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RESEARCH PAPER

EARLY MIDDLE PLEISTOCENE FAUNA OF FOSSIL RODENTS AND LOESS-PALEOSOL SERIES OF THE PEKLA KEY SECTION (TAMAN PENINSULA, RUSSIA)

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ABSTRACT. The history of the early Middle Pleistocene small mammal faunas of Eastern Europe is very complicated. The early Middle Pleistocene which spanned from the Brunhes-Matuyama transition (772.9 ka BP, within MIS 19) till the beginning of the Likhvin Interglacial (424 ka BP, MIS 11) includes a number of interglacials and glaciations. Rodent species of the Tiraspolian faunal assemblage were found in the Chaudian fluvial deposits of the Cape Pekla section (northern coast of the Taman Peninsula). The evolutional level of the Pekla rodents are similar to those from the stratotype section of the Tiraspolian faunal assemblage in the Kolkotova Balka in Moldova (MIS 17) , which includes *Eolagurus* sp., *Mimomys savini, Microtus (Terricola) arvalidens, Microtus (Alexandromys)* ex gr. *oeconomus* and other species. The Pekla fauna also resembles the rodent fauna from famous English West Runton Freshwater Bed locality formed during the Cromerian Interglacial II and some other East and West European faunas. In the current work the entire loess-paleosol sequence of the Pekla section was described with five paleosols from the Middle to the Late Pleistocene. The sequence reflects the complexity of climatic fluctuations from the early Middle Pleistocene to the Holocene.

KEYWORDS: Pleistocene, rodents, Taman Peninsula, loess, paleosols

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INTRODUCTION

Remains of fossil small mammals are often used for palaeogeographic and stratigraphical implications. In addition, the presence of certain small mammal species makes it possible to reconstruct the paleoenvironmental circumstances that existed at the time the fossil assemblage was formed. The evolutionary peculiarities of the mammals in the various phylogenetic lineages also make it possible to determine the age of the enclosing deposits. This is especially important for fossil deposits that cannot be determined using physical dating methods such as the radiocarbon method, OSL and others. When combined with geological and stratigraphic research, the study of fossil small mammal remains gives us a complete picture of the environment during the mammal community's time of existence.

The discovery of the small mammal locality at Cape Pekla (Taman Peninsula) provided additional arguments for reconstructing the environmental conditions and the time of their deposition. The corresponding geological conditions might now be clarified thanks to new studies on this area. In the present current paper we would like to consider the particularities of the small mammal community found in the described fluvial deposits and their position in the Pleistocene stratigraphy. We would also like to present the Pekla section's deposits in detail, playing special attention to the numerous fossil soils that were discovered there.

METHODS AND MATERIALS

Geographical setting of Pekla section

Cape Pekla is located in the northwestern part of the Taman Peninsula, between the Black Sea and the Sea of Azov. The study area is located on the southern coast of the Sea of Azov, in the northwestern part of the Taman Peninsula, which, together with Crimea, separates the waters of the Black and Azov Seas (Fig. 1a).

The studied Pekla section presents one of the variants of the structure of a vast outcrop on the Sea of Azov's southern coast, in the area of the village of Kuchugury in the Temryuk region of the Krasnodar Territory of the Russian Federation (Fig. 1b). Its geographic location is at N 45°25′56.1″ and E 36°55′12.0″. It is located on a high marine terrace 37 meters high, at the edge of a cirque-like depression into which several hollows are descended. The section is located on the outlier between two hollows. One of them descends into a depression in which the mud volcano Plevok is located. Another hollow leads to the sea.

The geological setting of the Pekla section with the exposure of several fossil soils divided by loess horizons was described by (Dodonov et al. 2006). In this paper, these fossil soils were described as Bryansk (MIS 3), Mikulino (MIS 5e), Inzhava (MIS 11) and Vorona (MIS 15) fossil soils according the terminology of (Velichko et al. 1992).

Later, this section was studied by specialists from the Institute of Geography of the RAS. The geological structure of the section and the peculiarities of the paleosols were described by S. A. Sycheva (Timireva et al. 2022). During the last studies, the geological-paleopedological investigations of the Pekla section were carried out. These studies were based on the macromorphological description of the deposits with special attention to the structure of the Holocene and Pleistocene paleosols, their genetic characteristics and the digenetic transformations. The samples were collected for every 6 cm. Some results of their analysis (granulometric analysis, magnetic susceptibility, OSL dating, and others) have been published (Timireva et al. 2022).

The small mammal remains were obtained from washing and screening (0.5 mm screen) the marine-liman deposits underlying the loess-paleosol series. The material was dried in the sun and then the fossil remains were collected for analysis. In the second phase, the fossils were examined under the binocular microscope (type SMC4, Askania) and were drawned with a help of the drawing apparatus.

The fossil remains are yellow in color and consist mainly of isolated teeth and bone fragments. Mandibles and maxillas are absent.

MATERIALS AND RESULTS OF THE INVESTIGATION

A geological and paleopedological study of the Pekla outcrop located on the steep southern coast of the Sea of Azov (Cape Pekla), was carried out. The study is based on a thorough macromorphological description. Special attention is paid to the analysis of the structure of the Holocene soil and the Pleistocene paleosols, their genetic properties and digenetic transformations.

