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New Stratigraphic Data on the Quaternary Sediments in the Peschanaya River Valley, Northwestern Altai

This paper presents new data on the structure and the lithological, pedological, paleontological, and paleomagnetic features of the Middle and Upper Quaternary sediments in the Peschanaya River valley, the foothills of northwestern Altai. Those horizons contain a loess-soil sequence and sediments relating to two Middle Pleistocene interglacials. On the basis of palynological characteristics of one of the Middle Pleistocene interglacials, the succession of floras during the respective stages is reconstructed. The Middle Pleistocene interglacial floras of Western Siberia are compared with that reconstructed on the basis of the Karama site, evidencing marked differences. The flora around Karama included broad-leaved taxa, which were absent during the Middle Pleistocene interglacials of Western Siberia, when apart from modern arboreal taxa, only cold-resistant broad-leaved ones were present (Tilia, Corylus, Ulmus, and Juglans). The Karama flora resembles the last Western Siberian thermophilic flora—Barnaul, which existed during the long climatic warming of the Early Pleistocene, corresponding to the Tiglian in northwestern Europe (2.23–1.59 Ma BP). Since the beginning of the Middle Pleistocene, interglacial floras of Western Siberia have resembled modern ones. In terms of phytocenotic and palaeoclimatic features, Middle Pleistocene interglacial environments of Western Siberia display a sharp contrast with those of Barnaul and Karama.

Keywords: *Stratigraphy, Quaternary, Paleolithic, Altai Mountains, Karama.*

Introduction

Determination of the geological age of Paleolithic sites beyond the possibilities of the radiocarbon method is a quite difficult task, which requires developing the fullest stratigraphic sequence of the Quaternary sediments located both in the area of archaeological studies and in the whole region. In the last decade, the discovery of Siberian Paleolithic sites, more ancient than those of the Late Pleistocene (Derevianko, 2005, 2009; Derevianko, Shunkov, 2009), has generated the need for development of detailed stratigraphy of the Middle and Early Pleistocene in this area. In this regard, special attention was paid to stratigraphic studies aimed at determining the stratigraphic position of Karama, the most ancient Early Paleolithic site in Northern Asia, whose geological age has been debated up to now (Bolikhovskaya, Shunkov, 2005, 2014; Zykin, 2012; Zykin et al., 2005; Zykin, Zykina, Smolyaninova, 2016). The recently obtained stratigraphic data (Baryshnikov, Maloletko, 1997, 1998; Bolikhovskaya, Shunkov, 2005, 2014; Derevianko, Laukhin, Kulikov et al., 1992; Derevianko, Laukhin, Malaeva et al., 1992; Derevianko, Laukhin, Shunkov, 1993; Derevianko, Ulyanov, Shunkov, 1999; Derevianko, Shunkov, Agadjanyan et al., 2003; Derevianko, Shunkov, Zykin et al., 2003; Zykin, 2012; Zykin et al., 2005; Zykin, Zykina, Smolyaninova, 2016; Zykina, Zykin, 2012; Popova et al., 1995) have allowed the considerable refinement of the structure, conditions of occurrence, and paleontological characteristics of the Quaternary sediments of the Altai Mountains. However, many regularities in their structure and formation, climate-stratigraphic breakdown, stratigraphic sequence of specific geological bodies, paleontological features of glacial and interglacial horizons, required for the development of Paleolithic periodization, remain insufficiently studied up to now. Creation of a reliable stratigraphic basis for periodization of the Paleolithic, and for dating the migration stages of ancient humans, implies that not only sections comprising culture-bearing layers are to be studied, but also geological features, in order to determine the complete sequence of Quaternary sedimentation, the characteristics of specific paleogeographic intervals, and the history of biota development.

In 2010, a team composed of V.S. Zykin, V.S. Zykina, and L.G. Smolyaninova conducted complex studies of a section of Quaternary sediments 60 km north of the Karama site. This section is located 6 km north of the place where a hillside surface of the piedmont plain leans against a sharp scarp (escarpment) of the Altai middle-mountains. It is a coastal cliff of the left valley-side slope of the Peschanaya River and the southeastern slope of the Anuy Ridge, 1.5 km below the village of Solonovka. The section was first mentioned in the paper by O.M. Adamenko (1974); however, its description was not provided. We have provided a detailed description, stratigraphic breakdown, and paleomagnetic study of the section. Bone remains of an ancient horse have been found by V.S. Zykin in the subaqueous lower portion of the section; they were studied by I.V. Foronova. Spore and pollen analysis of samples recovered from the lower portion of the section was conducted by N.A. Rudaya. Remains of small mammals have been collected and classified by D.G. Malikov. When indexing the genetic horizons of fossil soils, we follow the traditional system accepted in Russia at the present time (Klassifikatsiya… pochv SSSR, 1977; Klassifikatsiya… pochv Rossii, 2004). In addition, in this article, we adhere to the International (Chrono) Stratigraphic Scale (ISS) of the Quaternary System with the lower boundary at the level of 2.588 Ma BP, and subdivision of the Pleistocene to Lower, Middle, and Upper (Head et al., 2008). The boundary between the Lower and the Middle Pleistocene is drawn at a level of 0.78 Ma BP.

Subsurface geology of the Peschanaya River valley

In the Peschanaya River coastal cliff of 26 m height, 1.5 km below the village of Solonovka, the following strata, separated into subaerial and, predominantly, subaqueous series, are opened under the modern black soil from top to bottom (Fig. 1).

The subaerial series is represented by the following:

1. The Bagan loess (**bg**) is a loess-like loam: grayish-yellow, sandy, loosely compacted, porous, with numerous hollow root-holes and carbonates in the form of pseudomycelium and white soft spots. The transition to the underlying stratum is distinguishable by color and neoformations. The thickness is 1.5–2.8 m.

2. The Eltsovka loess (**el**) is a loess-like loam: grayish-brown, sandy, loosely compacted, porous, with carbonate pseudomycelium. In the medium portion of the stratum, accumulations of manganous specks, ferrugination spots and strips are observed. At a depth of 2.8–3.5 m, loose rounded gypseous concretions from 1.5 to 2.0 cm in size are encountered, while at a level of 4.3–4.8 m from the stratum's superface, vertical strips of gypseous concretions up to 1 cm in size are present. The transition to the underlying stratum is distinguishable by color. The thickness is 2.8–5.7 m.

3. The Iskitim pedocomplex ($\mathbf{is_1}$-$\mathbf{is_2}$), 1.85 cm thick, is represented by two fossil soils subdivided by a layer of loess-like loam 0.15 m thick. The upper soil profile consists of horizons Aca and BCca, cs. The humus (Aca) horizon, 0.45 m thick, is a sandy loam: gray with a slight brownish tone, porous, with root-holes, carbonate pseudomycelium, manganous specks, and small lenses of clay sand. The upper boundary is rough and clearly distinguishable in color, the lower boundary is undulating and distinguishable by color. The transition to the underlying stratum is gradual.

