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RECONSTRUCTION OF PALAEOTEMPERATURES OF PLEISTOCENE INTERGLACIAL INTERVALS OF BELARUS FROM PALYNOLOGICAL EVIDENCES

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Abstract. In this article you will find the results of palaeoclimatical reconstructions made for Belovezhian, Mogilevian, Alexandrian, Muravian interglacials Pleistocene of Belarus on the basis of detailed palynological studying of composition fossil pollen flora. A was used the method of overlapping of "climatic areals" plants — components of the fossil flora. Reconstruction of palaeotemperature ranges are made for each of the picked up regional pollen zones that has allowed to trace process of changing palaeotemperatures during chronologically consecutive phases in development of flora and vegetation of every interglacials. The reconstructions performed for four interglacials of the Pleistocene of Belarus have shown that temperatures of the warmest and coldest months were similar to each other and the highest ones recorded during the climatic optima of the Belovezhian and Muravian interglacials. The Mogilevian and Alexandrian interglacials were also similar in palaeotemperature parameters, but colder than the above-mentioned interglacials.

Key words: fossil palynoflora, reconstruction of palaeotemperatures, Pleistocene.

INTRODUCTION

The study of the climate represents one of the most topical problems of the present-day science. Data on the changes of climatic conditions in the past form the basis for revealing regular features in climatic changes in the future. Sharp climatic changes characteristic of the Quaternary, repeated occurrences and disappearances of glaciers essentially influenced the flora composition. Palynological data play an important part in the solution of problems associated with palaeoclimatic reconstructions as allow the fullest reproduction of the composition of fossil flora and, firstly, dendroflora. The latter is the most informative indicator of the climate. The principles of the vegetation changes during every interglacial are specific and differ from those peculiar to other interglacial intervals. This is demonstrated by sequences of pollen zones specific for every interglacial.

METHODS

Methods used to reconstruct climatic parameters from the data on the fossil flora composition are based on the information about climatic confinement of modern plant species which remains were revealed in the studied deposits. Two main ways of the definition of the palaeotemperature range from palynological data are known. The first one is based on a cartographic summation of recent areals of species included in the fossil flora composition with determination of their recent concentration centers. The second method is based on overlapping "of climatic areals" of plants, components of an investigated fossil flora and finding of that site, which is common for the whole floristic complex and, therefore, allows coexistence of all its members (Grichuk *et al*., 1987; Velichko *et al*., 2002, 2004). Definition of the species composition of the fossil pollen flora represents a very complicated and very difficult problem. However, execution of species definition is a necessary condition to solve the questions of stratigraphic position and flora correlation as in Russia so in Belarus, Lithuania and in others regions (Grichuk, 1960, 1961, 1989; Ananova, 1965; Ananova, Kultina, 1965; Makhnach *et al*., 1981; Bolikhovskaya, 1995; Kondratene, 1996).

For these investigations there was used the light mikroscope Ergaval with the working increase x400 and x1000. To determination the pollen and the spores there were used the numerous atlases of pollen and spores (Pokrovskaya, 1950; Ananova, 1965; Kupriyanova, 1965; Kupriyanova, Aleschina, 1972, 1978; Shimakura, 1973; Bobrov *et al*., 1983; Faegri, Iversen, 1989).

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The authors have already made a palaeoclimate reconstruction of the Alexandrian and Muravian interglacials of the Pleistocene in Belarus using the second method (Rylova, Savchenko, 2003). The purpose of the present work was a reconstruction of successive changes of temperature parameters using the method of overlapping of "climatic areals" in the Belovezhian and Mogilevian interglacials, and also the refinement of the data obtained earlier for the Alexandrian and Muravian interglacials of the Pleistocene of Belarus. The climatograms are constructed for all pollen zones, distinguish in interglacials. As an example, the climatograms constructed for the warmest phases of climatical optimums are presented in the illustation.

The data on the fossil flora composition obtained as a result of palynological analysis of the most representative sections served as materials for this work.

THE RESULTS OF PALAEOCLIMATICAL RECONSTRUCTION

BELOVEZHIAN INTERGLACIAL

To find out the composition of flora corresponding to each pollen zone of the Belovezhian Interglacial, data of palynological investigation of the following sections were used: the Nizhninsky Rov (Yelovicheva, 1979; Kondratene, Sanko, 1985), the profiles at Krasnaya Dubrova (Makhnach, Rylova, 1986), Borki (Yakubovskaya *et al*., 1991), Smolarka, Strigin (Velichkevich *et al*., 1993), Yatvez (Velichkevich *et al*., 1997), Bobruisk (Rylova *et al*., 2003) and other sites (Fig. 1).

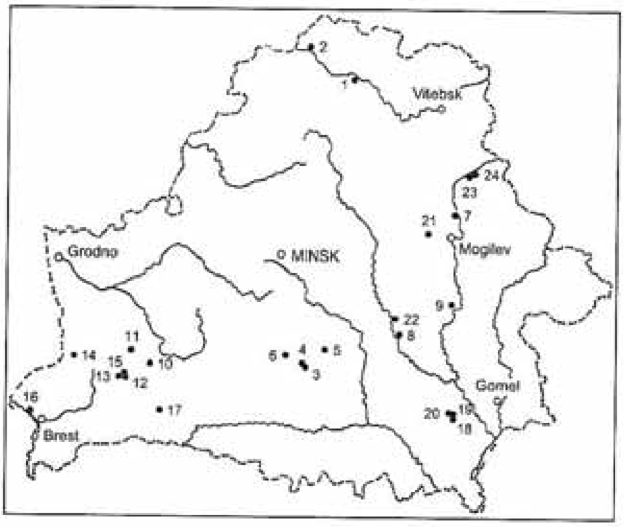

Fig. 1. The map of Belovezhian Interglacial localities palynologically investigated

1 — Pochtari; 2 — Obukhovo; 3 — Starobin; 4 — Pivashi; 5 — Kosteshi; 6 — Vygoda; 7 — Nizhninskiy Rov; 8 — Ugly; 9 — Rudnya; 10 — Yaglevichi; 11 — Yatvez; 12 — Strigin; 13 — Golitsy; 14 — Borki; 15 — Smolyarka; 16 — Rudavets; 17 — Motol; 18 — Krasnaya Dubrova; 19 — Rassvet; 20 — Chkalovo; 21 — Golubovka; 22 — Bobruysk; 23 — Stanislavovo; 24 — Maloe Bakhovo

An analysis of the most representative pollen diagrams of Belovezhian Interglacial deposits allowed their subdivision into 8 regional pollen zones: RPAZ bl 1–RPAZ bl 8 (Rylova, 1998). According to the differentiated pollen zones, the process of terraneous vegetation development is represented as follows.

