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Structure, Composition, and Depositional Environments of Recent Sediments in the Lower Kama River Basin

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Abstract—Complex investigations in the lower Kama River basin yielded the first detailed lithogeochemical, paleopedological, and paleontological data on recent sediments constituting the Razdol'nyi and Rybnaya Sloboda reference sections. These data served as a basis for facies–genetic discrimination, subdivision, and correlation of defined units with the Pleistocene time scale using paleopedological and paleontological data. This allowed environmental changes to be reconstructed for the Middle Pleistocene to Holocene period and stratigraphy of recent sediments in the region in question to be substantiated using climatic rhythms.

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During the last decades, scientists from the Faculty of Geography of the Moscow State University conducted complex investigations of heterogeneous and facies-variable recent sediments in the new reference and supplementing geological sections revealed in the glacial and periglacial zones of the Middle Volga River basin. By now, the database includes extensive information obtained by the geochemical, paleopedological, paleontological, and other methods of the paleogeographic analysis.

Many scientists contributed to the study of Pleistocene sediments of the Volga–Kama region: E.I. Milanovskii, G.F. Mirchink, A.N. Mazarovich, G.I. Goretskii, E.V. Shantser, A.I. Moskvitin, Yu.A. Lavrushin, V.A. Polyanin, A.P. Dedkov, G.P. Butakov, A.V. Kozhevnikov, Yu.V. Krylkov, and others. At all stages of the investigation of Pleistocene sediments in the Volga–Kama region, main attention was paid to fluvial sediments, while stratigraphy and paleogeography of subaerial sediments remained practically unknown. Shantser (1935), who presented data on Quaternary stratigraphy of the Middle Volga region, was the first to pay attention to fossil soils as reliable indicators of the climate at their burial time and emphasize their significance for Quaternary climatostratigraphy. This researcher demonstrated that glacial epochs were marked by intense slope processes with the accumulation of thick talus loams and interglacial epochs were marked by the formation of soils indicating the stability of slopes. Following this author, Moskvitin (1965) used paleosoils for the subdivision of slope sediments in the Middle Volga River basin.

The geological–geomorphological study revealed that the largest part of the investigated left side of the Kama River is composed of Pliocene sediments, which serve locally as material for the formation of recent (Holocene) soils. They are underlain by the Kazanian and Tatarian sediments of the Permian System. The oldest upper Kazanian strata are composed of dolomites and mudstones with marlstone and sandstone intercalations. The more widespread Tatarian sediments are represented by sandstones, dolomites, mudstones, marlstones, and limestones. These rocks crop out in the middle courses of the Bol'shoi Cheremshan River. They are overlain by Pliocene–Lower Pleistocene fluvial and lacustrine sediments, Middle Pleistocene loess–soil series, Dneprovian loess-type loams, Upper Pleistocene loess–soil series, and crowning recent (Holocene) soils (Glushankova, 1992, 1999, 2005, 2008a, 2008b). The similar structure is also characteristic of most sections in the Kama and Trans-Volga loess provinces. In these provinces, the Pleistocene loess blanket, which covers significant areas in the interfluves, is exposed in river valleys but missing on steep slopes and highest morphostructures. The total thickness of recent sediments in the lower reaches of the Kama River is variable and usually not more than 25–30 m.

The presence of natural outcrops along river valleys and in ravines with thick stratigraphically complete Pleistocene sections made it possible to study in detail both subaerial and subaqueous sediments. The following criteria were used for the stratigraphic–chronological subdivision of subaerial sediments in the reference sections: natural–historical stages in development of the loess–soil formation, complex of defined morphotype parameters, and specificity of soil horizons, which represent the main markers of individual geochronological Pleistocene stages. This provided grounds for a reliable recognition of different-age soils and their complexes in particular sections, as well as for their correlation over significant distances owing to

Pleistocene chronostratigraphic scale of the East European Plain

Division	Link	Glaciations, interglacials (Breslav et al., 1992; Shik, 1993)	Loess and fossil soil horizons (Velichko et al., 1997)		Horizons with cryogenic phenomena (Velichko et al., 1997)	Small mammal assemblages
Holocene			Holocene soil			
Neopleistocene	Upper	Late Valdaian glaciation	Altynov loess III		Yaroslav	Upper Paleolithic
			Trubchev soil			
			Desna loess II		Vladimir	
		Bryanskian (Dunaevian) interstadial	Bryansk soil			
		Early Valdaian glaciation	Khotylevo loess 1		Smolensk	
		Upper Volgian interstadial	Mezin LPC	Krutitsa soil		
		Cold epoch		Sevsk loess		
		Mikulinian interglacial		Salyn soil		
	Middle	Dneprovian glaciation	Moscow loess		Dnieper	Khazar
			Kursk soil			
			Dnieper loess			
		Romny warming	Romny soil			
		Orchik cooling	Orchik loess		Igorevsk	
		Kamenka interglacial	Kamenka soil			
		Cold epoch	Borisoglebsk loess		Wedge-shaped structures	
		Likhvinian interglacial	Inzhava soil			Singil
	Lower	Okan glaciation	Korostelevo loess		Wedge-shaped structures	Tiraspol
		Muchkapian interglacial	Vorona pedocomplex			
		Donian glaciation	Don loess		Wedge-shaped structures	
		Il'inian interglacial	Rzhaksa soil			
		Pokrovian glaciation	Bobrov loess +**B**		Wedge-shaped structures	
Eopleistocene		Petropavlovian interglacial	Balashov soil –**M**			Petropavlovka

genetic relations between soils in their fossil horizons. The Pleistocene stratigraphic scale of the East European Plain was used for defining the main epochs of intense pedogenesis (table).

