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Investigation of a Bronze Age tell using soil analysis data

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Abstract

Human presence leaves an imprint not only on its environment but also on the soil cover. Soils are capable of preserving the signs of all the natural and human-induced activities that ever affected them. Via the identification and understanding of these signs it is possible to reconstruct ancient environments and obtain an insight into the lives of ancient societies. This has been successfully proven in numerous studies in Hungary (e.g. BARCZI et al., 2009; KRAUSZ, 2014; PETŐ, et al. 2015). This paper aims at furthering the understanding and reconstruction of the history of the Százhalombatta-Földvár tell site by analysing soil science data. Tell sites are very complex, so parallel to traditional archaeological investigation, a range of natural sciences (e.g. plant, animal and geological sciences) are involved in their analysis. In this study, soil science techniques, namely soil analysis and thin-section soil micromorphological analysis were employed to gain an insight into the past 4 000 years of the settlement's history. The intensity and the variability of human activities are also investigated. The results revealed very intensive human influence and significant environmental changes in Százhalombatta-Földvár, demonstrating the importance of the area.

Historical, regional and geological setting

The Bronze Age tell settlement in Százhalombatta-Földvár is situated on a high plateau some 30 km south of Budapest, alongside the Danube. A tell is a series of layers of human-related materials, e.g. house remains, middens, rubble, tools, personal goods, jewels, etc., that create an artificial mound in the course of time. The first occupation of the site can be dated back to the Early Bronze Age (c. 2500 BC) and the presence of humans can be traced archaeologically until the Roman period (c. 200 AD). In the light of the archaeological evidence a highly diverse inhabitation of the area can be pictured. In 2000 BC (Early Bronze Age) the settlement was limited to groups of houses and farm buildings rather than being a village.

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Around 1800 BC, as a consequence of population growth, the number of houses increased, resulting in the formation of a small village. By 1500 BC the village developed into an "urban-like" settlement due to a further phase of population growth and enlargement. By 1200 BC (end of the Middle Bronze Age) life on the tell came to an end. This phenomenon was characteristic not only of Százhalombatta-Földvár, but of tells throughout Hungary. The reason for this is still a mystery and remains one of the most fascinating archaeological questions facing tell researchers. The site was only re-settled some 200–300 years later during the Late Bronze Age (c. 1000 BC). The initial phase of the Late Bronze/Early Iron Age rampart (retaining wall) was built around 800 BC. The burial mounds, after which Százhalombatta was named (Százhalombatta means "hundred burrows"), are also the remnants of this period. Due to the lack of research there is not much data on the settlement's Roman history, but the remains of a watchtower clearly indicate the Roman presence (POROSZLAI, 2000; VICZE, 2005; KOVÁCS et al., 2011).

The research area is part of the Mezőföld region (Transdanubia) where high quality clay deposits several metres thick were formed during the Middle Pliocene as a consequence of the gradual disappearance of the Pannonian Sea. At that time, intensive tectonic movements were responsible for surface formation. Driven by this massive force, the seabed started to rise but not at an equal rate. The eastern part rose to a higher level than the southern part, resulting in a slight north-west – south-east slope (PÉCSI, 1967). At the same time the whole plate began to break up, which created a chessboard-like surface. Along the breaklines certain areas started to sink while others evolved, forming elevations, like the area under investigation, on which human occupation later took place. The elevations were further shaped by erosion and sediment accumulated on the lower-lying areas. Due to the more humid conditions in the Pleistocene, fluvial erosion played the most important role in altering the surface. As a result, complex valley systems started to cut through the landscape. Ice Age loess deposition was the next major process, which created the basis for later soil development (FRISNYÁK et al., 1977) and appropriate conditions for human life.

The area under investigation is bordered by the Danube to the East, a former erosion gully to the North and an old quarry face to the South (Fig. 1). The settlement could only be entered from the South, as is also true today. The present dimensions of the tell are about 160 m in length and 40–60 m in width, which is only one fifth of its original extension. The rest of the site was destroyed as a consequence of clay mining for the nearby brick factory. The depth of the cultural layer varies between 2 to 6 m, with an average of 4 m (VARGA, 2000).

