poozerian contains an alternation of stadial and interstadial deposits (Rylova *et al*. 2008). The Poozerian Formation correlates with the Nemunas Formation in Lithuania.

The investigations point to the presence of non-glacial palaeoenvironments since the end of the Merkinė Interglacial, during the Early and Middle Nemunas. The alternation of stadial and interstadial climate conditions is characteristic for this time and it is rather well studied (Satkūnas, Grigienė 2012; Satkūnas *et al*. 1998; 2003; 2009). Most likely, the major part of the eastern Baltic area was not covered with ice until the Late Nemunas (Poozerian) Substage (Lunkka *et al*. 2004; Kalm 2006; Satkūnas *et al*. 2009).

The Middle Nemunas is still problematic from the point of view of stratigraphy and palaeogeography. The latest data suggest that a "part of the south–western margin of the Eurasian ice sheet could have been situated in the Lithuanian coastal region or in the whole western Lithuania during the Weichselian early pleniglacial maximum" (Molodkov *et al*. 2010). Possible presence of the early Middle Weichselian glaciation is suggested in Poland (Marks 2004), Latvia (Zelčs, Markots 2004) and Estonia (Kalm 2006).

The Upper Nemunas Formation is subdivided into two stratigraphical units: the Grūda and Baltija Subformations corresponding to stadials. No interstadial sediments of this period were determined in Lithuania (Satkūnas, Hütt 1999).

CONCLUSIONS

The complex data of the geological and palaeobotanical investigations enabled to compare the pairs of the Pleistocene stratigraphical subdivision in Lithuania and Belarus as follows: Lower Pleistocene: Daumantai vs. Brest; Middle Pleistocene: Dzūkija vs. Narev; Turgeliai vs. Mogilev; Dainava vs. Berezina; Butėnai vs. Alexandrian; Žemaitija vs. Dnieper; Medininkai vs. Sozh; Upper Pleistocene: Merkinė vs. Muravian, and Nemunas vs. Poozerian.

A set of stratigraphical problems has to be solved during the future detail investigations. More studies are required for the correlation of the Dvorets Formation with some parts of the Anykščiai Formation. The recently available data are insufficient to subdivide the Narev Formation into subformations and to distinguish the Korchev Interglacial. Further investigations are needed for an establishment of the Vindžiūnai Interglacial.

The reliable data have to be collected for the correlation of the Nizhninsky and Belovezhian Formations in Belarus with the appropriate sections in Lithuania. The analogous sections of the Snaigupėlė Interglacial should be defined or the correction of the stratigraphical position of this interglacial should be provided.

Some improvements of the stratigraphical chart of Belarus are proposed: to attribute the Dvorets and Brest Formations to the Lower Pleistocene; to place the Neogene/Pleistocene boundary between the Kholmech (Pliocene) and Dvorets Formations; to define the boundary between the Lower and Middle Pleistocene at the base of the Narev till; to exclude the Korchev Formation from the Narev Formation.

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REFERENCES

Arslanov, Kh. A., Maksimov, F. E., Kuznetsov, V. Yu., Chernov, S. B., Velichkevich, F. Yu., Razina, V. V., Kuzmin, G. F., Baranova, N. G., 2005. Uranium-thorium age and paleobotanical study of interglacial reference section Rodionovo. *Quarternary–2005. All-Russian Conference on study of the Quaternary,* Syktyvkar, 21–23 [In Russian].

Baltrūnas, V., 1995. *Pleistoceno stratigrafija ir koreliacija. [Stratigraphy and correlation of Pleistocene]*. Academia, Vilnius, 178 pp. [In Lithuanian with English summary].

Baltrūnas, V., Zinkutė, R., Šeirienė, V., Katinas, V., Karmaza, B., Kisielienė, D., Taraškevičius, R., Lagunavičienė, L., 2013. Sedimentary environment changes during the Early-Middle Pleistocene transition as recorded by the Daumantai sections in Lithuania. *Geological Quarterly 57 (1),* 45–60.

