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GEOGRAPHY

Kosa Mesolithic Sites in the Context of the Palaeoenvironmental History of the Upper Kama Basin in the Late Glacial and Early Holocene

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Abstract—The results of interdisciplinary (archaeological and palaeoecological) studies conducted in 2018–2021 in the northern part of Perm Territory at the confluence of the Kosa and Lolog rivers are given. Research has focused on the Mesolithic sites and their natural environment in the Late Glacial and Early Holocene. To identify attribution of the archaeological sites to certain landforms within the river valley, the paleochannel method was used. As a result, two terraces and the Holocene floodplain were identified. The natural conditions were reconstructed on the basis of the palynological and paleocarpological methods. To create the chronological framework for the study area, radiocarbon dating was used. To estimate the economic activities of the Mesolithic groups, osteological analysis was used. It was established that, in the Late Glacial, the study area was not yet inhabited by ancient people due to unfavorable natural environments. The settlement started only in the second half of the Boreal period of the Holocene, after the formation of the second floodplain terrace covered with taiga pine and birch formations with spruce. The Kosa I and Kosa II sites, located on the former banks of the Lolog River, should be referred to this time. The population was mostly engaged in hunting and, partly, fishing. The natural environments at the beginning of the Atlantic period of the Holocene were still favorable for the existence of human groups here. The formation of the first terrace in the Lolog River valley contributed to the human colonization of this area. The Kosa III site, the population of which continued to hunt and probably fish, should be associated with this time. Subsequently, due to the continuing lateral migration of the Kosa and Lolog channels to the east, as well as the expansion of a swamped floodplain, humans left these places and began to develop them again only in the Late Holocene.

Keywords: archaeology, Mesolithic, radiocarbon dating, paleochannel analysis, pollen analysis, paleocarpology, osteology, Late Glacial, Holocene

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INTRODUCTION

It is already difficult to imagine modern archeological science without the methods of natural sciences, because they are applied at all stages of archeological research. The methods of geochronometry (radiocarbon and method of optically stimulated luminescence (OSL)) and reconstruction of the natural environment (paleogeomorphological, paleocarpological, pollen, paleozoological) are most widespread. The information, obtained as a result of their application, allows an archaeologist to look at the colonization by ancient people of the studied territory from a different viewpoint, as well as to find out the predominant type of economy activity, climatic conditions, and dynamics of plant communities of the areas where ancient groups lived.

The Late Pleistocene–Early Holocene boundary is of particular interest in this respect. At that time, glacial areas and regions distant from a glacier experienced its indirect impact. In these areas, landscapes were significantly reorganized, which was associated with the formation of new river channels and terraces. This process was accompanied by rather rapid change in plant communities, which can be recorded by using pollen and paleocarpological analyses. Climatic

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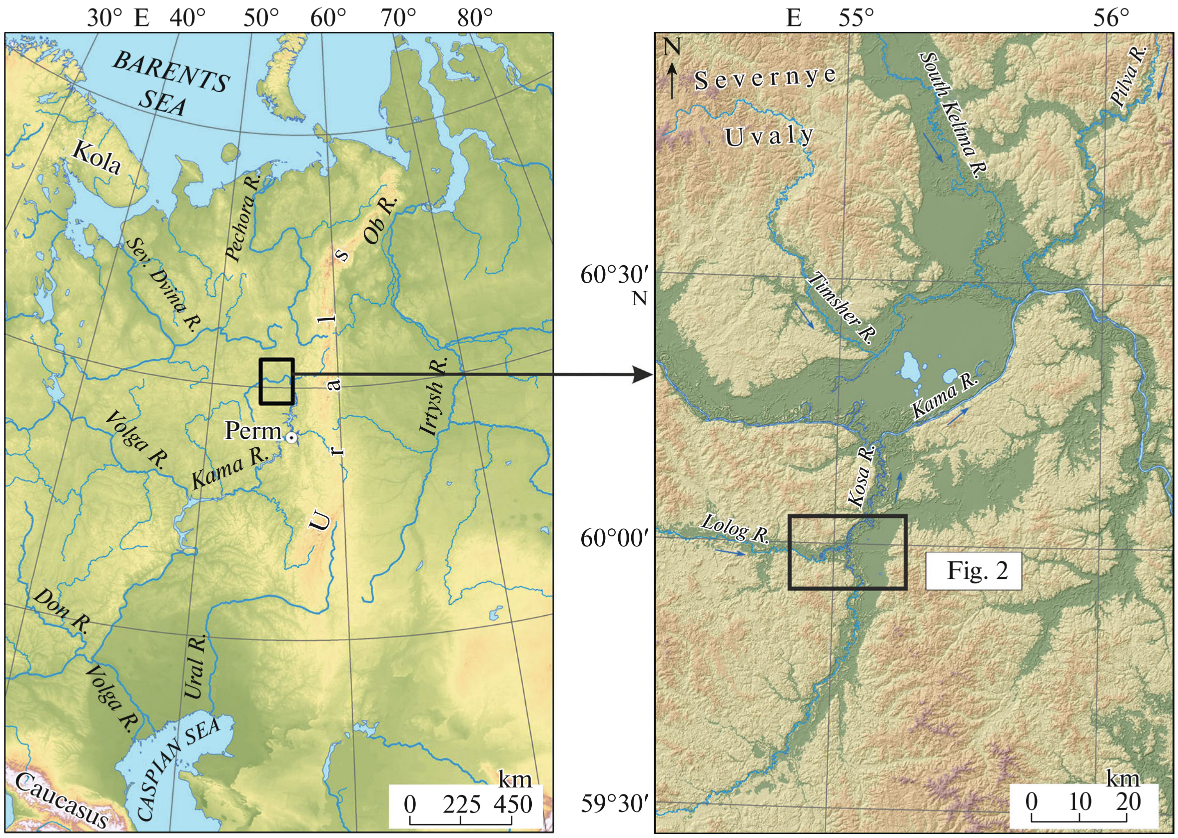


Fig. 1. The location map of the study area.

changes that led to the deglaciation and termination of the Eurasian ice sheets in the Pleistocene had a strong impact on the ability of people to survive in these northern landscapes [17].

In view of the limited possibilities of man to transform the environment (to create "second nature"), the development of territories depended largely on the formation of favorable natural conditions for his existence. The strong relationship between nature and man in ancient times forces us to consider the reasons for human advance to new areas caused by change in natural conditions. First of all, it concerns glacial zones.

The site of the confluence of the Lolog and Kosa rivers in the northern Kama basin (Fig. 1), where the first humans appeared in the Early Holocene, can be considered as such an area.

Previous studies have shown a rather close connection between the local natural conditions and the choice of settlement strategies of human societies in the Upper Kama valley in the Holocene [6, 7]. For the Late Pleistocene, the rather limited amount of works is devoted to reconstruction of the paleoenvironmental conditions [5, 18].

The purpose of this work is to reconstruct the natural environment of the Late Pleistocene and the living conditions of ancient man in the Early Holocene in the lower reaches of the Kosa River, at its confluence with the Lolog River.

