ГЕОМОРФОЛОГИЯ, 2022, том 53, № 3, с. 7–18

РЕКОНСТРУКЦИИ НА ОСНОВЕ ПАЛЕОБИОЛОГИЧЕСКИХ МЕТОДОВ

УДК 551.89 (470.311)

ИВАНЦЕВСКИЙ РАЗРЕЗ ПОГРЕБЕННЫХ СРЕДНЕ-ПОЗДНЕНЕОПЛЕЙСТОЦЕНОВЫХ ОЗЕРНО-БОЛОТНЫХ ОТЛОЖЕНИЙ НА ОКРАИНЕ г. ДМИТРОВ МОСКОВСКОЙ ОБЛАСТИ

© 2022 г. С. А. Кузьмина[1,*], С. А. Сычева[2], Е. Г. Ершова[3], И. С. Зюганова[2], А. Л. Захаров[2], Е. С. Горбатов[4], С. Ф. Колесников[5], П. Г. Панин[2]

[1] Палеонтологический институт РАН имени А.А. Борисяка, Москва, Россия
[2] Институт географии РАН, Москва, Россия
[3] Московский государственный университет имени М.В. Ломоносова, биологический факультет, Москва, Россия
[4] Институт физики Земли имени О.Ю. Шмидта РАН, Москва, Россия
[5] Московский государственный университет геодезии и картографии, Москва, Россия
**E-mail: svkuz@yandex.ru*

Поступила в редакцию 30.03.2022 г.
После доработки 10.04.2022 г.
Принята к публикации 15.04.2022 г.

Разрез Иванцево расположен в гравийно-песчаном карьере на окраине г. Дмитрова Московской области. В разрезе вскрыта толща песка, торфа, гиттии и алеврита, хорошо выражены криоструктуры, включая псевдоморфозы по ледяным жилам. Наблюдается неоднократная смена озерных и болотных условий осадконакопления. Озерно-болотный комплекс сформировался во время МИС 5-4, начиная с МИС 5е и включает 3–4 термохрона. В торфе, гиттии и алеврите были найдены насекомые (в основном жуки), мелкие пресноводные беспозвоночные, растительные макроостатки. Среди последних определены виды, характерные для микулинского межледниковья. Данные спорово-пыльцевого анализа показывают, что растительность развивалась от смешанных сосново-березовых лесов с участием широколиственных пород до хвойных лесов и далее до березовых редколесий, кустарников и светолюбивых трав, включая полынь. Разрез позволяет провести реконструкцию климата и природной обстановки с конца среднего неоплейстоцена (московско-днепровское оледенение) до середины позднего неоплейстоцена.

Ключевые слова: Микулинское межледниковье, Валдайское оледенение, климат, растительность, палеопочвы, криогенные структуры, пыльцевой анализ, карпологический анализ, жуки, беспозвоночные

DOI: 10.31857/S0435428122030087

1. INTRODUCTION

Buried peat is an excellent repository for various lithological and biological indicators of the past environment. These indicators allow for reconstructions of contemporaneous environment within the peatland and in its surrounding landscapes such as bogs and paleosols. The peat and peat-encasing deposits yield the information about the complex and continuous history of the landscape development over a long time. The finding of every new section of such deposits is rare and important.

Lacustrine-boggy deposits that include massive peat units have been studied in the Klin-Dmitrov Ridge of the Moscow region (Nosov and Skiba, 1975; Lazukov et al., 1982; Boyarskaya et al., 1983; Alekseev et al., 1997; Sudakova et al., 1997; Sudakova et al., 2002; Antonov et al., 2004; Karta..., 2010). The best-known sections are: Kunya River (Zagorsk Pumped Storage Station), Spass-Kamenetsky gravel pit near Iksha town, a gravel pit near Borisovo in vicinity of Dmitrov town and a gravel pit near a meat-packing factory at the outskirts of Dmitrov. Till and interglacial units of various ages are represented there, including peat units. For example, the 10 m thick body of silt and peat deposits of the Mikulino interglacial has been observed (Sudakova et al., 1997) in the Borisovo pit (Borisova Gora). The pollen spectrum from the middle part of the peat reflected broad-leaved forests.

2. REGIONAL SETTING

The study area is situated in the northern part of the Klin-Dmitrov Ridge in the lateral zone of the Moscow glaciation (MIS 6) (Alekseev et al., 1977). Local macro- and meso- terrain features are relatively young. There are secondary-glacial and water-glacial

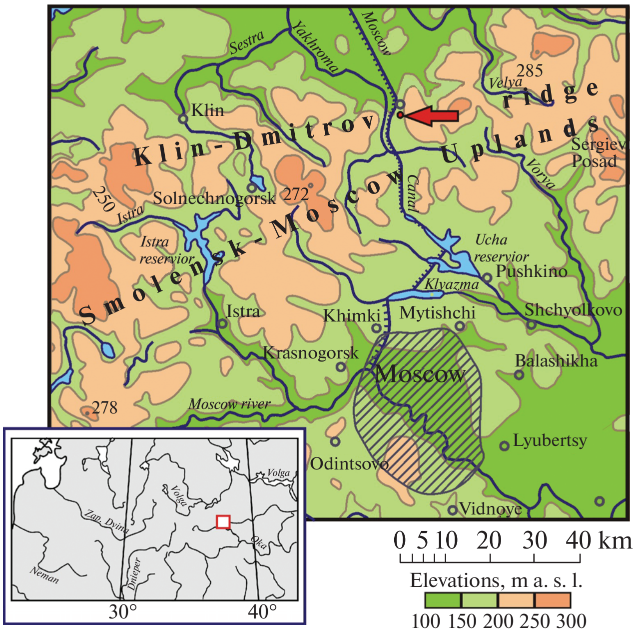

Fig. 1. Location of Ivantsevo section.
Рис. 1. Местоположение разреза Иванцево.

forms complicated by the late Pleistocene erosion system. The studied section is located inside an outwash terrain which is a large drainage gully filled by the glacial-lacustrine and glacial-fluvial deposits. These sediments were covered by polygenetic silt and sandy silt, mostly through the deluvial and eolian transport (Lazukov et al., 1982). Recently the valley-line of the depression where the studied section is situated (near its edge) was developed into the Moscow Canal.

The buried peat was discovered by S.F. Kolesnikov and S.A. Kuzmina in the summer of 2020. The peat has been exposed during excavations in the gravel pit (56°19′06.6″N 37°33′16.2″E, elevation 173 m) close to the railway station Ivantsevo near Dmitrov town in the Moscow Region (fig. 1). In the following year, a further development of the quarry exposed a new peat unit that was clearly divided into three beds; the new section allowed to trace the lateral extent of the peat unit that was described in 2020 (fig. 2). Here we report mostly results of the first year sampling.

3. MATERIAL AND METHODS

The section was examined by micro-morphological, lithological, palynological, and carpological methods; the samples with fossil insects and freshwater invertebrates were collected in 2020 (Ershova et al., 2020).

Three samples for OSL were treated in the OSL FGBU VSEGEI lab (Sankt-Petersburg) using the automatic system Risø TL/OSL Reader DA-20 C/D with a low-noise gamma ray spectrometer on the base of the clear germanium crystal CANBERRA BE3825.

The dating consists of two stages: paleo-dose determination and dose rate measuring. Sample tubes were exposed in the room with red light-emitting diode illumination. Edge parts of each tube (3–5 cm) were used for the dose rate, the rest inner part for the paleodose determination.

The paleosol microstructure was studied in thin sections <30 μm thick. The undisturbed samples were air dried and impregnated with polysynthetic resin and made into thin sections (Jongerius and Heintzberger, 1975). The thin sections were described and the soil-forming process interpretation was given according to published methods (Jongerius and Heintzberger, 1975; Gerasimova et al., 1992; Stoops et al., 2010).

Lithology. Granulometric composition (GC) was analyzed using the laser diffraction grain size analyzing device Malvern Mastersizer 3000. Organic-mineral samples were burnt in 30% H_2O_2 during 6 hours. Organic free samples were prepacked into 0.3 g of dry weight and were covered by 10% HCl for 1 hour. After that the samples were washed in distilled water by a centrifuge. 4% solution of $Na_4P_2O_7$ was used for the sample stabilization.

