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Negative Effects of Late Bronze Age Human Activity on Modern Soils and Landscapes, a Case-study on the Muradymovo Settlement, Urals, Russia

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A B S T R A C T

The study site is the Late Bronze Age (1750–1350 BC cal) settlement of Muradymovo located in the Urals, Russia (53°58′44.8″ N, 55°30′58.8″ E). Despite the presence of a humid climate, the modern soils of the study site contain more than 27% of gypsum at a depth of just 10 cm from the surface and have a microrelief typical of a gypsum desert. The nearby background Chernozems are gypsum-free to a depth of 2 metres. The ancient people of the "Srubno-Alakul" archaeological culture had a tradition of building their houses from gypsum rock. This is an excellent construction material in dry climates, but dissolves quickly under humid conditions. According to the archaeological data, the ancient people rebuilt their houses more than five times within a period of 200 years, thereby bringing a lot of gypsum to this site, which was later abandoned. At the present time, this area is still unsuitable for human settlement, because the water of the nearest small river is still contaminated by gypsum and has a bitter taste. The properties of modern soils directly affected by Late Bronze Age human activities have been identified as a result of our studies on soil morphology and chemistry (pH, Corg., P_{tot}, gypsum and calcium carbonate concentrations). Remarkably, there is residual soil contamination by gypsum even after 3,500 years since the abandonment of the site.

1. Introduction

Pedological studies on archaeological sites can often help to reconstruct the palaeoenvironment of an archaeological monument's functioning period (Weiss, Courty 1993; Redman 1999; Vrydaghs, Devos 2007; Zielinski *et al.* 2011; Sánchez-Pérez *et al.* 2013 and many others). This allows archaeologists to better understand the life-styles and economic activities of the ancient people and their interactions with the palaeoenvironment (Engovatova, Golyeva 2012; Jankowski, Kittel 2012; Goldie 2013; Markiewicz *et al.* 2013).

In some cases, the human impact on ancient landscapes has been so profound that local soils still remain significantly affected even after hundreds and thousands of years (Bettis 1988; Lima *et al.* 2002). There are no natural soils left within such sites, being replaced by completely different anthropogenic soils with specific properties (Woods, McCann 1999; Nicocia *et al.* 2011; Antisari *et al.* 2013; Pawłowski *et al.* 2015; Thy *et al.* 2015).

Studying the causes and implications of such negative influences of past human activities on soils and the environment is necessary to prevent similar accidents in the future. We believe this is an important research area at the present time, when anthropogenic pressures on the environment are increasing.

The present article describes a case-study of the extremely severe and long-lasting impact of ancient people on their soils and environment. The study site is the Late Bronze Age settlement of Muradymovo located in the Bashkortostan Republic (Urals region, Russia). The site and its area have a peculiar "hillocky" microrelief that does not occur anywhere else in the Bashkortostan Republic. The local residents assumed that the hillocks were old tree stumps overgrown with grass, but we suggested that they were traces of ancient human activity. According to the archaeological

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data (Shcherbakov *et al.* 2013; Shcharbakov *et al.* 2015), the Muradymovo people belonged to the "Srubno-Alakul" culture of the Late Bronze Age and came here from an extra arid semidesert region of the southern Kazakhstan, where they used to build their houses of gypsum rock. There is a deposit of gypsum rock just 5 km away from the Muradymovo settlement site.

Gypsum is an excellent construction material in the driest parts of arid regions, for example, within depressions that remain from former inland lakes or seas (Rosen, Warren 1990; Bolen *et al.* 1991). However, in humid climates gypsum is soluble and houses made of it undergo rapid degradation. The residual piles of gypsum rock account for the appearance of the aforementioned hillocky microrelief of the study site (Slavnyi 2003). A similar microrelief typically occurs in deserts (Gorbunova 1977; Watson 1985; Eckardt *et.al.* 2001; Warren 2006), but would not be expected to be found in this humid region of Urals. In addition, the ancient settlement site Muradymovo is located on a hill, and not within a depression.

The aim of our study was to investigate the properties of modern soils at the Bronze Age settlement site and understand more about the factors that led to their formation and transformation.

