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DYNAMICS OF VEGETATION AT THE LATE PLEISTOCENE GLACIAL/INTERGLACIAL TRANSITION (NEW DATA FROM THE CENTER OF THE EAST EUROPEAN PLAIN)

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Abstract. The organic sediments at the Cheremoshnik site (the centre of the East European Plain) have been reinvestigated by pollen and macrofossil analysis in order to gather more detailed information on vegetation dynamics during the Late Pleistocene Glacial/Interglacial transition (boundary between OIS 6 and OIS 5e). Two phases of vegetation can be determined: an earlier forest substage ("warm") and a later ("cold") substage, when the forest communities were reduced in their area. There are probably some similar features between the succession of vegetation at the end of Dnieper (Saale) cold epoch and during the Valdai (Weichselian) Late Glacial (Alleröd and Younger Dryas).

Key words: pollen records, vegetation dynamics, Eemian, the East European Plain.

INTRODUCTION

The events, which took place during the transitional intervals of the Late Pleistocene Glacial/Interglacial rhythm increasingly, attract close attention of researchers. At present climatic parameters may vary widely, deviating considerably from their mean values. Late glacial intervals were distinct for exceedingly unstable climate with abrupt fluctuations, so they may be taken as palaeo-analogs when considering a possible response of landscape constituents to such fluctuations.

A climate oscillation just below the Stage 6/5e boundary was first documented from Zeifen in Southern Germany (Jung *et al.*, 1972). Later, Woillard (1975) documented a short warming at La Grand Pile, below the Stage 6/5e boundary, correlated it to the event from Zeifen, and named it the Zeifen Interstadial. The stadial between the Zeifen Interstadial and Substage 5e was identified by Seidenkrantz (1993) on the base of benthic foraminiferal data and called the "Kattegat Stadial". The type locality for that stadial is the Anholt II borehole, Denmark. Differentiated Late Glacial pollen just below the Glacial/Interglacial boundary has been found in France (site, Les Echets: Beaulieu, Reille, 1984) and in Poland (Mamakowa, 1989).

In a numerous sites in the East European Plain the sediments belonging to the last part of the Dnieper (Saale) glacial epoch are attributed to biostratigraphic zone M1 in the Grichuk's scheme (Grichuk, 1982). In a number of cases this unit is not homogeneous. For example, two subzones can be confidently recognised in the lowermost part of the pollen diagram from the Nizhnyaya Boyarshchina section (the stratotype for the last Interglacial) in the Smolensk region (Grichuk, 1982).

The purpose of this work is to document the importance of Late Glacial phenomena by presenting new pollen and macrofossil data from the Cheremoshnik section in the center of the East European Plain (Fig. 1).

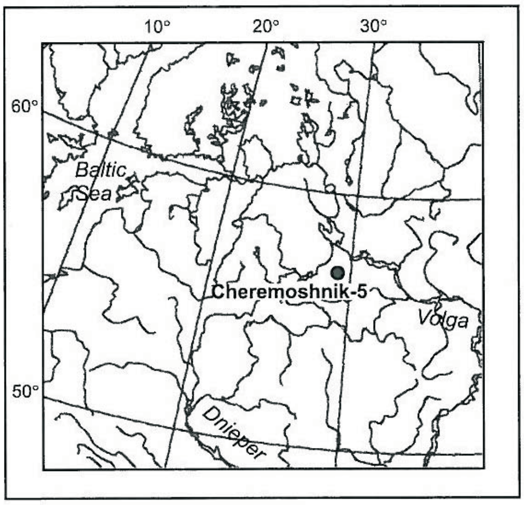

Fig. 1. Location of the Cheremoshnik-5 section

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The palaeobotanical researches on the section Cheremoshnik began fifty years ago (Tiuremnov, Vinogradova, 1952; Gorlova, 1968; Grichuk *et al.*, 1973). In 2002 field work and complex studies of this profile were accomplished within the frame of Russian-German collaboration. The considered section in vicinity of the village of Cheremoshnik is designated below as Cheremoshnik-5. The present palynological research is characterised by high-resolution pollen sampling and studies of pollen and spore concentration, these provides an opportunity of a new interpretation of the data. These results have been already published in short (Velichko *et al.*, 2005). The Cheremoshnik-5 pollen concentration diagram is first presented in this paper. Pollen data were supplemented by plant macrofossil studies.