THE STUDY AREA

The study area is located along the right-bank part of the Upper Kama basin, in the valleys of the Kosa and Lolog rivers (Fig. 1). There are three Mesolithic sites (Kosa I, Kosa II, and Kosa III) discovered in the second half of the 20th century.

The Kosa River is the largest right tributary of the Upper Kama. The channel width in the lower reaches is 60–70 m, and after the confluence of the Lolog River, it is 110–120 m. The average annual water discharge in the Kosa River is 43.9 m^3/s, in the Lolog River it is 12.5 m^3/s. The basin is fed by snow, which causes high floods followed by relatively low low-water periods. When water rises 5 m above the low-water line of the Lolog River, flooding of the floodplain and filling of oxbows on the right bank begins at the mouth of the river (Fig. 2).

The Kosa and Lolog valleys are wide; they consist of floodplains and terraces composed of alluvial sands and silts easily affected by erosion. These sediments are underlain by Permian sandstones, clays, and

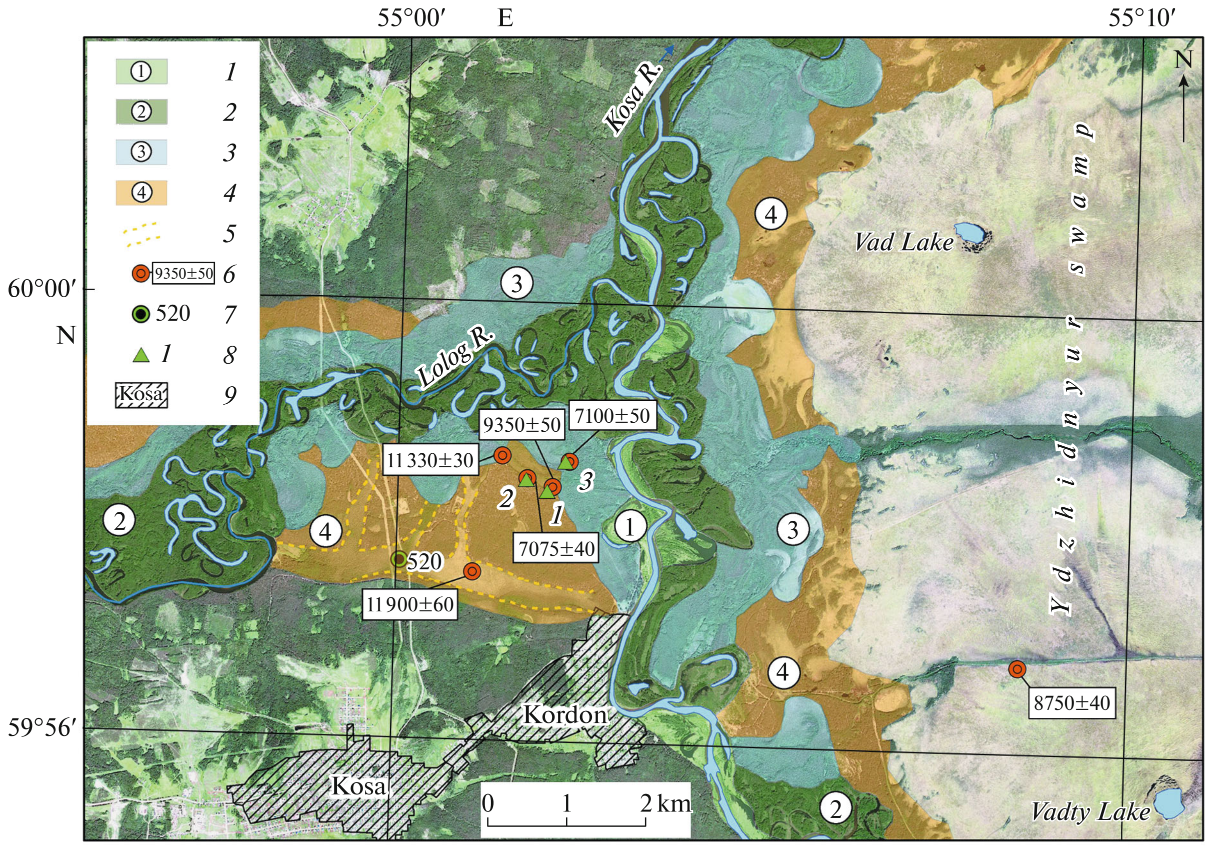


Fig. 2. The geomorphological map of the study area: *1*, low floodplain; *2*, high floodplain; *3*, the first terrace; *4*, the second terrace; *5*, a contour of swamped hollow (Lolog paleochannel) and its tributaries on the second floodplain terrace; *6*, location of drilled boreholes and radiocarbon dating; *7*, location of the borehole of the Kamskaya crew of the All-Union Hydrogeological Trust; *8*, the archaeological sites: 1, Kosa I; 2, Kosa II; 3, Kosa III; *9*, modern settlements.

marls. Willow and alder-birch thickets with clumps of spruces and pines on the high sites are encountered near the channel. The valleys are surrounded by slightly sloping watersheds covered with spruce forests. The right side of the Kosa valley is occupied by a vast ridge–hollow swamp (Ydzhidnyur). In height, the swamp corresponds to the first floodplain terrace, but it is completely devoid of traces of meander–ridge-and-swale fluvial relief. Small lakes (Vad, Vadty, Nizh. Kosinskoe, Markosh) occur within the swamp, probably being remnants of the ancient paleobasin.

The relative height of the first terrace is 7–8 m above the low-water line, while the height of the second terrace is 17–19 m above the low-water line. The floodplain occupies an almost continuous band 1–2 km wide along the Lolog and Kosa rivers, with its maximum development at their confluence (Fig. 2). Two levels are well distinguished; they differ in both the relative height and the type of vegetation. The low floodplain is rich in young ungrown oxbows, has a height of 2–3 m above the low-water line, and is occupied by flood meadows. The high floodplain has a relative height of 4–5 m above the low-water line and is mostly covered by a dark coniferous forest. Both levels are characterized by the development of numerous curved cut-off meander spurs that give the floodplain an undulating appearance.

METHODS

To determine attribution of the archaeological sites to the landscapes within the river valley, their mapping was carried out. The boundaries of the Kosa II and III sites were specified during pitting in 2018.

The Kosa II and III sites were excavated with three-dimensional recording of all finds, except for small chips. All ground was sieved on 0.5-cm sieves. Ground layers were removed by conditional horizons parallel to the day surface. The thickness of the horizons varied from 0.05 to 0.1 m, depending on the stratigraphic features of the particular site. In cases when organogenic material (charcoal) was recorded at the bottom of holes or some constructions, it was collected for radiocarbon analysis. Palynological columns were sampled at both sites.

