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GENESIS AND GEOGRAPHY OF SOILS

Reconstruction of Paleolandscape Conditions of the Early Scythian Soils in the Stavropol Region

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Abstract—The comparative study of humus, carbonate, and phytolithic profiles of dark chestnut soils buried under burial mounds and of the adjacent background territory has shown that the soil cover of Stavropol' region was subjected to strong anthropogenic impacts (grazing) as early as over 2000 years ago. The distinctions in the forms of carbonate concretions and the content of carbonates between the modern and the buried soils attest to more arid conditions during the period of formation of buried soils as compared to the modern climate. At the same time, the main trend of pedogenesis and the functioning of the steppe ecosystem have not changed greatly.

INTRODUCTION

Archaeological monuments, including burial mounds, contain much information, not only on the history of the society, but also on the history of nature, in particular, on the evolution of soils [7].

The burial mound no. 12, as well as the other mounds of the Novozavedenskii grave area, was made during the Early Scythian epoch; according to archaeological evidence, it dates back to the end of the 7th or the beginning of the 6th centuries BC (excavations were performed by V.G. Petrenko, Institute of Archaeology, Russian Academy of Sciences, 1994). The Early Scythian epoch is attributed to the boundary between the Subboreal and the Subatlantic periods of the Holocene; it was characterized by a considerable change in landscape structure at the boundary between the forest and steppe zones in the North Caucasian region [1]. The changes within the limits of the steppe zone proper were much weaker [4]. Paleobotanical investigations in the Northern Caucasus allowed the subdivision of the Holocene into the relatively humid Late Holocene epoch and the entirely hot and arid Middle Holocene epoch (2500–7000 years BP) [3]. The available archaeological evidences support the assumption that this region experienced significant climatic (and environmental) fluctuations in the period from 3500 to 2500 years ago [10]. However, in general, there is not much information on the history of environment and soils in the Northern Caucasus during the Early Scythian epoch. In particular, the role of anthropogenic factors in this history is open to argument. Therefore, the multiple studies of burial mound no. 12 aimed at revealing the paleolandscape conditions of that time are of great interest.

METHODS OF THE STUDY

Various field and laboratory methods can be used for the reconstruction of the paleoenvironment and for revealing the interactions between nature and the socioeconomic human activities. In our study, the following approaches were used:

(1) Investigation of soils and soil cover with the aim of reconstructing the paleoenvironment. The essence of this method consists of comparative analysis of the soils buried under the mounds and those occurring at the surface of surrounding territories. Morphological, physicochemical, and other soil properties and features are taken into account. In order to reveal the pedogenic processes that took place after the construction of mounds, the soils that formed in the material filling the trench along the periphery of the mound were studied as well. Soil analyses were performed according to routine methods [2];

(2) Radiocarbon dating;

(3) Paleobotanical research aimed at the reconstruction of paleoenvironmental conditions (pollen analysis and phytolith research).

It should be noted that the latter methods do not refer to the specific soil methods. However, there are strong grounds for distinguishing the pollen and the phytolithic profiles in the soils in the same manner as the other profiles (humus, carbonate, etc.) are distinguished. These profiles are formed in full agreement with the regularities of pedogenesis; the processes of migration, weathering, and pedoturbation lead to selective destruction, transfer, mixing, and, in part, to specific stratification of paleobotanical material in the soils. Therefore, while interpreting the results of paleobotanical studies,

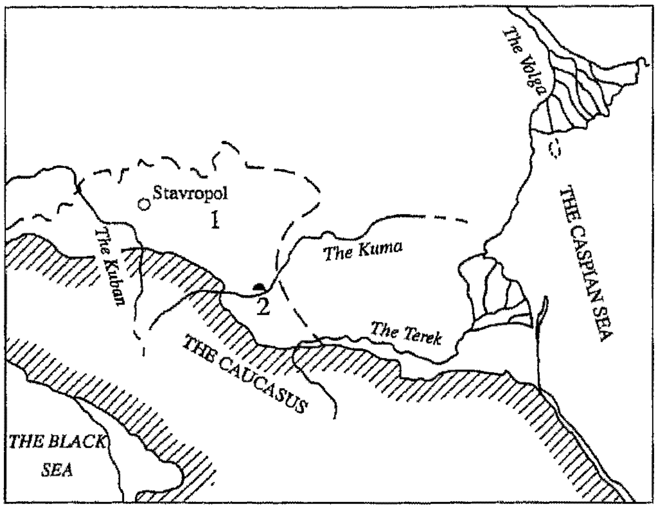

Fig. 1. Location of the studied burial mounds: (1) The Stavropol Upland; (2) mounds.

one should take into account existing pedological concepts.

OBJECTS OF THE STUDY

Landscapes

The region of our studies belongs to the zone of transition from the eastern gentle slope of the Stavropol' Upland to the Terek-Kuma Lowland; it represents a plateau-like lowered surface stretched along the Kuma river banks and is covered by loesses, on which the dark chestnut fine loamy soils have formed.

