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GEOGRAPHY

Development of the Steppe Zone in Southern Russia Based on the Reconstruction from the Loess-Soil Formation in the Don–Azov Region

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Abstract—Herbaceous communities in forest ecosystems on the southern part of the Russian Plain appeared in the Middle Miocene (~10 Ma BP). In the Late Miocene (~7 Ma BP), feather-grass steppe associations appeared among them. In the time span of 2.7 to 2.1 Ma BP (i.e., in the Early Quaternary, according to the current chronostratigraphic scale), the steppe zone arose on the southern Russian Plain in the Don–Azov Region. Seven stages of this zone development here have been distinguished throughout the Quaternary. The first one (Eopleistocene–Early Pleistocene) was characterized by savanna-like subtropic ecosystems. Then, in the Middle Pleistocene, the temperate zone ecosystems (tallgrass prairie-like steppes) developed here and were followed by steppe ecosystems close to the modern ones in Central Europe. The ecosystems of rich-species forb steppes developed in the Late Pleistocene. Finally, in the optimum of the modern interglacial (Holocene), steppes became similar to the modern ones here, but with a slightly higher precipitation. The general trend is characterized by reduction in heat and water provision and increase in aridization progressing from earlier to later stages.

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The emergence of the steppe zone is the most important event determining the foundation of the whole zonal structure of the modern landscape envelope of the Earth. The southern part of the East European Plain is one of the regions where this process is manifested quite completely. As early as the Sarmatian stage of the Miocene (about 10 Ma BP), these were grass–forb–goosefoot associations among warm temperate and subtropical forests; expansion of such a vegetation type in the Late Sarmatian (about 7 Ma BP) led to the appearance of proto-steppe aggregations. In the Meotice of the Late Miocene (about 6 Ma BP), the feather-grass steppe—true steppe—associations appeared [1]. However, based on the data from alluvial deposits of the seventh marine terrace of the Sea of Azov, steppes with participation of goosefoot, grasses, and wormwood appeared in a narrow zone near the coast only in the Middle Akchagyl (2.7–2.1 Ma BP) [2]; this can be considered as the initial stage of evolution for the steppe zone proper. The existence of arid open landscapes within the limits of the Don–Azov Region in this period is indicated by the faunal composition of the Khoper and Odessa complexes typically represented by animals such as ostrichs, giraffes, and horses [3].

The detailed studies implemented in the reference key points (Fig. 1a) by the researchers from the Laboratory of Evolution Geography (Institute of Geography of the Russian Academy of Sciences) in collaboration with those from the Institute of Arid Zones (South Science Center of the Russian Academy of Sciences), with the participation of colleagues from the Geological Institute, Russian Academy of Sciences, have allowed them to find the chronostratigraphic position of the transition from subaquatic deposits containing the mentioned fauna to early stages of the subaeral loess-soil formation (LSF), and then to trace the evolution stages of the arid zone on the basis of LSF study.

Determination of ages for the particular LSF horizons was based on various data obtained while implementing the works: the correlation between loess-soil series and chronology for the lagoon-marine and lagoon-alluvial deposits bedding in the foot of these series and identified in the Azov Region; on the results of geomagnetic studies; and on the data of faunal com-

