ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering

Tome XII [2014] – Fascicule 2 [May]
ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

[1.] Attila BARCZI, [2.] Katalin JOÓ, [3.] Attila CSANÁDI,
[4.] Tivadar M. TÓTH, [5.] Imre CZINKOTA, [6.] Ákos PETŐ

# GEOCHEMICAL EVOLUTION AND PALAEOPEDOLOGICAL ANALYSIS OF A COPPER AGE BURIAL MOUND (NORTHEAST HUNGARY)

[1-6.] Szent István Egyetem, Gödöllő, HUNGARY

**Abstract**: Soil profiles buried as a result of the ritual manifestation of late Copper and Early Bronze Age cultures provide unique opportunity to examine the former environment and to evaluate soil forming processes. The origin of the habitats linked to the appearance of alkaline soils on the Great Hungarian Plain has always been in the lime light of pedological and geochemical research. To assess the different scientific theories, we carried out pedological, geochemical and mineralogical examinations at Csípő-halom kurgan, situated in the Hortobágy region. Not only the buried soil horizons, but the cultural layers of the structure were analysed in order to understand vertical soil chemical processes within the kurgan. Steppe and alkaline steppe dominated soil evolutionary patterns underneath and on the surface of the earth mound were detected, which preseumes similar environmental conditions of the ancient landscape as it is seen today.
**Keywords**: Great Hungarian Plain, pedological and geochemical research, landscape

## 1. INTRODUCTION

The notion '*Anthropocene*' (Crutzen and Stoermer 2000, Crutzen 2002) – as an alternative denomination for the Holocene – refers to an era predominated by the impact of human kind on the landacape and environment.. Still, the second part of the Quaternary Period bears the most of the visible witnesses of human kind. Beside the rise and fall of civilizations, the effect and influence of mankind on its environment (landscape) can already be demonstrated in this period. This is a time when cultures appear and hydrological, geomorphological, zoological and botanical aspects of the Carpathian Basin are formed to their present state (Stefanovits et al. 1999). In comparison with the tectonic movements of the Pleistocene, the Holocene has been a 'quiet' period. Though the results of relevant research activity (Fűköh and Krolopp 1983; Willis et al. 1997, 1998; Magyari et al. 1999; Sümegi 1998) points out that sedimentary basins may have occured. With the examination of these, it is possible to demonstrate differences between Pleistocene and Holocene environmental evolution, and to examine the formation of Holocene environment in the Carpathian Basin.

According to climate change tendencies, the Holocene in the Carpatian Basin is divided to five phases, such as the *preboreal* (10 200-9000 years BP), *boreal* (9000-7500 years BP), *atlantic* (7500-5000 years BP), *subboreal* (5000-2500 years BP) and *subatlantic* (2500-present years BP). The length of the atlantic phase, which overlaps with the rise of Copper and Bronze Age cultures, covers a time intervall of approximately 2500-3000 years (Soó, 1965; Járainé, 1997). According to the scientific opinion of the previously cited authors, the mentioned phase can be generally characterised by warming climate, increasing precipitation, and therefore the spread of *Quercus petraea* dominated forest vegetation (Járainé 1997). The fall of temperature and the spread of coniferous species are the typical signs of the beginning of the subboreal phase (5000-2500 years BP). In the second part of this phase – around 3000 BP – a rise in annual precipitation has indicated stronger areal erosion, the appearance of significant mass movements and generation of shifting sand (Lovász, 2002). According to the above mentioned points, the Carpathian Basin has been occupied by forest vegetation and can be characterised by Luvisol evolution processes. A significant cultural turn, namely the spread of crop cultivation – as demonstrated by palinological record – and animal breeding has played an important role in the life of these societies. By the spread of cropping and animal breeding the territory of forest vegetation has been decreased, but on the whole the Chernozems of the boreal phase have transformed into Luvisols in the subboreal (Somogyi, 1988)

Other opinions hold that the spread of forests on the Great Hungarian Plain cannot be proved. According to Bodrogközy (1980) Chernozem type soil evolution has been predominant on the territory of the basin. The malacological examinations of Nyilas and Sümegi (1991) have supported the previous statement. On the basis of their results we may imagine macro and meso environmental mosaics already in the Pleistocene. This had presumably a significant buffer effect on soil evolution and vegetational processes, causing a different environmental pattern. Whereas the mosaic of the Pleistocene consisted of tundra, taiga, cold and/or moderate steppe vegetation (*Larix decidua, Pinus sylvestris, Picea abies, Pinus cembra*) (Sümegi et al. 2002), mosaics of the Holocene were formed by forest-steppe, dry steppe vegetation, alkaline territories and wetlands (Barczi et al. 2003).