Loess-like loam lying between soils is grayish-brown, sandy, compacted, with carbonate pseudomycelium and small spots, porous, with root-holes. The transition, distinguishable by color, is a BCca, cs horizon of upper soil.

The lower soil profile includes the Aca, cs and Bca horizons. The humus (Aca, cs) horizon 0.55 m thick is a sandy loam: brownish-gray, compacted, porous, with carbonate pseudomycelium and root-holes filled

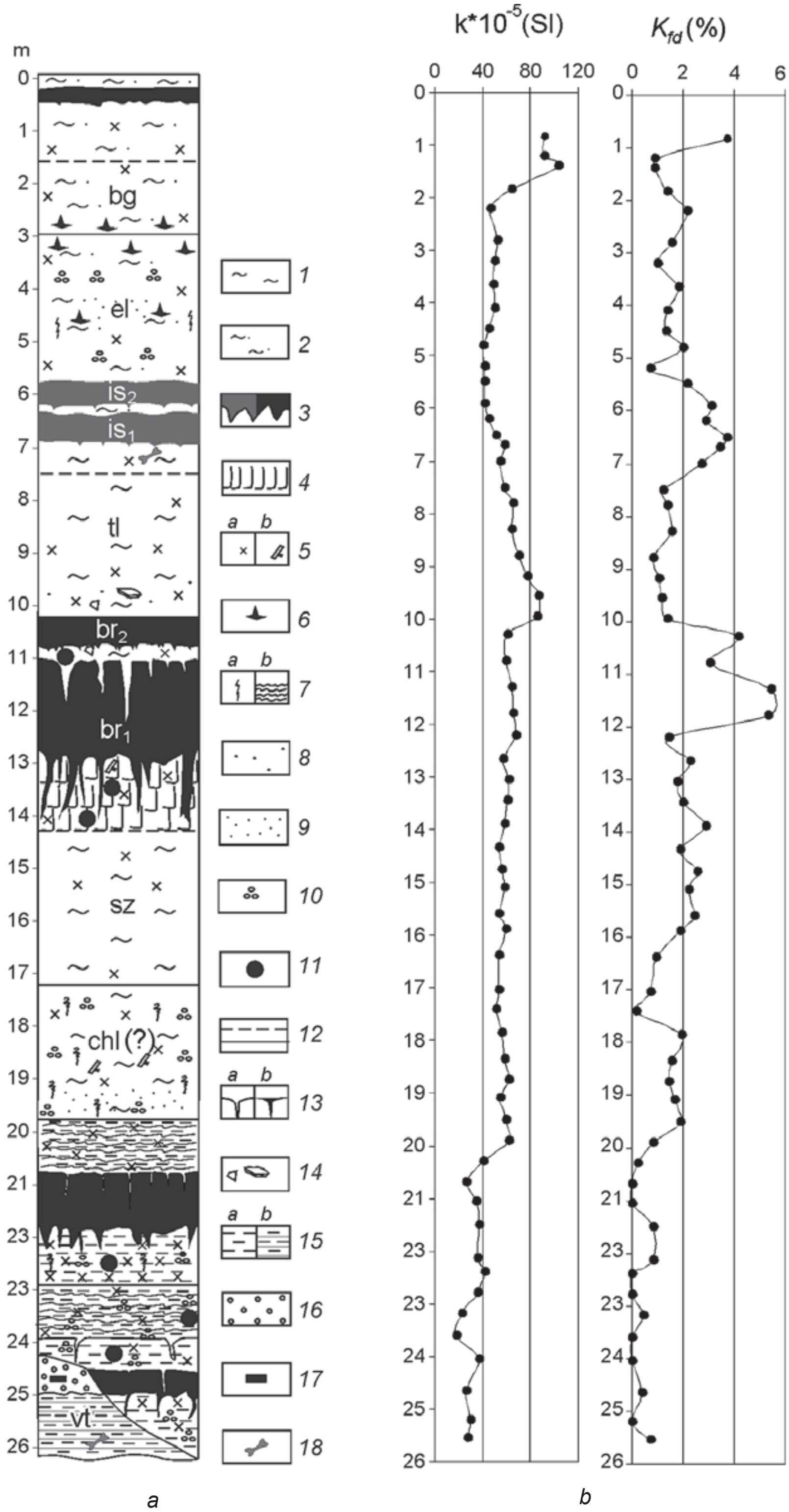

Fig. 1. Geological section (*a*) in the cliff of the left valley-side slope of the Peschanaya River near the Solonovka village, and its paleomagnetic characteristics (*b*).

1 – loam; *2* – sandy loam; *3* – humus horizon; *4* – illuvial horizon; *5*: *a* – carbonates, *b* – carbonate concretions; *6* – gypsum; *7* – Fe neoformations; *8* – Fe-Mn concretions; *9* – Mn specks; *10* – gleization; *11* – holes of burrowing animals; *12* – boundaries of horizons; *13*: *a* – shrinkage cracks; *b* – humus tongues; *14* – chippings and plates of slates; *15*: *a* – aleurite, *b* – horizontally laminated aleurite; *16* – gravel; *17* – remains of small mammals; *18* – remains of large mammals.

with humus loam; clay sand is present; small gypseous concretions of 0.5–1.0 cm are commonly found. The upper boundary is undulating and distinct, the lower boundary is gradual, discernible by color and abundance of black humus specks. The Bca horizon 0.7 m thick is a sandy loam: brownish-gray with a whitish tone, compacted, porous, with carbonate pseudomycelium and spots, with thin hollow root-holes, whose walls are commonly encrusted with humus. The transition to the underlying stratum is gradual.

4. The Tulinskoye loess (**tl**) is a loess-like loam: light brown, poorly porous, with carbonate pseudomycelium and a large number of root-holes filled with humus, which yields black specks and strips. In the lower part, loose small ferruginous pellets and chippings are encountered. The lower boundary is sharp and uneven. The thickness is non-uniform, from 2.9 to 7.3 m.

5. The Berdsk pedocomplex (**br_1-br_2**) is represented by two fossil soils subdivided by a layer of loess-like loam 0.3 m thick, which is the BCca horizon of the upper soil.

The upper soil is formed by the Aca and BCca horizons. The humus (Aca) horizon 0.4 m thick is composed of a dark gray, compact, poorly porous sandy loam with carbonate pseudomycelium and thin hollow root-holes outlined with humus. The upper boundary of the horizon is sharp and uneven, in the form of protruding elongated ovals, the lower boundary has humus tongues up to 10 cm deep and 2–5 cm wide. The BCca horizon 0.3 m thick is a grayish-yellow, compact, poorly porous loess-like loam with carbonate pseudomycelium and root-holes. Small plates of Paleozoic slates are encountered, and holes of burrowing animals are present. The transition to the underlying stratum is distinct.