The group of burial mounds (including mound no. 12) of the Early Scythian epoch is located in the peripheral part of the interfluve on the left bank of the Kuma river, in the upper reaches of the gentle slope of the river valley. The slightly undulating surface is composed of shallow and wide depressions stretching along the general slope in a northwest-southeastern direction and the ridges separating these depressions. The distance between the tops of the ridges reaches 2–5 km. The burial mounds are located on the tops of the ridges; sometimes the mounds are arranged in clusters. In particular, the group of mounds near the settlement Novozavedeno consists of 28 mounds. In the recent past, these mounds were up to 5 m in height.

The vegetation of watersheds and slopes was initially represented by sod-forming gramineous steppes dominated by feather grass, fescue, and Koeleria. Nowadays, most of the territory is plowed; the vegetation is represented by crops with an admixture of weeds.

Radiocarbon Dating

The time of soil burying under the mound was determined from archaeological evidences fairly exactly—the end of the 7th or the beginning of the 6th centuries BC. However, in agreement with the latest data on radiocarbon age, the time intervals of many archaeological cultures, especially of those of the Bronze and Stone Ages, have been considerably refined. There is good evidence to believe that the archaeological age of the Early Scythian epoch should be corrected for the radiocarbon age, or, at least, that all the dates should be correlated with each other. This correlation is especially important in the context of paleoenvironmental studies, because the schemes of landscape and climatic changes are mainly based on radiocarbon data.

The concentration of ^{14}C in the atmosphere was not stable during the Holocene [12]; therefore, the calibration of radiocarbon data is required for determination of the exact age of the objects. Calibrated dates show the exact (calendar) age of the objects and allow refinement of the chronological correlation. Various calibration scales—the Klein scale, the Washington University scale, the Groningen scale, etc.—are widely applied in studies [13, 14]. Most of these scales are based on dendrochronological investigations. The computer program of Washington University enables calculation of probabilistic time intervals and the averaged age in years BC (or in years BP, taking 1950 as the reference year). For the intervals of the strongest fluctuations in ^{14}C concentration, the program suggests several probable age values.

Radiocarbon dating of mound no. 12 and calibration of data were performed in the laboratories of the Institute of Radiochemistry of the Environment (Kiev), the Geological Institute and the Institute of Geography of the Russian Academy of Sciences (Moscow).

Wooden remains and bones from the burial site were used for radiocarbon dating. Two dates were obtained from microsamples. Until recently, samples of 0.5–1 g of wooden and other materials could not be dated by the routine methods, because of the need to use special equipment based on accelerators. These facilities are not available in the FSU countries. However, the new equipment in the laboratory in Kiev allows the determination of radiocarbon age in small samples by the routine method owing to very small dimensions of the furnace and other reservoirs, which considerably reduce the loss of ^{14}C in the course of analysis. The results of determination are given below.

(1) KI-5435. Novozavedennoe site, burial mound no. 12. Wood (chunk from the burial pit): 2670 ± 80 years BP. The age calibrated by the tables of Klein *et al.* [12] is 835 years BC. Calibration by the Washington University program gives two values (for two different curves): (a) 828 years BC (2777 years BP) and (b) 823 years BC (2772 years BP). The averaged age is 825 years BC (2774 years BP).

(2) KI-5436. The same site. Wood from the remains of the pillar at the bottom of the pit: 2590 ± 85 years BP; 717 years BC (calibration by the tables of Klein); 795 years BC (2744 years BP) and 799 years BC (2748 years BP), or 797 years BC (2746 years BP) on

the average (calibration by the Washington University program).

(3) GIN-8298. Novozavedennoe site, burial mound no. 12. Bones from the burial pit: 2590 ± 140 years BP; 717 years BC (calibration by the tables of Klein); 795 years BC (2744 years BP) and 799 years BC (2748 years BP), or 797 years BC (2746 years BP) on the average (calibration by the Washington University program).

As seen from these data, the noncalibrated radiocarbon age is close to the age determined by the archaeological method. However, the dates from different samples differ by 80 years, which is too great for samples from the same pit. The calibrated (calendar) age exceeds the archaeological age by 200 years. The latter age can be corrected for the age of the trees that were used for wooden constructions in the burial pit. This correction rejuvenates the calendar age by 50 years. Thus, the difference between the calibrated radiocarbon age and the archaeologically determined age of the burial constitutes 150 years. The amount of data for the correction of the archaeological age (i.e., for the assumption that the age of the burial mounds and the age of the Early Scythian epoch in the Northern Caucasus are 150 years older than it is believed at present) is insufficient. However, it is worthy to note that the difference between the age of different samples was considerably reduced after calibration and constituted less than 30 years (2774, 2746, and 2746 years BC) as compared to the 80-year difference between the usual (noncalibrated) data). This can be considered as good evidence of the validity of calibrated dates.

RESULTS AND DISCUSSION

Soil Morphology

The studied site, including burial mound no. 12, is located within the zone of dark chestnut and chestnut solonetzic soils, to the west of the boundary with the area of Ciscaucasian micellar-calcareous chernozems of the Stavropol' Upland.

The soil cover of the site is relatively homogeneous because of the homogeneity in soil-forming rocks (loesses) and a small amplitude of heights on the interfluve, to which the group of burial mounds is allocated. Initially, before the cultivation of land and the development of soil erosion, the soil cover of the plot was even more homogeneous. This homogeneity favors the comparative analysis of modern and buried soils and ensures the reliability of paleoenvironmental reconstruction on the basis of pedological data.