Baltrūnas, V., Zinkutė, R., Šeirienė, V., Karmaza, B., Katinas, V., Kisielienė, D., Stakėnienė, R., Pukelytė, V. 2014. The earliest Pleistocene interglacials in Lithuania in the context of global environmental change. *Geological Quarterly 58 (1)*, 145–162.

Behre, K. E., 1989. Biostratigraphy of the last Glacial Period in Europe. *Quaternary Science Reviews 8*, 25–44.

Berger, A., 1989. Response of the climate system to CO_2 and astronomical forcings. *Paleo-Analogs, IPCC Working Group I, Bath (20–21 November, 1989).*

Biriukov, I. P., Agadzhanian, A. K., Valuyeva M. N., Velichkevich, F. Y., Shik S. M., 1992. Chetvertichniye otlozheniya Roslavskogo stratotipicheskogo rayona. [Quaternary sediments of Roslav stratotype region]. *In* A. A. Velichko, S. M. Shik (eds), Stratigraphiya i paleogeographiya chetvertichnogo perioda vostochnoy Evropy. [Stratigraphy and palaeogeography of the Quaternary of Eastern Europe], Moscow, 152–180. [In Russian].

Erd, K., 1978. Pollenstratigraphie im Gebiet der skandinavischen Vereisungen. *Schriftenreihe für Geologische Wissenschaften 9*, 99–119.

Gaigalas, A., 1979. *Glaciosedimentation cycles of the Lithuanian Pleistocene.* Mokslas, Vilnius, 95 pp. [In Russian with English summary].

Gaigalas, A., 1987. Border layers and boundary between Quaternary and Neogene systems in the Baltic region. *In* Alekseev, M.N., Nikiforova, K.B. (eds), *Boundary between Neogene and Quaternary in USSR,* Nauka, Moscow, 13–26. [In Russian].

Gaigalas, A., Satkūnas, J., 1994. Evolution of the Quaternary stratigraphical scheme in Lithuania. *Geologija 17*, 152–158. [In Lithuanian with English summary].

Gaigalas, A., Molodkov, A., 2002. ESR ages of three Lithuanian Mid-Late Pleistocene interglacials: methodical and stratigraphical approach. *Geochronometria 21*, 57–64.

Gaigalas, A., Arslanov, Kh. A., Maksimov, F. E., Kuznetsov, V. Yu., Chernov, S. B., Melešytė, M., 2005. Results of uranium-thorium isochron dating of Netiesos section peat-bog in South Lithuania. *Geologija 51*, 29–38.

Gibbard, Ph. J., Head, M. J., 2010. The newly-ratified definition of the Quaternary System/Period and redefinition of the Pleistocene Series/Epoch, and comparison of proposals advanced prior to formal ratification. *Episodes 33 (3)*, 152–158.

Golubtsov, V. K. (Ed.), 1981. Resheniya mezhvedomstvennogo regionalnogo stratigraphicheskogo soveshtchaniya po razrabotke unifitsirovannich stratigraphicheskich schem Belorusii. [Resolution of the inter-institutional regional meeting on compilation of unified stratigraphic schemes of Belorus]. 279 pp. [In Russian].

Granoszewski, W., 2003. Late Pleistocene vegetation history and climatic changes at Horoszki Duze, Eastern Poland: a palaeobotanical study. *Acta Palaeobotanica 4,* 1–95.

Grigelis, A., Kondratienė, O., Paškevičius, J., Jankauskas, T., Satkūnas, J., 2002. *Lithuanian Stratigraphic Guide.* Vilnius, 163 pp. [In Lithuanian and English].

Grichuk, V. P., 1989. *Istoriya flory i rastitelnosti Russkoi ravniny v pleistotsene. [Flora and vegetation development history of Russian Plain in Pleistocene].* Moscow, 182 pp. [In Russian].

Guobytė, R., Satkūnas, J., 2011. Pleistocene glaciations in Lithuania. *In* J. Ehlers, P. L. Gibbard, P. D. Hughes (eds), *Developments in Quaternary Science 15*, Amsterdam, The Netherlands, 231–246.

