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New aspects of natural science studies of archaeological burial monuments (kurgans) in the southern Russian steppes

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ABSTRACT

Soil-archeological soil studies on the kurgan burial site 'Peregruznoe', located to the north of the Yergeninskaya upland 80 km from the city of Volgograd, Russia, were performed. For the first time, data on the structure of soil cover in the dry steppe zone during Sarmatian times (AD 1) were obtained. From paleosol data it was established that, in the second half of the first century AD, the prevailing humid climate progressively changed to more arid conditions similar to those of the modern time. Using the methodology and theoretical conceptions of archaeological soil science, the age of the monuments investigated was detailed. For one of the kurgans, the original technology involved in erecting the monument was reconstructed and the time of year when construction had taken place was determined. Principally, new information on the details of the funeral rites of the Middle Sarmatian tribes in the Lower Volga region was obtained.

1. Introduction

Integral archaeological study of funereal monuments (burial mounds or kurgans), which preserve ancient paleosols beneath their embankments and may also be considered as natural monuments, is a way of broadening our knowledge and enhancing the efficacy of studies on the evolution of soils and the natural environment, and on the development of human societies (Demkin, 1997; Ivanov and Demkin, 1999; Alexandrovskiy, 2000; Demkin et al., 2004). An opportunity to undertake direct comparative analysis of the status of soils and soil cover dating from different historical epochs enables elucidation of the details of the spiritual and economic life of ancient peoples and the role of the natural environment in the formation, functioning and eventual destruction of past ethnos (Demkin, 1997; Demkin et al., 2001, 2002a,b, 2004). Generalization of field and experimental data accumulated to date has given rise to a new scientific approach referred to as archaeological soil science (Demkin, 1993). The initial objects of study in this scientific discipline were monuments from ancient and medieval history associated with soil-ground materials and, in particular, with kurgan burial sites. These monuments are natural–anthropogenic systems comprising graves with attributes of funeral rites interwoven with man-made ground embankments. The embankments also overlap paleosols originating from the time of the monument's erection. Therefore, such studies are focused on buried paleosols; sub-paleosol depth; surface soils formed on kurgan embankments and adjacent ditches; organic and mineral matter connected with funeral rites; primary and secondary salts; gypsum; new formations of carbonates; and soil-ground mass used as construction materials for the kurgan. To this end, various methods of soil science are applied, including morphological, chemical, biological, microbiological, biochemical, molecular-genetic, mineralogical, biomorphic and isotopic (Demkin et al., 2001, 2004; Alekseeva et al., 2007; Khomutova et al., 2007; Pampura et al., 2008; Ryskov et al., 2009; Demkina et al., 2009, 2010).

In Russia, archaeological soil activities are concentrated on the study of kurgans, while in other countries the objects of study are mainly sites and settlements. This probably determines the Russian specificity of integral studies, with emphasis on questions connected to the spiritual and material cultures of ancient peoples.

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The methodology of archaeological soil science enables us to elucidate hitherto undiscovered details of the stratigraphy of archaeological burial monuments in the steppes of the Lower Volga region; and to reconstruct the technology, original architecture and time of year of erection (Demkin, 1993, 1997; Demkin et al., 2010). This effectively resolves the key questions regarding the relative and absolute chronology of the objects studied.

The key indicators in this respect are the various soil properties and signs (salinity, solonetz signs, value of magnetic susceptibility, humus profile, etc.), the development of which – and their presence or absence – provides clues for estimation of the relative age of monuments in relation to the known existence of particular cultural-historical societies and the timing of monument erection in cases of disturbance and absence of dating artefacts. The application of an assemblage of mineralogical and chemical-analytical methods used in soil science creates the potential to obtain new information on or define pre-existing conceptions on individual attributes of funeral rites (Demkin, 1997; Demkin and Demkina, 2000; Demkin et al., 2004). For example, the identification of funeral food in the pottery and fragments of minerals and rocks found in burials, 'chalky' dressings and whiting – which are often confused with accumulations of readily soluble salts formed *in situ* on the bottom and walls of burial pits and on funeral stocks, are valuable clues.

Recent progress on archaeological soil studies in the steppe zone of Russia, and the development and application of new methods and approaches in the study of kurgans, have allowed us to detail and widen the spectrum of issues resolved in the fields of paleopedology, paleoecology, archaeology and ethnography. A good example of this is our 2009–2011 study on the kurgan burial site 'Peregruznoe', located 80 km to the south-west of the city of Volgograd. Using methods and theoretical concepts of archaeological soil science for the first time, we were able to reconstruct centennial dynamics of climate humidity in the region for the Sarmatian period; to better determine the absolute and relative ages of separate monuments; to reconstruct the technology and elucidate the season of their erection; and to obtain essentially new information on the peculiarities of the funeral rites of the Middle Sarmatian tribes in the Lower Volga region. The key conclusions of these multidisciplinary studies are the aim of the present work.