The samples were taken every 6 cm from a continuous column. They were used to perform a series of analyses, the results of which (granulometric analysis, determination of loss on ignition, determination of magnetic susceptibility, optically stimulated luminescence (OSL)) have already been published (Timireva et al. 2022).

Pekla geological section

The Pekla outcrop section (Fig. 2 and Fig. 3) shows a complex sequence of eolian loess and loess-like deposits interstratified with well-developed paleosols about 11 meters thick (Timireva et al. 2022). The subaerial sequence overlies marine sands and clays.

The main part of the section may be divided into the upper part attributed to Holocene – Late Pleistocene loess-paleosol series (LPS) (layers 1–12 in Fig. 2) and the Lower part attributed to the Middle Pleistocene LPS (layers 14–19

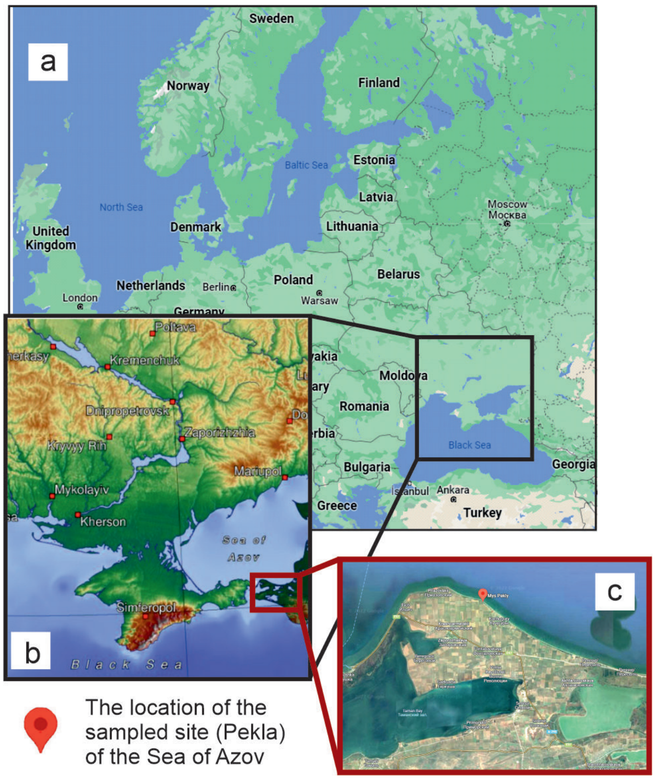

Fig. 1. The location of the Pekla section (Taman Peninsula, the Sea of Azov) a – map of Europe with countries and capitals, b – location of the Taman Peninsula, c – location of Cape Pekla on the Taman Peninsula

in Fig 2). These loess-paleosol sequences are separated by marine sand of layer 13 (Fig. 2). Marine sediments that are about 20 meters thick are also exposed at the base of the Pekla outcrop (Fig. 2 and Fig. 3). The upper sands in the lowermost marine bed yielded conspicuous remains of small mammals described in the next section.

Detailed morphological descriptions of paleosols are critical for robust paleopedological reconstructions. Hence, we focused in the field on both paleosol profile organization and the nature of disturbances along the contact between the paleosol and the loess cover. The latter allows us to comprehend the evolution of the paleosol before and after burial better. Overall, Late Pleistocene LPS includes three paleosols, while the Middle Pleistocene LPS includes two paleosols. All paleosols are represented by incomplete profiles lacking a surficial humus Ah horizon.

The evidence of the former Ah horizon is furnished either by humus-clay coatings in subsurface B horizons or by fillings of small mammal burrows (moleholes, or krotovina in Russian) by dark colored humified material of the topsoil. Ah horizon was no longer preserved maybe as a result of the truncation of a paleosol by denudation processes. These moleholes are readily distinguishable in the field against the yellowish B horizons of loess-derived paleosols. In this way one may conjecture whether paleosol underwent erosion prior to burial.

The upper LPS includes the PS0 Holocene chernozem on loess-like loam, a layer of typical loess and three closely spaced Late Pleistocene paleosols (PS 1-3) (Fig. 2).

Layers 1-5. Holocene chernozem has a well-developed profile: Ad (0-0.06 m)-Ah (0.06-0.42 m)-AB (0.42-0.78 m)-BkA (0.78 -1.08 m)-Bk (1.08-2.04 m). The Ah and AB horizons are heavily bioturbated by soil mesofauna (e.g.,