Similarly to the above mentioned theories, there is significant disagreement in terms of the evolution of the alkaline territories in the Carpathian Basin. On the Hortobágy (part of the Great Hungarian Plain) mosaics of alkaline soil territories alternate with steppe-lands. At the present, two different concepts are known, and both describe the evolution of this area differently.

According to the first concept the ancient loess-steppe territories – situated on higher ridges – were surrounded by closed forests, and alkaline territories only appeared in low extensions naturally. In this sense, the evolution of alkaline soil areas of the Hortobágy are secondary, and are the latter result of river regulations and deforestation (Soó 1929; Székely 1984; Járainé 1997). The other scientific tendency denies the long-existence of closed forest vegetation and puts emphasis on the salinization of the Hortobágy in the Pleistocene Epoch. The effects (such as the river regulations, the spread of stock-breeder cultures) of the Holocene Epoch 'fixed' and extended the process of salinization (Szabolcs et al. 1978; Szöőr et al. 1991). According to the second theory the salinization is the result of the special interaction of the parent material, climate and geomorphological position (Somogyi 1964; Bodrogközy, 1980; Szöőr et al. 1991; Barczi et al. 2006a).

The counterposing and the further analysis of the relevant theories bear significant importance in the judgement of the soil evolution (*pedogenesis*) of the Great Hungarian Plain and the Hortobágy. In the first case, their appearence on the subjected area can only be traced back to a few centuries, whilst in the light of the second theory the alkaline soil areas are characteristic phenomena of the Carpathian Basin for thousands of years. Beside all of these considerations, the Hortobágy is an Unesco World Heritage site in the category of human-induced (transformed) landscapes (whc.unesco.org/sites/474rev.htm UNESCO, 1999), though it can not be excluded with total satisfaction that the area had the similary scenery before the intensive human impact.

If we accept thestatement of Dokuchaev that „soil is the mirror of the landscape" , than pedological and geochemical examinations of buried paleosoils may help us to provide answers on ancient landcape forming processes. Most – not tropical – soils were generated in the last ten thousand years. Through the examination of soils, changes in the environment can be observed, whilst the stability of soil generation processes give a certain answer for an environmental optimum (Aleksandrovskii 1996). Though most of the soils in the Carpathian Basin derive from the Quaternary Period (Várallyay and Láng 2000), well-conserved buried profiles may be more suitable to reconstruct Holocene environment than those on the surface. Such formations are found buried beneath kurgans, the burials of the Copper and Bronze Age (Alexandrovsky 2000; Barczi et al., 2006a; 2006b).

Most of our knowledge concerning the Hungarian burial mounds (kurgans) comes from archaeological sources (Ecsedy 1979). These are focused on the function of these formations and the state of human impacts. There is very few known of the building methods and circumstances of these mounds. Most of these burials contains Copper and Early Bronze Age graves, Sarmatian, Germanic and Hungarian (from the time of the Hungarian settlement in the Carpathian Basin) cemeteries. Besides their significant archaeological and landscape value, they are bearers of certain botanical, pedological, and palaeoecological values as well. Their excellent value in botany is that they provide refuge areas for steppe-land associations (Barczi et al. 2004). With the observation of these mounds we may gain information on the pedological processes since the erection of the mound (Joó and Barczi 2001). As far as our knowledge has reached it may be supposed that these formations were built from the humic A-horizons of the surrounding soils. The isolated and conservated soil beneath the kurgan may bear the properties of ancient soil forming processes (Alexandrovsky, 2000).

Kurgans are – together with other geomorphologically similar, human-made, but functionally different formations – artificial geological structures, which bear a significant archaeological, botanical, zoological, cultural historical and scenic (landscape) value (Tóth 1999). Environmental studies of these formations in Hungary only began in the beginning of the 20$^{th}$ century, though complex archaeological and environmental surveys have only been undertaken recently. Palaeoecological researches began with the geoarcheological examination of the Bronze Age Test-halom kurgan (Sümegi et al. 1998). A Bronze Age tell has been examined by Füleky (2001). Beside the Büte-halom kurgan (Tóth 1999) more burial mounds have been examined by Joó (2003) on the territory of the Hortobágy National Park. Comparative botanical-pedological anaylses were carried out earlier on more kurgans by Barczi et al. (2004.).