Bone fossils were determined with use of the reference collection of skeletons from the museum of the Institute of Plant and Animal Ecology, Ural Branch,

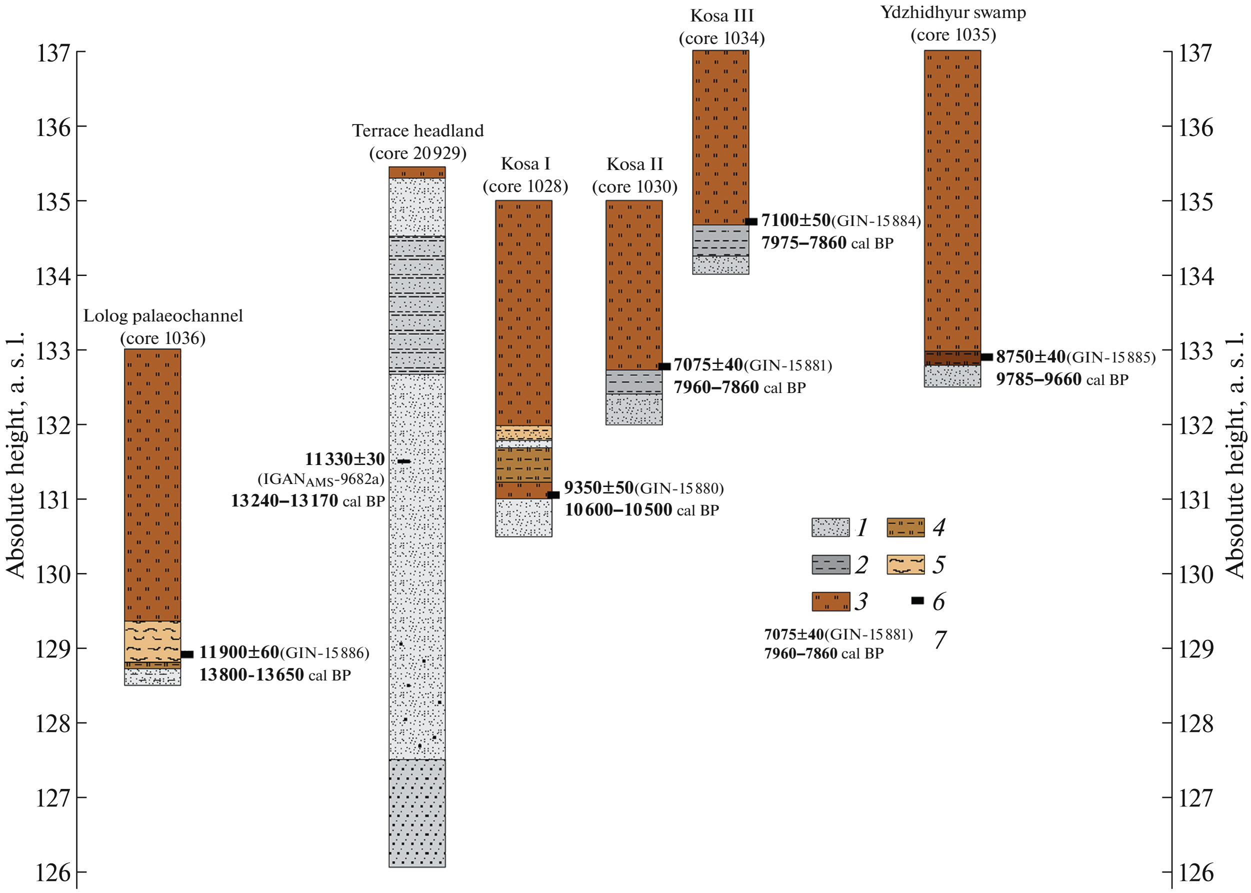


Fig. 3. The structure of the sections (boreholes) of the paleochannels in the vicinity of the Kosa sites and the results of radiocarbon dating. (*1*) Sand; (*2*) silt; (*3*) peat; (*4*) silty peat (peated silt); (*5*) gyttja; (*6*) sampling point of ^{14}C sample; (*7*) radiocarbon dates.

Russian Academy of Sciences. They are currently stored in the museum. The bones are highly fragmented and have sizes from 3 to 20 mm; therefore, it was not possible to determine most of the bones up to species. Based on the thickness of compact bones, they were divided into the following size groups: moose-sized; reindeer-sized; moose–reindeer-sized; small species, beaver-sized or smaller; undetectable.

Paleochannel analysis involved the study of the primary landforms and the structure of the floodplain and terraces. As a result, the paleoparameters of the rivers such as the water content and morphodynamical types of a channel—meandering and multi-channel structure—were determined [15]. Groups of floodplain segments, according which it is possible to reconstruct the position of the channel, have appeared at certain stages of the development of the rivers. In this regard, they can be combined into the coeval floodplain generations. To confirm the assumptions about the age of the generations and to verify the map, the radiocarbon dating of the floodplain sediment samples, collected in the most typical places of each generation from the bottoms of paleochannels and hollows, was performed (Figs. 2, 3).

The radiocarbon analysis was carried out at the Laboratory of Isotope Geochemistry and Geochronology, Geological Institute, Russian Academy of Sciences (index GIN) [20]; the Institute of History of Material Culture, Russian Academy of Sciences (St. Petersburg, index Le); and the Laboratory of Radiocarbon Dating and Electron Microscopy, Institute of Geography, Russian Academy of Sciences (index IGAN$_{AMS}$). All dates were calibrated (radiocarbon age conversion to calendar age) using the Calib 810 program (Table 1) and the IntCal 2020 calibration curve [19]. The age of the samples shows the time when the active channel began either to migrate laterally or to die off.

Palynological and paleocarpological studies were carried out to reconstruct the vegetation and climate reflecting the conditions, under which the settlements of ancient people existed. The materials for the study were selected by hand drilling from fills of hollows and paleochannels (Table 1; Figs. 2, 3).

Table 1. Description of the sections (boreholes) within the paleochannels in the vicinity of the Kosa sites and results of radiocarbon dating

