ISSN 0869-5938, Stratigraphy and Geological Correlation, 2019, Vol. 27, No. 4, pp. 475–497. © Pleiades Publishing, Ltd., 2019.
Russian Text © The Author(s), 2019, published in Stratigrafiya, Geologicheskaya Korrelyatsiya, 2019, Vol. 27, No. 4, pp. 93–116.

*Dedicated to the memory of the prominent Pleistocene researcher,
paleogeographer Andrei Alekseevich Velichko*

Changes in the Landscape and Climate of Eastern Europe in the Early Pleistocene

V. V. Pisareva[a, *], M. A. Faustova[a], I. S. Zyuganova[a, **], N. V. Karpukhina[a], A. L. Zakharov[a], E. A. Konstantinov[a], V. V. Semenov[a], and R. N. Kurbanov[a, b]

[a] *Institute of Geography, Russian Academy of Sciences, Moscow, Russia*
[b] *Moscow State University, Moscow, Russia*
**e-mail: vvpisareva@igras.ru*
***e-mail: iszyuganova@igras.ru*

Received June 1, 2017; revised November 22, 2017

Abstract—In the context of shifting the boundary of the Quaternary down to the level of 2.6 Ma and including the Gelasian Stage in the Quaternary System, the systematization of the original and published data on the geology and paleogeography of the Late Pliocene and Early Pleistocene of Eastern Europe has been carried out. It was established that, at the boundary of the Gauss and Matuyama paleomagnetic epochs, along with the general trend toward cooling and aridization, profound landscape and climate changes occurred and rhythmic fluctuations of the climate intensified. During the period from 2.6 to 1.8 Ma, corresponding to the Gelasian (pre-Tiglian and Tiglian of Western Europe or Paleopleistocene of Eastern Europe), there appeared subarctic landscapes. In the Eopleistocene (1.8–0.78 Ma) and the Early Neopleistocene (0.78–0.42 Ma), the climate became colder, and climatic zonality repeatedly underwent a complex restructuring, gradually approaching the modern one. Glacial deposits (layers of till) occurring in Eastern Europe date back to the Paleopleistocene. Evidence indicates that there were at least three independent glaciations in the Eopleistocene (1.8–0.78 Ma) and possibly four in the Early Neopleistocene. On the basis of studies of stratotypic sections, paragenetic links were established between sediments of different age within glacial and periglacial areas, and the paleogeographic events of the Early Pleistocene of Eastern Europe were correlated with those within the Western European region.

Keywords: East European Plain, lower boundary of the Quaternary, Paleopleistocene, Eopleistocene, Early Neopleistocene, glaciation, interglacial period, interstadial, till, soil, loess, fossil flora and fauna, correlation

DOI: 10.1134/S086959381904004X

INTRODUCTION

Modern ideas about stratigraphy and paleogeography of the Pliocene and Pleistocene of Eastern Europe were formed on the basis of many years of work by teams of researchers from the Geological Institute and Geographical Institute of the Russian Academy of Sciences, VSEGEI, Moscow and Voronezh State Universities, PGO Tsentrgeologiya Ltd., and other organizations. The extensive factual material was summarized in a series of publications (*Chetvertichnaya*…, 1997; Geologicheskie…, 2007; *Sovremennye*…, 2011; *Stratigrafiya*…, 1992; *Voprosy*…, 1981). A major contribution to the study of stratigraphy and correlation of Pliocene and Quaternary sediments was the work carried out in the 1980s in the framework of the International Project of Geological Correlation (*Granitsa*…,1987; Nikiforova, 1973; Nikiforova and Alekseev, 1997).

The new approved Quaternary boundary is found at the base of the pre-Tiglian within the time interval considered earlier in the East European region as the Late Pliocene. At that time, there were profound landscape and climate changes. As a result of a sharp cooling and aridization of the climate, the vegetation lost the most thermophilic representatives of the flora and acquired a modern appearance (*Izmenenie*…, 1999). *Villnia* sp., *Lemmus* sp., and other inhabitants of the cold forest steppe appeared in the fauna. This milestone roughly coincides with the Gauss/Matuyama magnetic reversal, with the beginning of the Middle Villafranchian, and the beginning of the Khapry fauna with the archaic elephant *Archidiskodon gromovi* Alekseeva et Garutt.

According to the recent studies, formation of ice sheets in the Western European region of the Northern Hemisphere occurred already in the Pliocene about

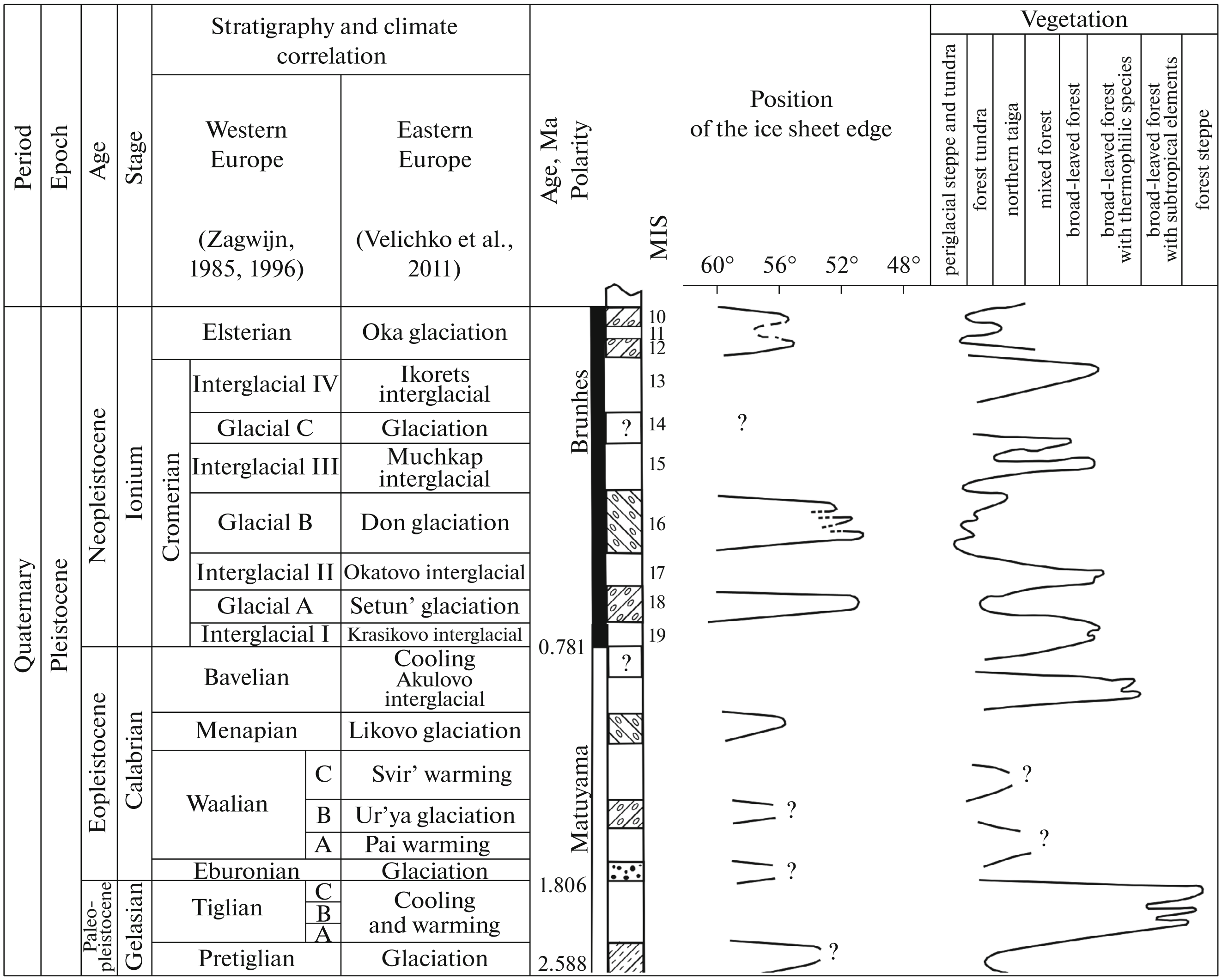


Fig. 1. The correlation scheme of chronostratigraphic units of the Early Pleistocene, the distribution of glaciations, and changes in vegetation in the basin of the Upper Volga, Kama, and Upper Don.

3.2 million years ago (Borzenkova and Zubakov, 1985; Mundelsee and Raymo, 2005); at the beginning of the Quaternary, the continental glaciations developed in middle latitudes. Evidence of a significant cooling and development of glaciations in the earliest and coldest epoch of the pre-Tiglian (from 2.6 to 2.4 Ma) was reported for many regions, including the North Atlantic, where evidence of iceberg rafting was found (Lee et al., 2011). Approximately 2.4 million years ago, the ice sheet expanded to Scandinavia and the Arctic archipelagoes of Svalbard, Severnaya Zemlya, and Novaya Zemlya, which occupied a significant part of the western sector of the Eurasian Arctic (Knies et al., 2009; Vorren et al., 2011). About 2 million years ago, the cold pre-Tiglian gave way to the warmer Tiglian with extremely unstable climate (Urban, 1978; Zagwijn, 1985).

One of the first researchers to substantiate the Akchagyl age of the oldest glacial till in the East European region was Moskvitin (1967). The development of the first continental glaciations here dates back to the beginning of the Matuyama chron, although the cooling of the climate here, as well as in Western Europe, occurred much earlier, at about the Hilbert/Gauss boundary. According to some researchers, this boundary can also be considered as one of the options for drawing the lower boundary of the Quaternary system (Grichuk, 1959; Tesakov, 2007; Zubakov, 2006). The later history of the Eopleistocene and the Neopleistocene is associated with the alternation of further cooling and warming, yet their rank and periodization have been repeatedly revised as new data have been accumulated (Fig. 1).

MATERIALS AND METHODS

The present paper is based on the results of our own field and analytical work carried out for stratotypical sections in the Sea of Azov and the Caspian Sea regions and in the basins of the Upper and Middle Volga, Don, Dnieper, Oka, Kama, and Unzha rivers. Samples for various types of studies were taken mainly from deep boreholes drilled during geological survey. The location of the reference and stratotypic sections is shown in Fig. 2. The correlation of sediments was performed using published geological, geomorphological, lithological, faunistic, paleobotanical, radiometric, and paleomagnetic data, which determined the position of the most important boundaries—Matuyama/Brunhes (0.78 Ma) and Gauss/Matuyama (2.58 Ma) reversals.

Paleobotanical and paleofaunistic (fauna of mammals and mollusks) studies allowed a comparison of marine and continental sediments to be made. Many of the reference sections under consideration were studied by well-known paleocarpologists: P.A. Nikitin, P.I. Dorofeev, F.Yu. Velichkevich, T.V. Yakubovskaya. This made it possible not only to refine the definitions of pollen and spores but also to supplement the fossil flora with the species that were not discovered during spore and pollen analysis. Interpretation of the palynological data included a paleogeographic analysis of fossil flora: the presence of extinct taxa was registered; the role of East Asian, North American, and Balkan-Colchian species and other representatives of the pranemoral flora was taken into account. Such an approach to the generalization of paleobotanical materials, proposed by W. Szafer (1946) and later developed by V.P. Grichuk (1959, 1989), enabled us to assess a reliable age of the fossil floras, to establish their stratigraphic sequence, to determine the rank of warming and cooling, and to outline the boundaries associated with which a sharp depletion of plant communities occurred. In order to perform paleogeographic reconstructions, the climatic optima were selected as the most indicative chronosections of the interglacial periods and interstadials, and the intervals with the least heat supply were selected as those of the glacial periods. In view of possible redeposition, the problem of interpreting palynological data was solved taking into account studies of lithologic facies, as well as on the basis of ecological and geographical analysis of flora and the degree of pollen and spore preservation. Methodological approaches to the correlation of interglacial, stadial and interstadial deposits with deposits of the periglacial zone were developed under the guidance of A.A. Velichko.

RESULTS AND DISCUSSION

Lowering the boundary of the Quarernary to the bottom of the Gelasian called for developing a common stratigraphic scale for this unit. Earlier studies indicate that, at the beginning of Gelasian, about 2.6 million years ago, global cooling developed in the Ponto-Caspian region, which led to continental glaciation and the filling of the Baltic and North Seas with Scandinavian ice. At the same time, the ice sheet of the Barents Sea arose (Zubakov, 2006). The cooling that caused this glaciation was considered in Western Europe as pre-Tiglian. It manifested itself in many areas and was reflected in the change in fauna. Invasion of northern species began in Western Europe (Menke, 1975; Zagwijn, 1985). Tundra vegetation (Grichuk, 1981) appeared on the territory of the Baltic States; plants characteristic of periglacial landscapes appeared in Belarus: *Betula nana* L., *Juniperus* sp., *Selaginella selaginoides* (L.) Shrank et Mart., *S. helvetica* (L.) Spring., *S. tetraedra* Wieliczk. (Rylova and Yakubovskaya, 1999). However, this paleoclimatic boundary is not universally accepted when determining the lower boundary of the Quaternary system owing to the different approach to interpreting the results of faunal, paleobotanical, and paleomagnetic studies (Schick et al., 2015). Therefore, it was necessary to continue the study of the development of the organic world of the Gelasian and to move on to the interregional correlation of the events of this stage. Below are the results of studies of the sections which are used for restoration of the landscape and climate of the Early Pleistocene.

Paleopleistocene (Gelasian), 2.588–1.806 Ma

In the Udmurt Kama region, the Late Pliocene and Gelasian (Paleopleistocene) sediments are those involved in filling the ancient overdeepened valleys of the Izh and Kyrykmas rivers of the Kama River basin (Fig. 2). Borehole 15, a reference section for the area, situated in the valley of Kyrykmas River, left tributary of the Izh River (1.1 km to the north of the village of Chilcha), revealed the Akchagyl sediments 132.2 m in thickness (Pisareva, 2006; Pisareva et al., 1981). Below, at a depth of 43 m, Permian rocks occur. According to lithological, paleofaunistic, and paleobotanical data, five stages of development of paleovalleys are distinguished (Fig. 3):

Stage 1 (127.0–165.7 m), associated with river runoff and alluvium accumulation;

Stage 2 (106.5–127.0 m), corresponding to the lifetime of a lake reservoir with an unstable hydrological regime;

Stage 3 (58.0–106.5 m), associated with the resumption of runoff and accumulation of lacustrine and alluvial sediments;

Stage 4 (42.0–58.0 m), corresponding to the existence of a low-flowing lake reservoir in which montmorillonite-chlorite-hydromica clay was deposited;

Stage 5 (33.5–42.0 m), corresponding to the restoration of the alluvial regime.

The first, second, and third stages belong to the Early Akchagyl, and the fourth and fifth stages belong to the Middle and Late Akchagyl—the Paleopleistocene (Gelasian).