RAZDOL'NYI SECTION

The Razdol'nyi reference section located in the key Komintern area (55°20′ N, 50°10′ E) approximately 100 km southwest of Chistopol and 1 km east of the Komintern Settlement is one of the most significant and stratigraphically complete Pleistocene sections in the lower courses of the Kama River. This section exhibits distinct climatic depositional features characteristic of the extraglacial zone of the Middle Volga region. It is composed of sediments of the Kama River old fossil terrace. Choice of this section for the first complex investigation is determined by the fortunate combination of several features: relatively well-exposed Pleistocene sequence traceable for over 5 km in bluff outcrops of the Kuibyshev reservoir downstream of the Kama River, significant thickness, genetic diversity, good preservation of fossil soils, their wide age range, and presence of paleontological remains.

Recent sediments of the Razdol'nyi reference section were investigated during four field seasons in a system of intercorrelated excavations located close to each other (Fig. 1). A brief description of the section is presented below (from the top to bottom):

(1) Recent soil represented by a typical chernozem (e IV, 0.0–2.5 m) with the following horizons defined in its profile: (A1) dark gray clotted-granular loam (0.0–0.8 m): (AB) brown clotted-granular loam with rare pseudomycelium and abundant mole casts filled with material from horizon A1 (0.8–1.4 m); (BCa) light brown clotted sandy loam, carbonate, with distinct lower contact (1.4–2.5 m).

(2) Loess-type light brown sandy carbonate loam (L III, 2.5–5.0 m) with abundant newly formed Fe–Mn aggregates and lilac gleization spots. It is complicated by frost deformations. The lower contact is indistinct in color and rock composition.

(3) The Bryansk fossil soil (e III br, 5.0–7.35 m) distorted by small wedge-shaped structures that appeared after soil formation. Due to cryogenic diagenesis, the humic horizon is confined to wedge-shaped structures 45–70 cm wide and 0.8–1.2 cm high. Their composition is nonuniform: more clayey and humic in the central part as compared with their peripheral parts. The paleosoil is divisible into the following horizons: (Al) grayish brown loam, gleyed, porous, ferruginate (0.0–0.7 m); (BCa) whitish brown, carbonate (concretions, pseudomycellium), intensely ferruginate, porous. The lower contact is uneven with leakages (0.7–1.35 m).

(4) Loess-type loam (L III, 7.35–9.20 m), light brown, bedded, with abundant dusty carbonates, slightly ferruginate. The horizon is thickness-variable, deformed, represented by alternating straw-colored light loam and brown to straw-colored medium loam with laminae ranging from 0.1 to 5.0 mm in thickness. The lower contact is gradual.

(5) The Mezin polygenic soil complex (e III mz, 9.2–11.3 m) is crossed by small wedge-shaped structures (35–40 cm high and 20–30 cm wide) forming a sequence, where they alternate with intervals of 80–120 cm. The pedocomplex is represented by the partly denudated Krutitsa soil of the early Valdaian interstadial. It is immediately underlain by the soil of the Salyn pedogenesis phase corresponding to the Mikulino interglacial. The pedocomplex consists of the following members: (Al, 0.7–0.9 m) loam, gray-brown, grading downward into dark brown, compact, ferruginate variety with humic leakages, which penetrate into underlying horizons, and abundant ferromanganese films. The lower boundary of the horizon AL is distorted by humic "tongues" and vertical fissures 30–40 cm long; (AB, 0.9–1.05 m) straw-colored to brown loam forming a discrete horizon with whitish powder along textural jointing surfaces; (Bt, 1.05–2.1 m) dark brown loam, aggregated, with abundant mole casts filled with material from the overlying horizons. The lower contact is uneven, with "tongues."

(6) Sandy loam, loam, and fine-grained sand (L, a II dn, 11.3–12.5 m), dark brown, intensely ferruginate, with rare manganese films, dusty carbonates, abundant mole casts (particularly at the contact with the overlying soil), and fine fissures.

(7) The Romny fossil soil (e II rom, 12.5–13.6 m) form the monolithic profile crossed by fine fissures and consisting of two genetic horizons: (A1) dark brown loam, compact, with abundant newly formed Fe–Mn aggregates, dark to light brown material intruded along vertical fissures, and uneven lower contact (0.0–0.75 m); (B, 0.75–1.10 m) light brown loam, compact with abundant ferromanganese spots, films, and mole casts filled with material from the humic horizon, and lower contact complicated by "tongues."