No.	Borehole no.	Structure of the section (borehole)	Index and number	^{14}C date, BP	Ca BP	Coordinates	Asl of the borehole mouths, m
1	1028 (at the Kosa I site)	0–2.95 m: reddish brown-brown, peat 2.95–3.02 m: reddish brown silty peat 3.02–3.2 m: interlayering of sandy silt and fine-grained–medium-grained, reddish brownish gray sand 3.2–3.25 m: sand medium-grained, gray, well-washed out sand 3.25–3.32 m: peaty silt 3.38–3.89 m: silty peat, replaced by peat down through the section (^{14}C: 3.75–3.9 m) 3.89–4.0 m: gray, medium-grained–coarse-grained, well-washed out sand	GIN-15880	9350 ± 50	10600–10500	59.978971° 55.035509°	135
2	20 929 (the terrace headland)	0–0.15 m: poorly decomposed peat 0.15–1.0 m: fine-grained, gray sand 1.0–2.8 m: interlayering of medium to heavy silt and siltstone, blue-gray 2.8–5.3 m: fine-grained, gray sand at a depth of 3.4 m, plant detritus (^{14}C) 5.3–6.6 m: fine-grained–medium-grained, gray sand 6.6–7.8 m: coarse-grained, gray sand with single gravel 7.8–9.5 m: coarse-grained–very coarse-grained with abundant gravel, gray sand	$IGAN_{AMS}$-9682a	11 330 ± 30	13240–13170	59.982030° 55.024200°	135.5
2	1030 (at the Kosa II site)	0–2.3 m: reddish brown-dark brown, dense peat (^{14}C: 2.2–2.3 m) 2.3–2.6 m: silt heavy, bluish-gray 2.6–2.95 m: sand fine-grained, gray, well-washed out	GIN-15881	7075 ± 40	7960–7860	59.980256° 55.029992°	135
3	1034 (at the Kosa III site)	0–2.05 m: dark brown, dense peat 2.05–2.35 m: reddish brown peat (^{14}C: 2.25–2.35 m) 2.35–2.75 m: reddish-brownish blue-gray silt 2.75–3.0 m: fine-grained, gray sand	GIN-15884	7100 ± 50	7975–7860	59.981931° 55.039249°	137
4	1035 (swamp Ydzhidnyur)	0–4.03 m: brown peat 4.03–4.17 m: silty peat, brown, reddish brown gyttja at the low edge (^{14}C: 4.03–4.17 m) 4.17–4.25 m: fine-grained, silty sand, gray on top	GIN-15885	8750 ± 40	9785–9660	59.960059° 55.141809°	137
5	1036 (paleo-channel of the Lolog River)	0–3.7 m: brown peat 3.7–4.2 m: gyttja gray granular, very dense, dry (^{14}C: 4.05-4.15 m) 4.2–4.34 m: clayey peat 4.34–4.4 m: gray, clayey sand	GIN-15886	11 900 ± 60	13650–13800	59.968608° 55.017849°	133
6	The Kosa II site	Hole 4, depth of –0.6 to –0.75 m, charcoal	Le-12162	6870 ± 180	7860–7575	59.979617° 55.030161°	137

Samples for the pollen analysis were treated with the alkaline method of von Post [13]. Palynological fossils were determined in the temporary glycerin with the use of the Olympus BX51 microscope at 400× magnification. The reference collection of modern pollen and spores from the Museum of the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, was used for the analysis. We counted 513–939 pollen grains of terrestrial plants with parallel registration of spores of higher spore plants and stomata of coniferous plants. Data were processed and plotted in the Tilia v. 2.0.41. program [17]. The share of pollen of the taxa of trees and shrubs, subshrubs and grasses, and spores of higher spore plants was calculated from the total amount of pollen of woody and herbaceous plants (taken as 100% and presented in a pollen diagram).

Paleocarpological samples were treated in laboratory conditions on soil sieves with a cell diameter of 0.25 mm, according to standard procedures [10]. The volume of the samples studied averaged 100 ml. In most cases, the fossils were well preserved. Plant macrofossils were identified on the basis of the analysis of the collection from the Museum of the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences.

RESULTS

Archaeological research. The Kosa sites (Kosa I–III) were discovered in 1962 during the exploration of V.P. Denisov. In August of the same year, he conducted excavations at the Kosa I site. The site is located on the edge of the second floodplain terrace, the surface of which rises above the swamped paleochannel not more than 6–7 m (Fig. 2). An area of 376 m^2 was excavated. The material was represented exclusively by flint and stone artefacts (2927 objects), among which 168 were tools. In addition, the osteological material, represented by fragments of calcified animal bones, was collected and analyzed. The remains of a light seasonal dugout dwelling of a rectangular shape with rounded corners 4.8 × 2.4 m in size were studied at the site. In the opinion of the authors of the excavations, the stone tools of the site reflect the final stage of Mesolithic occupation in the Upper Kama basin [4]. The Kosa II and Kosa III sites were investigated only with pits in a small area at that time.

Archaeological excavations at the Kosa II site were conducted from 2018 to 2021. The site is located on a gently sloping scarp of the second floodplain terrace. The surface of the site rises no more than 4 m above the swamped hollow (Fig. 2). As a result of the work, 65 m^2 of the territory of the site was studied. The collection of the finds consists of 3515 objects.

The authors of the excavations identified the following layers:

Layer 1: sod, 0.03 m thick, on average, approximately the same in the entire studied area.

Layer 2: light gray podzol, 0.15 m thick, on average, with local hollows in places of root systems of trees.

Layer 3: dark-brown moistened sandy loam with inclusions of ortsand (cultural layer), the thickness varies from 0 to 0.3 m (0.16 m, on average).

Layer 4: yellow–orange fine-grained loose sand with ortsand (natural ground);

Layer 5: moist yellow sandy loam with dispersed charcoal interlayers (cultural layer). This sequence represents the filling of pits, the origin of which we associate with the existence of the Mesolithic population. The average thickness of the layer is 0.23 m.

The main mass of the finds was attributed to the layer nos. 1–4 (0.1–0.25 m from the day surface) and was located in the lower part of light gray podzol and in the layer of dark-brown moistened sandy loam.

The stone artefacts are similar to those from the Kosa I site, which is evident in the raw materials used, the presence of large groups of lithic flakes and medium-sized blades, and the identical shapes of the tools. The osteological collection, obtained during the excavations, consists of fragments of calcified mammal and fish bones.

In 2018, a column of samples was collected from the pit wall at the site for the pollen analysis (Fig. 4).

We obtained rather uniform pollen spectra, characterized by an abundance of pine (*Pinus sylvestris*-type) pollen with the participation of spruce (*Picea*) and birch (*Betula* sect. Albae). They characterize the communities of taiga forests with the predominance of pine and the participation of spruce and birch, both before the appearance of ancient man and during the functioning of the site. The pollen spectrum with an abundance of willow (*Salix*) pollen in the lower part of the "cultural layer" may indicate the use of willow in human economic activity. In particular, it might have been used for making fish traps or basketry. The spectra of the "cultural layer" contain pollen grains of fireweed (*Chamaenerion angustifolium*), which is an indicator of the pyrogenic plant communities, as well as small particles of charcoal [3].

The petrographic analysis of stone row material from the Kosa II site was conducted in 2019. It allowed us to find that the main material for making tools was silicified jasper of volcanogenic–sedimentary origin. This material was used in more than 75% of the tools. No sources of jasper are known in the vicinity of the sites. The second group contains various kinds of flint. About 20% of the finds belong to this group [2].