Magnetic susceptibility measurements (MS) were carried out using the portable measuring instrument SM-150L. The samples were previously dried in 40°C. The measurements consist of two stages: with 500 Hz 320 A/m and with 4000 Hz 320 A/m. The ignition losses (IL) were made by heating the samples in a muffler in 105°C, 550°C, and 950°C. The samples were scaled after each heating (within the accuracy 0.01 g). This measurement shows content of organic carbon (after 550°C) and content of bound inorganic carbon (after 950°C) mainly $CaCO_3$. Ignition losses with 550°C shows the share of organic carbon. Ignition losses with 950°C shows the share of combined inorganic carbon, mostly $CaCO_3$. Magnetic susceptibility shows two curves which reflected 500 and 4000 Hz. Little difference between them does not allow to see any sedimentation anomaly or soil developing (fig. 3).

Freshwater invertebrates were picked from wet screened samples through a sieve with 0.1 mm mesh under the light optical microscope. Insect remains were picked from peat pieces in the field and from screened (with 0.4 mm mesh sieve) samples in the lab.

Plant macrofossils were extracted from the samples following the procedure suggested by V.P. Nikitin (1969). Carpological remains were picked out using stereomicroscope Altami CM-T and identified following atlases (Velichkevich and Zastavniak, 2006; 2008).

Samples for the pollen analysis were processed in the lab of the Department of Ecology and Geography of Plants of Moscow State University. The standard method of sediment processing was applied (Pyltsevoy analiz, 1950).

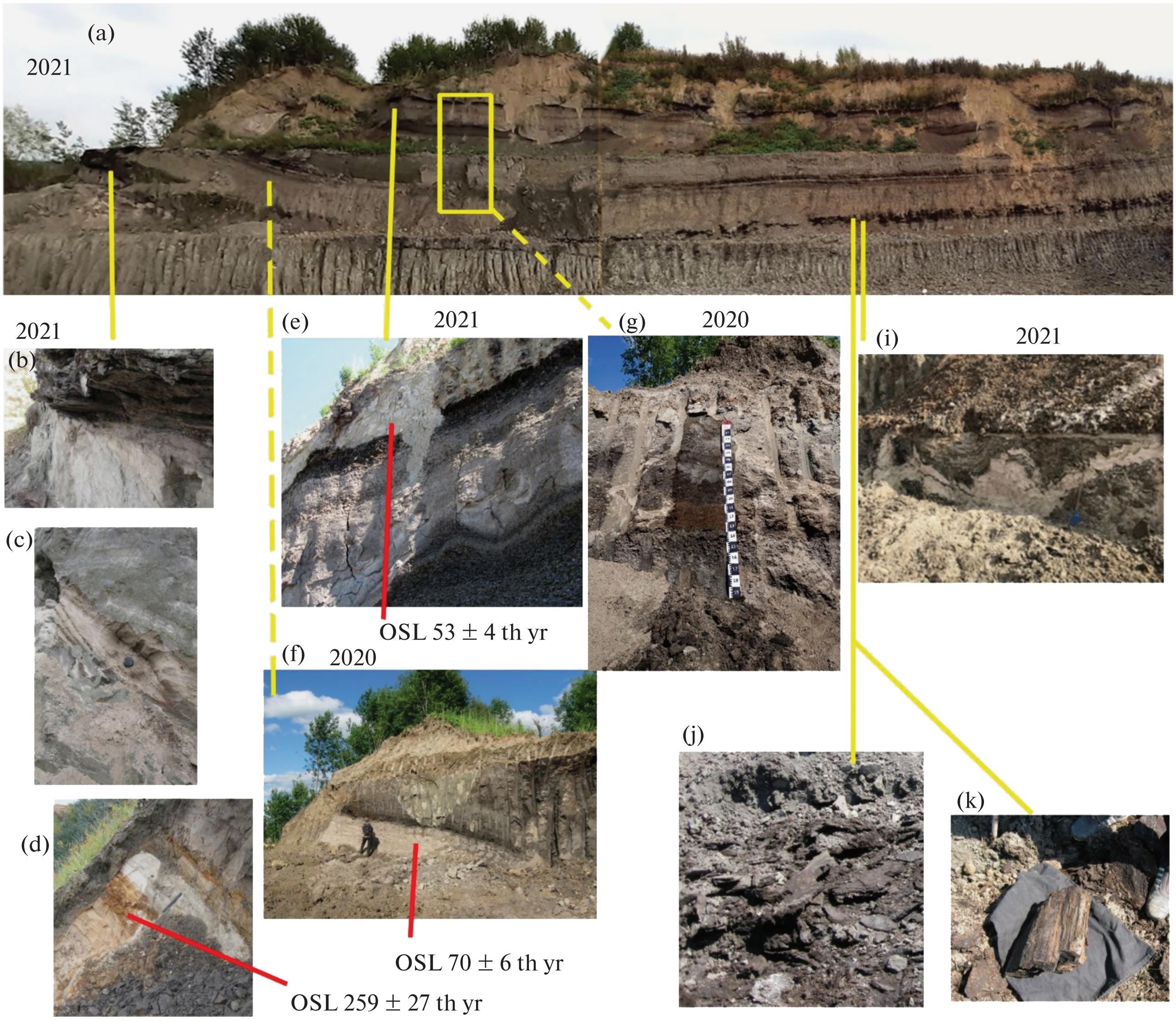

Fig. 2. Section composition in 2020 and 2021: (a) – common view, north and south sides (2021), (b) – lower peat with large wood fragment, (c) – sand, silt and gravel unit under peat, (d) – reddish brown sand of Moscow glaciation, (e) – upper part of the section in 2021 with ice wedge casts, (f) – north side of the section in 2020 with sand layer under peat, (g) – the main section in 2020, (i) – lower ice wedge casts and cryoturbations (j–k) lower peat bed where macro remains of thermophilous plants were found: (j) – peat pieces, (k) – wood fragment.

Рис. 2. Строение разреза в 2020 и 2021 годах: (a) – общий вид, северная и южная стороны (2021), (b) – нижний слой торфа с крупными фрагментами древесины, (c) – слой песка, гравия и глины под торфом, (d) – красно-коричневые пески Московского оледенения, (e) – верхняя часть разреза в 2021г. с псевдоморфозами по ледяным жилам, (f) – северная сторона разреза с горизонтом песка под торфом в 2020 г., (g) – основной разрез в 2020 г., (i) – нижний слой псевдоморфоз и криотурбации, (j–k) нижний слой торфа, где были найдены остатки теплолюбивых растений: (j) – фрагменты торфа, (k) – фрагменты древесины.

4. RESULTS

4.1. Geological composition of the section. The gravel pit wall in 2020 begun where the backhoe excavation stopped. In 2021 the exposure was extended below the step and to the left side (fig. 2). Because the section did not have a clear bottom, we have to start the description from the top.

Layer 1. 0–10 cm. Compacted brown and blue-brown silt.

2. 10–55 cm. Compacted light brown-gray small grain silt with humus stains and single inclusions of small size gravel and sand lenses. The lower part of the layer forms a system of the large wedge-shaped deformations (ice wedge casts). The size of these IWCs is: 0.5 m width, 3 m depth; the distance between IWC is 17–20 m. IWCs break all peat body.

3. 55–76 cm. Solid slightly decomposed grown peat with single twigs.