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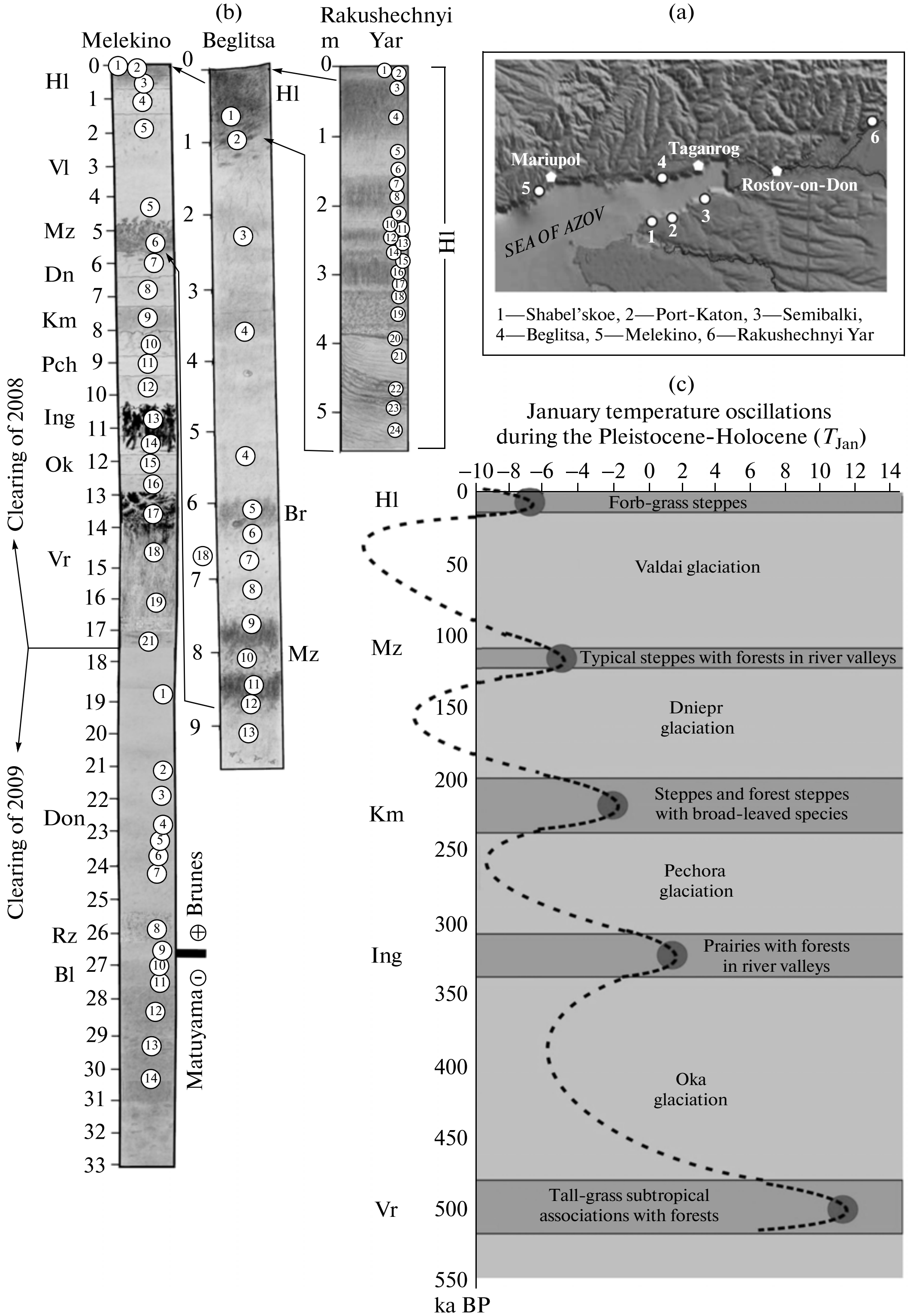

Fig. 1. Development of the steppe zone during the Quaternary (from the data of studying the loess-soil formation). (a) Scheme of reference section positions; (b) structure of loess-soil formation sections (based on field sketching by A.A. Velichko): *Melekino*: B1 is Balashov buried soil, Rz is the Rzhaksa buried soil, Don is the Don glaciation, Vr is the Vorona buried soil, Ok is the Oka glaciation, Ing is the Inzhavino buried soil, Pch is the Pechora glaciation, Km is the Kamenka buried soil, Dn is the Dniepr glaciation, Mz is the Mezin buried soil, Vl is the Valdai glaciation, Hl is the Holocene. In the clearing made in 2008, we found a loess-soil series containing a sequence from Vorona buried soil to the Holocene. An analogous sequence is presented in the Shabel'skoe, Port-Katon, and Semibalki sections. *Beglitsa*: Mz is the Mezin buried soil, Br is the Bryansk buried soil, Hl is the Holocene. *Rakushechnyi Yar*: Hl is the Holocene; (c) the evolutionary stages of the modern steppe zone.

position of small mammals from molecasts of buried soils and the underlying deposits [2–6].

For example, the sections at the Melekino reference point (Fig. 1b) revealed lagoon deposits with fauna of the Odessa complex in the lower part and small mammals of the Eopleistocene (*Lagurodon arankae, Allophaiomys* sp., and *Mimomys pusillus*) in their upper parts. In turn, this lagoon stratum is overlain by two buried soils (Balashov and Rzhaka, according to the names given in the summarized scheme [1, pp. 188–191]); between these soil layers, at the foot of Bobrov loess, the boundary between the Brunes and Matuyama paleomagnetic epochs of 780 ka BP in absolute age has been found [7].

Evolution of the landscape envelope in the discussed region has been recorded in the LSF starting from the Balashovo level and during the whole subsequent interval of the Quaternary. Because the modern epoch (Holocene) is an interglacial one, it is reasonable to trace first the changes in landscape systems and climates of interglacial epochs of the Pleistocene from earlier to later ones. These changes that led to the appearance of the modern steppe zone have been reconstructed using paleopedological, palynological, paleofaunal, and lithological–chemical methods and the method of quartz sand grain morphoscopy as well.