Humus (Aca) and illuvial (Bca) horizons are clearly isolated in the lower-soil profile. The humus (Aca) horizon, 1.8 m thick, is represented by sandy loam: dark gray with a brownish tone, heavy, compact, poorly porous, with carbonate pseudomycelium and root-holes filled with humus; rare manganous specks and small pellets are observed. The upper boundary of the horizon is uneven: rounded projections alternate with cracks 10–15 cm wide and 0.4–1.6 m deep. The lower portion of horizon is in the form of humus tongues up to 1 m deep. The transition to the illuvial horizon is distinct in color. The illuvial (Bca) horizon 1.5 m thickness is composed of a loess-like loam: grayish-brown, heavy, compact, poorly porous, with carbonate pseudomycelium and carbonate concretions in the upper portion of the horizon. It contains many holes (10–15 cm in diameter) of burrowing animals. The transition to the underlying stratum is gradual.

6. The Suzun loess (**sz**) is formed by a loess-like loam: light grayish-brown, heavy, compact, poorly porous, with carbonate pseudomycelium and hollow root-holes, whose walls are encrusted with carbonates. The lower boundary is distinct. The thickness is 3.0 m.

7. The Chulym loess (**chl** (?)) is a loess-like loam: light brown, heavy, compact, poorly porous, with carbonate pseudomycelium and single carbonate concretions of size up to 3 cm in the middle portion of the horizon; small spots of gley are encountered in the upper portion, and spots of size up to 7 cm are present in the lower portion. The number of ferruginous neoformations in the form of Liesegang rings, spots 0.7–5.0 cm in diameter, strips, and dots increases throughout the horizon towards the base. Manganous specks are present in the lower portion of the horizon. The lower boundary is distinct and uneven. The thickness is 2.6 m.

The subaqueous sequence is predominantly composed of:

8. Aleurite: bluish-gray, compact, heavily clayed, poorly porous, carbonate, with multiple root-holes, the maximum number of which falls on the lower portion of the horizon. Iron neoformations, in the form of horizontal-undulating strips and specks, are observed throughout the entire horizon. The upper boundary of the horizon is distinct and uneven, with small shrinkage wedges. The transition to the underlying stratum is distinct in color. The thickness is 0.95 m.

9. Fossil soil with the AUg, f and Gca, f profile. The humus (AUg, f) horizon 1.1 m thick is represented by sandy loam: heavy, predominantly dark gray, with areas of brownish-ochreous and dark gray color with a bluish tone, compact, poorly carbonate, with common ferrugination and gleization, and with a large number of ferruginized root-holes. The upper boundary of the horizon is uneven, blurry, with thin vertical cracks, the lower boundary is in the form of humus tongues up to 0.6 m deep. The transition is distinguishable by color and abundance of carbonate neoformations. The gley (Gca, f) horizon 1.1 m thick is composed of gleic loam: heavy, greenish-gray with ochreous tone, compact, poorly porous, with rare root-holes and carbonates in the form of spots and dots concentrated within a circle, and pseudomycelium; ferrugination is represented by spots, vertical strips, and dots. Holes of burrowing animals filled with a dark gray sandy loam are encountered. The transition to the underlying layer is distinguishable by color. The soil profile thickness is 2.2 m.

10. Aleurite: bluish-gray, compact, heavily clayed, carbonate, poorly porous, with carbonate pseudomycelium and rare root-holes; common ferrugination in the form of horizontal-undulating strips. At the base, there are holes (5 cm in diameter) of burrowing animals. The lower boundary of horizon is in the form of narrow wedges penetrating the underlying layer to a depth of 14 cm. The transition to the underlying stratum is distinct. The thickness is 1 m.

11. Aleurite: greenish-gray, compact, clayey, poorly porous, with carbonate spots and pseudomycelium,

carbonate tubes along the pores and root-holes. The lower boundary is distinct. The thickness is 0.6 m.

12. Fossil soil with a profile, in which AUg and Gca horizons are distinguishable. The humus (AUg) horizon, 0.4 m thick, is composed of a heavy black sandy loam of crumb structure, compact, with a small number of root-holes, poorly carbonate, fractured by narrow vertical cracks 0.2–0.3 cm wide and up to 10 cm deep, which are filled with sandy loam from the overlying horizon. The base of horizon is uneven, and has the form of small tongues up to 2 cm wide and 10 cm deep. The transition is distinct in color and in boundary of accumulation of carbonate neoformations. The gleization horizon (Gca) 1.2 m thick consists of heavy sandy loam: bluish-gray with a whitish tone, compact, carbonate, poorly porous, with dark interlayers and spots. In the lower portion, there are holes (10 cm in diameter) of burrowing animals. Below is the water edge. Soil is only encountered in the lowering developed in stratum 14 during formation of stratum 13, in the range of 130–160 m downstream of the mouth of a large ravine.

13. Irregularly-grained poorly graded gravel with a large amount of differently rounded (including well-rounded) fine pebbles of Paleozoic rocks. There are many poorly rounded marl concretions up to 5 cm in diameter. The bedding is lenticular, sometimes diagonal. Scattered remains of small mammals and vegetative detritus are rare. The lower boundary is sharp and uneven, up to 0.5 m thick. It forms the lens of channel alluvium of a small river in an area 57–130 m long downstream of the mouth of a large ravine.

14. Gray aleurite, very compact, very clayey, with non-uniform, predominantly fine horizontal minute bedding. In the upper portion, there are many holes of burrowing animals, filled with the stratum material. At a height of 0.5 m above the water edge, 90 m downstream of the mouth of a large ravine, in the middle portion of the stratum, a small accumulation of mammal-bones has been discovered (two articulated upper molars and a metatarsal bone) belonging to *Equus nalaikhaensis* Kuznetsova et Zhegallo. The stratum extends beneath the water edge. The apparent thickness is 1.2 m.

The three series that constitute the section are separated by a considerable interruption in sedimentation. On the basis of soil morphotypical features, structure of pedocomplexes, and lithological properties of loess horizons, the subaerial sediments (strata 1–7) 19.8 m thick, composed of loess-like loams and pedocomplexes, may be compared with the loess-soil sequence of Siberia relating to the Upper and, partially, Middle Neopleistocene (Zykina, Zykin, 2012; Zykina, Zykin, 2008). In this section, we can clearly identify five loess horizons: Bagan (MIS 2), Eltsovka (MIS 2), Tulinskoye (MIS 4), Suzun (MIS 6) and, possibly, Chulym (MIS 8); and two pedocomplexes: Iskitim (MIS 3) and Berdsk (MIS 5c, e). The Iskitim pedocomplex is represented by two underdeveloped chestnut soils with typical carbonate neoformations and gypsum concretions in the profile. The soils were formed in the dry-steppe conditions during the Karga interstadial. The Karga interstadial, whose age limits, according to TL and radiocarbon dates, are in the range of 24–53 ka BP (Zykina, Volkov, Dergacheva, 1981; Zander et al., 2003; Frechen et al., 2005), may be compared with MIS 3 (Bassinot et al., 1994). The Berdsk pedocomplex consists of two black soils. The upper soil, represented by underdeveloped black soil, differs markedly from the lower soil of pedocomplex in the profile of small thickness, and in the smaller duration of formation time. It was formed in steppe conditions during one of the warm intervals of the Early Zyryanka period, which, according to the TL-data (Zander et al., 2003; Frechen et al., 2005; Zykina, Zykin, 2012), corresponds to the MIS 5c substage (Bassinot et al., 1994). The morphotypical features and micromorphological characteristics of the lower soil make it possible to diagnose it as a well-developed, thick, ordinary chernozem inherent in the lower soil of Berdsk pedocomplex, which formed in the steppe conditions, in a warmer and sufficiently humid climate during the Kazantsevo interglacial period, which was an equivalent of the MIS 5e stage (Bassinot et al., 1994). This soil in the Kurtak section in Western Siberia is dated to the interval of 119–143 ka BP (Zander et al., 2003). Two lower strata of subaerial series, differing considerably in their lithological features and pertaining to the Suzun and Chulym loess horizons of the loess-soil sequence of Siberia, are compared with MIS 6 and 8.

