Introduction

Reactions of various components of the Pleistocene environment to multiple climatic changes are a global phenomenon. Because all elements of the landscape geosphere are closely interrelated, certain individual parameters of each element provide a potential source of qualitative assessment of all the remaining parameters, and of the entire environment. The source of evidence concerning the pattern of their temporal changes is marine and continental deposition sedimentation under various regimes.

Most of the paleoenvironmental records of the Quaternary, however, are limited in the degree of age control. Absolute dates are normally available for the latest time intervals lying within the range of the radiocarbon dating method (ca 30 ka and later). Earlier paleogeographical events are mostly dated indirectly, by their comparison with the deep-sea isotope record. The chronological scale of the latter was calibrated for age by the orbital tuning method (Imbrie et al., 1984) using the periodicity established by means of astronomical calculations that have yielded chronological ranges for the key levels of isotope curves.

Regrettably, the interpretation of isotope data is not always unequivocal, mostly due to the interruption of sedimentation, insufficient stratigraphic resolution, bioturbation, hypergenesis of sediments, and other factors which may create problems with the correlation between the continental and deep-sea records. Despite that, the oxygen isotope analysis of deep-sea sediments provides a rather complete record of climatic changes that occurred during the Quaternary, and it is still one of the most powerful tools for correlating and reconstructing paleoenvironments.

Among the Pleistocene continental generations, which are geologically no less complete than oceanic sediments, is the loess-paleosol formation (LPF). Unlike the glacial, alluvial, and other Late Cenozoic formations of North Eurasia, LPF is characterized by almost uninterrupted sections which, in various regions of its distribution area, are represented by sediments of one, two, or all stages of the Pleistocene. Their thickness in the southern East European Plain and in western Central Asia can be 100 m and more.

The most promising method used for climato-stratigraphic subdivision of the sediments and the periodization of paleoclimatic events of the Pleistocene is pollen analysis. Thanks to a detailed palynological study of reference sections of the most
characteristic loess regions, an uninterrupted succession of Late Cenozoic interglacial and glacial landscape-climatic sequences was reconstructed for the first time. These reconstructions reflect global climatic changes that occurred in various natural environments and evidently should have correlatives in paleoclimatic records of deep-sea sediments.

However, a meaningful interpretation of the results of LPF and a resolution of issues concerning the correlation of paleogeographical events in the glacial-periglacial and extraglacial continental zones with global climatic rhythms and fluctuations of the World Ocean level requires a reliable chronostratigraphic binding of identified paleoclimatic events with respective horizons. It is essential that relationships between independent climate-response records such as long continental pollen sequence and the global deep-sea oxygen isotope record, should be established using a combination of independent control levels such as dated horizons reflecting global environmental changes.

In coastal sediments, subfossil mollusk shells are frequently found. Here, because of the postglacial isostatic rise of the crust, they occur in formations now lying above the present sea level. The dating of these marine fossils provides an independent chronology of changes in the sea level and deglaciations. Considering the difficulties with establishing dates beyond the range available for the radiocarbon method, and the fact that the electron spin resonance (ESR) method enables one to establish the age of the shells not only of marine mollusks (Molodkov, 1988) but also of land and freshwater ones (Molodkov, 1993), the chronostratigraphy based on the ESR analysis of shells is a powerful tool for establishing direct sea-land correlations. The present study focuses on the palyno-chronostratigraphic reconstruction and correlation of Pleistocene climatic events using original pollen data concerning the loess-paleosol formation (Bolikhovskaya's 1967 – 2001 studies) and ESR-chronostratigraphy of marine and freshwater sediments as well as cave site deposits dating from the Stone Age (Molodkov's 1982 – 2001 studies).

**Methods**

The palynological analysis used in this study is of wide application employed in modern stratigrapho-paleogeographical research aimed at reconstructing landscape-climatic conditions of sedimentation, the assessment of the stratigraphic position of sediments, and carrying out intra-regional and interregional correlations of geological bodies and paleogeographical events. The key role of palynology in paleobotanical studies is mainly because pollen and spores of higher plants are the only important objects from the standpoint of both paleobotany and paleontology since they are present in deposits of all lithogenetic types. Thanks to that, pollen data make it possible to characterize all stages of Pleistocene sedimentation and reconstruct an uninterrupted succession of changes in fauna, vegetation, and climate within each stage. With regard to paleogeography of the loess-paleosol formation, this is the only climato-stratigraphic method capable of reconstructing landscape-climatic environments not only for the soil-formation periods, but for the loess-accumulation stages as well.

At present, results of palynological studies of reference sections of the glacial-periglacial and extraglacial zones, reflecting the succession of vegetation following changes of moisture and heat supply in the Pleistocene, yield the most complete record of climatic conditions on the land. The structure of this record can be directly compared with the climate-dependent curve of oxygen isotope of deep-sea sediments (Shackleton, Opdyke, 1973; Bassinot et al., 1994) and that of land formations (Winograd et al., 1992). However, here too, as in the case of any spatio-temporal comparison of paleogeographical events in Earth's geological history, it may be asked whether these correlations are chronologically reliable, especially considering the current controversy regarding the climatic periodization of the Late Cenozoic. Ideally, any stratigraphic study and the subsequent correlation of strata and events must be accompanied by establishing the absolute age of relevant deposits. Actually, however, because the available methods of absolute geochronology are few or inapplicable to the specific time range or to the specific objects, and due to other reasons as well, this condition is not frequently met. As a reasonable alternative, one can consider the possibility of establishing a temporal correspondence of climatic signals in various paleoenvironmental records, e.g., in terrestrial deposits and deep-sea sediments, by comparing these signals with the chronostratigraphic succession of geological bodies containing information about the changes of climatic conditions and environments.

Objects which appear to be among the most suitable for this task are uplifted marine deposits of the northern fringes of the Eurasian continent, where drastic changes of environments followed recurring glaciations and transgressions of the Polar Basin under the global warming. The application of the new version of the ESR method for dating mollusk skeletal remains introduced by one of the present authors (Molodkov, 1988, 1989a,b, 1992, 1993), has opened
up new possibilities for using fauna-bearing deposits of raised marine horizons in the geohistorical periodization of paleoclimatic events in the Quaternary history of continental fringes, and their correlation with highly diverse materials concerning loess-soil series and deep-sea sediments.

The ESR-dating of subfossil mollusk shells is based on the direct measurement of the amount of radiation-induced paramagnetic centers (carbonate centers) that have been created in shell substance due to natural radiation. The concentration of these defects is proportional to the paleodose accumulated over the relevant period. Their formation in the shell substance is caused by natural radiation resulting from radioactivity in the shell itself and from the environment (embedding matrix and cosmic). The intensity of the observed ESR signal is correlated with the number of radiation-induced defects and, consequently, with the accumulated paleodose and with the age of the shell. The latter may be considered synchronous with the enclosing deposits.