2. Materials and methods

2.1 Materials

2.1.1 Location and natural conditions at the site

The study site (53°58′44.8″ N, 55°30′58.8″ E) is located 2.5 km north of the village of Muradymovo, in the Aurgazinskiy District of the Bashkortostan Republic of Russia (Figure 1.1–2). The site of the Muradymovo ancient settlement with a total area of 6 ha is found within the Kamsko-Belsky Depression with generally a levelled topography resulting from denudation processes, on the first terrace of the right bank of the Urshak River, 0.2 km east of the mainstream, on a hill about 1.5–2 m high (Figure 1.4). The bedrock is composed of gypsum, anhydrite, dolomite and sandstone of the Kungur stage of the Permian Period. The bedrock is overlain by loess-like silty sediments of the Quaternary Period that serve as parent rocks for the soils.

The climate is continental, moderately cold. The mean annual air temperature is +2.5°C, the mean temperatures of January and July being –15°C and +19.5°C, respectively. The frost-free period lasts 140 days, being the longest within the Bashkortostan Republic. The mean annual precipitation is about 500 mm, with more than 300 mm falling during the growing season. The hydrothermal coefficient is about 1 (Atlas of the Bashkortostan Republic, 2005).

The typical modern vegetation is represented by steppe communities.

The typical soils are Greyzemic Chernozems (WRB, 2014) that are naturally gypsum-free to a depth of 2 metres (Bogomolov 1954; Khaziev 2007).

2.1.2 Archaeology

According to the archaeological data (Obydennova *et al.* 2008; Shuteleva *et al.* 2010), the settlement was built by ancient people of the "Srubno-Alakul" archaeological culture of the Late Bronze Age (1750–1350 BC cal), who lived here for no longer than 200–300 years. Later the settlement remained abandoned. At present, the site is covered with sparse steppe vegetation, partially used as a pasture and bordered by a gully from the west and north. There are six depressions (house pits) with areas from 260 to 300 m^2 and depths from 0.25 to 0.4 m recorded within the site.

We studied two pits (houses III and IV) with the most representative morphology of cultural layers (Figures 2.2 and 2.3). Their past uses were different: pit III was a farm building whereas pit IV was an inhabited house. The distance between the pits was no more than 50 m (Figure 1.3). Pit III contained the remains of a farm building constructed on a single occasion and used for keeping cattle, as was indicated by the archaeological finds. Pit IV included several layers of house remains (no less than 5) and a hearth, *i.e.* this residential house had been rebuilt several times.

Two background soils outcropping from the banks of a small river opposite to each other at a short distance from the archaeological excavation site were also studied. These soils were least affected by the ancient settlement construction. The first soil profile (background soil 1) was on the same river bank as the settlement and contained a white-coloured lens between the surface horizon and the humus horizon (Figure 2.1.1). The other profile (background soil 2) was on the opposite bank and had no traces of ancient human impact, such as a white lens near the surface of the first profile (Figure 2.1.2).

The modern microrelief consists of small hillocks separated by deep frost cracks, which cover the whole area of the study site and beyond, up to the banks of the river and gully. Frost cracks have resulted from the recent influence of the continental climate. The hillocks are about 50 cm high and 1.5–2.2 m long (Figure 1.4). Such a peculiar microrelief is absent on the other side of the gully.

2.2 Methods

Our study was designed to describe the morphological characteristics of the pits and profiles in the field (according to archaeological standards) and to conduct chemical analyses of the samples in the laboratory using conventional techniques (Arinushkina 1970; Vorobiova 1998; 2006). We collected samples in vertical columns from all pits and profiles studied. The samples were dried and prepared according to the requirements for each specific analysis.

2.2.1 Total phosphorus

We determined the total phosphorus (P_{tot}), as we agree with Holliday and Gartner (2007) that P_{tot} "seems to be the best indicator of human activity". The procedure included sample combustion with concentrated sulfuric acid. Phosphate in the extract was determined calorimetrically using a SPECOL