The middle series (strata 8–13), 6.35 m thick, is composed predominantly of aleurites that formed in shallow flood-plain water bodies. Two fossil soils of this portion of the section were formed on clayey aleurites in the central part of flood-plain, upon the drying of temporary water bodies under conditions of periodic water flooding and under the influence of ground waters, which were retained within the soil profile for a long time. These are alluvial meadow soils, which have a humus horizon of considerable thickness, with a distinct granular structure and traces of gleization, iron neoformations, and carbonates in the profile. The said soils are characterized by iron hydrogenous accumulation and gleization processes. Sharp boundaries of strata 8, 10, 11, and humus horizons of fossil soils with shrinkage cracks are indicative of periodic drying of flood-plain water bodies, and inconsiderable interruptions in sedimentation. Channel alluvium, preserved along the entire exposure only in the form of intermittent extended lenses up to 0.5 m thick, lies at the series base.

The lower series, rising to a height of 1.2 m above the water's edge in the river, has an erosion upper boundary and is composed of very compact, horizontally laminated, clayey aleurites. Taking into account the lithological features, their occurrence conditions, and paleontological characteristics, it can be assumed that the lower series was formed in the secondary flood-plain water-body, and pertains to the Vyatkino strata **(vt)** of the lower part of the Middle Pleistocene.

Remains of mammals

Fossil mammals have been recorded in two series of the section. Remains of an ancient horse have been found in the lower series (stratum 14), and the basal layer of middle series (stratum 13) contained remains of small mammals.

The upper molars (M2 and M3) and the metatarsal bone (MT III) from the lower series, according to analysis of morphometric data, belong to rather archaic gracile koulan-like horse of relatively small size. Such a form has been described as *Equus nalaikhaensis* Kuznetsova et Zhegallo (Kuznetsova, Zhegallo, 1996; Kuznetsova, 1996; Eisenmann, Kuznetsova, 2004) by the skull, fragments of jaws, and metapodial bones from the Nalaikha locality (Northern Mongolia). This peculiar horse is characterized by a mosaic combination of features of the Upper Eopleistocene (upper portion of the Lower Pleistocene according to the International Stratigraphic Scale) Asian *Equus sanmeniensis* Teilhard de Chardin et Piveteau and modern koulans, asses, and zebras (Kuznetsova, Zhegallo, 1996; Kuznetsova, 1996; Eisenmann, Kuznetsova, 2004). Obviously, *E. nalaikhaensis* is the most ancient koulan and is phyletically related to *E. sanmeniensis*, while emergence and evolution of the *Hemionus* subgenus took place within Central Asia (Kuznetsova, 1996). Horses of similar morphology were widespread during the said period also in Trans-Baikal region (Kalmykov, 1986) and in the south of Western Siberia (Foronova, 1990, 2001).

A complex of associated fauna (from sands and alluvial sandy clays of strata 6 and 7) from Nalaikha is represented by *Ochotona* sp., *Marmota* sp., *Citellus* sp., *Allactaga* sp., *Prosiphneus* sp., *Mammuthus* sp., *Coelodonta tologojensis* Beljaeva, *Equus nalaikhaensis* Kuznetsova et Zhegallo, *Equus* sp. (large), *Spirocerus kiakhtensis wongi* Teilhard de Chardin et Piveteau, *Gazella* (*Procapra*) cf. *Gutturosa* (Pallas), *Bison* sp., Megacerini gen. indet., *Xenocyon lycaonoides* Kretzoi, *Canis variabilis* Pei, *Ursus* sp., *Pachycrocuta brevirostris* (Aumard), *Panthera* cf. *gombaszoegensis* (Kretzoi) (Zhegallo et al., 1982; Sotnikova, 1988, 2016; Eisenmann, Kuznetsova, 2004; and others). The species composition and evolution level of this fauna suggest that the age of enclosing sediments corresponds to the Late Lower/Early Middle Pleistocene according to the International Stratigraphic Scale, or to the Upper Eopleistocene/Early Neopleistocene according to the General Stratigraphic Scale of Russia in the interval of 0.95–0.55 Ma BP (Zhegallo et al., 1982). The date range of this complex coincides with the period of the Vyatkino faunal complex of Western Siberia (Unifitsirovannaya regionalnaya stratigraficheskaya skhema…, 2000).

The structural features of dentition and limb bones indicate the adaptation of *E. nalaikhaensis* to arid herophytic expanses, i.e. to the conditions of open dry landscapes. The rather hypsodont teeth of this horse were adapted to feeding on grassland (mainly abrasive) vegetation of steppes and forest-steppes, while a relatively light gracile ("running") type of limb was suitable for intense movements across compact soils over large distances.

30 teeth of small mammals have been discovered in the basal layer of the middle series. Among these, representatives of 11 species of 8 geni have been determined: *Ochotona* sp., *Spermophilus* sp., *Myospalax* sp. (non-root-toothed), *Ellobius* ex gr. *talpinus* Pallas, *Clethrionomys rufocanus* Sundevall, *Clethrionomys rutilu* Pallas, *Eolagurus* cf. *luteus* Eversmann, *Lagurus lagurus* Pallas, *Microtus* sp., *Microtus oeconomus* Pallas, and *Microtus gregalis* Pallas. The presence of *L. lagurus* and *M. gregalis* gives evidence that this fauna belongs to the post-Vyatkino (post-Tiraspol) time. In the south of Western Siberia, these species are only known since the Middle Neopleistocene (Zazhigin, 1980; Krukover, 1992). The correspondence of the fauna's age to the Vyatkino period is supported by the fact that it contains red-backed voles *C. rufocanus* and *C. rutilu*, reliably known starting only from the Middle Neopleistocene, too (Zazhigin, 1980; Krukover, 1992).