Hahne, J., 1996. The interglacial site of Hunteburg near Quakenbrück (NW Germany). *In* Ch. Turner (Ed.), The Early Middle Pleistocene in Europe: Proceedings of the SEQS Cromer Symposium, Norwich, United Kingdom, 3–7 September 1990, A. A. Balkema, 181–185.

Janczyk-Kopikowa, Z., Mojski, I., Rzechowski, J., 1981. Position of the Ferdynandów Interglacial, middle Poland, in the Quaternary stratigraphy of the European Plain. *Biulletin Institut Geologiczny 325*, 65–79.

Kalm, V., 2006. Pleistocene chronostratigraphy in Estonia, southeastern sector of the Scandinavian glaciation. *Quaternary Science Review 25 (9–10)*, 960–975.

Kalnina, L., 2001. Middle and Late Pleistocene environmental changes recorded in the Latvian part of the Baltic Sea basin. *Quaternaria A (9),* Stockholm, 173 pp.

Klimašauskas, A., Prakapaitė, G., 1971. Lithologische Zusammensetzung der Ablagerungen des Unterpleistozäns Litauens *In* P. Vaitiekūnas, O. Kondratienė (eds), Aufbau, Lithologie und Stratigraphie der Ablagerungen des Unterpleistozäns in Litauen. Mintis, Vilnius, 35–56. [In Russian].

Kondratienė, O., 1996. *The Quaternary stratigraphy and paleogeography of Lithuania based on paleobotanic studies.* Academia, Vilnius, 212 pp. [In Russian with English summary].

Kondratienė, O., 2011. Problems of the Middle Pleistocene stratigraphy in Lithuania. *Baltica 24, Special Issue: Geosciences in Lithuania: Challenges and Perspectives*, 109–112.

Kondratienė, O., Sanko, A. F., 1985. Usloviya zaleganiya i palinologicheskaya charakteristika mezhlednikovych otlozheniy v ovrage Nizhninskiy Rov. *In* M.A. Valchik, A. F. Sanko (eds), *Problemy pleistotsena*, Nauka i Tekhnika Publishers, Minsk, 101–124. [In Russian].

Kondratienė, O., Khursevich, G. K., Loginova, L. P., 1985. Biostratigraphicheskoye obosnovaniye vozrasta ozernoy tolschi razreza Zhidini. *In* M. A. Valchik, A. F. Sanko (eds), *Problemy pleistotsena*, Nauka i Tekhnika Publishers, Minsk, 86–101. [In Russian].

Kondratienė, O., Bitinas, A., Šeirienė, V. 2003. Sediments of interglacial lake in the Kintai-19 section (Maritime Lowland, West Lithuania). *Geologija 44*, 48–61. [In Lithuanian with English summary].

Kruchek, S. A. (Ed.), 2010. Stratigraphicheskiye schemy dokembriyskich i fanerozoyskich otlozheniy Belarusi: Obyasnitelnaya zapiska. [Stratigraphic charts of Precambrian and Phanerozoic deposits of Belarus: Explanatory note]. Minsk, BelNIGRI, 282 pp. [In Russian].

Krupiński, K. M., 1995. Stratygrafia pyłkowa i sukcesia roślinności interglacjału mazowieckiego w świetle