The burial mounds are allocated to the elevations of the local relief; therefore, the background soils were studied at elevated positions or in the upper parts of slopes with similar conditions. The comparative characterization of the soil buried under the mound and the background modern soil is given below.

Background Soil

The typical profile of modern background dark chestnut soil was studied in pit Nz-1f, 40 m from burial mound no. 12, on cropland.

A1p (0–30 cm). Dark gray-brown clayey loam; loose; weak medium granular structure (plow horizon). The transition is abrupt, but not contrasting; by color.

A1k (30–50 cm). Dark gray-gray-brown clayey loam; the color becomes lighter downwards; loose; weak to strong medium granular structure; rare carbonate micellar-like neoformations; effervescence is observed from the depth of 35 cm. The transition is gradual.

ABk (50–65 cm). Gray-brown clayey loam; weak medium granular structure; the paths of earthworms and rare gray-brown and dark gray-brown streaks of earth-moving animals (krotovinas) are observed in the horizon. The transition is gradual.

BAk (65–80 cm). Grayish-brown clayey loam; slightly compact; with krotovinas. The transition is gradual.

Bk (80–110 cm). Pale-light brown loess-like clayey loam; loose, structureless, with diverse carbonate neoformations (white eyes (soft nodules of 1–1.5 cm in diameter); carbonate impregnation; small concretions in the paths of earthworms). Krotovinas of dark gray-brown color.

Buried Soil

The surface of the soil buried under the mound of 3 m in height is distinctly marked by the contrast in color between the pale mass of loessial loam, composing the mound, and the dark gray humus horizon of the buried soil. The transition between the covering deposits and the buried humus horizon is abrupt; the thickness of the transition zone does not exceed 2–3 mm. The profile of the buried soil was studied in pit Nz-3p. The depths of the horizons are measured from the surface of the buried soil.

A1kb* (0–27 cm). Dark gray-brown–gray-brown loam with medium granular structure; the upper 5 cm are structureless. Compacted. The upper part of the horizon contains secondary carbonates that were leached from the covering deposits. The morphology of the horizon is complicated by diagenetic (formed after burying) krotovinas and paths and coprolites of earthworms. The transition is gradual.

ABkb (27–45 cm). Gray-brown (grayish-brown in the lower part) loam with indistinct granular structure; coprolites of earthworms. The initial effervescence is observed from the depth of 25–30 cm. The transition is gradual.

* b designates the buried character of the horizon.

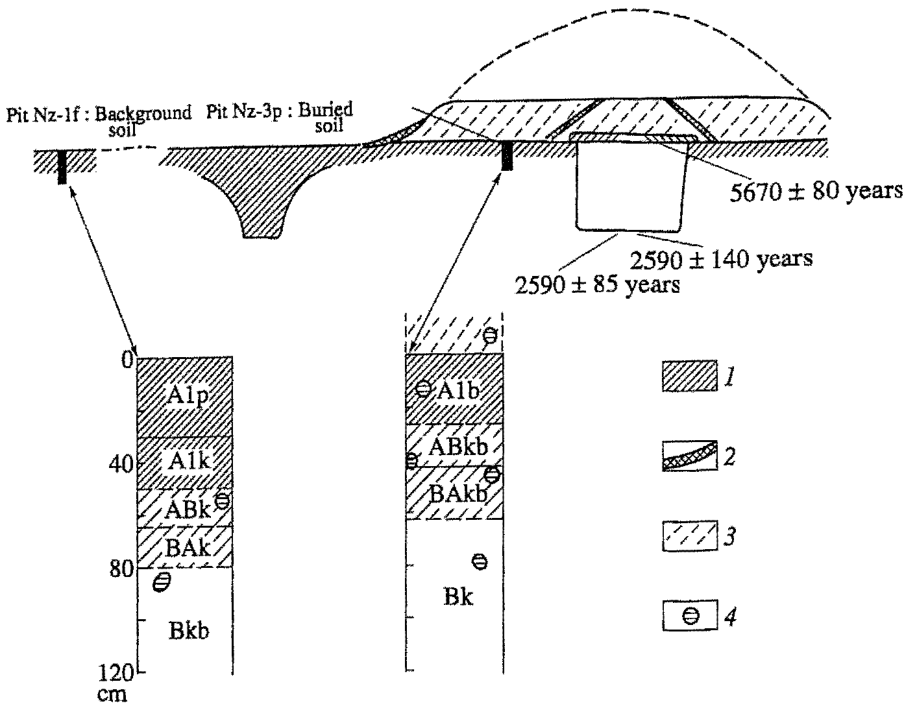

Fig. 2. Schematic drawing of the burial mound and the studied soil profiles: (*1*) humus horizons; (2) the horizon with vertic properties; (*3*) body of the mound; (*4*) krotovinas.

Bakb (45–65 (70) cm). Grayish-brown loam; carbonate-enriched; with weak granular structure; coprolites of earthworms. The transition is gradual.

Bkb (65 (70)–100 cm). Pale loess-like clayey loam; structureless. Abundant concretions of $CaCO_3$ of predominantly small size (3–5 mm) and rare moderately hard nodules (transitional from white eyes to calcareous dolls) are observed in the horizon.