2. Region, objects, and methods of studies

2.1. Region and objects of studies

The rite of erecting a hill from soil and ground material above the grave and the adjacent surface had emerged by the end of V mil. BC among the Eneolithic tribes of the steppe. Such monuments are known in the scientific literature as burial mounds or 'kurgans'. The funeral rites surrounding the erection of kurgans had existed among peoples of the Bronze (second half IV–II mil. BC), Early Iron (I mil. BC–AD IV) and Early and High Middle Ages (AD V–early XV). Since then, numerous kurgans have become an integral part of the steppe landscape. The paleosols buried beneath kurgans of varying age are promising objects for archaeological soil science, providing an opportunity to increase the reliability and detail of reconstructions of environmental-climatic conditions (Demkin et al., 2012a). The regularities revealed in regard to variability in the morphological, chemical and magnetic properties, and the biological activity of paleosols and their evolution, provide evidence that in the steppes of southern Russia during the past, climate was a key factor in soil formation. The centennial dynamics of climate humidity determined the direction, rate and scale of transformation of soil properties, influenced the intensity and direction of soil elementary processes and spatio-temporal organization of soil cover. Therefore, one of the key tasks of archaeological soil studies is reconstructing the variability of climatic conditions within the historical context. It is known that the validity and detail of environmental reconstructions depend largely on paleo-objects in retrospective investigations, which must meet the following requirements: position *in situ*; integral reflection of environmental conditions; precise, express and inexpensive dating; good preservation of original parameters; location in various landscape-geomorphologic regions; short (days, weeks) transition to conserved state (buried state); availability to register and excavate; and an opportunity to perform complex interdisciplinary investigations and apply various field and laboratory methods. The paleosols of kurgans meet in full all the above requirements. The erection of kurgans was performed continuously by ancient populations of the Eneolith, Bronze, Early Iron and Middle Ages between V mil. BC and early AD XV. Kurgan funeral rites in the steppe territory were generally performed during the period between melting and freezing of soil-ground depth (i.e. early spring to late autumn). Depending on the size of kurgan and number of people involved, its erection required from several days to 1–2 months. In general, the precision of estimating kurgan age and, hence, the timing of soil burial according to the analysis of archaeological excavation materials, was previously no more accurate than one or two centuries, and dating can be performed directly during field examinations. In the Eurasian steppes kurgans are widely distributed; in particular, only in southern Russia does their number reach several hundred thousand. They are located in various regions and are positioned on various relief elements (watersheds, slopes, outliers, river valleys, plain and foothill sites, etc.). They are often found in groups forming kurgan burial sites. As a rule, within the same burial site one can find monuments dating to different historical periods and, taking into account that they are located in the same climatic, geomorphologic, lithologic, geochemical and soil-vegetation conditions, the only difference is the timing of their erection. This provides the potential to study sub-kurgan pedochronosequences. Good conservation of the original properties of sub-kurgan paleosols is provided by peculiarities in the bioclimatic conditions of the steppe zone and the huge (between 2 and 3 m and 50–100 cm) overlapping embankments of semi-spherical shape. This is especially important in regard to the fact that soils integrally reflect the environmental conditions of their formation and functioning within a particular historical period. In studies of sub-kurgan paleosols aimed at reconstructing the dynamics of climatic humidity, various investigative methods are available including soil science, botany, soil microbiology, biochemistry, molecular biology, mineralogy, isotopic geochemistry, analytical chemistry, geophysics, agrochemistry, radiocarbon dating and electron microscopy.

Since 2000, the kurgan site 'Peregruznoe', located near the village of Peregruznoe (Oktyabrsky raion, Volgogradskaya oblast', Fig. 1) has been studied by a joint archaeological soil project of the Institute of Physicochemical and Biological Problems in Soil Science, Russian Academy of Sciences and Volgograd State University. Over 50 kurgans erected during the Eneolith, Bronze, Early Iron and Middle Ages (IV mil. BC–AD XIV) have been investigated. Monuments dating from Sarmatian cultural-historical society were most frequent found.

The final stage of the Bronze Age in the Eurasian steppes was accompanied by destruction of the lifestyle of their ancient populations. The appearance here in the Early Iron Age (from I mil. BC) of nomadic tribes is a unique event in world culture. The nomadic lifestyle was a means of adaptation by people to their environment. Within the historical period under consideration (VI BC–AD IV), the southern Russia steppes were inhabited by the Savromatians and Sarmatians. They left numerous burial complexes, which are the

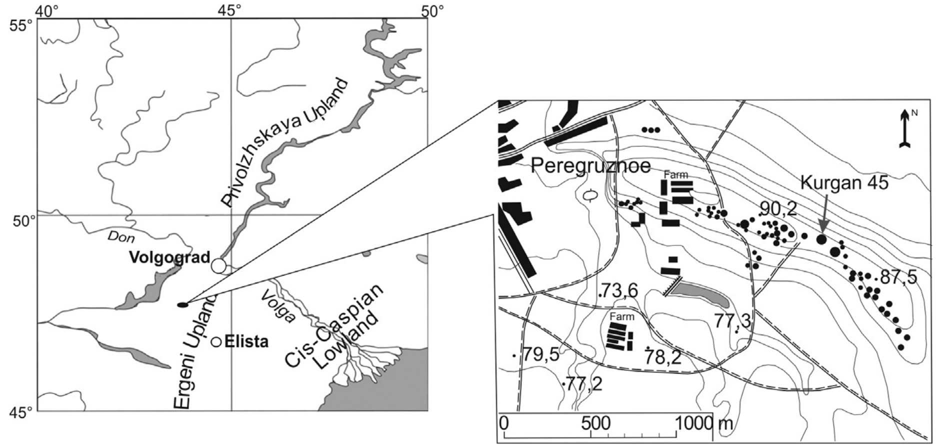

Fig. 1. Location and plan of the kurgan set "Peregruznoe".

main source of information about their history, culture, economy, migrations, etc.

The burial site studied is located on a flat inter-gully watershed of east–west orientation on the western slopes to the north of the Yergeninskaya upland, which runs gently towards the Don River valley. Surface elevation is about 90 m, and the surface here is composed of loess-like carbonate loams with groundwater deeper than 30 m. The natural vegetation cover is fescue–wormwood associations that occupy from 40 to 50 to 80–90% of the soil area. The study region comprises an eastern periphery of chestnut soils (Kastanozems) of dry steppe on the boundary with the desert–steppe zone, where light-chestnut soils are developed. The structure of soil cover is represented by a complex of genetically connected soils: solonetzes (cork, fine, moderate), chestnut (solonetzic, non-solonetzic) and meadow-like chestnut.

Within the 'Peregruznoe' burial site of special interest was one of largest kurgans – N45 – studied in 2010 (archaeological excavations led by Dr V.M. Klepikov, Fig. 2). The timing of kurgan erection was dated to I c. (Middle Sarmatian culture), and this was confirmed by the inventory found which is typical for Middle Sarmatian culture in the southern Russian steppes (Zakharov, 2000; Dvornichenko et al., 2002; Fedorov, 2011). This included a central massive bronze mirror salient with a ridge along the perimeter and right-angled side handle with two holes; a bone spoon with adornment at one end of the handle; two marble ritual vessels; bronze rings with a triple row of kernels along the rim; and an iron 'rod'. The height of the kurgan embankment exceeded 1 m, with a diameter of about 40 m, these dimensions having changed considerably due to anthropogenic impact: on the topographic map of 1961 the height exceeded 2 m. Agricultural activity in the area started in 1969, and undoubtedly the surface underwent melioration with an overcut of upper parts of the embankments. In particular, about 1 m of soil from the central part of kurgan N45 had been cut, and this was confirmed by the presence of an undisturbed soil cover (10–15 cm) buried beneath the tilled and displaced soil-ground layer of more than 30–35 cm. Melioration had also impinged on adjacent smaller embankments, and the upper horizons of several monuments studied were involved in the tilled layer.

