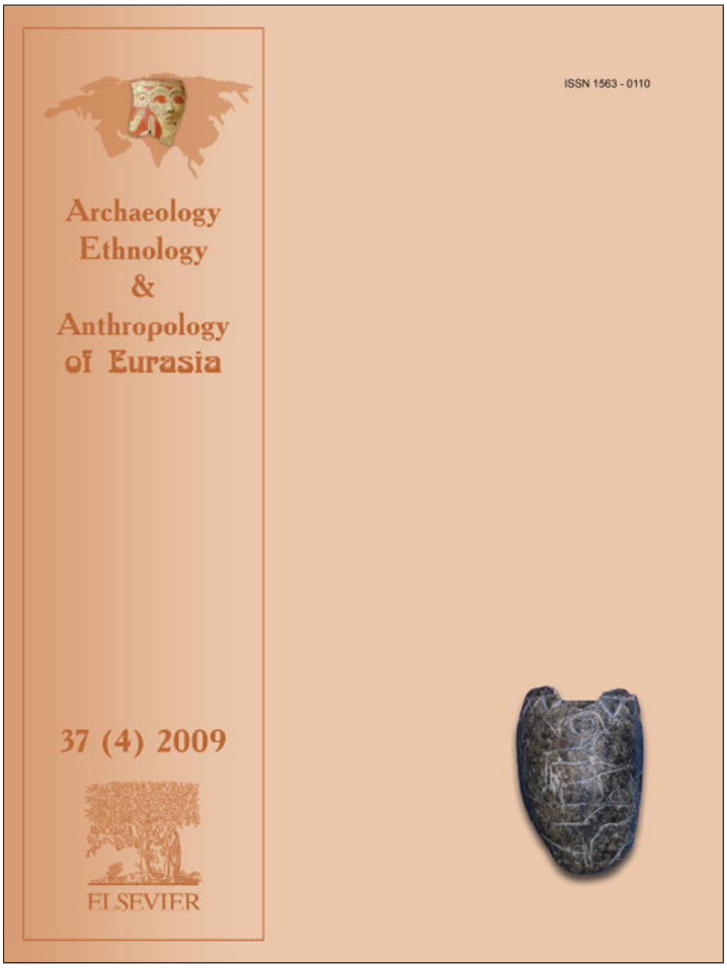
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PALEOENVIRONMENT. THE STONE AGE

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PALEOGEOGRAPHY OF KOSTENKI-14 (MARKINA GORA)*

Multidisciplinary geological and paleogeographical studies have demonstrated that the so-called humus strata in the deluvial apron of Kostenki-14 are paleosols of various origins. It has been shown that cryogenic deformations in the section were mainly caused by block displacements of the entire sequence rather than by solifluction. At the time corresponding to the earliest cultural layer IVb (ca 37–36 ka BP), a flat linear hollow with a brook at the bottom existed where currently the steep, convex slope ("promontory") of Markina Gora exists. The early stage of the site's existence (second half of the Middle Valdai megainterstadial) was marked by a mild climate, causing the spread of coniferous and broadleaved forests. Layer IVa (ca 33 ka BP) can be correlated with the beginning of cooling, when spruce forests still existed. At the end of the megainterstadial, the landscapes around the site varied from periglacial to tundra and forest-tundra. Layer I (ca 22 ka BP) correlates with the most severe cryoarid conditions of the pleniglacial.

Keywords: *Upper Pleistocene, Upper Paleolithic, chronostratigraphy, paleocryogenesis, environmental and climatic reconstructions.*

Introduction

The Kostenki–Borshchevo region is unique for its concentration of Upper Paleolithic sites. Those representing the Early Upper Paleolithic are of particular significance to understanding this pivotal point in human evolutionary history. In 1950s–1970s, A.N. Rogachev (1957) and P.I. Boriskovsky (1963) determined the chronostratigraphic sequence of cultural layers in the region. The sequence was partly based on geological and geomorphological studies of slope deposits (aprons) overlying the second terrace of the Don conducted by M.N. Grischenko (1950), G.I. Lazukov (1957), and later by A.A. Velichko (1961, 1963). This classification is still essentially valid. Subsequent studies carried out by N.D. Praslov (Praslov, Rogachev, 1982; Praslov, 1984), M.V. Anikovich (1993, 2003), A.A. Sinitsyn (2002, 1996, 2004), S.A. Lisitsyn (2004) and their colleagues have greatly contributed to the knowledge not only of archaeology in the early group of Upper Paleolithic sites, but also of their geology and paleogeography. One of the most important sites in this complex is Kostenki-14, which is currently being excavated by a team headed by A.A. Sinitsyn. The present article outlines the results of multidisciplinary studies conducted subsequent to 2002. Aside from environmental reconstructions of the site itself,

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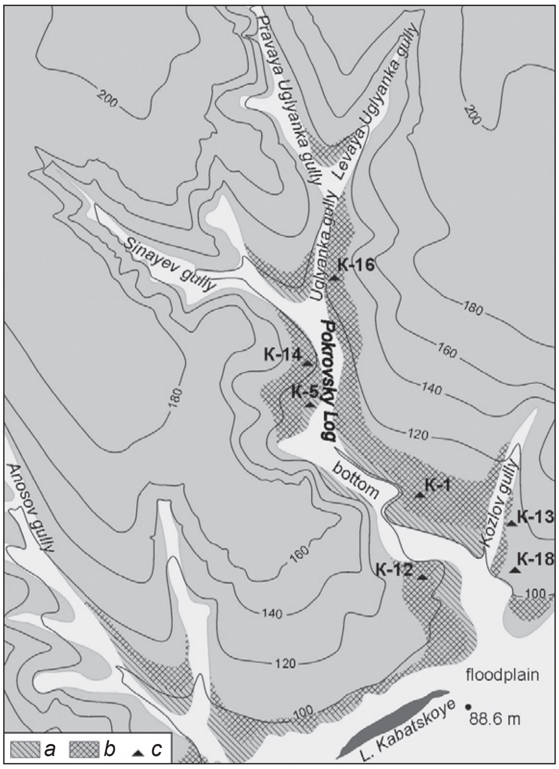


Fig. 1. Location of Early Upper Paleolithic sites in the Pokrovsky Log.
a – slope aprons associated with the first Don terrace;
b – slope aprons associated with the second terrace; *c* – sites.

the results of the studies in question are relevant in a broader context to the ecology of Early Upper Paleolithic humans in the East European Plain.

Geological and geomorphic setting of Kostenki-14

Kostenki-14 is located on the right slope of the Pokrovsky Log*, approximately 1.2 km from its mouth, between the Senyaev and Ermishev gullies. The local name of the promontory formed by these ravines is Markina Gora (Fig. 1), and the location is traditional to the Upper Paleolithic settlement pattern. The site area is 12–15 m above the Log bottom. Test pits and excavations revealed sediments of deluvial (slope wash) genesis overlying the second terrace of the Don (Lazukov, 1957; Velichko, 1961).

At the site, field and laboratory studies have focused on the southern wall of the excavated area. This approach was taken because the southern wall runs across the upper part of the promontory giving one to expect that certain structural and textural features of individual layers would be more apparent here than in lower parts affected by slope processes. At the same time, detailed observations and sampling conducted on all other walls and at the bottom of the excavation have made it possible to trace facial changes within separate stratigraphic units. Likewise, this research has provided a better understanding of environments recorded in the site's cultural layers at different stages of inhabitation (Fig. 2).

As a result of studies carried out during the period 2002–2007, the sequence exposed at the site has been subdivided into four major stratigraphic units (Fig. 3):

the first unit is mostly represented by loess-like loam with zones of ephemeral soil formation; the upper portion is transformed by the modern (Holocene) soil processes;

the second unit is correlated with the so-called upper humus stratum and contains soil complexes with heavily humified beds;

the third unit contains loam with lenses of volcanic ash and a zone of ephemeral soil formation;

the fourth unit shows a combination of erosional and accumulative subaqeous sediments with zones of soil formation, and pedosediments.