STUDY SITE

The site Cheremoshnik-5 (57°10’ N, 39°16’ E) is situated 8 km west of city of Rostov the Great in a vast depression of tectonic origin. A lacustrine regime repeatedly existed in it during Cenozoic. Today it represents a glaciodepression edged from the east, south and west terminal moraines, which may by considered as an eastern continuation of the Borisoglebsk upland. The maximum total thickness of Quaternary deposits within the basin exceeds 100 m. There is an evidence of the Middle Pleistocene sediments present in the sequence, but the territory acquired its present-day appearance during the Late Pleistocene. In Mikulino (Eemian) time, the depression was essentially a lake basin that was a part of great lake system of the East European Plain together with Mologa-Sheksna and Yaroslavl-Kostroma palaeolakes (Grichuk *et al.*, 1973).

The exposure is situated near the southern outskirts of the village of Cheremoshnik in a wall of a deep ravine. The sequence includes 8 main units (Fig. 2) the lowermost one is a till of Dnieper (Moscow stage) glaciation. The organic-rich deposits occur between depths 240 to 370 cm. They appear as a series of peat horizons interrupted by layer of gray laminated clay in interval 354–360 cm. The upper part of section is Late Valdai (Weichselian) silt with clay.

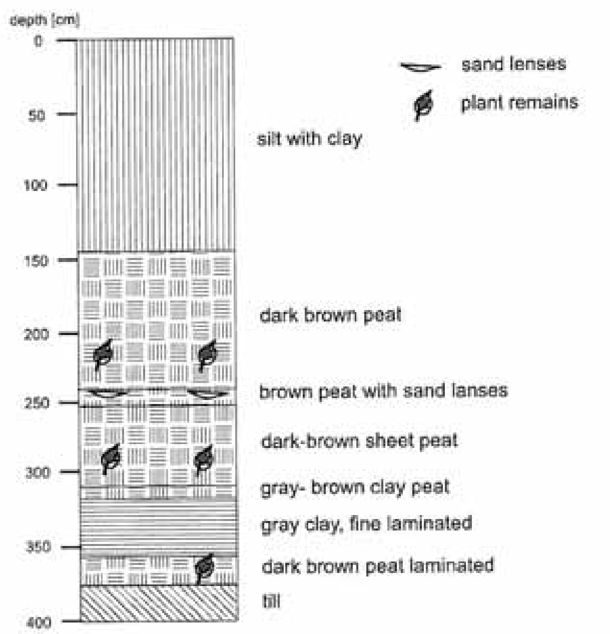

Fig. 2. Lithology sequence of Cheremoshnik-5 site

METHODS

The samples were processed for pollen analysis using the pollen extraction procedure developed by Grichuk (1940): The treatment included separation by heavy liquid (cadmium iodine) with the net weight of 2.2 gram/cm^3. A minimum of 500 pollen grains and spores per sample was counted. Relative frequency of pollen was calculated based upon the total terrestrial pollen sum, arboreal pollen (AP) plus non-arboreal pollen (NAP). Pollen of aquatic plants and spores were also calculated in relation to this sum (AP+NAP). To calculate the pollen concentrations, *Lycopodium* tablets (Stockmarr, 1971) were added to each sample prior to the maceration. Pollen diagrams were compiled using Tilia and TiliaGraph programs (Grimm, 1990).

The samples for macrofossil analysis were disintegrated with water and washed through a sieve with 0.25 mm mesh. Plant remains were picked out under binocular microscope.

RESULTS

POLLEN ANALYSIS

The pollen diagram of the Cheremoshnik profile has been divided into 7 local pollen assemblage zones (LPAZ) on the basis of changes in the composition of both pollen and spores, aided by pollen concentration (Figs. 3, 4).