Fig. 2. General view of the excavations of the kurgan N45.

2.2. Methods of studies

Opening of the embankment and upper part of the paleosol profiles of the kurgans was performed in either trenches (mechanically) or sectors (manually). Preliminary examination of the opened walls was aimed at estimating the variety of soil cover and choosing the most typical and undisturbed plots for further investigation. Profiles studied were the embankment, buried paleosol and a depth of at least 2 m below the ancient surface, plus simultaneous analysis of the background modern soil beyond the kurgan. Field morphological profile analysis of both buried and modern background soils included estimates of the depth of genetic horizons; their colour and structure; accumulated depth of carbonate, gypsum and salts; forms and number of various new formations; and position of the effervescence line using HCl (Kovda, 1973). Magnetic susceptibility was measured using a field kappameter (KT-6). Levelling of both ancient and adjacent modern background surfaces at intervals of 0.5 m was performed. The definitions of soil horizons were given according to FAO classification (Manual for the soil description, 2012).

Soil samples were collected from each soil horizon, air-dried, averaged, and sieved through a 2 mm screen prior to the laboratory analyses. The content of humus, carbonates, gypsum, soluble salts (sum of the contents of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), pH values, and particle-size distribution were determined by standard methods (Methods of Soil Analysis, 1994). For microbiological analyses, samples taken from AE, Bt, and Bk horizons of modern background and buried paleo- soils were placed into sterile plastic bags and transported to the laboratory. Until measurements were undertaken, the samples were kept in conditions similar to the moment of sampling with respect to moisture and temperature. Total number and relative abundance of microorganisms of different trophic groups of microbial communities in buried paleosols and modern soil were determined. This was done by measuring microbial colony forming units (CFU) by plate counting on three different types of carrier media: (i) rich medium (RM, in 1 l of tap water: 3 g nutritional agar, 3 g peptone, 1 g triptone, 1 g yeast extract, 1 g glucose, 20 g agar; Ananyeva and Vassilieva, 1985); (ii) on soil agar (SA, in 1 l of tap water: 200 g sterile soil, 20 g agar); and (iii) nitrite agar (NA, in 1 l of tap water: 2 g $NaNO_2$, 1 g Na_2CO_3, 0.5 g K_2HPO_4, 20 g agar; Tepper, 1976). All measurements were performed in three replicates and mean values with standard errors for each parameter determined.

3. Results and discussion

3.1. Technology and season of construction of kurgan N45

For construction of the kurgan embankment, ‘solid block’ technology was used. The construction materials were cubic or parallelepiped-shaped monoliths cut from the upper layers of ancient soil. As a rule, these monoliths were from AE and Bt horizons (whitish and brown–grey, respectively) of solonetzes and strongly solonetzic paleosols (Fig. 3). The chemical composition and magnetic susceptibility of these AE and Bt horizons were similar to those of modern analogues observed *in situ* (Table 1). It was recently claimed (Demkin et al., 2010) that such materials could be obtained exclusively at a certain humidity of the upper soil layer. In the study region, such levels of humidity may be reached in late spring (second half of April–May), and this was confirmed by data on the field moisture content of sub-kurgan paleosol and modern soil measured over the first 10 days of April (Table 2). The moisture content of samples of modern soil collected in July was considerably lower, having lost its plasticity and viscosity and become friable, and hence the cutting of solid blocks proved impossible. This led to the conclusion that construction of the kurgan had occurred no later than the end of April–first half of May.

3.2. Paleosols and climate humidity

The embankment of kurgan N45 overlapped ancient soil cover from the Middle Sarmatian time over an area of about 1000 m^2. Soil cover comprised fine and moderate paleosolonetzes and non-solonetzic and meadow-chestnut paleosols. For the first time, such a pattern of paleosols was studied in detail in the steppe region of the Lower Volga. Levelling of ancient surface was performed through five kurgan edges in order to fix the boundaries of various paleosol contours. For the first time, a hypsometric and paleosol skeleton map of a large area (>300 m^2) was compiled (Fig. 4). Maximal vertical drop within the area was 40–45 cm, and the grave pit was positioned on a micro-elevation. Although the micro-relief was indistinct, paleosol properties were sharply contrasted displaying a solonetz complex.

Studies of sub-kurgan paleosols were carried out in a trench about 4 m long and a set of pits. This allowed us to detail the above-mentioned morphological and chemical properties of paleosols and to elucidate the regularity of their spatial variability. Modern background chestnut soils and solonetzes were studied from several pits on a virgin plot adjacent to the tilled area 200 m from kurgan N45. The key results from comparative analysis of the various properties of sub-kurgan and modern soils were as follows (Tables 3–6). Certain morphological and chemical parameters of buried and modern solonetzes and chestnut soils were somewhat similar: particle size distribution (moderate–heavy loamy); depth of humus layer (AE + Bt horizons); position of effervescence line; mean weighed content of carbonates and readily soluble salts (0–150 cm layer); and gypsum (0–100 cm layer). The exception was modern fine solonetz, where the content of carbonates, salts and gypsum was one order higher. Paleosolonetzes were characterized by the sharpest differentiation in silt content in the upper part of the profile, with a ratio between the Bt and AE horizons of about 7. Sub-kurgan paleosols were characterized by higher humus content, and in the AE and Bt horizons it was at least 1.5–2-fold higher than in similar horizons of modern analogues. The pH values of paleosols were lower compared with their modern counterparts, varying within the ranges 7.6–8.4 and 7.9–9.1 in paleo and modern soils, respectively. Of interest was the presence of new formations of Mn of biogenic origin in the illuvial Bt horizon in sub-kurgan solonetzes and solonetzic chestnut paleosols. The content of these new formations decreased in the order fine solonetz > moderate solonetz > solonetzic chestnut soil. In non-solonetzic chestnut paleosols, such new formations were observed sporadically; and in sub-kurgan, no meadow-like chestnut and modern soils were found. Maximal values of magnetic susceptibility (>70 units SI) were fixed in the Bt horizon of paleosolonetzes. Taking into account pronounced differences in particle size distribution and water physical properties between AE and Bt horizons, one possible reason for the generation of new Mn formations might be higher atmospheric precipitation during previous winters compared with more recent ones. In spring, melting snow led to excessive moistening of the upper part of the profile and the solonetzic Bt horizon served as a waterproof layer due to its essential differences from the AE horizon in regard to density, particle size distribution and physical and physicochemical properties. As a result, in the Bt