RPAZ bl 1 Betula–Larix–Picea corresponds to a phase of abundant mixed birch-coniferous (spruce — larch — pine) and coniferous-birch forests. The main forest-forming species were *Betula pubescens* Ehrh., *B. pendula* Roth, Larix Mill. and *Picea abies* (L.) Karst. *Salix* sp., *Juniperus communis* L., *Ephedra distachya* L., *Betula nana* L. and *B. humilis* Schrank were also found. A role of the herbaceous vegetation was considerably reduced, compared to its contribution at the last phase of the preceding glaciation. Undoubtedly, at that time climatic conditions gradually improved. The revealed floristic composition suggests the following palaeotemperature ranges: $t°_{VII} = +11.5° \ldots +20°C$, $t°_{I} = 0° \ldots -16°C$ (t_{VII} — temperature in July; t_{I} — temperature in January).

R PAZ bl 2 Pinus–Betula reflects a phase of a widespread occurence of mixed pine-birch forests with an admixture of a larch, spruce, alder, deciduous tree species and hazel. *Betula nana* L. and *B. humilis* Schrank dropped out from the pollen flora composition, as compared with the composition of the previous phase, but *Alnus glutinosa* (L). Gaertn., *A. incana* (L). Moench, *Quercus robur* L., *Ulmus minor* L., *Corylus avellana* L. appeared. Temperature parameters ranged within the following limits: $t°_{VII} = +17° \ldots +20.5°C$, $t°_{I} = 0° \ldots -14°C$.

R PAZ bl 3 Quercus–Ulmus corresponds to a phase of a widespread occurrence of mixed deciduous-coniferous (oak — elm — pine) forests involving alder and birch. The main forests-formed species were *Quercus robur* L., *Q. pubescens* Willd, *Q. petraea* Liebl., *Ulmus laevis* Pall., *U. minor* Mill., *Pinus sylvestris* L. *Alnus glutinosa* (L.) Gaertn., *A. incana* (L.) Moench were widespread. There were also *Betula pubescens* Ehrh. and *B. pendula* Roth. In a composition of forest communities *Larix* Mill. and *Picea abies* (L.) Karst were practically absent, but at the same time *Acer platanoides* L., *Fraxinus excelsior* L., *Tilia cordata* Mill. appeared. The composition of vegetation testifies to the more favourable climatic conditions in comparison with initial phases of the interglacial. Temperatures ranged within: $t°_{VII} = +18° \ldots +21°C$, $t°_{I} = +3° \ldots -4°C$.

R PAZ bl 4 Quercus–Ulmus–Corylus reflects a phase of abundant deciduous forests represented by *Quercus robur* L., *Q. pubescens* Willd, *Q. petraea* Liebl, *Ulmus laevis* Pall., *U. minor* Mill, *Tilia platyphyllos* Scop., *T. cordata* Mill., *T. tomentosa* Moench, *Acer platanoides* L., *A. campestre* L., *Fraxinus excelsior* L. *Corylus avellana* L. was widespread. Pine, birch, occasionally spruce and fir grew as a small admixture. Unlike the preceding phase, *Ligustrum vulgare* L. and *Vitis* L. were present in the composition of forest communities. Alder forests were still widespread. The composition of vegetation suggests the warmest climate relative to the other phases of this interglacial. The reconstruction of palaeotemperature parameters demonstrates that the temperature ranged at this time within: $t°_{VII} = +19° \ldots +24.5°C$, $t°_{I} = +3° \ldots -4°C$ (Fig. 2).

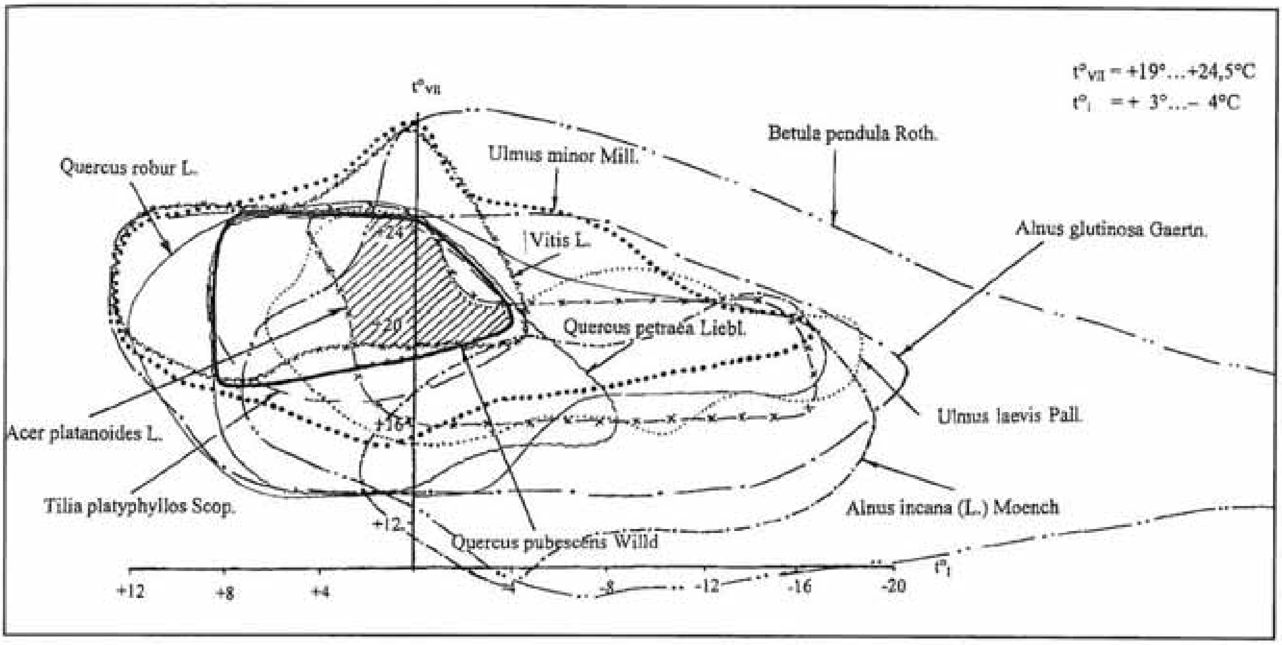

Fig. 2. Climatogram for the climatic optimum of the Belovezhian Interglacial (R PAZ b14 Quercus–Ulmus–Corylus)

R PAZ bl 5 Quercus–Picea (*Quercus–Picea–Abies* for western regions of Belarus) corresponds to a phase of the development of deciduous-coniferous forests where *Quercus robur* L., *Q. pubescens* Willd., *Q. petraea* Liebl., smaller value had *Ulmus minor* Mill., *U. laevis* Pall, *Tilia platyphyllos* Scop., *T. cordata* Mill., *T. tomentosa* Moench were of first importance among broad-leaved species. Hazel, privet, etc. grew in the underbrush. *Picea abies* (L.) Karst increased in importance in the coniferous vegetation composition, and in western regions *Abies alba* Mill. dominated and pine was of minor importance. Topographic lows were occupied by alder forests. The revealed flora composition suggests the more humid, though warm climate, favouring a widespread occurrence of a rich sylva. Thefollowing temperature parameters were obtained for this phase: $t°_{VII}$ = +18.5° …+20.5°C, $t°_{I}$ = +0.5°…–4°C.

