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GEOGRAPHY

Structural Specificity of Pleistocene Loessial and Soil Formation of the Southern Russian Plain According to Materials of Eastern Priazovie

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Eastern Priazovie is one of the primary regions for identification of the succession of the Pleistocene landscape–climatic cycle within the limits of the arid zone of southern European Russia. Here in a number of sections of the high coasts of Taganrog Bay, subaqueous sedimentation (alluvial brought by the Don, estuary, and estuary-marine of the Sea of Azov) overlapped by subaerial sediments related first of all to loessial and soil formation. Despite the more than one hundred year history, these sections have been studied unevenly: studies of subaerial subaqueous sediments are more advanced. Recent complex application of lithological, paleontological, and geomagnetic methods served to genetically differentiate and reliably classify subaqueous sediments into the series of terrace levels with different ages. A substantially smaller order is specific for genetic and chronological interpretation of loessial and soil sediments deposited on these levels. To identify reliable succession of loessial and soil cycle shifts within the Pleistocene period, it would be necessary not only to determine individual properties of soil horizons in the individual section but also to identify their spatial and genetic consistency (stability) and, what is especially important, to obtain paleontological data for individual horizons that would serve to estimate their chronological position.

To solve the specified problem, in 2003–2007 a group of basic sections (Shabelskoye, Port-Katon, Semibalki-1, and Semibalki-2) located along the southern coast of Taganrog Bay between Yeisk and Seminbalki was studied. Selection of the specified sections was determined by two prerequisites: (1) the available data including that obtained by the authors [1] have shown that, at the geomorphological levels to which these sections are dated, subaerial sediments represented by the loessial-soil complex are characterized by maximum completeness of the structure within the Pleistocene of the whole Eastern Priazovie; (2) underlying these sediments subaqueous sedimentation is divided into three terraces: the earliest is the Nogaisk and Taman fauna complex (eopleistocene) and two others attributed to the lower Pleistocene–Plato with early Tiraspol and Voznessensk and late Tiraspol fauna complexes [2–4], which allowed us during the preparatory stage to gain insight into the lower age boundary of subaerial sediments deposited on the terraces [5].

Investigation of proper loessial-soil series (LSS) in the key areas within the specified terraces served to determine the characteristics of the soil forming processes of individual soil complexes (SCs) and carry out their correlation with the use magnetic characteristics.

Sections of Eastern Priazovie correlate quite well on magnetic susceptibility (κ). An important datum point for the correlation of the studied sections is κ of the Voronskoye SC characterized with maximum values of this parameter (up to $981 \cdot 10^{-3}$ SI/G). The largest values of magnetic susceptibility in Voronskoye SC may be considered as a regional criterion for the correlation of the formation of loessial-soil sections of Eastern Priazovie (figure). Somewhat less precise correlation on κ of the Inzhavin and Kamensk SCs is realized. Mezinsk SC, which is more precisely compared with the later, is distinguished by a "peak" in all the studied sections (up to $704 \cdot 10^{-3}$ SI/G).

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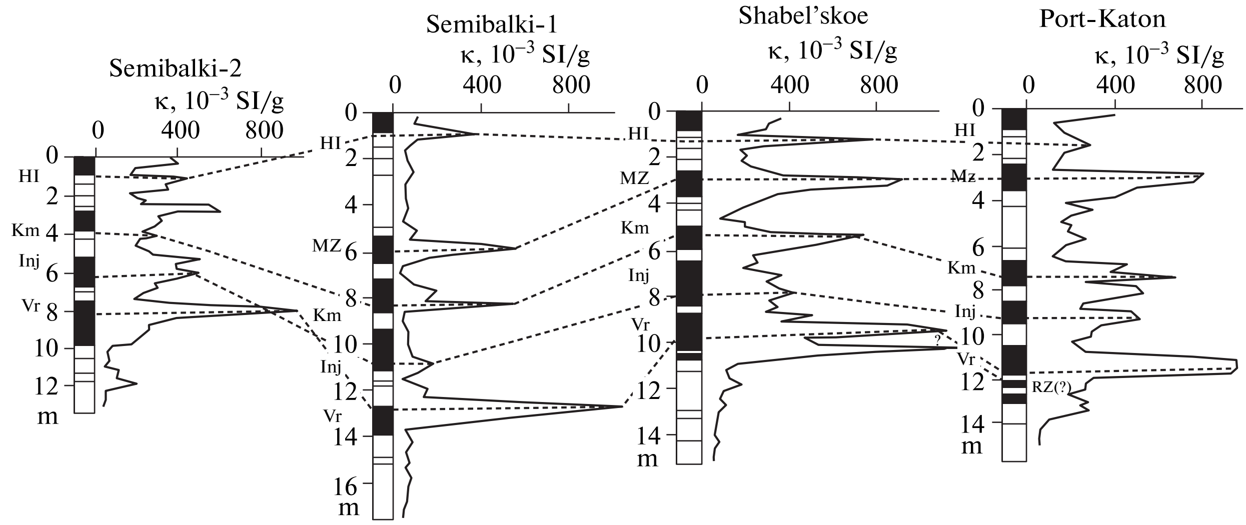