Following aims have been the motive power in recent years' palaeopedological work:

- Pedological examinations to determine the structural characteristics of the mound body, and to reveal the pedological attributes of the buried profile.
- Comparison of the modern topsoil with the buried profile and the profiles in the surroundings of the formation.
- To find regularities in and between the modern and ancient pedological processes of the soils of the Great Hungarian Plain (Carpathian Basin).
- To reconstruct the ancient soil forming factors and the ancient environment of the thousands of years old kurgan, and determine changes in soil formation.

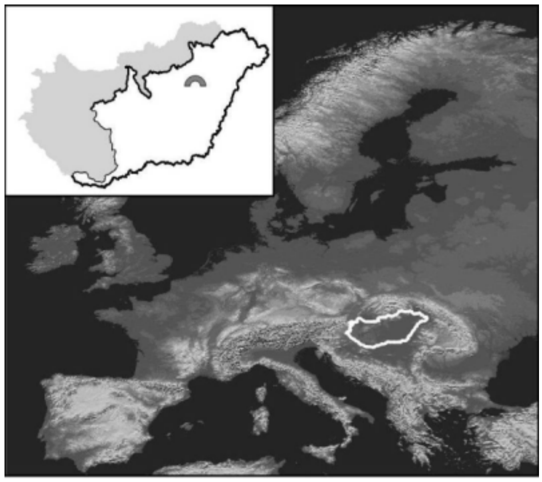


Figure 1. Location of the study site - mound icon shows the location of Csípő-halom kurgan within the territory of the Great Hungarian Plain (in white)

We were looking for a mound that is situated on a typical alkaline territory of the Great Hungarian Plain and may represent the environment of the Copper or Bronze Age. One of the main aspects of the selection was the state of disturbance (anthropogenic impact). The Csípő-halom kurgan – situated on the Hortobágy – turned out to be a burial mound that fits the requirements at most (Figure 1).

The Hortobágy can be characterised by monotonous geomorphological features as it is a typical plain area. The are does only exceed its typical 88-92 m elevation above see level on certain points, such as the sandhill ridges along the Tisza River (Marosi and Somogyi 1990; Pécsi 1969). In opposition, the area is highly diverse regarding its microrelief conditions due to the micro-geomorphology of alkaline territories. The plain area of the Hortobágy is situated in a basin formed by rivers during the Tertiary and Quaternary Periods. Due to the transport of rivers and creeks, 100-200 m high silt and clay sediment accumulated on the territory, which was later redeposited, redistributed by aeolian processes generating an uneven, rough surface. This stratum was than later covered with a loess-clay material in the Pleistocene Epoch. In the depression, the Tisza River accumulated its silt material. This caused the homogenization of the sediment layers and the surface roughness (Pécsi 1969; Kovácsné and Salamon 1976; Borsy 1989). The Hortobágy can be characterised by moderately warm and dry climate, especially when rainless periods are accompanied by high quantity of heat and intensive solar radiation. Mean annual temperature varies between 9,8-9,9 ºC, whilst the annual precipitation between 520-550 mm, with uneven frequencies. Surface watercourses do not spring on the territory, and those crossing it have a small fall. In summary the Hortobágy is a dry, strongly evaporative territory with scarce run-off (Kovácsné and Salamon 1976). Depth of ground water usually varies between 2-4 meters, but at the study site it does not exceed 2 meters. The hydrology of the Hortobágy was determined by the flow dynamics of the Tisza River. In case of floods, the Hortobágy was covered by water, even for month. In order the eliminate the danger of floods, river regulation plans have already been prepared in the 19$^{th}$ century. With the implementation of these plans the Hortobágy was almost completely isolated from the periodical water overflow.

## 2. MATERIALS AND METHODS

Pürckhauer soil sampler (Finnern 1994) was used to conduct preliminary soil mapping on the mound and in its surroundings. As all Hungarian kurgans and their valuable vegetation fall under the regulation and protection of law, the sampling was not carried out in open profiles, but a mapping coring (Birks and Birks 1980) was conducted with the help of Pál Sümegi, Head of the Department of Geology and Palaeontolgy at the University of Szeged.

Samples from the cores were separated according to genetic soil horizons, and paralelly samples were taken from each 20 cm-s. Basic pedological laboratory examinations were carried out on the samples, according to the relevant standards (Buzás 1988) as follows: carbonate content with Scheibler's method, total organic carbon (TOC) with loss-on-ignition (LOI) method, humus% (Tyurin's method), pH ($H_2O$ and KCl), electric conductivity (EC), total iron, cation and anion composition from watery extract and mechanical analysis.