R PAZ bl 6 Pinus–Picea (*Pinus–Picea–Abies* for western regions of Belarus) corresponds to a phase of abundant coniferous (pine, pine-spruce or pine-spruce-fir) forests including birch, alder, deciduous trees and hazel. A disappearance of thermophilous arboreal trees from the forest composition and an increas participation of cold-resistant ones testify to a gradual fall of temperature. A climagram constructed suggests, that palaeotemperatures of this period were as follows: $t°_{VII}$ = +15.5° … +19°C, $t°_{I}$ = 0° … –8°C.

PAZ bl 7 Pinus–Picea–Betula corresponds to a phase of a high development of the coniferous (pine and pine-spruce) forests involving birch. An impoverished flora composition (only *Pinus sylvestris* L., *Picea abies* (L.) Karst., *Betula pubescens* Ehrh., *Betula pendula* Roth were revealed) suggests further climate cooling. A climagram constructed shows a broad range of temperatures ($t°_{VII}$ = +11.5° … +20.5°C, $t°_{I}$ = +0.5° … –16°C), which can provide only a rough idea of palaeotemperature parameters at that time.

R PAZ bl 8 Pinus–Betula–Larix corresponds to a phase of a widespread occurence of coniferous — small-leaved sparse woods represented by pine, spruce, larch, fir, birch. The flora composition revealed and an inreased participation of herbaceous associations indicate the further decrease of heat supply to the terrain. An appearance of *Larix* sp. in the pollen flora composition did not changed a climagram constructed for the preceding phase, i.e. the same temperature parameters were obtained.

Available palynological diagrams of the Belovezhian Interglacial can be compared to diagrams of coeval age interglacial sediments in the neighbouring territories: Muchkap Interglacial of the Russian plane (Valueva *et al*., 1985; Birukov *et al*., 1992), Ferdynandów Interglacial of Poland (lower optimum) sections Ferdynandów (Janczyk-Kopikowa *et al*., 1981), Białobrzegi (Janczyk-Kopikowa, 1991), Popioły (Winter, 1992), Zdany (Pidek, 2003), Hunteburg Interglacial in Germany (Hahne *et al*., 1994). The similar succession of vegetation is also reflected in a pollen diagram of the Zhidiny section in Latvia (lower warm period) (Kondratene *et al*., 1985). In the territory of the Netherlands Westerhowen Interglacial (Cr2) is the most probable analogue of the Belovezhian Interglacial (Zagwijn, 1996).

MOGILEVIAN INTERGLACIAL

To reveal the composition of the pollen flora in the Mogilevian Interglacial data of palynological analysis of several sections were taken into account: Nizhninsky Rov (Yelovicheva, 1979; Kondratene, Sanko, 1985), Krasnaya Dubrova (Makhnach, Rylova, 1986), Smolarka (Velichkevich *et al*., 1997), Korchevo (Vaznyachuk *et al*., 1978) (Fig. 3).

An analysis of spore and pollen diagrams of the Mogilevian Interglacial allows their palynostratigraphic subdivision into 5

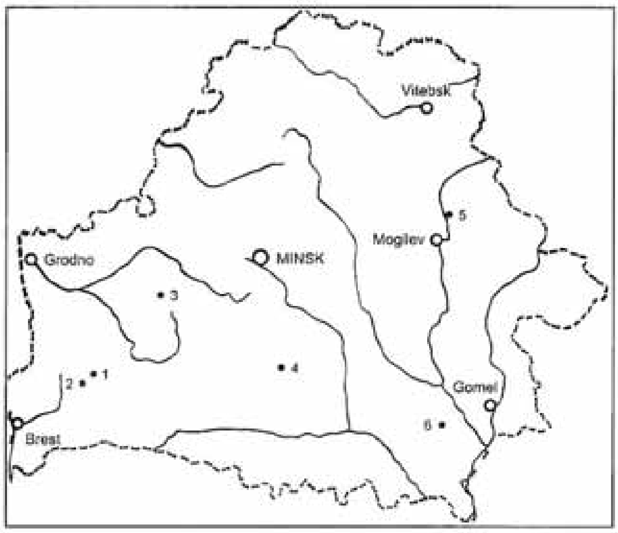

Fig. 3. The map of Mogilevian Interglacial localities palynologically investigated

1 — Smolyarka; 2 — Uglyany; 3 — Korchyovo; 4 — Pivashi; 5 — Nizhninskiy Rov; 6 — Krasnaya Dubrova

pollen zones, which regional importance should be further confirmed with more representative data used.

PAZ mg 1 Larix–Betula–Pinus reflects a phase of abundant birch-pine and pine-birch forests (*Betula pubescens* Ehrh., *B. pendula* Roth, *Pinus sylvestris* L.) with an admixture of *Larix* Mill. and *Picea abies* (L.) Karst.

PAZ mg 2 Quercus–Ulmus–Tilia corresponds to a phase of a high development of broad-leaved, predominantly oak-elm-lime forests, (*Quercus robur* L., *Quercus pubescens* Willd., *Quercus petraea* Liebl., *Ulmus minor* Mill., *Ulmus laevis* Pall, *Tilia platyphyllos* Scop., *Tilia cordata* Mill., *Tilia tomentosa* Moench) and broad-leaved-coniferous forests (coniferous trees are represented by *Pinus sylvestris* L. and *Picea abies* (L.) Karst) with participation of *Alnus glutinosa* (L.) Gaertn. and *A. incana* (L.) Moench.

PAZ mg 3 Carpinus–Quercus–Alnus reflects a phase of a widespread occurence of mixed coniferous-broad-leaved forests where the forest-forming species were *Carpinus betulus* L., *Quercus robur* L., *Q. pubescens* Willd., *Q. petraea* Liebl., *Tilia platyphyllos* Scop., *T. cordata* Mill. *T. tomentosa* Moench., *Ulmus laevis* Pall., *U. minor* Mill., *Corylus avellana* L., *Alnus incana* (L.) Moench, *A. glutinosa* Gaertn., *Betula pubescens* Ehrh., *B. pendula* Roth., and among coniferous trees — *Picea abies* (L.) Karst and *Pinus sylvestris* L. *Acer platanoides* L., *Fraxinus excelsior* L., and also *Vitis* L. and *Ligustrum vulgare* L. grew as an admixture.

PAZ mg 4 Picea–Pinus–Betula–Carpinus indicates an abudance of coniferous-deciduous forests, where the main forest-forming species were *Picea abies* (L.) Karst., *Pinus sylvestris* L. and *Carpinus betulus* L., more seldom oak, lime tree, elm and some other thermophilous species and also birch and alder.

PAZ mg 5 Betula–Pinus–Picea corresponds to a phase of abundant mixed pine-birch and birch-pine forests involving larch, spruce, juniper, unessentil insignificant admixture of hornbeam and some other broad-leaved trees. At that time herbaceous associations increase in importance. Changes in the vegetation pattern suggest a deterioration of climatic conditions and progressing fall of temperature.