The comparative morphological analysis of the buried and the modern background soils attests to their distinctions, which are manifested both in the thickness of humus horizons and in the depth of soil carbonates (Fig. 2). Humus profile of the buried soil is 10–15 cm shallower than that of the background soil. The relatively lighter color of the modern plow horizon, as compared with the color of the buried humus horizon, can be explained by the effect of humus mineralization under the influence of plowing. (The territory has been plowed for many years; on the map of 1925 this territory is shown as cropland).

The absence of structure in the uppermost 5 cm of the buried soil and the higher bulk density of this soil as compared to the modern soil can be explained both by the effects of diagenetic transformation and by the influence of anthropogenic activity on the surface of the buried soil before the burying. Probably, this influence was connected with the effect of grazing, because the burial mound belongs to the Early Scythian culture of cattle-breeding nomadic tribes.

The carbonate profile of the buried soil differs markedly from that of the background soil by its almost complete absence of soft nodules (white eyes). This, as well as the presence of leached-in carbonates in the uppermost horizon of the buried soil, can be explained by diagenetic processes. At the same time, the increased content of dense small concretions and the higher content of secondary carbonates in general through the whole profile of the buried soil attest to the more arid conditions of pedogenesis in the Early Scythian epoch.

Thus, the burial mound was made on the surface of the steppe chernozem, which was basically similar in its properties to the modern soils; before the burying, the soil could be subjected to anthropogenic load (grazing). The data for the North Caucasian region earlier obtained by us and by other researchers show that the soils buried under the mounds of the Bronze Age substantially differ from modern soils. Therefore, one can conclude that the main changes in morphology of chernozemic and chestnut soils of the region, in particular, the increase in their thickness, took place already before the 7–6th centuries BC. The less durable events, for instance, the increase in the aridity of the climate in the beginning of the first millennium BC, could exert an effect on the relatively changeable soil features, like the status of soil carbonate and soil salt profiles.

The soil that formed on the deluvial sediments filling the trench along the periphery of the mound—the washed-in chernozem with leached carbonates—is distinguished by its greater thickness and higher humus

Table 1. Chemical properties of soils and deposits in the area of burial mound no. 12

Pit no.; soil	Horizon; depth, cm		pH		CO_2 of carbonates, %	Humus, %	Cha/Cfa	N_{tot}, %	C/N
			H_2O	KCl					
Nz-1f (background surface soil)	A1p	0–30	8.6	7.5	1.08	3.15	1.4	0.246	7.4
	A1k	30–50	Not det.		2.61	2.21	Not det.	0.174	7.4
	ABk	50–65	8.8	7.7	4.09	1.52	1.1	Not det.	
	BAk	65–80	Not det.		5.16	1.14	Not det.		
	Bk	80–110	9.0	7.8	5.87	Not det.			
Nz-3p (buried soil)	Mound	30–0	Not det.		4.63	Not det.			
	A1kb	0–27	9.1	8.0	2.62	1.03	0.8	0.096	6.2
	ABkb	27–45	Not det.		3.48	0.98		0.096	5.9
	BAkb	45–65	"		4.85	0.76	0.9	Not det.	
	Bkb	65–100	8.9	7.9	5.25	Not det.			
Nz (soil of the trench)	A1'	60	Not det.		1.28	3.02	Not det.		
	AB'	140–150	"		2.66	1.36	"		
	BA'	250–270	"		4.78	Not det.	"		

content. The thick washed-in humus horizon is traced at the foot of the mound; owing to additional slope moistening, vertic properties have developed in this soil. These properties are manifested in the strong compactness of the soil mass and in the formation of a coarse angular-blocky structure.

Chemical Properties of Soils

Data of chemical analyses (Table 1) testify that the buried soil substantially differs from the modern (background) one in a number of chemical properties. These differences can be explained by the diagenetic transformation of the buried soil and by the initial difference in conditions of pedogenesis.

Carbonates in the buried soil are found 5 to 10 cm higher than in the background soil. This can be partly explained by the inwash of carbonates into the buried soil from the covering deposits; however, the main reason for the higher content and shallower depth of carbonates in the buried soil is the greater aridity of the climate during the Early Scythian epoch. Both soils have an alkaline reaction of soil solution throughout the whole profile, including the uppermost horizon of the background soil with partly leached carbonates. The differences in humus status of these soils can be attributed both to the effect of diagenetic processes and to the initially smaller content of humus in the buried soil (the initial content of humus in the A1kb and ABkb horizons of the buried soil, which was calculated with an account for diagenetic mineralization of humus [7], constitutes, respectively, 2.6 and 2.4%). Evidently, the short-term effect of grazing on the humus status of the buried soil resulted in the decrease of humus content in the uppermost horizon; the initial content of humus in this horizon is assessed at 3%. The loss of humus in the background soil under the effect of tillage and long-term grazing is more pronounced and extends to a greater depth. The initial content of humus in the modern A1p and A1k horizons is assessed at 4 and 2.5–3%, respectively (taking into account the correction for diagenetic processes).

The buried soil is characterized by a lower ratio between humic and fulvic acids. This fact gives us grounds to consider the buried soil within the subtype of dark chestnut soils. The differences in the value of the C/N ratio are mainly explained by the diagenesis of the buried soil.