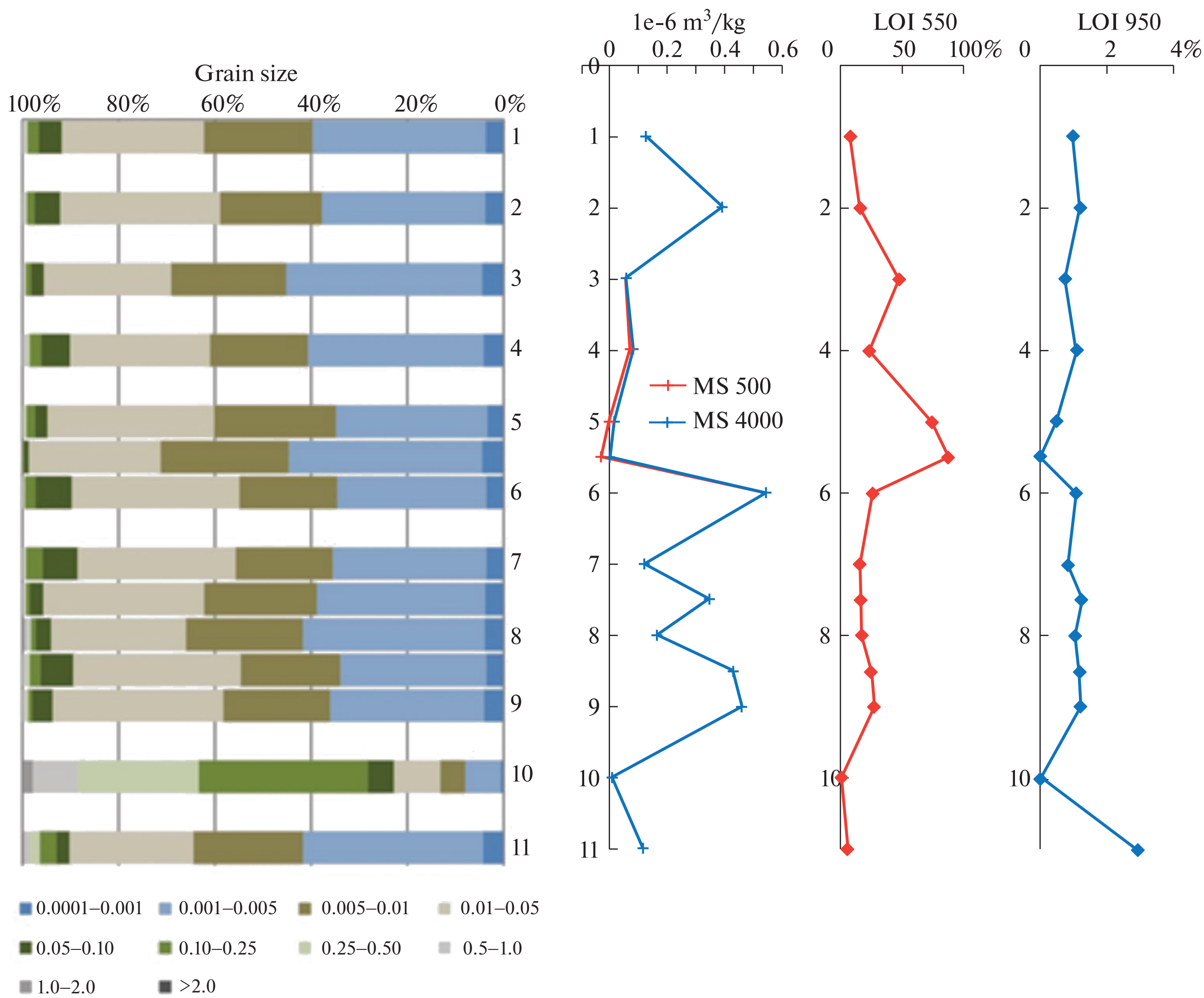

Fig. 3. Sediment analyzes of Ivantsevo section. LOI – Loss on Ignition; MS – Magnetic Susceptibility.
Рис. 3. Результаты лабораторных аналитических работ по разрезу Иванцевский. LOI – потери при прокаливании, MS – магнитная восприимчивость.

4. 76–90 cm. Solid well decomposed dark gray peat with rare plant remains and quartz grains.

5. 90–150 cm. Bedded slightly decomposed light brown peat; the upper 20 cm of the layer is darker with twigs; the lower part is lighter and wet. The lower border is sharp, uneven.

6. 150–179 cm. Solid dark peat and dark gray silt.

7. 179–259 cm. Solid gray-blue-dark and dark peat with dark silt.

8. 259–314 cm. Dark gray silt with plant remains and sand grains.

9. 314–364 cm. Compacted dark gray brownish gyttia with quartz grains. The lower border is sharp and uneven.

10. 364–474 cm. Loosely-packed unsorted sand with wood fragments, light brown layers are alternated with dark gray organic sand and oblique large grain sand.

11. 474–500 cm. Brown large grain sand and gravel.

12. 500–550 cm. Solid laminated dark brown peat with grass stems, moss and large flattened wood pieces. This bed is full of insect remains; many of them have excellent preservation (fig. 3).

Intensive excavation in the pit changed the appearance of the section by 2021. In 2020 we observed a thick (up to 3 m) inhomogeneous peat lens (fig. 2). The peat was underlain by black lacustrine clays (sapropel) and overlain by light gray silt, which filled the system of well-developed Ice wedge cast which penetrated to the peat body. The dark clay is replaced by bedded sand at the left side of the section.

Table 1. Climate and environmental reconstructions
Таблица 1. Реконструкции климата и природной обстановки

Layer	Climate (compare to recent) and environment		
	Plant macrofossils	Invertebrates	Spores and pollen
1–2	Eurythermic water plants	Cold lake	Much colder, tundra
2–5	Relatively thermophylous water plants, extinct *Potamogeton sukaczevii* and eurythermic swamp and bog plants	No data	Colder, spruce forest, bog
5–6	Eurythermic swamp and bog plants	No data	Much colder, birch forest-tundra, tundra, steppe-tundra
7	Some water plants, *Betula nana*	No data	Colder, pine and birch forest
7–9	Mostly water plants	No data	much colder, birch forest and grassland
9–10	Much colder, water, birch forest, shrub tundra	Water	Much colder, cold steppes
10	Recent but with extinct water plants	Recent, bog and terrestrial species	Recent, mixed forest
12	Warmer, broad-leaved trees, relict and extinct (*P. suckazcevii*) water plants		No data

The section composition has been changed in 2021 (fig. 2). A single whole peat body was divided into several beds: 4 peat layers up to 0.5 m and dark clay layers between them. The overlaid silt beard two levels of ice wedge casts. The lower peat layer also has signs of ice wedge casts (fig. 2).

4.2. Micromorphological features. There are four studied samples from the upper part of the peat unit (layers 2, 4, 7) and from the middle part of an ice wedge cast.

D2 – peatified silt loam, silt particles are unevenly distributed in the slide. There are many moderately decomposed plant remains, small charcoal pieces, and clusters of silt-sized quartz in pores and cracks. Small cracks are probably cryogenic. Organic remains have vertical orientation, but deposits are not laminated.

D4 – slightly decomposed peat with clear large plant inclusions, single chitin fragments and rare small charcoal pieces. The direction of the plant remains is horizontal. Dusty grains are more common than in the previous sample. Some quartz grains (about 0.5 mm) are round, other grains have irregular shape and are broken by frost. Cryogenic cracks are thin with iron-humus stains sometimes are filled by dust.

D7 – peatified silt, plant remains are well decomposed and are exposed as dark gray and dark brown spots, silt grains are numerous. The quartz grains are round similar to the sample D4, they have indistinct horizontal bedding. Large biogenic pores are filled by dark gray humic hypocutanes, clay papules, and clay stains. Small cryogenic cracks cut through plant remains. This layer has been affected by frost longer than the layers D2 and D4. Here we can see indicators of the soil development under the forest. Probably the forest grew here and it had been replaced by the bog later. Such cycles (forest-bog) probably repeated several times and as a result the peat became well decomposed.

DK (ice wedge filling) – silt loam, quartz grains are round, there are perfect round grains. Some quartz grains are placed in indistinct vertical direction. There are rare thin cracks. Small round ooid aggregates and small plant remains are found. Large pores sometimes are infilled by small ooids. There are remains of decomposed rhisolite or chitin. Small carbonate concretions are presented.

The sediment inside the ice wedge cast was secondary frozen (after filling). We can make a conclusion that the sediment was frozen completely because the studied sample was taken in the lower part of the cast but the frost influence was insignificant because the observed quartz grains gained cryogenic features before the cast in-filling.