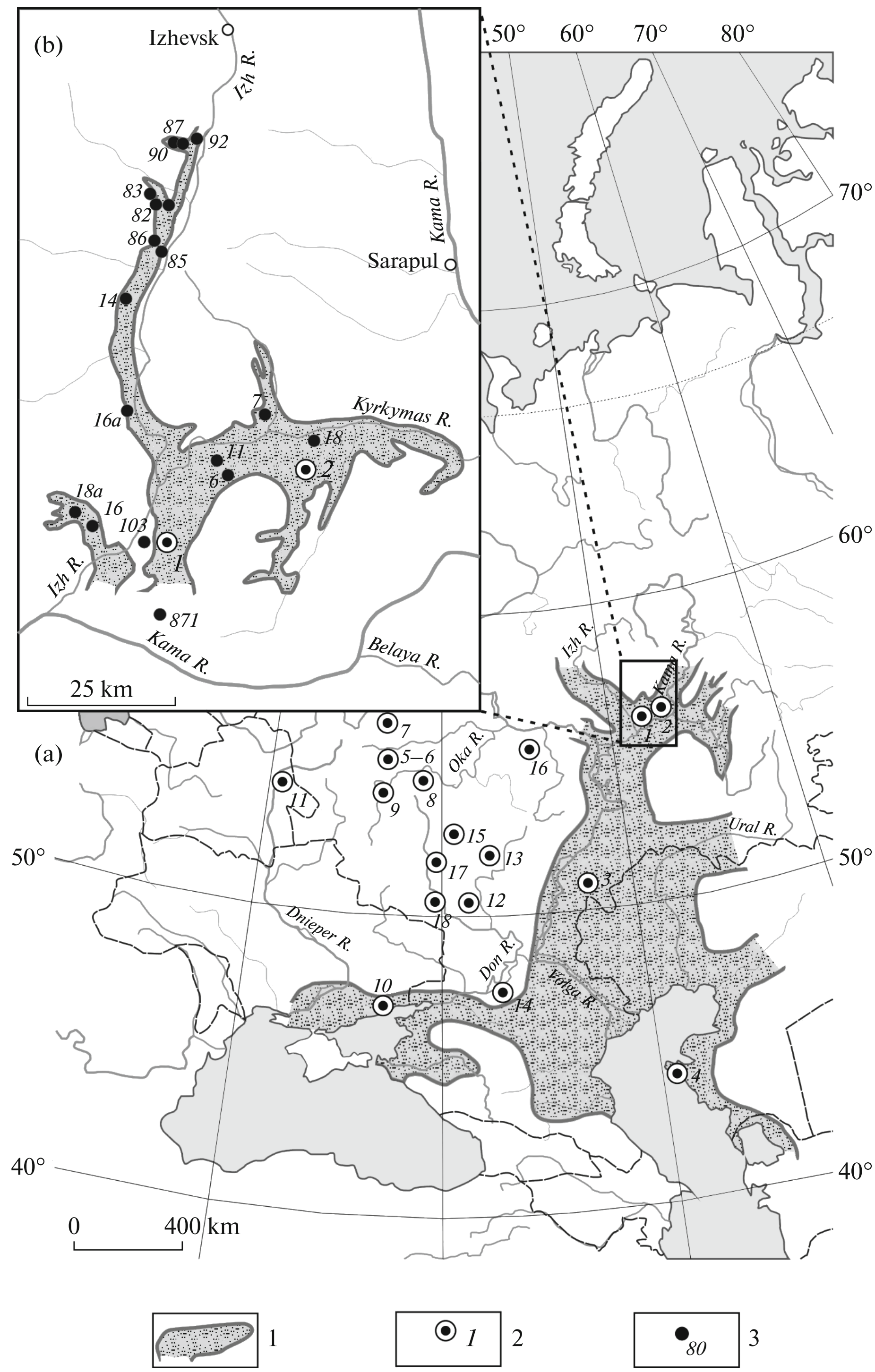


Fig. 2. The location of the reference and stratotypic sections. (a) Map of the sections referred to in the text; (b) map of the sections of the Akchagyl regional stage in the Udmurt area of Kama River basin. Legend: (1) area of maximum Akchagyl transgression; (2) reference sections and their numbers: *1*—Chilcha (borehole 15), *2*—Kasayevo (borehole 17), *3*—Altata, *4*—Mangyshlak, *5*–*6*—Akulovo, Okatovo, *7*—Krasikovo, *8*—Karamyshevo, *9*—Chekalin, *10*—Liventsovsky open pit, *11*—Smolensky ford, *12*—Mastyuzhenka, *13*—Korostylevo, *14*—Tsimlyansk Reservoir, *15*—Demshinsk (Nikolskoe), *16*—Lukoyanov, *17*—Belaya Gora, *18*—Uryv, Pokrovka; (3) mapping boreholes and their numbers.

The study of mollusks and ostracods have shown that the fauna throughout the section consisted mostly of freshwater species; however, in the sediments of the fourth stage, the halobionts of the genus *Galolimnocythere*, living at salinity up to 10‰, emerge among the rich and diverse association of ostracods. This is

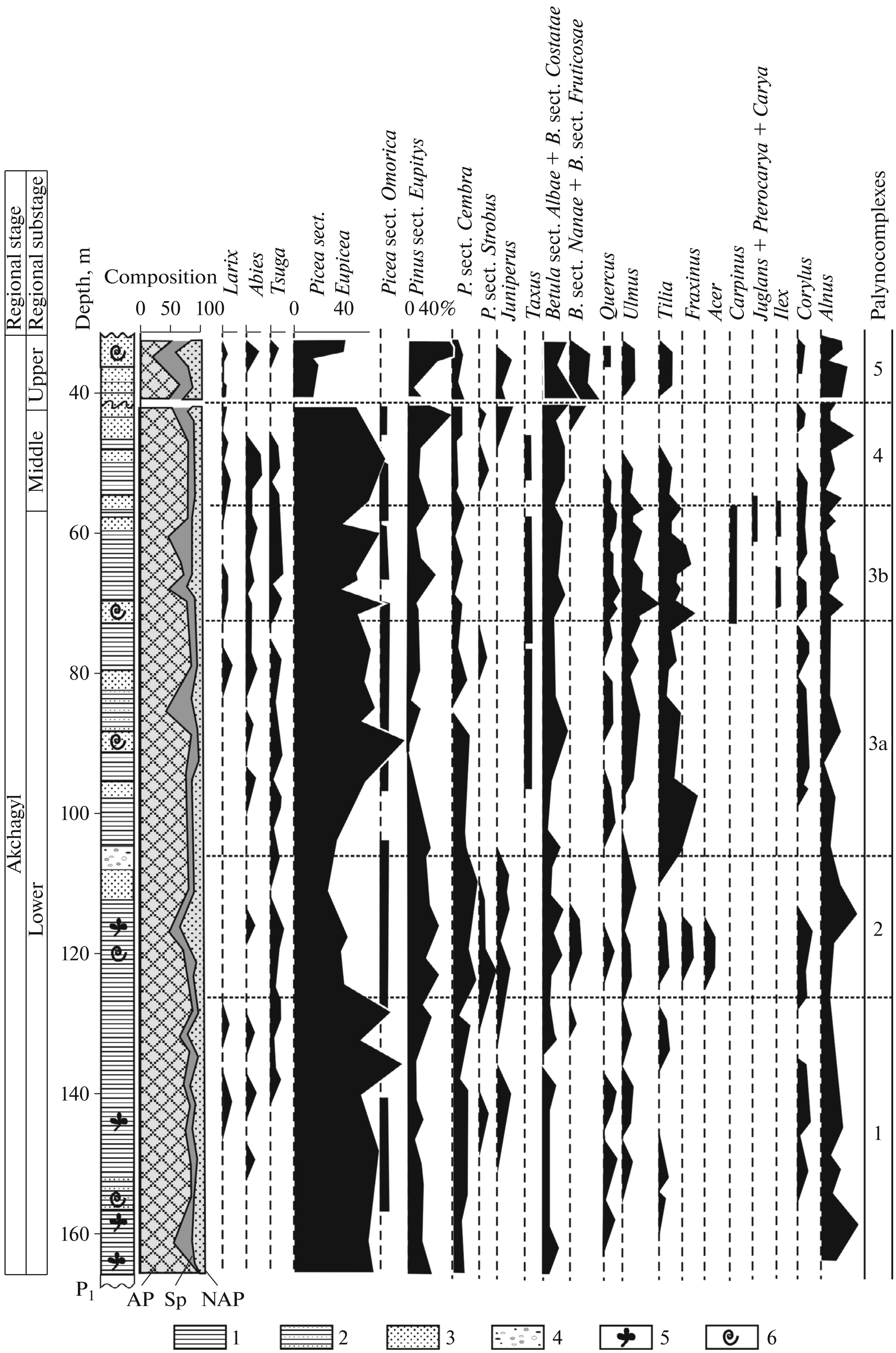


Fig. 3. Spore and pollen diagram of the borehole 15 (Chilcha, no. 1 in Fig. 2). Legend: (1) clays, (2) clays with sand interlayers, (3) sands, (4) gravel with pebbles, (5) plant macrofossils, (6) mollusk shells. Here and in Figs. 3–11: AP—pollen of trees and shrubs, Sp—spores, NAP—grass pollen.

probably associated with the ingression of the Akchagyl Sea. According to the palynological and paleocarpological data, three cooling periods occurred during sedimentation. The first of them (depth interval of 127.0–165.7 m, the Early Akchagyl) is associated with development of spruce forest formations involving spruce (*Picea omorikoides*), pine, fir, larch, hemlock, birch, and rare broad-leaved species—oak, elm, and linden (Fig. 3). Later, coniferous and broad-leaved forests with an admixture of relict tree species propagated: *Tsuga*, *Taxus*, *Juglans*, *Pterocarya*, *Carya*, *Ilex* shrubs, and herbaceous plants: *Polygonum pliocenicum* Dorof., *Scirpus pliocenicus* Szafer, *Eleocharis pseudoovata* Dorof., etc. (definitions by P.I. Dorofeev). Especially many extinct species were preserved among aquatic and marsh plant communities: *Najas pliocenica* Dorof., *N. lanceolata* C. et E.M. Reid, *N.* cf. *irtyshensis* Dorof., *Potamogeton crispoides* Dorof.

During the second cooling (depth interval of 42.0–58.0 m, the Middle Akchagyl), which was more extensive than the first, floristically depleted spruce forests similar to the modern northern taiga, with predomination of fir and larch, expanded. Along with them, there were heather forests, in some places with juniper thickets, and birch forests with the participation of Siberian species *Betula* aff. *exilis* Sucaczev and *Alnus* aff. *hirsuta* Turcz. Broad-leaved species gradually declined. Vegetation of the same composition was reconstructed for the time of formation of the alluvium of the Chistopol Horizon of the Kama River basin (Goretsky, 1964) and deposits of Zilim-Vasil'evo Horizon of Bashkiria, near the Ural Mountains, where the marine sediments of the Middle Akchagyl with cardiids and avimaktra near the village of Akkulaevo contained the Khapry fauna (according to the definitions of V.P. Sukhova) of small mammals (Nemkova et al., 1972). Later, the landscape-climatic record in the section on the Chilcha River was interrupted owing to a sedimentation hiatus. The aleurites and sands from the upper part of the section (depth interval of 33.5–42.0 m) were deposited during the period of a new cooling, the Late Akchagyl, when dark coniferous forests degraded and were replaced with pine and birch light forests. Sandy shores and other open areas were covered with wormwood and pigweeds (Chenopodiaceae family).

The advance of spruce and pine-birch forests with shrub birch, heath, and juniper to the south during the Middle Akchagyl was established on the basis of materials collected on the left bank of Volga River near Saratov (Kovalenko, 1971; Kuznetsova, 1971) and our own data.

Borehole 36, drilled near the village of Altata in the vicinity of the town of Yershov, below the Middle Pleistocene Khazar sediments opened a 70-m-thick layer of aleuritic clays containing marine mollusks. The spore and pollen diagram (Fig. 4) reflects two phases of the geological history of the basin and the corresponding phases of vegetation development. The first stage (78–100 m) corresponds to the maximum of the Akchagyl transgression and belongs to a period of the predominantly forest vegetation, at first, denser with prevailing spruce, pine, fir, hemlock, and larch and, then, sparser, consisting of birch with an addition of coniferous species and an abundance of ericales (Ericaceae). The second stage (30.0–78.0 m, Late Akchagyl) is associated with the regressive stage of the basin development and the beginning of spreading of grass and shrubs with predominance of xerophytes from the Chenopodiaceae family on the left bank of Volga River, near Saratov: *Eurotia ceratoides* C.A. Mey, *Atriplex cana* C.A. Mey, *Polycnemum arvense* L., *Kochia laniflora* (S.G. Gmel.) *Borbas*, *Kochia prostrata* (L.) Schrad, and plants typical of saline soils belonging to the genera *Salsola*, *Anabasis*, etc. The emergence of taiga forests during the first stage, associated with cooling and moistening of the climate in the Middle Akchagyl, was noted by N. D. Kovalenko in Volgograd oblast, as well as in other areas of the Northern Caspian; however, in these areas, pine was more common among trees (Kovalenko, 1971; Maslova, 1960; Naidina, 2007).

To the south, on the Mangyshlak Peninsula (near the town of Shevchenko), the Middle Akchagyl 70-m-thick sediments overlie limestones and clays of the Sarmatian. They were opened by borehole 17 (Fig. 5) in the core of the synclinal fold and are represented by calcareous clays with layers of marls and clay limestones with planktonic foraminifera from the orders Nonianida, Elphidiida, and Cassidullinida. Akchagyl age of this microfauna was determined by L.S. Pishvanova on the basis of its compositional similarity to the complex of foraminifers from the Middle Akchagyl of the Krasnovodsk Peninsula.

Pollen and spores in sufficient quantities for analysis were collected from the depth interval of 14.0–33.0 m. According to the spore and pollen analysis, two complexes were distinguished (Fig. 5). The first complex (depth 31.0–33.0 m) is characterized by the absolute predominance of graminaceous plants and brushwood, among which there are typical xerophytes: *Eurotia ceratoides*, *Polycnemum arvense*, *Kochia scoparia* (L.) Schrad., *Plumbaginaceae*, *Ephedra*. The data obtained indicate that there were steppes on the territory of Mangyshlak with wormwood-grass-quinoa vegetation. Similar vegetation was found in the sediments attributed to the first half of the Middle Akchagyl in other regions of Western Turkmenistan (Filippova, 1997).

The composition of the second complex (depth interval of 14.0–26.0 m) suggests a replacement of steppe vegetation by that characteristic of forest steppes. At that time, there appeared conifers—pine *Pinus* sect. *Eupitys*, *P.* sect. *Cembra*, *P. mirabilis* (Rudolph) Anan., *P. rosibirica* Anan., *P.* sect. *Strobus*, spruce *Picea* sect. Omorica, *P. cf. schrenkiana* (Fisch.)