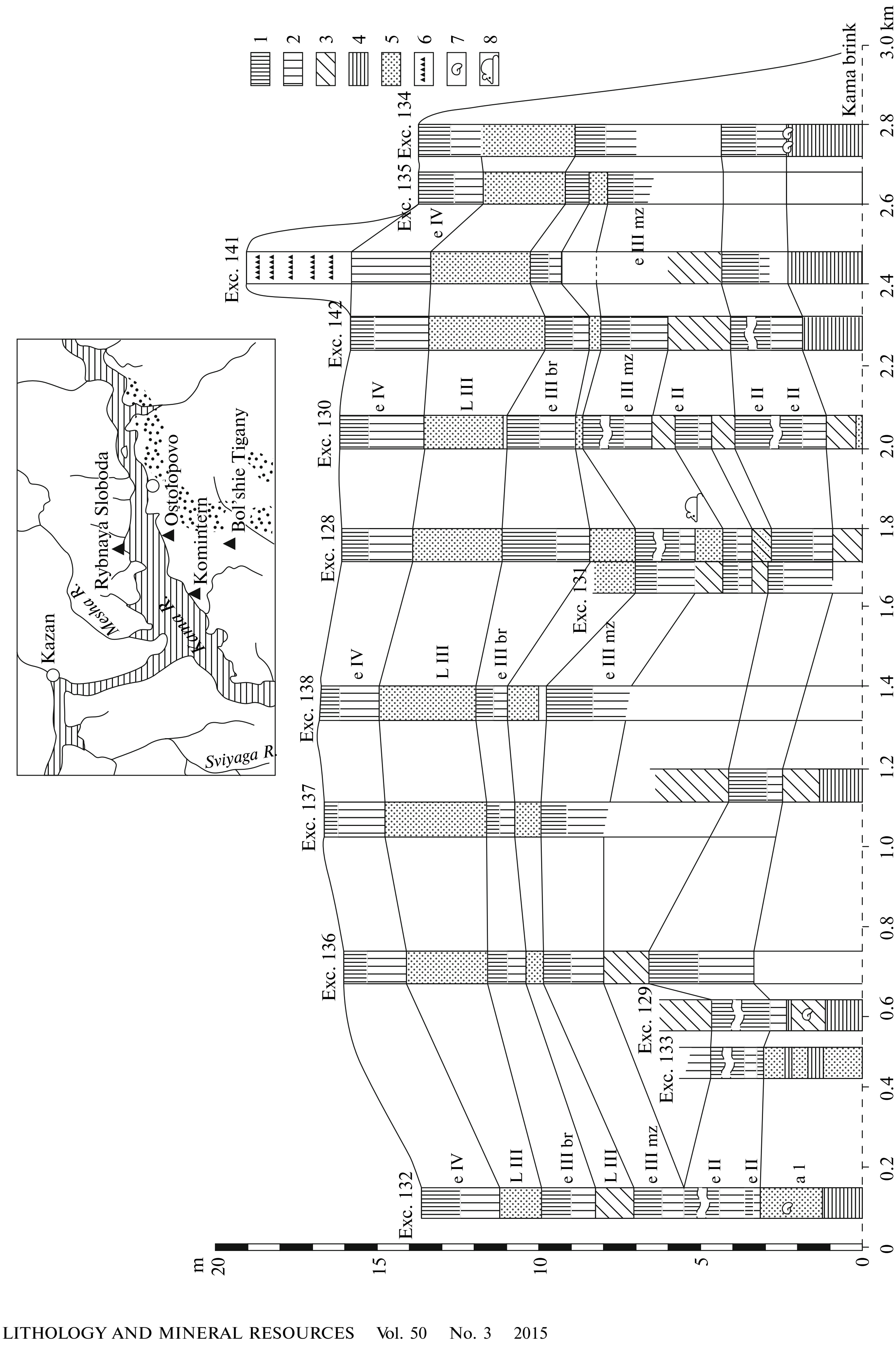
(8) Loess-type loam (L II, 13.6–13.8 m), brownish straw-colored, with ferromanganese and bluish-greenish films. The lower contact is indistinct, emphasized by changes in composition and coloration of sediments.

(9) The Kamenka fossil soil (e II kam, 13.8–15.2 m) with the complex profile crossed by abundant fissures. It is divided into the following genetic horizons: (Al' + Al, 0.0–0.85 m) grayish brown loam, compact, ferruginate, with organic matter filling vertical fissures; (AB, 0.85–1.55 m) whitish straw-colored loam, carbonate, containing ferromanganese moorpans and films (); (Bt, 1.55–2.6 m) lilac-brown to reddish brown (in the basal part) loam, clotted, porous, with ferromanganese moorpans, abundant mole casts filled with material from the overlying horizons, and distinct lower boundary complicated by large "tongues."

(10) Loam and clay (L II, 15.2–15.75 m), ocherous dark brown, with abundant ferruginate lenses and newly formed aggregates. The lower contact is distinct in color and rock composition.

(11) Sand (a 1, 15.75–16.05 m), brownish yellow, fine-grained, with lenses and intercalations of bluish loam and brown ferruginate sediments.

The Inzhava fossil soil and underlying sediments were investigated in excavation 134 (Fig. 1). In this area, the profile of well-preserved soil consists of the following genetic horizons: (Al, 0.0–0.7 m) grayish brown loam, clotted, with abundant ferromanganese moorpans, spots, films, mole casts, and material from the overlying horizons filling vertical fissures (its lower contact is uneven); (Bt, 0.7–1.9 m) bluish dark brown loam, sandy, with clotted-nuciform texture, whitish powder along parting surfaces, and abundant ferromanganese moorpans, films, mole casts, and material of the humic horizon along fissures; (C, 1.9–2.5 m)



Kazan
Mesha R.
Rybnaya Sloboda
Ostolopovo
Komintern
Kama R.
Bol'shie Tigany
Sviyaga R.
Exc. 132
Exc. 133
Exc. 129
Exc. 136
Exc. 137
Exc. 138
Exc. 131
Exc. 128
Exc. 130
Exc. 142
Exc. 141
Exc. 135
Exc. 134
Kama brink
e IV
L III
e III br
e III mz
e II
a 1
1
2
3
4
5
6
7
8
m
20
15
10
5
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0 km

reddish brown, compact viscous clay, sand, and loam with abundant ferromanganese moorpans, which are mostly confined to the basal part of the horizon. The fossil soil is underlain by inequigranular sands grading downward into the brownish crimson-colored Permian clay.

As is seen from this description, recent sediments in the Razdol'nyi section are characterized by the presence of two Late Pleistocene and three Middle Pleistocene complexes of fossil soils with different stratigraphic ranks separated by loess-type loams and sandy loams. Analysis of the structure of different-age loess–soil series in the section under consideration reveals a significant thickness of the well-preserved fossil soils. At the same time, thickness of the Dneprovian Horizon is reduced as compared with similar sediments in the Seim, Oka, and Don river basins. The particularly reduced thickness is characteristic of the loess-type loams that separate Middle Pleistocene soils up to their complete transformation by pedogenic processes.