LPAZ 1 (362–370cm). AP percentages are relatively high at the bottom of the zone (up to 55%), but decrease significantly toward its upper part. *Picea* pollen forms a considerable peak. *Pinus* and *Betula* pollen are also registered. Pollen of cold-resistant shrubs (*Betula nana, B. humilis, Alnus: Alnaster* type) contributes to the assemblages. The concentration of shrub pollen is higher than tree one against low total

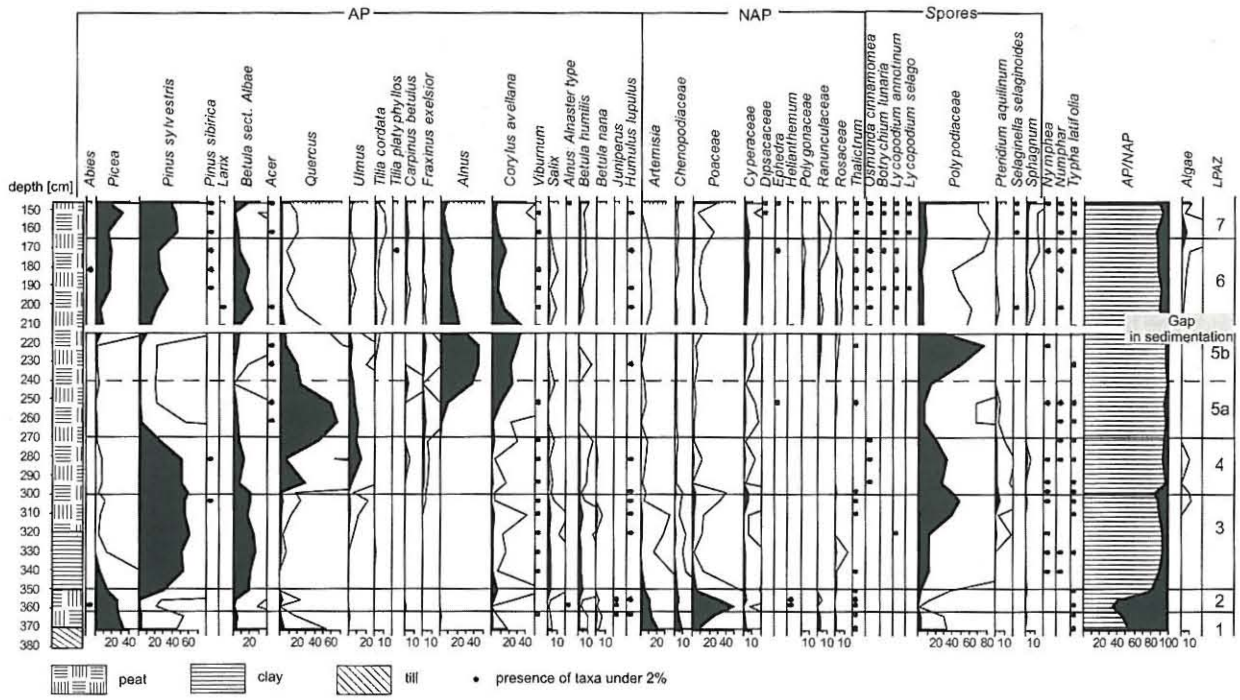

Fig. 3. Pollen diagram of Cheremoshnik-5 section

Pollen sum = AP+NAP; clear curves represent x10 exaggeration of base curves

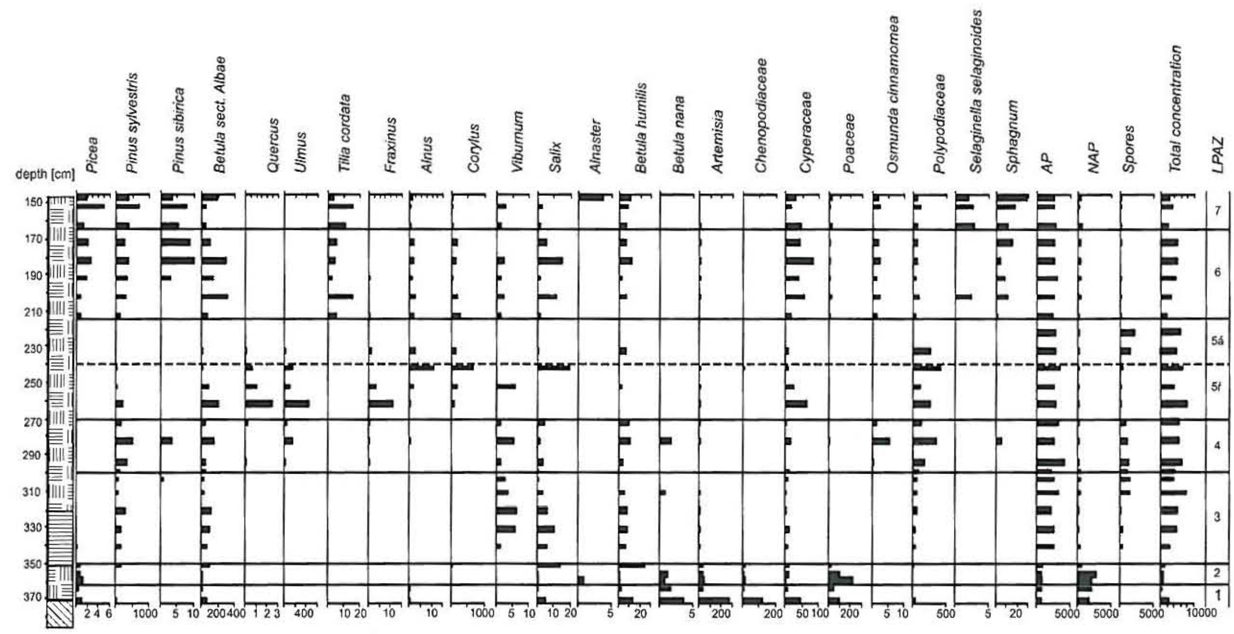

Fig. 4. Concentration pollen diagram of the Cheremoshnik-5 section (10^3 grains\cm^3)

For explanation see Fig. 3

pollen concentration. In the group of NAP Poaceae predominate, whilst pollen of *Ephedra, Artemisia*, Chenopodiaceae occur as well.

LPAZ 2 (350–362 cm). The role of the AP in spectra decreases noticeably (to 35%). The rises of the Poaceae curve and the increase in *Artemisia* and *Betula nana* pollen values are characteristic for this zone. Poaceae pollen concentration reaches the maximum values for the entire section. Pollen of Chenopodiaceae, Cyperaceae, Ericales occur as well. The important component of pollen composition of this zone is *Helianthemum*,

LPAZ 3 (300–350 cm). AP content is up to 90%. Pollen of *Betula* and Pinus dominate the spectra. The pollen of thermophilous trees, such as *Quercus* and *Ulmus* is present, but not abundant. Alder pollen (*Alnus glutinosa, A. incana*) and *Corylus* one appears. The content of spores (mainly Polypodiaceae) increases, as compared to previous zones.

LPAZ 4 (270–300 cm). AP content in this zone reaches 95–98%. *Pinus* and *Betula* pollen is still abundant. The frequencies of broad-leaved tree pollen (*Quercus* and *Ulmus*) increase progressively. Pollen of *Corylus* and *Fraxinus* occurs.

LPAZ 5 (215–270 cm). Pollen assemblages are dominated by AP (97–98%), mainly by that of *Quercus* and *Ulmus*. Oak pollen curve forms a high peak in subzone 5a (up to 65% of AP+NAP). The relative frequencies of *Alnus* and *Corylus* rise considerably in the subzone 5b. The first appearance of lime (*Tilia cordata* and *T. platyphyllos*) and *Carpinus* pollen should be noted. The high amount of Polypodiaceae spores is characteristic feature of this zone.