Paleobotanical Investigation of Soils

The analyses of spores, pollen, and phytoliths* contained in the profiles of buried and surface soils enabled us to reveal the history of the main soil-forming factors (climate, biota, and anthropogenic influence) for the modern period and for the period before soil burying (Table 2). Pollen and phytolith methods complement each other; therefore, we analyzed both the phytoliths and the pollen spectra for each of the genetic soil horizons.

Background soil (pit Nz-1f). Two samples—from the plow horizon (A1p 0–30 cm) and from the lower lying humus horizon (A1 30–50 cm) of the background chernozem—have been analyzed.

The concentration of pollen and spores in all the preparations, as well as the degree of pollen preservation in the soil, were relatively low. Many broken and

* Phytoliths are the opal bodies that form in the cells of plants; they are characterized by specific forms, tend to accumulate in soils and redeposited sediments, and can be used for the purpose of paleoenvironmental reconstruction [5, 8].

Table 2. The results of paleobotanical analyses of soils

Horizon; depths, cm	Phytoliths			Pollen			Reconstruction of the environment
	total amount	share of root phytoliths	vegetation (identification by phytoliths)	total amount	degree of preservation	vegetation	
Background soil (pit Nz-1f)							
A1p 0–30	+ Impoverished composition	+++	Scarce, suppressed; grasses and herbs	+	Poor; deformed shape; partly destroyed	Weeds	Plowland
A1k 30–50	++	+	Suppressed; grasses and herbs with the dominance of feather grass and participation of forest species	+	The same	Weeds and meadow herbs	Grazing; steppe; probable participation of forest species in the past
Buried soil (pit Nz-3p)							
0–2 A1	+ Small; impoverished composition	+++	Sparse, suppressed meadow	+	Poor; deformed shape	Weeds; meadow herbs;	Intensive grazing
2–4 A1	+ Impoverished composition	++	Suppressed meadow	+	Poor; partly destroyed	The same	Grazing
5–10 A1	+++	+	Rich meadow-steppe herbaceous vegetation dominated by feather grass	++	Good	Gramineous-herbaceous meadow with participation of xerophytic species	Steppe
Soil of the trench (pit Nz)							
60	+ Small	+	Herbs and grasses	++	Good	Homogeneous along the profile; similar to that of pit Nz-3p, but poorer in composition	Active sheet erosion and redeposition of sediments in the trench
140–150	+ Small	+	The same	++	Good		
250–270	++ Small	+	Grasses and herbs; predominance of feather grass and participation of forest species	++	Good	Share of weeds and ruderal plants is lower	Steppe; probable participation of forest species in the past

Note: The signs + designate the semiquantitative assessment of the samples (+, small amount; ++, medium amount; +++, large amount).

deformed pollen particles were observed under the microscope. The degree of preservation (completeness) of phytolithic spectra was much better.

Pollen and spore spectra of plow and subplow horizons of the background soil (Fig. 3) are dominated by the pollen of herbaceous plants (59–67%). The species of the Asteraceae (including the *Artemisia* genera), Cichoribaceae, Chenopodiaceae, Poaceae, Polygonaceae, Brassicaceae, Fabaceae, Malvaceae, and other families were identified. Their simultaneous presence in the soil attests to the impact of anthropogenic load on vegetation of the region. Most of the identified species typically develop in an environment disturbed by agricultural activities. The share of pollen of tree species constitutes 27–32% of the total amount of pollen and is represented by the pollen of birch and pine trees. This is conditioned by the great pollen-producing capacity of these trees and by the greatest flying ability of their light pollen particles. Taking into consideration the high degree of agricultural development of the territory and the widespread distribution of croplands, one can