All forms identified in this collection pertain to modern species and geni. The paucity of materials prevents from assessing the evolution-level of particular forms. However, it can be noted that the teeth of lemmings (*L. lagurus*, *E.* cf. *luteus*) have an almost modern structure. The teeth of *M. gregalis* also have the modern appearance, with three-flanged anteroconids and fully separated anteroconid triangles T4–T5. A relative abundance of remains of *L. lagurus* and *M. gregalis*, along with a small number of remains of *M. oeconomus*, *C. rufocanus*, and *C. rutilu*, allows the fauna of the site under consideration to be correlated with localities of the second half of the Middle Neopleistocene: Kartashovo, Bobkovo, Bolshaya Rechka, etc. (Zazhigin, 1980).

Thus, the fauna of small mammals of the locality of interest has a post-Vyatkino age. Its comparison with the fauna of other localities of Southern Siberia suggests formation of the locality in the Peschanaya River valley in the second half of the Middle Neopleistocene. This fauna has predominantly a steppe appearance, with the presence of forest and meadow species. The most probable landscape conditions include real steppes with areas of meadow and woody vegetation.

Palynological data

In order to conduct palynological analysis, 11 samples were recovered from strata 9–12 (with an interval of 0.3 m) of the middle series, from under the humus horizon of the upper soil. The samples were handled using Grichuk's separation technique (Pyltsevoy analiz, 1950) with addition of hydrofluoric acid to remove silicates. Sample-weights amounted to 35–42 grams of dry matter. Two club moss tables were added each time, to calculate the concentration. All samples, except one (Fig. 2), demonstrated low concentrations of pollen and spores. Quantity of pollen showing the signs of redeposition was small.

All the samples are dominated by conifer pollen. Dark coniferous species such as fir (*Picea*) and pine (*Pinus s/g Haploxylon*) play a key role. At a depth of 200 cm, predominance of fir pollen is changed to a dominance of pine pollen. All samples taken in the sediments lying above 200 cm contained pollen of silver fir (*Abies*). Foliage species are almost absent; small-leaved species such as birch, willow, and alder, and broad-leaved species such as walnut and lime occur occasionally. Exotic species are represented by a single pollen of hemlock at a depth of 150 cm. Spores are dominated by forest ferns such as bracken ferns (*Pteridium*) and grape ferns (*Botrychium*). Such a palynocomplex characterizes development of dark coniferous forests in the Peschanaya River neighborhood. Grass-pollen was produced mainly by wormwoods (*Artemisia*), grasses (*Poaceae*), sedges (*Cyperaceae*), pigweeds (*Chenopodiaceae*), and composite plants (*Asteraceae*). Generally, the range of herbs is sufficiently wide. This points to a close proximity of open steppe landscapes.

The composition of the palynological spectra of the section implies development of vegetable communities that were not associated with glacial periods. Such pollen spectra are typical rather for climatic conditions close to the modern, while the presence of walnut- and lime-pollen in them points to a somewhat warmer climate than exists today. Seed flora of the Vyatkino complex in the south of Western Siberia allows the reconstruction of open meadow associations. Tree species are represented by fir, willow, alder, and birch, which were grouped into small groves along the river valleys. Most probably, the Vyatkino flora indicates the warming phase (Ponomareva, 1982a). On the basis of palynological studies of the deep-water sediments of Lake Baikal (Kuzmin et al., 2008), the tendency to an increasing climate continentality in Eastern Siberia can be observed. Starting from the beginning of the Middle Pleistocene, the areas of pine, larch, and cedar growing increased, which reflects the rising diversity of vegetation living environments. From the mid-Middle Pleistocene and nearly up to its end, the role of silver fir in the forest vegetation of the region was reduced.

Paleomagnetic characteristics of the section

Three subsequent cuts of total thickness of 30 m, from the modern soil to the water's edge, have been studied. 63 hand specimens were selected with a step of

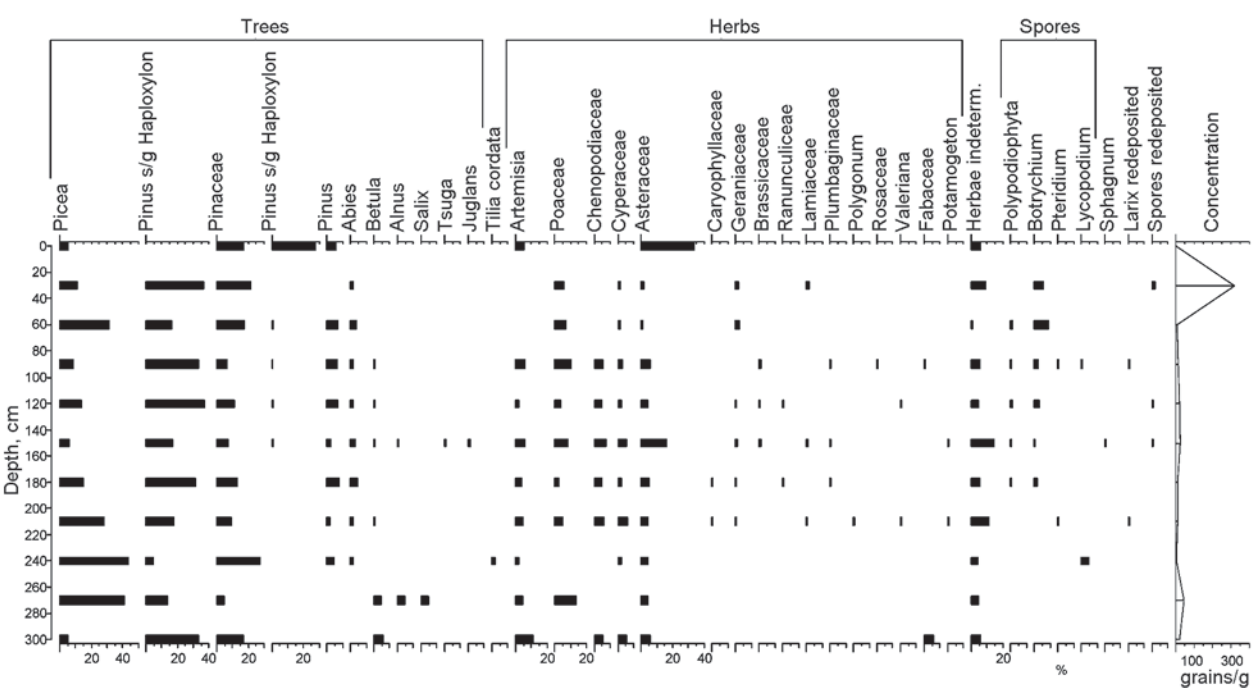

Fig. 2. Results of palynological studies of the section along the Peschanaya River.

30–40 cm, from which 378 oriented cube specimens with 2 cm edges were made.