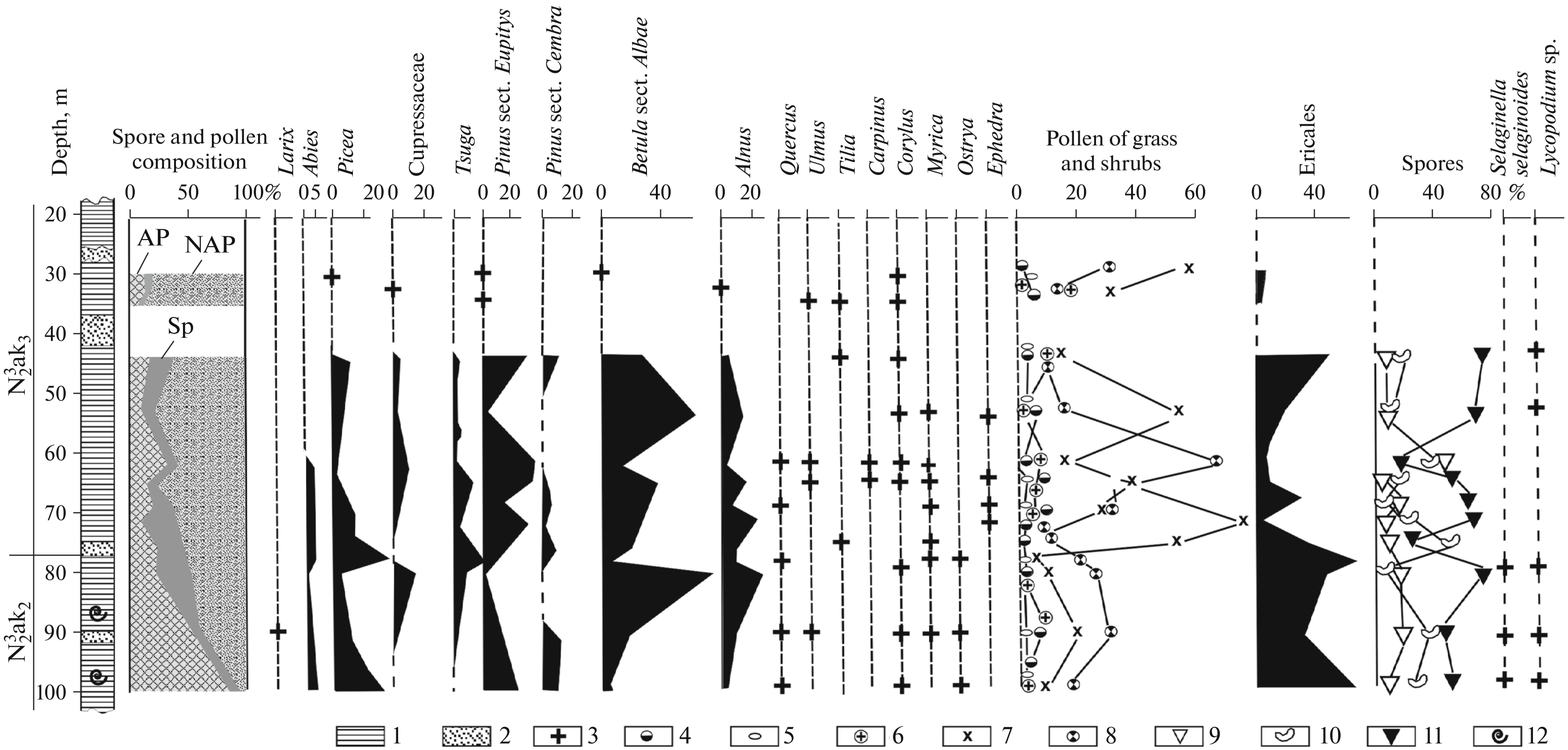


Fig. 4. Spore and pollen diagram of borehole 36 (right bank of the Altat River, Ershov, no. 3 in Fig. 2). Legend: (1) clay, (2) sand, (3) single pollen grains, (4) grass pollen, (5) sedge pollen, (6) wormwood pollen, (7) myrica pollen, (8) pollen of motley grass, (9) spores of green mosses, (10) spores of ferns; (11) spores of sphagnum mosses, (12) finds of mollusk fauna (definitions by Yu.G. Cheltsov): *Cardium limosum* Tscheltz., *Cardium* ex gr. *dombra* Andrus., *C. dombra* var. *kumuchica* Andrus., *C. pseudoedule* Andrus., *C. laticostoitum* Tscheltz, *Avimactra* cf. *subcaspia* (Andrus), *A.* cf. *karabugasica* Andrus., *Avicardium* sp., *Avimactra* sp., *Glessiniola polejaevi* Andrus. $N_2^3ak_2$—sediments of the Middle Akchagyl; $N_2^3ak_3$—sediments of the Upper Akchagyl.

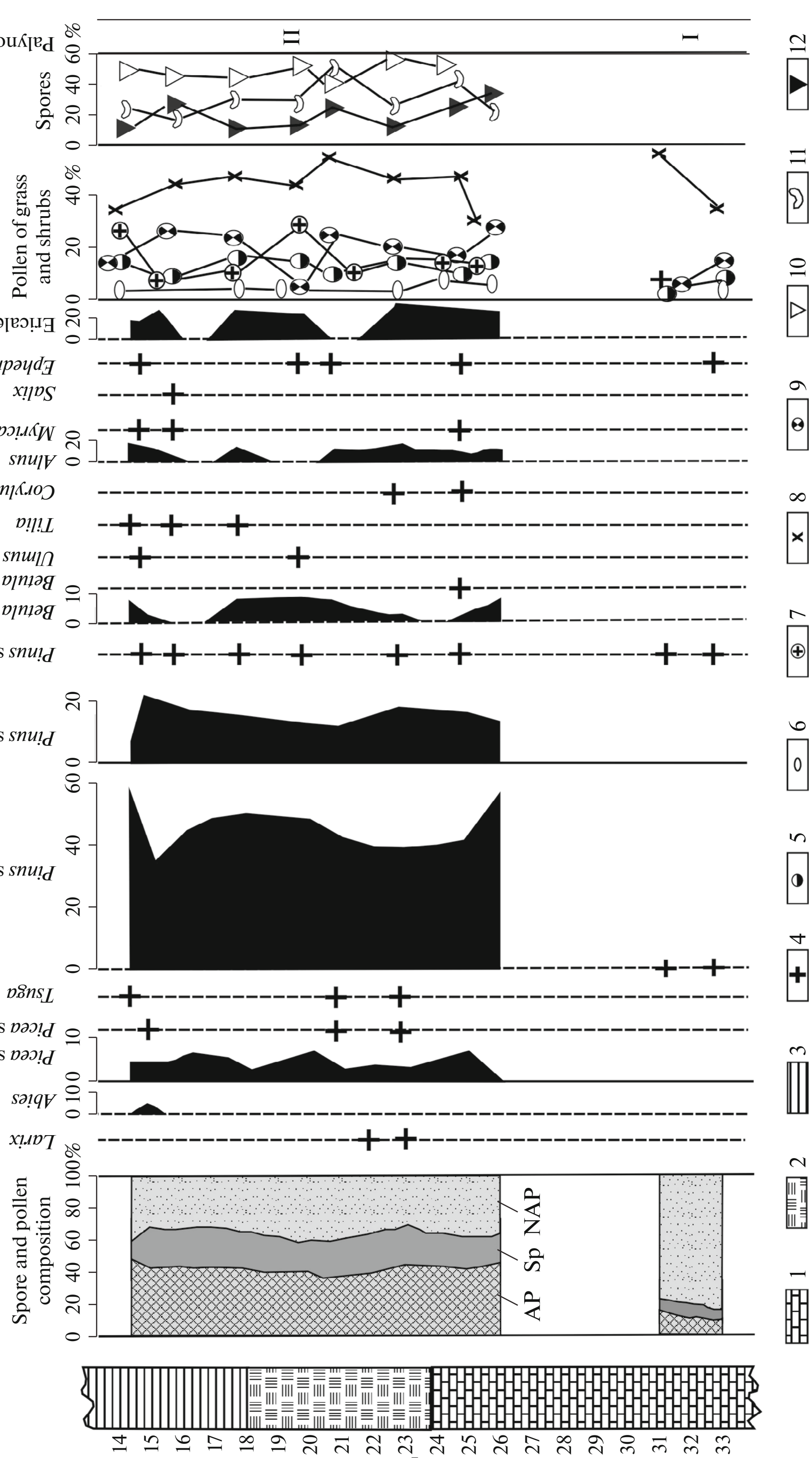


Fig. 5. Spore and pollen diagram of borehole 17 (Mangyshlak Peninsula, no. 4 in Fig. 2). Legend: (1) clay limestone, (2) marl, (3) clay, (4) single pollen grains, (5) grass pollen, (6) sedge pollen, (7) wormwood pollen, (8) myrica pollen, (9) pollen of motley grass, (10) spores of green mosses, (11) spores of ferns, (12) spores of sphagnum mosses. $N_2^3ak_2$—sediments of the Middle Akchagyl.

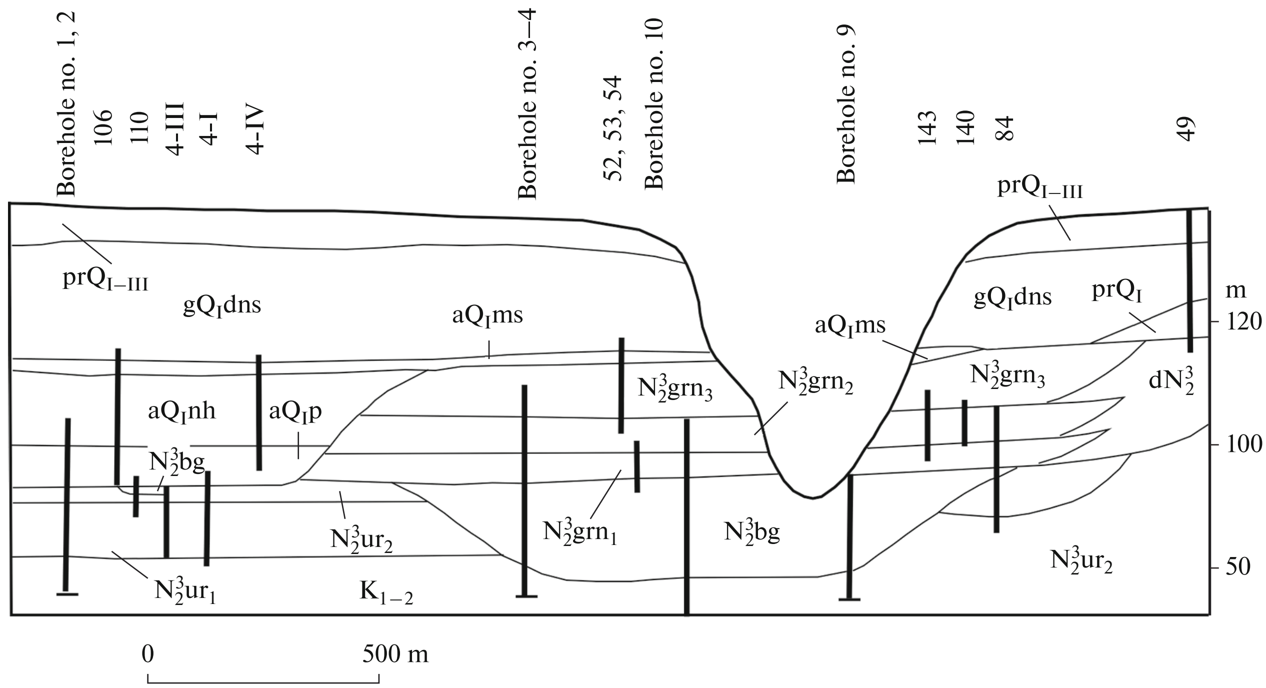


Fig. 6. Schematic section of the Uryv area (by R.V. Krasnenkov (1984)). K_{1-2}—Cretaceous sediments, Upper Pliocene: $N_2{}^3$—deluvial deposits; $N_2{}^3ur_1$—Lower Uryv subseries; $N_2{}^3ur_2$—Upper Uryv subseries; $N_2{}^3bg$—Belgorod Formation; $N_2{}^3grn_{1-3}$—Goryanskaya Formation; Quaternary deposits: aQ_Ip—Pokrovsky alluvium; gQ_Idns—deposits of the Don glaciation (till); aQ_Ims—Moiseevskii alluvium; aQ_Inh—Novokhopersky alluvium; prQ_{I-III}—covering deposits of the Lower and Upper Neopleistocene.

C.A. Mey., larch, fir, and hemlock; and there appeared small-leaved species—birch, alder, and willow. Occasionally, broad-leaved trees were found: oak, elm, and linden. Hazel and myrica (Myricaceae) grew in the undergrowth. The heather family (Ericaceae) played a prominent role, preferring conditions of a cool and humid oceanic climate, as well as ferns, sphagnum, and green mosses. The open areas were occupied by steppe vegetation, consisting of various species of pigweeds, wormwood, herbs, and ephedra.

Within the basin of the Upper Don River, the reference section of the Gelasian was the one near the village of Uryv, located in the Ostrogozhsky district of Voronezh oblast (Agadjanian, 2003; Piareva and Krasnenkov, 1979). In clearing K 4-1 on the right bank of the Don River, 0.32 km upstream from the pier, there were deposits of the Uryv Formation, divided at the base of the lignite marking horizon into the Upper Uryv and Lower Uryv deposits (Fig. 6). The latter are represented by a complete alluvial cycle from bed sands to floodplain sediments with traces of soil formation. According to I.M. Gromov, the sand from the bottom of the section contains the fauna of small mammals of the Khapry complex, characteristic of forest-meadow watershed areas (Iosifova, 1971). A.K. Agadjanian considered it transitional from the Moldavian complex to the Khapry complex and distinguished it as the Uryv complex of the MN16b Zone (Agadjanian, 2003; Agadjanian et al., 2009).

The data of the spore and pollen analysis were obtained for the floodplain clays of the Lower Uryv subseries, which accumulated in a colder climate than the modern one. At that time, sparse birch and pine-birch forests grew in the basin of the Upper Don (complex "a" in Fig. 7). The cryomer, known as the Khvorostyan' cryomer, was correlated by A.K. Agadjanian, Yu.I. Iosifovoi, and V.V. Semenov with the pre-Tiglian of Western Europe (Agadjanian et al., 2009).

The Upper Uryv sediments, attributed by Schick et al. (2015) to the Storozhevskii Horizon, were deposited during the warming period corresponding to the Tiglian A according to the schemes by B. Zagwijn and B. Urban (Urban, 1978; Zagwijn, 1985). They contain thermophilic mollusks of the genus *Parmacella*, currently distributed in the Mediterranean and Central Asia, and the hydrophilic species *Vertigo antivertigo* (Drap.), as well as the fauna of small mammals from the genera *Mimomys*, *Promimomys*, *Villania*, *Desmana*, and others (Agadjanian et al., 2009; Krasnenkov, 1984). Vegetation in the basin of the upper reaches of Don River was represented by broad-leaved and coniferous forests with undergrowth of the shrubs *Diervilla* and *Ligustrum* (complex "b" in Fig. 7). Most of the macrofossils in the lignite belong to aquatic and marsh plants (Nikitin, 1957). Of these, 70% are to a varying degree alien to the modern flora of the studied area. More than 13% belong to East Asian and North American species, 23% belong to extinct species, and the

