Biomorph indicators of human-induced transformation of soils under early nomad burial mounds in southern Russia

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ABSTRACT

Biomorph analysis was utilized to study soils buried under early nomad burial mounds (kurgans) in the Orenburg region (southern Russia). Biomorph analysis is the study of the macro- and micro-remains of biota (biomorphs) in the context of the conditions of their origin. The earliest of the studied kurgans (VI–V centuries B.C.) were constructed in an undisturbed meadow-steppe. The subsequent group (IV–II centuries B.C.) was built on a highly disturbed, eroded landsurface that was largely devoid of vegetation and topsoil. After a prolonged break, kurgans again were built in II–III centuries A.D., on a surface where the vegetation and soil cover had partly recovered from human occupation. Our results definitely show the human-induced transformation of soils before and/or during the course of kurgan construction. The grade of disturbance varies in the different historical epochs and reflects the intensity of anthropogenic impact on ecosystems and landscapes. When buried soils under kurgans are used for paleoclimatic studies, it should be taken into account that anthropogenic soil transformation can modify various parameters such as the thickness of the topsoil horizon and thus the depth to carbonate and salt horizons. These changes documented on the basis of morphological and analytical data could be misinterpreted as indicators of climatic change whereas biomorph analysis allows researchers to avoid this mistake.

Key words: biomorph analysis, anthropogenic factor, soils, kurgans, south of Russia.

RESUMEN

El análisis de biomorfos se utilizó para estudiar suelos sepultados bajo montículos o colinas de entierros nómadas (Kurgans) en la región de Orenburg, Rusia austral. Este tipo de análisis consiste en investigar los macro- y microrestos de biota (biomorfos) en el contexto de sus condiciones de origen. Los kurgans estudiados más antiguos (Siglos VI–V A.C.), fueron construidos en una pradera–estepa no perturbada. El grupo subsecuente (Siglos IV–II A.C.) fue construido en una geoforma muy perturbada y erosionada, que estuvo ampliamente desprovista tanto de vegetación como de suelo superficial. Después de un prolongado receso, de nuevo se edificaron los kurgans en los siglos II–III D.C., en una superficie donde la cubierta de vegetación y suelo se habían recuperado parcialmente de la ocupación humana. Definitivamente, nuestros resultados muestran la transformación de suelos inducida por el hombre antes y/o durante el curso de la construcción de los kurgans. El grado de perturbación varía en las diferentes épocas históricas y refleja la intensidad del impacto antropogénico en ecosistemas y paisajes. Cuando los suelos sepultados bajo kurgans se usan para estudios paleoclimáticos, se debe tomar en cuenta que la transformación antropogénica del suelo puede modificar varios parámetros, como el *espesor del horizonte superior del suelo y, por lo tanto, la profundidad de los horizontes de carbonatos y sales. Estos cambios documentados con datos morfológicos y analíticos podrían ser mal interpretados como indicadores de cambio climático, mientras que el análisis de biomorfos permite a los investigadores evitar este error.*

INTRODUCTION.

Pedological methods are widely used in the study of archaeological sites today, and the obtained results often provide a basis for paleoenvironmental reconstruction (Holliday, 1992; Chambers, 1993; Barham and Macphail, 1995; Brown, 1997) A new discipline, archaeological soil science, is quickly developing. In this paper we would like to draw attention of researchers involved in soil archaeological studies to the fact that, as far as burial mounds are artificial constructions, the soils below them are likely to be disturbed by human impact to some extent before or during the course of mound building.

When the disturbance is clearly seen in soil morphology (*e.g.*, cutting away some part of humus horizon) it usually is noticed by a researcher and interpreted correctly. However, if the upper part of the Ah horizon was transformed by the input of organic materials or redeposited due to erosion or overgrazing, it is difficult to identify these changes as human-induced. Ancient anthropogenic soil transformations can change soil parameters, such as the thickness of humus horizons and the depth of carbonate and salt horizons, which are commonly utilized to reconstruct natural environmental and climate change. If the upper layer was transformed, the localization of other diagnostic horizons and features, measured in relation to the ancient upper soil limit, would have also been changed. Additional disturbance after burial (*e.g.*, by soil-inhabiting mammals) further complicates the situation.

Biomorph analysis is the study of the macro- and micro- remains of biota (biomorphs) in the context of the conditions of their origin (Golyeva, 2001). Each of the biomorphs (phytoliths, pollen, diatoms, sponge spicules and others) characterizes the specific conditions of the origin and evolution of a soil profile (Table 1). Multiple biomorph analysis, that includes the study of as many different biomorphs as possible, provides additional information on the genesis and evolution of a soil in natural and anthropogenic conditions. Data from these studies complement each other (Rovner, 1988) and integrated analyses make it possible to reveal an unambiguous picture of the sequence of events in the development of a particular soil feature or soil stratigraphic sequence.