In 2020, a charcoal sample from the fill of hole no. 4, which was full of finds, was dated at 7860–7575 cal BP (6870 ± 180 BP, Le-12162). The hole was located beneath a modern ground road. The cultural layers of the site are sandy loams of various shades. We do not exclude the possibility that the younger organogenic

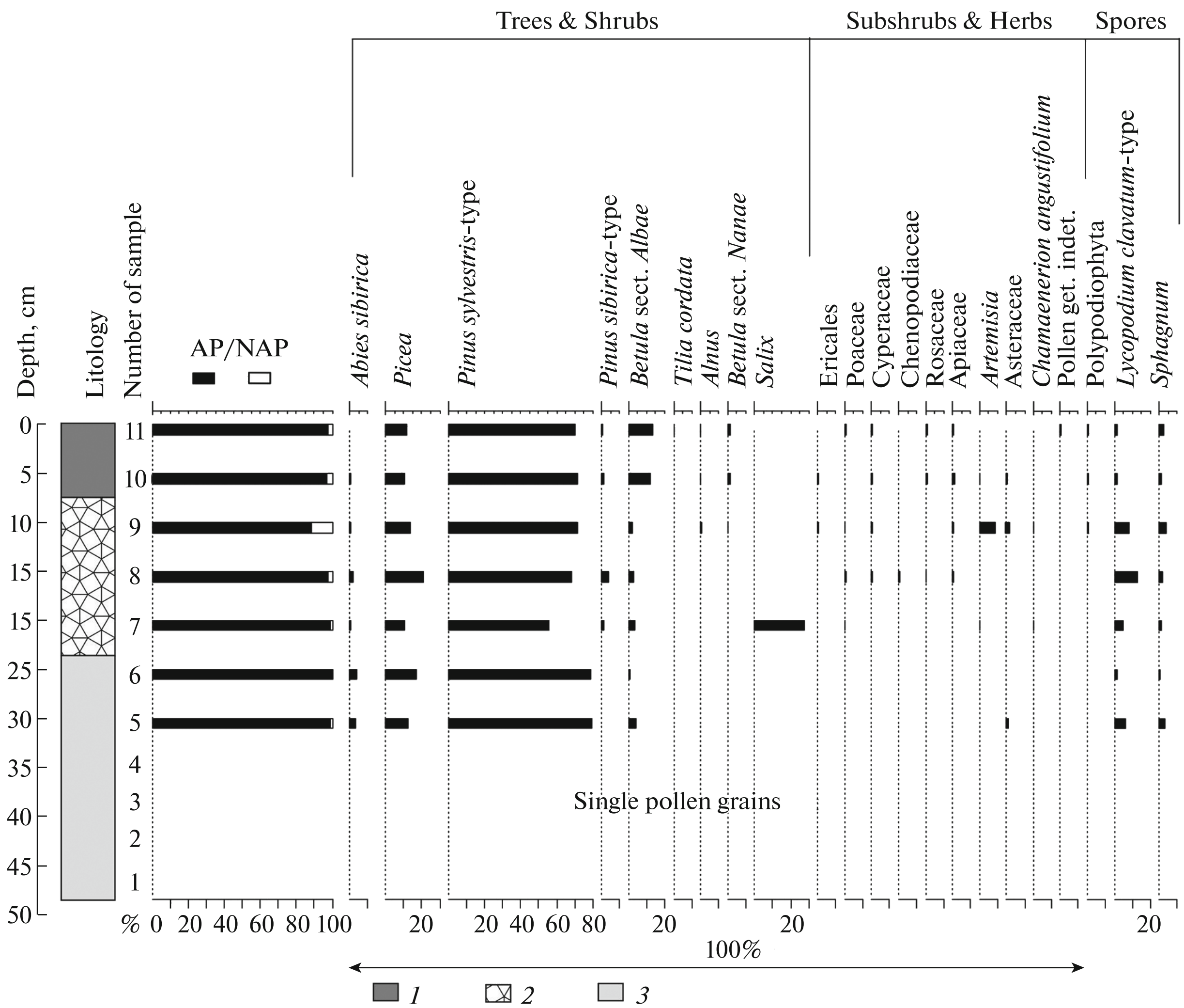


Fig. 4. The pollen diagram of the cultural layers and underlying sediments from the Kosa II site.

material could have entered the sample as a result of a modern anthropogenic impact, as well as the activity of the root system of trees. Therefore, this dating cannot be considered valid (Table 1).

In 2021, archaeological excavations began at the Kosa III site. The site is located on the first terrace, which has a meander–spur type of landform (Fig. 2). At the moment, 24 m^2 of the area of the site has been studied. The collection of the finds consists of 1511 objects.

The structure of the section is as follows:

Layer 1: sod, 0.04 m thick, on average, approximately the same over the entire excavation area.

Layer 2: light gray podzol, 0.2–0.25 m thick, on average.

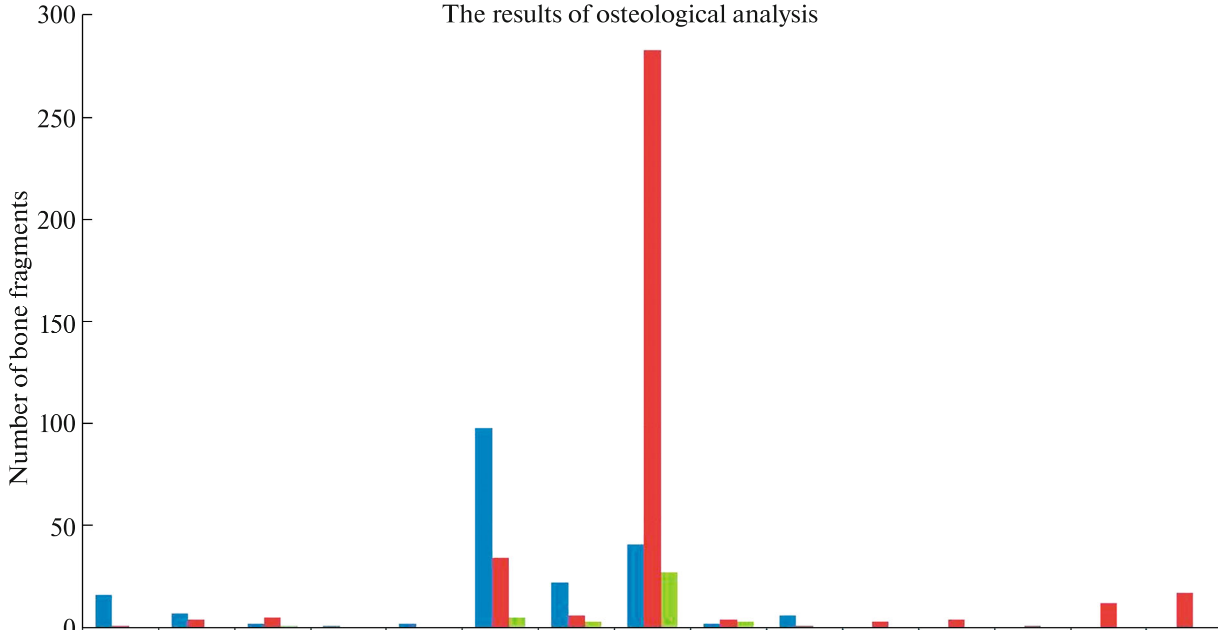
Layer 3: dark-brown moistened sandy loam with inclusions of ortsand (cultural layer). Its thickness varied within the excavation, but was up to 0.15 m, on average.

Layer 4: intermixed layers of dark-gray dense sandy loam, representing a road track.