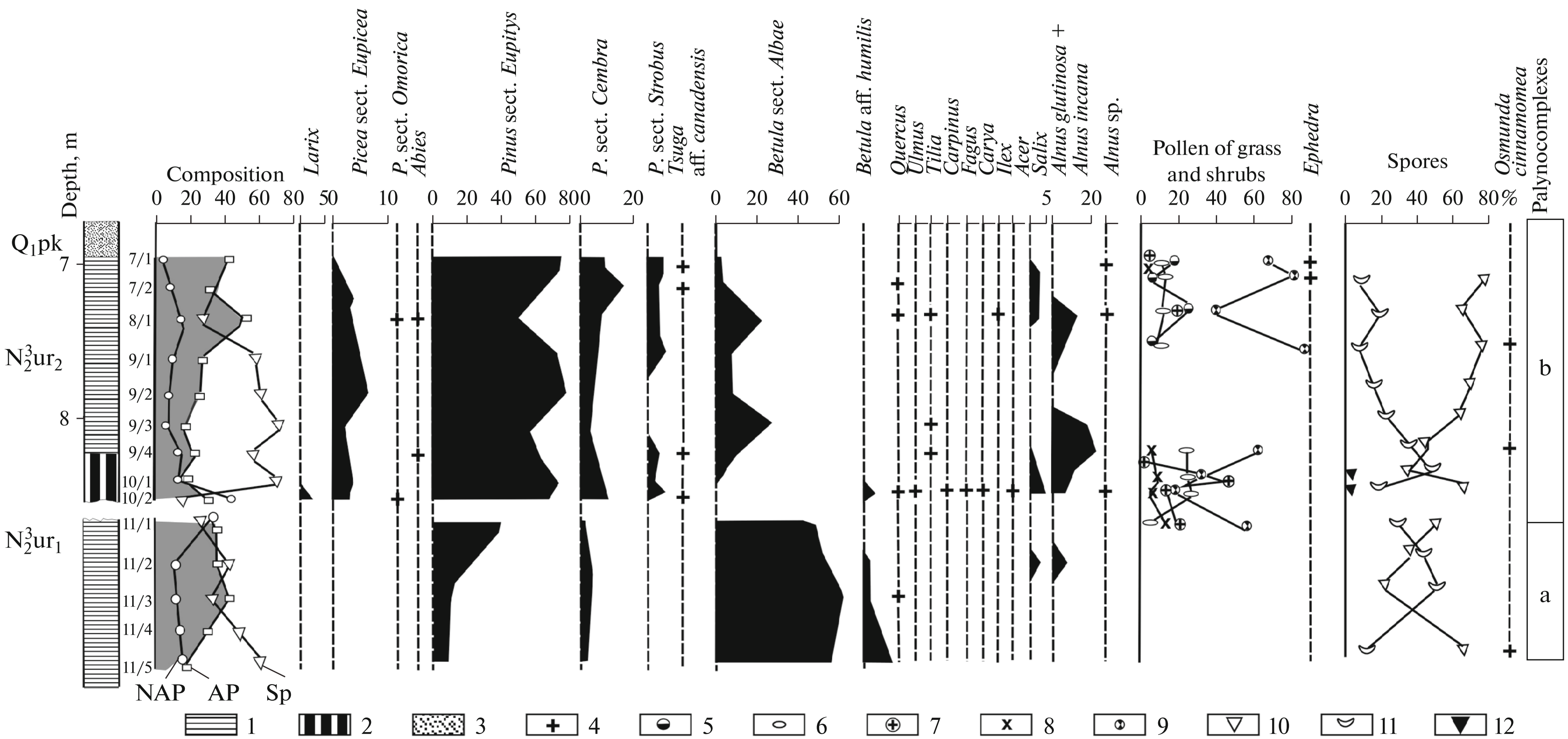


Fig. 7. Spore and pollen diagram of the Uryv layers in a section near the village of Uryv by the Don River (by Pisarev and Krasnenkov, 1979; no. 18 in Fig. 2). Legend: (1) clay, (2) peat, (3) sand, (4) single pollen grains, (5) grass pollen, (6) sedge pollen, (7) wormwood pollen, (8) myrica pollen, (9) pollen of motley grass, (10) spores of green mosses, (11) spores of ferns, (12) spores of sphagnum moss. $N_2{}^3ur_1$—Lower Uryv subseries, $N_2{}^3ur_2$—Upper Uryv subseries, Q_Ipk—Pokrovskaya Formation.

rest presently grow outside the basin of the Upper Don. Sediments with such a composition of flora were considered by Nikitin (1957) as Early to Middle Pliocene. Dorofeev (1979b) determined the age of macrofossils within the Middle Pliocene, yet he considered the flora of the section near the village of Uryv to be close to the flora of the Tiglian of Western Europe. On the paleomagnetic scale, Upper Uryv sediments belong to the Matuyama epoch, but in the upper part of the layer, a positive episode has been revealed, possibly Reunion.

The later warming, corresponding to the Krivskoye Horizon on the stratigraphic chart, includes the sands of the Krivskoye series with the fauna of small mammals of the Khapry complex, found in rock sequences on the southern bank of the Tsimlyansk reservoir (Dodonov et al., 2007). In the basin of the Upper Don, this horizon includes the sediments of the Belaya Gora Formation (Kholmovoy et al., 1985). The seed flora of this climatolite is less exotic compared to the warmer Storozhevskii interval (Nikitin, 1957). Sedimentation took place under the conditions of forest-steppe landscapes. R.S. Kholmovaya distinguished two warming periods with a short-term cooling between them for the time of accumulation of Krivskoye sediments near the Belaya Gora locality, 5 km north of Voronezh, in the cliff of the right bank of the Voronezh River. Paleocarpological data confirm the younger age of the Belaya Gora sediments compared to those of the Upper Uryv. The paleomagnetic characteristic of the Krivskoye Horizon corresponds to the Matuyama epoch (Kholmovoi et al., 1985).

The second half of the Paleopleistocene (Gelasian) includes another warming, corresponding to the Liventsovskii Horizon with the savanna fauna of the MN17 Zone (Agadjanian et al., 2009). It was revealed during the study of the Liventsovskii section near the village of Khapry to the west of Rostov-on-Don (Baigusheva, 1964).

The classic section of the Liventsovsky open pit with the Khapry faunistic complex, investigated by V.I. Gromov, V.S. Baygushevaya, V.V. Titov, L.P. Alexandrova, N.A. Lebedeva, A.S. Tesakov, V.I. Gromova, and others, unfortunately, has scarce palynological data. E.N. Ananova and M.P. Grichuk were able to reconstruct the development of steppe associations of flat interfluves only for several samples. These associations, according to V.S. Baigusheva, V.V. Titov, and other researchers, most likely correspond to the Upper Villanian fauna—MN17 (Baigusheva, 1964, 2006; Titov, 2008). The Paleopleistocene is completed with a cryomer (Tereshkovsky Horizon) containing the flora of cold-resistant plants. A.K. Agadjanian, Yu.I. Iosifova, and V.V. Semenov attributed it to the pre-Olduvai interval—the Matuyama chron (Aghajanyan et al., 2009). This cooling is traced everywhere. In Western Europe, it was accompanied by invasion of northern species: *Huperzia arctica* Sipliv., *Selaginella selaginoides*, *Betula* sect. *Fruticosae* (Kahlke and Ukraintseva, 1986).

Working on a regional stratigraphic scale of the Gelasian, researchers of flora and fauna had a disagreement over its lower boundary (Schick et al., 2015). It turned out that it is drawn at different stratigraphic levels. So, according to A.S. Tesakov, the archaic composition of the fauna of the MN16b Zone, close to the Moldavian Roussillon observed near the village of Kotlovina (Southwestern Ukraine), does not allow correlation of the Upper Uryv sediments with the Gelasian and should be attributed to the Piacenzian (*Reshenie*..., 2015). L.P. Alexandrova, N. A. Lebedeva, A.K. Agadjanian, and other researchers, on the other hand, regard the Kotlovina fauna as a transitional one from the Moldavian complex to the Khapry complex, considering it to be the early phase of the Khapry complex (Aleksandrova, 1976; Lebedeva, 1978). The latter viewpoint is supported by the presence of progressive species, such as *Villania petenyii* (Mehely.) (=*Mimomys praehungaricus* Schevtschenko) and *Mimomys* ex gr. *polonicus-pliocaenicus*. Its relation to the Khapry complex, correlated with the Middle Villafranchian of Western Europe, determines the presence of cement and low-cement forms in faunas, which are not characteristic of the more ancient Moldavian species (Lebedeva, 1978). Of the large animals in the composition of the Khapry H fauna, along with elephants, bulls, horses, and small camels, some members of the Russilonian fauna were able to be preserved.

Eopleistocene (Calabrian), 1.806–0.781 Ma

Starting from 1.8 million years ago, the trend toward cooling and the development of glaciations strengthened. In Western Europe, glaciation corresponding to the Eburonian occurred all over Scandinavia. In northern England, judging by the findings of rocks debris of Scandinavian origin in the alluvium, the glacier spread as far as the upper reaches of the Thames River (Clark et al., 2004). In the Barents Sea region, glaciers could have reached the edge of the shelf (Vorren et al., 2011). In the ancient river valleys of the northwestern regions of the East European Plain, glacial till of pre-Cromerian age and intermorainal sediments of the two moderate interglacials (Pai and Svir') were discovered (*Problemy*..., 2000). In the Moscow region, near the town of Odintsovo (Fig. 8), there was a till opened by boreholes below the Eopleistocene Akulovo interglacial sediments, which are believed to belong to the Lower Petropavlovka Horizon (up to 2.0 m thick); the till was named Likovo (Maudina et al., 1985). It is represented by black or greenish dark gray loam with small pebbles and gravel of pyroxenite, pink finely grained leucocratic granite, hyperbasites of the Polar Urals, banded jasper, and opal. The mineral composition corresponds to a disthene-epidote-garnet-staurolite association with predominance of pyrite among opaque minerals (according to M.I. Maudina). The Likovo till is overlain by fluvioglacial sands, correlated with the period of the glacier regression; only a few pollen grains of *Betula nana* and redeposited Mesozoic spores were found in them. According to the spectral analysis, the overlying oxbow sediments (gyttjas with interbeds of peat) 2.0 to 4.0 m in thickness differ from all other Quaternary sediments of the Odintsovo stratigraphic region in abnormally high contents of copper, molybdenum, lead, tin, and manganese. According to paleomagnetic data, they belong to the Upper Matuyama chron (Semenov, 2011).

Palynological studies of boreholes 8, 12, 146 were conducted by V.V. Pisareva and O.P. Kondratene; carpological studies were performed by F.Yu. Velichkevich and T.V. Yakubovskaya. Paleobotanical analysis of the three sections indicates the predominance of forest vegetation of rich floristic composition (Maudina et al., 1985; Pisareva, 1997). In the development of vegetation, the following three phases are distinguished (Fig. 9):

Phase 1 (depth 39.5–39.9 m): polydominant coniferous and broad-leaved forests, with the predominance of oak; other species are linden, elm, hornbeam, less commonly wingnut, walnut, chestnut, hop hornbeam, grapes, myrica, mulberry, and eucommia. This part of the section contains highest concentration of alder pollen. Among the conifers, along with pine *Pinus sect. Eupitys*, there were *Pinus* sect. *Cembra, Pinus* sect. *Strobus*, spruce, fir, larch, and hemlock. Generally heat-loving flora is combined with the finds of water chestnut, salvinia, and spores of *Polystichum aculeatum* (L.) Roth ex Mert., *Onoclea* sp., *Adiantum* sp., *Osmunda cinnamomea* (L.) C. Presl., *O. claytoniana* L., and *O. regalis* L.

Phase 2 (38.6–39.5 m): mixed pine and birch forests with oak, hornbeam, maple, and chestnut. This phase is characterized by the predominance of pollen of Scots pine and birch, as well as by a less diverse composition of deciduous species and a reduced amount of alder pollen.

Phase 3 (depth 37.8–38.6 m): recurring distribution of broad-leaved species with preservation of the floristic composition described for the previous intervals. Among macrofossils F.Yu. Velichkevich and T.V. Yakubovskaia discovered *Salvinia aphtosa* Wieliczk., *Azolla interglacialis* Nikit., *Aracites johnstrupii* Nikit., and *Pinus sect.* Strobus. On the basis of paleobotanical and paleomagnetic data, Akulovo sediments belong to the Petropavlovka Horizon and correlate with the Leerdam interglacial of the Bavelian Stage in Western Europe (Zagwijn, 1985).

The Akulovo interglacial may include also lacustrine and alluvial sediments near the village of Karamyshevo, Ryazan oblast, which were revealed by borehole 566 below the Don till (Grichuk, 1989; Iosifova et al., 2006; Valuev et al., 1983). P.I. Dorofeev determined extinct species with Pliocene bonds in these sediments: *Potamogeton* cf. *manshuriensis* A. Benn., *Nuphar* cf. *ovata* Dorof., *Carex paucifloroides* var. *minima* Dorof., *Ranunculus sceleratoides* Nikit., *Azolla interglacialica* Nikit., *Selaginella* cf. *helvetica*, and others. The pollen composition, along with the high content of pine pollen *Pinus* s/g *Haploxylon*, is distinguished by the presence of spruce, larch, and fir and pollen of broad-leaved trees—oak, elm, linden, hornbeam, walnut, and holly, not more than 20% in total. Alluvium of the Pokrovka Formation belongs to the time of the cooling in the basin of the Don.

Sediments from borehole 1028 drilled near the village of Krasikovo of the Konakovsky district of the Tver oblast, apparently, can be dated to the beginning of the Cromerian of Western Europe (Shik et al., 2006). The sediments were opened at a depth of 19.5 m under three layers of till—Moscow, Oka, and Don—and are represented by humified aleurites, loams, and clays with the interbeds of peat and gittja. The fluvioglacial sandy loams and sands lie below, and under them there are the Jurassic clays. Lacustrine sediments, according to V.V. Semenov, are normally magnetized with intervals of reverse polarity in their lower and upper parts. The spore and pollen diagram (Fig. 10) reflects the development of the vegetation cover of the whole interglacial. The following phases of vegetation development are distinguished:

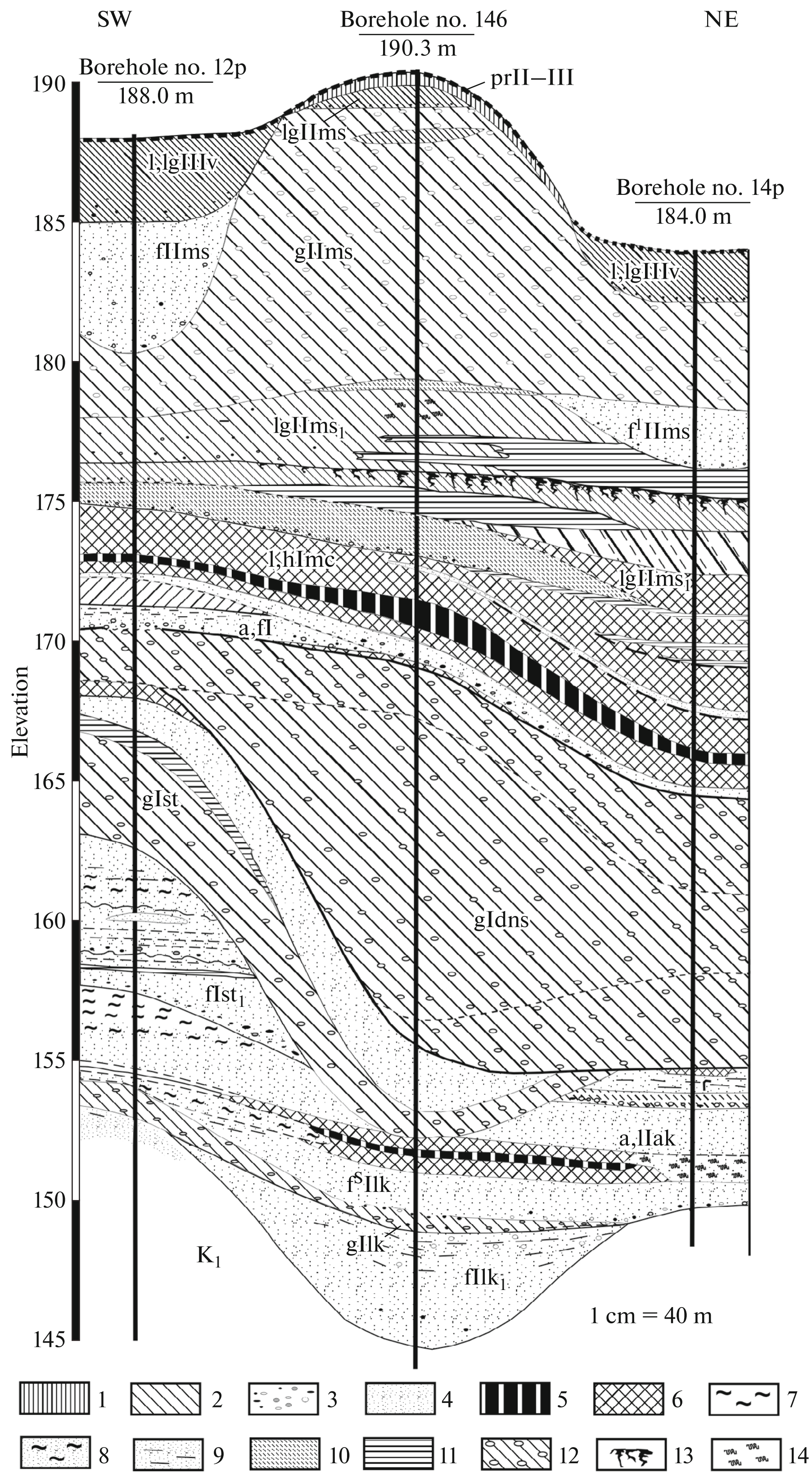
Phase 1 (42.2–42.7 m), dating to the cooling period preceding the interglacial: birch forests;

Phase 2 (39.2–42.2 m): spruce and pine-birch forests with larch, fir, hemlock, yew;

Phase 3 (37.5–39.2 m): the same forests as in the second phase, but with a minor participation of oak and elm;

Phase 4 (31.3–37.5 m): complex mixed forests that grew during the climatic optimum of the interglacial. Fir is typical of this time; among broad-leaved species are oak and elm, less often, linden and hornbeam,

Fig. 8. Geological section of Quaternary sediments near the village of Akulovo (Moscow oblast, no. 5 in Fig. 2). Legend: (1) cover loam; (2) loams; (3) gravel, pebbles, boulders; (4) sands; (5) peat; (6) gittja; (7) silt; (8) clay sands; (9) silty sands; (10) sandy loam; (11) clay; (12) boulder loam; (13) buried soils; (14) plant macrofossils. prII–III—Middle to Upper Pleistocene covering deposits; l,lgIIIv—lake and lacustrinoglacial deposits of the Valdai glaciation; lgIIms—lacustrinoglacial deposits of the Moscow glaciation; fIIms—fluvioglacial deposits of the Moscow glaciation; gIIms—till of the Moscow glaciation; $lgIIms_1$—lake deposits of the onset of the Moscow glaciation; l,hImc—lake and lake-marsh deposits of the Muchkap interglacial; a,fI—alluvial and fluvioglacial deposits of the Lower Pleistocene; gIdns—till of the Don glaciation; gIst—till of the Setun' glaciation; $fIst_1$—fluvioglacial deposits of the onset of the Setun' glaciation; a,lIak—alluvial and lake deposits of the Akulovo interglacial; $f^{S}Ilk$—fluvioglacial deposits of the Likovo glaciation retreat; gIlk—till of the Likovo glaciation; K_1—Lower Cretaceous sediments.