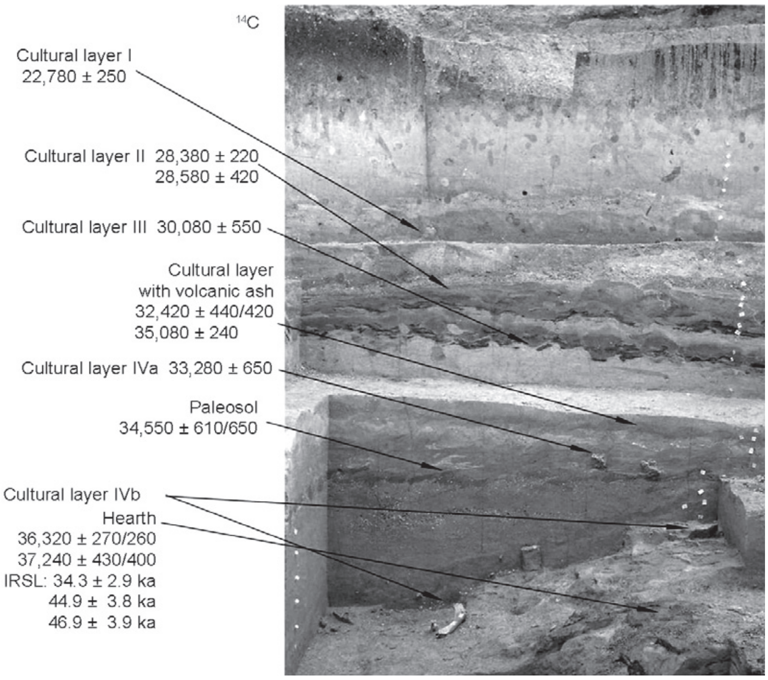


Fig. 2. Chronology of cultural layers and their position on the southern wall of the excavation (photoscheme by A.A. Sinitsyn).

*Log in Russian is a large, usually flat-bottomed gully.

The brief description of the units is given below.

Unit 4. This unit represents a complex of loams deposited by slope processes (including slope wash and ephemeral stream activity); it is split by an ancient ravine filled with horizontally-layered grayish-brown loam. Judging by the joint of the ravine side and the top of the enclosing sediment traceable on two mutually perpendicular walls (eastern and northern), the ravine adjoined a gently sloping surface (part of an ancient linear hollow) (Fig. 4). Layer 23 associated with this surface comprises cultural horizon IVb currently subdivided into IVb1 and IVb2 (Fig. 5). By the time of the initial human inhabitation of the site, i.e., ca 37–34 ka BP according to ^{14}C (or ca 46–45 ka BP according to IRSL) (Sinitsyn, Hoffecker, 2006), the surface had been covered by stable soil and vegetation. The angle of the surface slope was about 2–3°. The hollow length (measured along the centerline of the promontory) was at least 6–7 m, while its width approximated 15–25 m. Closer to the ravine, at a distance of 2–3 m from its side, the surface slope increased from 3° to 5–7° and to 30–45° at the ravine side. The ravine fill was excavated to a depth of 1.6–1.7 m. Under conditions of incipient cooling, the soil was seasonally affected by cryogenic processes as evidenced by wedge-shaped features. Subsequently a stage of loam sedimentation began. The horizontally-layered loams not only filled the ravine but also covered the surface (layer 22). The subaqueous origin of the loams and the character of stratification suggest that the sediment was formed in stagnant or slow-flowing water; such conditions could result either from damming or from the rise of the water level in the stream on the bottom of the main Pokrovsky Log, which was just a few meters below the estimated

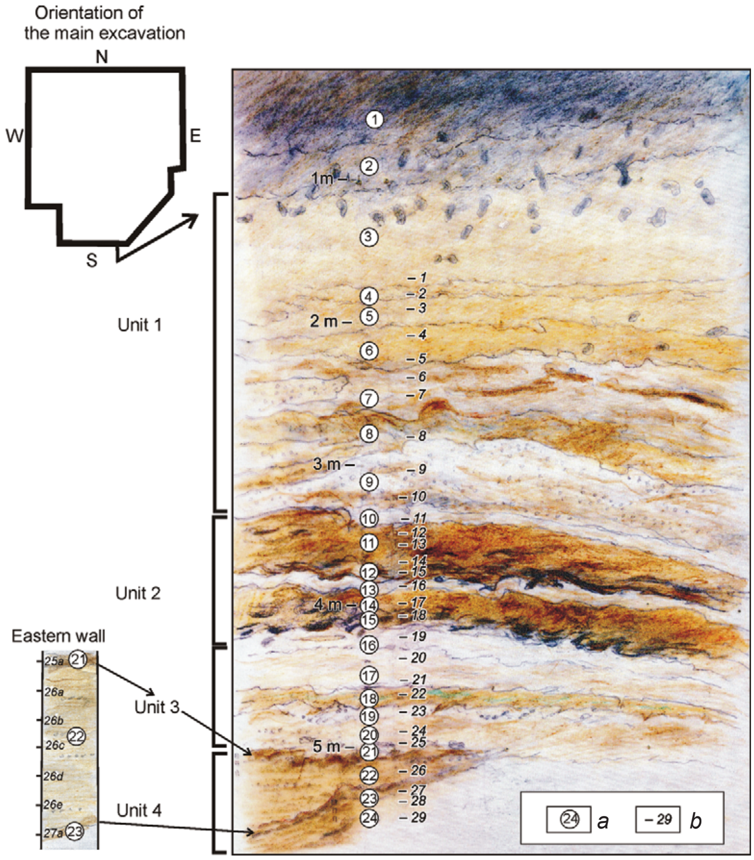


Fig. 3. Structure of the southern wall of the 2004 excavation subdivided into main units (see text for description).
a – layer number; *b* – sample number.

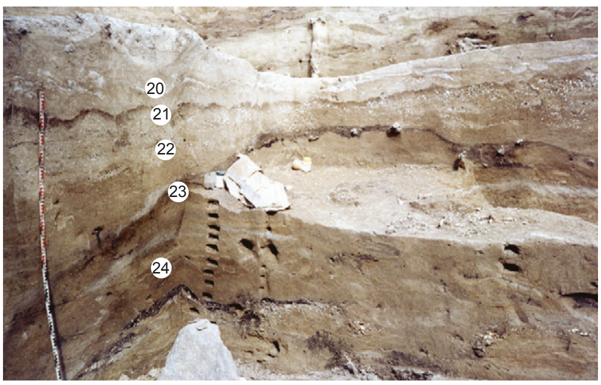


Fig. 4. Unit 4. Location of the ravine side as recorded in the paleosol with cultural layer IVb (lithological layer 23).

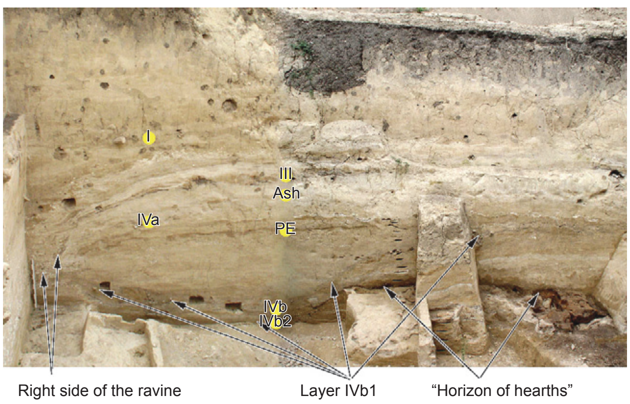


Fig. 5. Position of cultural layers on the northern wall in the ravine area. PE – paleomagnetic excursion.