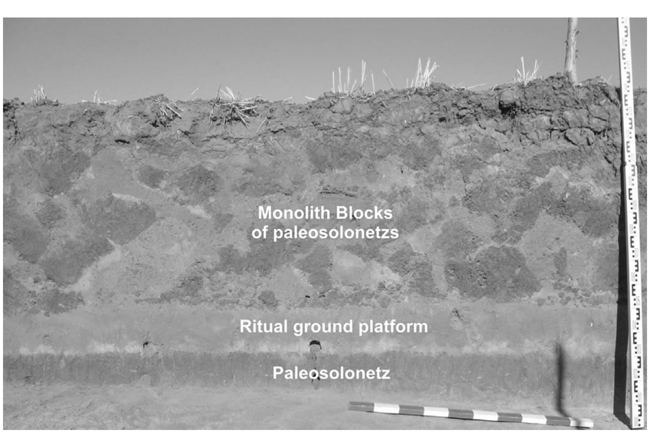

Fig. 3. Profile of the kurgan embankment and sub-kurgan paleosols (central part of the western side of the first eastern edge).

Table 1
Chemical properties of soil monolith blocks from the embankment of kurgan N45.

Horizon	Humus, %	pH_{H2O}	$CaCO_3$, %	$CaSO_4$, %	Silt, %	Clay, %	Sum of salts, %	MS,[a] $n \times 10^{-5}$ SI units
AE	0.82	8.4	0.9	0.00	11	25	0.29	67
Bt	0.81	7.8	2.0	0.00	33	51	0.59	79

[a] MS – magnetic susceptibility.

Table 2
Field moisture content of the sub-kurgan and modern soils (%).

Horizon	Sub-kurgan paleosol	Modern soil	
		April	July
AE	8.9	15.7	2.1
Bt	14.0	23.3	8.7
Bk	13.2	20.4	5.8

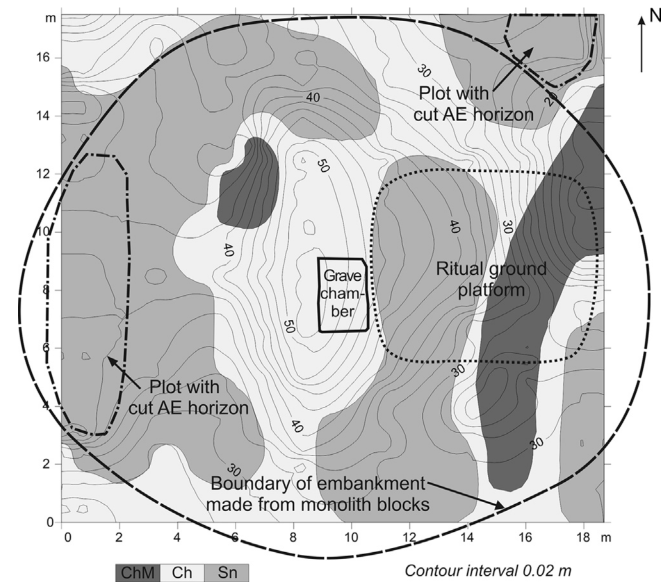

Fig. 4. Topo-plan of ancient surface, paleosol cover, and soil-ground constructions of kurgan N45 (*ChM* – meadow chestnut soil, *Ch* – chestnut soil, *Sn* – solonetz).

horizon a marked change in redox status favoured activation of *Metallogenium* sp. bacteria, in particular Mn-reducers, which in turn conditioned the formation of abundant new formations of Mn oxides.

The relatively high salinity of meadow-like chestnut paleosols is also atypical, as these soils usually are found in micro-depressions. The maximal content of readily soluble salts and gypsum in all soils studied was fixed in the main area of their accumulation on the Cy horizon. This level was 1% and higher: in meadow-like chestnut paleosols it exceeded 9% and its accumulation was observed 50–60 cm deeper compared with other soils. Of particular note were the following details in regard to the profile distribution of readily soluble salts and gypsum in sub-kurgan paleosols. First, the main accumulations were found at the same depth and they had an even, sharp upper boundary. Second, the upper 1 m layer of all paleosols

Table 3
Characterization of sub-kurgan paleosols (kurgan N45).

Parameter	Soils				
	Solonetzes		Chestnut		Meadow-chestnut
No of profile	D-760	D-753	D-754	D-755	D-759
Depth of humus layer (AE + Bt horizons), cm	26	31	32	35	40
Position of effervescence line, cm	23	26	27	25	29
Position of accumulation of readily soluble salts, cm	50	55	90	95	155
Position of gypsum accumulation, cm	95	95	90	95	155
Mean weighed content of $CaCO_3$ (%) in layers:					
0–50 cm	9.1	8.6	9.2	8.1	7.3
0–150 vm	9.0	8.8	9.3	9.1	9.1
Mean weighed content of readily soluble salts in 0–150 cm layer, %	0.71	0.69	0.65	0.61	0.53
Mean weighed content of gypsum in 0–100 cm layer, %	0.06	0.09	0.16	0.03	0.00
Ratio (Bt/AE horizons) of silt content	6.67	6.92	2.80	1.72	2.15
New formations of Mn oxides in Bt horizon	Abundant	Numerous		Single	Not found

Table 4
Characterization of modern soils.