The oldest soil units in the discussed region are two paleosoil levels, Balashovo and Rzhaksa, whose dates are the Late Eopleistocene and Early Pleistocene, respectively.

Balashov buried soil. Am-BCa, about 2 m thick. Humus horizon Am is dark fulvous with reddish tinge, platy structure, ancient molecasts, and fringy lower contact boundary. Humus content is 0.52–0.50%, which indicates a high initial humus share in the paleosoil. Analytically the $CaCO_3$ accumulation horizon is well expressed (the share of calcium carbonate is 15%). The grain-size composition of the soil is heavy clayey (up to 58% silt).

Rzhaksa buried soil. Am-Bm-BCa, thickness of the genetic profile is about 2 m. Am is dark red with brown tinge, contains abundant Fe–Mn smears. Bm is dense grayish brown flaked, containing Fe–Mn smears. Analytical data showed a highly humous soil (0.4–0.5% of remained humus). Carbonate illuvial horizon has not been found from the analyses.

Based on the micromorphological data, fulvous and red tones of the paleosoils are caused by iron hydroxides which were dispersed in clayey plasma as a result of fersialitization and rubification. These features allow us to identify the discussed paleosoils as fersialitic subtropical ones, which are close to red soils forming at winter temperatures of about +12...+15°C and precipitation of 620–670 mm per year.

The overlying *Don loess* (superimposed on the Rzhaksa soil) corresponds to Don glaciation and has a thickness of up to 9 m, which is more than for younger loess horizons. Its grain-size composition is predominantly silty, which indicates a heavy mechanical composition. The humus content is insignificant (less than 0.3%).

The soils of the main phase of the *Vorona soil complex* (Am-Bm-BCa), which is developed on loess of the Don glaciation, correlate to the main optimum of the Muchkap interglacial and the marine isotopic oxygen stage MIS13 (about 470–500 ka BP, Early–Middle Tiraspol). In their profile of about 2 m thick, we have identified the horizons Am (brown to dark gray with reddish tinge, humus–ferruginous–clayey plasma, presence of clayey and clayey-ferruginous units) and Bm-BCa (reddish fulvous, large-blocked, with flake-like precipitation of oxides in the soil fabric). Such properties of paleosoils imply their membership in the group of subtropical savanna soils. Such ecosystems existed under a climate with the January and July temperatures being about +12...+14°C and +24...+25°C, respectively, and the annual precipitation, P_{yr}, being about 550–650 mm (Fig. 1c).

The landscapes of the optimum epoch of the younger *Inzhavino soil complex* (Likhvin interglacial, MIS9, 300–340 ka BP, developed on Korostylevo loess of the Oka glaciation) corresponded to the moderate climatic zone.

In the interfluves, thick (more than 1.5 m), dark gray, initially highly humous soils were formed in this interglacial (the humus content is up to 0.7% even after long-term burial); their soil masses were highly aggregated. These features reflect the predominance of humus-accumulation soil-forming processes in the A-A1-BCa profile. In the lower part of the profile, many sections show clayey papula-like inclusions and rare clusters of iron hydroxides. The soils of such structures were referred to chernozem-like type of tall-grass prairies. In this period, river valleys were occupied in part by forests (alder and birch stands with a small share of dark coniferous species). The climatic parameters were close to the following: January temperatures, 0...+2°C; July temperatures, +22...+24°C; P_{yr} = 600–700 mm.

The soils of the *Kamenka soil complex* (Kamenka or Chekalin interglacial, MIS7, about 190–220 ka BP, developed on Borisoglebsk loess of the Pechora glacial epoch). The genetic profile is 1.1–1.2 m thick, and the sequence of horizons is Am-Bm-BCa. The Am horizon is brown; BCa, light brown with clusters of pulverescent carbonates and their deposition in pores.

Such soil features as a fragmentary microstructure, brown color from dispersed iron, and lamellar-fibrous microstructure of oriented clays argue for the effects of clayization and metamorphization. Additionally, the structure of these soils demonstrates similarity with the present-day brownish gray soils in the Danube Basin, Central Europe, where forest and steppe ecosystems are combined [8]. The climate corresponding to such ecosystems has winter temperatures slightly below zero (about 0...–2°C) and July temperatures about +20°C, P_{yr} = 500–700 mm.