Layer 5: yellow–orange fine-grained loose sand with ortsand (natural ground).

The maximum concentration of the finds was at a depth of 0.15–0.35 m. They were mostly attributed to the lower part of the layer, represented by light gray podzol and dark brown moistened sandy loam with inclusions of ortsand.

The stone artefacts differ from the materials of the Kosa I and Kosa II sites. The difference is observed in the raw material used (mainly pebble flint, jasper is practically not encountered), as well as in the presence of a large group of cortex flakes and in the absence of wide blades. The osteological collection consists of fragments of calcified mammalian bones. Modern methodological studies have confirmed Denisov's opinion that this site (Kosa III) is a little younger than the Kosa I and Kosa II sites.



	Moose	Reinder	Beaver	Hare	Wolf	Moose ?	Reinder ?	Moose-Reinder ?	Small mammals	Undetectable mammals	Pike	Perch	Zander	Cyprinidae	Undetectable fish
Kosa I, site	16	7	2	1	2	98	22	41	2	6	0	0	0	0	0
Kosa II, site	1	4	5	0	0	34	6	283	4	1	3	4	1	12	17
Kosa III, site	0	0	0	0	0	5	3	27	3	0	0	0	0	0	0

Fig. 5. Results of the osteological analysis. A question mark means that the bones belong to an animal comparable in size to the indicated one.

Osteological analysis. In the cultural layers of the Kosa I–III sites, bone fossils of animals were found (Kosa I, 197 fragments; Kosa II, 375 fragments; Kosa III, 39 fragments). All of them are calcified; i.e., they have been affected by high temperatures for a long time and, therefore, have been preserved. Most of the animal fossils belong to cloven-hoofed mammals (552 fragments out of 611). The bone fossils of other mammals are represented by single specimens. Fish fossils constitute a separate group (37 fragments).

The main activity of the population at all sites was hoofed game (moose, reindeer). Beaver hunting played a certain role too. Fishing was noted only on the Kosa II site; however, it was probably practiced by the population of all the sites to varying degrees. This information can only be confirmed by further research.

The species composition of fauna indicates the existence of sites in the taiga zone. The find of pike perch coincides with the northern boundary of its modern range [11]. The pike perch is a relatively thermophilic species, so at the time of the Kosa II site, the mean annual temperatures were not lower than the current ones (Fig. 5).

Paleochannel studies. In the area of the confluence of the Kosa and Lolog rivers, there is a "blind" swamped trough, which stretches sublatitudinally 2 km south of the modern channel of the Lolog River and ends 4 km upstream its mouth (Fig. 2). The smaller channel-like formations, presumably small tributaries of the ancient Lolog River open into the trough. The orientation of the trough probably indicates that it is the Lolog River paleochannel; its width (350–370 m) may indicate the width of the meandering belt of the stream. Similar landforms are also common in the left-bank part of the Upper Kama basin, in the interfluves of the Timsher, South Keltma, and Pilva [9].

The depth and type of paleochannel can be determined on the basis of borehole 520, drilled by the Kamskaya crew of the All-Union Hydrogeological Trust, which carried out the surveys for the construction of the Upper Kama water reservoir in 1959 (Fig. 2). The gravel–pebble layer 1.1 m thick was described at a depth of 14.7 m under a thick layer of sand, which becomes more quartz toward the bottom. The horizon is a channel facies represented by the interlayering of gray, quartz medium-grained sand and well-rounded pebbles up to 4 cm in size, consisting of quartz and quartz sandstone. A layer of Permian dark red clay with large quantities of breakstones of weathered limestone was uncovered at a depth of 16.1 m.

Before 13 800–13 500 cal BP (11 900 ± 60 BP, GIN-15 886), the territory of the Upper Kama right bank was supposedly more wet than in the later periods of the Late Glacial and the Holocene—the time of the active reconstruction of the hydrosystem. The rivers flowing through this area have formed wide valleys, which are currently imprinted in landforms and sediments of the second terrace [8]. The width of the pra-Kosa valley was 2.6–3 km (currently, it is 1–2 km). The periglacial conditions and strong winds that transported the sand determined the presence of thick aeolian deposits on the surface of the second terrace and the appearance of dunes. Landscapes of dry pine–green moss forests were formed within the dunes.

In the Allerød, the river network was rearranged in the Kosa–Lolog system: the Lolog River left the straight trough, which connected it to the Kosa River by the shortest distance, and deviated to the left, to the north, flowing around the remnant of the second terrace left by the river. Its surface acquired very comfortable conditions for human existence and activity. The age of plant detritus from fine-grained sand in borehole 20 929 at a depth of 3.4 m is 13240–13170 cal BP (11330 ± 30 BP, $IGAN_{AMS}$-9682a). This age corresponds to the time of the active Lolog River channel; the age of peat overlying well-washed out medium-grained sand in the borehole 1028 at the depth of 3.8 m corresponds to the beginning of the Holocene, the time when the Lolog River channel began to die off and the oxbow lake, near which the Kosa I and Kosa II sites were located, began to form (Table 1).

Access to water was provided by creeks, through which water still flowed, as well as by the relative proximity of the Lolog River channel in the north and the Kosa River channel in the east, which at that time formed the first terrace. The relative height of the sandy pine forest of the second terrace above the low-water line of these rivers was 7–8 m at that time.

The Younger Dryas and Early Holocene were characterized by a transition from the quasi-periglacial climate, cool with the possible presence of permafrost, to the relatively warm climate of the Early Atlantic. At that time, the Kosa and Lolog rivers formed the surface of the modern first terrace. The age of the deposits in the borehole 1034 was 7980–7860 cal BP (7100 ± 50 BP, GIN-15 884) (Fig. 2). It should be noted that the age of the Lolog and Kosa terraces is a little younger than that of the first terrace of the Kama River (about 8800–11000 cal BP). Due to the low activity of horizontal channel deformations of the Kosa and Lolog rivers, the younger segments were included in the surface of the first terrace. When mapping the bottom of the Kama valley, similar geomorphological elements were referred to the floodplain–terrace surface (7th floodplain generation) [7].

During the formation of the first terrace, the channels of both rivers meandered intensively. The traces of their meandering are well seen in the primary floodplain landforms. The dimensions of the bends of both rivers, formed in the Early Holocene, exceed the parameters of modern meanders. For example, the bend radius of paleochannels of the Lolog River are 400 m, while the modern values do not exceed 150 m, on average. On the Kosa River, the bend radius of oxbow lakes on the terrace are approximately 300 m, and the bends of the modern channel are bent to a value of 200 m. Based on the data obtained, we can conclude that, in the Early Holocene, the water content of the Lolog River was higher than that of the Kosa River.

During the Holocene, this difference began to decrease, then disappeared completely. This is evidenced by the parameters of the modern bends located within the floodplain. The water content of the Lolog River has decreased.