Originally the Danube flowed about 300 m away from its present bed and the once gently sloping banks became much steeper over time. To the South lies the valley of the Benta stream, where the above-mentioned brick factory was built during the 1870s to exploit the clay deposits. The quarry face is the reminder of the brick/making, which was discontinued in the 1990s. The present quarry side of the settlement has a very steep slope with overhanging cliffs and piles of rubble at the bottom.

Fig. 1
Aerial view of Százhalombatta-Földvár archaeological site

This side also reveals the Pannonian layers and the quarternary and recent sediments in the area. Earlier research on the clay quarry (KOÓS, 1975) revealed a 35 m thick series of layers containing clayey rock powder (loamy) and sandy layers. The clayey rock powder that dominates in the layers is suitable for ceramic making and was used both by ancient people and the modern brick factory. These layers are topped by hard, pale, grey marl containing carbonate, with 10–50 cm sandy sections. Above this is a crumbly layer of calcareous sandstone (0.8–1.2 m). The uppermost pleistocene layer is made up of moderately coarse, grey-brown sandstone with carbonate bands (1.5–2 m). The upper surface of the limestone is covered by a crust impregnated with limonite, known as iron pan.

Methodology

Soil analysis techniques (BUZÁS et al., 1988) were used to reconstruct the soil changes over time at Bronze Age tell settlement in Százhalombatta-Földvár. Conclusions were drawn from the results obtained for four major soil analysis parameters. These were soil texture, characterized by the Arany or plasticity (K_A) index, calcium carbonate content ($CaCO_3$%), humus content and total phosphorus (P).

The K_A index shows whether the soil in question is sand, loam or clay.

Once the properties of the original soil are known, the results obtained for later deposits can be compared to them. With the help of this method the origin and the deposition or re-deposition of the soil material can be tracked.

The lime content of the soil ($CaCO_3$%) is also a very important chemical property that can help in detecting soil changes.

The next indicator used during the research is the humus content (humus %). During natural soil formation its values gradually increase as the humus layer thickens. A higher humus content signals a long period of surface or subsurface exposure.

While humus content is a good indicator of natural processes, total phosphorus gives an excellent reflection of human activity. The average phosphorus content of soils in Hungary is ~1000 $mg \cdot kg^{-1}$ (FÜLEKY, 1973, 1983). Values higher than this indicate human impacts. It can be said that the higher the phosphorus quantity the stronger the human effect. The amount obviously increases over time and with the growth of the population via the deposition and accumulation of phosphorus-rich matter, such as bone, manure or plant materials.

Thin-section soil micromorphological samples were also gathered from three profiles on the quarry face to investigate the relationship between the natural (pre-occupation) and the human-related deposits (cultural layers). Thin-section soil micromorphology is a microscopic method that investigates undisturbed soils and sediments. So-called mammoth-sized thin sections (approx. 7 × 14 cm in size) are prepared from resin-impregnated soil blocks via grinding and polishing (MURPHY, 1986). The 15–30 micron thin sections are permeable to light, so they can be investigated with the aid of a petrographic microscope.

A range of magnifications and various types of lights (cross- and plain-polarized) are used for the identification of the various components. Natural (e.g. minerals, iron nodules, clay coatings) and human-related (e.g. ceramic fragments, daub fragments, plaster) compounds can easily be distinguished under the microscope (BULLOCK et al., 1985; FITZPATRICK, 1993; STOOPS, 2003).

Results and discussion of the soil analytical data

A total of 35 bulk soil samples were collected and analysed in order to reconstruct the Bronze Age environment and the effect of human activity in Százhalombatta-Földvár (Fig. 2).

Six samples represented the original soil (i.e. pre-occupation) of the area (Table 1), while six were collected within the area of the Bronze Age tell and 23 from outside the tell (Table 2).

The original buried, undisturbed soil (Fig. 3) was sampled on the face of the quarry in the vicinity of the settlement (Fig. 2).