4.3. Lithology data. The grain composition of the entire section studied in 2020 is quite similar despite differences in organic matter (fig. 3). Sediment is silt-clay (median grain size is (D×50) 5–9 μm for exception of the last (10) layer which is bedded sand – D×50 is 192 μm. Organics account 80–90% in the layer 5 in the middle part of the section. Other layers of peat and gyttia have more mineral matter (C is 10–50%). The sand layer has little organic content (<5%). Magnetic susceptibility (MS) measurement does not show a clear picture because of the small number of samples but we can notice a relatively high value in the level 5 and the high value in the level 6 (fig. 4). In the first case it could happen as a result of carrying out the measurement on the peat instead of the sediment. It has a low (almost zero and sometimes negative) MS due to the low mineral content. In general, the MS correlates with ignition losses at 950°C.

4.4. Optically stimulated luminescence data. Optically stimulated luminescence dating was carried out on quartz grains (table 1). The oldest date 259 ± 27 ka was from the sample D-21-01 from the brown fluvioglacial sand bed (fig. 2) which lies under the studied

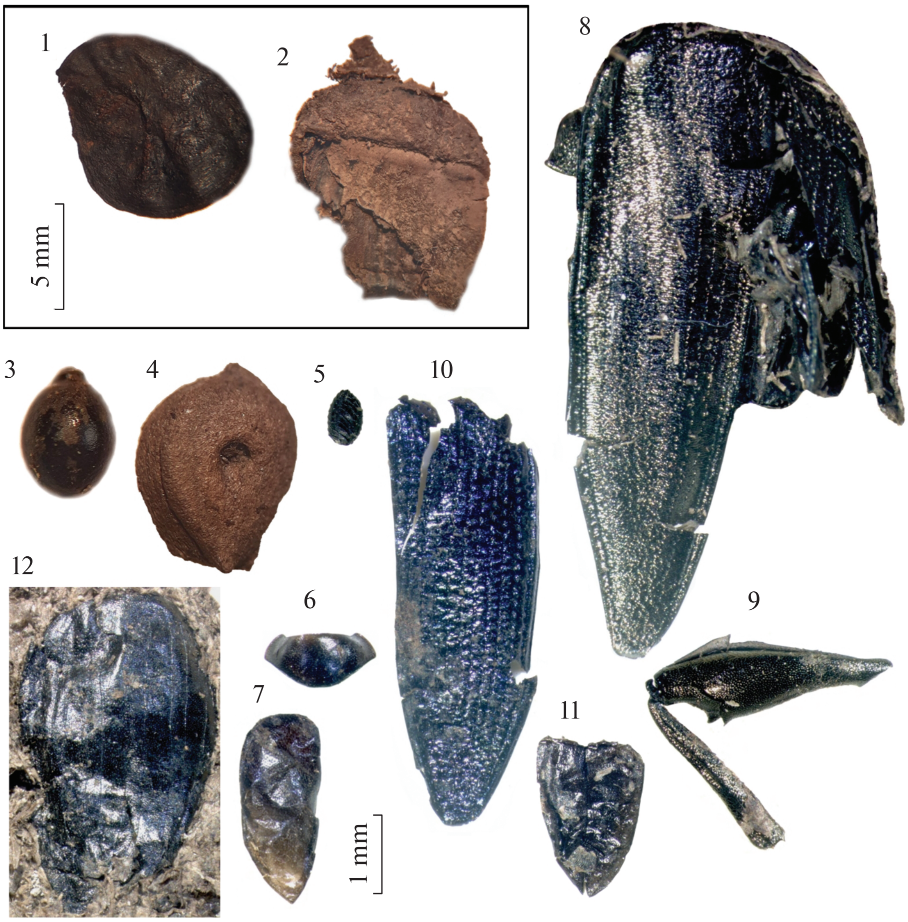

Fig. 4. Macro plant remains and insects from the lower peat (1–4, 6–12 Dm B5) and upper silt (5 Dm B6). Plants: 1 – *Acer* sp. (seed), 2 – *Quercus robur* (fragment of acorn), 3 – *Aldrovanda vesiculosa* (seed), 4 – *Potamogeton sukaczevii* (endocarp), 5 – oogonium of charophyte algae *Chara* sp. (oogonium). Insects: pronotum (6) and elytron (7) of the ladybird *Scymnus haemorrhoidalis*; elytra (8) and leg (9) of the leaf beetle *Donacia dentata*; 10 – elytron of the leaf beetle *Plateumaris braccata*; 11 – elytra of a predaceous diving beetle *Hydroporus* sp.; 12 – elytra and abdomen of a pill beetle *Byrrchus* sp. Scale bar for 1 and 2–5 mm, others 1 mm.

Рис. 4. Макроостатки растений и насекомые из нижнего горизонта торфа (1–4, 6–12 Dm B5) и верхнего суглинка (5 Dm B6). Растения: 1 – *Acer* sp. (семя), 2 – *Quercus robur* (фрагмент желудя), 3 – *Aldrovanda vesiculosa* (семя), 4 – *Potamogeton sukaczevii* (эндокарп), 5 – *Chara* sp. (оогоний). Насекомые: переднеспинка (6) и надкрылье (7) божьей коровки *Scymnus haemorrhoidalis*; надкрылья (8) и нога (9) листоеда *Donacia dentata*; 10 – надкрылье листоеда *Plateumaris braccata*; 11 – надкрылье плавунца *Hydroporus* sp.; 12 – надкрылья и брюшко пилюльщика *Byrrchus* sp. Шкала для 1 и 2–5 мм, остальные – 1 мм.

clay-peat section (depth 12 m). The sample which was taken from the layer 10 just below the peat provided the date 70 ± 6 ka. The youngest date 53 ± 4 ka comes from the ice wedge cast filling.

4.5. Plant macrofossils and invertebrate animal remains. This peat is a unique place in the Moscow region where fossil insects were found. Most of the well-preserved insects (fig. 4) and seeds come from the base peat layer 12. This layer was exposed at the right side of the main section at the base (about 5 m depth) in 2020. In 2021, the picture was more complex, with the insect rich peat bedded higher up at the left side of the unit (fig. 2). The basal peat created a step where excavators worked in 2020.

The peat yields remains of sedges, horsetails, and sphagnum and green mosses. Other plant macrofossils are represented by the dwarf shrub *Chamaedaphne calyculata* which is common on ombrotrophic bogs. Carpological remains of trees are represented by birch (*Betula* sect. *Betula*), hazel (*Corylus avellana*) and pine (*Pinus sylvestris*) and broadleaved trees: (*Quercus robur*, *Acer platanoides*). The most interesting find is numerous seeds of the waterwheel carnivorous plant *Aldrovanda vesiculosa* (fig. 4). The listed species are quiet typical of the Mikulino interglacial flora.

Insects are represented by the aquatic, riparian and terrestrial species. The assemblage (fig. 4) includes predaceous diving beetles *Hydroporus* sp. and *Agabus* sp., the riparian leaf beetles *Donacia dentata* (adult live on water-plantains and arrowheads, larvae on different sedges), *Plateumaris braccata* (reed beetle), the riparian ladybird *Scymnus haemorrhoidalis*; common bog rove beetles of *Olophrum* genus. Terrestrial insects are represented by rove beetle *Lathribium* sp., *Quedius* sp., round fungus beetles *Agathidium* sp., several species of small *Pterostichus* ground beetles, pill beetle *Byrrhus* sp. and different weevils. All these beetles could be found in the Moscow region recently. We can see a mixture of the insects who lived on the bog and habitants of surrounding meadows and forest floor.

Samples from gyttia (the layer 9) yield macro remains of water plants: *Caulinia flexilis*, *Potamogeton rutilus*, *Isoetes lacustris*, and small freshwater invertebrates such as ephippia of daphnia and freshwater Bryozoa statoblasts. These plants and animals indicate open standing water which was full of life. There are also fruits of birch shrub *Betula* cf. *nana* and trees *B.* sect. *Betula*. The presence of dwarf birch indicates the climate cooling.

Samples from the main peat body (the layer 7) include carpological remains of eurythermic water plants (*Potamogeton filiformis*, *P. rutilus*, *Batrachium* sp.) and single fruit of a birch tree (*Betula* sect. *Betula*). The next sample (the upper part of the layer 5) yields a few carpological remains of relatively thermophilous water plants such as *Nuphar lutea* and *Ceratophyllum demersum*. A few endocarps of the extinct species *Potamogeton sukaczevii* has been found there. Some endocarps of *P. sukaczevii* and a number of eurythermic water plant remains were also found in the sample from the layer 4. This species has been observed in the deposits both of the Mikulino interglaciation and the first stage of the Early Valdai interstadial. Cold interstadial climate conditions were more favorable for this water plant. However, *P. sukaczevii* wasn't reported from periglacial Early Valdai or interstadial Middle Valdai floras (Velichkevich and Zastavniak, 2006).