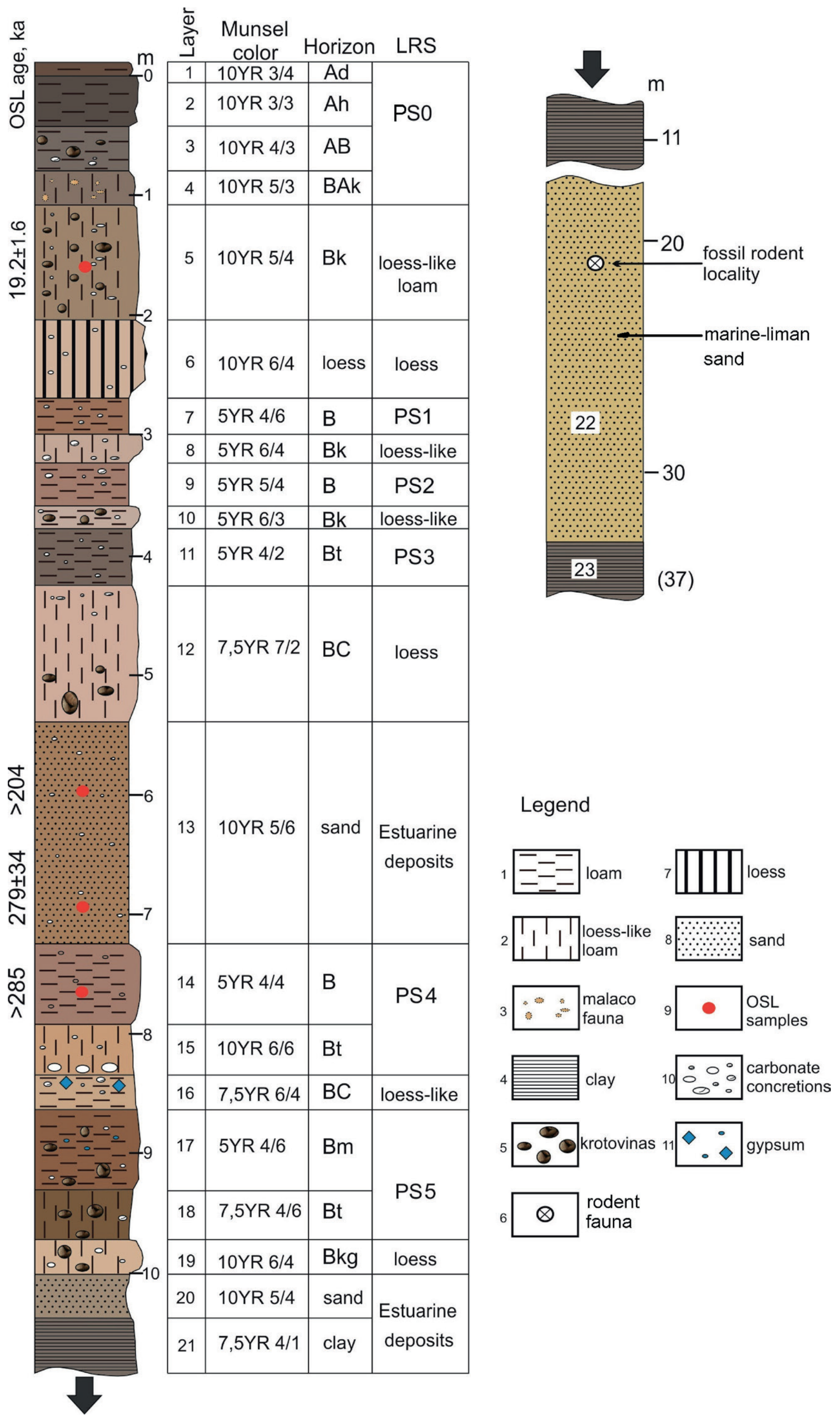

Fig. 2. Loess-paleosol thickness (LPS) and fluvial deposits of the Pekla section

earthworms), strongly humified, dark grey in color, and granular in structure. Carbonate pedofeatures in the form of pseudomycelia appear from the depth of 78 cm. When looking downward, the horizon appears to be loess-like loam (layer 5 on Fig. 2) that has been strongly bioturbated as evidenced by dark-colored moleholes that range in diameter from 5-7 cm to 10-12 cm. The Bk horizon is pale-brown (10YR 5/4 Munsell, Fig. 2). It is abundant with soft calcareous nodules that range in size from 0.5-2 cm to 2-3 cm. As a result, the surface soil is classified as ordinary micellar-carbonate chernozem according to Russian soil classification (Shishov et al. 2004) or Haplic Chernozem Loam according to WRB (2015). Significantly, the layer 5 was dated by OSL luminescence to 19.2 ± 1.6 thousand years (Timireva et al. 2022) and in this way it may corresponds to late Valdai (Weichselian) period.

Layer 6 (2.04-2.70 m) is a typical loess that has ancient moleholes. This layer is yellowish, silty, finely porous, calcareous silty loam. Its lower contact shows two types of disturbances: a) narrow subvertical fissures dissecting the underlying paleosol, and b) occasional dark-colored lenses filled with paleosol material displaced from below into loess. These features testify to intense disturbances at the time of paleosols burial.

Three paleosols from the Late Pleistocene LPS, each with incomplete profiles and showing transitional Bk horizons of varied thickness alone, are included in the LPS.

Layers 7, 8. Upper paleosol – PS1 has a profile: B (2.70 m-3.00 m) - Bk (3.00 m-3.24 m).

The B horizon is brown silty loam with reddish hue, small angular and granular structure, abundant Mn films in pores, some traces of clay illuviation and gleying. The paleosol can be defined as meadow soil (Chernozem Stagnic) apparently partially eroded. A linear, sharp transition from PS1 to lower PS2 paleosol is an indication of a stratigraphic and erosion gap of unknown duration.

Layers 9, 10. Middle paleosol – PS2 is represented by horizons: B (3.24-3.6 m) and the Bk horizon (3.6-3.78 m). The B horizon is dark brown loess-like silty loam, finely porous, while the Bk horizon shows prismatic structure and abundance of calcareous pedofeatures such as impregnation in the groundmass and pseudomycelia. The paleosol may be classified as eroded Chernozem-like soil (Haplic Chernozem).