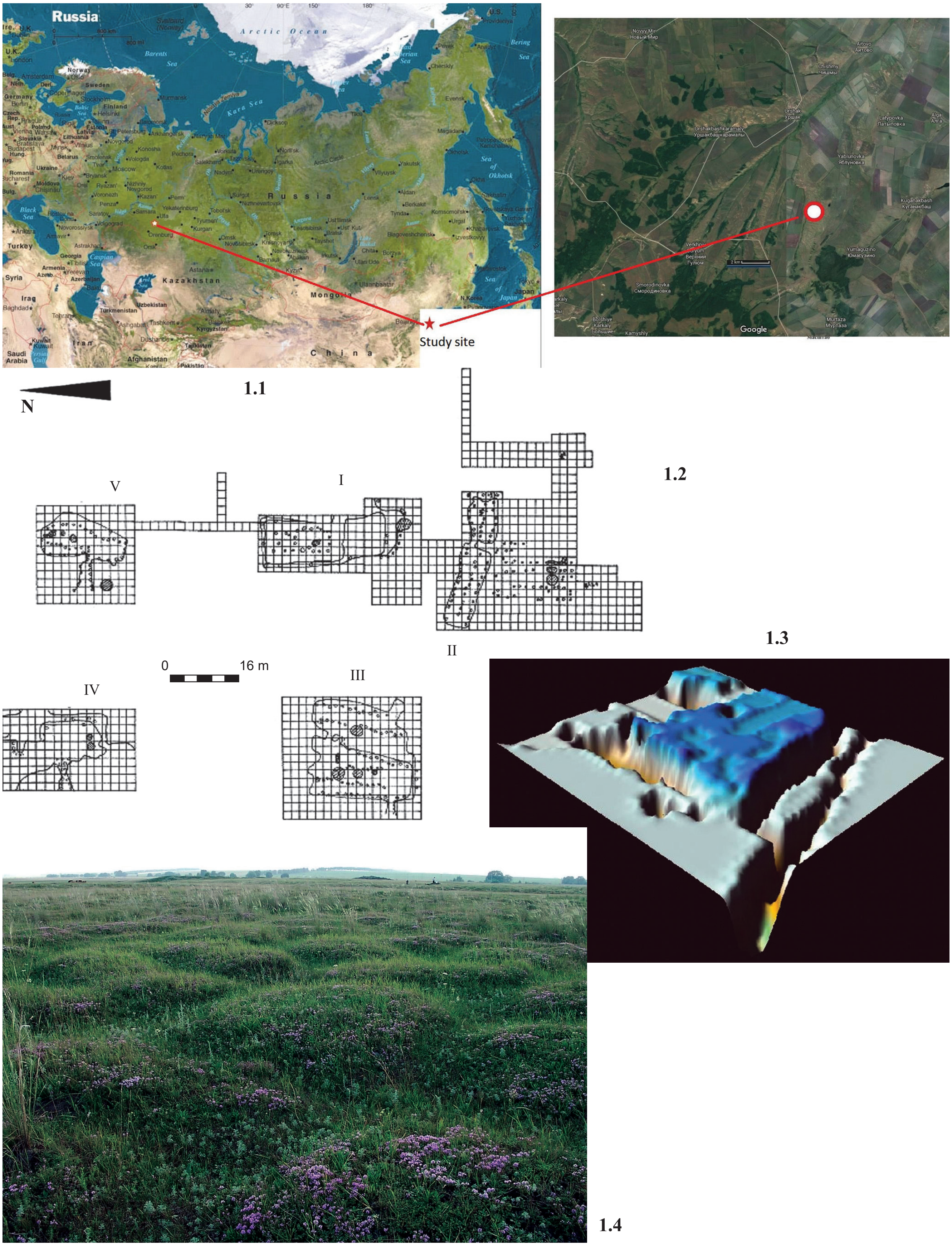

Figure 1. Study site locations: 1.1 Map of Russia with location of Muradymovo settlement (star) and areal map (Google) of Volga-Ural area with location of Muradymovo settlement (red ring). 1.2 Plan of the settlement area with excavated pits. 1.3 3D-reconstruction landscape of Muradymovo settlement by Golden Surfer Programme 9.0 Version. 1.4 Specific micro-relief on the surface of ancient settlement.