SW
Borehole no. 146
190.3 m
NE
Borehole no. 12p
188.0 m
prII–III
lgIIms
l,lgIIIv
Borehole no. 14p
184.0 m
fIIms
gIIms
l,lgIIIv
lgIIms1
f1IIms
l,hImc
lgIIms1
a,fI
Elevation
gIst
gIdns
fIst1
a,lIak
fSIlk
gIlk
K1
fIlk1
1 cm = 40 m
190
185
180
175
170
165
160
155
150
145
1
2
3
4
5
6
7
8
9
10
11
12
13
14

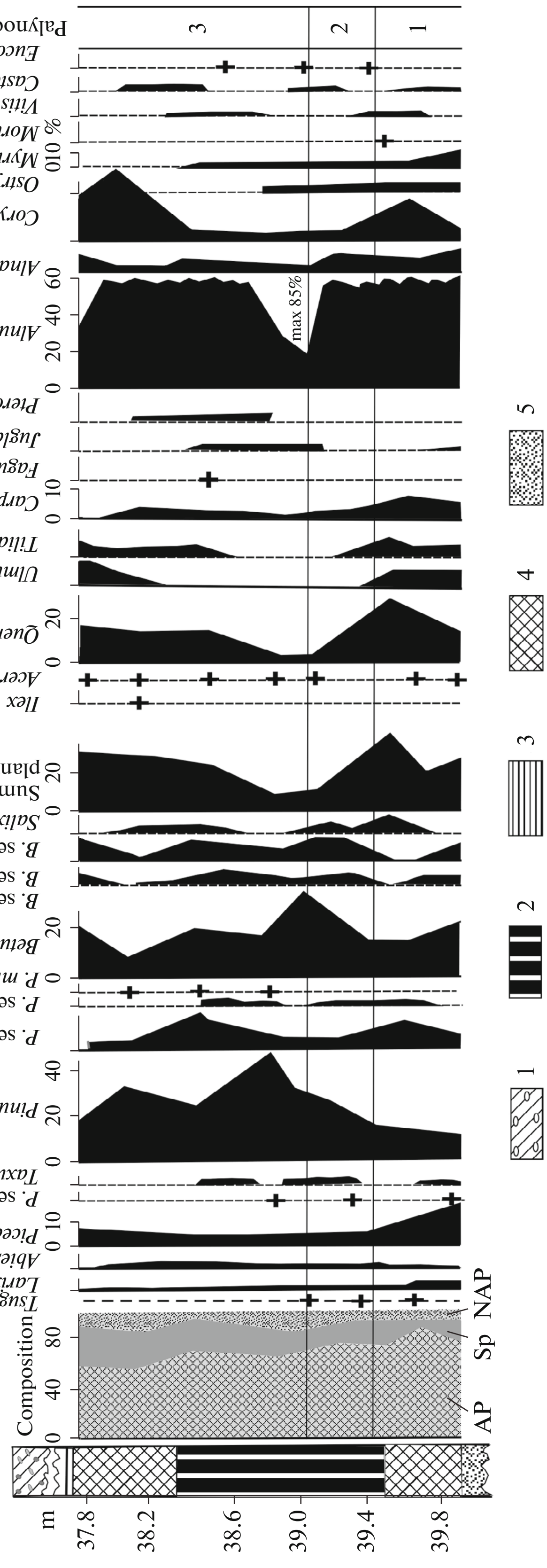


Fig. 9. Spore and pollen diagram of borehole 146 near the village of Akulovo (no. 5 in Fig. 2). Legend: (1) boulder loam; (2) peat; (3) clay; (4) gittja; (5) sand.

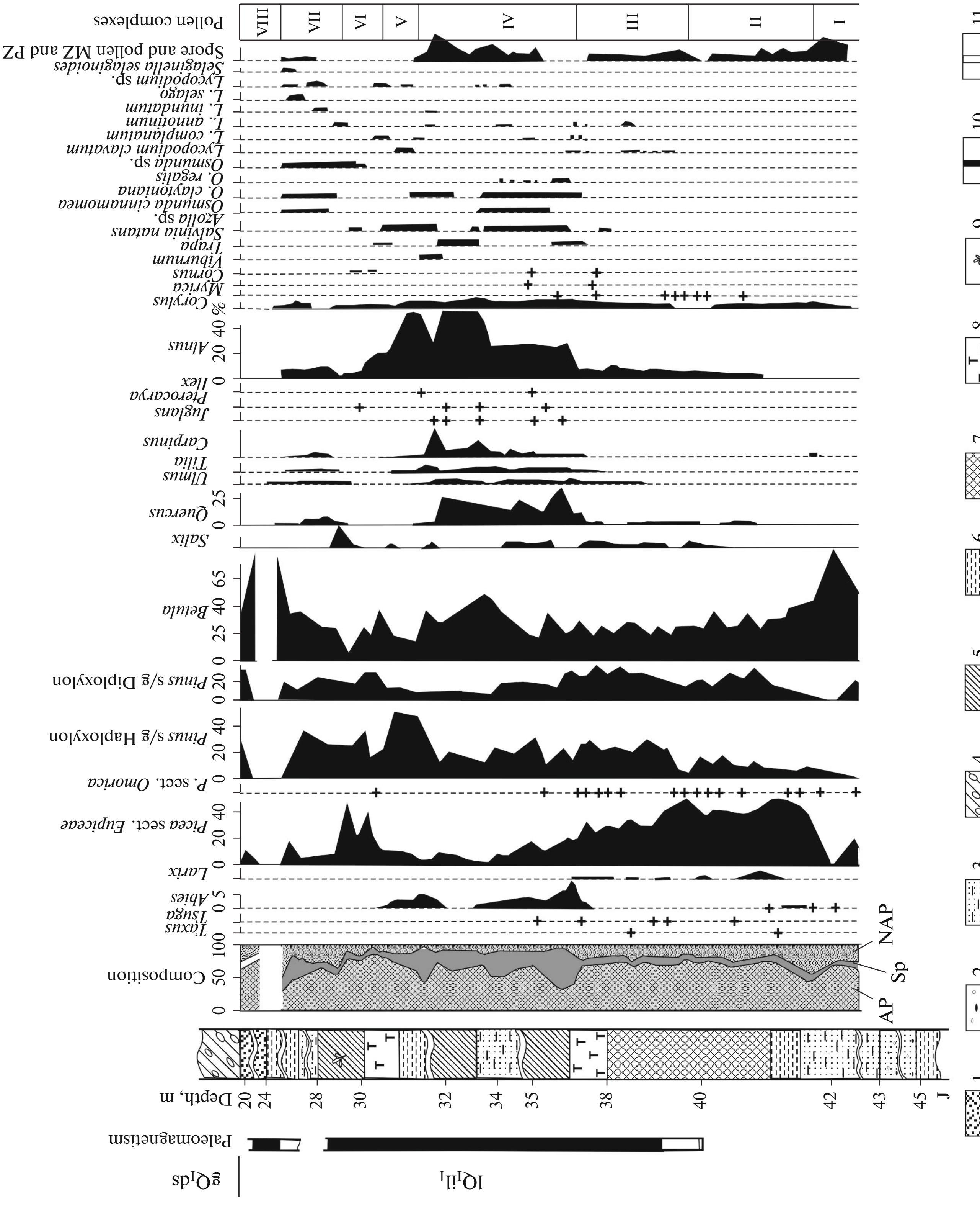


Fig. 10. Spore and pollen diagram of Upper Ilinsky deposits in borehole 1028 near the village of Krasikovo (Tver oblast; no. 7 in Fig. 2). Palynological analysis by A.A. Danilina with the participation of V.V. Pisareva; paleomagnetic analysis by V.V. Semenov. Legend: (1) sand; (2) gravel and pebbles; (3) sandy loam, aleurite; (4) loam rubbly; (5) loam lacustrine; (6) clay; (7) gittja; (8) peat; (9) plant macrofossils; (10, 11) magnetic polarity: (10) normal, (11) reverse; gQ_Ids—glacial deposits of the Don glaciation; lQ_Iil_1—lacustrine deposits of the Ilinsky Horizon; J—Jurassic deposits.

which become more frequent in the second half of the optimum along with alder. Walnut and wingnut were found in the plant formations; holly, dogwood, and cepiferous and other bushes formed undergrowth; and ferns of the genus *Osmunda* and forest species of moss were in the grassy cover. Among aquatic plants, *Salvinia* sp., *Trapa* sp., and *Azolla interglacialica* flourished.

Subsequent phases in the development of vegetation belong to the second half of the interglacial period, when, owing to the beginning of cooling, the most thermophilic species began to recede.

Phase 5 (30.5–31.3 m): domination of cedar forests with an admixture of spruce and fir, as well as mixed pine and birch forests;

Phase 6 (29.5–30.5 m): dark coniferous forests of spruce and cedar;

Phase 7 (27.0–29.5 m), attributable to the end of the interglacial: spruce-pine and pine-birch forests alternating with open spaces;

Phase 8 (26.0–27.0 m), corresponding to the time of substantial cooling: monodominant sparse birch forests.

In general, the fossil flora of the Krasikovo interglacial is less diverse than that of the Akulovo. There is no pine *Pinus* sect. *Mirabilis* encountered there; the finds of *Pinus* sect. *Strobus* are very rare; pollen of broad-leaved species is less diverse, among which pollen of the most thermophilic species—eukommia—is not found. The Krasikovo flora is determined by the significant participation of *Pinus* sect. *Cembra* in combination with other conifers (*Picea omoricoides*, fir, larch, hemlock, yew) and broad-leaved species. The change of these phases has no analogs among the vegetation cover of other warm rhythms and corresponds to an independent interglacial which was younger than Akulovo.

Outside the glacial area, there are two layers of the red-colored soils of the Balashov soil complex, formed under climate conditions close to subtropical, which probably correspond to the Akulovo and Krasikovo interglacials. Krasikov's warming in Eastern Europe corresponds to the beginning of the Cromerian Stage, which lasts from 780 to 480 ka (Houmark-Nielsen, 2011) and is characterized by the alternation of significant warming and cooling periods (Iosifova et al., 2006; Schick et al., 2006; Zagwijn, 1996).

The Matuyama/Brunhes reversal, known to correspond to the bottom of the marine isotopic stage 19 with an age of about 780 ka, and in the loess soil sections of the East European platform positioned above the Balashov soil complex, was used as the main reference for further chronostratigraphic reconstructions (Velichko et al., 2002).

Early Neopleistocene (Ionium, including the Cromerian and Elsterian of Western Europe)

The first cooling at the beginning of the Cromerian and the glaciation of stage A in Western Europe correlates with the advancement of the Setun' ice sheet along the Setun' River in the Moscow region to the East European Plain. The till of that ice sheet is traced from the Moscow region to the northern outskirts of Tula oblast (Schick, 1993). In the boreholes drilled near the village of Akulovo, it overlies the Akulovo interglacial deposits and is represented by massive brownish and greenish dark gray loams with fragments of Ladoga rapakivi, Shoksha sandstones, and biotite gneisses (after M.I. Maudina and A.Gaygalas). According to L.T. Semenenko, an amphibole-epidote-garnet-zircon association of heavy fraction minerals is characteristic of that till. The till thickness is on average 5–10 m, increasing in hollows of glacial plowing to 40 m. The analysis of detrital material inferred that the ice of the Setun' glaciation advanced into the Don basin from Scandinavia (Schick, 1993). In subaerial deposits, the Setun' cryochrone corresponds to the Bobrov loess.

The sediments of the Okatovo interglacial, which began after the Setun' glaciation, were first identified below the Don till in the sections near the village of Okatovo, 4.0 km east of the Vnukovo railway station in the Western Moscow region (Fursikova et al., 1992) and in the area of the Skhodnya station. Flora of Okatovo is by all means poorer than that of Akulovo and Krasikovo. *Pinus* sect. *Cembra* and *P.* sect. *Strobus* are less common; *P.* sect. *Mirabilis* and *Tsuga* are absent. At the beginning of the interglacial optimum, oak, elm, and linden with hazelnut and alder as undergrowth occurred; later, maple, ash, hornbeam, zelkova, walnut, wingnut, chestnut, cornel, honeysuckle, wild grapes, myrica, and green alder (*Alnus viridis* (Chaix) DC) propagated. According to the participation of the North American, East Asian, and Balkan-Colchian elements, making up in total 13%, and of extinct species (7%), the Okatovo flora is similar to the flora of the section near the village of Moiseevo, Tambov oblast, which Dorofeev (1979a) believed to be close to the Cromerian of England. The fauna of small mammals in the Moiseevo section was attributed by A.K. Agadjanian to the Tiraspol complex (Krasnenkov et al., 1981). In the periglacial zone, the soil of the Rzhaksinsky stratum, corresponding to the age of the Okatovo interglacial, is similar to prairie soils, while the more ancient, Balashov, soil is related to the humid subtropics (Velichko et al., 2012).

A severe cooling in the Middle Cromerian led to the development of maximum Don glaciation, correlated with the Cromerian glacial B. Its age is determined by the findings of the Late Tiraspol fossil fauna in the layers above and below the till (Agadjanian, 1986; Krasnenkov et al., 1997; Markova, 1982; *Vozrast*..., 1980) and confirmed by a detailed study of loess and soils. In the Moscow region, the bulk of larger fragments are sedimentary rocks (limestones and dolomites of the Upper Carboniferous). There is also a lot of siderite debris. Erratic material is represented mainly by gray granites, metamorphic rocks, and quartzite-like sandstones. The presence of numerous detached fragments of Okatovo sediments in the till in the sections of the Moscow region, the Ivanovo region, and the upper reaches of Dnieper indicates an extensive exaration effect of the Don ice sheet on the underlying rocks.