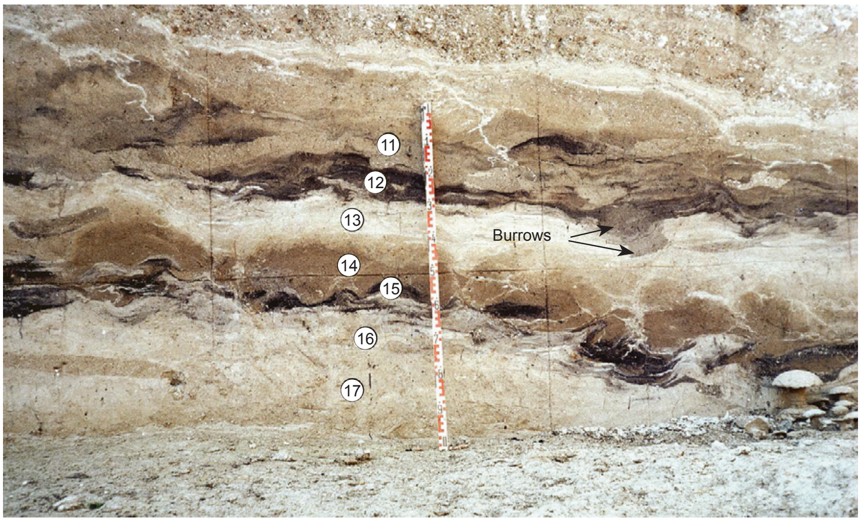


Fig. 6. Unit 2 with two paleosol zones (layers 11, 12 and 14, 15).

surface at that time (see the reconstruction in the concluding part of the article). Unit 4 terminates with the soil formation zone corresponding to layer 21. The layer displays a regular scalloped (festooned) structure on the northern profile wall. It corresponds to cultural layer IVa which is ca 33 thousand years old (Sinitsyn, 2006).

Unit 3. The upper portion of this unit (layers 16 and 17; Fig. 3) is represented by fine silty loam varying from light pale-yellow to off-white in color. This part of the profile was formed through the slow accumulation of material winnowed from the valley's chalky slopes. The formation of the lower portion of the unit (layers 19 and 20) was more intensive. The sediment contains lumps of chalk; in some places, chalk pieces form lens-like clusters. An alternation of whitish and light-brown–pale-yellow loams can be observed. The accumulation of the upper and lower portions of this unit was separated by a gap characterized by weak soil formation recorded in the section as a brown stratum with small tongue-like features at its lower boundary (layer 18) and a slightly lighter sediment underneath (layer 19). It was this surface that was covered by volcanic ash ca 32.5–32 ka BP (according to A.A. Sinitsyn's personal communication, the new date of 35,080 ± 240 BP (OxA–19021) has been obtained for the stratum). In profile walls, lenses of volcanic ash occur not only on the upper surface of the soil, but also inside it. This can be explained by the lateral displacement by mass movement and the penetration of lenses into the stratum due to the irregularities of the microrelief. The impact of cryogenic processes that were initiated subsequent to the fall of ash should also be taken into consideration. It should be also borne in mind that the cultural layer is associated with the soil formation zone. According to data obtained from the 1955 test pit (Velichko et al., 1997), a cavity dug up on the surface of this bed contained the well-known Upper Paleolithic burial.

Unit 2. This unit is often defined as the "upper humus stratum" (layers 11–15 on the southern wall; Fig. 3). Within it, two soil complexes (a and b) can be distinguished; these are most clearly seen on the southern wall of the excavation (Fig. 6). The lower complex corresponds to cultural layer III (ca 31–30 ka BP), while the upper complex can be correlated with cultural layer II (ca 29–28 ka BP) (Sinitsyn, Hoffecker, 2006; Haesaerts et al., 2004). According to the site's general stratigraphic scheme (Sinitsyn, 1996), three complexes (a, b, and c) are recognized within this zone. Both soil beds display a similar sequence of pedogenic horizons. The upper parts of the beds are represented by grayish-brown loam (layers 11 and 14, respectively). These are followed by a horizon composed of heavily humified loam varying in color from dark gray to black (layers 12 and 15); burrows filled with sediments from both beds occur there. Burrows filled with the sediment from the lower complex are encountered in the whitish (leached?) loam (layer 16) of unit 3.

In the course of the present study, indications of soil formation, including burrows, have been revealed for the first time in the so-called upper humus stratum. The lens-like, scalloped and fine-stratified structure of heavily humified beds in each of the soil complexes, are indicative of phases of cryogenic deformation.

When these levels are traced on the eastern wall running along the axial part of the promontory, downwards, toward the bottom of the Log, evidence of intense displacement is clearly visible. Humified beds are deformed as they dip at an angle of 3° to 5–7°. Traces of humification can be observed on the northern wall, above the two distinct zones of soil formation, although discernible features of genetic soil profile are absent.

Unit 1. This unit (Fig. 3) significantly differs in structure from the underlying one. On the northern wall, it is subdivided in two portions. The lower portion (layers 7–10) is represented by alternating grayish-brown loams with interbeds and lenses containing abundant chalk fragments up to 4–8 cm in diameter. The appearance of this series suggests intensified slope wash from weakly turfed chalky slopes and redeposition of sediments. The so-called Gmelin paleosol (layer 8) is distinguishable in the lower part of the series represented by brown and bluish-gray loam. The first cultural layer (ca 23–22 ka BP) is associated with this part of the profile.

The upper part of the unit (layers 3 and 4) is composed of cover loam accumulated not only due to slope processes, but also as a result of the input of wind-blown silt deposited in an arid periglacial environment. Brownish zones (layers 4 and 6) may correspond to phases of ephemeral soil formation at the point when the rate of silt accumulation decreased. On the western wall, the upper part of the unit is more fully represented, while the lower part containing lenses of chalk fragments is reduced. Nonetheless, Gmelin soil and the associated cultural layer are more distinct in the lower part.

Sediment deformation

In addition to the lithological characteristics of the four units given above, the genesis of deformation observed in the section should be considered in more detail. Deformations that co-occur with layer formation, i.e. "syn-event" (term introduced by A.A. Velichko (Velichko, Morozova, 1975)), are represented by shrinkage cracks on the eastern wall of the 2005 excavation. They show up in sediments underlying cultural layer IVb. Conditions of hard seasonal freezing or insular permafrost correspond to wedge-shaped formations that broke the soil cover associated with cultural layer IVb. Seasonal permafrost could account for the "fringeness" of the layer containing volcanic ash. Small polygons and cryoturbations formed under similar conditions in the soil complexes of the so-called upper humus stratum (unit 2).

"Post-event" deformations (according to A.A. Velichko's classification), i.e. occurring after the layer was formed, are represented by major disturbances observed in unit 2. Available data do not support conclusions concerning the solifluction genesis of deformations in the so-called upper humus stratum (if this were the case, the sequence would not have preserved elements of original soil profiles). Both zones of soil formation were displaced to the lower part of the slope in a single block. In the upper portion along the axis of the promontory, the range of displacement is 1.0–1.5 m at most. Judging by the eastern and northern walls of the excavation, in moving down the slope, the two zones converged and eventually merged (Fig. 7). The idea that the upper zone was formed by solifluction runs contrary both to radiocarbon estimates which indicate different ages of the zones, and the zones' association with cultural layers II and III which were formed independently. Finally, it should be stressed that the angle of tongues and cracks along the contacts of interbeds in the so-called upper humus stratum is similar to that of the underlying series of sediments (small tongues along the lower boundary of the soil zone at its contact with volcanic ash, wedge-shaped features and small cracks in units 3 and 4).

Recently obtained data are at odds with the hypothesis formerly put forward by some researchers including one of the present authors (Velichko, 1961) and with

Fig. 7. Character of soil movement in unit 2 down the ancient slope revealed on the northern wall of the excavation.

interpretations suggested by G.I. Lazukov (1982) and P. Haesaertz (Haesaertz et al., 2004). According to these researchers, solifluction was the main cause of deformation in the entire sequence of the sediments studied. The common character of textural and structural disturbances, specifically, the position of deformation features in strata of different ages, most probably points to a different process resulting in deformation, namely, mass movement down the ancient slope. Judging by the textural features, the displacement was uneven. Its range decreased with depth and also depended on the water content in various layers.

One possible cause of displacement could be freezing and thawing of the sediments. However, other process of stress character should not be excluded. Large lenses containing sizeable angular fragments of chalk recorded in the lower portion of unit 1 (layers 7 and 9) could serve as indirect evidence of stress, as they indicate a sudden discharge of detritus from the slopes located above.

Morphoscopy of quartz sand grains

Shape and surface features of quartz sand grains can provide important information concerning the character of processes responsible for sediment deposition (Krinsley, Doornkamp, 1973; Velichko, Timireva, 1995). A morphoscopic study of quartz sand grains (0.5–1.0 mm and 1.0–2.0 mm fractions) sampled from the lower portion of the southern wall (unit 4, layer 24) strongly suggests that most grains were to varying degrees affected by eolian processes (Fig. 8, 9). This is evidenced by typical micro-pits on the grain surface. The proportion of shiny grains indicative of water action is approx. 20–28 %. Some grains show traces of congelifraction (frost weathering) represented by small triangular pits and fresh conchoidal fractures. Grains from sediments filling the ancient ravine (layer 22, sample 26a) possess similar morphological characteristics.