Samples taken from each 20 cm were subjected to geochemical analyses. The XRF measurements were carried out on compressed pastille samples, with Mo K$\alpha$ radiation source, on 36 kV acceleration voltage, at 4mA amperage. Etalon 146, River 320 and NBS 612 fluvial sediment standards were used for standardization. Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Cu, As, Rb, Sr, Y and Zr quantities were measured as well. The Rock Eval data of the soil samples were determined using standard heating conditions with Oil Show Analyzer (OSA). The oven was programmed as follows: hold at 300 ºC for four minutes, then temperature was increased at the rate of 25ºC*min$^{-1}$ from 300 ºC to 600 ºC. During the isothermal phase at 300ºC thermally distilled free hydrocarbonacous compounds evolve (S1 peak) followed by hydrocarbonacous compounnds cracked from the organic matter (S2 peak). Flame ionization detection was used to monitor the evolution of hydrocarbonacous compounds with increasing temperature. Both isothermal volatilization ad thermal degradation were perfomed under helium flow in order to transport the pirolysis products rapidly to the detectors thus minimizing the secondary ceacking reactions. The total organic carbon (TOC) content was computed from S1 and S2. The temperature recorded for the S2 peak ($T_{max}$) varies as a function of the thermal maturity of the organic matter.

On the basis of the geochemical analyses 8 samples were choosen for minerological examinations, which was carried out with DRON UM-1 XRD, using Cu radiation source, 35 kV acceleration voltage, 20 mA amperage and LiF monochromator. In order to indentify secondary clay minerals, sedimented and distended (ethylene glicol was used) shots were compared. Data anaylses and processing was carried out with multivariable geomathematic methods with SPSS software. The examinations aimed to define those soil chemical parameters, which refer to importat soil foming processes. 1 dimensional flow simulations ran with the help of the VS2D/t hydrodynamic software. Basic data for the software was gained with soil machanical examinations.

## 3. RESULTS

### 3.1. Introduction of the studied burial mound

The Csípő-halom kurgan is situated on the Hortobágy. Its northern side is bordered by a road in a distance of 200-300 m-s. The Western Main Channel is situated to its eastern side, while another smaller channel to the south. Its elevation above see level is 91,5 m and emerges 5 m-s high from its surroundings. The eastern and westerns slopes bear a 17% ascent, while its southern and northern slope is slightly disformed (Figure 2).

Figure 2. View of the Csípő-halom kurgan

According to the radiocarbon dating, the soil underneath the structure was buried 6040±100 cal. BP (after Molnár et al. 2004) (Table 1). The age of soil matter (5630±100) of the mound body is very close in time to that of the buried soil profile's. Soil forming process and material movement took place inside the kurgan after it was erected, but the small difference in time refers to the fact that the mound was built in one single step. According to the measurements, soil generation on the surface lasted hundreds of years or even more (1200±50). It seems that this period was long enough for the generation of a Chernozem on an organic matter rich parent material.

Table 1. The radiocarbon age of the soil horizons of the Csípő-halom and its environment (Molnár *et al.* 2004) (Calendar ages were calibrated according to Stuiver *et al.* (1998)

| horizon | $^{14}C$ age (BP ± 1σ) | calibrated age (1δ) |
|---|---|---|
| Kurgan, modern A-horizon | 1200±50 | AD 780–880 |
| Kurgan, cultural layer | 5630±100 | BC 4550–4360 |
| Kurgan, palaeo $A_p$-horizon | 6040±100 | BC 5040–4800 |
| Environment, A-horizon | 2210±80 | BC 360–200 |

### 3.2. Soils and closer environment of the mound

Microrelief conditions are diverse in the surroundings of the kurgan – both vertically and horizontally (Figure 3). This geomorphological situation is a result of erosion processes that appear in mosaical territorries. Loess covered areas emerge to a height of 20-30 cm, creating continuous ridges. On these elevations, dry soils, while between the ridges hidromorph soils evolved, mainly due to the higher level of ground water and the effect of the irrigation channels in the close environment. Mosaics of Chernozems, Solonetzic soils and Vertisols alternate in the surrounding area of the mound. The mosaical dispersion of these profiles types are the results of variable ground water and (micro)geomorphological attributes of the territory.

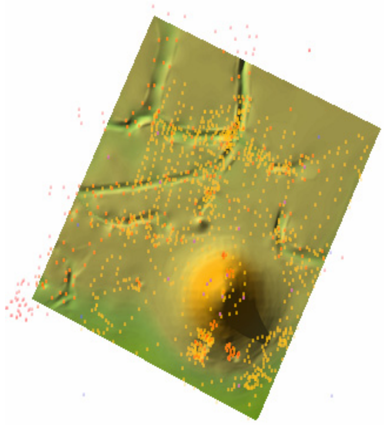


Figure 3. Micro-geomorphology of the kurgan and its surrounding area

### 3.3. Stratigraphy and soils of the mound

Altogether 5 locations were marked on the surface of the Csípő-mound to evaluate its stratigraphy throught corings: top, Northern, Southern, Eastern and Western slope. The cultural layer under the modern soil profile of the mound surface was found to be homogenous in colour. Laboratory analysis was carried out on the samples deriving from different layers, while the layers were identified according to on-site macromorphological evaluation. Because of the resemblence of the data gained from the corings, we only introduce the values of the western boring (Table 2). The material of the Western boring lacks any anthropogenic disturbance and is representative for all layers and horizons.