Sediments related to the regression of the Don glaciation were investigated in the basin of the Don River. They were opened by the borehole drilled near the village of Nikolskoye (formerly Demshinsk of Lipetsk oblast) above the Don till and under the sediments of the Muchkap interglacial and are represented by 8.6 m of lacustroglacial loams (Iosifova et al., 2006; Pisareva and Zyuganova, 2005; Turner et al., 2003). The lower part of the spore and pollen diagram (Fig. 11) gives an idea of the changes in the landscape during the regression. The vegetation in the basin of Don at that time was essentially periglacial: first, a steppe with a prevalence of wormwood and pigweed associations (palynocomplex 1); later, during interstadial warming, forest steppe (palynocomplex 2). The glacial period ends with the spread of periglacial steppe vegetation with participation of meadow associations (palynocomplex 3). Throughout the late glacial, wormwood and pigweeds played a significant role in the landscape. Among the latter, there are species that are now growing in a continental climate: *Polycnemum arvense*, *Dysphania botrys* (L.) Mosyakin et Clemants, *Krascheninnikovia ceratoides* (L.) Gueldenst., *Kochia prostrata*, *Suaeda* sp., and other xerophytes: *Ephedra* sp., *Helianthemum* sp., Plumbaginaceae, Saxifragaceae. Such species as *Artemisia vulgaris* L., *Plantago lanceolata* L., *Arctium* sp., and *Echinops* sp. grew on disturbed substrates.

Transition to the interglacial (palynocomplex 4) is marked by emergence of oak and elm in the forest formations. During the first (Glazovo) optimum (palynocomplexes 5 and 6), polydominant broad-leaved and coniferous–broad-leaved forests expanded. Conifers were represented by *Picea* sect. *Omorica*, *Pinus* sect. *Strobus*, *P.* sect *Cembra*, *Larix* sp., and *Abies alba* Mill.; broad-leaved species were represented by oak, elm, hackberry, linden, maple, chestnut, wingnut; and the undergrowth was represented by hazel, privet, hop, and myrica. The subsequent change in the natural environment was cooling and aridization of the climate. Open landscapes became dominant (palynocomplexes 7 and 8). During the second climatic optimum, Konahovka (palynocomplex 9), mixed coniferous and broad-leaved forests, with participation of hornbeam, spread again. At the end of the interglacial (palynocomplex 10), owing to the climate cooling, they were replaced by forests of pine and birch with *Betula nana* and *B. humilis*. The list of macroscopic fossils is dominated by aquatic, marsh, and meadow grassy plants, among which there are species that are now common in East Asia (Ussuriysk region, Manchuria, Korea, Japan) and extinct species inherited from the Pliocene: *Azolla interglacialica*, *Salvinia interglacialis* Dorof., *Alisma minimum* (Nikit.) Dorof., *Stratiotes intermedius* (Hartz.) Chandl., *Myriophyllum pseudoussuriensis* Dorof., *Betula diluviana* Dorof., etc. (Dorofeev, 1992; Zyuganov, 2004). Overlying lacustrine sediments with buried soils belong to the Middle Neopleistocene.

The Demshinsk section correlates with other Muchkap sections of the Don basin dated by the Tiraspol fauna of small mammals. It also reveals a close resemblance to the sections of the Yaroslavl interglacial area of the Moscow region (Maudina et al., 1985) and Smolensk oblast (Iosifova et al., 2006; Schick et al., 2006) and the Cromerian section of Ferdinanduv in Poland (Janczyk-Kopikova, 1975). Both climatic optima expressed in the spore and pollen diagram of the Demshinsk section probably correspond to the interglacial III of the Cromerian. A small amount of hornbeam pollen in the Konakhovka optimum is explained by its location in the steppe zone.

The analog of the terminal Cromerian—interglacial IV—is most likely the Ikorets interglacial. It was distinguished in the course of studying the sections of Voronezh oblast, namely, Ikorets quarry and Mastyuzhenka gully (20 km northeast of the town of Liski, in the basin of the Ikorets River, a tributary of the Don), and the section near the Shekhman township on the Matyra River in Tambov oblast, 50 km south of the town of Michurinsk (Agadjanian et al., 2009; Iosifova et al., 2009; Krasnenkov and Kazantseva, 1993). In the Mastyuzhenka section, the alluvial bone bed is separated from the Inzhavinskaya (Likhvinskaya) buried soil by sediments with the traces of permafrost deformations. The determination of bones enabled A.K. Agadzhanyan to find the missing link in the development of the fauna between the Tiraspol *Mimomys* and the Singilian *Arvicula*. According to A.K. Aghadzhanian, the change of faunas could have occurred before the onset of the Oka glaciation, during the final stage of the Cromerian, corresponding to MIS13 (Aghadzhanyan et al., 2009). The paleobotanical data for the Ikorets sediments of the Don basin have not yet been obtained, but the composition of the fauna suggests a warm moderately humid climate.

In the glacial area, sediments coeval with the Ikorets sediments may be those found in the Smolensky Brod tract on the Western Dvina River near the village of Yakhny, in the Velizhsky district of the Smolensk oblast, where *Arvicula* is more archaic than the one found in the the Likhvinskaya (Motuzko, 1985). Palynological studies of this section in different years were conducted by N.A. Makhnach, T.B. Rylovoy, Ya.K. Elovicheva, V.V. Pisareva, and others, and carpological studies were performed by F.Yu. Velichkevich and T.V. Yakubovskaya (Kozlov et al., 2011; Shik

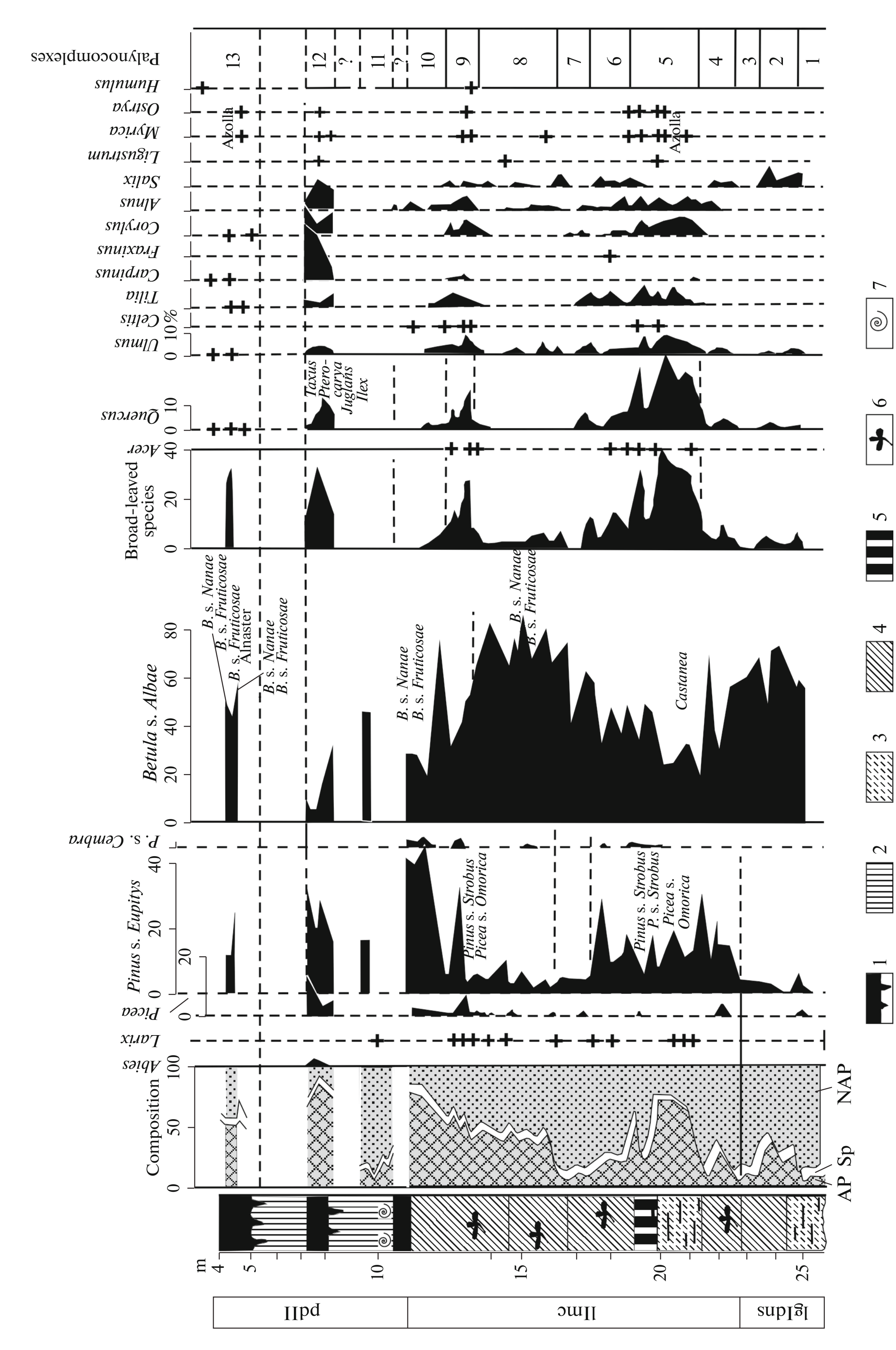


Fig. 11. Spore and pollen diagram of the Neopleistocene sediments of the reference section of Demshinsk (Nikolskoye) (no. 15 in Fig. 2). Legend: (1) buried soil; (2) loess; (3) loams; (4) sandy loam; (5) peat; (6) plant macrofossils; (7) mollusk shells. LgIdns—lacustrinoglacial deposits of the Don glaciation; IImc—lacustrine deposits of the Muchkap interglacial; pdII—loess soil sediments of the Middle Pleistocene.

and Yakubovskaya, 2016; Wozniachuk and Sanko, 1981). These studies have indicated that the sediments of Smolensky Brod are older than those of Likhvinskaya but younger than Muchkap judging by the composition of the fossil flora.

During the climatic optimum in the Dnieper bank near Smolensk, there were polydominant broad-leaved forests of oak, elm, linden, maple, hackberry, zelkova, and ash, dominated by hornbeam in the second half of the optimum. The presence of single pollen grains of wingnut, beech, and mulberry, as well as of myrica, ivy, and grapes, was revealed by a new study of this section conducted by V.V. Pisareva. The independence of this interglacial was proved by the fact that it was preceded by a significant cooling, characterized by periglacial vegetation.

Outside the glacial area, the second half of the Early Neopleistocene corresponds to the Voronskii polygenetic soil complex, studied in a number of reference sections near the Don and Dnieper. In the central regions of the East European Plain (Strelitsa, Korostelevo, and other sections), it is represented by at least two independent layers of paleosoil. During the early stage of development, the soil cover was chernozem-like prairie and meadow soils. A contrasting combination of chernozem-like and brown and in more southern areas reddish brown soils was predominant at the final stage (Velichko et al., 1992). The attribution of the Voronskii soil complex to the Early Pleistocene was justified by the presence of the Late Tiraspol fauna (Agadjanian, 1992; Agadjanian and Glushankova, 1987; Markova, 1982).

The Early Neopleistocene, according to the stratigraphic scale adopted in Russia, is concluded by the Oka glaciation, which is comparable to the Elsterian glaciation in Western Europe. It was assumed that it reached the basin of Oka River; however, the question of its borders remains controversial, since the Oka glacial sediments were in places destroyed by the exaration of younger ice sheets. Judging by the orientation of detrital material, the ice on the East European Plain moved from the north in the meridional direction. In the western regions, in the Baltic region, till of the Oka glaciation contains fragments of rock from the Aland Islands, from central Sweden, and from the bottom of the Baltic Sea. The stratigraphic position of the Oka till in the basins of Upper Volga and Upper Dnieper and in northern Moscow region is determined by its occurrence under the Likhvin lake deposits associated with it by a gradual transition.

The petrographic composition of the till within this territory is characterized by the presence of nepheline syenites of the Kola Peninsula and clay-amphibole schists of the Onega Bay (Shik and Biryukov, 1989). The glacial conditions of the Oka time are reflected in the lemming fauna of rodents found on the Oka-Don Plain in fluvioglacial sediments correlated with the till (Agadjanian and Glushankova, 1987) and in the species *Dicrostonyx simplicior okaensis* Alex. from the sands opened below the Likhvin sediments near the town of Chekalin (Aleksandrova, 1982).

The outcrop near the village of Narovatovo on the Moksha River can serve as a representative section for the Oka till (Runkov et al., 1993), where it lies below the buried Likhvin soil. In the boreholes by the town of Lukoyanov, the Oka till overlies the lake deposits of the Early Pleistocene (Pisareva, 1992). These data suggest that the Oka ice sheet reached the city of Arzamas in the Nizhny Novgorod region, i.e., much farther south than was previously thought.

In the basin of the Tesha River, interstadial sediments were identified between the two layers of till of the Oka glaciation, which are comparable with one of the horizons of the Venedskaya Formation. According to the palynological data, there was a periglacial type of vegetation during relative warming with a predominance of the flora typical of northern taiga with participation of *Selaginella selaginoides*, *Betula nana*, *B. humilis*, and *Azolla interglacialica*. In the cold intervals of the Venedskaya interstadial, there were periglacial steppes in the basin of Kama River (Ananova, 1959).

CONCLUSIONS

On the basis of paleobotanical studies, a change of vegetation from the Late Pliocene—the Early Akchagyl to the end of the Early Neopleistocene—was traced. A noticeable cooling of the climate was associated with the Early Akchagyl, when many plants inhabiting the areas with subtropical and mildly warm climate vanished from the flora. Development of the small Akchagyl transgression and the flooding of the river valleys flowing into the Caspian basin dates back to this time. A more significant cooling was established at the beginning of the Middle Akchagyl—approximately at the boundary of the Matuyama and Gauss chrons. The decrease in global temperature at the beginning of the Paleopleistocene (Gelasian) led to the development of continental glaciation in Scandinavia. The change of vegetation from zonal to hyperzonal is associated with this time. There was a degradation of forest vegetation in the northwest of Eastern Europe. In the basins of the Kama and the Upper and Middle Volga, forests were close in composition to the northern taiga; in the Lower Volga and Caspian regions, there were islands of pine, spruce, and birch forests. The maximum transgression of Caspian Sea was associated with the pluvial phase of the Middle Akchagyl.

The next cooling, less pronounced compared to the previous one, belongs to the Late Akchagyl. On a paleomagnetic scale, it corresponds to the base of the Olduvai subchron. This cooling was replaced by warming, corresponding to the Tiglian of Western Europe. As in Western Europe, it was interrupted by intervals with a decreased heat supply. According to the study of the sections in the basin of Don, there were at least two of them.

In the interval of 1.8–0.4 Ma, seven interglacial warmings alternating with cooling periods were distinguished. The warmings varied in the composition and the nature of the fossil flora. The glacial rank of some of the colder intervals requires additional investigation. It is also necessary to study the correlation of sediments from the glacial and periglacial zones.

The most noticeable episodes of fossil flora depletion, as already noted by previous researchers, were detected at the beginning of the Early Akchagyl, at the turn of the Early and Middle Akchagyl, and about 1.8 million years ago. The new materials we received confirm this conclusion. Changes in vegetation within the northwestern and central regions of Eastern Europe indicate that, starting from 2.58 million years ago, a trend toward global cooling was manifested. However, both the frequency of climate fluctuations and their intensity increased.

FUNDING

This work was carried out within the framework of the State Assignment Topic no. 0148-2019-0005.