The coefficient of roundness sharply increases (up to 82 %) in unit 3 (layers 19 and 20, samples 23, 24), while dullness is present in 49–58 %. Triangular pits visible on many grains evidence the congelifraction process. Samples taken from soil beds of unit 2 (layer 15, sample 18; layer 14, sample 17) contain grains demonstrating both evidence of eolian processing and scaly surface indicative of intensive chemical weathering processes. Unit 1 (layer 9, sample 10) displays a greater variety of quartz grains in comparison to the underlying strata. Five classes of roundness were established in 1.0–2.0 mm fraction. The coefficient of roundness is relatively high: 72 % in 0.5–1.0 mm fraction and 66 % in 1.0–2.0 mm fraction.

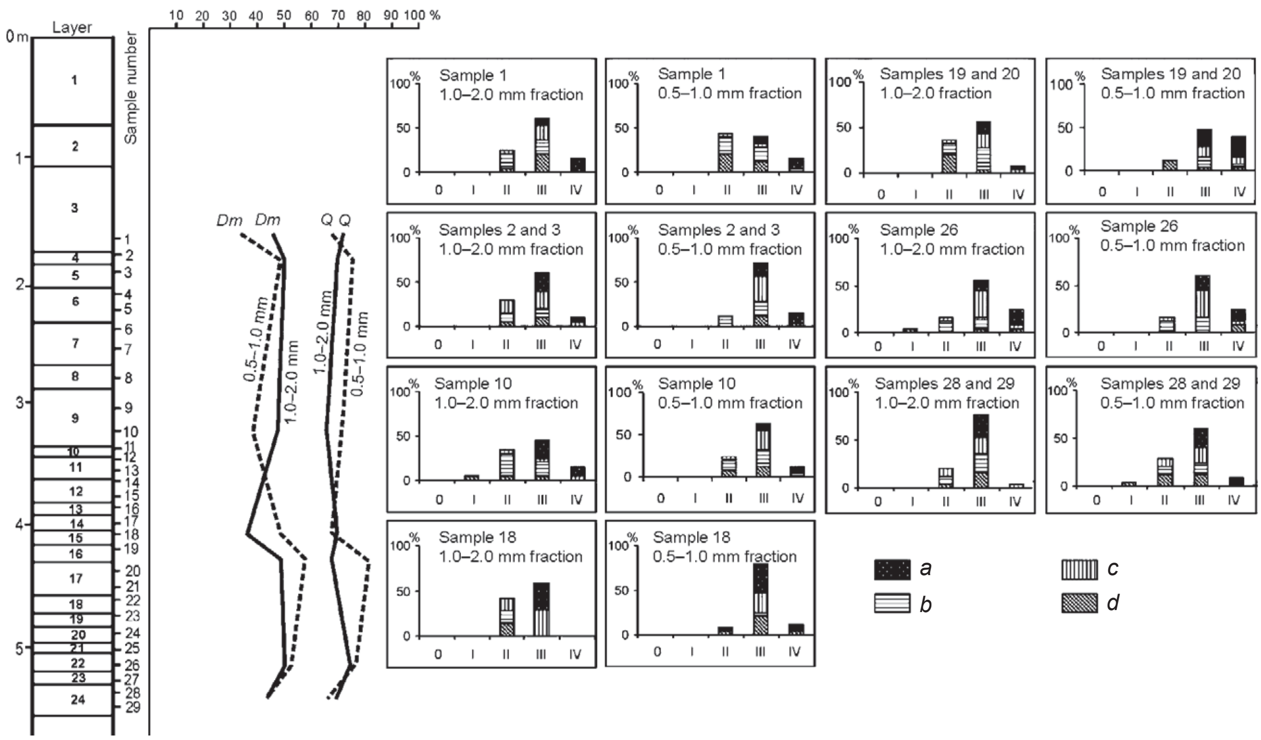


Fig. 8. Morphoscopic characteristics of quartz sand grain surfaces (analyses performed by S.N. Timireva).
Grain surface: *a* – mat; *b* – half-mat; *c* – quarter-mat; *d* – shiny. 0–IV – classes of roundness. *Dm* – degree of matting, *Q* – coefficient of roundness.

Fig. 9. Quartz sand grains from different units (1.0–2.0 mm fraction).
a – with traces of cryogenic and eolian processes (sample 1, unit 1); *b* – with traces of soil formation processes (sample 18, unit 2); *c* – with traces of water action (sample 26, unit 4); *d* – with traces of subaerial weathering (samples 28 and 29, unit 4).

Dullness of grains constitutes 39 and 48 %, respectively. Most grains were to a certain degree affected by the congelifraction and eolian processes.

Paleopedological study

Pleistocene paleosols revealed in the excavated area are thin (not exceeding 20 cm) and heavily disturbed by slope and cryogenic processes. Based on the correlation with sedimentary deposits, morphological characteristics, and degree of preservation, these can be classified into five series.

The lowermost paleosol K14/V (unit 4, layers 23 and 24) formed on the ancient flat hollow sloping toward the brook's side (ravine). The profile is represented by the series of horizons Ag–Big–CG up to 20 cm thick. Three wedge-shaped frost cracks measuring up to 40 cm wide and up to 15–20 cm deep are associated with this soil. The cracks are filled with material from horizon Ag. The soil is gleyed throughout the profile.

The overlying paleosol K14/IV (layer 21) is located at the top of unit 4. The paleosol is relatively well preserved on the eastern wall of the excavated area only. However, the horizons are disrupted and deformed by frost cracks and cryogenic bulges. The structure of the profile is A–AC. This paleosol unit corresponds to cultural layer IVb, one of the most abundant in artifacts.

Paleosol K14/III belongs to unit 3 (layers 18 and 19). The profile is thin and deformed; the coloration of horizons varies from yellowish-brown (AB) to whitish and whitish–pale yellow (BC–C). Importantly, the lenses of volcanic ash located at the same level and contacting with the sediment of horizon AB show quite distinct borders and are in no way affected by pedogenesis.

Paleosols K14/II (unit 2, layers 11–15) are the most distinct in terms of color and degree of profile development. Two paleosols (K14/IIa and K14/IIb) with similar structure can be traced within this unit: in both cases, profile A–BCk–C is overlain by gleyish horizon Bg. Another level represented only by horizon Bk has

Table 1. **Distribution of micromorphological features in paleosols of K14 section***

Paleosol	horizon	Pedoginic carbonates	Iron-manganese segregated formations	Disperse humus	Humified plant remains	Pedogenic microstructures	Coaly particles
Ia		++	±	–	–	++	+
Ib		++	±	–	–	++	–
IIa	Bg	+	++	–	–	++	–
	A	+++	–	++	+++	+++	+
	Bk	+++	–	–	–	++	–
IIb	Bg	+	++	–	–	+	–
	A	++	+	++	+++	+++	+
	Bk	+++	–	–	–	++	±
III		++	+	±	–	++	–
IV		+	++	±	–	+	+
V		+	+++	–	–	±	+

*Frequency of occurrence: +++ high; ++ medium; + low; ± sporadic, weak; – not found.

been identified on the northern wall of the excavation. Whitish horizons BCk saturated with mealy carbonates decrease in thickness from 20 cm in the lower paleosol to 7 cm in the upper paleosol. These horizons contain traces of soil mesofauna activity: channel-like biopores running from horizon A to Bk filled with dark humus-containing material. The maximum thickness of horizon Bg on the southern wall reaches 8 cm. It is light brown in color with an olive hue; in some places, the coloration is uneven showing numerous rusty spots.

Numerous rodent burrows constitute a characteristic feature of paleosols K14/II. Horizons A–BCk contain burrows "cut" by the overlying horizon Bg, while the latter displays tunnels "cut" by horizon C of the next (overlying) paleosol.

Paleosols K14/I (unit 1, layers 6–9) are immature, strongly deformed and displaced. Two discontinuous paleosols (K14/Ia and K14/Ib), each comprising horizons AB–BC–C in its profile, are separated by sediment unaffected by pedogenic process. The thickness of horizons AB–BC in both paleosols averages 5–7 cm; coloration brown and grayish-brown, slightly more intense in the lower soil profile. This zone is characterized by a better state of preservation and more developed pedogenic features. One may suppose its association with the Gmelin paleosol containing the upper cultural horizon of Kostenki-14.