Correlation of sections according to the data on magnetic susceptibility change κ.

Paleomagnetics component analysis of In rocks, including stepped thermal demagnetization of the samples to 550°C, has shown that incline (*D*°) changes within the limits of 344–19°C and declination (*J*°), from 55 to 63°C. This gives grounds to rank the loessial-soil sediment of the Northern Priazovie as not older than the age limit, i.e., the boundary of the Matuyama–Brunhes chronologies (780 000 years).

On the basis of comparative analysis of the morphotypical properties of these SCs with the ones determined for multi-age SCs of central regions of the Eastern European periglacial area [6], the following SCs were discerned (from top to bottom): Mezinsk (main phase is compared with the Mikulinsk interglacial period), Kamensk (main phase is the Kamensk interglacial period), Inzhavin (main phase is the Likhvinsk interglacial period), and Voronskoye (main phase is the Muchkapsk interglacial period).

At the same time, detailed field and laboratory studies have shown that the lowest part of LSS on each of terraces VI, V, and IV is characterized by some specific features in its structure connected with chronological differentiation.

The least complex structure is specific for the lower part on the terrace of late Tiraspol age, the level of which is observed along the eastern outskirts of Semibalka-2. Here in LSS sedimentation (Semibalka-1 section) under the loess level where Inzhavin SC is developed at the depth of ~12.5 m, there is a soil level with signs of a red bed of formed soil with a thickness of ~0.6 m considered as Voronskoye SC. Its horizon A represented by red-brown loam changes lower to the carbonate-molehill horizon B, the main part of which is developed directly on the clay-sandy alluvium of the terrace level proper.

Correlation of the Voronskoye SC and alluvium allows assuming that its formation was bound with the completion of the Tiraspol chronological stage, which fully complies with the position of this soil complex in other key reference sections of the Tiraspol chronological interval in Eastern Europe, such as Korostylevo in the Don basin and Kolkot ravine on the Dniester. This serves to tie the formation of the Voronskoye SC in Priazovie to the Muchkapsk interglacial period [7, 8]. Fauna of small mammals from this level include *Eolagurus* sp., *Lagurus* ex gr. Transiens-Lagurus, *Microtus* cf. *arvalidens, Spermophilus* sp.

A more complex structure is specific for the Voronskoye SC on terrace V (Plato) attributed by N.A. Lebedeva [2] to the main, i.e., earlier, part of the Tiraspol period. Fauna of small mammals from alluvial sediments underlying LSS near the villages of Semibalka and Plato belongs to the first half of the Tiraspol complex [9, 4]. Here in the sections of Semibalka-2 and Shabelskoye soil profile, Voronskoye consists of dark gray horizon A with a reddish hue (thickness 0.5–0.7 m) and horizon B in the upper part represented by loam with a red-brown color and molehill marks with high saturation by carbonate inclusions in the form of loams with white nodules (white-eye) (thickness 0.6–0.7 m). This level changes to loam of a lighter color (thickness 0.4–0.5 m), and lower there is a new red level (thickness 0.3–0.5 m) reflecting the earlier phase of soil formation. The lower contact of this level is soft, and multiple thin veins penetrate in the lower layer to a depth of 0.5–0.7 m. It is important to notice that the lower underlying layer is represented by loamy clay of a yellowy-straw-color (thickness of about 2 m) which on its habitus has a loessial-like character. In the section of Semibalka-2, this loam changes to greenish gray clays with streaks and lenses of sand with granules of different sizes that belong to proper subaqueous sediments of terrace V. In the section of Shabelskoye, the considered yellowy-straw-colored homogeneous loam is separated from subaqueous, sand, and clay sediments with one-and-a-half meters of dark gray to black clays with a large number of very dense carbonate inclusions that most probably have hydromorphous origin in the conditions of bogged soil crowning the estuary-alluvial complex. It is noteworthy that the upper contact of this layer is complicated by small cracks reaching a depth of 0.5 m and filled with material from the upper lying layer that points to the presence of open day ground, where, without any sign of wash-out, accumulation of the yellowy-straw-colored homogeneous loam started.