Parameter	Soils		
	Solonetzes		Chestnut
No of profiles	D-757	D-761	D-756
Depth of humus layer (AE + Bt horizons), cm	25	30	32
Position of effervescence line, cm	18	27	28
Position of accumulation of readily soluble salts, cm	55	65	70
Position of gypsum accumulation, cm	90	105	115
Mean weighed content of $CaCO_3$ (%) in layers:			
0–50 cm	10.4	7.7	6.3
0–150 cm	9.9	9.7	9.6
Mean weighed content of readily soluble salts in 0–150 cm layer, %	0.96	0.72	0.40
Mean weighed content of gypsum in 0–100 cm layer, %	0.40	0.04	0.05
Ratio (Bt/AE horizons) of silt content	5.19	3.64	3.54
New formations of Mn oxides in Bt horizon	Not found		

had a relatively high concentration of readily soluble salts (up to 0.5–0.6%) and was leached from gypsum (0.0–0.2%). Third, NaCl was the dominant salt in the 0–100 cm layer (e.g. in the AE horizon its concentration was one order higher than that of sulphates). Such a combination of salts in the profile unambiguously points to a change in the climatic conditions of soil formation, from relatively humid to more arid, at the time of kurgan erection. To the south-east of the Russian plain, aridization of climate was initially expressed as intensification of eolic transfer of readily soluble salts,

Table 5
Chemical properties of sub-kurgan paleosols (kurgan N45).

Horizon, depth, cm	Humus, %	pH_{H2O}	$CaCO_3$, %	$CaSO_4$, %	Silt, %	Clay, %	Sum of salts, %
Fine solonchakous solonetz (pit D-760)							
AE, 89–95	0.42	7.7	0.7	0.00	4	22	0.57
Bt, 95–115	0.56	8.0	2.1	0.00	24	53	0.55
Bk, 115–133	0.40	8.3	18.2	0.00	29	52	0.56
BCk, 133–158	0.15	8.2	13.4	0.00	26	47	0.55
C, 158–183	–	8.2	9.3	0.00	23	38	0.53
Cy,z, 183–270	–	7.8	7.4	0.94	16	29	0.98
Moderate solonchakous solonetz (pit D-753)							
AE, 90–101	0.57	7.8	0.8	0.05	6	24	0.20
Bt, 101–124	1.41	7.9	2.2	0.00	41	57	0.48
Bk, 124–142	0.66	8.4	19.6	0.10	27	52	0.51
BCk, 142–170	0.56	8.2	12.0	0.11	24	44	0.65
C, 170–188	–	8.1	9.5	0.14	24	38	0.50
Cy,z, 188–250	–	7.7	7.8	0.85	18	32	1.03
Chestnut solonetzic deeply solonchakous soil (pit D-754)							
AE, 93–105	0.97	7.3	1.1	0.01	11	28	0.28
Bt, 105–125	1.05	7.8	2.3	0.00	31	46	0.43
Bk, 125–138	0.67	7.8	24.3	0.17	28	53	0.53
BCk, 138–160	0.54	7.9	17.1	0.04	25	42	0.50
C, 160–183	–	7.9	9.8	0.08	21	38	0.42
Cy,z, 183–250	–	7.6	7.1	1.05	18	30	0.97
Chestnut non-solonetzic deeply solonchakous soil (pit D-755)							
AE, 95–107	1.20	8.1	1.5	0.00	16	34	0.28
Bt, 107–130	0.68	8.1	3.3	0.01	28	44	0.34
Bk, 130–145	0.67	8.1	20.7	0.09	30	55	0.53
BCk, 145–170	0.57	8.2	14.4	0.00	26	51	0.47
C, 170–190	–	8.3	10.1	0.02	24	39	0.40
Cy,z, 190–250	–	7.8	7.3	1.17	19	33	0.96
Meadow-chestnut deeply salted soil (pit D-759)							
AE, 104–117	1.70	7.6	1.4	0.00	12	35	0.54
B, 117–133	0.99	7.6	1.4	0.00	26	43	0.44
Bk, 133–144	0.73	7.8	10.7	0.00	26	47	0.46
BCk, 144–165	0.37	7.9	20.9	0.00	27	53	0.59
C, 165–260	–	7.6	8.7	0.00	22	38	0.53
Cz, 260–300	–	8.0	7.1	9.38	13	29	1.58

Table 6
Chemical properties of modern soils.

Horizon, depth, cm	Humus, %	pH_{H_2O}	$CaCO_3$, %	$CaSO_4$, %	Silt, %	Clay, %	Sum of salts, %
Fine solonchakous solonetz (pit D-757)							
AE, 0–5	1.36	7.9	0.7	0.00	6	23	0.03
Bt, 5–25	1.46	8.7	2.4	0.00	33	50	0.16
Bk, 25–40	0.52	8.5	19.8	0.08	25	49	0.62
BCk, 40–53	0.47	8.5	17.0	0.28	26	46	0.64
C, 53–90	–	8.3	10.6	0.00	23	39	0.75
Cy,z, 90–150	–	8.0	8.9	3.42	22	39	1.59
Moderate solonchakous solonetz (pit D-761)							
AE, 0–14	1.44	7.9	0.8	0.00	6	20	0.03
Bt, 14–30	1.13	8.9	2.4	0.04	21	51	0.12
Bk, 30–41	1.10	9.1	15.6	0.12	26	47	0.26
BCk, 41–72	0.35	8.7	15.8	0.12	27	47	0.45
C, 72–105	–	8.4	10.4	0.06	26	43	0.73
Cy,z, 105–150	–	8.1	8.9	1.43	24	41	1.42
Chestnut solonetzic solonchakous soil (pit D-756)							
AE, 0–13	2.55	7.7	1.2	0.00	8	22	0.03
Bt, 13–32	1.01	8.7	1.8	0.00	30	53	0.10
Bk, 32–45	0.89	8.9	13.8	0.05	29	49	0.23
BCk, 45–70	0.38	8.4	17.1	0.14	25	45	0.41
C, 70–115	–	8.4	10.3	0.02	25	41	0.40
Cy,z, 115–150	–	8.0	9.3	0.34	23	43	0.76

mainly NaCl, from the Caspian basin and from the surfaces of numerous solonchaks, with their further accumulation in upper soil horizons (Demkin et al., 2002a,b). Together with this process, as with most labile compounds, chlorides were also accumulated in the upper 1 m of the soil profile due to their upward migration from the accumulation zone in the Cy,z horizon, the latter being sharply intensified during dry climatic periods.