MATERIALS AND METHODS

We studied soils buried under kurgans of Early Iron Age: Savromatian (VI–V centuries B.C.), Early Sarmatian (IV–II centuries B.C.), and Late Sarmatian (II–III centuries A.D.) periods, as well as modern dark Kastanozems. The key sites for our study were burial grounds “Pokrovka 2, 7, 10” located near the village of Pokrovka in the Sol-Iletsk district of Orenburg region, Russia. The archaeological excavations of these burial grounds have been carried out since 1990 under the leadership of Prof. L.T. Yablonsky (Institute of Archaeology, RAS, Moscow). The contemporary climate of the region is continental, with a mean July temperature of $+16^{o}$C, a mean January temperature of -8^{o}C, a mean annual precipitation of 250–300 mm, a thin snow cover in winter, and frequent hot dry winds in summer.

Table 1. Information obtainable from different types of biomorphs.

Biomorphs	Type of interpretation	Comments and additions
Plant detritus Silicified cuticle casts	Recognition of surface horizons of modern and buried soils	In all displacements (vertical, horizontal) break to pieces, the quantity decreases
Diatoms Sponge spicules	Evidence of increased hydromorphism	1-3% (among all silica biomorphs) - are typical in the upper horizons of soils subjected to temporary accumulations of surface water; >5% silt
Phytoliths	Composition and evolution of the regional flora	Accumulates in the topsoil. Their amount is greatest in upper 5 cm (>150 units). Few abundance means erosion, tillage, grazing. Very few units of phytoliths (<10 units) – topsoil removed before burial.

In the course of field studies we observed marked variability in the preservation of parent material properties, due to the post-depositional development of carbonate horizons, the disturbance of buried soils by soil fauna and, sometimes, deep cultivation. These factors hampered the use of parameters such as horizon deepness and thickness, type of horizon boundary (*e.g.*, tonguing of the lower boundary of the Ah horizon), and carbonate content for pedogenic and paleoenvironmental interpretation (Khokhlova and Khokhlov, 2002). For these reasons, we applied biomorph analysis to study ancient pedogenesis.

We collected biomorph samples from buried soils beneath the kurgans, wherever the boundary between the kurgan and the pre-mound soil was clear, distinct, and relatively undisturbed. Such conditions are rare in kurgans and thus we could only sample the buried soils beneath nine of the 150 mounds known at Pokrovka. Wherever possible, we took three sets of samples from beneath each mound. Two samples from the uppermost and underlying horizons were collected from the control profiles, which are classified as modern dark Kastanozems, a type of Mollisol in the USDA classification system.

For biomorph analysis, specimens of phytoliths and other biomorphs were removed from 50 g samples of upper parts of morphologic horizons (0–5 cm). Light soil fractions, including the biogenic fractions, were separated from buried and modern soil samples and treated with 30% H_2O_2 to remove organic matter. The clay fraction was removed and the rest of the specimen was filled with a prepared water solution of CdI_2 and KI, specific gravity 2.3 g/cm^3. After a 10-minute centrifugation, the fraction concentrated in the upper part of the tube was washed with distilled water. A drop (0.5 mL) of each specimen was examined using an optical microscope at 250–300x magnifications. Phytoliths and spicules were counted and the percentages of the main groups were then calculated.

RESULTS AND PRIMARY INTERPRETATION

The main results are presented in the Tables 2 and 3 and Figure 1. The samples from soils under kurgans of the chronological interval VI–V centuries B.C. are characterized by abundance of all biomorph components. The phytolith assemblage presents a peculiar mixture of forms, which is typical for a transition from a forest to a steppe ecosystem. The overall combination suggests pasturage and the input of various phytoliths with animal excrements.

In one of the samples from the third kurgan of the Pokrovka burial complex (sample no. 3) we found very low biomorph content that is not typical for the upper soil horizon. Nevertheless, in two other samples from the same kurgan, biomorphs were abundant, and permitted paleovegetation reconstruction. We assume that sample no.

Table 2. Semiquantitative distribution of biomorphs in the buried and surface soils.