The composition of pollen assemblages changes abruptly at the boundary between LPAZ 5 and 6. Probably, the gap in sedimentation occurs at this level, and deposits of the final part of the interglacial optimum are lacking in the section.

LPAZ 6 (165–215 cm) and **LPAZ 7** (145–165 cm). NAP and spores percentages gradually increase throughout these zones. The pollen of trees and shrubs is dominated by spruce and pine, as well as by birch. Pollen of *Pinus sibirica* appears. The frequencies of broad-leaved tree pollen decrease until they disappear completely at the top of the zone 7. Pollen values of *Betula nana*, Poaceae, Cyperaceae rise noticeably in the zone 7. Spore content is low. Obviously, LPAZ 6 and 7 are attributed to the final part of the Interglacial.

PLANT MACROFOSSIL ANALYSIS

To obtain additional information about plant communities during the last Interglacial macrofossil remains from three samples have been investigated.

The macrofossil assemblage of sample from depth 340–350 cm is characterized by high diversity of plants. Tree remains are presented mainly by *Betula* sect. *Albae, Pinus sylvestris* and *Salix.* Fragments of *Picea* cf. *obovata* needles and fruit scales of *Betula humilis* occur as well. Rare fruits of *Alnus glutinosa and* seeds *Rubus ideaus* and *Rubus saxatilis* were identified. The group of herbaceous plants is represented by *Fragaria vesca, Caryophyllaceae* gen. indet. and *Polygonum* sp. Macrofossils of plants growing both in shallow water and on the wet shores (*Carex* sp.*,* *Scirpus lacustris* L. and *Typha* cf. *latifolia*) are registered. Remains of aquatic vegetation are dominated by species of genus *Potamogeton (P.* cf. *perfoliatus*, *P. natans*, *P. pusillus*), seeds of *Nuphar lutea, Nuphar* cf. *pumila* and *Nymphaea* cf. *alba* were found. *Chara* algae fragments are abundant.

The macrofossil composition of sample from the depth 310–320 cm is noticeably poorer than that of the lower sample. The most frequent remains are these of mosses. The remains of *Betula* sect. *Albae* and *Carex.* sp. div. occur in high amounts. The group of plants growing on wetlands is represented by *Comarum palustre, Lycopus europaeus, Menyanthes trifoliata;* a few nuts of *Scirpus lacustris* were identified. Of the aquatic species *Nuphar lutea* and *Chara* algae seldom occur. The low diversity of taxa in this sample can be explained by taphonomical condition in the peat horizon.

The macrofossil assemblages of the third sample (depth 150–169 cm) are dominated by remains of wetland plants (*Carex.* sp. div.*, Lycopus europaeus, Calla palustris*, *Comarum palustre*). Trees are represented by *Alnus glutinosa*, *Betula* sect. *Albae, Salix* sp. The remains of cold-tolerant species such as *Betula nana* (nuts and leaves) and *Selaginella selaginoides* (megaspores) are relatively abundant. Megaspores of *Salvinia natans* and a fragment of *Brasenia* sp. seed were found.

BIOSTRATIGRAPHIC CORRELATION

As the Eemian interval is beyond the range of radiocarbon dating, it seems reasonable that individual sections should be correlated on a biostratigraphic basis. In this paper, the scheme devised by Grichuk (1961) was adopted. The Table 1 shows the position of the Cheremoshnik-5 section according to the Grichuk's system and its correlation to the most frequently used zonations for the Eemian (Mikulino) Interglacial.

The composition of pollen assemblages of the lowermost part of the Cheremoshnik-5 section (LPAZ 1 and 2) suggests rather cold and unstable climatic conditions. The position of these sediments straight below the typical Mikulino sequences allows to date this part of profile to the Dnieper Late Glacial (zone M1). The Glacial/Interglacial boundary (LPAZ 2/3) is marked by a considerable drop in NAP pollen values, a rise of *Betula* and *Pinus* percentages as well as a significant increase of total pollen concentration.