LITHOGEOCHEMICAL AND PALEONTOLOGICAL CHARACTERISTICS OF THE RAZDOL'NYI SECTION

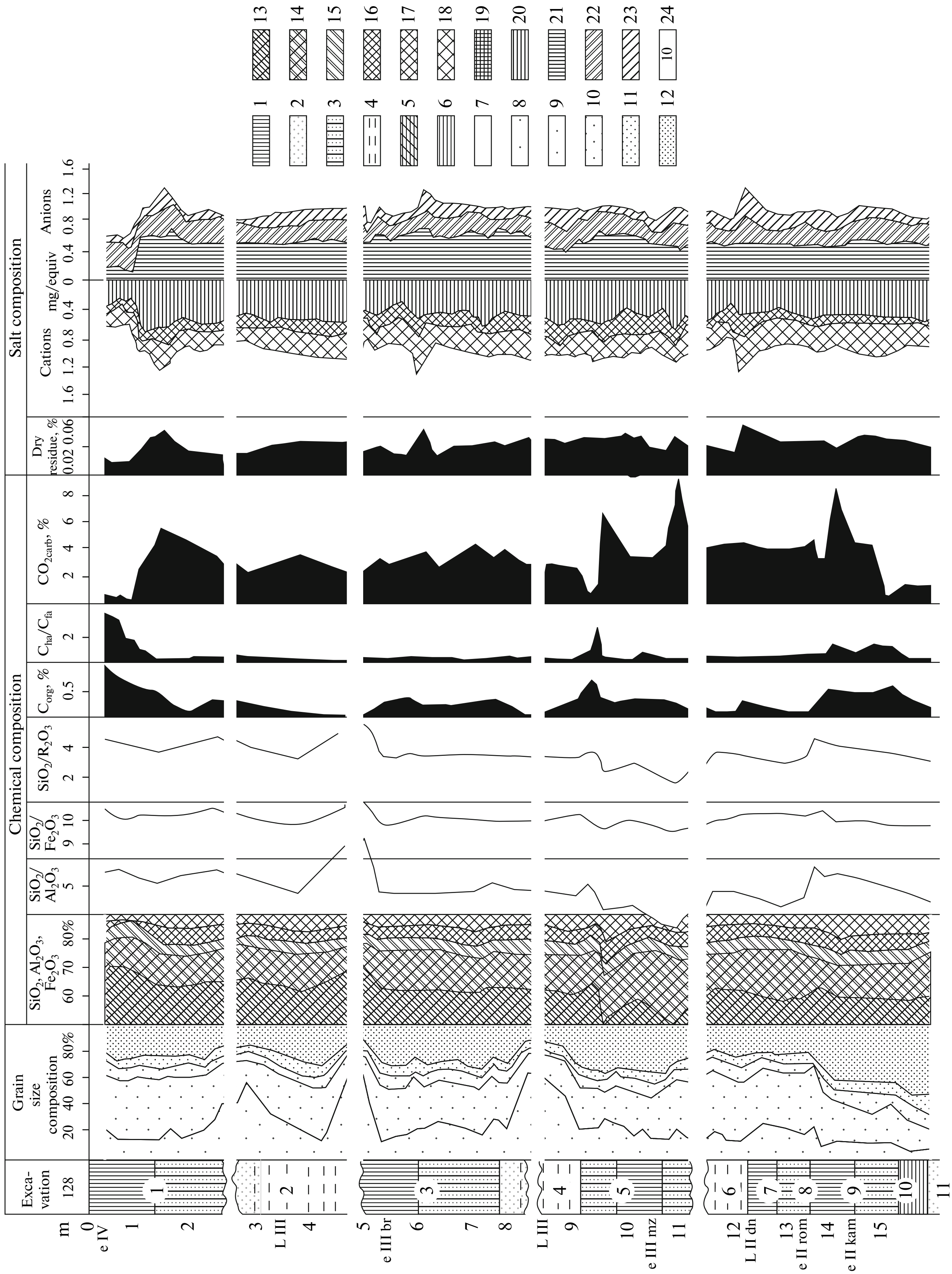
In the study area of the Lower Kama River basin, the Holocene section is represented by typical chernozem with typical morphological features and physicochemical parameters of soils in the central forest–steppe zone of the subboreal belt (Fig. 2, Bed 1). They contain abundant organic matter (C_{org} 0.24–2.47%) of the humate composition (C_{ha}/C_{fa} 1.8–2.0), the content of which gradually decreases downward. The physicochemical composition of soil is uniform: the distribution of the pelite fraction and Fe–Al sesquioxides is regular. The significant share of calcium carbonates (CO_{2carb} 1.64–4.35%) is confined to the basal part of the illuvial horizon (Fig. 2).

The recent soil is underlain by thickness-variable upper Valdaian carbonate (CO_{2carb} 2.52–3.93%) loess-type loams nonuniform in the grain-size and chemical composition (Bed 2). They are characterized by low humus content (C_{org} 0.13–0.32%) and fulvic composition of the organic matter. The complex of readily soluble salts is dominated by calcium hydrocarbonates (dry residue 0.041%). The absorbed complex includes Ca and Mg cations with some prevalence of the former.

The basal part of these sediments is represented by the slightly differentiated (with respect to the pelite fraction and sesquioxides) carbonate soil corresponding to the middle Valdaian interstadial warming phase (Bed 3). This soil is a stratigraphic analog of the Bryansk soil (MIS 3) previously investigated in the Desna, upper Oka, Seim, Don, and middle Volga river basins (Glushankova, 2008a). It is characterized by variable thickness in different intervals of the section (0.4–1.35 m) and consists of genetic Al–B–BCa horizons gradually replacing each other. By the grain size composition, this fossil soil belongs to the heavy and medium loam varieties. By its morphological features, physicochemical parameters, and organic matter properties, the soil in question is close to recent soils with the dominant soddy soil formation agent and coeval soils from the above-mentioned areas of the East European Plain. It exhibits gleization features in the upper and middle parts of the humic horizon marked by the maximum concentration of the pelite fraction and Fe–Al sesquioxides. The content of fulvic organic matter (C_{ha}/C_{fa} 0.58–0.67) in the fossil soil profile is relatively low (C_{org} 0.23–0.47%) with its maximum in the lower and middle (with "tongues") parts of the humic horizon. The elevated concentration of organic matter is also characteristic of the illuvial horizon, which is likely explained by its redistribution during diagenesis. Both morphological features and analytical investigation reveal a distinct carbonate horizon (CO_{2carb} 2.78–4.66%) and elevated content of mobile Fe relative to its concentrations in the under- and overlying sediments. Its highest concentrations are registered in the humic horizon, where Fe concentration is three times higher than in host sediments. The absorbed base elements are dominated by Ca and Mg with the Ca content being almost twice as high as Mg except for the basal part of the illuvial horizon, which is characterized by their almost equal proportions. As a whole, the absorption capacity of the fossil soil is low being close to that of the recent soil represented by typical chernozem. The insignificant difference is determined by the peculiar grain size composition of host sediments. The above-mentioned morphological features and geochemical parameters of the Bryansk fossil soil imply that the lower Kama River basin was characterized by wide development of soddy–carbonate soils in the middle Valdaian time and suprapermafrost–soddy–carbonate varieties, which are correlated with the straw-colored permafrost soils of extracontinental cryoarid areas of central Yakutia, at terminal stages of pedogenesis.