In all the paleosols, the micromorphological indicators of soil forming processes are mainly represented by pedogenic micro-aggregates (primarily associated with mesofauna activity and, possibly, with cryogenic structuring), carbonate and iron-manganese formations, as well as by organic components (dispersal humus, humified plant remains, and coaly particles) (Table 1). Some particularities of paleosol microstructure relevant to pedogenic and paleogeographic interpretations are worthy of note*. Paleosol K14/V is characterized by abundant and diverse indications of reductive-oxidative processes. Exclusively in this unit, ferriferous films indicative of long-term overwetting of the soil are observed on pore walls (Fig. 10, *a*). This soil contains components that were supposedly introduced by humans: microfragments of charred bone (Fig. 10, *b*) and charcoals. In addition to dispersal colloid humus unevenly pigmenting the soil mass, paleosols K14/II abound in fragments of half-decomposed plant tissues of two kinds: black isotropic and lighter brown, locally anisotropic due to partial carbonization (Fig. 10, *c*). The granular texture of apparently zoogenic origin is well developed. In some places, aggregate-coprolites form a specific loose substance filling biogenic pores (Fig. 10, *d*). The mass of calcareous horizons BCk of fossil soils K14/II is generally more compact. It contains ooid pedogenic aggregates and is impregnated with microcrystalline calcite – micrite (carbonate plasma) (Fig. 10, *e*). Pedogenic microstructure and associated inter-aggregate porosity is surprisingly well

*The authors wish to thank A.A. Kazdym for his assistance in making the thin sections.

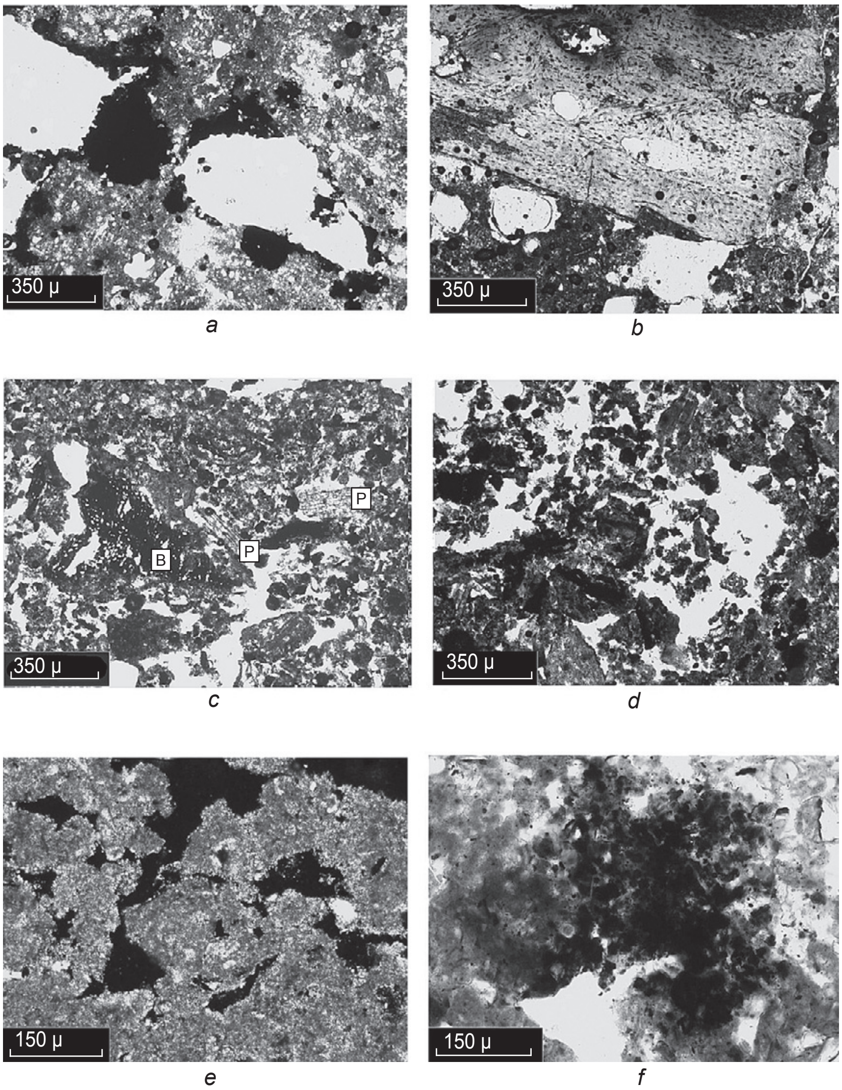


Fig. 10. Micromorphology of paleosols (analyses performed by S.N. Sedov).
a – ferriferous concretions and films on pore walls (paleosol K14/V, horizon Bg, without analyzer); *b* – fragment of charred bone (paleosol K14/V, horizon Ag, without analyzer); *c* – black (B) and lighter brown (P) plant remains (paleosol K14/IIa, horizon A, without analyzer); *d* – pore-chambers filled with loose substance of mesofauna aggregate-coprolites (paleosol K14/IIa, horizon A, without analyzer); *e* – pedogenic microstructure; the soil mass is saturated with microcrystalline calcite (paleosol K14/IIa, horizon BCk, Nicoli X); *f* – ferriferous concretion (paleosol K14/IIa, horizon Bg, without analyzer).

developed in horizons Bg of the "Bryansk" soils. The micromorphological features of gleying are represented by ferriferous formations – spots and concretions (Fig. 10, *f*). Pedogenic carbonates, same as in horizons BCk, are represented by micrite only, although it is less abundant and unevenly distributed.

The "memory" of Late Pleistocene paleosols is limited due to a number of factors responsible for the formation and preservation of soil profiles. Firstly, as illustrated by the chronostratigraphic scheme, pedogenic stages were short (the first millennia at most). Time shortage limited the level of evolution caused by medium and slow pedogenic processes such as weathering, secondary mineral formation, and illuviation, responsible for the origin of the most informative and stable paleosol features. Secondly, the severe climate of the Valdai stage affected pedogenesis and accelerated the slope and cryogenic processes destroying the soils.

The analysis of the totality of paleosols reveals a distinct tendency: the lower levels (K14/III–V) are characterized by greater gleying, whereas the upper levels K14/I and II show a more expressed pedogenic structure and a redistribution of carbonates. This tendency is clearly illustrated by micromorphological observations (Table 1).

Reductive conditions causing gleyization correlate with high humidity, suggesting that in comparison to the upper paleosols, the lower paleosols, especially K14/V, were formed under more humid conditions.

The origin of the most developed and well pronounced genetic horizons A and BCk in paleosols K14/I and K14/II was hotly debated by pedologists participating in the study of the K14 section. According to M. Skripnikova (personal communication, 2003, quoted by Holliday et al. (2007)), these paleosols correspond to a hydromorphic soil or even to a pedosediment formed under conditions of waterlogging by groundwater. Horizon A is regarded as peaty or humous, and horizon BCk as a zone where hydrogenic carbonates accumulated. It appears, however, that some characteristics of these horizons disagree with the "hydromorphic" hypothesis:

– while the presence of organic matter in horizons A is beyond doubt, judging by the dark color, its absolute content is low (approximately 1 %) – lower than in peaty and humous horizons;

– numerous traces of the soil mesofauna activity, a distinctly granular structure, and a high inter-aggregate porosity are suggestive of automorphic organogenic accumulative horizons rather than of hydromorphic ones;

– the abundance of burrows suggests that these zones were inhabited by small mammals, unlikely to have inhabited water-saturated soil.

While additional wetting and input of some substances (such as carbonates) by lateral throughflow is not ruled out, it is the authors' view that the formation of the considered paleosols was automorphic. As far as their modern analogues are concerned, the present-day steppe cryoarid soils of Eastern Siberia may be considered as the closest (Volkovincer, 1978). Both the fossil and modern soils are distinct in their small profile thickness consisting of only two horizons: humus and illuvial-carbonate. The former horizon contains both dispersed colloidal humus and vegetable detritus, whereas the latter contains mostly powdery carbonates. The transition from cryoarid soil (A–BCk) to gleyzem (Bg) within each stage of K14/II may indicate a certain increase in climate humidity.