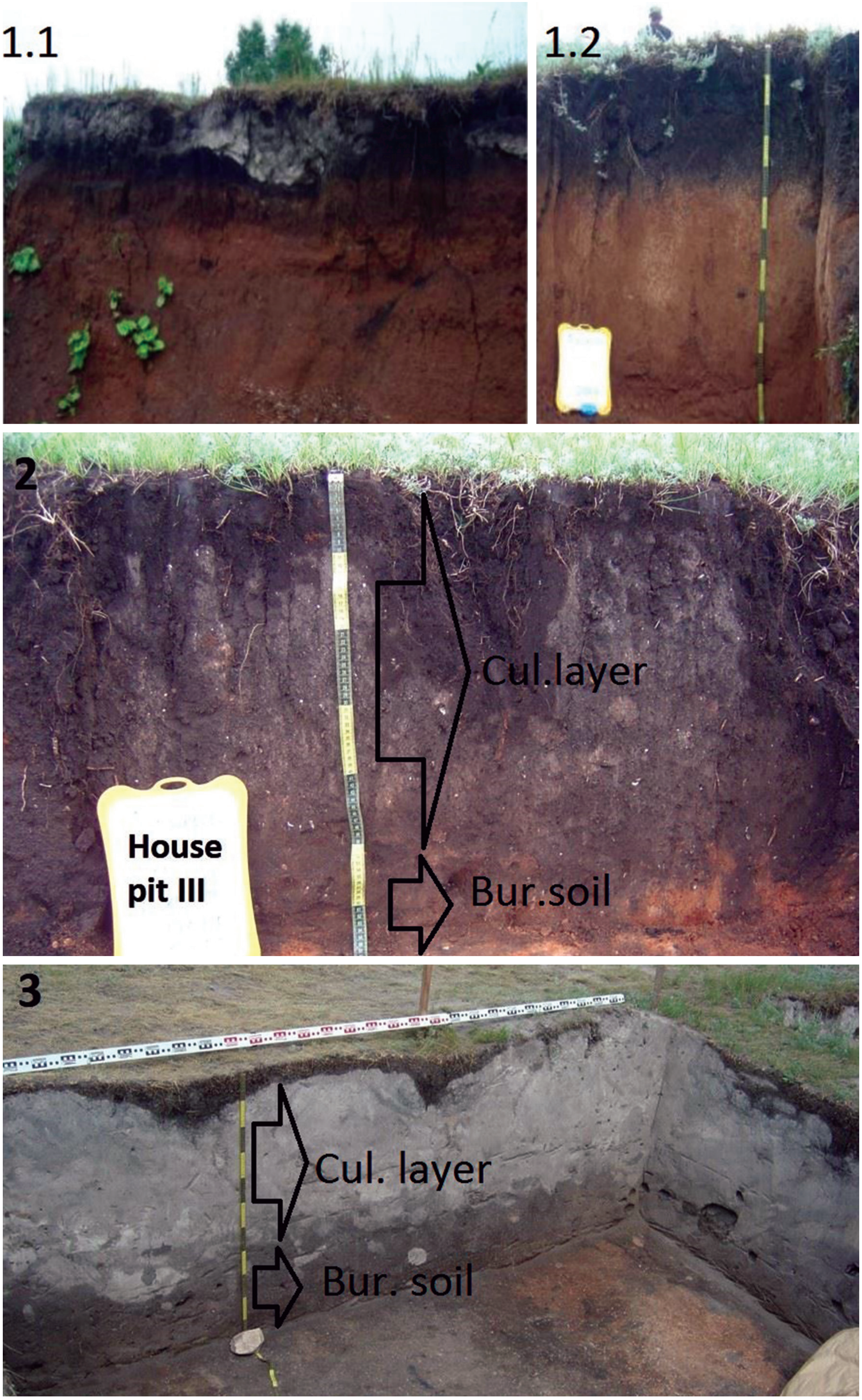

Figure 2. Soil profiles: 1.1 – Background soil 1 with gypsum lens on the surface. 1.2 – Background soil 2 without gypsum. 2 – Excavation pit III. 3 – Excavation pit IV. The thickness of cultural layers and burial soils are shown on both excavation pits.

211 spectrophotometer and a blue ammonium molybdate method with ascorbic acid as a reducing agent (Vorobiova, 1998; 2006).