The Bryansk fossil soil is underlain by the nonuniform (in structure and grain size composition) lower Valdaian sediments (Bed 4). The maximum concentrations of the pelite fraction and sesquioxides are confined to the uppermost part of the section. It is also characterized by maximum organic matter (C_{org} 0.36) and carbonate (CO_{2carb} 4.43–4.76%) contents. Their absorption capacity is low (12.9–18.7 mg/equiv/100 g

Fig. 1. Correlation of main sequences of recent sediments in the Razdol'nyi section. (1) Recent and fossil soils; (2) loess-type loam; (3) loam; (4) clay; (5) sand; (6) upper Paleolithic cultural layers; (7) molluscan shells; (8) bone remains of small mammals. The inset shows location of the Komintern area.



Salt composition
Anions
Cations
mg/equiv
Dry residue, %
Chemical composition
CO_{2carb}, %
C_{ha}/C_{fa}
C_{org}, %
SiO_2/R_2O_3
SiO_2/Fe_2O_3
SiO_2/Al_2O_3
SiO_2, Al_2O_3, Fe_2O_3
Grain size composition
Excavation 128
m
e IV
L III
e III br
e III mz
L II dn
e II rom
e II kam

rock) with Ca prevailing over Mg among the absorbed bases. The sediments are also characterized by low concentrations of the mobile Fe.

The underlying soil complex consisting of successive soil horizons corresponding to the early Valdaian interstadial and Mikulino interglacial is correlated with the Mezin pedocomplex (MIS 5) in western and central areas of the loess province of the East European Plain (Bed 5). The significant thickness (0.8–1.5 m) and dark coloration of the humus-bearing horizon combined with the distinct illuvial horizon are atypical of recent soils of the forest–steppe zone. Such a structure of the soil profile may be explained only by its formation during two different stages. The features of the first phase, which is attributed to the Mikulino interglacial, are visually distinguishable only in the form of illuvial horizons. In some excavations, this level in the fossil soil exhibits a silica powder. The humic horizon of this soil is likely hidden within the soil profile of the subsequent pedogenesis phase corresponding to the early Valdaian interstadial. The pedocomplex is mostly represented by finely dispersed fractions. An insignificant increase in the pelite fraction is observable in the middle and lower parts of the humic horizon. With respect to the content of main components of the whole-rock chemical composition, the pedocomplex is slightly differentiated and relatively uniform. There is only a relative enrichment with sesquioxides in humic horizons of fossil soils constituting the pedocomplex. The content of organic matter (C_{org} 0.14–0.53%) of the fulvic–humate and humate composition (C_{ha}/C_{fa} 1.3–3.1) decreases gradually downward, resulting in two maximums confined to the humic horizons of fossil soils. The similar distribution is also characteristic of Fe. The absorption capacity of the pedocomplex is relatively high. Moreover, it is higher in the upper soil (as compared with the lower one) and is close to that of the recent chernozem. Among the absorbed bases of the early Valdaian soil, the Ca content is almost equal to that of Mg, while Ca prevails over Mg in the Mikulino soil. The distribution of carbonates demonstrates several distinct maximums. One of them is confined to the illuvial horizon of the interstadial soil (CO_{2carb} 4.3%). Two others are registered in the humic (CO_{2carb} 7.62%) and upper part of the illuvial (CO_{2carb} 7.27%) horizons of the interglacial soil. The above-mentioned lithogeochemical features (Fig. 2) combined with morphotypical parameters are typical of the soil cover in the present-day forest–steppe and steppe zones.

The structure of the soil cover during the Mikulino interglacial was characterized by the complex combination of several soil types each occupying certain landscape positions. The interfluves with the plateau-shaped or slightly undulating relief were marked by the formation of soils similar to their gray forest counterparts with the differentiated eluvial–illuvial properties and chernozems (podzolized, leached). Ancient depressions hosted soils with the differentiated profile of the A1–A2–Bt–C and A2–Bt–BC–BCa types. In the middle part of their profile, the contents of the pelite fraction and Fe–Al sesquioxides are higher than in host sediments. The soil formation in these depressions proceeded under additional moistening most likely according to the eluvial or eluvial–gleyey mode. As the present-day soils, such combinations were also typical of the past forest–steppe landscapes. The soils in interdepression areas were characterized by the A1–B–C profile probably representing analogs of recent chernozems.

The Mezin pedocomplex is underlain by the carbonate (CO_{2carb} 3.9–4.2%) humified (C_{org} 0.31–0.37%, C_{ha}/C_{fa} 0.34–0.42) sandy loams, loams, and sands correlated with sediments of the cold Dneprovian stage (Bed 6). Their thickness in separate excavations of the Razdol'nyi section varies from 0.8 to 1.35 m. The grain size composition is dominated by silt and sand fractions with the subordinate share of the pelite fraction. The notable role among the readily soluble salts belongs to sodium sulfates in addition to calcium hydrocarbonates. The content of exchangeable cations in these sediments is lower as compared with that in the overlying pedocomplex and the absorbed complex is dominated by Ca (Fig. 2).