No.	Kurgan group// No. of kurgan	Horizon, depth, (cm)	Detritus	Roots	Cuticle copies	Phytoliths	Diatom	Spicules
VI – V ages BC								
1	2 // 8	[A], 0-10	+++	+++	++	+++	Single	-
2	2 // 9	"	+++	-	-	+++	Single	Single
3	10 // 3	"	++	Single	-	Single	-	-
4	"	"	++	-	Single	+	-	+
5	"	"	+++	-	Single	+	Single	+
IV – II ages BC								
6	7 // 1	[A], 0-5	++	Single	Single	Single	-	-
7	"	"	+	-	-	+	-	+
8	"	"	+	-	-	+	-	Single
9	7 // 9	[A], 0-20	+	Single	-	Single	-	-
10	"	"	+	-	-	Single	-	-
11	"	"	+	-	-	Single	-	+
II – III ages AD								
12	10 // 90	[A], 0-5	+++	+	++	+++	-	-
13	"	[A], 5-10	++	Single	-	+	-	-
14	10 // 63	[A]	++	++	-	+	-	-
15	"	"	+++	++	-	+	Single	-
16	"	"	+++	+++	+	++	+	-
17	10 // 108	[A]	+	Single	-	Single	-	-
18	"	"	+++	+	-	++	-	+
19	"	"	+	Ед.	-	+	-	-
Modern Kastanozem soil								
20	10	A., 0-5	+++	+++	-	+++	+	Single
21	"	A, 20-30	Single	Single	-	-	-	-

Note: +++ = many (>100 particles); ++ = middle (40-100 particles); + = little (5-40 particles); single = 1-5 particles; - = absent.

3 was from a locally disturbed portion of the buried paleosol, where the upper horizon was destroyed during the course of kurgan construction.

All samples from kurgans dating to the interval IV–II centuries B.C. contain very few biomorphs and are not sufficient to reconstruct paleovegetation. Phytoliths are few, most of them are corroded and have signs of redeposition. In samples 7, 8, and 11, up to 30% of silica biomorphs are sponge spicules; these samples have also somewhat higher phytolith content compared to other samples of this interval. High spicule content is not typical for upland soils, but it is usual for lake and fluvial sediments. We believe that ancient peoples brought lacustrine or alluvial deposits to the site as part of the burial ritual. It is highly probable that at least some phytoliths from the spicule-rich samples were also brought in with the human transported lacustrine or alluvial deposits. At present it is impossible to discriminate between these allochthonous phytoliths and those originating from the soil that was buried under the kurgan. Thus, the phytolith assemblages of samples 7, 8, and 11 are not believed to be indicative of the paleovegetation of Pokrovka.

The other three samples from early Sarmatian kurgans are characterized by very low quantities of all biomorphs, including phytoliths. This is not typical for the topsoil here. Since the samples were collected from the uppermost part of the buried soil horizon beneath the kurgans, we conclude that the pre-mound humus was severely disturbed and eroded before earthwork construction.

The data from the samples of II–III centuries A.D. interval produced a rather heterogeneous picture of the paleoenvironments of this period. In some samples (no. 12, 15–17), the quantity and variety of biomorphs is high enough to be typical for upper soil horizons. The phytolith assemblages from these samples indicate unequivocally the presence of meadow-steppe vegetation. On the other hand, some samples from this set have a very low biomorph content with very few phytoliths. This is not at all typical of a topsoil horizon. The overall distribution of samples with a low biomorph content and those with a high biomorph content indicate the localized disturbance of soil and vegetation cover at some sites For those areas exhibiting signs of disturbance, it is worth noting that biomorph frequencies varied in the samples taken from beneath a single mound. We conclude that the soils were disturbed locally only in some parts of the area covered by a kurgan, most probably during the course of mound construction.

The samples from our control profile, the modern surface Kastanozem, exhibit a biomorph assemblage typical for cultivated soils. Few diatom shells and sponge spicules suggest recent and short-term excessive moisture retention at the site, most probably in spring after the snowmelt. The phytolith assemblage is heterogeneous and includes forms characteristic of different ecosystems. We suspect phytolith inputs from organic manures and the excrements of cattle.

Table 3. Abundance (number of grains/%) of silica biomorphs in buried and modern soils.