Palynological studies

The first palynological studies in the Kostenki-Borschevo region were carried out in the 1950s, subsequent to the publishing of the first results of spore-and-pollen analysis of Upper Don alluvial deposits (Grischenko, 1950). Later studies were continued by M.P. Grichuk (Lazukov, 1957), R.V. Fedorova (1963), E.A. Spiridonova (2002), and G.M. Levkovskaya et al. (2005).

Here we examine the results of pollen analysis in deposits from the 2004 excavation (unit 4, layers 23 and 24) of Kostenki-14 (Fig. 11). The earliest levels contain a small amount of pollen of mostly ruderal plants – Cichoriaceae, Asteraceae, burdock (*Arctium* sp.), fleabane (*Erigeron* sp.), knotweed (*Polygonum* sp.), buckwheat (*Fagopirum* sp.), and Lamiaceae. *Artemisia* sp. and Chenopodiaceae are also present. Pollen of spruce and pine is represented by solitary underdeveloped grains. In layer 23, the quantity of meadow plants increases. Here pollen of hemp agrimony (*Eupatorium cannabinum*) growing on riverbanks and on boggy meadows appear, as well as the pollen of perennial herbs belonging to the Ranunculaceae and Onagraceae families. The occurrence of some Onagraceae species is associated with sites where there would have been fire (Travyanistye rasteniya..., 1971).

The initial stage of accumulation in layer 22 coincides with the development of monodominant spruce forests. Later, these were replaced by composite spruce forests with an admixture of birch, alder, hazel, and broadleaved species (elm and linden). In the ground cover, herbal associations comprising forest and meadow plants display considerable species diversity (Poaceae, Fabaceae, Ranunculaceae, Polygonaceae, Valerianaceae, Silenaceae, *Thalictrum* sp., and others). Pollen of water plants is also present: yellow waterlily (*Nuphar* sp.), water milfoil (*Myriophyllum* sp.), and algae (*Pediastrum* sp.).

The following degradation of spruce forests entailed the proliferation of both tall and shrub birches. Open areas were covered by various meadow herbs. The final stage of deposition associated with the formation of medium-humified loam in layer 21 was marked by the expansion of spruce forests.

Volcanic ash divides unit 3 into two parts. The period corresponding to the lower part is characterized by the reduction of spruce forests, expansion of open pine forests on flat interfluves, the development of yernik (dwarf birch) communities, the spread of plants that currently grow in cold and cold-temperate climate zones in the Northern Hemisphere (*Antennaria* sp. of Compositae fam., *Bupleurum* sp. of Umbelliferae fam, *Armeria* sp. of Plumbafinaceae fam., Saxifragaceae), and the appearance of undershrub sunrose (*Helianthemum* sp.) that prefers rocky slopes and chalk exposures. The noted dominance of spruce pollen in the arboreal group does not necessarily reflect the true role of this tree, since many grains are poorly preserved and thus are likely to have been redeposited. The upper part of unit 3 is characterized by the further expansion of open landscapes with *Artemisia* and *Chenopodiaceae*. Meadow herbs are less abundant. Birch and yernik replaced spruce.

Despite the strong humification of loams, pollen and spores are in fact absent in the lower portion of unit 2 (layers 14–16). This is probably caused by unfavorable conditions for conservation – chemical and biological

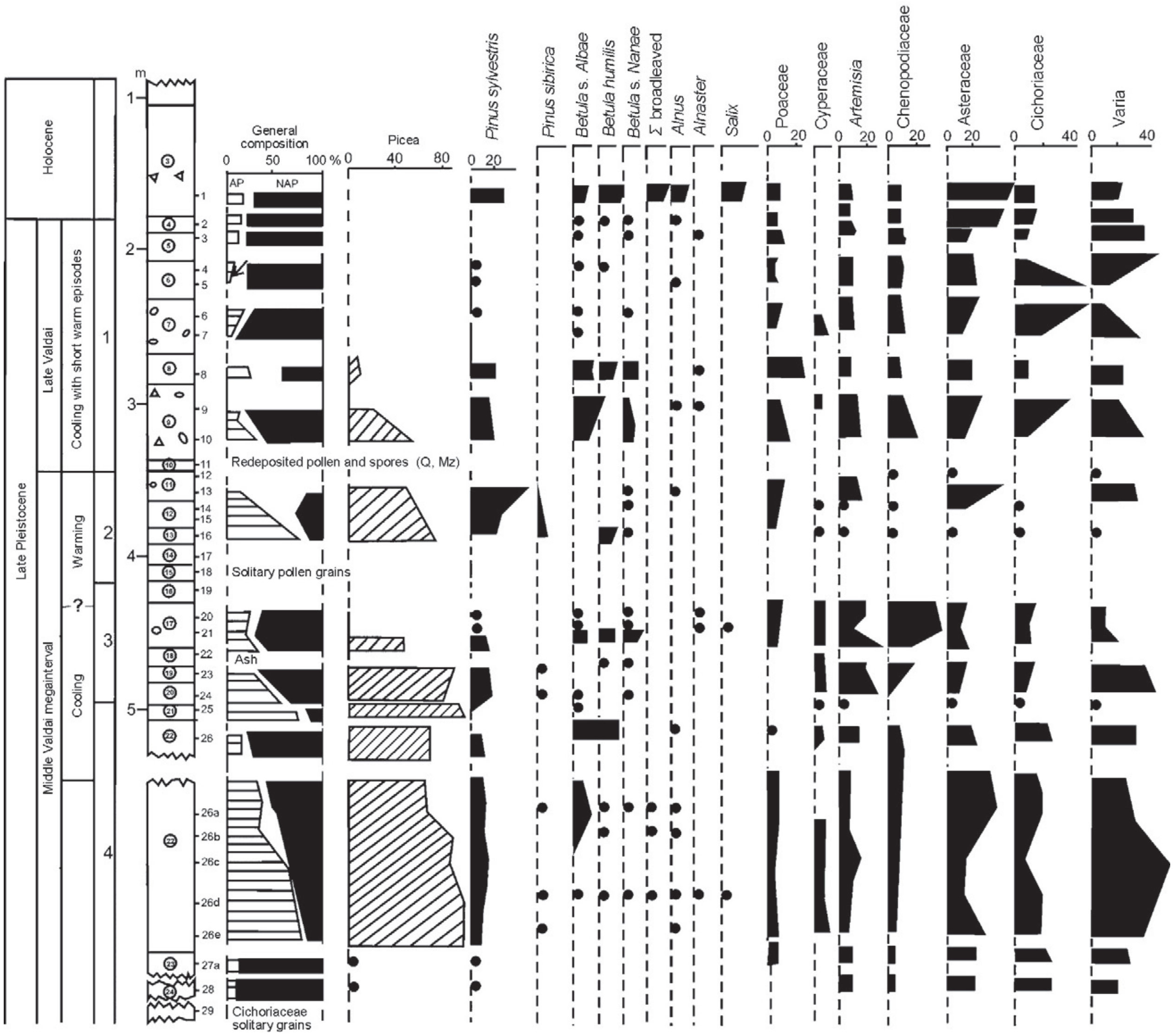


Fig. 11. Pollen diagram (analysis performed by V.V. Pisareva). Circles denote solitary grains.

action destroying the coat of pollen grains and spores. Data obtained for layers 11, 12, and partially 13 suggest the afforestation of the region. Spruce again became the dominant tree, although pines (*Pinus sylvestris* and *P. sibirica*) were constantly present. Alder and birches appeared (*Betula humilis* and *B. nana*), as well as evergreen heather (*Calluna*) growing under the pine forest canopy and on peat bogs. The spore composition is highly diverse containing green moss and sphagnum, adder's-tongue (*Ophioglossum vulgatum*), and leathery (broadleaved) grape-fern (*Botrychium multifidum*) growing on mossy meadows, in pine forests and heathy lands. Later, judging by pollen analysis data from samples in layer 10, climatic and environmental changes occurred. Spruce gave way to Scotch pine, while green mosses spread on the ground cover. Generally, sedimentation conditions in unit 2 were quite different from modern conditions; in terms of vegetation, they were similar to those of the end of the Bryansk (Dunayevo) warm stage of the Middle Valdai.