The upper part of the section yielded abundant bone remains of small mammals dominated by sousliks and voles (Komintern locality). The souslik remains form two groups. One of them consists of representatives of the subgenus *Citellus* close to the recent *Spermophilus* (*Citellus*) *suslicus Giildtnstaedt*. Another belongs to the subgenus *Colobotis* and is readily correlated with the Late Pleistocene *S.* (*Colobotis*) *superciliosus* Kaup. The vole remains are dominated by the narrow-skulled form exceeding in abundance all other voles. The notable share of the assemblage is also represented by bank vole. The subordinate role belongs to steppe and gray lemmings. The oryctocoenosis in the Komintern locality is characterized by relatively low diversity with the dominant role of steppe forms and presence of boreal elements. This provides grounds for the assumption that the assemblage in question characterizes cool arid climatic environments. The prevalence of the silt and fine-gained sand faction in these sediments indicates their accumulation in subaqueous

Fig. 2. Stratigraphy and lithology of recent sediments in the Razdol'nyi section. (1–7) Horizons: (1) humic, (2) illuvial, (3) loess-type loam, (4) silt, (5) sandy loam, (6) clay, (7) sand; (8–12) grain size composition (fractions, mm): (8) 0.5–0.05, (9) 0.05–0.01, (10) 0.01–0.005, (11) 0.005–0.001, (12) <0.001; (13–17) whole-rock chemical composition: (13) SiO_2, (14) Al_2O_3, (15) Fe_2O_3, (16) CaO, (17) MgO, MnO, Na_2O_3, K_2O; (18–23) salt composition: (18) Na^+, (19) Mg^{2+}, (20) Ca^{2+}, (21) HCO_3, (22) Cl; (23) SO_4; (24) bed numbers; (C_{ha}/C_{fa}) humic/fulvic acid ratio.

low-energy hydrodynamic settings of small well-aerated basins. The similar community is now dwelling in the area under consideration. The fossil assemblage is unambiguously dated back to the late Middle–initial Late Pleistocene. Most of its species are close to Late Pleistocene forms. Such assemblages reflect most likely the terminal Middle Pleistocene (Moskovian) cooling phase and onset of the Mikulino interglacial epoch (Agadzhanyan, 2009).

The existence of small intermittently desiccated basins is confirmed by the composition of the molluscan assemblage, which includes the following species: *Valvata (Valvata) pulshella* Studer, *Bithynia inflata, B. (Bithynia) troshell* Paash., *Planorbis planorbis* (L.), and *Lymnaea (Stagnicola) vulnerata* Ktister (identifications by M.F. Ivakhnenko, Paleontological Institute, Russian Academy of Sciences). Most abundant of them are dwellers of shallow-water and intermittent basins. The distribution area of most species comprises Europe and Siberia. The sole exception is *Lymnaea (Stagnicola) vulnerata*, the distribution of which is limited by the southwestern part of European Russia. The terrestrial forms of the genus *Oxyloma* are amphibionts dwelling on plants in the coastal zone of basins. Nowadays, they are found through the entire Paleoarctic region except for *Succinella oblonga elongata*, which dwelt in mesoxerophylic environments. The existence of floodplain settings in the landscapes is evident from the species composition of the bird community dominated by lamellirostral ducks: *Anas* cf. *clypeata*, *A. crecca, A.* cf. *crecca*, *Anatinae* sp., *Porzana, Gallinago* sp., and *Musicapidae* (identifications by A.A. Karkhu, Paleontological Institute, Russian Academy of Sciences). According to the palynological assemblages from coeval sediments in the Mesha River valley, the climate was relatively cool at that time (Aver'yanov et al., 1981; Bludorova and Fomicheva, 1985).

The basal part of the Dneprovian section is represented by dark brown illuvial–carbonate fossil soil (0.9–1.1 m) (Bed 7). In its monolithic poorly differentiated profile with features of gleization and cryogenic deformations, the dark brown horizon Al is underlain by the bleached horizon BCa with dusty carbonates and mole casts. On the basis of morphotypical features and position in the section, this soil is correlated with the Romny fossil soil (MIS 7) of the Oka, Seim, and Don river basins. It is less distinct in both genetic and climatostratigraphic respects as compared with the latter. Many researchers defined this horizon as an autonomous soil considering the latter to be interglacial in origin (Velichko et al., 1997). V.P. Udartsev (private communication) suggested its interstadial origin in sections of the Oka and Don river basins, Similar standpoint is also shared by Dlusskii (2001). There is also the assumption that the intercalations of brownish and gleyed loams, the formation of which is related to destruction of the interglacial soil correlated with the pre-Dneprovian soil of the Dnieper region, are present at the contact between the Kamenka soil and Dneprovian loess in the central part of the East European Plain (*Izmeneniya klimata* ..., 1999).

In the Razdol'nyi reference section, the Romny soil forms a distinct autonomous stratigraphic unit separated from the underlying soil by a bed of loess-type loam (0.2–0.4 m) substantially transformed by pedogenic processes. The microtheriofaunal remains from mole casts in the coeval soil of the Priluki section are attributed to the Khazarian faunal assemblage. Their low-diversity assemblage represented by remains of *Citellus* sp., *Lagurus* aff. *transiens* Janossy, and *L. lagurus* Pall. indicates the existence of open landscapes in the Sula River valley during the formation of the soil cover at the terminal stage of the Middle Pleistocene pedogenesis (Markova, 2004).

Analysis of the mineral mass reveals the absence of its differentiation in the monolithic profile. Instead, only gleization features are documented in the upper and middle parts of the humic horizon, which are marked by maximum contents of the pelite fraction and Fe–Al sesquioxides. It is characterized by the elevated humus (C_{org} 0.25–0.57%) and carbonate (CO_{2carb} 4.28–5.04%) contents and fulvic composition of humus (C_{ha}/C_{fa} 0.5–0.6). The concentration of readily soluble salts dominated by calcium hydrocabonates is low (dry residue 0.08%). Among exchangeable cations, Ca prevails considerably over Mg (Fig. 2). The above-mentioned morphological features and lithogeochemical parameters make the Romny fossil soil similar with the present-day soddy–gleyey soils (Glushankova, 2003, 2004, 2005, 2008a, 2008b). Loess-type loams (Bed 8) dominated by the silt and pelite fractions served as sediment-forming material for the Romny soil. Their peculiar geochemical property is evident also from the absence of readily soluble salts, low concentration of organic matter (0.22%), and relatively high carbonate content (3.6–3.9%).