Studies of numerous sub-kurgan pedochronosequences in the dry and desert steppes of southern Russia allowed us to determine a complex of typical paleosol signs and properties reflecting the status and centennial dynamics of climate humidity at various periods of history (Demkin et al., 2010). These include the following: depth of accumulations of carbonates, gypsum and readily soluble salts in the profile; their mean weighed content in the layers 0–50, 0–100 (200) and 0–200 cm, respectively; new formations of carbonates; morphological and physicochemical signs of the solonetz process; presence/absence of new formations of Mn oxides in the illuvial horizon; colour and thickness of the humus layer (AE + Bt horizons); content and composition of humus; structure of humus components; values of magnetic susceptibility in the AE horizon; and composition and structure of soil cover. It has been established that in arid climatic epochs the soil profile of stocks of readily soluble salts, gypsum and carbonates increased and the accumulation line shifted towards the surface; new formations of carbonates were transformed; the thickness of the humus horizon and humus content decreased; eolic erosion and salt impulverization from solonchaks and the Caspian Sea surface intensified; and convergence of soil cover occurred. In addition, during humid periods desalinization of soil depth occurred; the content of humus and values of magnetic susceptibility in the AE horizon increased; actual signs of solonetzes were transformed into residual ones with the preservation of texture differentiation; abundant Mn oxides formed in the Bt horizon; and the process of divergence dominated in the development of soil cover.

We believe that one of methodological approaches for reconstruction of levels of atmospheric precipitation within past historical epochs is based on the actuality principle. This indicates that, from comparative analysis of sub-kurgan paleosols and their modern analogues by taxonomy and classification, the qualitative and quantitative parameters of the content of salts, carbonates, humus, signs of the solonetz process, microbiological activity, etc., we can estimate the annual rate of precipitation in former times relative to that of modern rates. Let us consider such reconstructions based on data from sub-kurgan paleosols in the dry and desert steppes of the Lower Volga region. In this region, a decreased rate of precipitation is regularly seen from north-west to south-east and mean annual rates in the subzones of dark-chestnut, chestnut, light-chestnut and brown semi-desert soils are 400–450, 350–370, 250–280 and 200–250 mm, respectively (Atlas of the Volgogradskaya oblast', 1993). The change in soil subtype mirrors this range, with a general decrease in annual precipitation rate in the subzones of 60–70 mm. Therefore, we may suppose that the evolutionary transformation of soils in this region at the type/subtype level in previous times could have occurred only with a decrease/increase in mean annual precipitation rate of over 60–70 mm. In other words, in regard to all objects from the Sarmatian period, the changes in paleosol properties did not lead to their evolution at either the type or subtype level. Therefore, we may consider that the dynamics of mean annual precipitation rate in the steppes of the Lower Volga region within the time window of 2000–1700 years ago did not exceed ±40–50 mm.

3.3. Relative age of kurgans according to paleosol and microbiological data

In the territory of the northern Yergeninskaya upland, within the 'Peregruznoe' burial site we studied a range of kurgans of the Early (second half II–I BC), Middle (AD I) and Late Sarmatian (AD second half II–first half III) time windows (Fig. 1). Data on the morphological, chemical and magnetic properties of sub-kurgan paleosols pointed to elevation of climate humidity in the region during the period I BC–AD I in comparison with modern conditions. This, together with the elevated chloride content fixed in the upper horizons of the Middle Sarmatian paleosols in the kurgans studied (N42, N44, N45), pointed to the beginning of climate aridization. Moreover, the salt content in the profiles of these paleosols was even and several times higher compared with Early Sarmatian paleosols. Properties of sub-kurgan paleosols of the Late Sarmatian period suggested more arid climatic conditions in the region compared with the previous Middle Sarmatian period (Demkin et al., 2012b). Taking these data into consideration, we believe that erection of the Middle Sarmatian kurgans N42, N44 and N45 most probably took place at the end of AD I–beginning of II, and the paleosol data allowed us to narrow the time window for erection of these monuments to ~1900 years ago. Of interest were the results of microbiological studies of paleosols of the Middle Sarmatian kurgans. We recently demonstrated that the sub-kurgan paleosols of the southern Russia steppes have preserved microbial communities that have existed from the time of monument erection to the present, reflecting the soil-forming conditions of past epochs (Demkina et al., 2000; Khomutova et al., 2007). It was established that the historical changes in arid and humid climatic epochs were fixed in the structure of microbial communities at the ecological-trophic, metabolic and genetic levels (Demkina et al., 2008, 2010). Estimation of the number and ecological-trophic structure of microbial communities in soil profiles of the three Middle Sarmatian kurgans studied allowed us to estimate their relative age. Microbial parameters (Fig. 5) regularly decreased first in the AE horizon, followed by the deeper Bt and Bk horizons. This was conditioned by a stepwise aridization of climate in the second half of AD I. Thus, from paleosol-microbiological data we may conclude that kurgans N42, N44 and N45 of the 'Peregruznoe' burial site were constructed in the above-mentioned sequence,

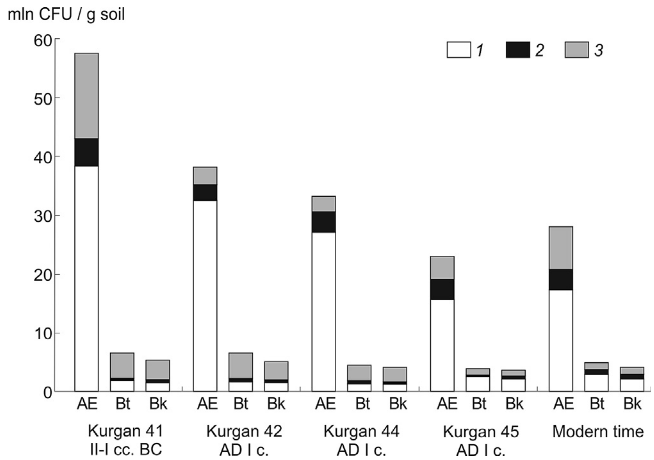

Fig. 5. Number of microorganisms of different trophic groups in AE, Bt, and Bk horizons of the sub-kurgan and modern soils (1 – microorganisms grown of soil agar and utilizing dispersed nutrients; 2 – microorganisms grown on nitrite agar and utilizing not readily available organic matter – soil humus; 3 – microorganisms grown on rich nutrient medium and utilizing readily available organic matter – plant residues).

probably within a time window of 20 years at the end of AD I–beginning of II.