According to the lithological homogeneity, the color of this layer, and its involvement in soil formation as parent material, we can assume its subaerial genesis preceding the process of loess formation. Sandy clays in the basis of the section over hydromorphous soil are characterized with the association of small mammals including *Lagurus transiens, Miscrotus gregaloides, Microtus* ex gr. Arvalis, *Eolagurus* sp., *Ellobius* (*Ellobius*) sp., *Spermophillus* sp., etc. This fauna clearly dates the bearing sediments to the second half of the Tiraspol complex.

All in all, we can see that, compared with terrace IV, on terrace V the lower part of subaerial sediment is complimented with significant specificity. Here, along with the much more completely developed upper main part of the Voronskoye SC, presented by the profile in the form of well-expressed horizons of reddish brown color A and red Bca-molehill, below there is one more red level.

A new important component in the structure of the lower part of the subaerial sediment is fixed within the limits of the more ancient terrace VI (Nogaisk). One of the key sections determinative for the Taman age of alluvial-estuary depositions of this terrace [2, 10, 4, 11] is Port-Katon. In its main part, the LSS structure comes to light; it is similar to the Plato terrace up to the point that here, the same as LSS on terrace V, the Voronskoye complex is represented by several phases of soil formation. Its upper main phase underlying at a depth of 11.50 m has dark, brownish gray humus loam (~0.45 m) saturated with newly formed secondary carbonates of the white-eye and molehill type and under it lies one more reddish brown level with white-eye and molehills (~0.4 m) that belongs to an earlier phase of soil formation. However, in the base of the section lower than this earlier phase of Voronskoye complex and the layer of yellowy-straw-colored loam underlying it, in the near-contact zone with sandy estuary-alluvial clays, there is the earliest level of soil formation preserved as a carbonate (in the form of white-eye) horizon (thickness ~0.4 m), saturated with large (to 10–15 cm in diameter) molehills with filling from brownish brown loam.

To obtain age estimates of the considered LSS horizons in the studied sections, a dating method was applied; it is based on aspectual determination of fauna of small mammals according to their bone remains in ancient molehills of the fossil soils. It is known that, despite the small number of bones remains, these findings, unlike the ones brought and redeposited by water currents, have high chronological and paleo-ecological value since they contain information related directly to this period of soil formation [12].

Flushing of molehill material from the earliest level of soil formation separated from the Voronskoye complex by subaerial yellowy-straw-colored loamy clays and presented by the horizon Bca-mole has revealed the following fauna (table).

The obtained association includes *Prolagurus* ex gr. *Panninicus-posterius, Microtin* gen., *Spermophilus* (*Urocitellus*) sp. The evolution stage of the lemming *Prolagurus* transitional from *P. pannonicus* of Taman fauna complex to *Lagurus posterius* of the early phase of the Tiraspol complex sometimes is segregated into the separate specific taxon *Lagurus transilvanicus Lagurus transilvanicus* Terzea, 1989. This form is specific for the so-called Petropavlovsk fauna attributed by different researchers to the Taman or already Tiraspol complexes and tied to the very end of the paleomagnetic period of the Matuyama epoch. From the same sediments (clayey layer sands and hydromorphous soils), remains of the field-vole *Microtus* ex gr. *Hintoni* (primitive morphotype), also clearly indicating the transition period between the Taman and Tiraspol complexes, were obtained.