2.2.2 Gypsum
Gypsum was determined using 10% $BaCl_2$ solution (Arinushkina 1970). Each sample was boiled for 3 minutes in 0.2N HCl, cooled for 30 minutes and passed through a filter. The filtrate was diluted with distilled water and passed through H-cationite. The resulting solution was titrated with $BaCl_2$ solution. The obtained values of SO_4 concentrations were recalculated for gypsum ($CaSO_4 \times 2H_2O$).

2.2.3 Water pH
Water pH (pH_{H_2O}) was determined using a potentiometer, in suspension with soil to water ratio of 1:2.5, after a single shaking followed by settling for 30 min (Arinushkina 1970).

2.2.4 Organic carbon
The organic carbon was determined by the Tyurin method, which included the wet combustion of organic substance in a mixture of 0.4 N $K_2Cr_2O_7$ and concentrated H_2SO_4 (1:1) at 150°C for 20 min. The measurements were performed by photometry on a SPECOL 211 spectrometer at 590 nm (Arinushkina 1970).

2.2.5 Calcium carbonate
Calcium carbonate concentrations in the samples were determined by alkalimetry using the Kozlovskii procedure. A soil sample was treated with 2 M HCl; the released CO_2 was absorbed by a 0.4 M NaOH solution. Then a saturated $BaCl_2$ solution was added to the tube with NaOH, and the excess of alkali was titrated with 0.2 M HCl (Vorobiova 1998; 2006). The obtained values of the carbonate ion concentrations were recalculated for calcium carbonates.

3. Results

3.1 Morphological description
The soils studied were considerably different from each other (Figure 2).

The background soil 1 had a light-coloured lens from 5 to 20 cm thick, containing powdery gypsum and no artefacts. The lens occurred between the surface litter and the humus horizon. All other morphological characteristics of background soil 1 were typical for Chernozems: high content of organic carbon and the secondary calcic horizon under the mollic horizon.

The background soil 2 had features of typical Chernozem, with the organic horizon thicker than 25 cm, underlain by the calcic horizon.

Soil of excavation pit IV had an 80-cm-thick, light-coloured surface layer containing diffuse secondary calcium sulfate and abundant artefacts – pottery, bones and charcoal (Shuteleva *et al.* 2010). This layer was underlain by buried Chernozem.

Soil of excavation pit III had a dark organic surface horizon, gypsum free. There were numerous artefacts within the upper 60 cm of this soil.

3.2 Chemical analyses
The results of chemical analyses are presented in Table 1.

3.2.1 Background soils
Both background soils are alkaline throughout the profile and strongly alkaline at the bottom. Alkalinity of the lower layers is generally typical and connected with the presence of calcium carbonate, but the alkalinity of the uppermost part of the soil profile is atypical.

The organic carbon content and distribution are typical for Greyzemic Chernozems (IUSS Working Group WRB,

Table 1. Chemical properties of soils and cultural layers.

Depth, cm	pH_{H2O}	Corg, %	P tot, %,	$CaCO_3$, %	$CaSO_4$, % (gypsum)
Pit IV, inhabited house					
0–5	7.90	14.38	0.48	3.4	0.7
5–10	8.25	11.37	0.64	15.3	1.9
10–20	8.25	3.83	0.26	9.5	49.8
20–30	8.20	2.65	0.29	13.6	49.9
30–40	8.15	2.91	0.42	15.3	39.2
40–50	8.20	2.31	0.50	14.4	38.2
50–60	8.00	2.67	0.48	19.4	8.0
60–70	7.90	2.18	0.48	15.9	31.4
70–80	7.90	1.54	0.45	18.4	25.6
80–86	8.00	2.06	0.38	24.6	3.9
86–96	8.40	2.38	0.21	33.1	1.3
96–106	8.60	1.79	0.19	38.3	2.7
106–116	9.10	1.59	0.19	42.2	2.3

Table 1. Chemical properties of soils and cultural layers. (*Continuation*)