The age of the shells is evaluated using the ratio of the accumulated paleodose (measured by means of the ESR analysis of the shell substance) to the total intensity of alpha and beta particle flux as well as that of gamma quanta and cosmic radiation. The version of ESR method used in this study enables one to estimate the age of shells within the range of several hundred to about a million years.

Concerning the correlation of Pleistocene events, the ESR dating method is highly promising because it allows the use of subfossil mollusk shells (the most frequent and widespread group of paleo faunistic remains in Pleistocene deposits) in determining the ages of many geological formations of the Pleistocene, quite diverse in origin, such as marine and paleolacustrine sediments, loesses, paleosols, glacial lacustrine loam, cave deposits, archaeological sites, etc. ESR analysis of shells provides a basis for a detailed chronostratigraphic binding and for an inter-regional correlation of fauna-bearing deposits belonging to different facies.

**Objects and regions studied**

The objects chosen for the reconstruction of a continuous paleogeographical record of the Pleistocene are reference sections of the central and southern areas of the East European Plain (Fig. 1). Due to the repeated development of continental ice sheets, permafrost, and loess formation, as well as to the transgressions and regressions of the southern seas in the Pleistocene, this territory is one of the key areas of North Eurasia where the establishment of the climatic stratigraphy of deposits and the periodization of paleoclimatic events over the past 800 ka have proved successful.

**The East Caucasian Piedmont** is one of the most distant loess areas from the continental ice sheet. It is here that the largest profiles of the European LPF are situated. A comprehensive study into the Pleistocene subaerial, deluvial-proluvial, and alluvial deposits, the total depth of which is 140 m, was carried out by N.S. Bolikhovskaya, A.A. Velichko, E.I. Virina, A.K. Markova, T.D. Morozova, V.P. Udartsev, and others, using bore-holes and outcrops near Otkaznoe. Changes of landscape-climatic conditions over all the 15 interglacial and glacial events of the Brunhes chron were reconstructed (Bolikhovskaya, 1995) (Fig. 2, A). Judging by palynological data, the Matuyama-Brunhes reversal is situated in the upper part of the Pokrovka deposits.

**The Oka-Don glacial-periglacial region** occupies the respective plain and the eastern fringes of the Central Russian Upland within the area of the Don glacial till. Here, near Strelitsa (20 km west of Voronezh) on the watershed and the adjoining slope, Neogene-Pleistocene deposits, over 60 m in total thickness, were revealed by quarries. Their comprehensive study was carried out by A.K. Agadjanian, N.S. Bolikhovskaya, A.A. Velichko, E.I. Virina, E.P. Zarrina, I.I. Krasnov, T.D. Morozova, V.P. Udartsev, and others. The results of the palynological analysis obtained on subaerial, alluvial, lacustrine, and fluvioglacial formations underlying and overlying the Don glacial till have made it possible to reconstruct the vegetation and climate of all the interglacial and glacial stages over the past 780 ka (Ibid.) (Fig. 2, B). No less important are the data concerning the loess-paleosol series (LPS) underlying the till and overlying the red-coloured soil. LPS is represented here by two paleosols separated by a horizon of loess-like loam. LPS pollen spectra reflect the successions of vegetation and climate of two interglacial events and an intermediate cooling. Based on a comparison of these climato-phytocoenotic reconstructions with paleogeographical materials from Novotroitskoe, Petropavlovka, Otkaznoe, and other sections, the Strelitsa LPS corresponds to the II'inka horizon of the inter-regional scale. Since the first representative paleobotanical data that allowed a climatostratigraphic subdivision of II'inka deposits came from the Strelitsa section, it was proposed to describe the early II'inka interglacial as Gremyachie, the late II'inka interglacial as Semiluki, and the cooling event separating them as Devitsa, after the respective toponyms (the Devitsa is a river, and Gremyachie and Semiluki are villages) (Bolikhovskaya, 1994a).
The Northern Central Russian glacial-periglacial region is situated in the northern part of the Central Russian Upland within the area of the Dnieper ice sheet. Here, the composition and structure of Quaternary deposits and most paleogeographical events of the Pleistocene are reflected by the Likhvin section situated on the left bank of the Oka River, 1 km north of Chekalin (formerly Likhvin). The section is a stratotype of the Likhvin interglacial of East Europe. Results of its comprehensive study were published by N.N. Bogolyubov, V.N. Sukachev, V.P. Grichuk, K.A. Ushko, E.N. Ananova, A.K. Agadjanian, N.S. Bolikhovskaya, N.I. Glushankova, N.G. Sudakova, etc. An outcrop, stretching over 2 km along the river, as well as additional trenches and bore-holes reveal a 50-meter-thick succession of loess-paleosol, glacial (till and lacustrine-glacial), alluvial, and lacustrine sediments. The palynological characteristics of the entire succession of the deposits have made it possible to establish their detailed stratigraphic subdivision and reconstruct a vast diversity of landscape and climatic changes that occurred on the Upper Oka from the Don glacial to the Holocene. New findings shed light on the interglacial/glacial status of the Oka-Dnieper warm and cold intervals that were previously merged into a long and complex formation referred to by us as "Macro-Likhvin" (Bolikhovskaya, 1975). The section, then, is a stratotype of not just the Likhvin s. str. interglacial, but of subsequent pre-Dnieper intervals including the Kaluga glacial (cooling), Chekalin interglacial, Zhizdra glacial (cooling), and Cherepet interglacial. To coordinate these with the interregional scale, it was suggested to merge the Oka-Dnieper thermo- and cryochrons into the Likhvin complex regarding it as a superhorizon (Bolikhovskaya, 1994b).

The most detailed studies of Late Pleistocene loess-paleosol horizons were carried out in two regions. One is the Desna-Dnieper glacial-periglacial region situated in the northeastern Dnieper Lowland within the area of the Dnieper glacial. Here, in the Arapovichi section on the right bank of the Desna River, 12 km southwest of Novgorod-Seversky,
Fig. 2. Lithology of loess-paleosol sections at Otkaznoe (A) and Strelitsa (B) with climatostratigraphic subdivision and reconstruction of vegetation and climate using palynological data (after Bolikhovskaya, 1995).