Fig. 2
Location of the bulk soil samples (1: inside the tell; 2: on the small rampart; 3: on the side of the retaining wall; 4–6: 2, 17 and 50 m from the side of the retaining wall;
7: original soil profile)

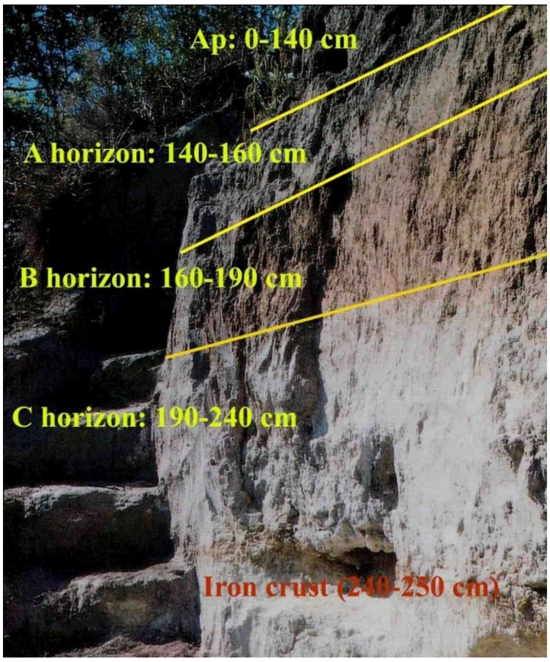


Fig. 3
Original (pre-occupation) soil profile

An approximately 1.4 m cultural layer (full of Bronze Age finds) developed over time on top of the buried (pre-occupation) soil. This recent sediment consists of a disturbed layer of dark brown sandy loam with a crumbly structure, containing gravel and mollusc shells, with a thick network of roots at the top.

Under this is the humus layer (A horizon) of the undisturbed soil, with a somewhat higher sand content. The accumulation layer (B horizon) of the original soil cover can be characterized by reddish brown colour and low $CaCO_3$ and humus content. The underlying C horizon showed high quantities of $CaCO_3$. The upper surface of the calcareous parent material is covered by an iron pan. This can be identified over the entire width of the quarry face. It is most probable that the iron pan is part of the erosion surface formed during the warm, wet period in the lower pleistocene.

Compared to the original soil profile the most significant difference could be detected in the total phosphorus contents of the different horizons. The cultural layer exhibited more than 2 000 $mg \cdot kg^{-1}$ phosphorus, while the A horizon of the original soil contained only 791 $mg \cdot kg^{-1}$ (Table 1).

This result clearly indicates the difference between natural and human-affected layers. The data of the original soil profile can be used to detect and distinguish natural soils and human-related sediments. Various locations were sampled to detect soil changes in the settlement and its immediate surroundings. Samples were gathered from the inside of the tell, on the small rampart, on the side of the retaining wall and 2, 17 and 50 metres from the side of this wall (Table 2).

Table 1

Characteristics of the original soil and the underlaying geological layers

Genetic layer (cm)	Soil layers	Texture (K_A)	$CaCO_3$	Humus	Total P
		-	%	%	$mg \cdot kg^{-1}$
A_{cult} (0–140)	Brown mixed	38 (loam)	10.5	1.88	2004
A (140–160)	Brown	30 (sand)	1.1	0.80	791
B (160–190)	Reddish-brown	32 (sandy loam)	0.6	0.44	670
C (190–240)	Grey sand	30 (sand)	20.6	0.31	779
C (240–250)	Iron crust	37 (sandy loam)	11.6	0.10	488
250-	White tubercular limestone	45 (clay loam)	40.9	0.30	730
-	Grey loamy marl	47 (clay loam)	21.8	0.14	725
-	Grey clay marl	-	-	-	-
-	Greyish yellow marl	-	-	-	-