Reviewer Yu.A. Lavrushin

REFERENCES

Agadjanian, A.K., Stages of evolution of small mammals in the central areas of the East European Platform, in *Reshenie 2-go Mezhved. Soveshch. po chetvertichnoi sisteme Vostochno-Evropeiskoi platformy* (Res. 2nd Interdepart. Conf. on the Quaternary of the East European Platform), Leningrad: Vseross. Nauchno-Issled. Geol. Inst., 1986, pp. 67–73.

Agadjanian, A.K., Stages of evolution of small Pleistocene mammals of the Central Russian Plain, in *Stratigrafiya i paleogeografiya chetvertichnogo perioda Vostochnoi Evropy* (Quaternary Stratigraphy and Paleogeography of Eastern Europe), Moscow: Inst. Geol. RAN, 1992, pp. 37–49

Agadjanian, A.K., Middle Pliocene small mammals of the Russian Plain, *Stratigr. Geol. Correl.*, 2003, vol. 11, no. 6, pp. 682–688.

Agadjanian, A.K. and Glushankova, N.I., Pleistocene paleogeography of the Oka–Don Plain, in *Teoreticheskie i metodicheskie problemy paleogeografii* (Theoretical and Methodical Problems of Paleogeography), Moscow: Mosk. Gos. Univ., 1987, pp. 145–170.

Agadjanian, A.K., Iosifova, Yu.I., and Shik, S.M., The lower Neopleistocene Mastyuzhenka (Upper Don) section and its significance for regional stratigraphy, in *Mater. Vseross. nauchn. Soveshch. "Aktual'nye problemy neogenovoi i chetvertichnoi stratigrafii i ikh obsuzhdenie na 33-m Mezhdunarodnom geologicheskom kongresse (Norvegiya, 2008 g.)", Moskva, 13 aprelya 2009 g.* (Proc. All-Rus. Sci. Meet. "Discussion of Actual Problems of Neogene and Quaternary Stratigraphy on 33rd Int. Geol. Congr. (Norway, 2008), Moscow, April 13, 2009), Moscow: GEOS, 2009, pp. 20–24.

Aleksandrova, L.P., Antropogene rodents of the European USSR, in *Tr. GIN AN SSSR. Vyp. 291* (Trans. Geol. Inst. USSR Acad. Sci., Vol. 291), 1976.

Aleksandrova, L.P., The new species of pied Lemming (Dicrostonyx okaensis sp. nov.) and its significance for distinguishing the age of the Oka Glaciation in the Likhvin stratotype section, in *Stratigrafiya i paleogeografiya antropogena* (Stratigraphy and Paleogeography of the Anthropogene), Moscow: Nauka, 1982, pp. 17–21.

Ananova, E.N., The periglacial flora from ancient Quaternary deposits of the Kama River, in *Problemy botaniki. Vyp. IV* (Problems of Botany. Vol. IV), Moscow–Leningrad: Izd. Akad. Nauk SSSR, 1959, pp. 92–104.

Baigusheva, V.S., The Khaprov fauna from the Liventsovsky sandy quarry (Rostov Region), *Byull. Komissii po Izucheniyu Chetvertichnogo Perioda*, 1964, no. 29, pp. 44–50.

Baigusheva, V.S., The Late Pliocene continental theriocomplex of the Pryazovia in the geological history of ecosystems of the Northern Arid Zone, in *Mater. Mezhd. simp. "Pozdnekainozoiskaya geologicheskaya istoriya Severa aridnoi zony". Azov, Rostov na Donu, 26-29 sentyabrya 2006 g.* (Proc. Int. Symp. "Late Cenozoic Geological History of the Northern Arid Zone". Rostov-on-Don, September, 26–29, 2006), Rostov-on-Don: Izd. Yuzhn. Nauch, Tsentr RAN, 2006, pp. 185–187.

Borzenkova, I.I. and Zubakov, V.A., The climate change in Late Miocene and Pliocene, in *Tr. Gos. Gidrol. Inst.* (Trans. State Hydrol. Inst.), 1985, vol. 339, pp. 93–118.

Chetvertichnaya geologiya i paleogeografiya Rossii (Quternary Geology and Paleogeography of Russia), Alekseev, M.N., Ed., Moscow: GEOS, 1997 [in Russian].

Clark. Ch., Gibbard, Ph.L. and Rose, J., Pleistocene glacial limits in England, Scotland and Wales, in *Quaternary Glaciations – Extent and Chronology. Developments in Quaternary Sciences, Ch. 2. P. 1. Europe*, Ehlers, J. and Gibbard Ph.L., Eds., Amsterdam: Elsevier, 2004, pp. 47–82.

Dodonov, A.E., Tesakov, A.S., Titov, V.V., et al., New data on the stratigraphy of the Pliocene–Quaternary deposits of the Lower Don, sections of the Tsimlyansk waterpond coast, in *Mater. Vseross. Nauchn. soveshch. "Geologicheskie sobytiya neogena i kvartera Rossii: sovremennoe sostoyanie stratigraficheskikh skhem i paleogeograficheskie rekonstruktsii". Moskva, 27–30 marta 2007 g.* (Proc. All-Russ. Sci. Conf. "Geologic Events in the Neogene and Quaternary of Russia: Present State of Stratigraphic Scales and Paleogeographic Reconstructions", Moscow, March, 27–30, 2007), Moscow: GEOS, 2007, pp. 43–52.

Dorofeev, P.I., The Pliocene flora from the Dan'shino village area (Don River), in *Problemy antropogena tsentral'nykh raionov Russkoi platformy* (Problems of the Anthropogene of the Central Russian Plain), Voronezh: Voronezh. Gos. Univ., 1979a, pp. 87–93.

Dorofeev, P.I., *Some conclusions and problems of the Soviet paleocarpology, Sov. Paleokarpol.*, Moscow: Nauka, 1979b, pp. 13–25.

Dorofeev, P.I., The Lower Pleistocene overmoraine seed flora from the Nikol'skoe (Demshinsk) reference section, in *Stratigrafiya i paleogeografiya chetvertichnogo perioda Vostochnoi Evropy* (Quaternary Stratigraphy and Paleogeography of the Eastern Europe), Moscow: Inst. Geol. Ross. Akad. Nauk, 1992, pp. 199–221.

Filippova, N.Yu., *Palinologiya verkhnego pliotsena-srednego pleistotsena yuga Kaspiiskoi oblasti* (Palinology of the Upper Pliocene–Middle Pleistocene of the Southern Caspian Region), Leonov, Yu.G., Ed., Moscow: GEOS, 1987 [in Russian].

Fursikova, I.V., Pisareva, V.V., Yakubovskaya, T.V., et al., The Pleistocene reference section I the Okatovo village area (western Moscow Region), in *Stratigrafiya fanerozoya tsen-*

tra Vostochno-Evropeiskoi platformy (Phanerozoic Stratigraphy of the Central Part of the East European Platform), Moscow: Rosgeolfond, 1992, pp. 59–82.

Geologicheskie sobytiya neogena i kvartera Rossii: sovremennoe sostoyanie stratigraficheskikh skhem i paleogeograficheskie rekonstruktsii. Mater. Vseross. nauchn. soveshch., Moskva, 27–30 marta 2007 g. (Proc. All-Russ. Sci. Conf. "Geologic Events in the Neogene and Quaternary of Russia: Present State of Stratigraphic Scales and Paleogeographic Reconstructions", Moscow, March, 27–30, 2007), Gladenkov, Yu.B., Ed., Moscow: GEOS, 2007.

Goretskii, G.I., *Allyuvii velikikh antropogenovykh prarek Russkoi ravniny* (Alluvium of Great Anthropogenic Pra-Rivers of the Russian Plain), Moscow: Nauka, 1964 [in Russian].

Granitsa mezhdu neogenovoi i chetvertichnoi sistemami v SSSR (The Neogene–Quaternary Boundary in the USSR), Alekseev, M.N. and Nikiforov, K.V., Eds., Moscow: Nauka, 1987 [in Russian].

Grichuk, V.P., The lower boundary of the Quaternary period (system) and its stratigraphic position in the Russian Plain, in *Tr. IGAN SSSR. Vyp. 77* (Trans. Geol. Inst. USSR. Vol. 77), Moscow: Izd. Akad. Nauk SSSR, 1959, pp. 5–90.

Grichuk, V.P., The ancient inland glaciation epoch in Europe, its signs and stratigraphic position, in *Voprosy paleogeografii pleistotsena lednikovykh i periglyatsial'nykh oblastei* (Problems of Pleistocene Paleogeography in Glacial and Periglacial Regions), Moscow: Nauka, 1981, pp. 7–35.

Grichuk, V.P., *Istoriya flory i rastitel'nosti Russkoi ravniny v pleistotsene* (The Evolution of Flora and Vegetation of the Russian Plain in the Pleistocene), Moscow: Nauka, 1989 [in Russian].

Houmark-Nielsen, M., Pleistocene glaciations in Denmark: chronology, ice dynamics and landforms, in *Quaternary Glaciations – Extent and Chronology. A Closer Look. Developments in Quaternary Sciences, Ch. 15*, Ehlers, J., Gibbard, P.L., Hughes, P.D., Eds., Amsterdam: Elsevier, 2011, pp. 47–58.

Iosifova, Yu.I., Some problems of the Neogene stratigraphy of the Oka–Don plain, in *Stratigrafiya neogena Vostoka Evropeiskoi chasti SSSR* (The Neogene Stratigraphy of the Eastern Part of the European USSR), Moscow: Izd. Nedra, 1971, pp. 202–220.

Iosifova, Yu.I., Agadjanian, A.K., Pisareva, V.V., and Semenov, V.V., The Upper Don basin as stratotype region of the Middle Pleistocene in the Russian Plain, in *Palinologicheskie, klimatostratigraficheskie i geoekologicheskie rekonstruktsii. Tez. Konf. posvyashch. pamyati E.N. Ananovoi* (Proc. Conf. Devoted to E.N. Ananova "Palynological, Climatostratigraphic, and Geoecological Reconstructions"), St. Petersburg: Nedra, 2006, pp. 41–84.

Iosifova, Yu.I., Agadjanian, A.K., and Semenov, V.V., Climatic events in the Upper Don during the Pleistocene, in *Mater. Vseross. nauchn. soveshch. "Aktual'nye problemy neogenovoi i chetvertichnoi stratigrafii i ikh obsuzhdenie na 33-m Mezhdunarodnom geologicheskom kongresse (Norvegiya, 2008)". Moskva, 1–3 aprelya 2009 g.* (Proc. All-Rus. Sci. Meet. "Discussion of Actual Problems of Neogene and Quaternary Stratigraphy on 33rd Int. Geol. Congr. (Norway, 2008), Moscow, April 13, 2009), Moscow: GEOS, 2009, pp. 64–68.

Izmenenie klimata i landshaftov za poslednie 65 mln. let (Changes in the Climate and Landscapes over the Last 65 Ma), Velichko, A.A., Ed., Moscow: GEOS, 1999 [in Russian].

Janczyk-Kopikowa, Z., Flora interglacialu Mazowieckiego w Ferdinandowie, *Biul. Int. Geol.*, 1975, vol. 290, pp. 1–94.

Kahlke, H.D. and Ukraintseva, V.V., The Late Pliocene flora, vegetation and fauna of the Southern Thuringia (Suhl, GDR), *Botan. Zh.*, 1986, vol. 71, no. 1, pp. 16–22.

Kholmovoi, G.V., Krasnenkov, R.V., and Iosifova, Yu.I., *Verkhnii pliotsen basseina Verkhnego Dona* (Upper Pliocene in the Upper Don River Basin), Voronezh: Voronezh. Gos. Univ., 1985 [in Russian].

Knies, J., Matthiessen, J., Vogt, C., et al., The Plio–Pleistocene glaciation of the Barents Sea-Svalbard region: a new model, based on revised chronostratigraphy, *Quat. Sci. Rev.*, 2009, vol. 28, pp. 812–829.

Kovalenko, N.D., The palynological characteristics of the Upper Pliocene deposits of the Northern Cis-Caspian and Saratov Trans-Volgian, in *Stratigrafiya neogena Vostoka Evropeiskoi chasti SSSR* (The Neogene Stratigraphy of the Eastern Part of the European USSR), Moscow: Nedra, 1971, pp. 99–106.

Kozlov, V.B., Kremen', A.S., Iosifova, Yu.I., et al., New study results of interglacial deposits of the Smolenskii Brod reference section (Western Dvina), in *Tvorcheskoe nasledie V.V. Dokuchaeva i sovremennost'. Nauchno-prakticheskaya konferentsiya molodykh uchenykh, Smolensk, 19-20 maya 2011 g.* (Proc. Sci.-Pract. Conf. of Young Scientists "Creative Legacy of V.V. Dokuchaev and Modernity", Smolensk, May 19–20, 2011), Smolensk: Smolensk. Gos. Univ., 2011, pp. 228–234.

Krasnenkov, R.V., *Opornye razrezy nizhnego pleistotsena basseina Verkhnego Dona* (Lower Pleistocene Reference Sections in the Upper Don River Basin), Voronezh: Voronezh. Gos. Univ., 1984 [in Russian].

Krasnenkov, R.V. and Kazantseva, N.E., The discovery of the early Dnieper alluvium in the Upper Don terraces, in *Byull. RMSK po Tsentru i Yugu Russkoi platformy. Vyp. 2* (Bull. Reg. Interdepart. Stratigr. Com. on Central and Southern Russian Platform. Iss. 2), 1993, pp. 153–162.

Krasnenkov, R.V., Iosifova, Yu.I., and Shuleshkina, E.A., The Lower Pleistocene reference section in the Ilovai River basin near the Michurinska village, in *Novye dannye po stratigrafii i paleogeografii verkhnego pliotsena i pleistotsena tsentral'nykh raionov Evropeiskoi chasti SSSR (K KhI Kongressu Mezhdunarodnogo soyuza po izucheniyu chetvertichnogo perioda)* (New Data on Pliocene and Pleistocene Stratigraphy and Paleogeography of the Central Part of the European USSR (to XI Congr. Int. Union for Quat. Res.), Moscow: Geol. Fond RSFSR, 1981, pp. 14–31.

Krasnenkov, R.V., Iosifova, Yu.I., and Semenov, V.V., The Upper Don River basin – a key stratotype region for climatostratigraphy of the lower Middle Pleistocene (Lower Pleistocene of Russia), in *Chetvertichnaya geologiya i paleogeografiya Rossii* (Quaternary Geology and Paleogeography of Russia), Moscow: GEOS, 1997, pp. 82–96.

Kuznetsova, T.A., Significance of spore-pollen spectra for subdivision and correlation of the Upper Pliocene marine and continental deposits of the Volga Region and adjacent areas, in *Stratigrafiya neogena Vostoka Evropeiskoi chasti SSSR* (The Neogene Stratigraphy of the Eastern Part of the European USSR), Moscow: Nedra, 1971, pp. 65–81.

Lebedeva, N.A., *Korrelyatsiya antropogenovykh tolshch Ponto-Kaspiya* (Correlation of the Anthropogenic Sequences of the Ponto-Caspian), Moscow: Nauka, 1978 (in Russian).

Lee, J.R., Rose, JB., Hamblin, R.J.O., et al., The Glacial History of the British Isles during the Early and Middle

Pleistocene: Implications for the long-term development of the British Ice Sheet, in *Quaternary glaciations – Extent and Chronology. A Closer Look. Developments in Quaternary Sciences, Ch. 15*, Ehlers, J., Gibbard, P.L., AND Hughes, P.D., Eds., Amsterdam: Elsevier, 2011, PP. 59–74.

Markova, A.K., *Pleistotsenovye gryzuny Russkoi ravniny* (Pleistocene Rodents in the Russian Plain), Moscow: Nauka, 1982 [in Russian].