The East Caucasian Piedmont region (A): 1 – periglacial semi-deserts and dry steppes; 2 – periglacial steppes; 3 – periglacial forest-steppes; 4 – birch and coniferous-birch open woodlands; 5 – extraglacial forest-steppes; 6 – extraglacial birch open woodlands; 7 – extraglacial spruce and cedar- spruce forests; 8 – birch open woodlands with broad-leaved tree species; 9 – birch forests with broad-leaved tree species; 10 – coniferous-birch and birch-coniferous forests with broad-leaved tree species; 11 – forest-steppes; 12 – steppes; 13 – piedmont forest-steppes; 14 – shrub hornbeam groves; 15 – elm-oak, oak, and hornbeam-oak forests; 16 – hornbeam forests; 17 – oligo- and polymonodominant broad-leaved forests; 18 – polymonodominant broad-leaved forests with subtropical taxa.

the Dnieper till is overlain by 14-meter-thick Late Pleistocene loesses and paleosols. The pollen spectra of this formation characterize the successions of vegetation and climate of the Mikulino interglacial and of most Valdai interstadials and stadials. In the extraglacial zone, a detailed subdivision of Late Pleistocene horizons and landscape-climatic reconstructions were carried out for the Middle Dniester drainage basin belonging to the Dniester-Prut region. Here, the most representative Late Pleistocene formations were revealed by sections of the second flood-plain terrace of the Dniester composed of 10-meter-thick alluvial sediments, and a more than 25-meter-thick loess aeolian-deluvial formations with eight paleosols. It is on the second Dniester flood-plain terrace that the well-known Paleolithic sites are situated. Based on the data from Molodova I and V, Korman IV, Ketrosy, and other sections studied by I.K. Ivanova, A.P. Chernysh, A.K. Agadjanian, N.K. Anisyutkin, S.V. Gubin, N.V. Rengarten, and others, and on the results of pollen analysis (Pashkevich, 1977; Bolikhovskaya, 1981, 1982, 1987), stages of vegetation and climate development of the Mikulino interglacial as well as those of 19 Valdai intervals (9 interstadials and 10 stadials) were characterized.

A radiometrically based proxy record of climate and sea level changes over the past 600 ka was obtained using more than 230 mollusk shell samples collected mostly from climate-controlled marine sediments along the continental fringes of North Eurasia (see Fig. 1). The shells were dated using the ESR method to produce an independent mollusk-based chronology for multiply marine transgression (relatively high sea-level stands) during which large epicontinental basins occupied vast territories of North Eurasia coast. Some high sea-level evidence has also been obtained from sites in the Caspian and Black Sea basins. In addition, dating results on freshwater mollusk shell samples from interglacial lacustrine deposits in the Southern Baltic and terrestrial mollusk fossils from a Lower Paleolithic culture-bearing deposits in the Northern Caucasus have also been used.

Climato-stratigraphic subdivision of Pleistocene deposits of the glacial-periglacial, and extraglacial zones of the East European Plain

At present, various versions of correlating the principal stages of LPF evolution with stratigraphic subdivisions of the oxygen isotope scale of deep marine and oceanic sediments have been developed (Peci, 1993; Veklich, 1995; etc.). However, they cannot be accepted without certain reservations. The survey of scholarship reveals that due to the lack of representative pollen data nearly all modern researchers firmly adhere to an erroneous belief that throughout Eurasia loesses correspond to glacial and paleosols to interglacials or interstadials (Veklich, 1982; Velichko et al., 1984, 1989; Kukla, 1987; Maruszczak, 1986; Peci, 1993; Dodonov, 2001). This view is disproved by the results of paleobotanical, microtheriological, and palynological analyses of loess-paleosol sections (Pashkevich, 1977; Bolikhovskaya, 1982, 1987, 1993, 1995; Velichko, Morozova, 1982; Markova, 1982).

Based on extensive original and literary data incorporating the results of palynological and complex analyses of Pleistocene sections representing various natural historical regions, their climato-stratigraphic subdivision was carried out, and detailed landscape-climatic and lithofacial reconstructions were made, providing a possibility to trace the successions of flora and climate within each warm and cool stage over the past 800 ka (Bolikhovskaya, 1995, 1996). Thanks to these studies, it became possible to specify relationships between lithostratigraphic and climatostratigraphic subdivisions of LPF. It became evident that borders between loesses and paleosols do not necessarily coincide with borders of glacial and interglacial climatic rhythms; that the paleosol may correspond to just one stage of the interglacial rhythm rather than to the entire interglacial; and that loes or a loess-like substance may have formed during endothermal coolings within the interglacials (or during the thermoxerotic stages of interglacials in the southernmost loess regions) rather than under the glacial climate alone. The idea that loes is a solely glacial formation holds for the central East European Plain only, according to Likhvin (the Upper Oka), and Streltisa (the Upper Don) sections. Palynospectra of Arapovich, the Middle Desna, Molodova, the Middle Dniester, Otkaznoe, the Middle Kuma,
etc., demonstrate that the accumulation of loess horizons in the southern East European Plain occurred not only during the glacial, but during the thermosteric and endothermal coolings within the interglacials as well. Paleosols formed here during the interglacials and interstadials as well as during the cryohygrotic stages of glacials.

The integration of results of a detailed palynological analysis and those of comprehensive research into reference sections of the glacial-periglacial and extraglacial zones has enabled Bolikhovskaya (1995), who accepted the inter-regional scale of the East European Platform and the scheme elaborated at the Institute of Geology (IG) of the Russian Academy of Sciences (Moscow) as a basis, to carry out a detailed climatostratigraphic subdivision of LPF, specify regional stratigraphic schemes for certain loess regions as well as interglacial and glacial climatic rhythms within the Brunhes chron, and assess the correct position of the Matuyama-Brunhes paleomagnetic reversal on the climatostratigraphic scale of the Pleistocene.

It was demonstrated that environmental changes on the East European Plain in the Pleistocene were caused by the successions of 17 global climatic events: nine interglacials separated by eight glacial or coolings having a glacial rank (Table 1). Fourteen successive interglacial and glacial stages in the formation of loess, loess-like deposits, paleosols, and paragenetically related glacial, alluvial, lacustrine, and other deposits within the Middle Pleistocene, were shown to be correlated with glacial and interglacial paleogeographical events of the West European schemes: Petrovlovskaya interglacial (Interglacial I, Waardenburgian, Osterholzian), Pokrovka cooling (Glacial A), Greymarche interglacial (Early Il'inka, Interglacial II, Westerhovenian, Harreskovian), Devitsa cooling (Middle Il'inka, Glacial B, Unstratian), Semiluki interglacial (Late Il'inka, Interglacial III, Rosmalen, Arternian), Don glacial (Glacial C), Muchkap interglacial (Belovezhsk, Interglacial IV, Noordergumian, Voigtstedtian), Oka glacial (Elsterian), Likhvin s. str. interglacial (Holsteinian), Kaluga cooling (Borisoglebsk, Fuhne), Chekalin interglacial (Kamenka, Dömnitzian), Zhizdra glacial (Orchik, Drenthe), Berep interglacial (Romny, Drenthe/Warthe), and Dnieper glacial (Saalian). Mikulino interglacial (Eemian), and Valdai glacial (Weichselian), the latter consisting of at least 19 warmings and coolings of an interstadial/stadial rank, and the ongoing Holocene interglacial are the main stages in the evolution of landscapes and climate of the loess regions during the Late Pleistocene and Holocene. Due to the absence of representative paleobotanical characteristics that would support the limits of the reconstructed interglacial and glacial epochs in the stratotypes of Borisoglebsk, Kamenka, Orchik, and Romny horizons, according to IG scheme, or strata of the loess-paleosol formation characterizing the subdivisions within Il'inka, synchronous stages were named after the sections where they were revealed not only by a complex analysis but also by means of a detailed palynological characteristics which made it possible to specify these limits.