Table 2
Characteristics of the soil samples at the various sampling locations

Sampling site	Drilling depth	Texture (K_A)	$CaCO_3$	Humus	Total P
	m	-	%	%	mg·kg^{-1}
Inside the tell	0–0.20	39 (loam)	11.5	3.60	3955
	0.20–0.40	39 (loam)	11.7	3.12	3833
	0.40–0.60	48 (clay loam)	16.4	3.40	4150
On the small rampart	0–0.20	40 (loam)	11.9	3.74	3605
	0.20–0.40	40 (loam)	15.7	3.02	3635
	0.40–0.60	40 (loam)	21.6	1.80	3174
The side of the retaining wall	0–0.20	50 (clay loam)	16.2	5.71	3751
	0.20–0.40	50 (clay loam)	17.0	4.49	4191
	0.40–0.60	45 (clay loam)	18.2	3.62	4269
2 m from the side of the retaining wall	0–0.20	48 (clay loam)	16.0	4.00	4617
	0.20–0.40	45 (clay loam)	16.4	2.73	4663
	0.40–0.60	43 (clay loam)	19.4	2.23	4632
	0.60–0.80	46 (clay loam)	21.7	2.03	5263
	0.80–1.00	46 (clay loam)	16.9	1.88	5872
	1.00–1.20	41 (loam)	14.4	1.89	6155
	1.20–1.60	41 (loam)	11.7	4.09	3739
	1.60–1.80	41 (loam)	14.0	1.96	4226
17 m from the side of the retaining wall	0–0.40	40 (loam)	11.5	3.27	3441
	0.40–0.80	37 (sandy loam)	13.9	2.72	3223
	0.80–1.00	31 (sandy loam)	19.3	1.37	1958
	1.10–1.20	27 (sand)	34.2	0.60	974
50 m from the side of the retaining wall	0–0.40	38 (loam)	10.0	3.20	2975
	0.40–0.80	42 (clay loam)	10.7	2.47	3027
	0.80–1.00	40 (loam)	15.4	2.27	3563
	1.20–1.60	39 (loam)	18.6	1.84	3696
	1.60–2.00	42 (clay loam)	31.9	2.22	5486
	2.00–2.40	42 (clay loam)	12.8	1.88	3757
	2.40–2.80	38 (loam)	13.7	1.74	4213
	2.80–3.20	40 (loam)	15.1	2.22	4399

As can be seen in Table 2, very high contents of phosphorus were detected in the soil samples. Sandy soil structure and low phosphorus concentration could only be registered in a single case, for a sample taken 17 metres from the retaining wall. The texture, the $CaCO_3$%, the humus % and the P_{total} all suggest that the level of the original soil was only reached at this location. All the other core samples remained within the cultural layer. As elevated amounts of phosphorus were measured both within the tell and on the flat area to the North, it is evident that not only the area of the tell, but also its surroundings were intensively utilized. Such high phosphorus amounts can only be the result of the actual inhabitation of the area. The core samples demonstrated that the steep 2–3 m retaining wall on the north side of the tell was the result of landscaping in ancient times. This is confirmed by the fact that the effect of erosion is hardly visible on the flat area north of the retaining wall, although the steep-walled gully leading down to the Danube must have had its origin in an erosion gully on the upper area. At present there is a narrow ridge above the steep gully, which prevents erosion by diverting the water in a sideways direction. As a result of soil disturbance the flora of the retaining wall is quite distinct from that of the surrounding areas (KOVÁCS, 2005).

The results of coring showed that prior to the Bronze Age the area of the settlement sloped gently upwards from East to West and and from North to South. Traces of ditches and low ramparts could be detected below the present retaining wall, which served for the protection of the settlement (FÜLEKY et al., 2002).

Modelling the enlargement of the settlement based on the calculation of the phosphorus balance

As mentioned earlier, the average phosphorus content of the soils in Hungary is around 1 000 mg·kg^{-1} (FÜLEKY, 1973, 1983). As shown by soil analysis data, this initial value rose to around 4 000 mg P·kg^{-1} (see Table 2), which can only have been the consequence of human occupation. The high concentration of phosphorus makes it possible to estimate the amount of food consumed in the settlement. This is an indirect indicator of the population and the growth of the settlement. During the Bronze Age the accumulation of the cultural layers was 4 m on average (VARGA, 2000). During this period the mass of the sediment increased by 35 000 t. Calculating with 3 000 mg P·kg^{-1} soil (3 000 g P·t^{-1} = 3 kg P·t^{-1} = 3 t P·1000 t^{-1}), this is equivalent to 3 x 35 = 105 t P for 35 000 t. Among the foodstuffs and building materials used by the inhabitants, wood contains 0.1% P and vegetables contain 0.1% P, while bones contain 18% P. Assuming that the 105 t P accumulated on the area of the tell was derived only from bones this would require 583 t of bones.

Assuming that the tell was inhabited for a 600-year period, this represents an annual accumulation of 1 t of bones. Although this calculation is very simple, it suggests a densely populated settlement.

Results and discussion of the thin section soil micromorphological analysis

The ongoing work of recent excavation has not yet reached the earliest phase of occupation, let alone the state prior to human appearance, but it was possible to presample these layers due to the destruction caused by quarrying (Fig. 4).