3.4. Reconstruction of funeral rite using natural science methods

Kurgan N45 proved to be unique in regard to its paleosol, and to ethno-archaeological studies. The natural science–archaeological complex approach followed during examination of this monument allowed us to discover a number of important and probably novel details of the funeral rites of the Middle Sarmatian tribes in the Lower Volga region. On the ancient surface in an eastward direction from the main grave (N3), a west–east-oriented ritual ground platform of oval or semi-parallelepiped shape adjoining the border of the grave pit was found (Figs. 3 and 4). Its size was about 10 × 8 m and the depth in the central part was about 20 cm, decreasing towards the periphery to 5–10 cm. Model field experiments demonstrated that the ground platform had been constructed from a homogenous greyish-yellow mixture of AE and C horizons of paleosolonetzes and strongly solonetzic chestnut paleosols. Chemical analyses established that this mixture had a relatively high content of humus, light loamy composition, low carbonate content, absence of gypsum and an insignificant content of readily soluble salts (Table 6). To estimate the proportion of AE and C horizons in ground platform material we prepared a model mixture of the above-mentioned horizons (1:1, Table 7). The chemical composition of this mixture was somewhat similar to that of the ground. However, higher humus and lower carbonate, silt, clay and readily soluble salt contents indicated that the proportion of AE horizon in the ritual platform material was somewhat higher, but did not exceed 60%. This conclusion is supported by simple calculation. The sources of soil-ground material used for construction of the ritual ground platform were analysed. Examination of kurgan edges within the area of paleosolonetzes and strongly

Table 7
Chemical properties of the material from the ritual ground platform and a model mixture of AE + C horizons (50 + 50%).

Object	Humus, %	pH_{H_2O}	$CaCO_3$, %	$CaSO_4$, %	Silt, %	Clay, %	Sum of salts, %
Ritual ground platform	0.72	8.4	2.4	0.00	9.0	25.0	0.33
Model mixture	0.28	8.3	5.4	0.00	14.7	29.6	0.38

solonetzic chestnut paleosols located to the west and north-east of the grave (Figs. 4 and 6) revealed that the whitish AE horizon had been cut down to the illuvial brown–grey Bt horizon. Another source evident was the C yellow horizon taken from the grave pit. Material from this horizon was all used for platform construction because in its original state it was not found at the edges. Material taken from the grave pit was observed to the south of the grave and showed an even mixture of AE, Bt, Bk and BCk horizons of ancient soil. The volume of material used for platform construction was about 12 m^3, as calculated from its dimensions (10 × 8 m) and depth (0.15 cm). The depth of the C horizon opened within the grave pit (2.8 × 1.9 m) was about 1.0 m, yielding a volume of 5 m^3. In this case the AE horizon occupied 7 m^3, or 60% of the total volume of mixed material. Taking into account the depth of the AE horizon (10 cm), the area of cut ancient surface was 70 m^2. In our opinion, this ground platform had ritual funeral significance for funerals, where a leave-taking ceremony took place. After a certain period of exposure, the burial was closed.

The most intriguing item in regard to the natural science study of kurgan N45 is the reconstruction of the funeral ritual. At the bottom of the grave chamber of the main burial (N3), entirely within the wooden construction (partly rested, probably a deck) where the body of deceased was placed, we found a layer of loose material of organic origin comprising fine, oval (mainly 1–3 mm) whitish formations (Fig. 7). Beneath various parts of the skeleton, the depth of this layer reached 5 mm. Microscopically, this formations was identified as the well-preserved dried chitin covers of maggots. It is known that chitin is a hard, stable, decomposable organic compound and may be preserved in soils for hundreds and even thousands years. We failed to identify the species involved in this case, but they may have belonged to the Dipteran families Calliphoridae or Sarcophagidae (Vasil'ev, 2005) that inhabit the steppe zone of Russia. It is known that the presence of a cadaver is the biological signal for its initial decomposition by numerous animals and insects. At hydrothermal conditions providing maximal activity, maggots may completely skeletonize a cadaver in 2–4 weeks (Forensic Medicine, 2008). In contrast, at the threshold temperature (<20 °C) and when there is an oxygen deficit they die almost immediately. In the burial site of kurgan N45, because empty pupa covers were not observed we consider that the biological cycle of fly development had been interrupted at the maggot stage due to such unfavourable conditions (i.e. low temperature, oxygen deficit).

To summarize, we can surmise the following sequence of the funeral ritual for burial in kurgan N45. It started with digging of the grave pit, when the upper horizons of paleosol (AE–Bk) were laid as a mixture in a semi-circle towards the south. Since soil-forming rock (C horizon) had been opened, this was mixed to a homogenous state with material cut from the AE horizon. The soil-ground mixture obtained was used for construction of the ritual ground platform eastward from the grave chamber. Application of such material for construction can be explained as follows. First, the loamy C horizon cemented loose and pulverescent material of the AE horizon, which was leached from the silt fraction. Second, such combination of soil horizons might also have ritual meaning, symbolizing the unity of the domain of the living (root-habitable, 'alive' AE horizon) and that of the deceased ('dead' C horizon). Preparation of the grave chamber and ritual ground platform evidently took several days. Then, on the platform was placed a wooden deck containing the body and implements for the funeral rites. We surmise that the head and a ceramic vessel at the feet were laid on ground 'pillows' for better stabilization. During public display the cadaver was colonized by flies, their maggots commencing active decomposition of the soft tissues at temperatures above 20 °C in an oxygenated atmosphere. However, because