Measurements of the magnetic susceptibility (k) and the frequency-dependent magnetic susceptibility (K_{fd}) were conducted using the MS2 system (Bartington, England). The magnetic susceptibility of sediments fluctuates from 22.6 × 10^{-5} to 103.0 × 10^{-5} SI units per volume of 11.15 cm^3. Parameter K_{fd} was calculated by formula: $(K_{fd})\ \% = (K_{lf} - K_{hf}) / K_{lf} \times 100$, where K_{lf} is the magnetic susceptibility at a measurement frequency of 460 Hz, and K_{hf} is the magnetic susceptibility at a frequency of 4600 Hz. The magnitude of frequency-dependent magnetic susceptibility K_{fd} reflects the presence of ferrimagnetic substances in the superparamagnetic state in the rock; these substances are usually formed during chemical reactions in soils (Pilipenko et al., 2010). The values of frequency-dependent magnetic susceptibility K_{fd} markedly increase in the first and second soils, while the soil in the lower portion of section is not distinguished by this parameter (see Fig. 1). Thermoanalysis of magnetic susceptibility k demonstrated that magnetite with a Curie temperature of 580 °C was the main carrier of magnetism in the section along the Peschanaya River.

Magnetic cleaning of specimens was performed using the method of stepwise thermal demagnetization on the TD-48 (USA) unit up to 600 °C. The remanent magnetization (J) was measured using the JR-6A magnetometer (Czech Republic). Remasoft 3.0 software was used to analyze the obtained data. Consideration of behavior of magnetization vectors during stepwise thermomagnetic cleaning in the section specimens has established that the direction of vectors changes insignificantly. At the same time, changes in the remanent magnetization values point to the presence of two components: an unstable viscous component in the interval of 200–300 °C, and a more stable primary detrital component from 200–300 °C to Curie temperatures (Fig. 3).

Distribution of remanence vectors before magnetic cleaning has the same character as after removal of viscous magnetization. This points to stability of the magnetic field direction in the interval from the time of sedimentation of the stratigraphic levels under study to the present day. Inclination $D^o = 352^o$ and dip $I^o = 69^o$, statistically average through the section, correspond to the direction of modern magnetic field (Fig. 4).

The results of paleomagnetic analysis allow the conclusion that all sediments of this section are normally magnetized. Taking into account the stratigraphic range of *E. nalaikhaensis* remains in the lower portion of the section, and the composition of fauna of small mammals represented in the lower portion of the middle series, the normally magnetized zone should be referred to the Brunhes orthozone.

Discussion

Stratigraphic, pedological, lithological, paleontological, and palynological data, obtained when studying the section along the Peschanaya River near Solonovka, have allowed us to distinguish three series thereof, separated by long interruptions in sedimentation. The upper subaerial series, corresponding to the upper part of the loess-soil sequence of Western Siberia, was formed within the Upper Pleistocene–Late Middle Pleistocene. The Chulym loess, lying at its base, corresponds to MIS 8 (Zykina, Zykin, 2012; Zykina, Zykin, 2008), whose age has been determined as falling in the interval of 301–242 ka BP (Bassinot et al., 1994).

According to the composition of small mammals, represented in its basal layer, the middle (subaqueous) series with two hydromorphic fossil soils is younger than the Vyatkino layers. Its fauna can be compared with the faunas of localities of small mammals dated to the second half of the Middle Pleistocene, which should be placed before the stratigraphic border of the beginning of the eight stage of the oxygen-isotope scale. Judging by the content of remains of modern plants in palynoflora of the middle series, among which walnut- and lime -pollen is present, its formation can be related to one of the interglacials of the second half of the Middle Pleistocene.

Taking into account the stratigraphic range of *E. nalaikhaensis* and the positive magnetization of the section sediments, the lower subaqueous series, obviously, pertains to the lower part of the Middle Pleistocene. It is conceivable that the time of its formation, according to paleomagnetic and paleontological data, corresponds approximately to the range from 0.78 to 0.55 Ma BP. The lithological features, stratigraphic position, paleomagnetic and paleontological data allow us to assign the lower subaqueous series to the Vyatkino layers in the south of Western Siberia described by O.M. Adamenko (1968), S.A. Arkhipov, A.A. Krukover, V.N. Shelkoplyas (1989), and V.S. Zazhigin (1980), and distinguished today at the base of the Middle Pleistocene (Zykina, Zykin, 2012; Unifitsirovannaya regionalnaya stratigraficheskaya skhema…, 2000). In the stratotype, the Vyatkino layers are characterized by the homonymous fauna of mammals (Arkhipov et al., 1989; Zazhigin, 1980). On the strength of all the biostratigraphic, paleomagnetic, and palaeoclimatic data, formation of the lower series, like the Vyatkino layers in general, apparently corresponds to MIS 17 of the Quaternary Chronostratigraphical Scale (Gibbard, Cohen, 2008) and pertains to the early interglacial of the Pleistocene. Detailed biostratigraphic characteristics of this interval, and the stratigraphic position of Vyatkino layers are of major importance for determining the stratigraphic position of the Karama site, formation of which, according to some researchers, could