Fig. 4
Location of soil profiles prepared for thin-section soil morphological sampling/analysis (1: original soil profile, 3–4: soil profiles under the settlement)

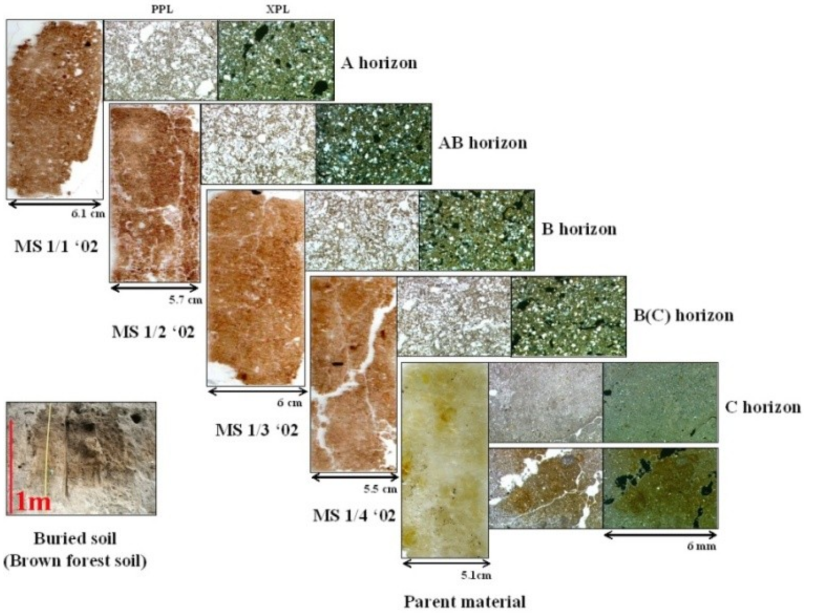
The original soil profile and two additional ones (Fig. 4) along the quarry face were sampled to investigate the effect of human occupation and its impact on the immediate environment.

As mentioned earlier, various scientific methods are employed to obtain an insight into the processes (both natural and human-related) that affected the site and its immediate surroundings over the past 4 000 years. Pollen (SÜMEGI & BODOR, 2000) and botanical analysis (TERPÓ, 2005) have already revealed that the area was covered by forest vegetation prior to the Bronze Age, which can only have resulted in the formation of a brown forest soil. Consequently, it was no surprise to find the remnants of the buried forest soil in the micromorphological thin sections (Fig. 5), similarly to the soil coring results (Tables 1 and 2).

The horizons in the pre-Bronze Age buried brown forest soil are rather coarse, porous and mainly mineral in composition with no trace of anthropogenic inclusions. The only exception is the brownish coloured, sandy loam A horizon, where various anthropogenic inclusions (i.e. organic material, charcoal, bone, pottery and daub fragments) were detected. However, these inclusions only occur at very low frequency (< 2%). This profile is located on the outskirts of the tell settlement, so the very low frequency rates and the very limited type of waste fragments are indicative of the small-scale utilization of the area (also shown by the low total phosphorus amount: 791 $mg \cdot kg^{-1}$). The A horizon, which is rich in organic matter due to the intensive floral/faunal activity (shown by the disruption and mixing of the soil material and the occurrence of numerous channels and earthworm granules) has bigger pore spaces and is much looser in comparison with the other soil horizons present. The accumulation horizon (B horizon) is a reddish brown sandy loam. Very small charcoal fragments are occasionally found in this horizon, but in an insignificant amount, which could easily have got into the horizon from the A horizon through the various channels and cracks that the sample displays.

The B horizon of the buried soil can be described as rather compact as compared to the A horizon, with many pore infills. The deposition of the various components that fill the pore spaces is responsible for the "compaction" of this layer. The soil characteristics of the B horizon alone create favourable conditions for human settling, especially for building purposes.

Thin section soil micromorphology not only became a new source of scientific evidence of the environmental aspect of the research project, but it turned out to be fundamental during the examination of human-environment relationship. One of the major advantages of micromorphological thin sections is that opposed to other scientific methods, this technique makes the investigation of intact stratigraphical horizons possible. The micromorphological analysis showed that forest clearance was the first human act and the starting point of the several hundreds years of occupation at the site.