A comparative analysis of climatic rhythms reconstructed on the basis of pollen data and the results of paleomagnetic studies carried out in various parts of the Eastern European loess province indicate that the Brunhes chron encompasses eight interglacials separated by seven glacial periods. A reconstruction of a continuous succession of interglacial and glacial events has made it possible to specify the position of the Matuyama-Brunhes reversal within the system of Pleistocene climatic rhythms: it is situated between the eighth interglacial and eighth glacial, counting from the present. In Strelitsa, Otkaznoe, Liventsovka, and Margaritovka sections (the last two are in the northeastern Azov region) the Matuyama-Brunhes reversal marks the transition from Pokrovka glacial to Greymarche interglacial horizon.

Reconstruction of paleoclimatic events

The most important paleogeographical events reconstructed by means of the palynological analysis of Pleistocene deposits of the East European Plain include global climatic fluctuations manifested in successions of interglacial and glacial rhythms, and regional environmental changes induced by them: floristic and phytocoenotic successions, transgressive and regressive fluctuations of the level of marginal and inland sea basins, change of facial conditions of the continental sedimentation resulting in the formation of till horizons in the glacial zone, and in lithological phenomena such as loesses and thick paleosol complexes in the glacial-periglacial and extraglacial zones. In the present article, chronostratigraphic schemes and thorough correlations of reconstructed paleoclimatic events are supported by the results of climatostratigraphic subdivision of Pleistocene deposits of the southern part of the East European Plain based on their detailed palynological and complex paleogeographical study and by the ESR determination of the absolute age of fauna-bearing deposits of uplifted marine horizons as well as other geological formations associated with climatic warming.
Table 1. Comparison of stratigraphic subdivisions of periodization schemes for loesses and paleosols of the East European Plain

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<td>Late</td>
<td>Holocene interglacial IV</td>
<td>Holocene soil</td>
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<td>Valdai glacial horizon</td>
<td>Valdai glacial IIIv</td>
<td>42</td>
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<td>Mikulino interglacial horizon</td>
<td>Mikulino interglacial III mk</td>
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<td>Central Russian glacial horizon</td>
<td>Dnieper glacial II dn</td>
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<td>Likhvin interglacial superhorizon</td>
<td>Cherepet' interglacial II chr</td>
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<td>Zhizdra interglacial II zh</td>
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<td>Chekalin interglacial II ch</td>
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<td>Kaluga glacial II kl</td>
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<td>Likhvin interglacial</td>
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<td>Oka glacial horizon</td>
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<td>Don glacial I dns</td>
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<td>II'inka interglacial superhorizon</td>
<td>Semiluki (Late II'inka) interglacial I sm</td>
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<td>Devitsa (Middle II'inka) glacial I dv</td>
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<td>Gremyachie (Early II'inka) interglacial I gr</td>
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<td>Pokrovka glacial horizon</td>
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<td>Petropavlovka interglacial horizon</td>
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In the East European Plain, like in other continental regions of North Eurasia, climatostratigraphic schemes for the earliest stage of the Pleistocene are the most controversial. Specifically, while the Oka-Don region is the best studied using the entire set of paleogeographical techniques, the subdivision of deposits underlying the Don glacial till is far from complete. This is evidenced by discrepancies between the researchers’ views regarding the structure and age of subaerial formations underlying the till in the Upper Don basin (Velichko et al., 1984; Krasnoknev et al., 1993; etc.). The main reason for the controversy is the impossibility to assess the climatostratigraphic rank of each loess and paleosol horizons as well as the borders of estimated climatochrons based on lithofacial features of deposits and numerous but scattered faunal data alone. These paleoclimatic reconstructions were hampered by the absence of stratum-by-stratum palynological characteristics for most sections in which paleofaunal remains were found and the Matuyama-Brunhes reversal, dated at 780 ka, was pinpointed. To make up for this blank, a comprehensive study of Otkaznoe, Strelitsa and Lower Don sections had to be undertaken.

**Petropavlovka interglacial and Pokrovka cooling.**
Landscape-climatic conditions of these intervals were reconstructed by us using the results of a complex analysis of deposits of Liventsova section on the right bank of the Don near the western fringes of Rostov-na-Donu (Razrez..., 1976). Here, the Sarmatian limestones underlie the Pliocene alluvial-delta deposits which, according to V.I. Gromov, A.K. Agadjanian, L.I. Alekseeva, V.S. Baygusheva, and others, contain remains of large mammals of the Khapry faunal assemblage and late Khapry small mammal fauna. Above, there are Early Pleistocene alluvial sediments and Early Pleistocene – Early Middle Pleistocene gray Scythian clays with two horizons of red-brown paleosols. The upper part of the section consists of loess-like loams overlaid by the modern chernozem. Nearly all strata have a reverse magnetization. The Matuyama-Brunhes reversal was discovered by E.I. Virina and S.S. Faustov in the upper part of the red-colored soil overlying the Scythian clays at the depth of 1.6 m. Using the results of the palynological analysis carried out by M.P. Grichuk and G.M. Shumova, we performed a climatostratigraphic subdivision of the section.

During the Petropavlovka thermochron, the lower red-colored soil formed as well the lower part of the overlying gray Scythian clays. The principal role in the automorphous landscapes of the Lower Don at that time was played by elm, hornbeam, and oak woodland, whereas less favorable habitats were occupied by pine, cedar, fir, spruce, and birch forests. During the Pokrovka cooling, periglacial steppes dominated most East European loess regions. In the Liventsova section, this is reflected in palynospectra of the upper part of the gray clays and horizon B of the upper red-colored soil, suggesting that in the Upper Don area, this was the time when the predominant landscapes were periglacial tundras and forest-steppes with mostly dwarf birch woodlands that included Betula fruticosa, Alnaster fruticosus, and Salix sp., as well as coniferous-birch open woodlands and steppe biotopes.