The underlying polygenic interglacial soil demonstrates features indicating at least two phases of pedogenesis (Bed 9). The soil profile (Al–AlA2–Bt) 1.85–2.85 m thick is disturbed by subvertical fissures. This pedocomplex corresponds to the Kamenka soil in the regional stratigraphic scale (MIS 9) and is correlated on the basis of some morphological features with soils of the post-Likhvinian interglacial investigated previously in the Seim, Oka, and Don river basins. In the middle Volga and lower Kama river basins, it represents an excellent marker of the Middle Pleistocene loess–soil complexes (table; Figs. 1, 2).

Judging from the distribution of the pelite fraction and Fe–Al compounds, differentiation of the profile is related to eluvial–illuvial processes. The maximum concentration of these elements is registered in the illuvial horizon Bt. Concentration of pelite in horizons AB and Bt is likely determined both by its influx from the overlying sediments and in situ gleization. This process was accompanied by high accumulation rates of organic matter (C_{org} 0.26–0.49%) with the humate–

fulvic composition (C_{ha}/C_{fa} 0.9–1.5), removal of the readily soluble compounds, accumulation of carbonates (CO_{2carb} 3.6–6.4%), gleization, and loessization confined to the early pedogenesis phase. The absorbed bases are dominated by Ca. Combination of intense humus accumulation, moderate metamorphic gleization, slight loessization, and illuviation of hummus, and gleization in the lower part of the profile emphasizes some features in pedogenesis of the Kamenka fossil soil, which make it similar both with recent leached chernozems and brunizems. It may be assumed that indications of organic matter loessization and slight illuviation preserved in the Kamenka soil profile are asynchronous with the formation of the upper part of its humus horizon. They likely reflect the earlier stage in development of this polygenic soil and its different formation environments. The formation of the soil cover proceeded in forest–steppe landscapes with local broad-leaved forest massifs at the early stage of its development and under mixed herbs–graminaceous vegetation of meadow landscapes at the subsequent stage.

The basal part of the Middle Pleistocene sequence corresponds to the polygenic profile of the Inzhava fossil soil (MIS 11), which was formed during the Likhvinian interglacial (table). This is confirmed by finds of the Singil microtheriofaunal remains in fluvial sediments underlying the Kamenka soil in the Rybnaya Sloboda section (55°38′ N, 50°25′ E) located on the right side of the lower Kama River (Fig. 1). The generalized structure of recent sediments in this section may be presented in the following way: (1) recent soil (e IV, 0.0–2.3 m); (2) loess-type loam and sandy loam (L III, 2.3–5.8 m); (3) Bryansk soil (e III br, 5.8–7.2 m); (4) loess-type loam (L III, 7.2–8.4 m); (5) Mezin pedocomplex (e IIImz, 8.4–10.8 m); (6) loess-type loam, sandy loam (L II dn, 10.8–12.6 m); (7) Romny soil (e II rom, 12.6–14.8 m); (8) loess-type loam (L II, 14.8–15.3 m); (9) Kamenka soil (e II kam, 15.3–18.5 m); and (10) fluvial complex (a II-1, 18.5–32.8 m).

Correlation between the Razdol'nyi and Rybnaya Sloboda sections reveals the significant similarity in their structure and morphotypical features of different-age fossil soils. The differences consist only in the degree of preservation, thickness, evidence of some genetic horizons of fossil soils, and replacement of the Inzhava soil by fluvial sediments with the Singil microtheriofauna at the base of the section. The assemblage of small mammals from the fluvial sediments includes abundant remains of archaic water voles *Arvicola Cantianus, Clethrionomys glareolus, C. rufocanus, Microtus (Stenocranius) gregalis, Microtus agrestis, M. oeconomus*, and some others. Based on the composition of dominant species, the faunal assemblage from the Rybnaya Sloboda section implies the prevalence of forest landscapes during the formation of the locality under consideration. Remains of the red-gray vole *Clethrionomys rufocanus* represent a sole find of this species in the East European Plain and suggest the probable presence of elements of taiga vegetation in the Kama River mouth area. Rare bone remains of steppe and yellow lemmings, dwellers of open landscapes are identified as *Lagurus transiens* and *Eolagurus luteus Volgensis*. The tooth morphology of water vole, steppe and yellow steppe lemmings, and common vole makes it possible to correlate the faunal assemblage from the Rybnaya Sloboda section with diverse faunas of the Likhvinian interglacial of the East European Plain and attribute it to the Singil (Gun'kovo) assemblage of small mammals. Comparison of the faunal assemblage in question with faunas of the Oka glaciation is impossible, since it is lacking any cold-resistant species. Faunas of the earlier Muchkapian interglacial differ from that under consideration by the presence of tooth-rooted vole forms from the genus *Mimomys (M. savini = M. intermedius), Microtus (Stenocranius) gregalis*, and *M. (Terricola) arvalidens*. The stratigraphic position of the layer with bone remains in the Rybnaya Sloboda section confirms the reliability of correlation between this locality and the Likhvinian warming episode, i.e., with the onset of the Middle Pleistocene. Faunas close in their evolutionary level are described from localities in West Europe. They are attributed to the Holsteinian interglacial and correlated with MIS 11 (~430–360 ka ago) (Markova, 2004).

Morphological structural features and data on the grain size and chemical compositions of the Inzhava soil in the Razdol'nyi section indicate eluvial–illuvial differentiation of its profile. Maximum concentrations of Fe–Al oxides are recorded in horizon Bt (Fig. 2). The bleached horizon AB is characterized by minimum contents of iron oxides, which decrease downward. The content of aluminum oxides is minimum in the humic horizon and increases beginning from the transitional horizon. The soil is characterized by low concentrations of fulvic and humate–fulvic organic matter with the low content of humic acids closely associated with Ca and relatively low optical density of humic acids. All these data indicate the leading role of the eluvial–illuvial differentiation processes that are characteristic of a wide spectrum of recent forest and forest–steppe soils. The largest part of the Likhvinian interglacial was characterized by the milder climate as compared with the present-day one. The formation of the soil cover occurred in forest–steppe landscapes under the thermophilic vegetation of the subboreal belt. The gray forest soils (leached chernozems) could serve as their close present-day analogs.