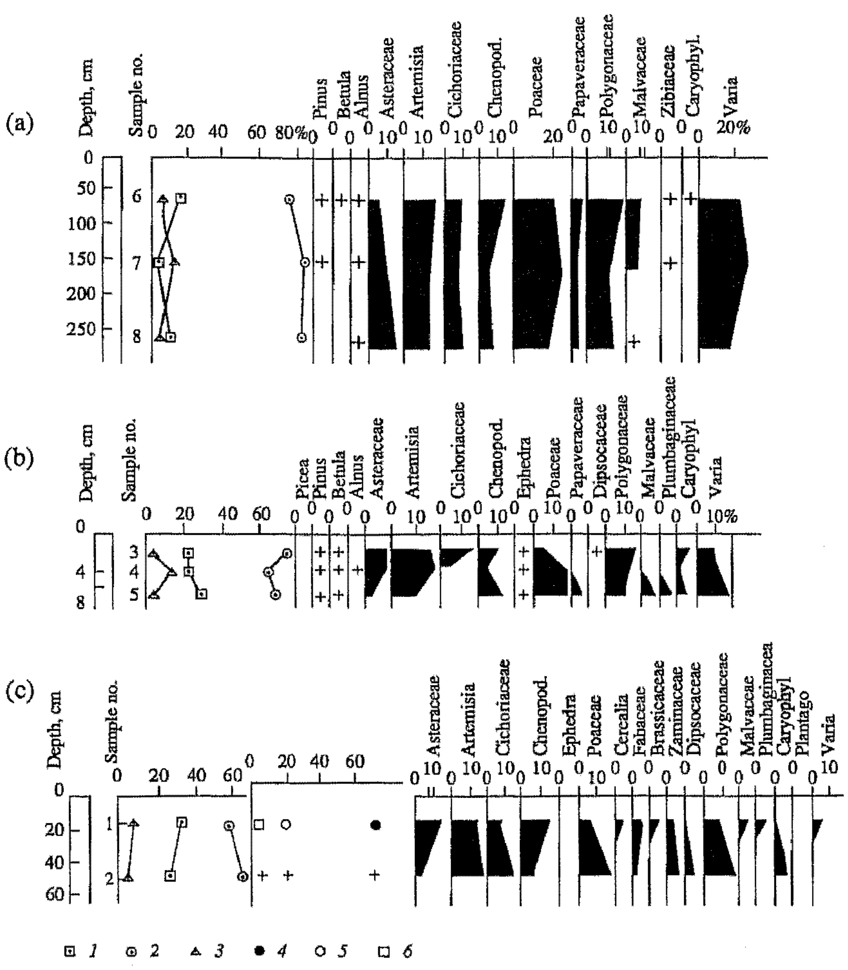

Fig. 3. Spore-Pollen diagrams: (a) background soil; (b) buried soil; (c) soil of the former trench zone; (*1*) pollen of tree species; (*2*) pollen of herbaceous species; (*3*) spores; (*4*) pine tree; (*5*) birch tree; (*6*) alder tree.

deduce that the pollen of trees has an allochthonous origin. It is known that the proportion of allochthonous tree pollen in the general composition of pollen spectra increases with the degradation of the natural plant cover under the impact of grazing and with its substitution by crops. In general, the pollen spectra of background soils reflects the steppe character of vegetation, which was substantially modified by anthropogenic activity.

A more detailed examination of pollen spectra from the two sampled horizons (Fig. 3) allows one to notice some distinctions between them. For example, the pollen spectrum from the lower horizon (no. 2) is characterized by a greater share of pollen from wormwood, chicory, cereals, buckwheat, and statice species, i.e., from plants that prefer more compact soils. The pollen of plantain is identified in this horizon as well. Pollen spectrum of the upper horizon (no. 1) is characterized by a greater species diversity; most of the identified species are typical for the disturbed and ruderal ecosystems. Some of them occur as weeds on croplands (Asteraceae, Chenopodiaceae, Polygonaceae, Fabaceae, etc.). The presence (up to 3%) of pollen of cultural cereals (Cerealia) attests to the predominance of croplands within this zone.

Pollen data testify that the formation of pollen spectrum in the lower horizon (at the depth of 30–50 cm) took place before the extensive cultivation of land. In that time, the territory was mainly used as grazing land. The pollen spectrum of the upper horizon (0–30 cm) has formed within the last 100–150 years, when the territory has been subjected to intensive tillage.

The phytolithic complex of topsoil (0–30 cm) is characterized by the presence of coarse brown fragments of the silicified cuticle layer. However, the species diversity of phytoliths in this layer is impoverished. The phytoliths of herbaceous vegetation predominate. There are also many phytoliths produced by roots. These features of the phytolithic spectrum are characteristic for plow horizons [11].

The subplow A1k horizon (30–50 cm) distinctly differs from the plow horizon in its abundant and diverse phytoliths. All these forms can be colorless, or have black and brown colors. The phytoliths of feather grass and the phytoliths of meadow phytocenoses predominate. The phytoliths of tree species are identified as well, but in very small quantities. Since the lower lying horizons have not been investigated, it is difficult to judge definitely whether these phytoliths were formed *in situ* or were introduced into this horizon from the lower horizons via the earth-moving activities of soil fauna. In general, the phytolithic spectrum of the subplow horizon can be characterized as a steppe one, with an admixture of meadow vegetation. The studies of phytoliths in this horizon do not permit definite judgment on the period of soil development under grazing loads, because following the subsequent plowing, many phytoliths became mixed in the soil matrix and the initial phytolithic complex characteristic for grazing lands was destroyed.

Thus, the phytolith research of the background soil shows the change in the vegetation cover of the site from the initial steppe cover with probable participation of forest species to modern crops.

Data of both paleobotanical methods are in good agreement with each other; they attest to durable and continuously increasing anthropogenic impact on vegetation of the territory and to the changes in the character of land use (replacement of grazeland by cropland). The presence of phytoliths of forest species in the subplow horizon enables us to assume that this territory could have been partly covered by forests before the modern period of active agricultural development. It is important to note that in contrast to pollen, the leaves and other parts of the plants producing phytoliths are characterized by a low ability for distant flight. Therefore, while interpreting the phytolithic spectrum composed of the phytoliths derived from different plant communities (in one sample), we can suppose that such a complex spectrum is the result of stadial changes in vegetation (plant successions) at a given site, and not the result of distant migration, which can be assumed only for pollen spectrum.

Buried soil (pit Nz-3p). In order to trace a detailed record of environmental events before the burying, we sampled the humus horizon of the buried soil by thin layers. The layers from 0 to 4 cm in depth are distinguished by the great specificity of their phytoliths and pollen that attests to the disturbed character of vegetation prior to burying.