Insects from the main peat body (mostly layer 4) are represented by water beetles (genus *Agabus*, *Hydroporus, Colymbetes*), riparian species of ground beetles (genus *Agonum, Bembidion, Elaphrus, Nebria*) and some terrestrial weevils, leiodid and rove beetles. All these beetles were common in boggy areas of the Moscow region recently.

Sample from the layer 2 (silt which filled an ice wedge cast) yields macro remains of water plants (a water buttercup *Batrachium* sp., the pondweed *Potamogeton filiformis*), *Chara* oogonia, and remains of small freshwater invertebrates (*Planaria* eggs). Such finds allow us to make a conclusion about the origin of the upper unit which overlays the peat. This silt was formed in open shallow clear stagnant water.

4.6. Pollen analysis. Samples for the pollen study were collected from the layers 11–2 (fig. 5). The main section (see description above) is situated on the left side, so the lower 2 layers are different: in the main section they are represented by sand and gravel but on the right (about 10 m) by dark clay (fig. 2).

We can recognize several pollen zones (LPZ) in the pollen diagram (fig. 5):

LPZ1 depth 420–450 cm (layer 10). The percentage of arboreal pollen (AP) is 50–70%, there are: *Betula* (up to 20%), *Alnus* (15%), *Pinus* (10%), *Corylus* (10%). Thermophilous plant pollen is presented in low volume (*Tilia, Quercus, Fagus, Carpinus, Ulmus*), each is no more than 1–2%, at the same time we notice the presence of tundra shrubs and dwarf shrubs (*Salix, Alnus viridis, Betula nana, Ericales*). Nonarboreal (NAP) group is up to 50%, *Artemisia* dominates (up to 25%), the group includes also grasses (6–8%), numerous meadow and tundra herbs: Amaranthaceae, Caryophyllaceae, *Polygonum*, *Ranunculus*, Asteraceae, Fabaceae, Apiaceae, Rosaceae, *Rumex, Filipendula*. Spores are represented by *Sphagnum* (6–8%) and single spores of club-mosses and ferns. This zone reflects partly open landscape which combines mixed birch and pine forest with inclusion of rare broadleaved trees and open steppe or tundra-steppe areas. The presence of *Alnus*, Cyperaceae, and *Sparganium* pollen and *Sphagnum* spores indicates early stages of a mire formation.

Samples from the upper part of this zone include many micro charcoal fragments. Pollen composition from here shows sharp decreasing of AP group (to 42%); pollen of pine, alder and all broadleaved trees disappeared, share of *Artemisia* (35%) and *Filipendula* (8%) increased; some tundra taxa such as *Dryas*, *Geranium, Scabiosa* appeared but pollen of aquatic plant disappeared. This level reflects a sharp climate change. The climate became drier, forest fires destroyed trees and a mire has been drained.

LPZ2, 360–420 cm (layers 9–10). AP group dominates (80–90%) here but mostly because of the high role of birch and partly of hazel (up to 10%), other trees form less than 1%. Tundra dwarf shrubs are absent. NAP group makes 10–20%: there are mostly *Artemisia* (5%) and Poaceae (5–10%), *Armeria*, Apiaceae, Asteraceae, Amaranthaceae, Caryophyllaceae, *Filipendula* play secondary roles. Hydrophilic plants (Cyperaceae, *Comarum, Alisma, Sparganium, Osmunda*) are presented again. This zone reflects birch forest or forest-tundra reoccupation and a new bog formation.

LPZ3, 230–360 cm (layers 7–9). AP group still dominates (80–90%) in this zone. Pine plays a more important role (30–60%), spruce forms up to 6%; single alder and broad-leaved trees (oak, linden, elm, hornbeam) are presented. NAP group makes 10–20%, there are no clear dominants; *Artemisia* (6–8%), Poaceae (up to 10%), Cyperaceae, Asteraceae, Liliaceae, Amaranthaceae, Apiaceae, Caryophyllaceae, *Scabiosa, Ranunculus, Polygonum, Thalictrum*, Onagraceae are presented. Hydrophilic plants are almost absent, contribution of spores is low (<5%).

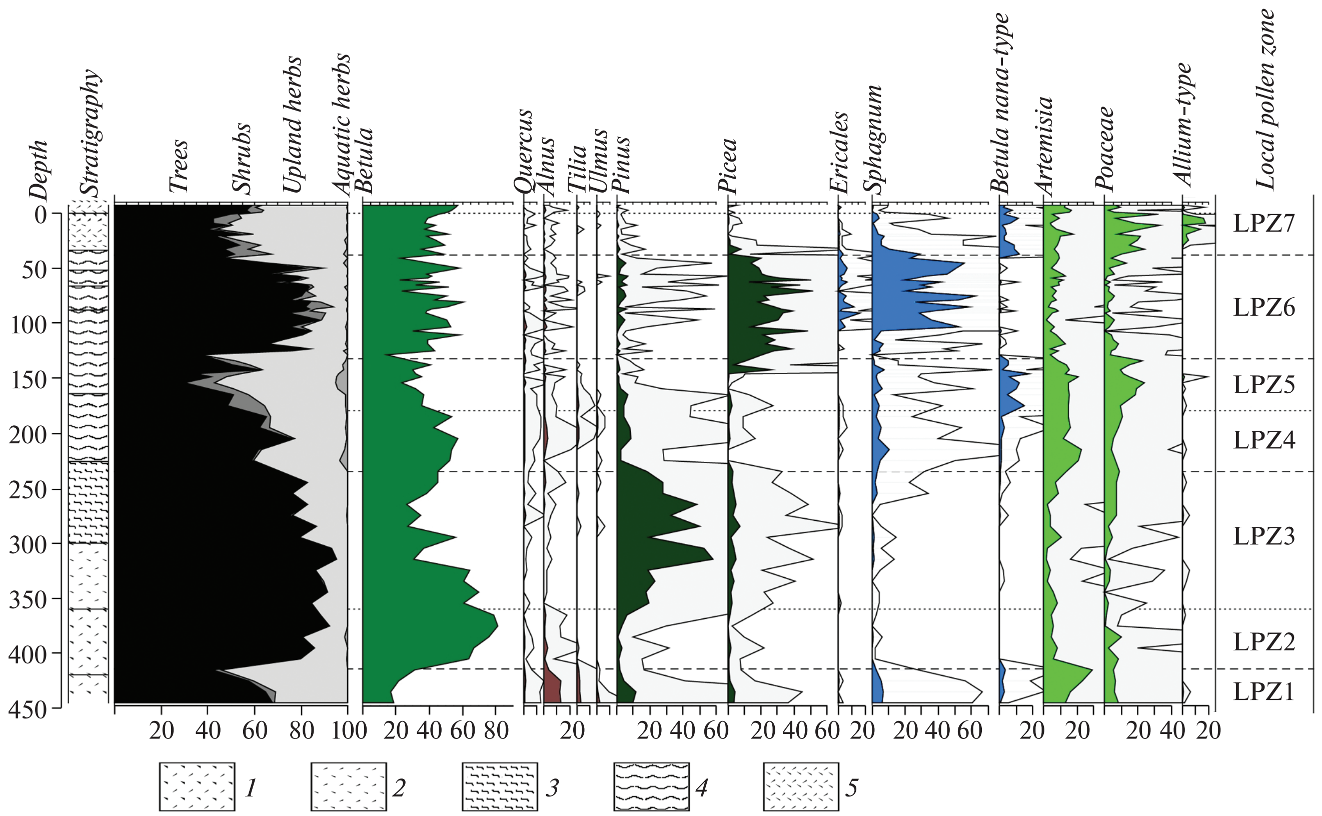

Fig. 5. Pollen diagram of the Ivantsevo section. *1* – sand and gravel, *2* – sand, *3* – gyttia, *4* – peat, *5* – silt.
Рис. 5. Спорово-пыльцевая диаграмма разреза Иванцево. *1* – песок и гравий, *2* – песок, *3* – гиттия, *4* – торф, *5* – алеврит.