The data of LPAZ 3, 4 and 5 recorded a characteristic succession of forest communities during the Mikulino Interglacial in the East European Plain that enable us to correlate them to M2, M3 and M4 zones respectively. Unfortunately, the upper part of the interglacial optimum has been eroded, and the overlying sediments (LPAZ 6 and 7) belong to the interglacial/glacial transition (zone M7).

Table 1

The biostratigraphic position of Cheremoshnik-5 section

Cheremoshnik-5 section	V.P. Grichuk (1982)	B.Menke, R.Tynni (1984)	K. Mamakowa (1989)
LPAZ 7	M_8 *Pinus–Picea–Betula*	E7	E7
LPAZ 6	M_7 *Picea*	E6	E6
Gap in sedimentation	M_6 *Carpinus*	E5	E5
	M_5 *Tilia–Quercus–Ulmus–Corylus*	E4b	E4
LPAZ 5b	M_4 *Quercus–Ulmus–Corylus*	E4a	
LPAZ 5a			
		E3	E3
LPAZ 4	M_3 *Pinus–Betula–(Quercus–Ulmus–Corylus)*	E2	E2
LPAZ 3	M_2 *Betula*	E1	E1
LPAZ 2	M_1 *Picea*		Late Glacial
LPAZ 1			

RECONSTRUCTION OF VEGETATION DURING LATE GLACIAL

Palynological study of the Cheremoshnik-5 sequence enables us to reconstruct the vegetation history of in the region during the Late Glacial. It is very likely that these successions were influenced by climatic changes.

The pollen diagram of the section suggests contrasting changes of the Late Glacial plant cover in the centre of the East European Plain. Two stages of the vegetation development can be identified. Spruce forest with an admixture of pine and birch, shrubs and elements of periglacial-steppe vegetation occurred at the earliest phase. Macrofossil finds prove the Siberian spruce (*Picea obovata* or *P. abies* subsp. *obovata)* occurred in the investigated region. This species is more resistant to cold and dry climate than the European spruce (*Picea abies* subsp. *excelsa*), it can grow under conditions of permafrost lying close to the surface (Sukachev, 1968). The Late Glacial forest communities were more open then the spruce forest at the end of the Mikulino. It can be proved by substantial values of NAP in pollen assemblages, as well as by presence of relatively light-demanding species, typical for open forest (*Pteridium aquilinum,* various species of *Thalictrum*). A conception of parkland character of the forest is supported by the data of pollen concentration of the section (Fig. 4). For example, spruce pollen concentration is one order of magnitude smaller than that in the late Mikulino layer (in the “upper maximum of spruce”).

The pollen assemblages of the latest phase are characterised by noticeable fall of the AP percentages. The role of bushes and components of steppe-like communities (Poaceae, *Ephedra, Artemisia*, Chenopodiaceae) increase considerably. Although the pollen value of spruce decreases in this part of section, its concentrations do not reduce but remain approximately the same. Obviously, spruce woodlands existed in complex vegetation. Cooling of that interval is reflected in higher percentages of cold-tolerant plants (*Betula nana, B. humilis, Alnus (Alnaster) viridis* subsp. *fruticosa*). The pollen assemblages indicate wide occurrence of periglacial forest-steppe with spruce, birch and pine as zonal vegetation over the territory under consideration. High values of reworked pollen and spores suggest intensive soil erosion process on the adjacent landscape.

Vegetation dynamics during two stages of the Late Glacial were characterised by alterations of proportion of the area, occupied by various plan communities, at the same time floristic composition of plant cover did not change radically.