Migrations of the Lolog and Kosa channels to the north and to the east forced Mesolithic man to move his habitat about 500 m northeast of the previous one (Kosa III, site). The Kosa River channel now lies 400 m to the east of the site. This site was located on a low sand dune, which modifies the surface of the first terrace of the Kosa River.

In the Middle and Late Holocene, the floodplain began to develop actively on both rivers. Channel deformations on the Kosa and Lolog rivers were intensified together with the repeatedly increase in the water content. The meandering belt in both rivers increased, and the formation of new very wet floodplain massifs, modified by numerous swales and oxbows, became more intensive (Fig. 2).

Pollen and paleocarpological analyses. The pollen spectrum for the interval of 13800–13500 cal BP (11900 ± 60 BP, GIN-15 886) (Fig. 3) (Table 1) characterize the plant communities of periglacial landscapes typical of the Late Glacial due to predomination of subshrubs and herbaceous plant pollen (86%) and due to the ratio of xerophytic (*Artemisia* sp, Poaceae, and Chenopodiaceae, etc.), boreal (*Larix, Picea, Pinus sylvestris*-type, *Betula* sect. Albae), and arctic–boreal (*Betula* sect. Nanae, Ericaceae) taxa (Fig. 6a).

The grass cover of the floodplain and dry meadows was formed by species of sedges (Cyperaceae, about 80%) and gramineous (Poaceae) with the participation of ericaceous shrubs (Ericaceae) and motley grasses. *Artemisia* and Chenopodiaceae species were found on unsodded substrates. Shrub thickets were formed by *Betula* sect. Nanae. Individual larches (*Larix*) and possibly spruces (*Picea*) may have grown. Similar Late Glacial periglacial plant communities were reconstructed for the Vychegda River basin and its tributaries north of the study area [1].

Data on plant macrofossils showed that shrub birches *Betula humilis* dominated in the landscape. Relatively psychrophilous species—*Selaginella selaginoides* and *Potamogeton sibiricus* (endemic to the Urals)—were encountered [14]. The shallow-water vegetation of *Hippuris vulgaris* and *Sparganium* was developed. *Carex*, as well as *Eleocharis palustris* and *Ranunculus gmelinii,* dominate among the near-water species indicating the existence of shallows. In the cold climate of the Late Glacial, there was a reservoir

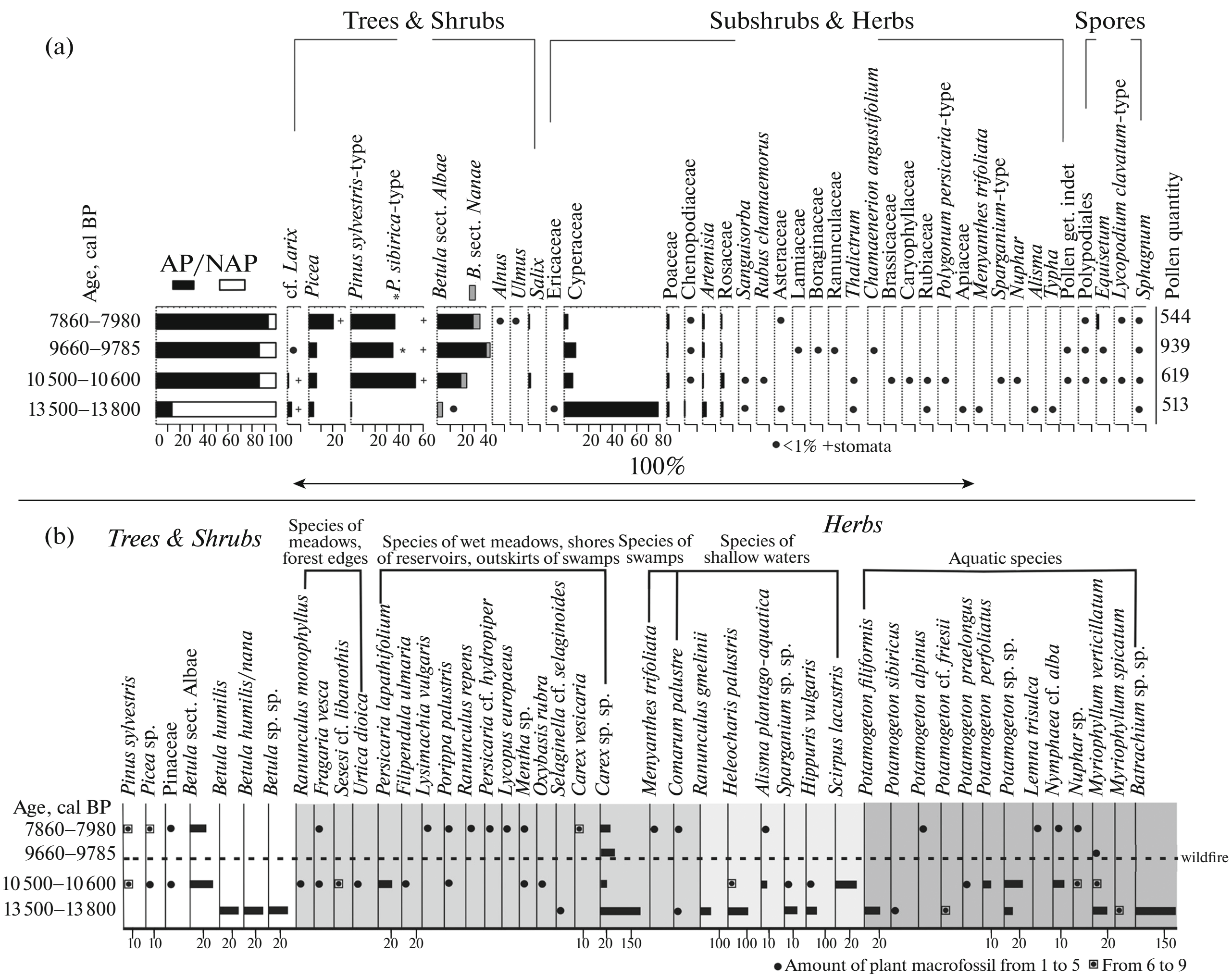


Fig. 6. Results of pollen and paleocarpological analyses: (a) Summary pollen diagram of the Kosa boreholes; (b) Summary carpogram of the Kosa boreholes.

with low-growing near-water vegetation and shrub birch thickets along the banks (Fig. 6b).

The pollen spectrum for the interval of 10600–10500 cal BP (9350 ± 50 BP, GIN-15 880) (Fig. 3) (Table 1), corresponding to the Holocene Preboreal period, reflects a forest type of vegetation by the predomination of woody species pollen at 87% (Fig. 6a). Light coniferous–small-leaved forests were spread with the predomination of pine (*Pinus sylvestris*-type, more than 50%) and birch (*Betula* sect. Albae, about 20%) with the participation of larch and spruce, were common. Shrubby birch was found in the undergrowth. The grass cover was formed by species of sedges, gramineous plants, and motley grasses. At the same time, in the interfluves of the Vyatka and Kama rivers, pine and birch dominated in the forest stand, spruce played a secondary role, and shrub birch was encountered in the undergrowth [12].