This zone reflects forests dominated by pine and birch, with the presence of spruce and a single admixture of broad-leaved trees.

LPZ4, 180–230 cm (layer 7). The share of AP group decreased to 60%, pine (>10%) and spruce (>2%) became less important, birch is still dominant (50%). Single pollens of some broad-leaved trees (*Quercus, Tilia, Ulmus, Carpinus*) are still presented. NAP group plays a more important role (up to 30%), mainly due to *Artemisia* (20%). Other herbaceous taxa are the same but new hydrophilic taxa (*Myriophyllum, Alisma, Comarum, Sparganium, Saggilaria*) were found. We can see *Sphagnum* spores (up to 10%) again.

This zone reflects the decreasing of the coniferous forest role in the landscape. Open steppe-tundra grassland and sparse birch forest spread across this land.

LPZ5, 130–180 cm (lower part of layer 5, layer 6). The share of AP group decreases to 40% and less, only birch remains dominant (20–35%), all other trees including pine and spruce are singles. Shrubs and dwarf shrubs became more common: *Betula nana* (10–15%), *Frangula, Salix, Alnus viridis*, *Juniperus*. NAP group (60%) dominates the spectrum, there are many *Artemisia* (up to 20%) and Poaceae (up to 20%); we can see high taxonomic diversity of herbaceous taxa: Cyperaceae, Asteraceae, Liliaceae, Boraginaceae, *Saxifraga*, Fabaceae, Rubiaceae, *Polygonum, Polemonium*, Amaranthaceae, Apiaceae, Caryophyllaceae, *Scabiosa, Ranunculus, Thalictrum*, Onagraceae, Lamiaceae, *Viola*. Hydrophilic plants form 6% of the spectrum; there are *Sparganium, Myriophyllum, Alisma, Comarum*, *Typha latifolia*.

This zone reflects the maximum of the forest decline and the domination of the tundra and steppe-tundra communities during serious cooling. The moisture level remained the same and quite high which provided good conditions for the boggy shallow lake developing.

LPZ6, 35–130 cm (layer 2–5). We can notice the increase of AP group up to 80–85%; spruce (20–50%) became dominant here. All other trees except birch (40–50%) are poorly represented (*Abies, Larix* и *Pinus sibirica* type). *Betula nana* disappeared but the share of Ericales was increased up to 15%. The proportion of NAP group was decreased up to 10–15%, and its diversity became poor; Poacea (>5%) and *Artemisia* (5–10%) roles sharply dropped. Hydrophilic taxa still existed but, in less volume, (*Alisma*, *Sparganium, Typha*). There are two clear peaks of the sedge pollen: at the beginning and at the end of the zone. *Sphagnum* spores became abundant (60%). All samples yield micro charcoal fragments.

This zone reflects a sphagnum bog existing. This bog was surrounded by spruce forest during a relatively warm and wet climate.

LPZ7, 0–35 cm (layers 1–2). AP group became less important (50%); almost all trees except birch have disappeared. We observe the decreasing of Ericales, the increase of shrub birch *Betula nana* (up to 10%), the appearance of Salix (about 2%) and *Rubus chamaemorus*. Herbs and grasses play important role: Poaceae (up to 30%), Liliaceae (up to 25%), *Artemisia* (up to 15%); we also found *Saxifraga*, *Ranunculus, Filipendula, Dryas, Polemonium, Polygonum, Sanquisorba, Scabiosa, Thalictrum*, Asteraceae, Apiaceae, Caryophyllaceae, Amaranthaceae, Fabaceae, Lamiaceae, Onagraceae. *Sphagnum* role decreased to 5%, *Osmunda* pollen (about 5%), and single club-moss spores were found.

This upper zone reflects mostly treeless landscape with dominance of grass and shrub-grass tundra communities during cooling and drying. Hydrophilic plant pollen is absent in the sample of the upper layer but we have observed (see above) the presence of water plant remains, *Chara* oogonia and remains of freshwater invertebrates. The sedimentation occurred in the shallow lake which is hardly recognized on the basis of pollen method.

5. DISCUSSION

Different features such as sediment colour caused by the organic and iron content (fig. 2) were important field criterions for correlation of the section beds with the glacial, interstadial and interglacial intervals. We can describe three stratigraphic units. 1 (lower) belongs to the Moscow glaciation. It is represented by oblique beds of unsorted, iron rich reddish-brown sands. The sands are of fluvioglacial origin. This sediment accumulated in oxidative condition which caused iron accumulation due to the low supply of organics. 2 (middle): Milulino-Early Valdai interglacial-interstadial unit. This part is represented by the dark clay, peat, gyttia and peat. The light colorued sand and gravel bedded directly under the main peat bed may also belong to this unit (if the OSL date 70 ± 6 ka (table 1) is correct). 3 (upper): the Middle Valdai (MIS 3) interval. This unit is represented by the light gray silt with carbonate concretions; it overlays the peat with unconformity and forms ice wedge casts.

Intensive mining is changing the section dramatically. In the early June of 2020 we observed only the upper part of the section (clay, one peat bed and cover silt). Two week later a sand-gravel lens was exposed at the left side. In 2021 the peat unit was represented by four layers with clay in between, and a lower part of the section has been exposed.

The two-year observations show that the lacustrine-bog structure has an asymmetric shape. Its left side is evidently steeper. The peat layer (the layer 12) which yielded the strongest warm-climate signal according to seed finds was not exposed in the center of this mould in 2020, but became exposed in 2021. Probably, peat accumulation was more or less continuous at the edges of the mould but intermittent in the center where a lake was formed periodically.

The presence of the periglacial environment was marked by post cryogenic features in the lower and upper part of the section (fig. 2). Two levels of ice wedge casts inside the Valdai unit and a fine-grained texture of the two upper gyttia layers (traces of the melted ice schlieres) suggest that the permafrost existed in this area at least during the MIS 4. Micromorphological study shows that the silt that filled the ice wedge cast was periodically frozen. It could happen if a lake (and the freshwater invertebrates doubtlessly indicate the lake depositional environment) and its sediment froze to the bottom. Such shallow lakes are common in the cold climates.

Ice wedge casts at the base of the lacustrine-bog structure have been formed in subaquatic conditions. This conclusion is based on the presence of the distinctive bedded lake sediment (Rasskazov and Gorbatov, 2019).

Fossil plant and animal assemblages proved meaningful information for the environment reconstruction and local conditions in the lake-bog-paleosol cycles.

The lowermost peat (layer 12) yielded a carpological assemblage typical for the Mikulino interglaciation (fig. 4) which includes fruits and seeds of broad-leaved trees (maple, oak), the extinct pondweed *Potamogeton sukaczevii*, and the relict water plant *Aldrovanda vesiculosa*. It should be noted that acorns are rarely recorded in the deposits of the Mikulino interglacial due to the poor preservation of these fruits. They was found only in several sections in the East European Plain: Jonyonis-1, Cherikov-1, Loev-1 and Kashino (Velichkevich, 1982). Pollen analysis was not carried out in this layer.

The next units are characterized by the palynological analysis. This record allows recognizing 7 stages of the vegetation changes that complement and extend the record from plant macroremains (table 1). There is evidence of strong cooling events when the area was occupied by steppe-tundra, birch forest tundra and tundra. We cannot correlate the peat of Ivantsevo section with the visually similar peat units of the Mikulino age from other sections near Dmitrov town (Nosov and Skiba, 1975; Sudakova et al., 1997; Sudakova et al., 2002).

OSL dates from fluvioglacial sands (259 ± 27 ka), a sand-gravel lens (layer 11 – 70 ± 6 ka) and cover silt (layer 2 – 53 ± 4 ka) also suggest that accumulation of the peat-clay unit continued after the end of the

Mikulino interglaciation. The picture where ice wedge casts penetrate a peat is typical for the Valdai interval of the Russian Plain. Probably this part of the section is correlated with the Selikhodvorsky cryogenic horizon by S.A. Sycheva (Sycheva et al., 2002; Sycheva, 2012). The date 53 ± 4 ka from the upper layer is consistent with the final cold stadial of the Early Valdai time (MIS 4).