A considerable amount of palynological data is available on the Valdai (Weichselian)/Holocene timeinterval in the center of the East European Plain (Khotinskii, 1977; Khotinskii, *et al*., 1991; Kremenetski *et al*., 2000; *etc.*). It seems reasonable to compare dynamics of the vegetation during the Valdai Late Glacial and pre-Mikulino interval. Pollen assemblages of the Alleröd from pollen diagram of Polovesko-Kupanskoye peat-bog (fig. 5; Khotinskii, 1977), located in the same region as the Cheremoshnik-5 section, are characterised by high percentages of AP (*Picea* dominates). In the Dryas 3 (Dr-3) phase the AP content decreases, while the *Artemisia* proportion rises significantly as well as that of shrub birch. Obviously, spruce forests, spread there during the Alleröd (Al), were then partially replaced by shrubs and steppe-like communities.

A group of heliophilous plants, such as *Hippophae rhamnoides, Helianthemum* and some others were highly typical for the Valdai Late Glacial sequences in the centre of the East European Plain (Zelikson, 1997; Kremenetski *et al.*, 2000). It is noteworthy that these species are found in the pollen assemblages of the Cheremoshnik-5 section as well.

Therefore, there is a certain similarity between the Dnieper Late Glacial vegetation succession and that at the Valdai/Holocene transition (Alleröd and Dryas 3).

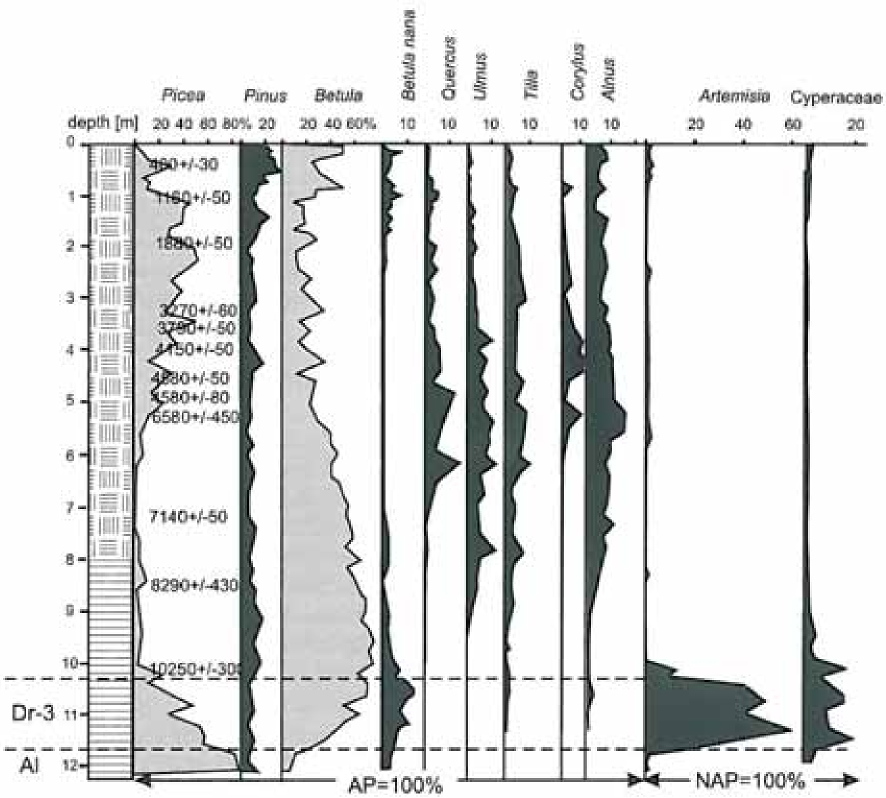

Fig. 5. Pollen diagram of Polovesko-Kupanskoye peat-bog (after Khotinskii, 1977; simplified)

For explanations see Fig. 3

CONCLUSIONS

As follows from the presented data, the short-periodical changes of plant cover were clearly pronounced in the centre of the East European Plain. Two phases of Late Glacial vegetation can determine in the pollen diagram: an earlier forest substage ("warm") and a later ("cold") substage, when the forest communities reduced their areas. The fluctuations at the Dnieper/Mikulino boundary (transition from OIS 6 to OIS 5e) were similar to those detected at the transition from the Late Valdai to the Holocene (Alleröd and Dryas 3).

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