Table 2. Results of laboratory analysis of the layers and horizons of the Csípő-mound

| horizon | depth cm | pH ($H_2O$) | pH (KCl) | $CaCO_3$ % | humus % | TOC % | EC 2.5 mS/cm | Fe mg/kg | $K_A$ | mechanical analyses % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | clay | silt | sand |
| A | 0-20 | 8.14 | 7.05 | 0.28 | 3.00 | 6.36 | 0.325 | 6364 | 42 | 42 | 23 | 35 |
| B | 20-80 | 9.19 | 7.60 | 1.88 | 2.68 | 6.16 | 0.88 | 5241 | 39 | 39 | 33 | 28 |
| K2 | 80-220 | 8.45 | 7.50 | 0.06 | 2.74 | 5.45 | 3.06 | 85878 | 41 | 45 | 30 | 25 |
| K1 | 220-260 | 9.15 | 7.76 | 1.11 | 2.68 | 5.75 | 1.91 | 4670 | 41 | 40 | 33 | 27 |
| Ap | 260-300 | 9.55 | 8.04 | 2.7 | 1.95 | 5.79 | 0.49 | 18167 | 41 | 39 | 36 | 25 |
| Bp | 300-360 | 9.56 | 8.07 | 14.7 | 0.57 | 5.36 | 0.55 | 14332 | 42 | 40 | 32 | 28 |
| C1 | 360-380 | 9.66 | 8.05 | 15.2 | 0.37 | 3.84 | 0.58 | 12659 | 42 | 36 | 35 | 29 |
| C2 | 380-400 | 9.73 | 8.06 | 12.9 | 0.33 | 3.38 | 0.64 | 6455 | 41 | 32 | 35 | 33 |

The A-horizon of the modern soil profile is slightly alkaline and its carbonate content reaches 0.3%. Humus content (3.0%) is high compared to the other layers and horizons. Because of intensive biological and root activity, the total organic carbon (TOC) content is high (6.36%). Total iron content is the lowest in this horizon, which indicates the lack of water-induced development. Texture of the horizon is silt. The B-horizon shows typical Chernozem dynamics. Organic matter and humus content decreases slightly, while carbonate and pH increases. The amount of iron rises showing more intensive soil moisture dynamics in the B-horizon. Because of surplus water, reduced forms of iron appeares. Conductivity increases as well. The cultural layer (K) beneath the modern soil profile bears similar pH. While $CaCO_3$ content strongly decreases. Organic matter of this cultural layer is similar to B-horizon of the modern soil and the paleo A-horizon. The iron content heavily increases in the cultural layer, and so does the value of conductivity. All this information strenghtens the hypothesis that the mound was built of the A-horizon of the surrounding soil profiles.

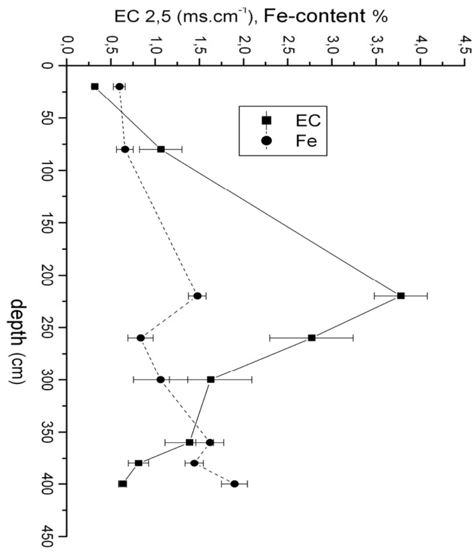


Figure 4. Conductivity and Fe content along the profile of the Csípő-halom kurgan

Further investigations were necessary to find an explanation for the abrupt change in some soil properties in the middle of the structure. The increased salt content and disappearing carbonate content was already shown by alkaline vegetation that appeared on the disturbed Southern slope of the mound (Joó 2003). For the above mentioned reason we have undertaken ion component analysis in samples taken from each 20 cm of the core. Conductivity reaches its maximum between 1-2 meters, while in the same depth pH shows its minimum value (Figure 4, Table 3)