The pollen record reflects the enough cold climatic conditions during the accumulation of the lake-bog sediments. However, the AP group predominates the most of local pollen zones. The non-arboreal pollen predominates only the spectra in the upper part of LPZ-1, as well as LPZ-5 and LPZ-7. The phase of the spruce dispersal (LPAZ-6) cannot be attributed to the end of MIS-4, when open landscapes (tundra and steppe phytocenoses with forest outliers) dominated the study area (Chebotareva, Makarycheva, 1974; Grichuk, 1989). At the same time, the occurrence of *Potamogeton sukazcevii* endocarps allow attributing the peaty deposits characterized by LPZ4-LPZ-6 to the beginning of the Early Valdai glacial epoch (post-Mikulino cooling and the first Early Valdai interstadial).

Similar contradictions between paleobotanical records and OSL dating were noted in some other Upper Pleistocene sections in the East-European Plain. For example, in the Kileshino section (South of the Valdai Hills), buried lake-fen deposits were compared to MIS-4 and MIS-3 based on a series of OSL and ^{14}C dates (Lasberg, 2014). The recent paleobotanical and geomorphological studies (Karpukhina et al., 2020) have confirmed the Mikulino (MIS-5e) and Early Valdai (MIS-5a-d) age suggested by earlier researchers (Giterman et al., 1975) for buried lake-fen deposits in this section.

Complicated composition of the Ivantsevo lake-bog unit and possibility of stratigraphic disconformities make the interpretation univalent. The section needs future research especially carefully age determination.

The geological record allows reconstructing the history of sedimentary environments. Development of the studied lacustrine-bog formation begun on a glaciofluvial substratum. The glaciofluvial gravel and sand with high concentration of iron oxides and hydroxides were formed by the flow of melted ice that carried poorly sorted sediments of various grain sizes. Probably, by the end of Moscow glaciation (during one of its last interstadials) an oligotrophic wetland had been formed. This wetland was affected by the permafrost, as indicated by small ice wedges. At the beginning of the Mikulino interglaciation the ice wedges melted away forming a system of ice wedge casts. Thermokarst helped to form a large depression where the lake, bog and land changed each other during next several tens of thousands of years.

The warmest time corresponded with the formation of the peat containing large wood fragments. This peat is of a complex origin; probably it includes several cycles of the water invasion and draining. The unit appears to be a swamped forest paleosol. Abundance of riparian insects indicates that a significant part of accumulation happened on sedge-reed margins of a small shallow lake.

The next stage of the local landscape history includes flooding (horizontal bedded sand and silt just above the basal peat at the left side of the section). Probably there was a mesotrophic flowing lake with a moderate level of biogenic sedimentation. The climate turned to cooling.

Limitation of the mineral supply led to predominantly organic sedimentation. Dark brown gyttia has been formed as a result of the early stage of sapropel lithification. The gyttia layers are associated with the periods of eutrophication of the reservoir. Lake-bog sedimentation have changed repeatedly according to finding of 4 peat layers separated by gyttia in 2021.

Later the climate became colder, the lake has been drained (maybe twice) or was frozen entirely; two levels of ice wedges appeared. At the beginning of the Middle Valdai interval (MIS3) the ice wedges melted, and ice wedge casts were filled by the light gray silt with the low organic content. Remains of water plants and invertebrates indicate that the condition was not subaerial but subaqueous.

6. CONCLUSION

The studied section provides a record of climate and environment since Moscow glaciation (the Middle Pleistocene). We can recognize the warm and wet climate of Mikulino interglaciation, and the relatively cold and dry climate of the Valdai time. The presence of different types of sediment, from sand to clay and peat is typical for the lacustrine and boggy-lacustrine lithogenesis (Rasskazov and Gorbatov, 2019). The comparison of the studied section with the other sections of the same region and similar age (Geologiya SSSR..., 1971) shows certain similarity in the lithology of these units, which indicates similarity of their genesis. Our section is unique because this is a large exposure while the other contemporary deposits were exposed in small natural outcrops or boreholes. Such a feature accentuates the uniqueness of the section.

This section enabled the complex study of the lithological composition, minerals, geochemistry, pollen assemblages, plant macrofossils and remains of invertebrate animals of the last interglaciation and the followed cooling from MIS 5 to (probably) the early MIS 3. We were able to trace lake-bog-land succession over that time. Here, in the same depression, lakes existed with several breaks in a course of at least 30 ka, in different climates and environments. This paleolake is an outstanding source of paleontological information.

1. At least several warming events were recognized in one lacustrine-peat section. They are different by

the grade: Mikulino interglaciation, probably, the first Early Valdai interstadial (MIS 5c), and MIS 3 (if the uppermost OSL date is correct).

2. Tree levels of paleocryogenic deformations were described. The first one is correlated with late Moscow glaciation and the last two were formed during Valdai cooling intervals. The lower level from the two Valdai paleocryogenic deformations is correlated with Early Valdai stage (MIS 4).

3. Early Valdai (Kalinin) till did not observed in the section. Cryogenic structures confirm indirectly the lack of moraine in this time.

4. Two years of observations in the working pit show the changes of the local lake-bog system in the space and time. The section of 2020 exposed an edge of the ancient depression where peat accumulation took place. In 2021 the picture has been changed; the older part of the buried depression was exposed. Alternation of different stages of the local geosystem was recorded: repeatedly draining of the water body and new peat accumulation.

Excellent preservation of insects, crustaceous, bryozoans, worms, mosses, plant macrofossils and other provide vast opportunities for the future research.

Ivantsevo Section of the Buried Middle and Late Pleistocene Lake-Bog Deposits Near the Town Dmitrov, Moscow Region

S. A. Kuzmina[a,#], S. A. Sycheva[b], E. K. Ershova[c], I. S. Zyuganova[b], A. L. Zakharov[b], E. S. Gorbatov[d], S. F. Kolesnikov[e], and P. G. Panin[b]

[a] *Boryssyak Paleontological Institute RAS, Moscow, Russia*
[b] *Institute of Geography RAS, Moscow, Russia*
[c] *Lomonosov Moscow State University, Faculty of Biology, Moscow, Russia*
[d] *Schmidt Institute of Physics of the Earth RAS, Moscow, Russia*
[e] *Moscow State University of Geodesy and Cartography, Moscow, Russia*
[#] *E-mail: svkuz@yandex.ru*

The Ivantsevo section is located in a gravel pit at an outskirt of Dmitrow town, Moscow region. The section consists of sand, peat, gyttia, and silt; cryogenic structures including ice wedge casts are well developed. Repeatedly lake-bog sedimentation changes were observed there. The lake-boggy unit has been formed during MIS5 since MIS 5e, it includes 3–4 warm intervals. The peat yields fossil insects (mainly beetles), small freshwater invertebrates, and plant macrofossils. Carpological remains include some typical for Mikulino interglaciation species. Pollen record allow recognizing the vegetation changes from mixed pine-birch with single broad-leaved trees to coniferous forests and open communities dominated by birch, shrubs, light-demanding grasses, and Artemisia. The section allows to reconstruct the history of the climate and environment from the Middle Pleistocene (Moscovian Dnieper glaciation) to the early stages of the Late Pleistocene.

Keywords: Mikulino interglaciation, Valdai glaciation, climate, vegetation, paleosols, cryogenic structures, pollen analysis, carpological analysis, beetles, invertebrates

ACKNOWLEDGEMENTS

This research was supported by a grant RFFI No. 19-29-05024 mk, and as a part of the government tasks of the Institute of Geography RAS: AAAA-A19-119022190169-5 (FMGE-2019-0006) and AAAA-A19-119021990091-4 (FMGE-2019-0005) (plant macrofossil analysis).

REFERENCES

Alekseev M.N., Gablina S.S., Lavrushin Yu.A., Hyutt G.A., and Yakimenko E.Yu. *Stratigrafiya i geologicheskie sobytiya srednego i pozdnego pleistotsena Podmoskov'ya. Geologiya i paleogeographiya Rossii* (Stratigraphy and geological events of the Middle and Late Pleistocene of the Moscow Region Quaternary). Geology and Paleogeorgaphy of Russia. A.L. Yashin, A.L. Aleksandrovsky, M.N. Alekseev at al. (Eds). Moscow: GEOS (Publ.), 1997. P. 15–24 (in Russ.)