Samples derived from loams with chalk fragments (unit 1, layer 9) are dominated by the pollen of plants growing in unsodded areas (Asteraceae and Cichoriaceae families) including talus slopes (globe thistle – *Echinops* sp.). Many can be encountered in the forest-steppe and steppe zones. The character of the pollen spectrum changes in layer 8. The proportions of pine and birch (including the dwarf variety) notably increase; alder and spruce (possibly, in valleys) are also present. During the deposition period of this layer, open areas were occupied by grasses and meadow herbs of Brassicaceae, Fabaceae, and Polygonaceae families. In general, the vegetation during this time interval corresponds to the periglacial forest-steppe. The upper part of the subaerial sediments (layers 4–7) accumulated under conditions of cold continental climate. At that time, periglacial steppes and forest-steppes existed in the study area.

The complex pattern of climatic and landscape changes, the presence of sedimentation gaps, and occurrence of redeposited pollen and spores in deluvial sediments make it difficult even to correlate sections in close proximity. Nevertheless, certain approaches to correlating sections studied in recent years can be suggested. Thus the pollen spectra from sediments of the lower series of layer 22 (samples 26, 26a, 26b), dominated by spruce with some pine and a few broadleaved species, but also with a high amount of grasses and herbs, correspond to results published by E.A. Spiridonova (2002). The pollen spectra of layer 21 showing a maximal amount of spruce, exposed on the southern and eastern walls, are very similar to those of the paleosol zone revealed on the northern wall which A.A. Sinitsyn (2006) correlates with the Lachamp-Kargopolovo event. The fall-out of volcanic ash generally appears to have coincided with marked cooling. The deluvial deposits of unit 1 accumulated under the extremely harsh conditions of the Late Valdai interrupted by short periods of warmer climate. The most distinct among these periods was probably the Gmelin identified by Spiridonova (2002) on the eastern wall and by the current authors on the southern wall (layer 8).

The stage characterized by coniferous-broadleaved forest with some species typical of nemoral flora as described by M.P. Grichuk (Lazukov, 1957) has not been identified as a separate stage at Kostenki-14 (unit 4). Its absence has likewise been noted by other researchers (Malyasova, Spiridonova, 1982; Spiridonova, 2002). Further studies are required in order to resolve the issue.

Summary of results

Multidisciplinary geological and geographical studies conducted at Kostenki-14, based on archaeological findings and the chronology of cultural layers (Sinitsyn et al., 2004; Sinitsyn, 2006) provide solid grounds for the following synthesis. The analysis of deposits enclosing the cultural horizons has greatly enhanced knowledge of deposits associated with the Early Upper Paleolithic sites of the Kostenki-Borschevo region. Specifically, the lower humus stratum, identified in other sections and dated to this chronological interval, is replaced at Kostenki-14 by unit 4 of composite structure. It comprises stratified sediments formed in slowly-flowing water; these fill the ravine and overlie the surface of the flat hollow. Another component is the soil formation zone lying above (layer 23). This series can be regarded as a fragment corresponding to the lower humus stratum. This is particularly indicated by the age of the cultural layer IVb associated with the soil (~36–37 ka BP according to ^{14}C, before ~44 ka according to IRSL), which falls within the chronological range of cultural layers associated with the lower humus stratum at Kostenki-1 and -12 (Anikovich, 2005).

An important result of the study is the establishment of the pedogenic character of the horizons constituting the so-called upper humus stratum (unit 2). Previously their formation was accounted for by solifluction processes. Apart from the paleosols mentioned, a series of ephemeral soil formation zones can be distinguished in the section. Some are of local character and are probably associated with slope processes. Solifluction can hardly be considered the key factor responsible for the entire complex of deformations recognizable in the section. Specifically, the presence of automorphic soil horizons contradicts this supposition. It is also important that the section is characterized by uniformity in the textural features of deformations in layers of different ages (the total thickness of these layers composing units 2, 3, and the upper portion of unit 4 measures approximately 2 m). The fact that the tongue-like contacts of all interbeds within these layers have the same inclination suggests that the entire two-meter thick unit moved downslope as a single block and that the differences between the layers in displacement degree are due to the different moisture capacity of layers with differing lithological characteristics. The total movement, judging by the "stretching" of sublayers, did not exceed 1.3–1.5 m.

In general, the aggregated results obtained by the multidisciplinary study have revealed the following characteristics in the evolution of the environment during the Middle and partially the Late Valdai, i.e., periods coinciding with the human occupation of the site. The geomorphological situation of the earliest stage that can be correlated with cultural layer IVb (radiocarbon dated to ca 37–36 ka BP) differs significantly from that of the subsequent stages. In order to reconstruct the conditions of habitation existing at this stage, it seems important to determine the position of the local relief of the study area within the whole system of the Pokrovsky Log as it was in the past. Firstly, the height of the promontory surface above the Log's bottom should be estimated. The reconstruction is based on the following suppositions. Currently, the Don floodplain serves as the base level of erosion (i.e., at the mouth of the Log, its bottom adjoins the floodplain surface). Upstream of the Log, the surface bed gradually rises, so that at the foot of Markina Gora it is approximately 18–20 m above the Don floodplain. During the epoch under study, the floor of the Don valley was hypsometrically higher than at present; actually, it forms the Don's contemporary second terrace which is overlain by slope deposits in its back part (colluvial-deluvial apron); the latter merges laterally with analogous apron at the Pokrovsky Log side incorporating the Kostenki-14 site (Lazukov, 1957; Velichko, 1963). Based on the well-known geomorphological correlation between the floodplain level of the Don as the erosion basis and the changes in the height of the Log bottom upstream, it can be concluded that during the period under consideration, in the Markina Gora area, the Pokrovsky Log bottom was approximately 15–20 m higher than at present. The promontory surface in turn was below the modern level by the entire depth of deposits overlying cultural layer IVb, i.e., by 3.5–4.0 m. According to this reconstruction, at the early stage of human habitation, the site's area was 1.5–2.0 m above the bottom of the Log, while the ravine was associated with the Log's streambed (Fig. 12).

These considerations agree with the reconstructed vegetation typical of riverine biotas and marshy meadows. Hydromorphic features in the soil of cultural layer IVb point to high humidity. This is confirmed in studies by A.F. Sanko and A.A. Sinitsyn (2004) who concluded that the malacofauna of deposits associated with unit 4 is typical of moist biotopes such as marsh coasts and shallow reservoirs. The mammoth bones recorded in the infill of the ravine suggest that the animal may have slipped down the edge of the flat hollow and sunk in the wet mud.

Notably, the quantity of pollen in cultural layer IVb is low, and mostly ruderal plants typical of disturbed ground are present. Most likely, this was caused by human occupation of the area. The presence of hearth fill (that yielded the specific pollen spectrum) and burnt loam at the level of this cultural layer corroborates this supposition. The former fire-site was overgrown with typical grass vegetation, including Onagracea. The soil contained charred bone remains. The surface of the layer displays micro-landforms due to heaving processes entailed by fire that most likely occurred during the winter season. The absence of data on vegetation cover at the site area can probably be explained by intensive human activity and the consequences of fire. It can be assumed with a relative degree of certainty that the pollen spectra from sediments associated with the slow-flowing water (layer 22), which silted the surface of the cultural layer and contained material from the site's environs, will provide such information. The composition of pollen in samples from the lower portion of this series suggests that at first, spruce forests developed and then complex forest communities with spruce and broadleaved trees (elm, linden, and hazel) expanded in the site area.

However the question of whether this environment correlates with layer IVb requires additional examination. Specifically, the presence of cryogenic deformations of seasonal character in the soil (layer 23) comprising this layer is noteworthy. These deformations, however, could have appeared during a low-temperature winter season.