No.	Kurgan group// No. of kurgan	Total	Diatoms	Spicules	Phytoliths	Dicotyledonous plants	Forest grasses	Meadow grasses	Steppe grasses	Arid grasses	Other forms (incl. mosses)
VI – V ages BC											
1	2 // 8	203/100	2/1	-	201/99	91/45	-	9/5	38/19	8/4	55/27
2	2 // 9	110/100	1/1	2/2	107/97	75/70	6/6	5/5	13/12	-	8/7
3	10 // 3	4/100	-	-	4/100	4/100	-	-	-	-	-
4	"	67/100	-	4/6	63/94	46/73	-	10/16	5/8	-	2/3
5	"	84/100	1/1	8/10	75/89	54/72	-	14/19	3/4	1/1	3/4
IV – II ages BC											
6	7 // 1	6/100	-	-	6/100	5/83	-	-	1/17	-	-
7	"	39/100	-	4/10	35/90*	24/69	-	9/26	2/5	-	-
8	"	25/100	-	2/8	23/92*	17/74	-	5/22	-	-	-
9	7 // 9	2/100	-	-	2/100	2/100	-	-	-	-	-
10	"	5/100	-	-	5/100	5/100	-	-	-	-	-
11	"	10/100	-	3/30	7/70*	3/44	-	2/28	2/28	-	-
II – III ages AD											
12	10 // 90	150/100	-	-	150/100	69/46	-	18/12	24/16	2/1	37/25
13	"	30/100	-	-	30/100	17/57	-	1/3	3/10	-	9/30
14	10 // 63	11/100	-	-	11/100	11/100	-	-	-	-	-
15	"	15/100	3/20	-	12/80	9/75	-	-	3/25	-	-
16	"	80/100	5/6	-	75/94	58/77	-	-	9/12	8/11	
17	10 // 108	48/100	-	3/6	45/94	36/80	-	9/20	-	-	-
18	"	3/100	-	-	3/100	3/100	-	-	-	-	-
19	"	12/100	-	-	12/100	12/100	-	-	-	-	-
Modern Kastanozem soil											
20	10	170/100	4/2	1/1	165/97	97/59	6/4	7/4	17/10	-	38/23
21	"	-	-	-	-	-	-	-	-	-	-