Antonov S., Rychagov G.I., and Sudakova N.G. Middle Pleistocene glaciations in the center of the Russian Plain. Problems of stratigraphy and paleogeography *Bull. comm. Quarter. per.* 2004. Vol. 65. P. 5–16. (in Russ.)

Boyarskaya T.D., Nemtsova G.M., and Sudakova N.G. *K stratigrafii i paleogeografii pleistotsena Klinsko-Dmitrovskoi vozvyshennosti (razrez na r. Kune). Priroda-naselenie-khozyaistvo* (On the Pleistocene stratigraphy and paleogeography of the Klin-Dmitrov Upland (section at the Kunya River)) Nature Population Economy. M.M. Golubchik (Ed.). Saransk: MGY (Publ.),1983. P. 61–64. (in Russ.)

Chebotareva N.S. and Makarycheva I.A. *Poslednee oledenenie Evropy i ego geokhronologiya* (The Last Glaciation of Europe and its geochronology). Moscow: Nauka (Publ.), 1974. (in Russ.)

Ershova E., Sycheva S., Kuzmina S., Zuganova I., Panin P., and Meteleva M. Preliminary results of a multidisciplinary study of the buried peatland and host sediments of the Moscow-Valdai age (Dmitrov, Moscow region, Russia). EGU General Assembly 2021. https://doi.org/10.5194/egusphere-egu21-12664

Geologiya SSSR. Tom IV (Geology of the USSR. Vol IV). I.N. Leonenko A.V. Sidorenko and S.M. Shik. (Eds). Moscow: Nedra (Publ.), 1971. 742 p. (in Russ.)

Gerasimova M.I., Gubin S.V., and Shoba S.A. *Micromorfologia pochv prirodnykh zon SSSR* (Micromorpholo-gical features of the USSR zonal soils). Pushchino: Pushchino science center (Publ.), 1992. 219 p. (in Russ.)

Giterman R.E., Kuprina N.P., and Shancer E.V. About the Mikulino age of interglacial layers near the village of Kileshino (Upper Volga). *Bull. Komis. po izuch. chetvertichn. perioda*. 1975. No. 44. P. 84–88. (in Russ.)

Grichuk V.P. *Istoriya flory i rastitel'nosti Russkoi ravniny v pleistotsene* (The history of flora and vegetation of the Russian Plain in the Pleistocene). Moscow: Nauka (Publ.), 1989. 181 p. (in Russ.)

Jongerius A. and Heintzberger G. Methods in soil micromorphology: a technique for the preparation of large thin sections *Soil Survey Papers*. Vol. 10 (Wageningen: Netherlands Soil Survey Institute). 1975. 48 p.

Karpukhina N.V., Pisareva V.V., Zyuganova I.S., Konstantinov E.A., Zakharov A.L., Baranov D.V., Utkina A.O., and Panin A.V. New data about the section stratigraphy near Kileshino (Tver Oblast, Russia) – the key for understanding boundaries of glaciations on the Valdai Hills in the Upper Pleistocene. *Izvestiya RAN. Seriya geograficheskaya*. 2021. 84 (6). P. 874–887. (in Russ.). https://doi.org/10.31857/S2587556620060060

Karta chetvertichnykh obrazovanii masshtaba 1:2 500 000 territorii Rossiiskoi Federatsii. (Map of Quaternary formations, scale 1:2 500 000 of the territory of the Russian Federation). O.V. Petrov (Ed.). S.–P.: Ministry of Natural Resources of Russia, Rosnedra, FSUE VSEGEI, FSUE VNIIOkeangeologiya (Publ.), 2010. http://arcgisportal.vsegei.ru/portal/apps/webappviewer/index.html?id=15974bcda12249678b9b078aa32b8d86 (in Russ.)

Lasberg K., Kalm V., and Kihno K. Ice-free interval corresponding to Marine Isotope Stages 4 and 3 at the Last Glacial Maximum position at Kileshino, Valdaj Upland, Russia. *Estonian Journal of Earth Sciences*. 2014. No. 63 (2). P. 88–96. https://doi.org/10.3176/earth.2014.08

Lazukov G.I., Sudakova N.G., and Faustov S.S. *Analiz lednikovykh otlozhenii Klinsko-Dmitrovskoi vozvyshennosti v svyazi s problemami stratigrafii i paleogeorgafii. Noveishaya tektonika, noveishie otlozheniya, chelovek* (Analysis of glacial deposits of the Klin-Dmitrov Upland and the problems of stratigraphy and paleogeography Naimark A.A. and N.I. Nikolaev (Eds.). Recent tectonics, recent deposits, man. Vol. 8. 1982. P. 86–101. (in Russ.)

Nikitin V.P. *Paleokarpologicheskii metod* (Paleocarpological method). Tomsk: Izd-vo Tomskogo un-ta (Publ.), 1969. 81 p. (in Russ.)

Nosov A.A. and Skiba L.A. Deposits of the Iksha (?) interstadial near Dmitrov town. *Bull. com. Quarter. per*. 1975. Vol. 44. P. 122–125. (in Russ.)

Pyltsevoi analiz (Palynology) I.M. Pokrovskaya Ed. Moscow: Gos. izd. geol. lit. (Publ.), 1950. 424 p. (in Russ.).

Rasskazov A.A. and Gorbatov E.S. *Limnogeologiya i evolyutsiya ozernogo litogeneza* (Limnogeology and evo-lution of lacustrine lithogenesis). Moscow: IFZ RAS (Publ.), 2019. 192 p. (in Russ.)

Stoops G., Marcelino V., and Mees F. (Eds). Interpretation of micromorphological features of soils and regoliths. Amsterdam: Elsevier (Publ.), 2010. 720 p.

Sudakova N.G., Vvedenskaya A.I., Vaskovskaya L.T., and Pisareva V.V. *K probleme stratigrafii Klinsko-Dmitrovskoi vozvyshennosti* (To problem of stratigraphy of the Pleistocene of the Klin-Dmitrov Ridge. Quaternary Geology and Paleogeorgaphy of Russia). A.L. Yashin (Ed.). Moscow: GEOS (Publ.), 1997. P. 171–180. (in Russ.).

Sudakova N.G., Vvedenskaya A.I., Vaskovskaya L.T., Nemtsova G.M., Nosov A.A., and Pisareva V.V. *Novye dannye ob oledeneniyakh Klinsko-Dmitrovskoi vozvyshennosti v svete lednikovoi teorii P.A. Kropotkina. Trudy mezhdunarodnoi konferentsii posvyashchennoi 150-letiyu so dnya rozhdeniya P.A. Kropotkina, Vyp. 4.* (New data about glaciations of Klin-Dmitrov Ridge in point of glacial theory of P.A. Kropotkin). Ideas P.A. Kropotkin and natural science. Vol. 4. 2002. P. 88–100. (in Russ.)

Sycheva S.A. Paleocryogenic events in periglacial area of the Central Russian upland at the end of the Middle and Late Pleistocene. *Kisophera Zemli*. 2012. Vol. 16. No. 4. P. 45–56. (in Russ.)

Sycheva S.A., Khokhlova O.S., and Pushkina P.R. Structure of the Late Pleistocene climate rhythm inferred from the detailed soil-sedimentation archive of the extraglacial region of the East European Plain (Aleksandrovka Quarry). *Stratigraphy and Geological Correlation*. 2021. Vol. 29. No. 3. P. 368–387. https://doi.org/10.1134/S0869593821030084

Velichkevich F.Yu. *Pleistotsenovye flory lednikovykh oblastei Vostochno-Evropeiskoi ravniny* (Pleistocene Floras of Glacial Areas of the East European Plain). Minsk: Nauka i tehnika (Publ.), 1982. 239 p. (In Russ.).

Velichkevich F.Yu. and Zastawniak E. *Atlas of the vascular plant macrofossils of Central and Eastern Europe Part 1.* Kraków: W. Szafer Inst. of Bot. (Publ.), 2006. 224 p.

Velichkevich F.Yu. and Zastawniak E. *Atlas of the vascular plant macrofossils of Central and Eastern Europe. Part 2.* Kraków: W. Szafer Inst. of Bot. (Publ.), 2008. 380 p.