Maslova, I.V., Results of the study of spore-pollen spectra of Pliocene and Quaternary deposits from the core section of the Aleksandriisk stratigraphic borehole (Kizlyar town area), in *Tr. VNII Prirod. Gazov. Vyp. 10* (Translation), 1960, pp. 37–45.

Maudina, M.I., Pisareva, V.V., and Velichkevich, F.Yu., The Odintsovo stratotype in the light of new data, *Dokl. Akad. Nauk SSSR*, 1985, vol. 284, no. 5, pp. 1195–1199.

Moskvitin, A.I., The Pleistocene stratigraphy of the European USSR, in *Tr. GIN AN SSSR. Vyp. 156* (Trans. Geol. Inst. USSR Acad. Sci. Vol. 156), Moscow: Nauka, 1967.

Motuzko, A.N., Anthropogenic mammals of Belorussia and adjacent areas, in *Problemy pleistotsen*a (Problems of Pleistocene), Minsk: Nauka i tekhnika, 1985, pp. 173–188.

Mundelsee, M. and Raymo, M.E., Slow dynamics of the northern hemisphere glaciation, *Paleoceanography*, 2005, vol. 20, PA4022.
https://doi.org/10.1029/2005PA001153

Menke, B., Vegetationsgeschichte und florenstratigraphie Nordwestdeutschlands im Pliozän und Frühquartär. Mit einem Beitrag zur biostratigraphie des Weichselfrühglacials, *Geol. Jahrb.*, 1975, no. 26, pp. 3–151.

Naidina, O.D., Climatic changes in the Northern Cis-Caspian during the Akchagylian transgression based on the data of the spore-pollen analysis: correlation of regional and global changes, in *Mater. Vseross. nauchn. soveshch., Moskva, 27-30 marta 2007 g.* (Proc. All-Russ. Sci. Conf. Moscow, March 27–30, 2007), Moscow: GEOS, 2007, pp. 92–96.

Nemkova, V.K., Popov, G.I., Popova-L'vova, M.G., et al., *Fauna i flora Akkulaevo (opornyi razrez srednego akchagyla-srednego apsherona Bashkirii)* (Fauna and Flora from the Akkulaevo (Middle Akchagilian–Middle Apsheronian Reference Section of Bashkiria)), Ufa: Bashkir. Fil. Akad. Nauk SSSR, 1972 [in Russian].

Nikiforova, K.V., The lower boundary of the Quaternary (Anthropogen) System, in *Stratigrafiya. Paleontologiya. Tom 4. Itogi nauki i tekhniki* (Stratigraphy. Paleontology. Vol. 4. Achivements of Science and Technology), Moscow: VINITI, 1973, pp. 50–102.

Nikiforova, K.V. and Alekseev, M.N., International Geological Correlation Program. Project 41: Neogene–Quaternary Boundary, in *The Pleistocene Boundary and the Beginning of the Quaternary*, Van Couvering, J.A., Ed., Cambridge: Cambridge Univ. Press, 1997, pp. 3–12.

Nikitin, P.A., *Pliotsenovye i chetvertichnye flory Voronezhskoi oblasti* (Pliocene and Quternary Floras of the Voronezh Region), Moscow–Leningrad: Izd. Akad. Nauk SSSR, 1957 [in Russian].

Pisareva, V.V., The interglacial deposits in the area of Lukoyanov village, in *Stratigrafiya fanerozoya tsentra Vostochno-Evropeiskoi platformy* (Phanerozoic Stratigraphy in the Central Part of the East European Platform), Moscow: Rosgeolfond, 1992, pp. 82–96.

Pisareva, V.V., The Akchagylian flora and vegetation of the Udmurtian Kama River Region, *Paleontol. J.*, vol. 40, no. 5, 2006, pp. 648–655.

Pisareva, V.V., Interglacial Flora and Vegetation of the Early and Middle in Central Regions of Eastern Europe, in *Chetvertichnaya geologiya i paleogeografiya Rossii* (Quaternary Geology and Paleogeography of Russia), Moscow: GEOS, 1997, pp. 124–133.

Pisareva, V.V. and Krasnenkov, R.V., The palynological characteristics of the Pliocene deposits from the Uryv village area (Don River), in *Problemy antropogena tsentral'nykh raionov Russkoi platformy* (Problems of the Anthropogene Deposits in the Central Areas of Russian Platform), Voronezh: Voronezh. Gos. Univ., 1979, pp. 36–42.

Pisareva, V.V. and Zyuganova, I.S., Problems of subdivision of Early and Middle Pleistocene deposits from the Don River basin (based on paleobotanical data), in *Geologiya i evolyutsionnaya geografiya* (Geology and Evolutionary Geography) Nesterov, E.M., Ed., St. Petersburg, Epigraf, 2005, pp. 203–208.

Pisareva, V.V., Postnikova, E.V., Motuz, V.M., et al., The Akchagylian deposits in the southeastern Udmurtia, in *Pliotsen i pleistotsen Volgo-Ural'skoi oblasti* (Pliocene and Pleistocene of the Volga–Ural Region), Moscow: Nauka, 1981, pp. 86–95.

Problems of Quaternary Stratigraphy and Marginal Glacial Sediments of the Vologda Region (Northwestern Russia), in *Mater. Mezhd. simp*. (Proc. Int. Symp.), Moscow: GEOS, 2000.

Resolution of RISC Byuro on November 25, 2014, in *Byull. RMSK po tsentru i yugu Russkoi platformy. Vyp. 6* (Bull. Reg. Interdepart. Stratigr. Com. on Central and Southern Russian Platform. Iss. 6), Moscow: Mosk. Gos. Univ., 2015, pp. 13–21.

Runkov, S.I., Bol'shakov, V.A., Nemtsov,a G.M., et al., The Pleistocene reference section near the Narovatovo village (Moksha River), in *Byull. RMSK po Tsentru i Yugu Russkoi Platformy. Vyp. 2* (Bull. Reg. Interdepart. Stratigr. Com. on Central and Southern Russian Platform. Vol. 2), Moscow: Rosgeolfond, 1993, pp. 144–152.

Rylova, T.B. and Yakubovskaya, T V., An analysis of the Preteglenian in the territory of Belorussia based on paleobotanical data, in *Tez. IX Vseross. Palinol. Konf. "Aktual'nye problemy palinologii na rubezhe tret'ego tysyacheletiya", Moskva, 13–17 sentyabrya 1999 g.* (Proc. IX All-Russ. Palynol. Conf. "Actual Problems of Palynology at the Turn of the Third Millennium), Moscow: IGIRGI, 1999, pp. 253–254.

Semenov, V.V., Excursions of the geomagnetic field in Pleistocene deposits of the East European Plain and their paleoclimatic significance, in *Mater. Mezhd. Nauchn. Konf., Rostov-na-Donu, 6-10 iyunya 2011 g.* (Proc. Int. Sci. Conf. Rostov-on-Don, June 6–10, 2011), Rostov-na-Donu: Izd. Yuzhn. Nauchn. Tsentra Ross. Akad. NAuk, 2011, pp. 208–209.

Shik, S.M., Climatic rhythmic in the Pleistocene of the East European Platform, *Stratigr. Geol. Correl.*, 1993, vol. 1, no. 4, pp. 105–109.

Shik, S.M. and Biryukov, I.P., Stratigraphy of the Lower and Middle Pleistocene in the central part of the European SSSR, in *Chetvertichnyi period. Stratigrafiya* (Quaternary Period. Stratigraphy). Moscow: Nauka, 1989, pp. 27–35.

Shik, S.M. and Yakubovskaya, T.V., On the age of interglacial deposits of the Smolenskii Brod section, in *Byull. Regional. Mezhved. Stratigr. komissii po tsentru i yugu Russkoi platformy. Vyp. 6* (Bull. Reg. Interdepart. Stratigr. Com. on Central and Southern Russian Platform. Vol. 6), 2016, pp. 108–115.

Shik, S.M., Zarina, E.P., and Pisareva, V.V., Neopleistocene stratigraphy and paleogeography of the central and northwestern parts of the European Russia, in *Palinologicheskie, klimatostratigraficheskie i geoekologicheskie rekonstruktsii* (Palynological, Climatostratigraphic, and Geoecological Reconstructions), St. Petersburg: Nedra, 2006, pp. 85–121.

Shik, S.M., Tesakov, A.S., Agadjanian, A.K., et al., The project of regional stratigraphic scale for the Eopleistocene and Gelasian (Paleopleistocene) of the central and southern parts of the European Russia, in *Byull. Regional. Mezhved. Stratigr. komissii po tsentru i yugu Russkoi platformy. Vyp. 6* (Bull. Reg. Interdepart. Stratigr. Com. on Central and Southern Russian Platform. Vol. 6), 2015, pp. 97–107.

Sovremennye problemy stratigrafii neogena i kvartera Rossii. Mater.Vseross. nauchn. Soveshch., Moskva, 31 marta-1 aprelya 2011 g (Proc. All-Russ. Sci. Conf. "Current Problems of the Neogene and Quaternary Stratigraphy of Russia." Moscow, March 31–April 1, 2011), Gladenkov, Yu.B., Ed., Moscow: GEOS, 2011 [in Russian].

Stratigrafiya i paleogeografiya chetvertichnogo perioda Vostochnoi Evropy (Stratigraphy and Paleogeography of the Quaternary Period of Eastern Europe), Velichko, A.A. and Shik, S.M., Eds., Moscow. Inst. Geol. Ross. Akad. Nauk, 1992 [in Russian].

Szafer, W., Flora pliocenska z Kroscienka nad Dunajcem, *Rozp. Polsk. Akad. Umiej. Wydz. Mat. Przyr. PAU*, 1946, vol. 72, nos. 1–2, pp. 1–375.

Tesakov, A.S., The modern discussion about the Neogene–Quaternary boundary, in *Mater. Vseross. nauchn. soveshch.* "Geologicheskie sobytiya neogena i kvartera Rossii: sovremennoe sostoyanie, stratigraficheskie rekonstruktsii", *Moskva, 27–30 marta 2007 g.* (Proc. All-Russ. Sci. Conf. "Geologic Events in the Neogene and Quaternary of Russia: Present State of Stratigraphic Scales and Paleogeographic Reconstructions", Moscow, March, 27–30, 2007), Moscow: GEOS, 2007, pp. 90–95.

Titov, V.V., *Krupnye mlekopitayushchie pozdnego pliotsena Severo-Vostochnogo Priazov'ya* (Late Pliocene Large Mammals from the Northeastern Sea of Azov Region), Rostov-on-Don: Izd. Yuzhn. Nauchn. Tsentra Ross. Akad. Nauk, 2008 [in Russian].

Turner, C., Iosifova, J., Pisareva, V., and Semenov, V., Records of sequence of temperate and cold stages from early Middle Pleistocene lacustrine deposits at Demshinsk, Lipetsk district, Central European Russia, in *XVI INQUA Congr. Sess. 45. Book of Abstracts*, Reno, Nevada, 2003.

Urban, B., *Vegetationsgeschichtliche Untersuchungen zur Gliederung des Altquartärs der Niederrheinischen Bucht, Sonderveröff*, Geol. Inst. Univ. Köln, 1978, vol. 34.

Valueva, M.N., Tsukurova, A.M., and Krasnenkov, R.V., Ancient interglacial flora from the Karamyshevo village area (Oka River), *Dokl. AN SSSR*, 1983, vol. 273, no. 1, pp. 166–170.

Velichko, A.A., Morozova, T.D., Nechaev, V.P., et al., Problems of chronostratigraphy and correlation of the loess-soil formation of the Russian Plain, in *Stratigrafiya i paleogeografiya chetvertichnogo perioda Vostochnoi Evropy* (Stratigraphy and Paleogeography of the Quaternary Period of Eastern Europe), Moscow: IG RAN, 1992, pp. 115–140.

Velichko, A.A, Semenov, V.V., Pospelova, G.A., et al., New data on the paleomagnetic Matuyama–Bryunes boundary position within the loess–glacial formation of the East European Plain, *Dokl. Earth Sci.*, 2002, vol. 386, no. 7, pp. 807–813.

Velichko, A.A., Pisareva, V.V., and Faustova, M.A., On the problem of the Pliocene and Early Pleistocene paleogeography of the Eastern Europe, in *Mater. VII Vseross. Soveshch. po izucheniyu chetvertichnogo perioda "Kvarter vo vsem ego mnogoobrazii. Fundamental'nye problemy, itogi izucheniya i osnovnye napravleniya dal'neishikh issledovanii". Tom 1 (*Proc. VII All-Russ. Quat. Conf. "The Quaternary in All of its Variety. Basic Issues, Results, and Major Trends of Further Research", Vol. 1. Apatity, September 12–17, 2011), Apatity–St. Petersburg, 2011, pp. 104–107.

Velichko, A.A., Morozova, T.D., Borisova, O.K., et al., Development of the steppe zone in southern Russia based on the reconstruction from the loess-soil formation in the Don–Azov Region, *Dokl. Earth Sci.*, 2012, vol. 445, no. 2, pp. 999–1002.

Voprosy paleogeografii pleistotsena lednikovykh i periglyatsial'nykh oblastei (Probelms of Pleistocene Paleogeography in the Glacial and Periglacial Zones), Velichko, A.A. and Grichuk, V.P., Eds., Moscow: Наукa, 1981 [in Russian].

Vorren, T.O., Landvik, J.Y., Andreassen, K., and Laberg, J.S., Glacial history of the Barents Sea Region, in *Quaternary glaciations – Extent and Chronology. A Closer Look. Developments in Quaternary Sciences, Ch. 15*, Ehlers, J., Gibbard, P.L., and Hughes, P.D. Eds., Amsterdam: Elsevier, 2011, pp. 361–372.

Vozniachuk, L.N. and San'ko, A.F., The Pleistocene reference section in the Smolenskii Brod area, in *Kompleksnoe izuchenie opornykh razrezov nizhnego i srednego pleistotsena Evropeiskoi chasti SSSR* (Complex Study of Reference sections of the Lower and Middle Pleistocene in the European Part of the USSR), Moscow–Leningrad: Leningrad. Kartfabr. Vseross. Nauchno-Issled. Geol. Inst., 1981, pp. 50–54.

Vozrast i rasprostranenie maksimal'nogo oledeneniya Vostochnoi Evropy (Age and Distribution of the Maximum Glaciation in Eastern Europe), Velichko, A.A. and Grichuk, V.P., Eds., Moscow: Nauka, 1980 [in Russian].

Zagwijn, W.H., An outline of the Quaternary stratigraphy of the Netherlands, *Geol. Mijnbouw*, 1985, vol. 64, pp. 17–24.

Zagwijn, W.H., The Cromerian complex stage of the Netherlands and correlation with other areas in Europe, in *The Middle Pleistocene*, Turner, Ch., Ed., Rotterdam: Balkema, 1996, pp. 145–173.

Zubakov, V.A., The great Barents Sea–Akchagyl glaciation (2.55–2.44 Ma), in *Mater. Mezhd. simp. "Pozdnekainozoiskaya geologicheskaya istoriya severa aridnoi zony". Azov, Rostov-na-Donu, 26–29 sentyabrya 2006* g. (Proc. Int. Symp. "Late Cenozoic Geological History of the Northern Arid Zone". Azov, Rostov-on-Don, September 26–29, 2006), Rostov-on-Don: Izd. Yuzh. Nauchn. Tsentr RAN, 2006, pp. 73–76.

Zyuganova, I.S., The Lower Neopleistocene paleocarpological complex iz razreza "Demshinsk", Lipetsk Region, *Byull. Kom. po Izucheniyu Chetvertichnogo Perioda*, 2004, no. 65, pp. 203–209.

Translated by M. Hannibal