A climatic optimum of the Mogilevian Interglacial was revealed in all the studied sections, and the initial and final phases are not always shown in diagrams. Therefore, the authors performed palaeoclimatical reconstructions for the phase mg 3 only, which corresponds to the climatic optimum. A climagram (Fig. 4) demonstrates that during the studied phase, palaeotemperatures varied over the following range: t°VII = +19° …+20.5°C, t°I = +0.5°…–4°C.

It is too early to make any inferences about palaeographical conditions of the Mogilevian Interglacial. However, it can be

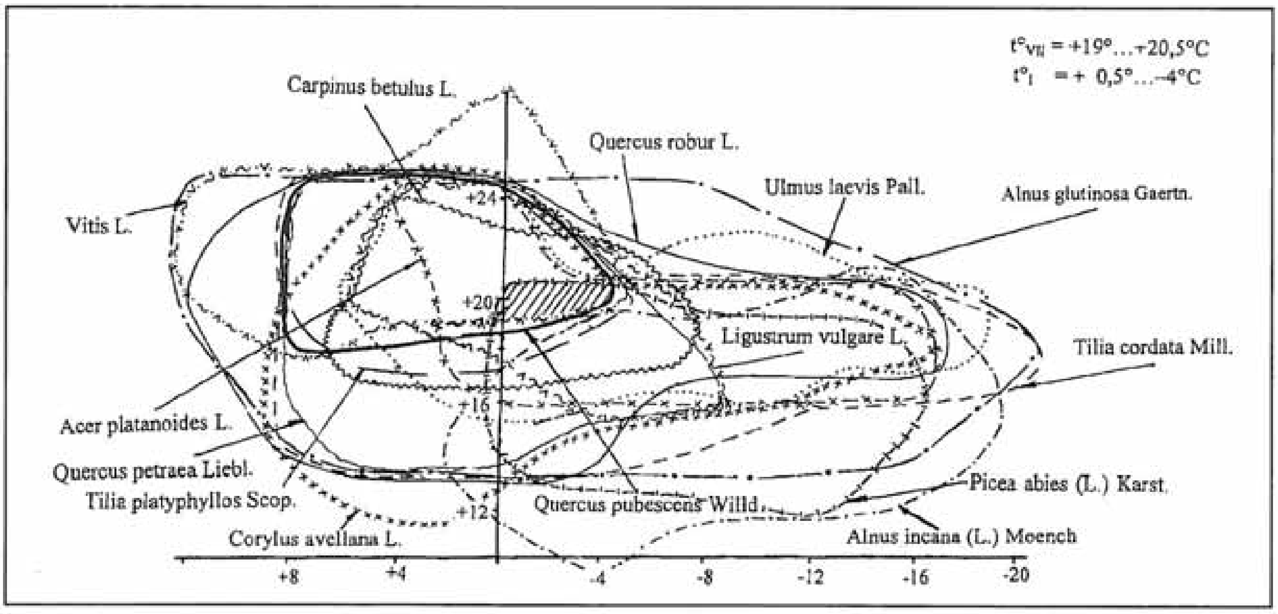

Fig. 4. Climatogram for the climatic optimum of the Mogilevian Interglacial (PAZ mg 3 Carpinus–Quercus–Alnus)

confirmed that this interglacial had characteristic features that distinguish it from the other interglacials of the Pleistocene.

The natural process during the Mogilevian Interglacial developed similarly in central regions of Russia in Konakhovka time (Biryukov *et al.*, 1992) and also in Latvia, during the formation of the upper interglacial horizon in the Zhidiny section (Kondratene *et al.*, 1985). In the territory of Lithuania the Turgelai Interglacial is an analogue of the Mogilevian Interglacial (Kondratene, 1996). In Poland an analogue of the Mogilevian Interglacial is represented by the upper climatic optimum of the Ferdinandów Interglacial — sections of Ferdinandów (Janczyk-Kopikowa, 1981), Białobrzegi (Janczyk-Kopikowa, 1991), Podgórze (Mamakowa, 1996), Zdany (Pidek, 2003), *etc*. The Augustovian Interglacial is also its probable analogue — sections of Szczerba (Janczyk-Kopikowa, 1996), Kalejty (the upper warm interval; Winter, 2001), *etc*.

The similar succession of vegetation seems likely to occur in the territory of Germany (Homann, Lepper, 1994). The available palynological evidences allows now enough confident correlation of the Narev–Belovezhian–Nizhninsky–Mogilevian complex of Belarus and the Cromer complex of Western Europe, particulary, of the Belovezhian interval with Interglacial II (Westerhowen) and the Mogilevian one with Interglacial III (Rosmalen) (Zagwijn, 1996) and to confirm that the other interglacials of the Cromer complex in the territory of Belarus have not been revealed yet.

ALEXANDRIAN INTERGLACIAL

To find out the pollen flora composition of the Alexandrian Interglacial of Belarus, evidences of palynological analysis in the sections of Matveev Rov (Makhnach, 1971), Dobraya (Rylova et al., 1999), Seylovichy (Rylova, Khursevich, 1999), *etc.* (Fig. 5).

The analysis of the above pollen diagrams allowed a palynostratigraphic subdivision of appropriate deposits in 5 regional pollen zones (R PAZ alk 1–R PAZ alk 5), which correspond to certain phases of the vegetation evolution (Rylova, 1998).

R PAZ alk 1 Betula–Pinus corresponds to a phase of a widespread occurence of birch and birch-pine forests (*Betula pubescens* Ehrh., *B. pendula* Roth., *Pinus sylvestris* L.), involving *Picea abies* (L.) Karst, *Larix* Mill., *Juniperus communis* L., occasionally — *Alnus glutinosa* (L.) Gaertn., *A. incana* (L.) Moench and *Salix* sp. The contribution of herbaceous plants sharply reduced in comparison with the final phase of the preceding glaciation. The composition of vegetation is indicative of a considerable improvement of the territory heat supply. The pollen flora composition has reveals the following palaeotemperature range: t°VII = +13° …+19°C, t°I = –1°…–16°C.

R PAZ alk 2 Picea–Pinus–Alnus corresponds to a phase of a high development of spruce and spruce-pine forests with the participation of birch, alder and a small admixture of broad-leaved trees. *Picea abies* (L). Karst., *Pinus sylvestris* L., *Betula pubescens* Ehrh., *B. pendula* Roth, *Alnus incana* (L). Moench, *A. glutinosa* Gaertn. were revealed in the pollen flora composition. The participation of birch in the forest composition gradually reduced, but broad-leaved trees appeared: *Quercus robur* L., *Q. petraea* Liebl., *Ulmus laevis* Pall., *U. minor* Mill., *T. cordata* Mill. and *Corylus avellana* L. The constructed climagram shows that palaeotemperatures in this period varied within the following limits: t°VII = +15° …+19°C, t°I = +0.5°…–7°C.