Table 3. Data of the conductivity and ion composition of the Csípő-halom

| depth cm | EC 2.5 mS/cm | EC 5 mS/cm | $Mg^{2+}$ mg/kg | $Ca^{2+}$ mg/kg | $Na^{+}$ mg/kg | $K^{+}$ mg/kg | $Cl^{-}$ mg/kg | $NO_3^{-}$ mg/kg | $SO_4^{2-}$ mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| 0-20 | 0.237 | 0.118 | 25.5 | 81.2 | 13.85 | 52.7 | 28.83 | 0.58 | 15.18 |
| 20-40 | 0.242 | 0.136 | 16.5 | 80.0 | 44.70 | 10.5 | 15.40 | 0.58 | 9.20 |
| 40-60 | 0.439 | 0.303 | 27.0 | 85.3 | 254.5 | 9.1 | 49.33 | 0.56 | 15.12 |
| 60-80 | 1.448 | 0.907 | 35.0 | 57.0 | 180.0 | 64.0 | 512.32 | 1.52 | 213.27 |
| 80-100 | 1.663 | 1.029 | 21.0 | 58.1 | 200.0 | 19.5 | 911.50 | 0.67 | 261.39 |
| 100-120 | 3.170 | 1.921 | 23.0 | 64.9 | 370.0 | 14.6 | 1675.15 | 1.61 | 715.74 |
| 120-140 | 2.640 | 1.645 | 26.0 | 74.7 | 295.5 | 18.5 | 1631.05 | 0.08 | 433.17 |
| 140-160 | 3.080 | 1.981 | 39.0 | 58.9 | 353.0 | 52.9 | 1922.88 | 3.23 | 478.12 |
| 160-180 | 2.550 | 1.591 | 22.2 | 72.5 | 282.5 | 17.5 | 1729.90 | 0.35 | 317.84 |
| 180-200 | 2.890 | 1.813 | 23.1 | 45.5 | 334.0 | 64.4 | 1937.11 | 1.43 | 321.63 |
| 200-220 | 2.360 | 1.478 | 30.3 | 43.4 | 294.0 | 46.0 | 1470.77 | 1.34 | 244.45 |
| 220-240 | 2.550 | 1.520 | 37.8 | 45.8 | 282.5 | 56.0 | 1539.92 | 1.74 | 185.92 |
| 240-260 | 2.050 | 1.244 | 85.0 | 67.5 | 242.5 | 158.0 | 1456.55 | 1.41 | 135.12 |
| 260-280 | 1.660 | 1.070 | 98.0 | 50.6 | 204.0 | 321.0 | 900.35 | 0.24 | 154.53 |
| 280-300 | 1.710 | 1.082 | 103.0 | 64.0 | 221.5 | 152.0 | 1082.05 | 1.17 | 87.28 |
| 300-320 | 1.643 | 1.060 | 50.8 | 141.0 | 213.0 | 78.0 | 1154.90 | 0.99 | 104.19 |
| 320-360 | 1.202 | 0.856 | 27.0 | 237.8 | 161.0 | 23.7 | 966.95 | 0.42 | 36.84 |
| 360-380 | 1.256 | 0.942 | 35.0 | 165.0 | 187.2 | 21.0 | 896.00 | 0.47 | 43.00 |
| 380-400 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