Layers 11, 12. Lower paleosol (PS3) is represented by horizons: Bt (3.78-4.26 m) - Bk (4.26-5.4 m). The Bt horizon is dark brown loam, with angular aggregates covered by dark humus-clay coatings as indication of the process of clay illuviation. Lower in the profile in the Bk horizon calcareous pedofeatures are superposed on clay coatings. In addition, small dense carbonate concretions from 0.5 to 1 cm in diameter are present. The described features definitely indicate changes in humidity during the apparently long period of soil formation. The paleosol is classified as eroded Dark Gray soil (Phaeozem Calcic).

Upper lying marine deposits

Layer 13, depth 5.4-7.26 m. The sand layer (Fig. 2) is dark yellow (10YR 5/6), contains abundant wormholes throughout, rare gypsum and carbonate nodules. The sand is probably of marine origin (beach facies). OSL dating from the lower part of the sand layer is 279.4 ± 34.6 ka BP (Timireva et al. 2022). It is possible that most of it was formed in MIS 7. However, this date refers to MIS 8 (Lisiecki and Raymo 2005). And therefore, it can be assumed that the Uzunlar transgression began at the end of MIS 8 and continued in MIS 7.

The Middle Pleistocene LPS includes two paleosols.

Layers 14, 15. The PS4 paleosol: Bth horizon (7.26-7.92 m) and Bk (7.92-8.34 m) horizon. The Bth horizon is dark-yellow loam, fine- and medium-porous, with fine-diamond-shaped structure; faces of angular peds are covered by humus-clay and clay coatings, occasionally superposed with gypsum crystals and brown iron-staining mottles. The Bk horizon is brownish-yellow loess-like loam with thin clay and manganese coatings along with large carbonate concretions up to 10 cm in size. The paleosol may be defined as eroded Black Meadow Chernozem (Luvic Chernozem Stagnic).

Layer 16 (8.34-8.64 m; Fig. 2). The brown loess-like loam shows pronounced disturbances in the form of vertical cracks 4-5 cm wide. Notably, the layer contains manganese films in pores along with gypsum druses and dense carbonate concretions.

Layers 17, 18, 19. PS5 paleosol shows the strongest and most complex polygenetic profile consisting of the subsurface Bs horizon (8.64-9.3 m), Bk horizon (9.3-9.72 m) and lowermost Bgk horizon (9.72-10.02 m). The Bs horizon is strong red-brown dense loam, strong angular aggregates, and abundant Mn coatings in pores and upon aggregates. The Bk shows complex multi-layered coatings suggesting several stages of soil development. Strong bioturbation with molehills infilled with red-brown loam is indication of steppic stage in the polygenetic history of the paleosol formation. The lower Bgk horizon is bluish-yellow (10YR 6/4 Munsell) loam, reflecting the initial hydromorphic conditions of paleosol formation. The PS5 paleosol may be defined as Chromic Luvisol Calcic.

Underlying marine-liman deposits

Layer 20. Dark yellow sand (10.02–10.38 m), processed in the upper part by soil formation processes, broken up by veinlets from the overlying soil with cutane inclusions.

Layer 21. Dislocated firth-marine black clays (10.38-10.8 m).

Layer 22. A sequence of alluvial-estuary deposits of the Chaudian age (~20 m thick), represented mainly by sands (Svitoch and Novichkova 2001; Dodonov et al. 2006). The remains of fossil rodents were found in the upper part of this sequence (Fig. 2 and Fig. 3).

Fig. 3. Pekla section (photo of A.E. Dodonov)

Layer 23. The lowermost deposits exposed at the site are represented by dark clay attributed to Neogene (Dodonov et al. 2006).

Fossil rodents

The fossil rodent remains were recovered from the fluvial deposits below the loess-paleosol sequence during the field works of complex geology-paleontological studies headed by A.E. Dodonov (Geological Institute of the Russian Academy of Sciences) (Dodonov et al. 2006). The rodent locality was found in the sand deposits 5 meters below the Vorona paleosol (the lower paleosol of the Pekla section) (Markova 2002). This complicated paleosol was formed during the Muchkap and maybe also the Ikoretsk Interglacials (Shik 2014).

The following rodent species were distinguished (number of specimens in brackets): *Spermophilus* sp. (1), *Eolagurus* sp. (7), *Mimomys savini* Hinton (4), *Microtus (Terricola) arvalidens* Kretzoi (4), *Microtus (Alexandromys)* ex gr. *oeconomus* Pallas (1), Arvicolinae indet. (10) (Fig. 4). This species composition is characteristic of the faunas of the Tiraspolian faunal assemblage. The combination of species such as voles of the genus *Mimomys* with the vole species *Microtus (Terricola) arvalidens* is typical of the developed Tiraspolian faunas and in particular of the stratotype section from the Kolkotova Balka section near the city of Tiraspol (Nikiforova et al. 1971; Alexandrova 1976).

These deposits also include the Chaudian mollusk fauna with *Didacna baericrassa, Monodacna subcolorata, Adacna* aff. *plicata, Dreissena polymorpha, Dr. rostriformis, Paludina dresseli, Bythinia vucotinovici, Didacna rudi, Monodacna subcolorata, Unio* ex gr. *pictorum* (Svitoch and Novichkova 2001).