The layer of 0–2 cm is impoverished in phytoliths. Most of the phytoliths are very small. The phytoliths of roots predominate over the phytoliths of above-ground parts of plants. Such a proportion is not typical for the upper humus horizons of undisturbed soils; it testifies that the input of above-ground plant remains into the soil was low or that these remains were in suppressed form. The small amount of phytoliths from the above-ground parts of plants belongs to the species of meadow herbs. Evidently, this site was under intensive grazing before the soil burying.

The layer of 2–4 cm is almost identical by the composition of phytoliths to the one described above. However, the total content of phytoliths and the share of phytoliths from the above-ground parts of plants are higher. Though this increase is rather small, one can assume that the intensity of grazing during the period of formation of phytoliths in this layer was lower.

Data of pollen analysis of the samples from the depth of 0–4 cm testify that this horizon contains more pollen from plants which grow on disturbed sites (the families of Cichoriaceae, Polygonaceae, etc.), as compared to the lower lying horizon. Evidently, the disturbance was induced by grazing and by the use of the territory for settlements.

The layer of 5–10 cm contains the maximum amount of phytoliths. The composition of phytoliths in this layer is different from the upper horizon. Thus, the content of phytoliths produced by the above-ground parts of the plants exceeds the content of root phytoliths; the phytoliths of the new shape characteristic for feather grass and other steppe species appear in this horizon. In general, the phytolithic complex can be defined as a meadow-steppe one, with steppe vegetation predominant. At the same time, the proportion between the phytoliths of roots and stems of plants is greater than in virgin steppes, which makes it possible to assume that grazing exerted a certain effect on vegetation in that time as well. The phytolithic complex from this horizon is close in composition to the phytolithic complex of the subplow horizon in the background soil. Probably, both of these complexes reflect the same stages in soil development. However, there are no phytoliths of tree species in the buried soil. Therefore, we can suppose that the forest stage in soil development took place after the creation of the burial mound.

The pollen spectrum from this horizon is dominated by the pollen of cereals and herbs. Pollen of xerophytic plants (*Artemisia*, Chenopodiaceae) is identified as well. The pollen of herbs that prefer meadow conditions and are tolerant to the increased salinity of soils is rather diverse; we have identified the pollen of such families as Papaveraceae, Caryaphyllaceae, Laminaceae, Plumbaginaceae, Dipaocaceae, etc. Thus, we can assume that the climatic conditions of that time were relatively arid. The comparison of pollen spectrum from this horizon with pollen spectra of modern surface soils leads to the conclusion that the impact of anthropogenic activity on the environment was relatively small. For example, both the content and the species diversity of the pollen of herbs, which are referred to ruderal vegetation, are substantially lower in the buried soil.

In general, the upper part of the buried soil was affected by grazing. The degree of manifestation of grazing-induced disturbances in the buried soil increases in the upward direction; this can be seen from the increase in the share of root phytoliths as compared to the phytoliths of above-ground parts of plants and from the occurrence of new specific phytolithic complexes in the topmost horizons. These complexes are notable for the absence of distinct and characteristic forms of phytoliths, which impedes the exact reconstruction of vegetation of that period.

Pollen spectra of all samples reveal the steppe character of vegetation. There are some evidences of a more arid climate in the past as compared to the modern one.

The soil of the trench along the mound is distinguished by its gray color and increased thickness of humus horizon (A1 + AB).

Data on phytolithic and pollen analyses of this soil are presented below. The description is given in the reverse order (from bottom to top).

250–270 cm. Bottom of the trench. This layer, as well as some other layers of the soil that has formed in the sediments filling the trench, is distinguished by the absolute dominance of small forms of phytoliths (falling into the particle-size fractions of fine silt and clay). Scarce large phytoliths (coarse and medium sand fractions) are represented by slightly curved rods with smooth edges and belong to the species of meadow herbs. The small phytoliths are diverse in nature and are composed of steppe, meadow, and forest forms. This can be explained by the deluvial origin of the sediments filling the trench; during the redeposition, phytoliths were subjected to mixing and particle-size sorting. The studies of phytoliths enabled us to identify such plant species as feather grass (steppe phytocenosis), orchard grass and dog's-tail grass (meadow phytocenosis), hair grass, and love grass (forest phytocenosis). Thus, we can assume that the trench was surrounded by meadow-steppe vegetation, probably with some participation of tree species.

140–150 cm. The size-distribution of phytoliths is the same as in the above-described horizon—small phytoliths predominate and large phytoliths are rare in number; however, the total content of phytoliths is smaller. The decrease in the amount of phytoliths could be a result of more intensive erosion and sedimentation processes, so that the eroded surfaces could not restore the initial composition of their phytolithic complexes. The phytoliths of forest cenoses are not observed in this horizon. Phytoliths of feather grass (steppe phytocenosis), orchard grass, brome grass, and Cynosurus (meadow phytocenosis) are identified in this horizon; thus, the phytolithic spectrum attests to the substitution of meadow and steppe phytocenoses for the forest ones.

60 cm. The size distribution of phytoliths is the same; the total amount of phytoliths is smaller than in the above-described samples. This testifies that the vegetation of the site experienced further degradation under the impact of erosional processes. The species composition of the phytolithic complex is similar to that of the underlying horizon, but the share of phytoliths of steppe vegetation (feather grass) is greater. Thus, we can conclude that the filling of the trench with sediments was accompanied by the progressive development of steppe vegetation within the surrounding landscapes.