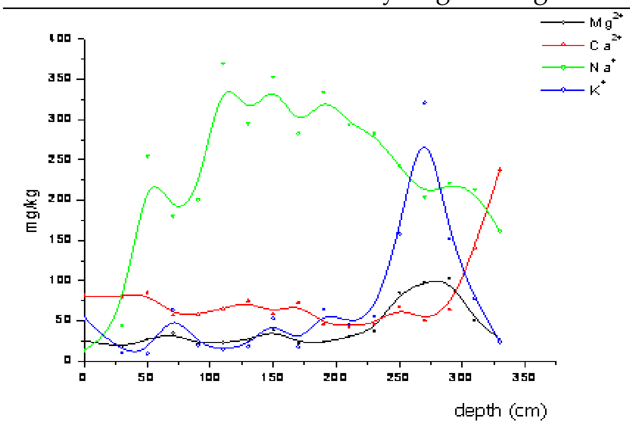


Figure 5. Distribution of cations of the sampled profile

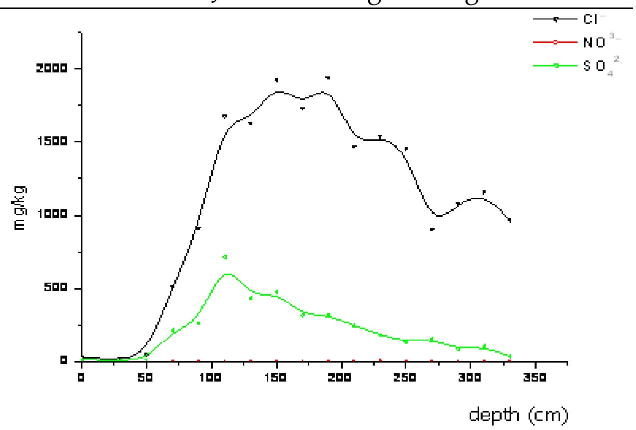


Figure 6. Distribution of the anions in depth of the sampled profile

Based on the previous observation, it is probable that non-carbonate salts cause the increased conductivity. Among the cations, the $Na^+$ has its maximum in the relevant depth (Figure 5). The amount of $Ca^{2+}$ cation starts to increase only in the depth of the buried paleosoil and reaches its maximum in the parent material. $K^+$ and $Mg^{2+}$ cations reach their maximum on the boundary of the cultural layer and the buried soil profile, and have a second maximum in the parent material as well. Among the anions, $NO_3^-$ is only present in small quantities. The amount of $SO_4^{2-}$ anions increase in the mound body, but not exactly in the depth of the highest conductivity value. On the other hand, $Cl^-$ anion has its maximum in the relevant depth (Figure 6).

Based on these observation, we aimed to find correlation among the distribution of these ions. The linear correlation between $Na^+$ and $Cl^-$ ions is given with bivariate linear regression. The value of the correlation coefficient (R) was found to be 0.83892. Based on this, it is assumed that there is strong correlation between the appearance of these two ions. On the other hand, the regression coefficient (B) shows anion surplus (Figure 7).

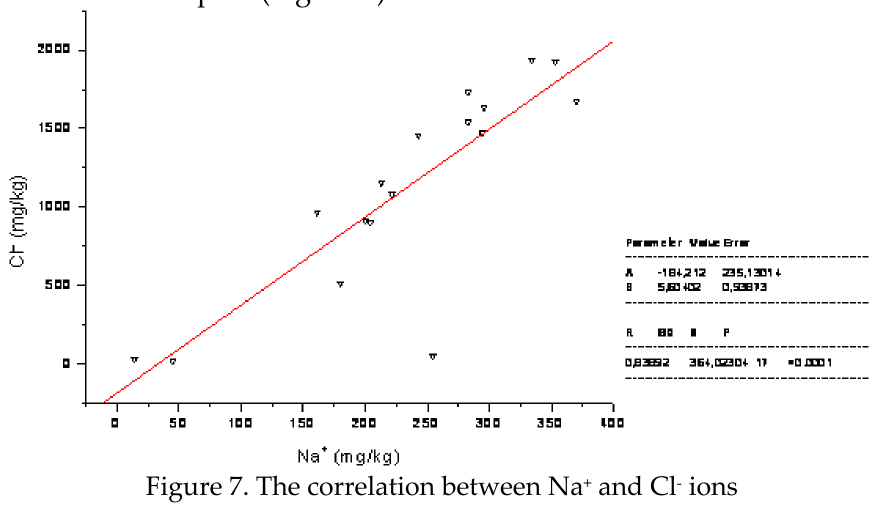


Figure 7. The correlation between $Na^+$ and $Cl^-$ ions

On the basis of the strong correlation between $Na^+$ and $Cl^-$ ions, the increased conductvity can be the result of the salt composed of the two relevant ions. Since NaCl does not cause alkaline pH, it is an explanation why pH in this depth did not change extremely. Our first hypothesis was that appearance of high salt content in the mound body is in correspondance with the original salt content of the soil matter, which was used to build the kurgan. A further fact to underline this idea is the phenomenon of leaching, as salt content from the modern A- and B-horizon may have effected the vertical migration of salts. At the same time, signs of strong leaching, such as lessivage, was not detectable in the samples. Soil properties change in the $A_p$-horizon of the buried soil profile. Humus content decreases slightly, but the high TOC value indicates a formerly active soil surface. Carbonate content and pH increases as well. Texture of the horizon is silt. The higher amount of iron may indicate an ancient waterlogged environment or it is an effect of the

ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]

alternating groundwater that filled the buried soil profile from time to time. This idea is underlined by the fact that the groundwater level is approximately 30 cm higher under the kurgan as in the surroundings. Organic matter steadily decreases downwards in the $B_p$-horizon and in the parent material. $CaCO_3$ content and pH increases towards the parent material and reaches 14%. Iron content is high both in the $B_p$-horizon and in the parent material. It can be a sign for the hydromorph development of these horizons. Conductivity remains under 1mS/cm, while the texture is still silt.