Depth, cm	pH_{H2O}	Corg, %	P tot, %,	$CaCO_3$, %	$CaSO_4$, % (gypsum)
			Pit III, farm building		
0–8	8.30	7.31	0.29	12.7	0.07
10–20	8.70	5.67	0.31	16.9	0.09
20–30	8.95	4.83	0.31	20.3	0.16
30–40	9.00	3.39	0.30	24.4	0.18
40–50	9.10	3.22	0.34	25.8	0.18
50–60	9.25	2.22	0.25	30.1	0.09
60–70	9.20	0.41	0.13	37.4	0.39
			Background soil 1		
0–10	8.00	8.25	0.22	3.7	1.5
10–20	8.10	5.84	0.16	1.5	20.8
20–30	7.85	3.75	0.14	0.3	5.1
30–40	8.15	2.41	0.09	1.7	4.8
40–50	8.30	0.83	0.09	5.3	3.9
50–60	8.55	0.45	0.07	13.1	2.1
60–70	8.90	0.35	0.07	18.9	0.8
70–80	8.85	0.20	0.07	21.0	0.7
80–90	8.95	0.18	0.07	20.9	0.2
90–100	9.00	0.14	0.07	20.3	0.0
100–110	8.80	–	0.07	21.6	0.0
110–120	8.90	–	0.08	21.3	0.3
120–130	9.00	–	0.08	23.5	0.3
130–140	9.00	–	0.08	23.3	0.3
140–150	9.00	–	0.08	22.2	0.4
			Background soil 2		
0–10	7.35	12.72	0.21	3.4	0.0
10–20	7.95	5.36	0.17	1.7	0.0
20–30	8.15	4.65	0.15	0.0	0.0
30–40	8.15	3.07	0.10	0.0	0.0
40–50	8.25	2.19	0.08	1.8	0.0
50–60	8.30	2.47	0.08	4.5	0.0
60–70	8.30	1.19	0.07	9.3	0.0
70–80	8.15	0.88	0.07	15.7	0.0
80–90	8.15	0.45	0.07	18.6	0.2
90–100	8.20	0.16	0.08	23.2	0.2
100–110	8.25	–	0.08	23.3	0.3

2014), with the maximal organic carbon content within the upper 50 cm followed by a sharp decrease in deeper layers.

The content of P_{tot} in both background soils is low in comparison with the anthropogenic soils of the excavation pits. The highest values (0.21–0.22%) occur within the litter horizon, while the mineral horizons have a uniform small concentration of phosphorus, which is typical for native soils.

Calcium carbonate content is low (1.6%) within the upper 40-cm-thick layer and significantly increases in deeper layers, which is also typical for native soils.

The only difference between the background soils 1 and 2 is connected with the presence of the gypsum lens in the former. There is a sharp peak of gypsum content at a depth of 10–20 cm in this profile, corresponding to the clearly delineated white lens between the darker surface horizon and the humus horizon. Lower down, the gypsum content sharply decreases to almost zero at deeper than 70 cm. At the very bottom of the profile, there is a very small peak of gypsum concentration (50 times smaller than above).

4.2.2 Excavation pit IV (residential house)

The soil has a neutral reaction within its upper part and alkaline within its lower part. A similar pH distribution pattern is typical for the native soils of the study region and reflects the general trend of downward migration of calcareous soil solutions. The organic matter content is high throughout the soil profile. The maximum amount of organic matter is concentrated within the upper 10-cm-thick layer, which is generally typical for Chernozems.

The P_{tot} distribution is irregular. The cultural layers occurring at 0–86 cm depth are characterized by a high content of total phosphorus (0.26–0.64%). The buried Chernozem (86–96 cm depth) has a lower P_{tot} content, virtually equal to that of the uppermost layer of the modern background soil.

The $CaCO_3$ content is high throughout the profile, being slightly higher in its lower part.

The gypsum content and distribution are very unusual. In the field, at a macromorphological scale, the cultural layers of the excavation pit appeared to be composed of a whitish-grey, ash-like material, relatively homogeneous, compacted, with inclusions of various artefacts. The laboratory analyses have revealed that the cultural layers are composed of a mixture of gypsum and organic matter, with a small amount of calcium carbonate. The data obtained (Table 1) show that a high content of gypsum (more than 49%) is registered within the cultural layers at depths from 10 to 86 cm, with a gradual downward decrease. The surface layer (0–10 cm) is relatively impoverished in gypsum (1.3%) as a result of leaching.

4.2.3 Excavation pit III (farm building)

The excavation pit III contains the remains of a farm building constructed on a single occasion, in contrast to the series of houses in pit IV. This accounts for certain differences in the chemical characteristics as presented below.