* Most of the phytoliths are corroded

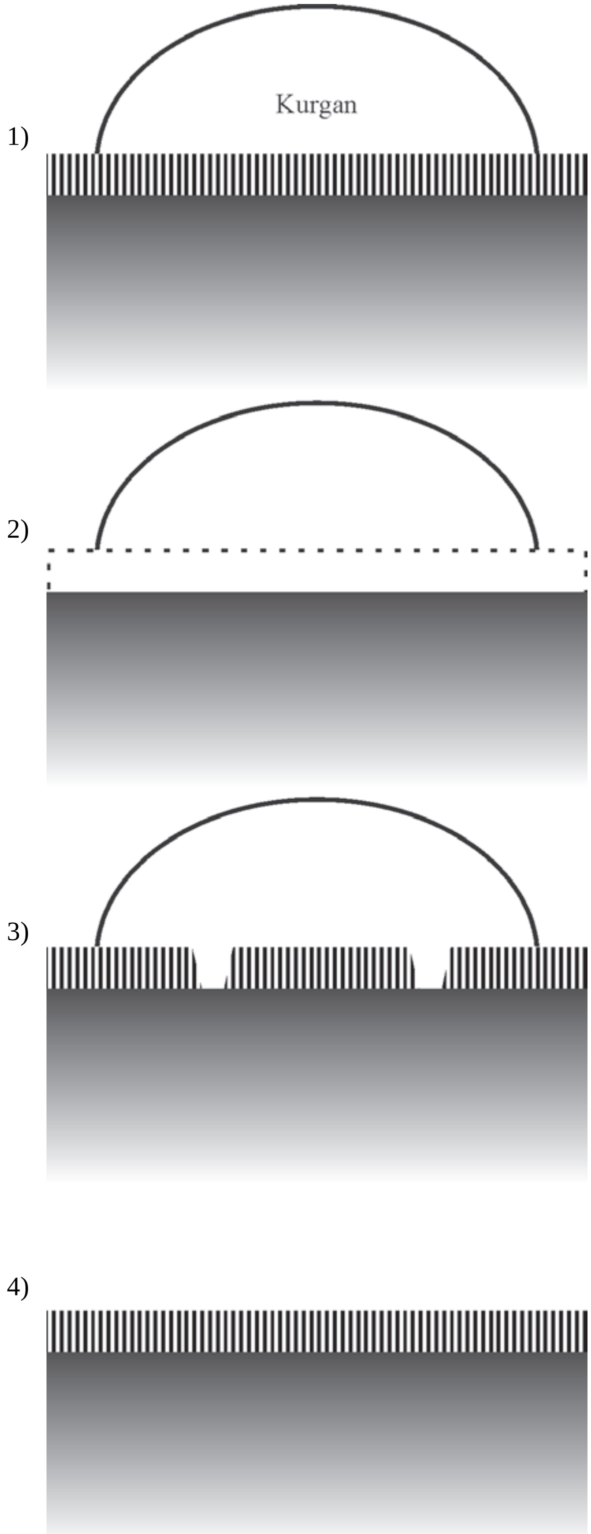

Figure 1. Reconstructed development of soil and plant cover. 1) Chronointerval VI–V ages B.C. Dark Kastanozem soils and luxuriant mixed grass steppe without signs of anthropogenic disturbance on their surface; 2) Chronointerval IV–II ages B.C. Eroded soils without plant cover on their surface; 3) Chronointerval II–III ages A.D. Dark Kastanozem soils and meadow-steppe plant cover on their surface. Spots with disturbance plant cover are likely to be due to the process of kurgan construction; 4) Modern Dark Kastanozem soils and mixed grass steppe on their surface.

DISCUSSION

During VI–V centuries B.C., the study region had a rather rich floristic variety, as it was covered with grassland that included the plants from both meadow-steppe and dry steppe ecosystems. The diverse phytolith assemblages indicate that some phytoliths were introduced to the soil with animal excrements. Kurgan construction significantly disturbed the topsoil at only one locale (sample no. 3). In sum, we did not find evidence for any significant and widespread disturbance of the soils buried under the kurgans of this period.

A dramatic change occurred during the subsequent early Sarmatian period. Stable low phytolith quantities in the samples of the upper horizons of soils buried under kurgans of this period are not typical for the topsoil of natural profiles formed in mature ecosystems. These phytolith concentrations are usually found at a depth of more than 5 cm below the buried soil surface. We conclude that the soil had already lost the upper part of its humus horizon (5 cm or more) prior to Sarmatian period kurgan construction. The reasons for this loss could be anthropogenic or natural. Possible anthropogenic agents include the disturbance of the ground surface during the course of kurgan construction as a part of the burial ritual and human-induced erosion due to overgrazing. Possible natural reasons include accelerated erosion as a result of a shift in the climate regime to drier conditions and the subsequent impoverishment of plant cover. Both processes may have led to the loss of vegetation and of the upper soil layer prior to kurgan building.

In late Sarmatian times, the vegetation around Pokrovka returned to a relatively undisturbed plant cover dominated by meadow-steppe associations with a few dry steppe species present. Erosion processes were weak or nearly absent.

The contemporary plant cover is somewhat similar to that of VI–V centuries B.C. and II–III centuries A.D. However, various aspects of the human impact of recent decades, such as cultivation, fertilization, and the planting of tree strips can be detected.

Summarizing these results we conclude that some buried soils show the signs of plant cover and surface stability while others exhibit the indicators of degradation. The paleovegetation and soils buried under the early Sarmatian kurgans suffered the most severe disturbance, which is reflected in the biomorph assemblages of modern soils.

CONCLUSIONS

The results of our research clearly demonstrate anthropogenic soil disturbance before or during the course of kurgan construction. The type and degree of buried soil disturbances were not similar in different historic epochs and reflects the level of anthropogenic pressure on the territory and its vegetal resources. When studying the soils buried under archaeological monuments (*e.g.*, kurgans) for paleoenvironmental reconstruction, it is important to take into account the fact that land-use and monument construction alter the characteristics of the existing soil such as epipedon thickness and, as a consequence, the depth to carbonate and salt horizons. These changes may not be detected by a morphological study or through the analysis of physical and chemical properties (humus content, etc.), whereas the biomorph method may identify them. Thus soils under kurgans, if they were human modified, can give incorrect information about the natural environmental conditions of a given historical period.

Earlier, a number of researchers hypothesized large-scale anthropogenic soil and vegetation changes in the Eurasian steppe during the second half of the Holocene, relying on palynological, paleofauna and archaeological data (Dinesman, 1976; Ivanov and Vasilyev, 1995; Nikolaev, 1997). Biomorph analysis allows us to evaluate the intensity and grade of the upper soil horizon transformation at the moment of kurgan building. This method should be included in the complex investigation of soils buried under archaeological constructions.

It should be mentioned that paleovegetation reconstruction based on biomorph data from only one sample in a buried paleosol is not sufficient and could lead to erroneous conclusions. For reliable interpretation, at least three samples from an ancient surface layer should be taken in different sectors of a kurgan.

Biomorph analysis suggests that the rituals accompanying mound construction and burial ceremonies may be more complicated than previously supposed and may have changed through time. Sponge spicules and phytoliths indicate that Early Sarmatian people brought lacustrine or alluvial deposits to the site for kurgan construction.

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