R PAZ alk 3 Abies–Carpinus–Quercus corresponds to the development of coniferous fir-spruce, fir-spruce-pine and mixed coniferous — deciduous forests. *Abies alba* Mill., *Picea abies* (L.) Karst., *Pinus sylvestris* L., *Taxus baccata* L., *Carpinus betulus* L., *Quercus robur* L., *Q. pubescens* Willd., *Q. petraea* Liebl., *Tilia platyphyllos* Scop., *T. cordata* Mill., *T. tomentosa* Moench., *Ulmus laevis* Pall., *U. minor* Mill., *Corylus avellana* L., *Alnus incana* (L.) Moench, *A. glutinosa* Gaertn. were revealed in the pollen flora composition. In the western and southwestern regions of Belarus *Pterocarya, Buxus, Vitis* and *Ligustrum* are regulary present. The composition of revealed pollen flora showed the following range of palaeotemperatures: t°VII = +18.5° …+20.5°C, t°I = +0.5°…–1°C (for the western and southwestern regions) (Fig. 6) and t°VII = +18.5°…+20.5°C, t°I = +0.5°…–4°C (for the northen and eastern regions) (Fig. 7).

R PAZ alk 4 Abies–Picea–Pinus reflects a phase of a widespread occurence of coniferous fir-spruse-pine forests with a small participation of *Betula*, *Alnus* and *Carpinus*. Other thermophilous species were practically absent, or were found in insignificant amounts. The vegetation pattern testifies to a considerable cooling of the climate: t°VII = +16.5° …+19°C, t°I = +0.5°…–4°C.

R PAZ alk 5 Pinus–Betula–Larix corresponds to a phase of abundant mixed pine forests involving spruce and larch. Changes in the forest composition are indicative of the further

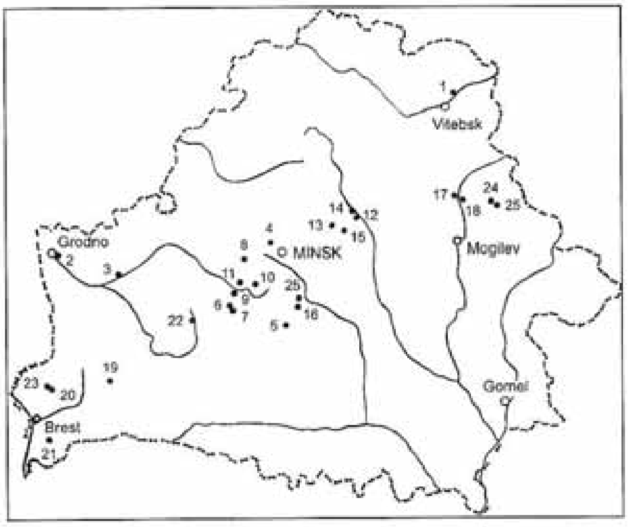

Fig. 5. The map of Alexandrian Interglacial localities palynologically investigated

1 — Ruba; 2 — Prinemanskaya; 3 — Zaborye; 4 — Laperovichi; 5 — B. Olshanka; 6 — Seylovichi; 7 — Rapovichi; 8 — Telyashevichi; 9 — Vyazovets; 10 — Sverinovo; 11 — Okinchitsy; 12 — Sivitsa; 13 — Gryadki; 14 — Pechi; 15 — Zelyony Bor; 16 — Gresk; 17 — Matveev Rov; 18 — St. Stayki; 19 — Ogorodniki; 20 — Kukulchitsy; 21 — Gvoznitsa; 22 — Baranovichi; 23 — Shcherbovo; 24 —Ovsyanka; 25 —Dobraya; 26 — Belyy Bor

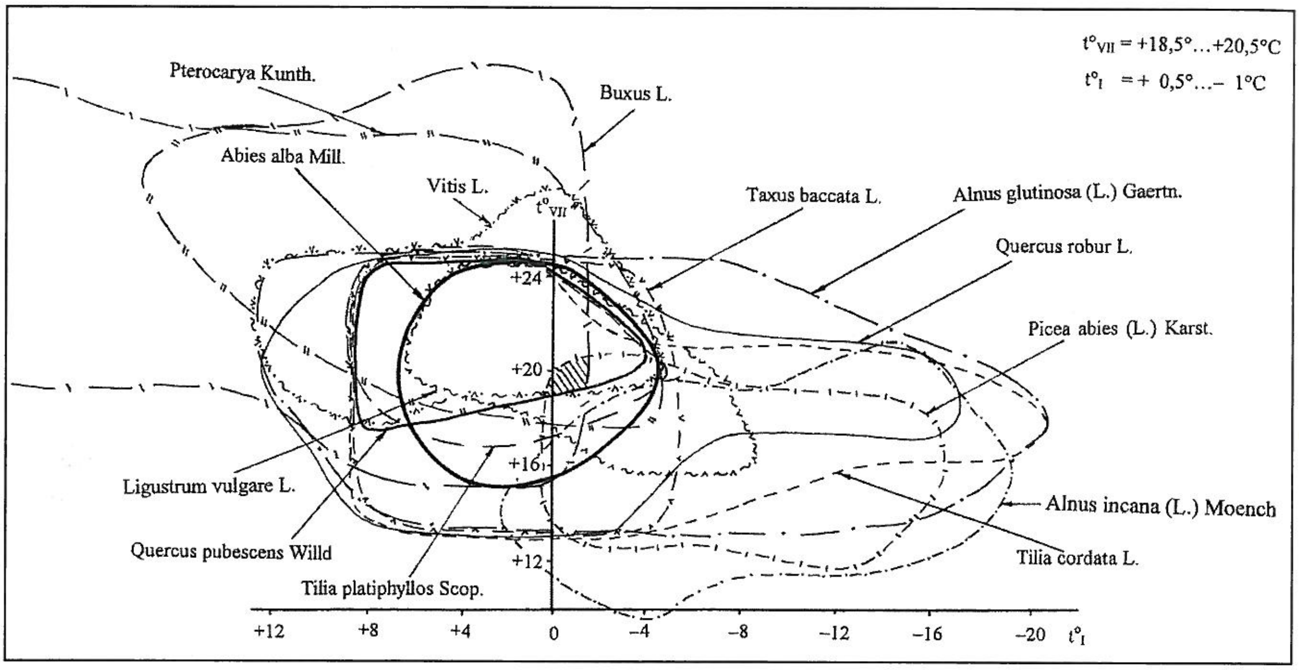

Fig. 6. Climatogram for the climatic optimum of the Alexandrian Interglacial (for the western and southwestern regions; R PAZ alk 3 Carpinus–Quercus–Alnus)