badań osadów z Podlasia. *Acta Geographica Lodzziensia 70*, 200 pp. [In Polish].
Liivrand, E., 1991. Biostratigraphy of the Pleistocene deposits in Estonia and correlations in the Baltic region. *Doctoral thesis*. Stockholm, 114 pp.
Loutre, M. F., Berger, A., 2003. Marine Isotope Stage 11 as an analogue for the present interglacial. *Global and Planetary Change*, *36*, 209–217.
Lunkka, J. P., Johansson, P., Saarnisto, M., Sallasmaa, O., 2004. Glaciation of Finland. *In* J. Ehlers, P. L. Gibbard (eds), *Quaternary Glaciations–Extent and Chronology. Part I: Europe*, Elsevier, Amsterdam, 93–100.
Makhnach, N. A., Rylova, T. B., 1986. Stratigraphicheskoye raschleneniye drevneozernyh pleistotsenovyh otlozheniy Rechitskogo Pridneproviya. *In* R. A. Zinova (Ed.), *Pleistotsen Rechitskogo Pridneproviya Belarusi,* Minsk, 56–75. [In Russian].
Mamakowa, K., 1989. Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wroclaw and the pollen stratigraphy of this part of the Pleistocene in Poland. *Acta Palaeobotanica 29 (1),* 229 pp.
Mamakowa, K., Rylova, T. B., 2007. The interglacial from Korchevo in Belarus in the light of new palaeobotanical studies. *Acta Palaeobotanica 47 (2),* 425–453.
Marks, L., 2004. Pleistocene glacial limit in Poland. *In* J. Ehlers, P. L. Gibbard (eds), *Quaternary Glaciations–Extent and Chronology. Part I: Europe,* Elsevier, Amsterdam, 296–300.
Matveyev, A.V. (Ed.), 2002. *Paleogeographiya Kainozoya Belarusi.* Minsk, 164 pp. [In Russian].
Molodkov, A., Bitinas, A., Damušytė A., 2010. IR-OSL studies of till and inter-till deposits from the Lithuanian Maritime Region. *Quaternary Geochronology 5*, 263–268.
Pidek, I. A., 2003. *Mesopleistocene vegetation history in the Northern Foreland of the Lublin Upland based on palaeobotanical studies of the profiles from Zdany and Brus sites.* Lublin, 96 pp.
Pisareva, V. V., 1997. Flora i rastitelnost mezhlednikoviy rannego i srednego pleistotsena centralnich rayonov Vostochnoy Evropy. *In* M. N. Alekseev, I. M. Choreva (eds), *Chetvertichnaya geologiya i paleogeographiya,* GEOS, Moscow, 124–133. [In Russian].
Rylova, T. B., 1998. Biostratigraficheskoe raschleneniye belovezhskogo i alexandriyskogo mezhlednikovyh gorizontov pleistotsena na territorii Belarusi. *Doklady NAN Belarusi 42 (4),* 114–117. [In Russian].
Rylova, T. B., 2006. O vozraste i stratigraphicheskom polozchenii mezchlednikovyh otlozheniy razreza Korchevo. *Doklady NAN Belarusi 50 (3),* 97–101. [In Russian].
Rylova, T. B., Savchenko, I. E., 2006. Rastitelnost i klimat mezhlednikovych intervalov v pleistotsene Belarusi po dannym palinologicheskih issledovaniy. *Litasfera 1 (24),* 12–26. [In Russian].
Rylova, T. B., Savchenko, I. E., 2011. Alexandriyskoye mezhlednikoviye Belarusi po dannim palinologicheskih issledovaniy. *Litasfera 1 (34*), 54–67. [In Russian].
Rylova, T. B., Savchenko, I. E., Granoshevskij, V., Winter, K. H., 2008. Interregional correlation of Upper Pripyat (Upper Wartanian), Murava (Eemian) and Lower Poozeric (Lower Vistulian) pollen zones of Belarus and Poland, *Litasfera 1 (28),* 64–75. [In Russian].
Sanko, A. F., Moiseev, E. I., 1996. The first detection of Brunhes/Matuyama boundary in Belarus. *Reports of Academy of Sciences of Belarus 50 (5),* 106–109. [In Russian].
Satkūnas, J., 1993. Conditions of occurrence, structure and forming peculiarities of the interglacial sediments in eastern Lithuania. *Abstract of doctoral thesis*, Vilnius, 26 pp. [In Lithuanian].
Satkūnas, J., Bitinas, A., 1995. The lithological composition of Saalian tills in Lithuania as a criterion for lithostratigraphical subdivision. *Acta Geographica Lodziensia 68,* 173–180.
Satkūnas, J., Hutt, G., 1999. Stratigraphy of the section Antaviliai, eastern Lithuania, and its implication for the Upper Weichselian climatostratigraphic subdivision. *Geological Quaterly 43 (2),* 213–218.
Satkūnas, J., Grigienė, A., 2012. Eemian-Weichselian palaeoenvironmental record from the Mickūnai glacial depression (Eastern Lithuania). *Geologija 54 (2),* 35–51.
Satkūnas, J., Molodkov, A., 2005. Middle Pleistocene stratigraphy in the light of data from the Vilkiškės site, eastern Lithuania. *Polish Geological Institute Special Papers 16,* 94–102.
Satkūnas, J., Grigiene, A., Robertsson, A. M., 1998. An Eemian-Middle Weichselian sequence from the Jonionys site, Southern Lithuania. *Geologija 25*, 82–91.
Satkūnas, J., Grigienė, A., Velichkevich, F., Robertsson, A.-M., Sandgren, P., 2003. Upper Pleistocene stratigraphy at the Medininkai site, eastern Lithuania: a continuous record of the Eemian. *Boreas 32*, 627–641.
Satkūnas, J., Grigienė, A., Jusienė, A., Damušytė, A., Mažeika, J., 2009. Middle-Weichselian palaeolacustrine basin in the Venta river valley and vicinity (northwest Lithuania), exemplified by the Purviai outcrop. *Quaternary International 207,* 14–25.
Stuchlik, L., 1994. Some late Pliocene and early Pleistocene pollen profiles from Poland. *In* M. C. Boulter, H. C. Fisher (eds.), *Cenozoic Plants and Climates of the Arctic. NATO Asi Series I, vol. 27*. Springer-Verlag, 371–382.
Vaitiekūnas, P., 1977. Pre-pleistocene deposits in basin of the river Šventoji. *Geography. Geology 13*, 73–90. [In Russian].
Vaznyachuk, L. N., 1985. Problemy glaciopleistotsena Vostochno-Evropeyskoy ravnini. *In* M. A. Valchik, A. F. Sanko (eds), *Problemy pleistotsena*, Nauka i Tekhnika Publishers, Minsk, 8–55. [In Russian].
Velichkevich, F. Yu., Sanko, A. F, Rylova, T. B., Nazarov, V. I. Khursevich, G. K., Litviniuk, G. I., 1996. Stratigraphic scheme of the Pleistocene deposits of Belarus. *Stratigraphiya Geologicheskaya korrelatsiya 4 (6),* 75–87. [In Russian].