The rather small Pekla fauna includes the extinct species *Mimomys savini* and M. (T.) *arvalidens*. Their ecology is unclear. The presence of the remains of the yellow steppe lemming, *Eolagurus*, indicates the distribution of open environments near the section. The vole *Microtus oeconomus* is native to the vicinity of water reservoirs of different genesis (rivers, lakes and others). Its range extends from the northern forest-tundra to the southern steppe and semi-desert. It is very likely that the open steppe-like environments existed during the deposition of marine-liman sand deposits.

It is important to note that M. (T.) *arvalidens* is absent from older Tiraspolian faunas, for example it is absent from the Shamin fauna (Don basin) (Markova 1982, 2007; Markova and Puzachenko 2016, 2018). The species composition of small mammals from Shamin includes *Mimomys pusillus, Prolagurus posterius, Eolagurus* cf. *argyropuloi, Allophaiomys pliocaenicus, Lasiopodomys (Stenocranius) hintoni, Microtus* ex gr. oeconomus, *M. arvalinus (= M. nivaloides)* and others.

M. (T.) arvalidens is also absent from the Litvin small mammal fauna found in the deposits from the beginning of the Chauda transgression (Taman Peninsula) (Markova

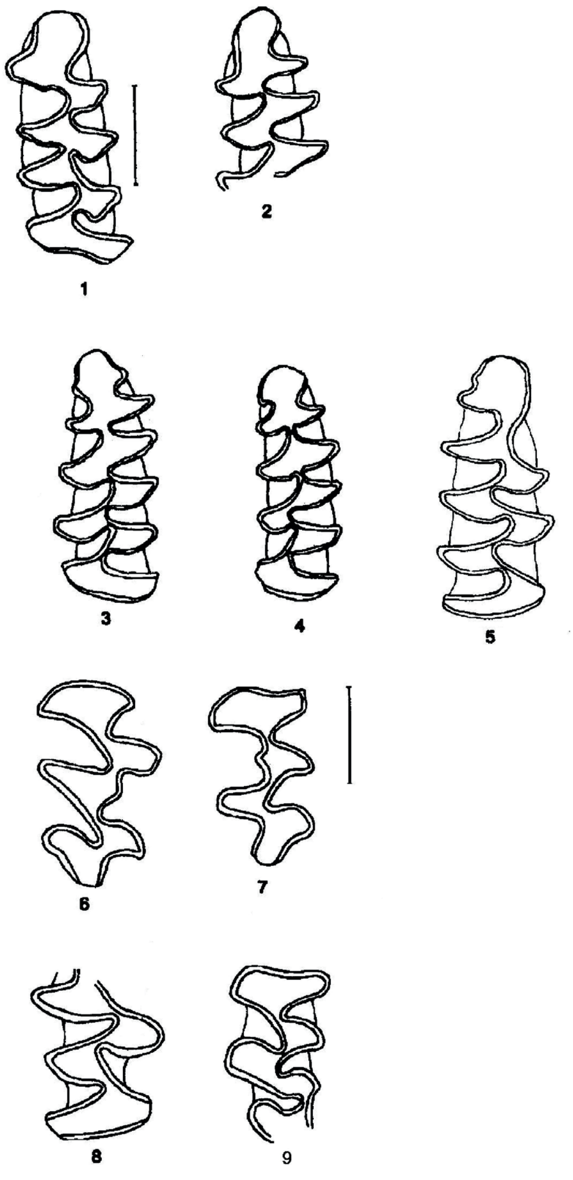

Fig. 4. Rodent species. 1-4 – m1 *Microtus (Terricola) arvalidens*; 5 – m1 *Microtus (Alexandromys) oeconomus*; 6 – M1, 7 – M2 – *Eolagurus* sp.; 8 - m1 (fragment), 9 – M3 - *Mimomys savini*

2014; Markova and Puzachenko 2018). The Litvin locality includes *Ochotona* sp., *Allactaga* sp., *Mimomys savini, Borsodia fejervaryi, Prolagurus pannonicus, Eolagurus simplicidens gromovi, Allophaiomys pliocaenicus, Lasiopodomys (Stenocranius) hintoni-gregaloides, Microtus oeconomus* and others. This fauna is older than that of Pekla.

Palaeomagnetic studies indicated a reverse magnetization of the deposits, which included the Shamin locality (Velichko et al. 1983b). This site is located in deposits correlated with the uppermost interval of the Maruyama palaeomagnetic epoch.

In contrast, the Litvin fauna was found in the Chauda deposits formed at the beginning of the Brunhes palaeomagnetic epoch (Zubakov 2005). The early Tiraspolian faunas thus existed both during the end of Matuyama epoch, and at the beginning of the Bruhnes epoch.

More advanced evolutional features have the small mammals discovered in the fluvial deposits of the VI Dniester terrace in the Kolkotova Balka section. Based on geological and faunistic (mammals, mollusks) arguments the finds from Kolkotova Balka were assigned to the so-called "Tiraspolian faunal assemblage" (Nikiforova et al. 1971). There remains were found of *Mimomys savini, Prolagurus posterius, Lagurus transiens, Microtus (Terricola) arvalidens, M. arvalinus* (Alexandrova 1976). The Levada small mammal locality (Moldova), which was found in the fluvial deposits of VI Dniester terrace, also contained a similar mammal species (Markova et al. 2021).

The faunas of this evolutionary level are correlated with MIS 17 (Markova and Puzachenko 2018). The species composition of the Pekla fauna is similar to these faunas and could also be correlated with MIS 17 (Fig. 5).