The reaction of soil solution is from alkaline at the top to highly alkaline at the bottom of the profile, being generally typical for all the excavation pits within the ancient settlement.

The organic carbon content is characterized by a gradual decrease with depth, unlike the irregular "saw-tooth" distribution pattern in pit IV.

The P_{tot} content within the cultural layer is high (more than 0.3%). The 60 cm depth can be considered as a lower border of the cultural layer, with the natural parent rock of the soil occurring below.

The calcium carbonate content is high at the surface (12.7%) and clearly increases with depth.

4. Discussion

The upper horizons of pits III and IV are the ancient cultural layers (with anthropogenic genesis) according to their morphological characteristics and the archaeological data (Shuteleva *et al.* 2010). The background soils bear no traces of former human impact.

4.1 Background soils

By the content and distribution of P_{tot}, both background soils adequately reflect its natural background level, which can be used as a reference for separating the natural and anthropogenic layers: the former are poor in phosphorus, while the latter are characterized by a P_{tot} content above 0.22–0.23%.

A small amount of calcium carbonate within the uppermost horizon has a biogenic origin, resulting from the calcium carbonate uptake by plant roots and its return to soil upon the roots' death and decay (Afanasyeva 1966; Khokhlova *et.al.* 2001; Khokhlova, Kouznetsova 2004; Kouznetsova, Khokhlova 2010). This is a general natural phenomenon. A slightly "stretched" $CaCO_3$ distribution pattern can be due to the migration of calcium carbonate solutions in soils under the humid conditions of the region.

The very limited amount of gypsum in background soil 2 is natural for soils formed in humid climates (Khaziev 2007). But the presence of a gypsum lens within the upper part of background soil 1 is very untypical and indicative of secondary salinization. Judging from the low content of gypsum at the bottom of the profile, the salinization could not have developed from below, as a result of groundwater evaporation. The sources of gypsum either came from the surface or from seepage from higher slopes. The latter seems most probable because of the layered texture of the gypsum lens in background soil 1. Similar forms of gypsum occur within the A horizon of background soil 1.

In general, background soil 1 represents a typical anthropogenic profile, with secondary gypsum accumulation being its single distinction from native soils. Most likely, this process is recent and associated with an additional horizontal influx of salts from higher topographic positions with the hummocky microrelief. When dry gypsum gets wet, it swells and increases in volume. Because of the large quantities of gypsum present in the soil, such shrink-swell phenomena lead to the formation of an uneven (hummocky) microrelief. The homogeneous stratum of microcrystalline gypsum is broken by frost cracks, which become major channels for the vertical movement of salt solutions. In summer, when many cracks occlude, the main direction of flow is horizontal, and the lower areas of hummocky microrelief are enriched in gypsum and carbonates.

4.2 Excavation pit IV

There is an overall decrease of organic matter content with depth, with occasional humus-rich lenses. These lenses in the upper layers apparently result from man-made depositions of organic matter during the period of settlement building and exploitation and indicate the anthropogenic origin of the cultural layers. Similar lenses in the lower layers, deeper than 86 cm, are a part of the organic matter of the buried paleosol.

The "saw-tooth" pattern of the P_{tot} distribution within the total depth of the cultural layers reflects the stages of increase and decrease of anthropogenic pressure during the settlement's period of functioning (Hamond 1983; Holliday, Gartner 2007; Engovatova, Golyeva 2012; Golyeva *et al.* 2014). There is no phosphorus depletion within the upper 10 cm, which is surprising after such a long period (more than 3000 years) following the abandonment of this site. Perhaps the site was later visited by people and/or another cause of the presence of phosphorus within the surface layer could be its uptake by plants with subsequent decomposition of plant material.

In this excavation pit, the content of calcium carbonate is significantly higher than that in both background soils. The latter are calcareous only at depths more than 50 cm, while the excavation pit profile is calcareous from a depth of 5 cm. Taking into account the relatively high solubility of calcium carbonate, its occurrence in large concentrations at a shallow depth in soils under a percolative water regime is unusual (Khokhlova *et al.* 2001). However, such large concentrations at a shallow depth are typical for the sites of ancient settlements (Golyeva 2014). They are residues of limestone that was used as house building material. Calcium carbonate forms almost insoluble complexes with phosphates and organic matter (Hamond 1983). That is why even under a percolative water regime the cultural layers of settlements are calcareous.