**Il’inka period.** The climatic rhythmicities of the Il’inka horizon of the inter-regional scale, according to palynological data, correspond to two interglacials separated by a cooling. In most loess regions of East Europe, the predominant landscape during these interglacials was forest-steppe with an arid summer and a moist winter. A long and complex Il’inka interval (ca 780 – 660 ka) was characterized in detail based on sections in the Upper Don and Middle Kuma basins. In Strelitsa, it corresponds to a loess-paleosol series overlying the red-colored soils of Early Pleistocene and underlying the till. It is represented by two paleosols separated by a loess-like sandy loam. The lower soil of this series formed during the Gremyachie (Early Il’inka) period in the interglacial steppes and forest steppes. During the Devitsa (Middle Il’inka) cooling, a loess-like horizon separating the soils formed, as well as the parent rock of the alluvial horizon B and the lower strata of humus-accumulative horizon A1 of the upper soil. The larger part of the thick humic horizon of the upper soil, the roof of which was cut off probably by the Don till, formed during the Semiluki (Late Il’inka) thermochron.

**The Don glacial period.** At Strelitsa, the Upper Don basin, the Don glacial assemblage is represented by the following horizons, listed from bottom to top: grayish-black till, gray and yellowish-brown sands, grayish-green and brick-red till, and fluvio-glacial sands. The accumulation of most sands separating the tills occurred in the periglacial tundras. Periglacial-steppe coenoses reconstructed for the sedimentation period of the lower part of these sands reflect the vegetation of the Middle Don interstadial. In Likhvin, during the Don cryochron, lacustrine-glacial sediments were accumulating, evidenced by the predominance of cryophytes in pollen spectra.

The Don glacial (ca 660 – 610 ka) we associated with the oxygen-isotope stage (OIS) 16. During its climatic pessimum, periglacial tundras and forest-tundras dominated in the glacial-periglacial zone in the Upper Oka and Upper Don drainage basins, periglacial forest-steppes and steppes spread over
extraglacial areas of the Dnieper Lowland; and open coniferous and birch forests with cold-tolerant dwarf shrubs (yernik) occupied the East Caucasian piedmonts (Bolikhovskaya, 1995).

**Muchkap (Belovezhsk) interglacial.** Based on ESR data, the formation of this global warming dates to 610 – 535 ka. Using fauna-bearing marine sediments of that period, ESR-dates were obtained on shell sample from the Novosibirsk Islands and Severnaya Zemlya in the Arctic (555 – 550 ka) (Molodkov et al., 1992), and on the Taymyr Peninsula (535.5 ka) (Bolshiyyanov, Molodkov, 1999). With regard to the reconstruction of paleoclimate and the periodization of the final Early Middle Pleistocene, chronostratigraphic studies of Treugol’naya Cave in the North Caucasus, the most ancient Early Acheulean cave-site in the Russian Federation, discovered in 1986 by L.V. Golovanova and V.B. Doronichev, are highly important (Molodkov, 2001).

The cave is situated on the northern slope of the Greater Caucasus, in the Urup River basin at approximately 43°54’ North 41°12’ East at an absolute height of ca 1510 m above sea level in the zone of a periodical development of mountain-valley glaciations, as evidenced by the lithostratigraphy of the cave and by the alternation of cultural levels with sterile ones. The latter may be indicative of the time when man left the cave shelter. It might have been due to a remarkable cooling of the climate during which the mountain glaciation developed and the altitude of the snow line fell well below the cave bottom.

The deposits of the cave reference section (Fig. 3) are divided into 14 lithological layers some of which can be further subdivided. According to faunal, lithological, and archaeological data, the cave deposits cover the time span from the Günz-Mindel (layers 7 and 6) to the Holocene (layers 2 and 1). All stratigraphic levels of the cave formed during the Brunhes chron (Pospelova et al., 1996) and therefore should not be older than 780 ka. Layers 7a, 5a, 5b, 4a, and 4b contain Early Acheulean stone industries, layers 7b and 6 are archaeologically sterile, and layer 8 is the bottom of the cave (Doronichev, 1991). Cultural layers 7a and 5b were dated with the ESR method using the abundant samples of land mollusk remains. The mean age of layer 7a is 583 ± 25 ka, and that of 5b, 393 ± 27 ka (Molodkov, 2001), making it possible to relate the first cultural layer of the cave and the first appearance of Acheulean man in it to the beginning of the “warm” stage 15. It is quite likely that humans crossed the Greater Caucasian range at approximately the same time, when the total area of mountain glaciers decreased considerably. Layer 6, which is archaeologically sterile, could have formed around 500 ka, when, following the advance of glaciers, considerable downward shift of mountain landscape belts, and a dramatic decrease of territories suitable for human settlement, ancient people moved to piedmont valleys and southern regions of the East European Plain. The subsequent improvement of climate and the shift to the interglacial environment may have resulted in further migration of man into the plain. This is evidenced by finds from the Early Acheulean sites in the Lower Don area (Mikhajlovskoe, Khryaschehi) and in the northern Azov coast (Gerasimovka): lithic tools accompanied by remains of mammals of the Tiraspol fauna complex and mollusks of the Baku period (Paleolit..., 1984).

According to palynological evidence, during the climatic optimum of the Muchkap interglacial, most of the East European loess province was dominated by coniferous deciduous forests with some Neogene exotes, and the Caucasian piedmonts were mostly covered by polydominant broad-leaved forests consisting of Carpinus, Fagus, Carya, Pterocarya, Liquidambar, Juglans, Castanea, and other heat- and hydrophilous species (Bolikhovskaya, 1995). The most complete succession of vegetation typical of the Muchkap (Belovezhsk) interglacial is present in sections studied in the Upper Don and the Middle Kuma basins. In Strelitsa, at that time, the Vorona pedocomplex (PC) formed on the till (its horizon A1' is an exception). During most of the interglacial, forest vegetation predominated, specifically birch-pine forests with spruce, oak, elm, and zelkova during Bv1; polydominant dark-coniferous broad-leaved forests consisting of fir, spruce (including s. Omorica), and s.s. Cembra and Strobus, stone oak, common and Caucasian hornbeam, nut, broad-leaved linden, etc., during Bv2 (maximal heat and moisture supply); pine-birch and oak-hornbeam forests during Bv3; birch and spruce-pine forests during the endothermal cooling of Bv4; birch forests with pine, linden, etc. during Bv5; spruce-pine-birch and hornbeam-oak forests during Bv6; and forest-steppes with patches of spruce-pine and birch forests during Bv7. In the Likhvin section, there are no deposits dating from the early or final phases of the interglacial. This section is represented by lacustrine sediments corresponding to the optimal phases separated by an endothermal cooling. This succession is marked by a change in the proportion of coniferous and coniferous-broad-leaved forests that dominated the Upper Oka region (Fig. 4). Climatic and floristic peculiarity of the period is reflected by the proportion of both typical plants such as Tsuga canadensis, Picea s. Omorica, P. s. Eupicea, Abies sp., Pinus s. Cembra, P. s. Strobus, Larix sp., cf. Rhus sp., Carpinus betulus, C. orientalis, Fagus sylvatica, Quercus robur.
Q. pubescens, Tilia platyphyllos, T. cordata, Ilex aquifolium, Ulmus laevis, U. glabra, U. campestris, Osmunda cinnamomea, O. claytoniana, etc.) and exotic taxa including Cedrus sp. (introduced from afar), Tilia amurensis, Osmunda regalis, Woodsia manchuriensis, and W. fragilis.