Younger Tiraspolian faunas were described from the deposits of the Don Glaciation (MIS 16) and the Muchkap Interglacial (MIS 15).

A fauna with cold-adapted species *Dicrostonyx* ex gr. *simplicior*, and also *Lasiopodomys (Stenocranius) gregaloides, Prolagurus* cf. *pannonicus, Microtus* ex gr. *hyperboreus, M. oeconomus* was discovered in the Bogdanovka locality (Don basin), located directly below the Don till, down to the fluvio-glacial deposits with moraine gravel (Markova 1990, 1992). This fauna is correlated with MIS 16 (Fig. 5)

The first appearance of *Lasiopodomys (Stenocranius) gregalis* is found in the faunas of the Muchkap Interglacial. Besides *L. (S.) gregalis, Mimomys savini, Lagurus transiens, M. (T.) arvalidens* also occurred in this interglacial (Fig. 5). Such faunas were found in several regions of the Russian Plain – in the Danube basin (Suvorovo locality), in the Don basin (Korotoyak 4, Korostylevo 2, Kuznetsovka, Perevoz, Posevkino and many other localities). All of these sites are deposited above the Don till in the Don basin. The first appearance of *L. (S.) gregalis* reflects the more advanced stage in the evolution of the Tiraspolian small mammal faunas correlated with the Muchkap Interglacial (Agadjanian 2009; Mikhailesku and Markova 1992; Markova 1992; Markova and Puzachenko 2018).

DISCUSSION

Many researchers studying the structure of LPS in the Sea of Azov and the Northern Black Sea region for decades have identified paleosols and pedocomplexes of different ages corresponding to interglacials and interstadials (e.g., Dodonov et al. 2006; Pilipenko and Trubikhin 2011; Pilipenko et al. 2010; Timireva et al. 2022; Velichko et al. 1973a; Zubakov 1988).

The paleosols we studied in the Pekla section did not retain their original appearance, as they were largely exposed to wind and water erosion and other diagenetic changes: cracking as a result of desiccation and, possibly, freezing, secondary biogenic overgrowth, and the impact of soil solutions after burial. Therefore, their diagnosis is difficult. Nevertheless, the morphotypic appearance of some of the paleosols has been preserved. Their stratigraphic position and the results of OSL dating allow us to draw the following conclusions:

The Holocene chernozem was formed in MIS 1, initially transforming the upper part of loess-like loams (layers 4 and 5) accumulated in the second half of MIS 2. This is confirmed by the OSL date of 19.2 ± 1.6 ka (Timireva et al. 2022).

A typical loess (layer 6) was deposited during the maximum of the Valdai glaciation, in the first half of MIS 2. The severity of the conditions at that time is evidenced by subvertical cracks of cryogenic origin, breaking up the PS1 paleosol.

This PS1 paleosol (layer 7) formed in the Middle Valdai Megainterstadial (MIS 3) before the last glacial maximum. In the Pekla section, it does not have properties characteristic of typical Bryansk soils of the East European Plain (Velichko and Morozova 2010). It is characterized by a finely ridged structure, clay coats along the edges of the peds, and reddish tones in color. Perhaps these differences are related to the zonality of the soil cover (southern variant of the soil), but, more likely, to the earlier generation. Most likely, it can be compared with the Alexandrovka paleosol, which was formed at the beginning of MIS 3 (Sycheva et al. 2021). Thermoluminescence dating – 40 ± 5 ka, obtained from a sample of the uppermost loess horizon (above the first paleosol) in a nearby outcrop at the southern end of lake Tsokur (Taman Peninsula) (Zubakov 1988) gives grounds to attribute the formation of this paleosol to the first half of MIS 3.

The erosional contact between the upper paleosol PS1 and the underlying loess indicates a break in loess accumulation, as well as a rearrangement of the relief form during the transition from the cold time (MIS 4) to the megainterstadial (MIS 3). The loess, subsequently transformed into the carbonate horizon of the PS1 paleosol (layer 8), thus accumulated in MIS 4.

In the Pekla section, the next two paleosols, an interstadial (PS2, layer 9) and an interglacial (PS3, layer 11), have been separated by loess, and transformed into the carbonate horizon of the second soil (layer 10) formed in MIS 5. Both soils are forest-steppe soils, but the lower one is more developed and originated in more humid conditions. The second soil, the Krutitsa soil according to (Velichko et al. 1997) or the Kukuevka paleosol according to (Sycheva et al. 2020) was formed in one of the two interstadials of the Early Valdai, rather the first one (MIS 5c). The third paleosol has all the diagnostic characteristics of the soil of the Mikulino Interglacial (MIS 5e): the Salyn paleosol according to (Velichko et al. 1997) or its temporary analogue, the Ryshkovo paleosol according to (Sycheva et al. 2020). These characteristics are a bright brown illuvial-clayey horizon with a nutty structure and abundant clay coatings along the edges of soil aggregates, indicating the accumulation of illuvial clay from the overlying but not preserved horizon. Interglacial paleosol PS3 is developed on loesses (layer 12) of the end of the Moscow glaciation (MIS 6) and is a horizon marking the boundary between the Middle and Upper Pleistocene. This soil is represented in many reference sections of the Russian Plain and in other areas, as well as in the Northern and Southern Sea of Azov

(Panin et al. 2018; Sedov et al. 2013; Sycheva and Sedov 2012; Velichko et al. 1977).