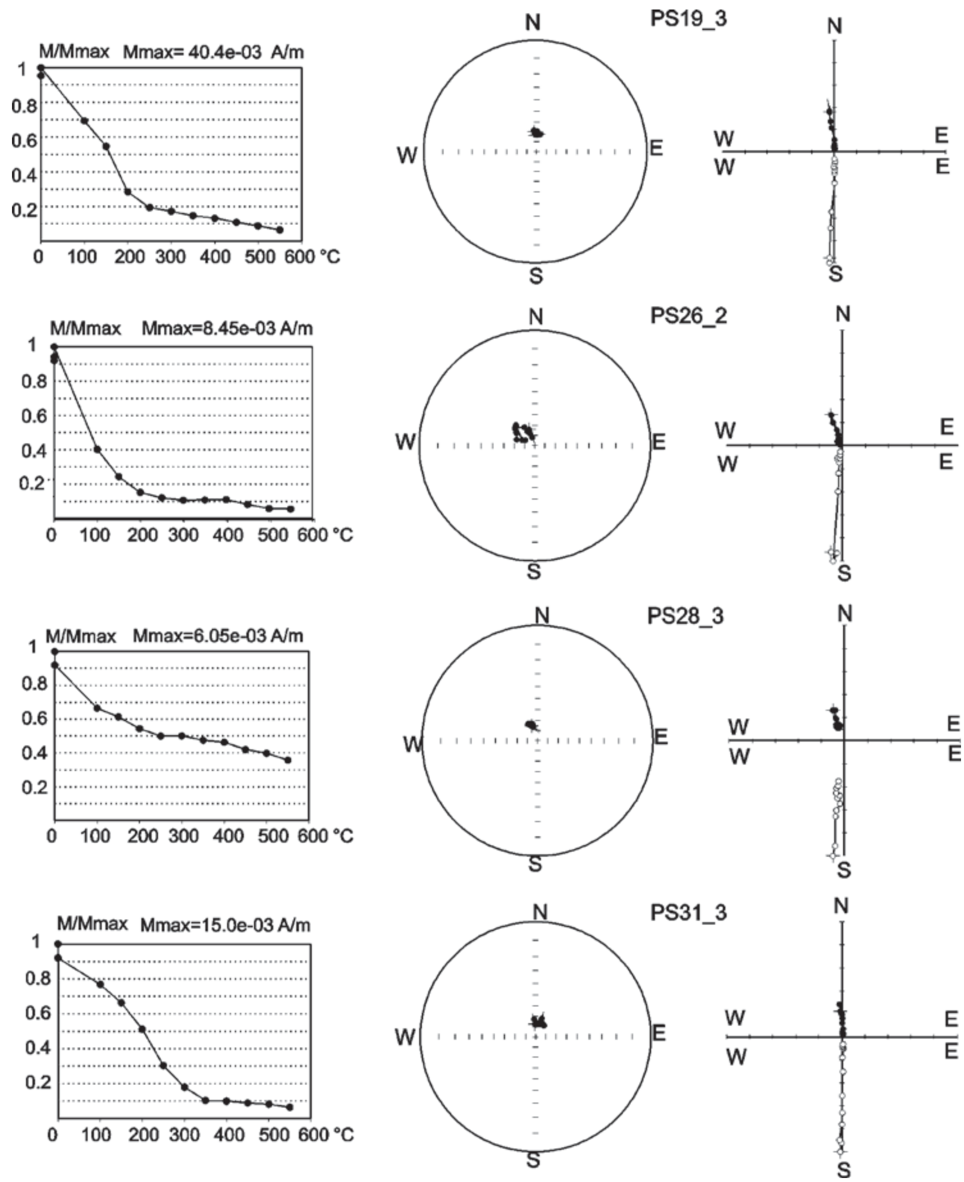

Fig. 3. Characteristic plots of varying values of remanence vectors (*J*), stereograms and Zuiderweld diagrams according to the results of stepwise thermal demagnetization of samples.

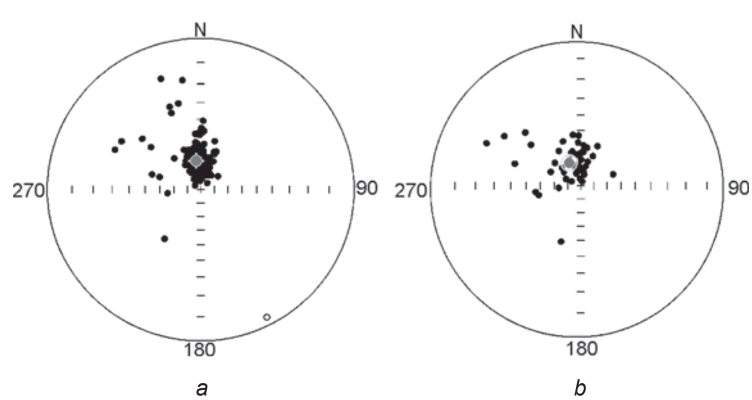

Fig. 4. Stereograms showing distribution of remanence vectors of the section along the Peschanaya River before (*a*) and after (*b*) the declination needle.

have also taken place in the second half of the Middle Pleistocene, within 800–400 ka BP (Bolikhovskaya, Shunkov, 2005, 2014; Derevianko, Shunkov, 2005). Since this presumption about the age of Karama is based mainly on interpretation of palynological data, it is necessary to conduct a comparative analysis of the flora that characterizes cultural layers of Karama, and interglacial flora of the Middle Pleistocene of Western Siberia. The systematic composition of Vyatkino flora is determined by seed flora of the Vyatkino stratotype established by E.A. Ponomareva (Arkhipov, Krukover, Shelkoplyas, 1989; Ponomareva, 1982a, 1986). This flora is characterized by the abundance of *Bunias sukaczewii* silicules and *Zannichellia pedunculata* endocarps. The flora is composed of swamp and mesophytic species. Among the latter, species of erosiofils are especially numerous. The presence of representatives of the pigweeds, pink family, and cabbage family points to some aridization of climate. Meadow associations can be reconstructed. Tree species are represented by fir, willow, alder, and birch, which were grouped into small forests along the river valleys. According to Ponomareva (1982b, 1986), the Vyatkino flora, unlike the preceding Erestnaya and Tishino floras, indicates a warmer and drier environment of one of the climate warming periods. In terms of the stratigraphic position, the Vyatkino layers are closely matched by the Gornofilenskoye layers, whose fossil seed floras, according to the data by Ponomareva, show resemblance to each other in the general composition (Volkova et al., 2002). In the stratoregion, these layers are associated with the buried valley in the lower reaches of the Irtysh River. Gornofilenskoye and Vyatkino layers pertain to the Gornofilenskoye interglacial horizon distinguished by Arkhipov (1987; Arkhipov, Volkova, 1994; Volkova et al., 2002). In the loess-soil sequence of Siberia, the said horizon is matched by the Belovo pedocomplex (Zykina, Zykin, 2012). In the Gornofilenskoye period, according to the palynology data presented by V.S. Volkova (1991; Arkhipov, Volkova, 1994), southern-taiga forest vegetation, which included only moderately thermophilic broad-leaved species such as lime and elm, was developed in Western Siberia. There were lots of silver firs and alders. As part of the grassland and aquatic vegetation, plants alien to the flora of the central part of Western Siberia lived out in the form of relics (Arkhipov, Volkova, 1994). Herbaceous-subshrub plants were dominated by pollen of grasses (up to 55 %), wormwoods, and composite plants. In general, the flora composition allows the drawing of a conclusion that the climate in the lower Irtysh was warmer than it is today. The Gornofilenskoye interglacial, like the Kazantsevo one, in the opinion of Volkova (Ibid.; Volkova et al., 2002), was one of the warmest interglacial epochs of the Middle and Upper Pleistocene of Western Siberia, which was characterized by moderately warm climate.

The subsequent (later) Talagayka interglacial was cooler (Ibid.). Talagayka sediments are distributed mostly in the lower Irtysh, where they are associated with the deeply incised river valley. In the southern region of the West Siberian Plain, this interglacial is matched by Volodarsk pedocomplex of the loess-soil sequence (Zykina, Zykin, 2012). According to palynological data, in that time, the central part of the plain was rich in forest middle-taiga vegetation, which occupied the entire periglacial and glacial zones. The vegetational zonation resembled the modern one, however, the boundaries of zones passed somewhat further north (Arkhipov, Volkova, 1994). No broad-leaved species have been revealed in the composition of Western Siberian forest vegetation for that time. Judging by the presence of walnut and lime pollen, the Middle Pleistocene flora of the studied section (see Fig. 2) was somewhat warmer than flora of the Talagayka, Gornofilenskoye and Vyatkino interglacials.

Thus, according to the published palynological and paleocarpological data (Arkhipov, Volkova, 1994; Volkova, 1977, 1991; Ponomareva, 1982a, 1986; and others) and materials of the studied section, apart from the modern plants, only the most cold-resistant broad-leaved plants such as *Tilia*, *Corylus*, *Ulmus*, and *Juglans* are present in the floras of interglacials of the Middle Pleistocene in Western Siberia. During these interglacials, the climate approached to the modern one or was somewhat warmer (Zykin, Zykina, Orlova, 2000).