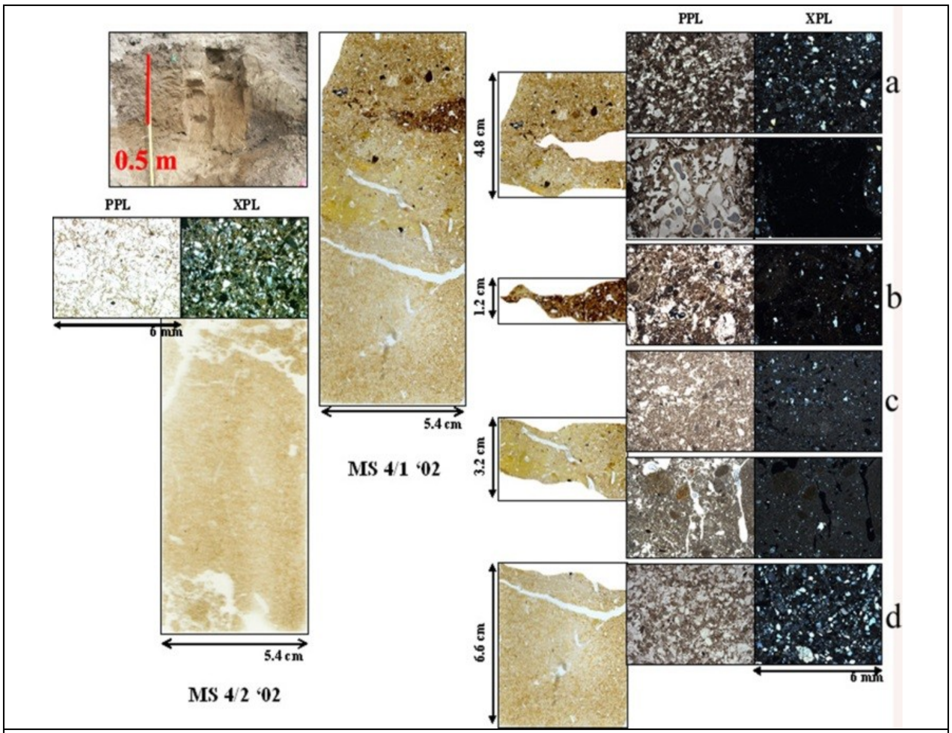


A horizon: Coarser (c/f 100: 50/50), moderately porous (porosity: 20–30%), slightly/moderately bioturbated, mainly mineral horizon with occasional phytoliths, charcoal, bone, pottery and daub fragments (< 2%).
B horizon: Coarse (c/f 100: 70/30), moderately porous (porosity: 15–25%), slightly bioturbated, mineral horizon with occasional charcoal fragments (< 2%).
C horizon (Parent material): Very fine (c/f 100: 95), porous (porosity: 25–35%), undisturbed, mineral horizon without traces of anthropogenic inclusions.

Fig. 5
Thin sections prepared from the original soil profile

No remnants of the A horizon of the buried soil could be detected underneath the tell, which seems to be the consequence of deliberate human action.

The A horizon of the original brown forest soil was entirely, and its B horizon was partially truncated. Remnant of a plaster floor was found in one of the samples, preaped immediately on top of the truncated B horizon (Fig. 6).



a: Coarser (c/f 100: 50/50), rather compact (10–20%), moderately bioturbated horizon. Bone and pottery fragments (5–10%) dominate with some phytoliths, charcoal and daub (2–5%) and with occasional burnt bone and non-metallurgic slag fragments (< 2%).

b: Fine (c/f 100: 10/90), moderately porous (porosity: 20–30%), highly bioturbated horizon with the dominance of charcoal (20–30%) and with some daub fragments (2–5%) and phytoliths (< 2%).

c: Fine (c/f 100: 30/70), rather compact (porosity: 10–15%), moderately to highly bioturbated, mainly mineral horizon with some charcoal, phytoliths, ash and pottery (2–5%) and with occasional bone, burnt bone, daub and non-metallurgic slag fragments (< 2%).

d: Coarse (c/f 100: 70/30), moderately porous (porosity: 20–30%), slightly bioturbated, mainly mineral horizon with occasional charcoal fragments (< 2%).