The *Mezin soil complex*, which is developed on Dniepr loess, belongs to the beginning of the Late Pleistocene. The main phase of this paleocomplex corresponds to Mikulino interglacial (MIS5e, 135–117 ka BP). In the near-Azov Region, soils of the Mikulino interglacial are of the chernozem type. Their genetic type comprises A'-A1-B_{mole}-BCa horizons. The humus horizon is dark gray, aggregated. The horizon BCa is abundantly saturated with pulverescent calcite. The characteristic features are also clear bioturbation by soil fauna and abundant molecasts. The obtained data allow us to suggest the predominance of steppes with mainly leached chernozems and meadow chernozems covered with typically steppe vegetation similar to the modern one.

Tree vegetation (birch, alder, hazel, and rarely spruce) remained only in gullies and river valleys. The climatic conditions were characterized by a decrease in winter temperatures relative to the previous Kamenka interglacial (down to –2...–4°C), with further lowering of the annual precipitation (down to 500–600 mm). Summer temperatures were about +20...+21°C.

In some sections of the near-Azov Region, one can see the poorly retained soil horizon above the Mikulino soil; this horizon is preliminarily referred to the Bryansk interval (MIS3, 60–25 ka BP); however, investigation of its genetic properties is not yet complete.

Finally, the youngest interglacial interval is the Holocene (MIS1, its beginning is 10 300 years BP based on the ^{14}C); its postoptimal phase coincides with the present-day period. During the Holocene optimum (at the end of the so-called Atlantic, about 6–5.5 ka BP based on ^{14}C), the soil cover at the zonal level was represented by common chernozems, i.e., a soil type close to the modern ones (common and south chernozems), but differing owing to higher humus and water content. The higher water content is indicated by the zonal vegetation type reconstructed (in the Don downstream), which was species-rich forb–grass steppe, in contrast to the modern type, which is forb–sheep-fescue–feather-grass steppe [8]. The conclusion about more favorable conditions in the Holocene optimum (in comparison with the modern time) is also consistent with the paleoclimatic reconstructions [9]: summer temperatures were close to the modern ones (slightly warmer than them, by about 1–2°C), but annual precipitation grew significantly (by 50 to 100 mm).

The process discussed above of steppe evolution, seen in the clearest way in the state of ecosystems during the Pleistocene interglacial epochs, was not linear. It was clearly discrete for at least one million years, because every stage discussed above of steppe-alteration in interglacial epochs was interrupted by expansion of a special hyperzonal type of open-type extra-arid periglacial ecosystem (semisteppe–semidesert) with the surface being unstable due to quasi-permanent loess accumulation.

The regular alternation (or interchange) of two principally different ecosystem types is a clear reflection of two (to a certain degree, opposite) regimes existing in the landscape envelope. In fact, every subsequent stage of the steppe zone evolution started "from the very beginning."

In general, we observe a settled trend characterized by reduction in heat and water provision and increase in aridization progressing from earlier to later stages.

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REFERENCES

1. *Climate and Landscape Changes during the Last 65 Millions Years (Cenozoic: from Paleocene to Holocene)*, Ed. by A.A. Velichko (Geos, Moscow, 1999) [in Russian].
2. N. A. Lebedeva, Tr. Geol. In-ta AN SSSR, no. 84 (1963).
3. V. V. Titov, *Large Mammals of Late Pliocene in the Northeast Near-Azov Region* (Izd. YuNTs RAN, Rostov-on-Don, 2008) [in Russian].
4. Ivanov, I.V., *Evolution of Soils of the Steppe Zone during the Holocene*, (Nauka, Moscow, 1992) [in Russian].
5. A. A. Velichko, N. R. Katto, A. S. Tesakov, et al., Dokl. Akad. Nauk **429**, 1364–1368 (2009).
6. A. A. Velichko, N. R. Katto, A. S. Tesakov, et al., in *Present Situation and Technologies of Monitoring of Arid and Semi-Arid Ecosystems of the South of Russia* (Izd. YuNTs RAN, Rostov-on-Don, 2010), pp. 52–64.
7. V. V. Semenov, in *Paleomagnetism and Magnetism of Rocks: Theory, Practice, Experiment* (IFZ RAN, Moscow, 2011), pp. 211–214.
8. *Physiographic Atlas of the World*, Ed. by I.P. Gerasimov (Izd. AN SSSR, Moscow, 1964) [in Russian].
9. V. A. Klimanov, in *Climates and Landscapes of the Northern Eurasia in Conditions of Global Warming: Retrospective Analysis and Scenarios* (Geos, Moscow, 2010), vol. 3, pp. 70–86.