The Oka glacial. On the Upper Oka, the Oka till, up to 5-m-thick, is seen in outcrops along the Likhvinka stream and near the village of Bryanskovo. On the Upper Don, periglacial landscapes representing the Oka cold stage (ca 535 – 455 ka) were tundra-steppes and tundra-forest-steppes. At that time, periglacial steppes existed in the extraglacial areas of the Dnieper basin, and periglacial forest-steppes in the East Caucasian piedmonts.

Likhvin s. str. interglacial. Its chronological range is about 455 to 360 ka. Most ESR dates are derived from transgressive sediments of Arctic Seas (Molodkov et al., 1992) and from a complex analysis of lake-and-bog deposits of the Butenai interglacial in Lithuania (Gaigalis, Molodkov, 1993). Culture-bearing layer 5 in Treugol'naya Cave falls in the same interval (Molodkov, 2001).

In the stratotype of this interglacial (the Likhvin section) a detailed analysis of the entire 20-meter-thick suite of lacustrine, bog, and alluvial deposits representing Likhvin s. str. interstadial was performed by us. The typical interglacial taxa are representatives of the European Mediterranean, East Asian, and North American flora: Larix sp., Abies alba, Picea s. Omorica, P. excelsa, Pinus s. Cembra, P. s. Strobus, P. sylvestris, Betula s. Costatae, B. pendula, B. pubescens, Juglans regia, Carpinus betulus, Fagus sylvatica, Quercus petraea, Q. robur, Q. pubescens.
Zelkova sp., Celtis sp., Ulmus propinqua, U. laevis, U. campestris, Fraxinus sp., Tilia platyphyllos, T. tomentosa, T. cordata, Acer sp., Corylus columna, C. avellana, Alnus glutinosa, A. incana, Ligustrina amurensis, Rhododendron sp., Vitis sp., Myrica sp., Osmunda cinnamomea, Salvinia natans, etc., including characteristic species such as Tsuga canadensis, Taxus baccata, Pterocarya fraxinifolia, Juglans cinerea, Castanea sativa, Ilex aquifolium, Fagus orientalis, Quercus castaneifolia, Buxus sp., Osmunda claytoniana, etc. The predominant landscapes during the climatic optimum of the Likhvin thermochron in Central Eastern Europe were initially oak-hornbeam and then spruce-fir and hornbeam-beech-oak forests. During the thermoxerotic maximum coinciding with the first half of the interglacial, grasses and other herbaceous steppes dominated the respective zones of the loess regions in the East European Plain. The thermohygrotic maximum registered in the second half of the interglacial was characterized by a wide expansion of thermo- and hydrophilous taxa such as Tsuga, Pterocarya fraxinifolia, Juglans regia, Fagus orientalis, F. sylvatica, Carpinus betulus, etc. into the forest and forest-steppes that were widely distributed at that time (the last in the southwest).

The warmest interglacial stage over the past 600 ka, Likhvin, corresponding to OIS 11, was associated with the highest sea level stand recorded at ca +20 m above MSL (Howard, 1997; Rohling et al., 1998). From this stratigraphic level and upward the warm-climate-related signals recognised by us show correlation with the time of formation of sapropel horizons (Sap11 – Sap1) (Rossignol-Strick et al., 1998) in the eastern Mediterranean (see Fig. 4): clearly, these coincide with periods of global improvement of climate and with the recently published data (Rohling et al., 1998) concerning the global sea-level stands over the past 500 ka.

Kaluga cooling. In this interval (ca 360 – 340 ka), lacustrine and alluvial deposits, the overlying soil PS7, and the parent rock of PS6 soil having a postcryogenic texture formed in the Likhvin section (Bolikhovskaya, 1995). During the coldest phases of the Kaluga cooling, coinciding with stage 10 of the oxygen-isotope scale, the Upper Oka and the Upper Don basins were covered with periglacial tundras and forest-tundras with patches of tundra-forest-steppes and tundra-steppes, and in the southern part of the extraglacial zone of the East European Plain the predominant landscapes were periglacial forest-steppes and steppes.

Chekalin interglacial. The Eastern European loess areas studied were covered by forest and forest-steppe vegetation characterized by a radical drop in the number of Pliocene exotes compared with the preceding interglacials. The paleoclimatic signal of interglacial character, observed in various environments, falls, according to our data, in the 340 – 280 ka range (OIS 9 and early part of OIS 8). This is the date of the later horizons of lacustrine sediments attributed to the second sedimentation interval of the Butėnai interglacial in Lithuania (Gaigalas, Molodkov, 1993, 1997) and the marine sediments of the Taymyr – Severnaya Zemlya region (Molodkov, 1995; Molodkov et al., 1992; Bolshiyanov, Molodkov, 1999). Correlated formations are clearly seen in the Likhvin section as a well-expressed paleosol complex (reddish soil PS5 and podzol PS6) that developed in the forest landscapes (see Fig. 4). During the time of optimal heat- and moisture supply, the Upper Oka basin was mainly occupied by spruce-linden-elm-oak forests.

Zhizdra cooling. This cooling correlates with the larger part of oxygen isotope stage 8. In the East European loess province, it resulted in the predominance of periglacial tundras, forest-tundras, and steppes in the northern periglacial regions, and the cryo-arid landscapes of the eastern Caucasian piedmonts were predominated by open birch woodlands and yernik formations. The species composition of the periglacial forest-tundra that dominated the Upper Oka basin resembled that of the preceding Kaluga cryochron represented by Larix sp., Pinus sylvestris, Betula pubescens, B. pendula, B. fruticosa, B. nana, Alnaster fruticosus, Dryas octopetala, Selaginella sibirica, Lycopodium appressum, L. pungens, Artemisia s.g. Seriphidium, Thalictrum sp., etc., differing from it by a lesser diversity of cryptophytes.