Fig. 6

Thin-section showing the inital settling of the area. Note: the B horizon of the buried brown forest soil in the lower half of the thin section (d), the yellow floor (c) and the above laying cultural layers immediately on top of it (a and b)

The missing A horizon and the very distinctive and sharp boundry between the natural and the human related matters is an unquestionable evidence of landscape alterion of prehistoric times.

The floor and its building matter are rather fine, which suggests that a solid base was produced prior to the plastering, which was stable enough for housing the first floor of the Bronze Age. Most probably trees were cut down initially and their roots were entirely cleared as well. Not only the trunks and roots were removed, but also the topsoil and part of the lower layer. The clear and sharp boundary that separates the latter occupation layers from the original soil would appear as mixed horizons otherwise. Forest clearance and topsoil removal is most probably not universal to the entire site, as the A horizon was found in some of the prevoius soil corings (FÜLEKY, 2005).

In the light of the soil micromorphological analysis it is most likely that this practice was limited to specific areas (e.g areas prepared for construction). This hypothesis will be further tested when the ongoing excavation reaches this depth.

Calculation of the number of Bronze Age houses

Four-fifths of the settlement is missing and the remaining fifth is still far too large to be excavated. However, a simple calculation of the number of houses can give an idea of the intensity of habitation at the research site. Since the original dimensions of the site are hypothetical, the current measurements were used for the calculation.

To reconstruct the number of houses that stood on the tell at any given time the increase in the mass of the tell has to be calculated.

Calculation of the volume of the tell: Full length of the tell
160 m (90 m, 40 m, 30 m)
Width of the tell
60 m, 50 m, 40 m
Height of the tell
4 m, 1.5 m, 2 m

Volume of the middle part: 90 m x 4 m x 60 m = 21 600 m^3
Volume of the lower part: 40 m x 1.5 m x 50 m = 3 000 m^3
Volume of the upper part: 30 m x 2 m x 40 m = 2 400 m^3
Total: 27 000 m^3
Volume of one house:
8 m wide 2 x 8 = 16 m
10 m long 2 x 10 = 20 m
1.8 m high 36 x 1.8 = 64.8 m^2
0.12 m wall thickness 64.8 x 0.12 = 7.78 m^3
0.15 m floor thickness 8 x 10 = 80 x 0.15 = 12 m^2
Volume of one house: 7.78 + 12 = 20 m^3

Assuming the same bulk density for a wattle and daub house as for the soil, a total of 1 350 houses (27 000 m^3 : 20 m^3) on the area of the tell since its establishment. This quantity of material must have been transported from the claypit in the side of the hill on which the tell is situated.

The time span of the site is about 600–700 years, which can be divided into eight periods. 1 350 : 8 ≈ 170 houses must have existed on the given area in each period. Assuming a life span of 30 years for each house, the houses must have been rebuilt three times during each 90-year period, so approximately 170 : 3 = 56 houses must have stood on the area at any one time.

Area of 56 houses: 58 x 80 = 4 480 m^2
Area of the tell: (90 x 60) + (30 x 40) + (40 x 50) = 8 600 m^2
8 600: 4 480 ≈ 2, i.e. more than 50% of the land was built on.

If this appears to be exaggerated, it may be that the 30-year amortisation period should be reduced to 10 years, in which case there were only about 20 houses on the tell at any selected period in the tell's life.

Conclusions

The analysis of the original soil profile showed that the area was covered by forest vegetation prior to human occupation. This was clearly indicated by the reddish-brown accumulation horizon that could be traced under the tell, which is typical of soils developed under forest vegetation. This was further proven by the results of the micromorphological analysis. Furthermore, it was showed that at some places the A horizon of the original soil was entirely removed to create proper conditions for living.

Using the soil data of the original (buried) soil it was possible to look for the same soil horizons under the cultural layers, i.e. to determine the thickness of the cultural layer at various locations. The very high phosphorus content found to a depth of several metres indicates that human activity was very intensive and lasted for a considerable length of time. The coring samples proved that not only the higher-lying central part of the tell was inhabited, but also the surrounding areas.

Keywords: Soil analytical data, thin section soil micromorphology, environmental reconstruction, Bronze Age, Százhalombatta-Földvár tell settlement

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