All in all, studies of subaerial loessial-soil series of the Eastern Priazovie at the terrace levels of alluvial and estuary sediments with different ages, from the Khaprovskii to the late Pleistocene [2, 12, 5, 1, 10, 40], have shown that the most complete LSSs are present in terraces VI, V, and IV (Nogaisk, Plato, and Voznessensk according to Lebedeva).

At all three levels, the consistency of soil complexes reflecting the stages of interglacial soil formation within the Pleistocene is observed. the chronological position of SCs is based on the structure of small mammal fauna from different SCs as well as on the correlation of individual SCs with underlying alluvial-estuary sediments of the late Tiraspol, Tiraspol, and Taman ages.

On the basis of the data on small mammal fauna, it has become possible to determine the beginning time of loessial-soil sediment formation tied with specified terraces and late Taman time.

Data on fauna remains from fossil soils of the studied sections

Layer	Semibalki-2	Semibalki-1	Shabelskoe	Port-Katon
Present-day soil	–	*Lemming Lagurus* sp., ground mollusk *Valvata* sp.	–*	–
Mezinsk SC	–	Ground Squirrel *Spermophilus* sp., lemming *Lagurus lagurus*, lizard *Lacertidae* gen. A g e : late Pleistocene	Insectivorous *Insectivora* gen., ground Squirrel *Spermophilus* sp., ground mollusk *Valvata* sp., *Chondrula tridens*	Lemming *Lagurini* gen., reptiles Reptilia
Kamensk SC	–	–*	Ground Squirrel *Spermophilus* sp., mole-rat *Spalax* sp., lemming *Lagurus* sp., field-vole *Microtus* sp., ground mollusk *Valvata* sp., *Chondrula tridens*	Lemming *Lagurini* gen., field-vole *Microtus* sp., field-vole *Microtini* gen.? lizard Reptilia: *Squamata*?
Inzhavinsk SC	*Spermophilus* sp.	–*	Shrew *Sorex* sp., ordinary field-vole *Microtus* ex gr. *Arvalis*, field-vole *Microtus* sp.	–
Voronskoye SC		Ground Squirrel *Spermophilus* sp, steppe lemming *Lagurus* ex gr. transiens-lagurus, yelow lemming *Eolagurus* sp., field-vole *Microtus* cf. *arvalidens*, *amphibia* Anura, mollusk *Chondrula tridens*. A g e : end of early–beginning of middle Pleistocene, late Tiraspol complex	Ground Squirrel *Spermophilus* sp.	
Earlier reduced SC			*Ochotona* sp., *Spermophilus* sp., *Pygeretmus* sp., *Spalas* sp., *Ellobius* (*Ellobius*) sp., *Lagurus transiens, Eolagurus* sp., *Microtus gregaloides, Microtus* ex gr. arvalis, *Microtus* sp., bones of amphibian and reptiles. A g e : second half of early Pleistocene, Tiraspol complex	Ground Squirrel *Spermophilus* (*Urocitellus*) sp., lemming *Prolagurus* ex gr. *pannonicus–posterius,* field-vole *Microtus* ex gr. *hintoni, Lagurini* gen. A g e : transition from eopleistocene to early Pleistocene (transition from Taman to Tiraspol complex)

Data of paleomagnetic measurements made on the studied sections of all three levels show that all LSSs considered in this publication are attributed to the Brunhess period.

In the LSS structure, we find a consecutive series of soil components reflecting the evolution of interglacial stages of Pleistocene soil formation in the periglacial–loessial zone of Eastern Europe from the Mezinsk (Mikulinsk interglacial period), Kamensk (Kamenk interglacial period), Inzhavin (Lizhvinsk interglacial period), and Voronskoye, main phase (Muchkapsk interglacial period). The fauna structure based on the flushings from the above-mentioned sections agrees with the upper Pleistocene (Mezinsk SC) and middle Pleistocene (Kamensk and Inzhavin SCs) age of the main part of LSSs lying on the three terrace levels considered.

The rank of the early phase of Voronskoye SC requires special investigation; most likely it answers the first optimum of the complex Muchkapsk interglacial period [14], but an independent rank of this phase is also possible.

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