Cherepet interglacial. A significant warming in a rank of interglacial, predating penultimate glaciation (OIS 6), is established by ESR data in the time interval about 220 ka (OIS 7) on the transgressive marine deposits. Throughout the loess regions of the East European Plain, the predominant forests during this period were those with a considerable proportion of xerophytic-broad-leaved formations consisting of Carpinus orientalis, Ostrya sp., O. carpinifolia, etc. In the Likhvin section, the Cherepet’ warming is correlated with the boggy-gley soil PS4 (see Fig. 4). During the most optimal phases of vegetation development, hornbeam-oak and cedar-broad-leaved formations dominated the Upper Oka region.

The Dnieper glacial. In Likhvin, the Dnieper stage s. lato (ca 200 to 145 ka), corresponding to greater part of the oxygen-isotope stage 6, is represented by a long suite consisting of (1) Early Dnieper fluvioglacial aleurites with a lemming fauna (Dicrostonyx cf. simplicior, Lemmus sibiricus, etc.) (Agadjanian,
Fig. 4. Chronology and correlation of the main paleogeographic events over the past 600 ka.
1971) and mostly tundra-steppe pollen spectra; (2) three-layered till corresponding to the Dnieper and Moscow stadials and the Dnieper-Moscow interstadial with the predominance of open pine woodland, and alder and yernik thickets; and (3) Late Moscow loess-like sandy loam. During the Early Dnieper interstadial, traced in the upper part of the aleurites underlying the till, periglacial pine open woodlands predominated. The Late Moscow interstadial warming is represented in ferrous sands overlying the till by a phase of periglacial birch open woodlands with *Betula fruticosa* in the shrub belt and a grass-and-shrub vegetation with *Arctous alpina*, *Cannabis sp.*, *Artemisia s.g.* *Seriphidium*, *Thalictrum cf. alpinum*, etc. Judging by the totality of pollen data, periglacial landscapes of the Upper Oka and Upper Dnieper during the interstadials of the Dnieper period were tundra-stepses stretching further east into the Upper Don valley where they alternated with periglacial forest-tundras and tundra-forest-stepses. In extraglacial loess regions periglacial steppes and forest-stepses predominated at that time, and in the extreme southeast, they intermixed with periglacial semideserts during certain phases. **Mikulino interglacial and Valdai glacial.** Late Pleistocene deposits are characterized by analytical data in much greater detail than they are for other sediments. To trace the climatic rhythms of the past 200 ka, Bolikhovskaya generalized the results of a complex analysis of more than 40 Dnieper – Late Pleistocene sections in the southern half of the East European Plain and compiled detailed schemes of their climatostratigraphic subdivision, landscape-climatic fluctuations and zonal types of periglacial and interglacial vegetation for each reconstructed stage. These results will be outlined in detail in a forthcoming publication. For our present purposes, it will suffice to mention that within the Valdai glacial climatic rhythm, dated by us to 70 – 10 ka (OIS 4 – 2), three Early Valdai, three Middle Valdai, and three Late Valdai interstadials, as well as ten cold stadials were reconstructed. Each of these has its own floral, phytocoenotic, and climatic characteristics (Bolikhovskaya, 1987, 1993, 1995, etc.).

The Mikulino (*s. lato*) interglacial, which we correlate with OIS 5, had a complex climatic structure as well (Bolikhovskaya, 2000). Before the mid-1960s, most researchers correlated stage 5, too, with Mikulino (Eemian) interglacial (pollen zones *M*<sub>5</sub> – *M*<sub>s</sub> (Grichuk, 1961, 1989, etc.), that had lasted for ca 50 ka (Velichko, 1982). However, after the publications of Shackleton (1969) and then Mangerud et al. (1979), more and more researchers began to correlate the latter interglacial with substage 5e alone, ca 10 ka in duration (Müller, 1974). The chronology of the interglacial flora characterized by pollen zones *M*<sub>5</sub> – *M*<sub>s</sub> was revised accordingly. Substages 5d – 5a began to be viewed as the early stage of the Valdai (Weichsel) glacial (Mangerud et al., 1979). Many researchers believe that during the coldest intervals 5d and 5b significant glacier advance occurred often hundreds of kilometers from glaciation centers. The sea level, judging by the increase in the proportion of "heavy" oxygen isotopes, was 55 – 60 m below the modern one (Shackleton, 1987). Huge territories that had been submerged by the Boreal Sea in the Eurasian north, became dry land, that should have affected the marine sedimentation in the coastal areas.

However, recent ESR-chronostratigraphic analyses of mollusk shells from marine sediments of Northern Eurasia (Molodkov, 1988, 1995; Molodkov et al., 1992; Bolshiyanov, Molodkov, 1999; Molodkov, Raukas, 1998) and paleolacustrine sediments in Lithuania (Gaigalas, Molodkov, 1993, 1997), suggest that the sea transgression and the accumulation of lacustrine interglacial sediments in this region likely falls in the 145 – 70 ka interval, corresponding to the entire OIS 5 and to the final phase of OIS 6 (see Fig. 4).

The time-dependent frequency distribution of all the ESR-dates obtained by us for the last interglacial mostly on uplifted marine sediments along the marginal zone of the North Eurasia demonstrates the presence of high-frequency intervals (peaks I – V; Fig. 5) at ca 135, 120, 110, 90, and 70 ka, which may be correlated with periods of a relatively warm climate and the submergence of coastal parts of the land. Low-frequency intervals (troughs b – e; Fig. 5) at 130, 115, 100 and 75 ka may be correlated with coolings and phases of sea regression.

Our findings concerning the frequency distribution of ESR-dates for northern Eurasia are in good agreement with the results of isotope and chronological analyses of speleothems from the caves of Stordalsgrotta and Ökshola northern Norway (Fig. 5). A continuous growth of speleothems in the interval of 150 – 71 ka, indicates the absence of thick ice cover (i.e., interstadial or glacial conditions) at that time (Lauritzen, 1995). Periods of cooling which, however, did not result in a considerable growth of the Scandinavian glaciation or the emergence of an ice sheet in the coastal zone of northern Norway in the vicinity of the caves, were registered here at ca 145, 139, 129, 114, and 100 ka (according to U-series dating). Although the cold interval at 75 ka has not been revealed in these caves, its isotope temperature signal is clearly visible in speleothems from caves in northwestern Romania (Lauritzen, Onac, 1999). Also, in the series of sections from the eastern coast of the White Sea studied by us (Molodkov, Raukas, 1998) there is no interruption of marine sedimentation during the 120 – 75.5 ka interval; neither were any deposits suggestive of glaciation revealed for that period.
All the above observations attest to a higher sea level, greater duration of the first Late Pleistocene transgression and, possibly, of the interglacial period than it would follow from the oxygen isotope curve or from the correlation of the Mikulino (Eemian) interglacial with substage 5e alone. Also, our findings agree with the recent results of multidisciplinary studies in the Western Hemisphere; the data indicate that full interglacial conditions there span a time interval comparable with the entire stage 5 (Bischoff et al., 1997).