Previously, the OSL age of sandy rocks from the Pekla section separating the paleosols was determined to be 156 ± 10 ka without correction for bleaching, and >204 ka, considering the bleaching rate (Pilipenko et al. 2010). Based on this date, the authors reasonably attributed the accumulation of these deposits to the Uzunlar transgression of the Black Sea. The available information on the date of this transgression suggests that a marine basin here between 240 and 280 thousand years ago, that is, in MIS 7 (Svitoch et al. 1998). For the lower part of the layer of coastal-marine sands (layer 13), the new OSL date of 279.4 ± 34.6 ka turned out to be significantly older than the previous one (Timireva et al. 2022).

The deposition of the sands (layer 13) probably started at the end of MIS 8, i.e., in the initial phase of the Uzunlar transgression. The age of the coastal-marine sands (layer 13) underlying the loess (layer 12) is 279.4±34.6 ka and their stratigraphic position in the section makes it possible to compare the time of their accumulation with the Uzunlar transgression (Timireva et al. 2022). The Uzunlar transgression of the Black Sea occurred in the period from 220 to 280 thousand years ago, that is, in MIS 7-8 and probably extended to the Azov region (Svitoch et al. 1998). The new data obtained show that the sand deposition most likely began at the end of MIS 8 and continued in MIS 7.

The underlying Middle Pleistocene loess-soil series contains two interglacial paleosols. The main phase of the late Middle Pleistocene soil is correlated with the Inzhavino paleosol (PS 4, layers 14, 15), which was formed during the Likhvin interglacial (MIS 11). This soil's tendency to divide into separate blocks, as well as the quantity of humus-clay and clay films on the faces of diamond-shaped peds, are defining characteristics of its morphology (Iosifova et al. 2009; Panin et al. 2018, 2019; Velichko and Morozova 2010). It was formed in the warm temperate climate of the steppes.

The four upper soils thus formed under forest-steppe and steppe conditions of temperate and temperate warm climates. Only the lower one, or rather the PS 5 pedocomplex (layers 17-18), developed during its main period in a subtropical climate. The large thickness of the profile and the complex structure of this pedocomplex indicate several stages of development. This suggests that the PS 5 pedocomplex developed during not just one, but two interglacials. There is no doubt that this paleosol can be compared with the Middle Pleistocene Vorona pedocomplex, whose profile contains at least two interglacial soil phases (Panin et al. 2018; Velichko et al. 1973 a, b; Velichko et al. 1992; Velichko and Morozova 1973, 2010). Moreover, the two-phase nature of the pedocomplex is also clearly seen in the studied Pekla section. The lower horizon has distinctive features indicating the soil formation under subtropical conditions. It shows the most differentiated profile, a complexly organized structure, and bright red tones. Its first and main, warmer and wetter phase is associated with the Muchkap Interglacial (MIS 15), and the second phase is associated with the Ikoretsk Interglacial (MIS 13).

What is the reason for the absence of the several Late and Middle Pleistocene paleosols, one should ponder. There are no paleosols formed in MIS 7 (Romny paleosol) and in MIS 9 (Kamenka paleosol), which is obviously due to the palaeogeomorphological position of the section. Second, in MIS 7–8 and in MIS 17, during the transgressions of the Black Sea, there was a depression here, a marine bay or estuary. Despite partial filling with subaerial deposits, the depression continued in the interglacial that followed the transgression. This contributed to a more complete preservation of the soils formed at that time and already buried in the next cold period. At the same time, the elevation sites paleosols were destroyed and not preserved. However, over time, the depression became more and more filled with sediments and no longer served as a reliable repository for paleosols (Sycheva 2008). Therefore, those paleosols formed during subsequent warmings (interglacials and interstadials) after the formation of depressions are better preserved in the studied section – marine bays or estuaries during the transgressions.