It is interesting to note that the phytoliths of the soil of the trench zone are represented by two different groups, i.e., by the group of very small phytoliths (smaller than usual) and by the group of very large phytoliths, the former being predominant. This fact can be explained by the continuous sorting of phytoliths during the redeposition of sediments. Small phytoliths, being more easily transported, migrated to a greater distance and accumulated in the central part of the trench. Evidently, the process of accumulation was not continuous. It was interrupted by periods of stabilization of the surface and the development of herbaceous vegetation. These pioneer groups of plants usually have large sizes; correspondingly, the phytoliths derived from such plants had large sizes as well. The absence of medium-sized phytoliths suggests that the periods of stabilization were relatively short, so that the steady-state phytocenoses could not form. The new cycles of erosion destroyed the pioneer vegetation and the new portion of sediments was accumulated on the soil surface.

The diagram of pollen analysis is relatively homogeneous and monotonous (Fig. 3). This testifies that the filling of the trench zone with sediments did not take much time. Pollen spectra are identical to those of the buried soil, although somewhat impoverished in species composition. In contrast to the spectra of modern soil, the content of pollen of ruderal plants and weeds is substantially lower.

Thus, we can conclude that the filling of the trench zone with sediments occurred rather rapidly and was completed not much later than the time of burying, in similar environmental conditions. However, this process was not quite even. The studies of phytoliths in the soil of the trench zone allow us to draw the following picture of vegetation development at this site.

(1) The area around the trench was subjected to continuous sheet erosion leading to degradation of vegetation, which is evident from the distribution of phytoliths in the sediments of the trench zone (a higher content of phytoliths is observed in the bottom horizons) and from the character of pollen spectra.

(2) The development of surface erosion was interrupted by short periods of relative stability, during which the pioneer herbaceous vegetation appeared on the surface. However, these periods were so short that steady-state phytocenoses could not form.

(3) Against the background of erosional processes, the local changes in the composition of vegetation can be traced: the phytoliths of forest phytocenoses are found only in the bottom layer of the soil; in the upper layer, the phytoliths of steppe vegetation (feather grass) dominate over the phytoliths of meadow vegetation. Therefore, the filling of the trench zone with sediments was accompanied by certain changes in the environmental conditions. At the early stage, the additional moistening of the trench zone favored the development of tree species.

Later, as the trench was filled with sediments and dried, steppe vegetation became dominant.

CONCLUSION

Our investigation shows that the studied site has been subjected to anthropogenic loads (grazing and plowing) for more than 2000 years. The intensity of anthropogenic impacts on the soils was not even. There were periods of relative stabilization, when the native vegetation could recover, with a simultaneous improvement of the soil structure and humus status.

The dark chestnut soil buried under burial mound no. 12 is generally similar in morphology with modern background soils and has the same steppe origin. However, it is marked by a lower content of humus, shallower depth of carbonates, and a greater amount of carbonate concretions. These features attest to the more arid conditions that existed for several hundreds of years before the burying. At the same time, the main trend of soil formation at this site remained principally the same, in spite of the variations in climate (in contrast to strong changes that occurred at the boundary between the steppe and forest zones). This is explained by the preservation of the steppe environment and the absence of drastic changes in the functioning of steppe ecosystems.

The complex of morphological, chemical, and paleobotanical data testifies that this site was strongly affected by grazing before the time of construction of the burial mound. However, the anthropogenic disturbance is traced only within the upper 4–5 cm of the buried soil. Below this horizon, the structure and chemical properties of the buried soil do not differ from those of virgin soils. On the basis of data on the rate of zooturbation and accumulation of fine earth fractions on the soil surface, the duration of the period of intensive grazing before the soil burying is assessed at 50–100 years.

The phytolithic spectrum of background soil is strongly disturbed by plowing. The phytoliths and wooden microfossils of forest species lacking in the buried soil are found in the subplow horizon of modern surface soil. Therefore, the development of forest vegetation at the site took place after the Early Scythian time, probably during the period of a relative decrease in the degree of anthropogenic load.

The great amount of phytoliths of forest species in the soil material, which fills the bottom of the trench around the burial mound, points to the local development of forest vegetation during the initial stages of filling the trench, when it had a sufficient depth and served as a water reservoir. After the trench filled with sediments, it became dry; insufficient moistening caused the extinction of forest species, which were replaced by steppe vegetation. The development of sheet erosion and the redeposition of sediments within the trench zone was accompanied by the sorting of phytoliths. As a result, the phytoliths of the trench have a specific size distribution, with a predominance of easily movable small phytoliths and the presence of rare large phytoliths. The latter were produced by pioneer groups of herbs, which developed on the surface during the short periods of attenuation of erosion. This fact may have methodological significance for interpreting the results of phytolithic studies.

Paleophytolithic profiles of soils preserve very valuable information required for the reconstruction of paleoenvironmental conditions. In contrast to carbonate, humus, and other particular profiles of the soils, the pollen and phytolithic profiles usually preserve the initial stratification and contain much information on the species composition of vegetation.

Pollen and phytolithic analyses should be considered as complementary. Owing to the low flying ability of phytoliths, they help to identify only the local vegetation; the presence of complex mixed phytolithic spectra in a given soil layer attests to the stadial succession changes in vegetation.

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