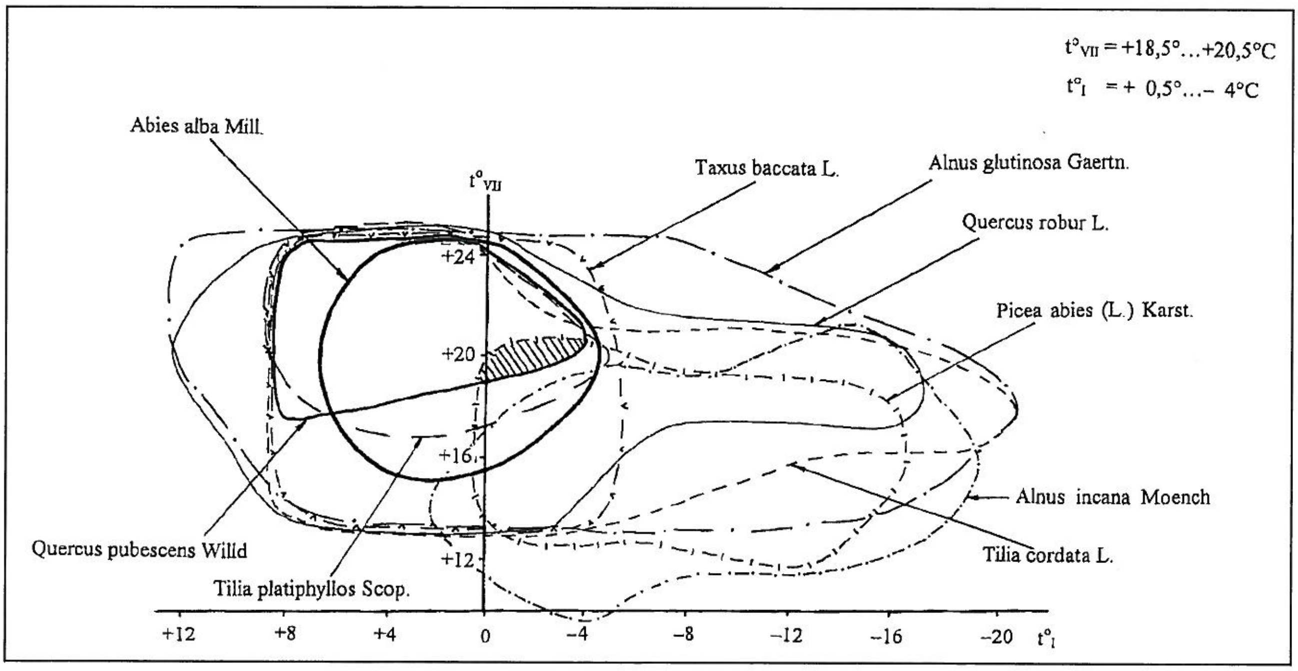

Fig. 7. Climatogram for the climatic optimum of the Alexandrian Interglacial (for the northern and eastern regions; R PAZ alk 3 Carpinus–Quercus–Alnus)

cooling and decrease of climate humidity. The impoverished composition of the pollen flora allowed a climagraph to be constructed with a broad temperature range which may provide only a rough idea of climatic conditions at that time: t°VII = +11.5° …+20.5°C, t°I = 0°…–16°C.

The development of vegetation and evolution of the natural process during the Alexandrian Interglacial were the same as during the Likhvin Inetglacial of Russia (Grichuk, 1961; Bolikhovskaya, 1995, *etc.*); during the Butensky Interglacial of Lithuania: sections of Butenay, Gailunay, etc., (Kondratene, 1996); during the Mazovian Interglacial of Poland: sections of Nowiny Żukowskie (Dyakowska, 1952); Krępiec (Janczyk-Kopikowa, 1981), Biała Podlaska, Komarno, Ossówka (Krupiński, 1995), Brus (Pidek, 2003), *etc.*; during the Holstein Interglacial of Germany: sections of Granzin, Prellheide, Pritzwalk, *etc.* (Erd, 1969, 1978; Erd, Müller, 1977; *etc.*).

MURAVIAN INTERGLACIAL

Deposits of the Muravian Interglacial horizon in the territory of Belarus were studied by the palynological method in more than a hundred of locations: sections of Murava (Valchik *et al.*, 1989), Zhukevichi (Sanko *et al.*, 2000), Ponemun (Rylova, Khursevich, 1978), Svetlogorsk (Khursevich *et al.*, 1995), Borhov (Makhnach, 1971), Azarichi (Savchenko, Pavlovskaya, 1999), Cherny Bereg (Sanko, 1987), *etc*. (Fig. 8).

The materials of research were used as the basis for palynostratigraphic subdivision of these deposits into 10 regional pollen zones (R PAZ mr 1–R PAZ mr 10) (Savchenko, Rylova, 2001).

The process of the vegetation evolution during the Muravian Interglacial is presented below.

R PAZ mr 1 Pinus–Betula–Picea reflects a phase of the high development of mixed birch-pine and pine-birch forests involving *Picea obovata* Ledeb., where the main forest-forming species were *Betula pendula* Roth., *B. pubescens* Ehrh., *Pinus sylvestris* L. *Larix* Mill. and *Juniperus communis* L. were found as an insignificant admixture. The role of herbaceous associations was reduced in comparison with the end of the glacial period. Changes in the vegetation composition indicate the climate warming. The reconstruction of palaeotemperatures showed their variation in the following range: t°VII = +11° …+16.5°C, t°I = –11°…–21.5°C.

R PAZ mr 2 Pinus–Betula–Quercus corresponds to a phase of abundant mixed pine-birch forests with an admixture of deciduous species. An appearance of the first representatives of deciduous species, such as *Quercus robur* L., *Ulmus laevis* Pall., *U. campestris* L., which participation increased even more testifies to the further improvement of climatic conditions. The following palaeotemperatures were obtained for this phase: t°VII = +15° …+21°C, t°I = +6°…–17°C.

R PAZ mr 3 Quercu–Pinus–Corylus reflects a phase of a widespread occurence of deciduous and deciduous-coniferous (oak, oak-elm with participation of pine) forests. *Quercus robur* L., *Q. pubescens* Willd., *Ulmus laevis* Pall., *U. campestris* L., and also *Acer platanoides* L., *Fraxinus excelsior* L., *Pinus sylvestris* L. were revealed there. The composition of forest communities of this phase testifies to an essential increase of the heat supply in this territory: t°VII = +18° …+21°C, t°I = +3°…–4°C.

R PAZ mr 4 Corylus–Quercus–Ulmus corresponds to a phase of deciduous oak and oak-elm forests and hazel, and also to the beginning of a widespread occurrence of alder forests. This was a time when *Ulmus laevis* Pall. and *U. minor* Mill. were most abundant. A characteristic feature of vegetation during this period was a high participation of *Corylus avellana* L. which was maximum for the whole Pleistocene. Alder forests had considerable spreading. As it can be seen from the climagram constructed (Fig. 9), palaeotemperatures varied the following range: t°VII = +18° …+21°C, t°I = +3°…–4°C. When analyzing the climate of the Eemian Interglacial in Western and Central Europe, Zagwijn (1996) noted the maximum summer temperature + 19°C and winter temperature to +3°C. These temperatures fit the range obtained by the authors.