Results of a detailed pollen analysis of loess-paleosol and other continental deposits that formed during the post-Dnieper (post-Moscow) period do not contradict these conclusions.

In the central regions of East Europe, now situated in the mixed forest subzone, the richest water supply during the Late Pleistocene was characteristic of the interval from the beginning of the Mikulino interglacial up to the end of the first Early Valdai (Ketrosy) interstadial, and in the southwestern parts, now occupied by broad-leaved forests, up to the end of the second Early Valdai (Kishlyansky) interstadial (Table 2). A complex pattern of change of the Mikulino vegetation, a distinct climatic subdivision of this interglacial, and the presence within it of several coolings (or endothermals after Bolikhovskaya (1991)) which are distinctly correlated with coolings at ca 107 and 90 ka, registered in La Grande Pile section, France (Kukla et al., 1997), suggest that the Mikulino interglacial was a long one. The comparison of floristic, phytocoenotic, and climatic successions of the Mikulino period (reconstructed according to LPP sections) and Holocene, too, clearly demonstrate that the Mikulino thermochron was several times longer than is the modern interglacial that has lasted just 10 ka.

The above can be illustrated by materials from the Arapovichi section in the northeastern Dnieper Lowland. Here, the Dnieper till is overlain by 14-meter-thick Late Pleistocene loesses and paleosols (see Fig. 4). According to the palynological analysis, sands and loams overlying the till and most of the Mezin paleosols overlying them (Salyn lessive and the lower third of the sod-chernozem Krutitsa soil) are dated as the Mikulino interglacial in age. The Ketrosy interstadial was registered in the middle of this soil. Over the entire Mikulino period, under relatively high heat and moisture supply, most of this territory was covered by forests. Climato-phytocenotic and floral features of Mikulino interglacial forests fall into 11 successive stages: Mk1 – pine-birch forests with oak,
Table 2. Reconstruction of principal stages of the evolution of vegetation and climate in the East European Plain over the past 200 ka based on sections of modern subzones of mixed and broad-leaved forests

<table>
<thead>
<tr>
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<td>40.0</td>
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Notes. PT, periglacial tundra; PFT, periglacial forest-tundra; TFS, tundra-forest-steppe; PS, periglacial steppe; PFS, periglacial forest-steppe; POW, periglacial open woodland; PF, periglacial forests; ES, extraglacial steppe; EFS, periglacial forest-steppe; IFS, interglacial forest-steppe; IF, interglacial forests. 1 – mixed forests; 2 – broad-leaved forests.

hornbeam, and elm; Mk2 – pine-birch forests with spruce and undergrowth of Betula fruticosa (first endothermal); Mk3 – birch forests with Carpinus betulus, Quercus robur, Q. petrea, Tilia cordata, T. tomentosa, Corylus colurna, Ulmus laevis, etc.; Mk4 – pine-spruce forests with oak, hornbeam, elm, etc.; Mk5 – hornbeam-oak forests (thermo-xerotic maximum); Mk6 – birch-cedar-spruce and hornbeam-oak forests; Mk7 – pine forests with birch and yernik tier (second endothermal); Mk8 – birch-spruce-cedar forest.
and hornbeam-oak forests with beech, linden, elms, hazel tree, etc.; Mk9 - oak-hornbeam forests (thermo-hygrotic maximum); Mk10 - birch-pine forests with oak, hornbeam, linden, and elm; Mk11 - cedar-spruce and birch forests. As we see, even endothermal coolings were characterized by a rather moist climate. The first Early Valdai cooling resulted in the expansion of open pine-birch forests with *Betula nana*, *B. fruticosa*, and *Alnus fruticosa* in the undergrowth into this territory. However, during the subsequent Ketrosy interstadial pine-birch forests with oak, linden and hornbeam, similar to interglacial forests of the same territory, were predominant. Only from the second Early Valdai cooling and almost up to the early Holocene (with the possible exclusion of 16.5 - 15.0 ka interstadial) was the Desna Valley occupied by periglacial forest-steppes, steppes, and tundra that developed under low temperatures and precipitation below 350 - 450 mm a year, i.e., under conditions corresponding to a low level of northern seas characteristic of the Valdai period.

Findings from the entire East European loess province suggest that forest formations typical of optimal phases and represented by broad-leaved and coniferous-broad-leaved associations of European and Panholarctic elements of dendroflora, predominated during the Mikulino interglacial in the Volyn-Podol, in the northern part of the Central Russian Upland and in the Dnieper Lowland, as well as in the Eastern Caucasian piedmonts. At that time, the Dniester and the Oka-Don loess regions were occupied by forest-steppe landscapes with a lesser supply of moisture. The reconstruction points towards the necessity of taking into account regional peculiarities of paleoclimatic changes on various territories when any correlations are being attempted.

Thus, our results, as a whole, support the hypothesis that implies longer (up to 70 ka) duration of the first Late Pleistocene marine transgression and, in all probability, of the last interglacial. Notably, judging from the ESR-dates obtained close to 145 ka and numerous indications of a drastic warming of the climate in the end of OIS 6, the sea level rise and the global warming may have started much earlier than suggested by the oxygen isotope chronology (ca 128 ka) (Martinson et al., 1987).

**Conclusion**

Thanks to the comprehensive approach to the construction of chronostratigraphic framework, reconstruction and global correlation of environmental changes based on two independent sources of climato-chronostratigraphic information, a record of paleoenvironmental changes in the Mid-Late Pleistocene was constructed and supported by the data of absolute geochronology for the last 600 ka. The findings suggest that during that period, the climate in North Eurasia was characterized by periodic changes and was directly related to sea-level fluctuations and the global ice volume changes. The comparison of ESR chronostatigraphic levels and climate-related features of pollen spectra in the LPF sections with oxygen-isotope curves of deep-sea sediments reveal a good agreement between them for the 11 upper stages.

The comparison of nine successive interglacial palynofloras in the most complete, nearly uninterrupted Pleistocene suites of loess regions of the East European Plain and phytocoenotic successions of nine interglacial climatic rhythms has made it possible to establish that among the interglacial stages in vegetation evolution over the past 600 ka, the most humid thermochron was the Muchkap interglacial, the warmest one was the Likhvin interglacial, and the most continental climate (apart from the Holocene) existed during the Mikulino interglacial.

The comparison of ESR-dated warm-climate-related deposits with phytocoenotic and climatic successions of the interglacial climatic rhythms in LPF sections demonstrates the absence of considerable stratigraphic breaks in the latter, at least during the Brunhes chron.

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