The fossil palynoflora of Karama cultural layers, established by N.S. Bolikhovskaya (Bolikhovskaya, Shunkov, 2005, 2014; Bolikhovskaya et al., 2011; Derevianko et al., 2004), among 130 taxa of various ranks, contains a considerable number of nemoral dendroflora elements exotic for Western Siberia, including: *Picea* sect. *Omorica, P.* cf. *koraiensis, Alnus glutinosa, Corylus* sp., *C. avellana, Juglans mandshurica, Carpinus betulus, C. cordata, C. orientalis, Ostrya* sp., *Quercus* sp., *Q. robur, Tilia cordata, T. amurensis, T. mandshurica, T. sibirica, Ulmus pumila, Morus* sp., and others. The composition of fossil flora is in good agreement with the presence of compact soils in the section, which are formed in a warm climate; and this is indicative of the absence of pollen redeposition (Zykin et al., 2005). In the opinion of Bolikhovskaya expressed in 2005, the presence of pollen of *Ostrya* sp. and *Morus* sp., belonging to the group of American-Mediterranean-Asian species and represented in the Lower Neopleistocene sediments of the Lower Cis-Baikal region and the Upper Amur region, and the absence of pollen grains of subtropical broad-leaved species (*Pterocarya*, *Carya*, *Zelkova*, *Celtis*, *Ilex*, and others), hemlock, and other exotic taxa of the pine family that are typical of the Eopleistocene sediments of adjoining regions of Northern Eurasia, give no way of suggesting that the lower layers of Karama pertain to the Eopleistocene, but allow a conclusion to be drawn that they are not younger than the Middle Pleistocene according to the International Stratigraphic Scale (Early Neopleistocene, according to the General Stratigraphic Scale of Russia) (Bolikhovskaya, Shunkov, 2005). Later, pointing out that interglacial floras of Karama existed in considerably warmer and less continental climatic conditions than modern ones, and considering the climatic conditions of Barnaul flora expansion (without conducting a flora composition analysis) close to modern ones, Bolikhovskaya rejected the possibility of comparing the Barnaul and Karama floras (Bolikhovskaya, Shunkov, 2014). She relates the formation of strata 13–10 of the Karama section to MIS 19, or Gremyachye interglacial stage of the East European Plain, "which is dated to the interval of 790–760 ka BP according to correlation calculations" (Ibid.: 7), and formation of stratum 9—to a cold epoch corresponding to MIS 18. According to Bolikhovskaya, stratum 8 and the major part of stratum 7 were accumulated during the next interglacial, compared with MIS 17 or with the Semiluki interglacial.

Comparative analysis of the taxonomic composition of Western Siberian fossil floras, described in numerous papers (Arkhipov, Volkova, 1994; Volkova, 1977; Volkova et al., 2002; Giterman et al., 1968; Istoriya…, 1970; Nikitin, 2006; Ponomareva, 1982a, b; 1986), has revealed the greatest resemblance in the composition between the Karama and Barnaul floras. Notably, the latter is poorly characterized by palynological data, which are most comprehensively presented in a paper by Volkova (1977). Among modern broad-leaved plants, only lime and elm are included in the Barnaul palynoflora. A more comprehensive idea of the flora taxonomic composition is provided by paleocarpological data (Nikitin, 1970, 2006; Ponomareva, 1982a), which were not taken into account in the age interpretation of Karama fossil flora (Bolikhovskaya, Shunkov, 2005, 2014; Bolikhovskaya et al., 2011). The Barnaul flora is the last thermophilic flora in Western Siberia, which, along with the modern species (60 %), contains a considerable number of broad-leaved geni representatives (*Quercus, Ulmus, Tilia, Morus, Leitneria, Aralia, Weigela, Phellodendron, Phyllanthus, Vitis, Sumducus*) needing the same growing conditions as nemoral taxa of the Karama dendroflora. A noticeable share of exotic species in the composition of woody vegetation points to a relative antiquity of the compared floristic complexes. In terms of the taxonomic composition and a considerable content of thermophilic broad-leaved taxa, the Karama palynoflora resembles only the Barnaul flora. Correlation of the Barnaul suite of the south of Western Siberia with the Mukkur suite of the Northern Kazakhstan allows us to attribute the Barnaul flora to the Tegelenskoye period of prolonged moderately-warm climate in northwestern Europe (Zykin, 2012; Zykin, Zykina, Smolyaninova, 2016) dated to the 2.23–1.59 Ma BP (Zubakov, 1990).

The Middle Pleistocene early interglacial floras of Western Siberia show drastic differences with the flora of cultural layers of the Karama site. Many of broad-leaved taxa typical for the Karama palynoflora (*Carpinus cordata, C. orientalis, Ostrya* sp., *Quercus robur, Tilia cordata, T. amurensis, T. manshurica, Ulmus pumila, Morus* sp.) are absent in the Middle and Upper Pleistocene flora of the West Siberian Plain (Volkova, 1977, 1991; and others) and in the Middle Pleistocene flora of the Northwestern Altai (Derevianko, Malaeva, Shunkov, 2000; Razrez…, 1978; and others). The Barnaul flora and floras of early Western Siberian interglacials are separated by a long time interval filled with Tishino and Erestnaya floras, which were formed in a rather cool climate. The early interglacial floras of the Middle Pleistocene of Western Siberia, apart from the modern plants, contain only most cold-resistant broad-leaved plants such as *Tilia*, *Corylus*, *Ulmus*, and *Juglans*. During these interglacials, the climate approached to the modern one or was somewhat warmer.

Conclusions

The use of lithological, pedological, paleontological, and paleomagnetic data has allowed us to distinguish the Upper and Middle Pleistocene horizons of loess-soil sequence and sediments of two Middle Pleistocene interglacials in a section of the Altai Mountains foothills, in the Peschanaya River valley. Palynological characteristics of one of the Middle Pleistocene interglacials have also been obtained. Sequential analysis of the Middle Pleistocene interglacial floras of Western Siberia in comparison with palynoflora of cultural layers of the Karama site has revealed their marked differences. The palynoflora of the Karama cultural layers included a considerable number of broad-leaved taxa, which were absent in the Middle Pleistocene early interglacials of Western Siberia. In terms of the taxonomic composition and a substantial content of thermophilic broad-leaved taxa, the Karama palynoflora resembles only the last western Siberian thermophilic flora, Barnaul, which existed in Western Siberia during the long climatic warming of the Early Pleistocene, corresponding to the Tiglian in northwestern Europe (2.23–1.59 Ma BP). Since the beginning of the Middle Pleistocene, interglacial floras of Western Siberia have resembled modern ones in terms of their taxonomic composition. Apart from modern cold-resistant small-leaved Western Siberian taxa, they included *Tilia, Corylus, Ulmus, Juglans*—the most cold-resistant broad-leaved plants. In terms of floristic, phytocenotic, and paleoclimatic features, the Middle Pleistocene interglacial environments of Western Siberia display a sharp contrast with the warm period of Barnaul and Karama floras formation.

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