R PAZ mr 5 Tilia–Corylus–Carpinus reflects a phase of deciduous forests where the main forest-forming species was *Tilia cordata* Mill., *T. platyphyllos* Scop., hazel played a considerable part, oak, elm, and at the end of the phase *Carpinus betulus* L. also participated. The role of lime-tree in the composition of forest communities was maximum in the Pleistocene. A widespread occurrence of alder forests and appearance of hornbeam indicate a progressing increase of the climate humidity. For this phase the following palaeotemperature ranges wese obtained: t°VII = +17° …+24°C, t°I = +4.5°…–5°C.

R PAZ mr 6 Carpinus–Tilia corresponds to a phase of a widespread occurence of deciduous hornbeam-lime forests with hazel underbrush and also abundant alder forests. *Carpinus betulus* L., *Tilia cordata* Mill., *T. platyphyllos* Scop. were the main forest-forming species. *Ulmus minor* Mill., *U. laevis* Pall., *Quercus robur* L., *Q. pubescens* Willd, *Acer platanoides* L., *Fraxinus excelsior* L. were associated species. palaeotemperatures changed within the following limits: t°VII = +17° …+21°C, t°I = +3°…–5°C.

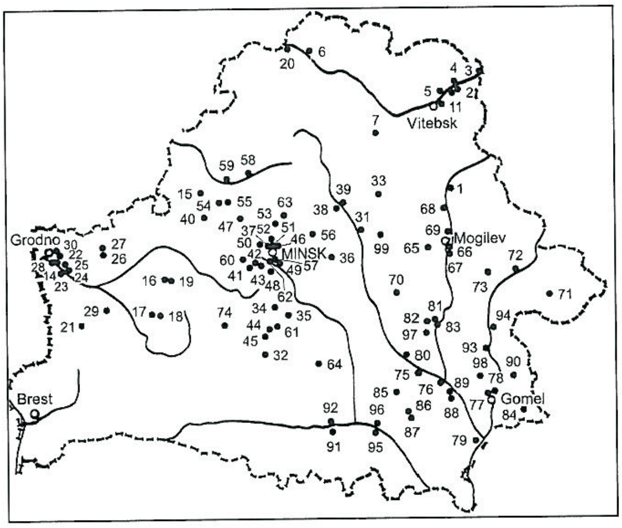

Fig. 8. The map of Muravian Interglacial localities palynologically investigated

1 — Klyuchnikovo; 2 — Chyorny Bereg; 3 — Orlyaki; 4 — Disneninovo; 5 — Gralyovo; 6— Verkhnedvinsk; 7 — Chaschniki; 11 — Avdeevichi–Kashino; 14 — Komotovo; 15 — Karachyovshchina; 16 — Novyye Lagodki; 17, 18 — Serebrishshche; 19 — Timoshkovichi; 20 — Drissa; 21 — Novosady; 22 — Kovaltsy; 23 — Ponemun; 24 — Knyazhevodtsy; 25 — Samostrelniki; 26 — Psyartsy; 27 — Kurki; 28 — Zhukevichi; 29 — Zelva; 30 — Kamenka; 31 — Murava; 32 — Kulaki; 33 — Raditsa; 34 — Zamostye; 35 — Pader; 36 — Gatets; 37 — Aronova Sloboda; 38 — Selitrenniki; 39 — Nemanitsa; 40 — Nareyki; 41 — Gnetki; 42 — Malye Novoselki; 43 — Petkovichi; 44 — Dolgoe; 45 — Shitino; 46 — Nelidovichi; 47 — Zatemen; 48 — Morkovichi; 49 — Machulishchi; 50 — Zaslavl; 51 — Borovlyany; 52 — Vishnyovka; 53 — Kovshovo; 54 — Sovlovo; 55 — Molodechno; 56 — Yalovitsa; 57 — Goncharovka; 58 — Tereshki; 59 — Porsy — Makovoe; 60 — Latushki; 61 — Gorokhovka; 62 — Tarasovo; 63 — Kuzevichi; 64 — Kuzmichi; 65 — Dosovichi; 66 — Grebenyovo; 67 — Polna; 68 — Maloe Ulanovo; 69 — Staraya Vodva; 70 — Novye Maksimovichi; 71 — Kolodezskaya; 72 — Cherikov; 73 — Azarichi; 74 — Leonovichi-Kukovichi; 75 — Svetlogorsk; 76 — Boroviki; 77 — Mostishche; 78 — Pokalyubichi; 79 — Loev; 80 — Pekalichi; 81 — Vitsin-Madory; 82 — Rogacheov; 83 — Zborovo; 84 — Bereznyaki; 85 — Lyuban; 86 — Vedrech; 87 — Prudishchye; 88 — Zhary; 89 — Borkhov; 90 — Glukhovka; 91 — Lyaskovichi; 92 Doroshevichi; 93 — Berdyzh; 94 — Litvinovichi; 95 — Drozdy; 96 — Mozyr; 97 — Lebedevka; 98 — b 6276; 99 — Chernoosovo

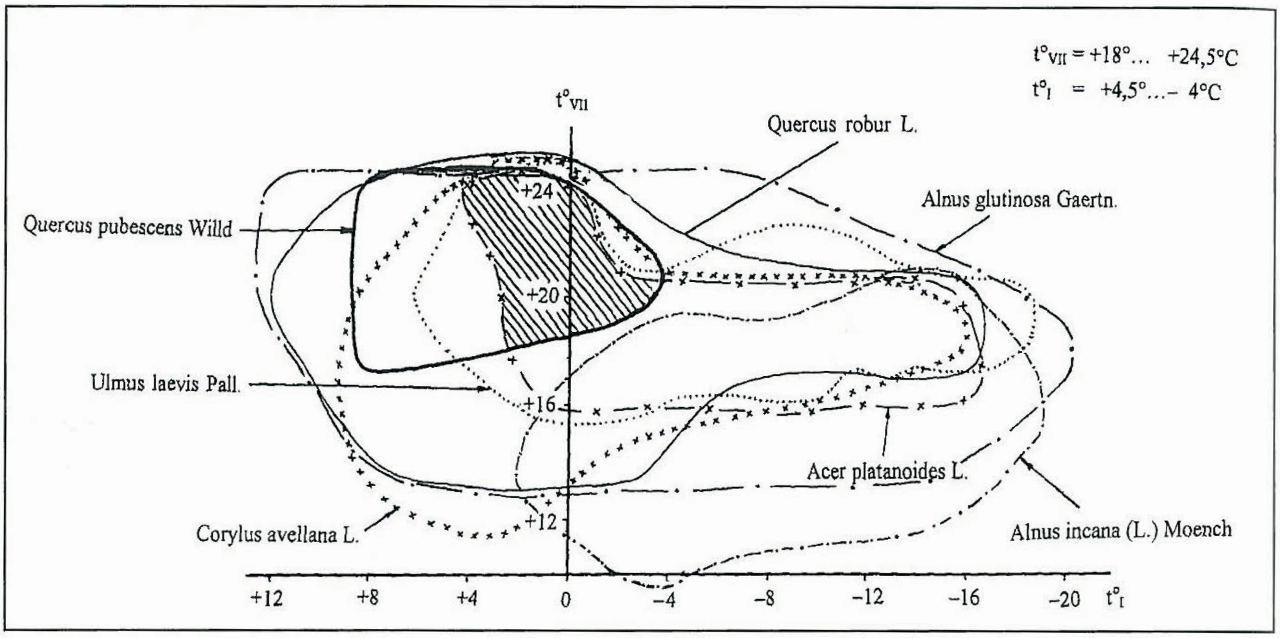

Fig. 9. Climatogram for the climatic optimum of the Alexandrian Interglacial (R PAZ mr 4 Corylus–Quercus–Ulmus)