Macrofossils of plants (pondweed *Potamogeton praelongus*, water-lilies *Nymphaea alba*, *Nuphar*) characterize the conditions of a relatively deep paleolake or series of lakes (probably remnants of the Lolog River channel migrated to the north). In the vicinity of the lake, a birch forest with spruce and pine trees was growing. The species composition of paleoflora is similar to the modern vegetation, which suggests the presence of similar climatic conditions here (Fig. 6b).

In the pollen spectrum for the interval 9785–9660 cal BP (8750 ± 40 BP, GIN-15885) (Fig. 3) (Table 1), corresponding to the Holocene boreal period, the pollen of woody species prevails (85%), which characterizes the predomination of the forest-type vegetation (Fig. 6a). Taiga forests with the predomination of the pine and birch formations with the participation of spruce were common. Shrubby birches were encountered in the undergrowth. The abundance of birch pollen may reflect the distribution of the secondary birch forests on fire-sites. This circumstance is also indirectly confirmed by the presence of pollen of willow–herb (*Chamaenerion angustifolium*), which is a pioneer species of pyrogenic plant communities. In the Boreal period, pine and birch forests with a significant presence of shrub birches and a small presence of spruce were common on the territory of the Vyatka–Kama interfluve [12]. In the interfluve of the Kama and Vychegda rivers, forests were generally formed by pine and spruce with the participation of birch [1].

The complex of plant macrofossils consists of *Carex*, among which there are many charred seeds (33 specimens). Remains of the aquatic species *Myriophyllum verticillatum* are scarce. Most likely, such a poor composition of paleoflora is associated with the fire event. In this regard, it is difficult to reconstruct plant communities. In the sample taken above the dated layer, we also found charred macrofossils of sedges and spruce needles (Fig. 6b).

The pollen spectrum for the interval 7980–7860 cal BP (7100 ± 50 BP, GIN-15 884) (Fig. 3) (Table 1), corresponding to the Atlantic period, reflects a forest-type vegetation with predomination of pollen of woody species (93%). Along with birch–pine forests, spruce forests began to form (the share of *Picea* pollen increased to 20% with an almost equal content of *Betula* sect. Albae and *Pinus sylvestris*-type (Fig. 6a)). Pollen grains of alder (*Alnus* sp.) and Elm (*Ulmus* sp.) appeared in single numbers. Elm and alder began to spread in the floodplains of the Upper Kama basin around this time [7]. Pine and birch continued to dominate in the Kama–Vyatka interfluve in the first half of the Atlantic period; spruce formations began to spread at the same time. As before, shrub birches were found in the undergrowth. Broadleaved species appeared in the forests [12]. In the basin of the Vychegda River and its tributaries, broadleaved species were also encountered in coniferous forests [1].

The data on plant macrofossils show that residual lakes with slowly flowing or stagnant water still existed in the studied area during this period (*Lemna* cassava and swamp species appear). A mixed coniferous–birch forest was growing in the vicinity of the water reservoir (Fig. 6b).

DISCUSSION

Three chronological stages associated with changes in the paleogeographic conditions in the study area were distinguished as the results of this study.

The first stage is associated with the Late Glacial. It was characterized by a rather cold climate, high humidity, periglacial landscapes, the absence of forests as natural protection from strong winds, and the habitat of large hooved animals (moose). The second terrace was in the formation stage and could not be regarded as a convenient site even for short-term human presence on the bank of a water reservoir with low-growing near-water vegetation. All these conditions were unfavorable for human habitation. This is confirmed by the fact that there are no the Paleolithic sites in the vicinity of the Upper Kama to the north, as well as in the latitude of the study area. The nearest sites of the Final Paleolithic (Ust-Pozhva I-V) are on the right bank of the Kama, 100 km south of the confluence of Kosa and Lolog rivers.

The next stage belongs to the Early Holocene (Preboreal and Boreal periods). At that time, the surface of the second terrace was finally formed due to the restructuring of the Lolog River channel. It became comfortable for human development, rising 7–8 m above the low-water line of the Lolog and Kosa rivers. The terrace surface was covered by taiga pine and birch formations with spruce. Paleocarpological data indicate the presence of deep residual lakes here.

We assume that all of the above listed conditions led to the appearance of the Kosa I and II sites (spaced 120 m apart) on the edge of the second terrace at the end of this period (Fig. 2). They probably reflect the life of a single Mesolithic collective, which was engaged in hunting hooved mammals in the local taiga forests, as well as fishing in the lakes in the immediate vicinity of the sites. Temporary dugout seasonal dwellings, discovered during the excavations of the Kosa I site [4], as well as traces of fishing from the Kosa II site, probably indicate the partial settled life style of the local population.

The final chronological stage corresponds to the Early Atlantic period. Climate warming and active meandering of the Lolog and Kosa rivers led to the formation of the surface that became the first terrace during the subsequent cut-off of both rivers. The main channels of the Lolog and Kosa migrated to the north and to the east of the study area; however, a paleolake with slow-flowing or stagnant water remained here for some time. The role of spruce increased in the existing small-leaved light-coniferous forests, and elm probably appeared. Migrations of the Lolog and Kosa river channels led to the human occupation of a low sand dune, which formed on the surface of the first terrace of the Kosa River. Thus, the Kosa III site appeared. The population of the site was engaged in hooved mammal hunting, probably fishing, similarly to the sites of Kosa I and II.

In the second half of the Middle Holocene, these sites were no longer considered suitable even for the short-term human habitation, because they were far from the main river channels and due to the periodically increasing water content, which led to overwetting of the floodplain and the first terrace. The transition first to partial and then to a full settled life style in the developed Neolithic–Chalcolithic (as evidenced by the appearance of long-term semi-dugout dwellings) dictated a new strategy in the choice of sites for settlement. The first terraces of large rivers, which were not flooded during floods, as well as the shores of ancient oxbow lakes, were considered as such sites [6, 7].

CONCLUSIONS

In the course of this study, it was found that the conditions favorable for human occupation of this region developed during the Preboreal–Boreal Holocene periods, when pine and birch forests, rich in game animals, were widespread. At that time, a series of rather large residual lakes existed on the site of the future first terrace. The dry and sufficiently high second terrace, not affected by floodwaters, was a convenient place for the habitation of ancient man. Individual hunting of large hooved mammals and beaver was the main activity of the population. Fishing was of auxiliary importance.

At the beginning of the Atlantic period, the conditions for the appropriative economy remained generally favorable, although the lower levels of waters in both rivers during the low-water period led to gradual reduction, drainage, and bogging of water reservoirs. Perhaps, at that time, the moose and reindeer hunting played an even more important role than fishing.

Later, humans left these places due to the displacement of the Kosa and Lolog channels to the east and the formation of overmoistened floodplains.

The people appeared again in the vicinity of Kosa site only in the epoch of the Great Migration of Peoples. At that time, they inhabited either native riverbanks or valleys of small rivers and streams. The same situation persisted in the Middle Ages.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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