Velichkevich, F. Yu., Khursevich, G. K., Rylova, T. B., Litvinyuk, G. I., 1997. K stratigrafii srednego pleistotsena Belarusi. *Stratigraphiya Geologicheskaya korrelatsiya 5(4),* 68–84. [In Russian].

Yakubovskaya, T. V., Rylova, T. B., 1992. Late Cenozoic flora of the Neogene karst in Bereza area. *In* N. A. Makhnach, T. V. Yakubovskaya (eds), *Cenozoic Flora and Fauna of Belarus,* Nauka i Tekhnika Publishers, Minsk, 76–94. [In Russian].

Yarcev, V. I., Visockyi, E. A., Gubin, V. N., Ilkevich, G. I., Gurinovich, A. I., 2002. Poiski i razvedka mestorozhdeniy mineralnogo sirya, 66 pp. [In Russian].

Zagwijn, W. H. 1996. The Cromerian Complex Stage of the Netherlands and correlation with other areas in Europe. *In* Ch. Turner (Ed.), *The Early Middle Pleistocene in Europe,* Rotterdam, A. A. Balkema Publishers, 145–172.

Zelčs, V., Markots, A., 2004. Deglaciation history of Latvia. *In* J. Ehlers, P. L. Gibbard (eds), *Quaternary Glaciations–Extent and Chronology, Part I: Europe*, Elsevier, Amsterdam, 225–243.

Zhamoida A. I. (Ed.), 2006. Stratigraphic Code of Russia. Third edition. VSEGEI, Saint Petersburg, 96 pp. [In Russian].