The horizontally bedded low-carbonate (CO_{2carb} 1.6–1.9%) fine-grained sands, sandy loams, and aqueous loams significantly transformed by cryogenic processes during the Oka glaciation served as soil-forming sediments. They are characterized by discrete distribution in the section investigated only in some excavations (Fig. 1). They are dominated by the fine-grained sand and silt fractions. Contents of the pelite and silt fractions are only insignificantly elevated in the middle and basal parts of the section, respectively. The organic matter (C_{org} 0.09–0.22%) and carbonate concentrations are relatively low and only the upper part of the section (at the boundary with the overlying fossil soil) demonstrates elevated contents of carbonates (CO_{2carb} 3.57%). The absorbed cations are represented by Ca and Mg with the significant prevalence of the former element. The absorption capacity is low (8.9–12.4 mg/equiv/100 g sediment). The sandy loam–loam material is enriched with Fe. In periglacial areas of the East European Plain adjacent to the study region, landscapes reconstructed for this period are characterized by severe climatic conditions. The development of periglacial landscapes of the Oka time is evident from the wide distribution of the Arctic and common lemmings, whose distribution areas reached 50–55° N (Markova, 2004).

The sediments in question are underlain by Permian brownish crimson clays. They are dominated by fine fractions with the pelitic one demonstrating maximum concentrations for the entire section. They are characterized by highest values of the bulk (7.79%) and mobile Fe and low concentrations of humic matter (C_{org} 0.1%) and carbonates (CO_{2carb} 1.98%). The absorbing complex is almost completely saturated by bases with the distinct dominant role of Ca. The cation exchange capacity is substantially higher as compared with that in the overlying sediments being as high as 23.6 mg/equiv/100 g sediment (Fig. 2).

Comparative analysis of the composition of recent sediments constituting the Razdol'nyi section revealed that loess-type sediments corresponding to different cold Pleistocene epochs differ from each other in the composition, although they demonstrate some similarity in the proportion-variable presence of the silt fraction, carbonate salts, and organic matter. The thickest horizon of loess-type loams and sandy loams sandwiched between the recent and Bryansk fossil soils corresponds to the epoch of the late Valdaian glaciation and maximum cooling episode for the entire Pleistocene. With respect to their grain size composition, these sediments are dominated by the coarse silt and sand fractions. They are characterized by the highest carbonate and lowest humic matter contents as compared with older loess horizons. The loess-type loam horizon underlying the Bryansk soil and overlying the Mezin pedocomplex represents a thin member formed during the early Valdaian glaciation accompanied by activation of permafrost processes: deformations of phase "a" of the Smolensk cryogenic horizon (Velichko et al., 1997). Unlike the overlying horizon, it is dominated by the sand fraction with a subordinate share of the silt and pelite fractions. The sediments are characterized by the lower carbonate and higher humic matter contents as compared with the overlying loess horizon. The thin sequence of loess-type sandy loams, loams, and sands of Dneprovian age sandwiched between the Late Pleistocene Mezin pedocomplex and Middle Pleistocene Romny fossil soil is dominated by the silt fraction with the subordinate share of pelite and sand fractions. These features make it different from Late Pleistocene varieties. It exceeds Late Pleistocene loess in terms of the carbonate content and is similar with the latter in the humus concentration.

The study of primary properties of Middle Pleistocene loess horizons is complicated by certain difficulties. This is explained by the fact that the loess–soil series, which represent alternating soils and host loess, contain thick horizons of fossil soils and pedocomplexes. The pedogenic processes also involved the underlying loess horizons. Therefore, unaltered Middle Pleistocene loess horizons are virtually missing in the section. The sole exception is represented by a thin horizon of loess-type loams sandwiched between the Romny and Kamenka fossil soils. In contrast with Upper Pleistocene varieties, it is characterized by the clayey–silty grain size composition, low concentrations of humic matter, and relatively high carbonate contents.

The comparative analysis of Late Pleistocene interstadial soils (Bryansk and Krutitsa units representing the upper soil of the Mezin pedocomplex) reveals some similarity in their grain size composition, which is characterized by the dominant role of the silt and pelite fractions constituting together more than 50% of soils. They also demonstrate the highest concentration of fine and medium dust. As compared to interglacial soils, the interstadial sediments are inferior in terms of the share of sand fractions but superior in terms of organic matter and carbonate concentrations.

The typologically different interglacial soils demonstrate different grain size compositions. For example, the content of the pelite fraction in the Inzhava soil of the Likhvinian interglacial significantly prevails over its concentration in the Kamenka and Mikulino fossil soils. Other parameters of the grain size composition exhibit less notable differences. The Kamenka fossil soil is characterized by the highest carbonate concentration among interglacial soils, while the Inzhava soil is inferior to other different-age soils by the content of organic matter.

CONCLUSIONS

The thorough complex investigations of the Pleistocene Razdol'nyi section made it possible: (1) to carry out stratigraphic subdivision and facies–genetic discrimination of recent sediments distributed beyond the ancient ice covers; (2) to characterize the general structure of the subaerial sequence and regional features of loess–soil series corresponding to the known Middle and Late Pleistocene climatoliths; (3) to trace the trend of pedogenic processes during four interglacial and two interstadial epochs; (4) to reconstruct the complex dynamics of environmental changes during the last ~450 ka; and (5) to specify some known aspects of stratigraphy and paleogeography of recent sediments in the eastern segment of the Russian Plain concerning, for example, the loess–soil formation widespread in the lower Kama River basin, which remain poorly investigated and, thus, practically undivided into stratigraphic units. In general, the obtained data correlate with similar materials from adjacent areas and provide grounds for extensive paleogeographic reconstructions and interregional correlations.

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