R PAZ mr 7 Carpinus–Picea reflects a phase of expansion of hornbeam and hornbeam-spruce forests with hazel in the underbrush and with an admixture of oak and elm, as well as alder forests. A change of vegetative associations with an increased participation of *Picea abies* (L). Karst. testifies to the climate cooling: t°VII = +13.5° …+19°C, t°I = +0.5°…–16°C.

R PAZ mr 8 Picea–Pinus corresponds to a phase of a widespread occurence of coniferous, predominantly spruce forests involving pine and birch. The main forest-forming species was *Picea abies* (L.) Karst. With a continuous participation of *Pinus sylvestris* L., *Betula pendula* Roth. and *B. pubescens* Ehrh. were found more seldom. Disappearance of thermophilous species indicates further climate cooling: t°VII = +13.5° …+19°C, t°I = +0.5°…–16°C.

R PAZ mr 9 Pinus reflects a phase of abundant coniferous-pine forests with a small participation of spruce and birch and testifies to a steady decrease the heat supply in the territory. The poor pollen flora composition has allowed only anapproximate estimate of palaeotemperature ranges: t°VII = +11.5° …+20.5°C, t°I = +0.5°…–16°C.

R PAZ mr 10 Betula corresponds to a phase of a widespread occurence of birch forests with an admixture of coniferous species. The main forest-forming species were *Betula pendula* Roth.., *B. pubescens* Ehrh. With a continuous participation of *Pinus sylvestris* L., *Picea abies* (L). Karst., *Juniperus, Salix* were met too. At that time the role of herbaceous vegetation increased, and wood massifs became to be reduced.

Palynological data suggest that the development of vegetation and climatic changes during the Muravian Interglacial proceeded similar by in the neighbouring territories: in the Mikulino Interglacial of Russia (Grichuk, 1961, 1989, *etc.*), in the Miarkin Interglacial of Lithuania: sections Yonenis, Niatesos, *etc.* (Kondratene, 1996), in the Eemian Interglacial of Poland: sections in Warsaw (Krupiński, 1988); Imbramowice (Mamakowa, 1989); Ostrowia (Klatkowa, Winter, 1990); Horoszki Duże (Granoszewski, 2003), *etc.*, in the Eemian Interglacial of Germany: sections of Kittlitz Niederlausitz (Erd, 1973), Oerel Oe 61 (Behre, 1989), Gröbern (Litt, 1990), Quakenbrück (Hahne *et al.*, 1994), *etc.*, and also in the Netherlandes: section of Amersfoort (Cleveringa *et al.*, 2000), *etc.*

FINAL REMARKS

A possibility of correlation of the main phases of vegetation evolution in interglacial intervals of the Pleistocene in the territory of Belarus and the neighbouring regions testifies that natural processes in the territory of Western and Eastern Europe proceeded similarly.

An analysis of palynological materials has described a specific character of flora and vegetation in the Belovezhian, Mogilevian, Alexandrian and Muravian interglacials, and also of the palaeotemperature changes during chronologically successive phases in the development of flora and vegetation of every interglacial interval.

Palaeoclimatical parameters obtained for different interglacials are graphically presented on Figure 10. Their comparison allows a conclusion that mean temperatures of the warmest and coldest months were highest and similar to each other during the climatic optima of the Belovezhian and

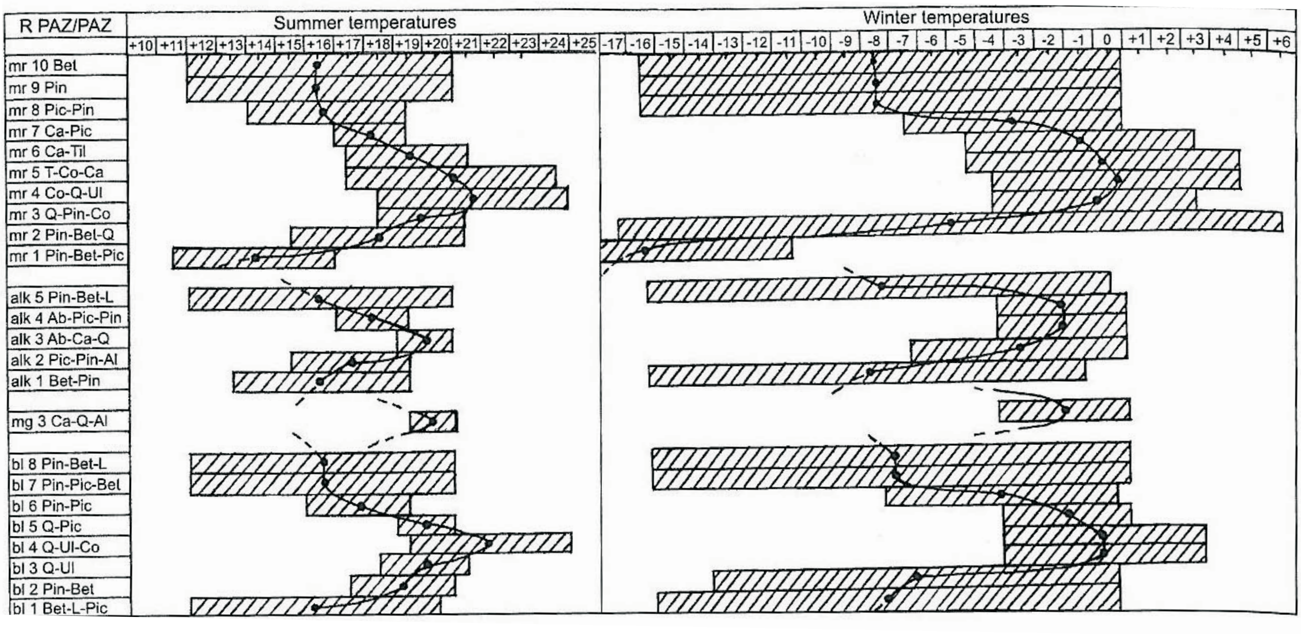

Fig. 10. The summer (July) and winter (January) palaeotemperatures of the interglacial intervals of the Pleistocene of Belarus

Muravian interglacials. The Mogilevian and Alexandrian interglacials were also similar in palaeotemperature parameters, but cooler than those mentioned above.

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