Comparing the content of gypsum and calcium carbonates revealed a change in the use of bonding agents used in the mud-bricks for house building (Shutileva *et al.* 2010). The bonding agents were $CaCO_3$-based at the beginning of site occupation and later changed to gypsum. At the final stages of settlement existence gypsum was used with little or no calcium carbonate content.

The present day gradual dissolution of these salts results in the wider distribution of saline solutions beyond the settlement area. The high rainfall of the region causes calcium sulfate swelling, which leads to significant increases in the volume of the gypsum horizon and the further development of the characteristic hummocky microrelief. This microrelief is now observed not only within the settlement area but also far beyond, even in the background soil profile (Figures 2 and 1). Such a microrelief is typical for gypsum deserts (Nettleton *et al.* 1982; Minashina, Shishov 2002) and absent in the study region, which is within the natural steppe zone.

4.3 Excavation pit III

A series of peaks in the organic matter content identified within the cultural layer may be associated with a series of superimposed layers of ruined houses.

In contrast to excavation pit IV, the distribution of phosphorus in excavation pit III is relatively uniform, without any sharp peaks, and in general, with relatively small amounts of phosphorus.

The principal distinctive feature of excavation pit III is an absence of gypsum, which indicates that the former farm building was constructed using only calcium carbonate and without any gypsum.

Because excavation pits III and IV are both located in close proximity to each other, *i.e.* in similar lithological, geomorphological and climatic conditions and with a common geological and natural history of development, the considerable differences in gypsum content in these pits are uniquely associated with human activity. People brought gypsum from a nearby mine to build their residential houses.

When gypsum-bearing soils become dry, they can become very dense, so after heavy rain the surface run-off is very abundant with little amounts of water absorbed by the local soils. Soils at the bottom of the slope, by the river bank, have become enriched in gypsum and calcium carbonate, despite being far away from the former buildings. These lateral inputs of gypsum and calcium carbonate have resulted in the formation of gypsum and calcareous pedofeatures within the humus horizon of these modern soils.

Gypsum, calcium carbonate and other salts were most likely leached through soils into the groundwater during the period of the settlement building and habitation and later led to severe salinization of the groundwater forcing the inhabitants to abandon the site.

5. Conclusion

On the basis of the data obtained it can be confidently concluded that the gypsum-bearing strata in the upper parts of the excavation pits have anthropogenic origin. In other words, people built their houses of mud-bricks made of a mixture of gypsum and organic matter, occasionally with the addition of small amounts of calcareous rocks.

This hypothesis is supported by the differences in gypsum content in excavation pits III and IV. The former is gypsum-free and represents a single-stage farm building, while the latter contains almost pure gypsum within the upper layers and represents a consecutive series of houses built one after another at the same place. The accumulation of large amounts of gypsum rocks within the ancient settlement site resulted in contamination of the environment with gypsum.

The Muradymovo settlement site is located in a humid climatic zone with frequent rainfall, especially in summer. Gypsum solubility in water is relatively high, which causes a gradual deterioration of houses constructed of gypsum and a subsequent contamination of the surrounding areas with gypsum. With a high degree of confidence it can be stated that the abandonment of this area was caused by a human-induced ecological disaster, *i.e.* severe salinization of the groundwater, which made it impossible to stay in this area.

During the period of abandonment of this site, the natural processes homogenized the cultural layers of the construction pits. The leaching of salts during the wet seasons was accompanied by the process of upward migration and precipitation of salts during occasional summer droughts as well as severe frosts. Still, the residual amount of gypsum is still large after more than 3000 years following the contamination. Therefore, it can be assumed that the initial man-made soil contamination by gypsum was extremely strong. The properties of the modern soils are being directly affected by the Late Bronze Age human activities, with 3.5 thousand years being an insufficient timescale to restore the soils to be naturally gypsum-free.

Recently, many more settlements belonging to the "Srubno-Alakul" archaeological culture have been discovered along the Urshak River. We have observed similar cases of gypsum contamination in five sites of these settlements. Therefore, it can be concluded that the extremely negative influence of the Late Bronze Age human activity on modern soils and landscapes has occurred in several locations within this region.

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