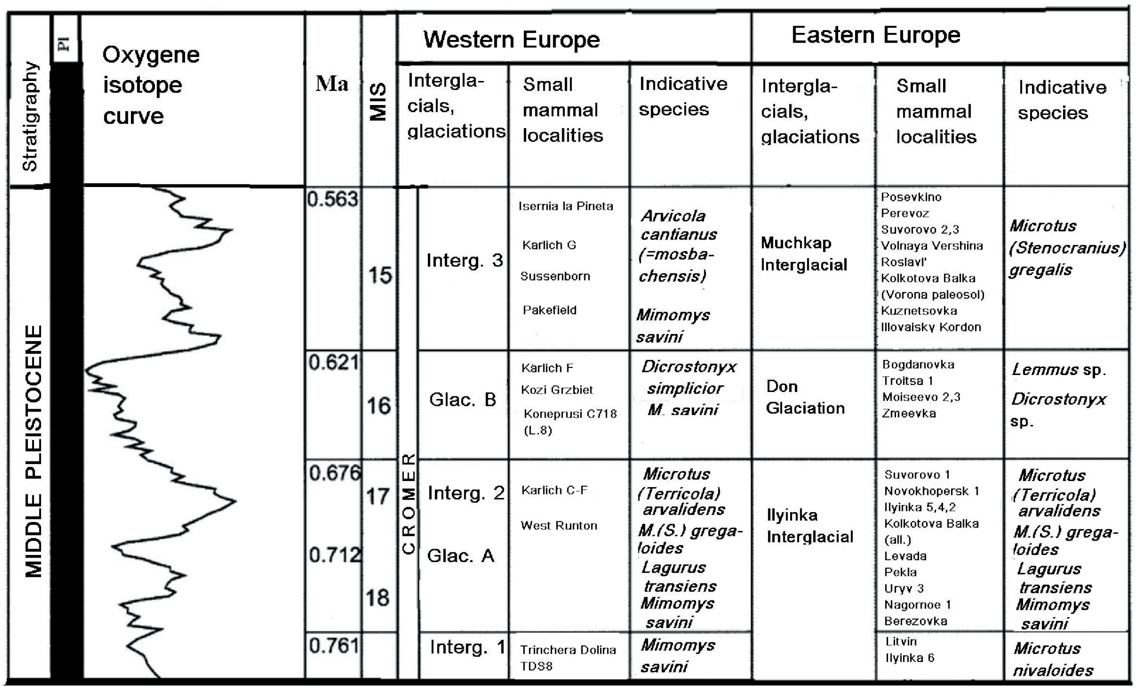

Fig. 5. Biostratigraphical subdivision of the early Middle Pleistocene based on small mammals (after Agadjanian 2009; van Kolfschoten and Turner 1996; Markova 1916; Markova and Puzachenko 2018; Maul and Parfitt 2010; Nadachowski 1985; Stuart 1996; Stuart and Lister 2010 and others)

CONCLUSION

The entire sequence of the Tiraspolian small mammal faunas is correlated with the early Middle Pleistocene (from the Brunhes – Matuyama boundary to the beginning of the Ikoretsk Interglacial (MIS 13), when the first archaic water voles appeared in Eastern Europe (Iosifova et al. 2009; Shik 2014). The evolutionary characteristics of the small mammals from the Pekla section suggests that this fauna could be correlated with faunas from the fluvial deposits of the VI Dniester terrace in Kolkotova Balka, the stratotype section of the Tiraspolian faunal assemblage, situated near the city of Tiraspol (Moldova) and in the Levada section (VI terrace of Dniester River) (Alexandrova 1976; Markova 2016; Markova et al. 2021; Markova and Puzachenko 2018). The Novokhopersk and the Ilyinka 5, 4, 2 faunas (Don basin) possess a similar species composition (Agadjanian 2009). These faunas are correlated with the complicated Ilyinskian Interglacial (MIS 17 and 18) (Shik 2014).

The faunas of this evolutional level are very close to the famous British fauna from the West Runton Freshwater Bed, which includes *Clethrionomys hintonianus, Pliomys episcopalis, Mimomys savini, Microtus* sp. *("arvalinus"), L. (Stenocranius) gregaloides, Microtus "ratticepoides", M. (Terricola) arvalidens,* and *Apodemus* cf. *sylvaticus* (Stuart 1996; Maul and Parfitt 2010). Maul and Parfitt (2010) correlate this fauna with the beginning of the Cromer Interglacial II. The Pekla fauna is also close to the fauna of the German multilayer locality Kärlich C-F (van Kolfschoten and Turner 1996). All faunas of this evolutional level are correlated with the MIS 17 (Fig. 5).

The rodent fauna of Pekla thus has a distinct position on the stratigraphical scale. It is younger than Early Tiraspolian faunas from Litvin (Taman Peninsula) and Shamin (Don R. basin), but older than Late Tiraspolian faunas correlated with the Don Glaciation (MIS 16) and the Muchkap Interglacial (MIS 15), where the first *Lasiopodomys (Stenocranius) gregalis* appear (Markova and Puzachenko 2016, 2018) (Fig. 5).

The characteristics of the paleosols, and the structure of the Pekla section with two loess-soil series (upper and lower, separating and underlying marine sands and clays with OSL dates), made it possible to reconstruct the sequence of events in the Late and the Middle Pleistocene and compare them with marine isotope stages.

The lower soil (PS 5) is the Vorona pedocomplex. It formed in a subtropical climate during the Muchkap Interglacial (MIS 15) and in a temperate climate during the subsequent Interglacial (MIS 13). Its stratigraphic position is in the early Middle Pleistocene, which is in good agreement with the small mammal studies presented in this paper.

The Inzhavino paleosol (PS 4) was formed under the steppe conditions of a temperate climate. The time of its formation falls in the Likhvin interglacial (MIS 11), and its stratigraphic position corresponds to the beginning of the late Middle Pleistocene.

The upper three paleosols belong to the Late Pleistocene: the lower one to the Mikulino Interglacial (MIS 5e), the second to the Early Valdai Interstadial (MIS 5c), and the upper one to the Middle Valdai Interstadial (beginning of MIS 3).

Thus, the upper LPS is the Late Pleistocene ones (PS 3-1), while the lower one is the late Middle Pleistocene (PS 4) and the early one (PS 5) corresponds to the Muchkap and Ikoretsk Interglacials (MIS 15 and MIS 13).

The findings of rodent locality of the evolved Tiraspolian stage (MIS 17) beneath the paleosol 5 (PS5) in the marine-liman deposits of the Pekla section proves the soil's age and the veracity of its correspondence to the Vorona fossil soil (MIS 15 and MIS 13).

A significant contribution to the paleogeography and stratigraphy of this time period has been made by the newly discovered palaeopedological and micromammalian data from the Pekla section. These data allow us to improve our understanding of natural events for a lengthy period of time, from the early Middle Pleistocene to the Holocene.

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