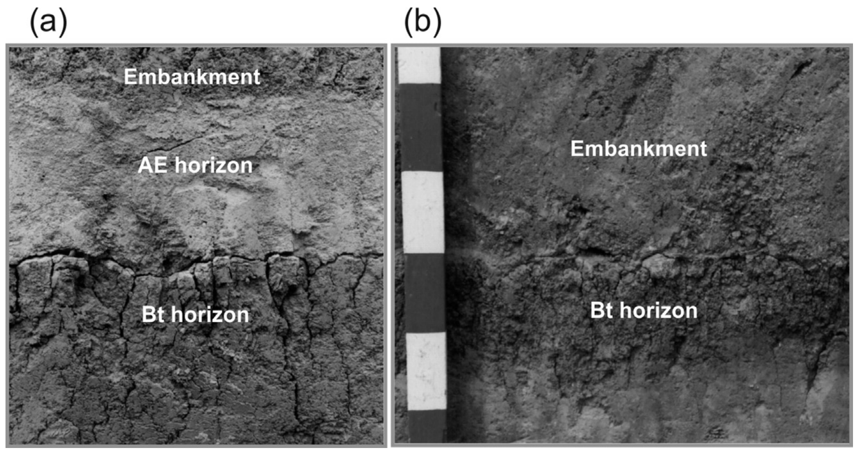

Fig. 6. Sub-kurgan paleosolonetzes with undisturbed (a) and cut (b) AE horizon.

the insect cycle did not reach the pupal stage the cadaver would have been exposed on the ritual platform for no longer than 2 weeks. It was then dismembered, with the skull, several dorsal vertebrae and the feet (with the tibial bones) being removed, and the ceramic vessel broken. The deck, with partly skeletonized and dismembered cadaver, was covered by a mantle adorned with golden patches and placed within the grave chamber. The severed parts of the body, some funeral implements (fragments of iron, silver, bronze items, several golden patches, fragments of wooden and ceramic vessels) and the fragments of the broken ceramic vessel were placed on the wooden cover of the grave chamber. The accuracy of these details of the funeral procedure is supported by evidence derived from the location of fragments of the skeleton and artefacts that were found at the same level (about 20–30 cm from the bottom), of the golden patches, of where the feet (severed and removed) would have been, and from maggot accumulations entirely within the wooden decked area. Under conditions of oxygen deficiency and low temperature (no higher than 10–15 °C), maggots rapidly die and the cycle of development is interrupted. The final stage in the funeral ritual was construction of the embankment above the grave chamber. Taking into consideration the various sizes and execution of monoliths within the embankment, the construction took rather a long time (possibly several weeks). During this period the moisture level in the upper paleosol horizon would have decreased in a stepwise manner, which would have hampered the cutting of blocks and altered their density. The best-defined block-type structure in the embankment was revealed in the profile of the first eastern and western edges, and in the northern and southern parts of the central edge. Therefore, the construction of the embankment had seemingly started from the periphery towards the centre, immediately after placement of the cadaver on the deck of the ritual ground platform. The central part of the embankment above the grave chamber was composed of more dry, mixed soil-ground material with relatively small fragments of AE and Bt horizons.

Fig. 7. Fly larva (maggots) under the microscope.

In regard to the above-mentioned funeral details, also of interest is the excavation of over 60 burial complexes at the ancient centre of the Mochica culture (AD I–VIII) near *Huaca de la Luna* and *Huaca del Sol* in northern Peru (Huchet and Greenberg, 2010). A considerable amount of well-preserved insect remains was recovered here from graves directly associated with human skeletons, suggesting that the corpses had been exposed prior to burial. Using data on funerary archaeoentomology, the post-mortem interval, or duration of exposure of the cadaver to the open air from death to burial, could be determined. The Mochica funeral practice included the rite of release of the soul from the body by flies. This was confirmed not only by observations of fly puparia in burial sites, but also by numerous exceptionally informative pictograms on textile, ceramic and metal goods, sculptures depicting their importance in the funeral ceremony, and economic activity and mythological imagination (Berezkin, 1983; Benson, 1975). It was supposed (Jakobsen, 2011) that the body of the deceased – generally with the lower limbs dismembered – was exposed prior to burial in the open for about 1 month. During such exposure, partial or complete skeletonization of the corpse by maggots and other insects occurred. Burials were performed in adobe chambers, the deceased being covered by a mat placed over the back, together with various funereal inventories depending on social rank. At the end of VII–beginning of VIII the Mochica culture disappeared, probably due to the adverse effects of both natural and social events (Berezkin, 1983). However, according to Spanish chronicles of XVI–XVII (Jakobsen, 2011) ritual, release of the soul of the deceased by flies was also prevalent in later Southern American cultures.

4. Conclusions

Data on the morphological, chemical and magnetic properties of sub-kurgan paleosols obtained provided evidence of elevated atmospheric humidity in the dry steppes of the northern Yergeninskaya upland region within the Middle Sarmatian time window (AD I); this exceeded modern levels by 40–50 mm per year. Together with the increased chloride content found in the upper horizons of sub-kurgan paleosols, this indicates the beginning of the arid period. Studies on sub-kurgan paleosols of the Late Sarmatian time window performed in the Yergeninskaya and Privolzhskaya uplands and Cis-Caspian lowland (Demkina et al., 2009, Demkin et al., 2012b) demonstrated that, during the second half of II–first half of III, the prevailing climate in the region was more arid compared with that in the previous Middle Sarmatian period, with a decrease in mean annual precipitation of about 50 mm. Taking into account these data and the above-mentioned studies on sub-kurgan paleosols, we consider that erection of kurgan N45 at the 'Peregruznoe' burial site took place at the end of I–beginning of II. The morphological and chemical properties of sub-kurgan paleosols, the soil-architectural peculiarities of the kurgan embankment and enhanced insect activity (as evidenced by the abundance of maggots) point to the erection of kurgan N45 having taken place within the first weeks of May about 1900 years ago. The interval between death and burial did not exceed 2 weeks.

Findings from natural science studies have allowed us to investigate archaeological ground monuments in the Eurasian steppes and, for the first time, burial complexes, as a unique historical-natural archive. These man-made constructions offer the potential to acquire diverse information on the Holocene evolution of soils, climate dynamics and the spiritual and economic life of steppe peoples of the past.

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