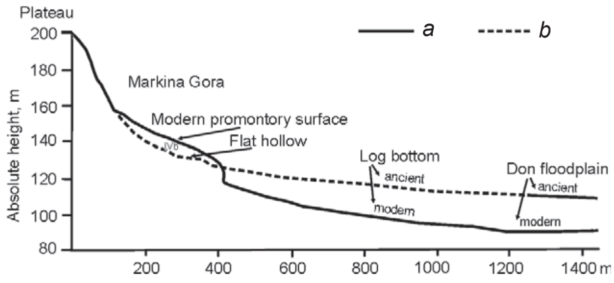


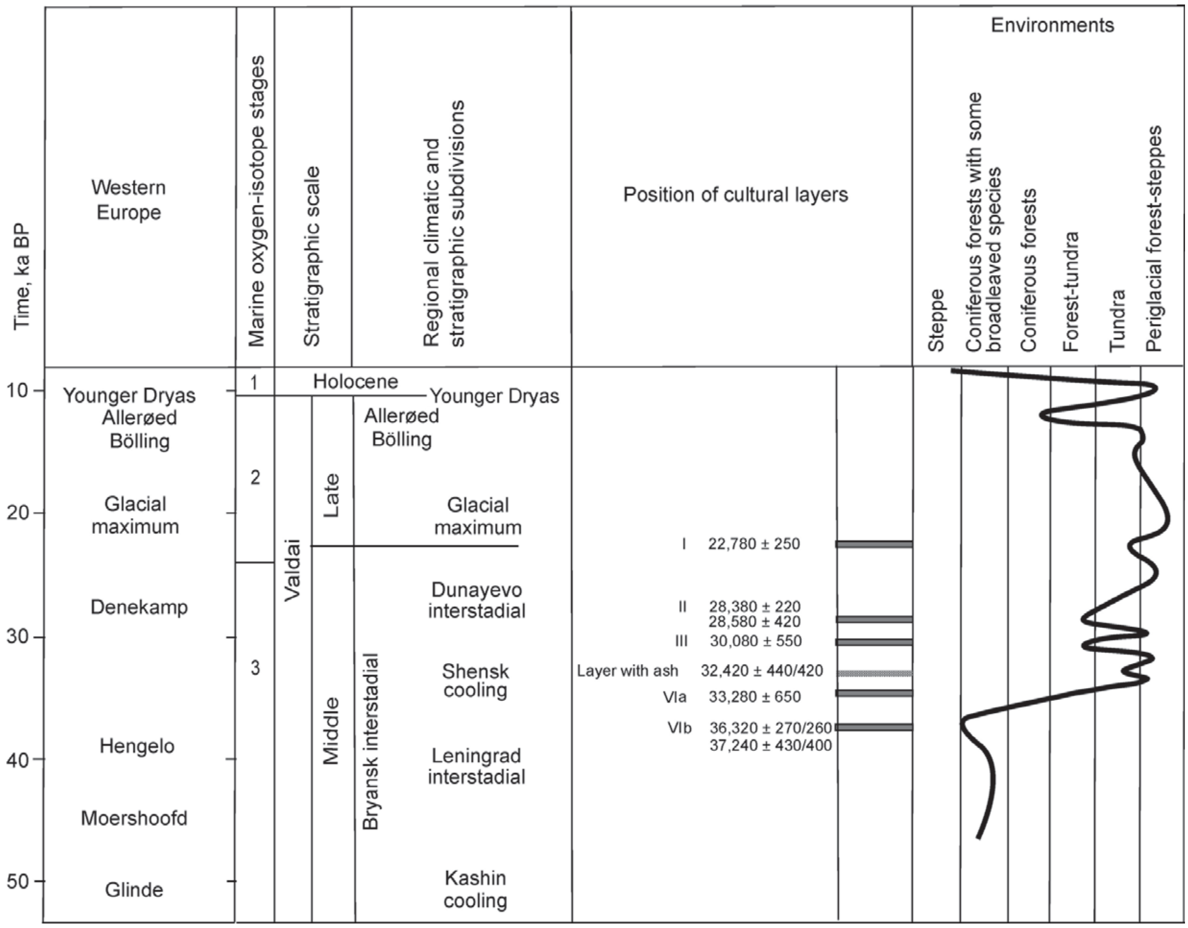
Fig. 12. Reconstructed position of the flat linear hollow and the Pokrovsky Log bottom profile (compiled by A.A. Velichko).
a – modern profile; *b* – ancient profile (period of cultural layer IVb).

Generally, it can be suggested that at the earliest stage of human habitation, a flat surface of linear hollow, just several meters above the Pokrtovsky Log's bottom, existed where the convex steep slope of the Markina Gora promontory is presently located. A brook cut through the hollow and ran into the main gully channel. The environment of this chronological level, if considered within the framework of the entire unit 4, was more favorable compared to preceding stages of habitation (Table 2).

In the second half of the period marked by aquatic sediment deposition, broadleaved species disappeared, while impoverished spruce communities persisted under cold climatic conditions and increased in significance during the process of soil formation (layer 21) crowning unit 4. Approximately 34–35 thousand years ago, a quite distinct soil formed on the dried, smoothed surface of the stratified sediments. Circumstances changed with the beginning of the accumulation of unit 3. Intensified deluvial accumulation processes triggered the formation of the promontory's convex slope. During the transition to the stage corresponding to unit 3 (ca 33 ka BP), the site was again occupied by humans (cultural layer IVa). The next occupation episode coincided with the period of volcanic ashfall (ca 32 ka BP). Both cultural layers were synchronous with the periglacial forest-steppe environment characterized by open landscapes alternating with spruce forest.

The absence of pollen in the layer containing volcanic ash is also of note. It may be that the ashfall process created a specific geochemical medium resulting in the complete destruction of vegetation and pollen (as observed in similar situation at the present time). Generally, from the interval of ca 34–33 ka BP onwards, climatic cooling occurred and seasonal cryogenic processes intensified, their role remaining stable over subsequent stages.

Table 2. **Position of cultural layers on the chronological scale of the Late Pleistocene and the environments of the site during the same interval (compiled by A.A. Velichko)**



A complex change in environmental and climatic conditions coincided with the formation of unit 2 (the so-called upper humus stratum). The presence of two autonomous zones of soil formation suggests two phases of climatic fluctuation of the interstadial character within the interval 30–28 ka BP. Interestingly, there are soil horizons dated to the same chronological range described at a number of other localities: in slope loess deposits of the Kurtak section on the Yenisei River (Frechen et al., 2005); in the Lake Aksor basin on the Irtysh River (Zykin et al., 2002), and in the "ice complex" in northeastern Asia, within the Indigirka-Kolyma lowland (Gubin, 1998; Gubin et al., 2008). In the locality mentioned last, just as in unit 2 of Kostenki-14 (the so-called upper humus stratum), there are two distinct soil horizons (33–31 ka BP and ca 20 ka BP), broadly synchronous with those at Kostenki. These are also attributable to the type of soil formed under conditions of periglacial tundra during some intervals of warmer and moister climate. This lends support to identifying the Kostenki paleosols as stable and chronologically distinct units within the Middle Valdai megainterval.

In sum, the totality of chronostratigraphic, paleobotanic, and paleopedological data strongly suggests the existence of two relatively warm phases separated by a cooling within the 30–28 ka BP interval. Each phase, judging by the structure of soil complexes, in turn falls into two smaller (secondary) phases separated by second-order cooling. The lower level of both pedocomplexes corresponds to cold and dry conditions close to those of Eastern Siberia, but possibly wetter, suggested by the presence of spruce and pine groves (periglacial forest-steppe?). The upper (gleyzem) level is likely suggestive of forest-tundra or tundra. Relatively warm phases, especially the late one, were accompanied by a greater intensity of seasonal cryogenic processes. The lower levels of both pedocomplexes are associated with the second and third cultural layers dated to 30 ka BP and 28 ka BP, respectively.

At the final stage of habitation, associated with unit 1, the climate was cold and arid. The subaeral condition in open spaces was characterized by a much higher rate of slope wash and eolian process, and by the formation of loess-like deposits. The transportation of chalky detritus down the slope became especially intense during the transition from moist conditions (unit 2) to cryoarid conditions (unit 1). The principal interfluve and slope surfaces around the site were mostly occupied by periglacial-steppe biomes. Trees could have survived near the bottom of the Log only and in the Don valley. However, even during this interval, certain phases marked by a milder climate occurred. One such phase (the most pronounced) corresponds to the Gmelin paleosol associated with the upper cultural layer.

In general, the reconstructed environments at Kostenki-14 reveal a complex pattern of climatic and environmental changes in the second half of the Middle Valdai (Middle Weichselian) megainterval corresponding to marine oxygen-isotope stage 3.

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