**3.4. Soil chemical characteristics**

After the pedological tests, we have continued the research with the analysis of inorganic chemical parameters in order to explain the salt accumulation in the cultural layer and to strengthen the tendencies shown by the pedological data. Despite the fact that the single data of most elements have not shown any detectable changes along the profile, according to the results after standardization of specific elements of the XRF and Rock-Eval measurements, the univariate analysis of the measured inorganic chemical data has shown a normal distribution.Thus, their multivariate geostatistical analysis has become possible as well. During the factor analysis of the pH($H_2O$), conductivity, anions, and cations, the rotated component matrix has separated two extremely relevant factor groups (Table 4).

Table 4. Results of the factor analysis (groups)

| The factor analysis determined four main factors |
|---|
| F1 ("soil components") factor: ($SiO_2$, $K_2O$, Rb, $Fe_2O_3$, MnO, TOC, -Sr, -CaO) |
| F2 ("organic matter") factor: (TOC, S1, S2) |
| F3 ("mobile elements, redox indicators") factor: (Cr, As) |
| F4 ("immobile elements") factor: (Ti, Zr, Y) |

The elements of the first group are: EC5, $Cl^-$, $NO_3^-$, $SO_4^{2-}$, $HCO_3^-$, $Na^+$, EC2.5, and pH($H_2O$). The second group contains $Mg^{2+}$ and $K^+$. Subsequently, we have carried out a further factor analysis in order to assort the inorganic chemical parameters, according to which, the rotated component matrix indicated four major factor groups (Figure 8).

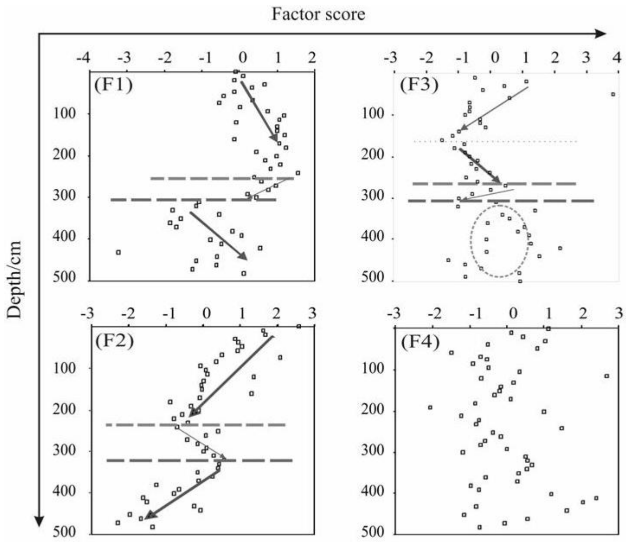



Figure 8. Variation of the factor values along the profile; F(Cs)1, F(Cs)2, F(Cs)3 and F(Cs)4

The first factor (F1) can be interpreted as the joint change of silica, clay, carbonates, ferrous oxides and manganese oxides, i.e. it shows the parameters together that play the most important role in soil formation. The change of the carbonates represented by Sr and CaO shows opposite tendency in comparison to silica and clay, i.e. the increase of one puts the other in disadvantage. The changing of F1 along the section indicates two geochemical boundary surfaces. A really sharp boundary is located 3 meters deep, and another, less strong at around 270 cm. The F1 shows a clear growth tendency with the depth in the mound core, and under 3 meters. In the part between the two boundaries, at the depth of the buried A-horizon, this tendency turns around, suggesting that element migration processes are taking place in the soil system; therefore geochemical connection is established between two sediments with different genetics.

The elements of the second factor (F2) are TOC, S1 and S2. After the soil formation processes, the amount and maturity of the organic matter is the second most important factor, which created the geochemical pattern. The values of F2 show decreasing tendency with the depth, and the 'transitional zone' observed in case of F1 can be found here as well, in the same depth region (approx. 3 meters).

The elements of the third factor (F3) are Cr, As and Zn, which belong to the mobile elements in the wide pH and Eh range, and upon the impact of the changes in the redox conditions get mobilized. The behaviour of the mobile chalcophilic element group (Cr, As, Zn) along the profile, at the boundary located over the depth around 200 cm, shows a periodic run down; however, under this boundary it shows a chaotic behaviour. The amount of Fe and Mn stabilises under the same depth, and in this same layer the amount of reduced iron is present in the silt based on earlier measurements (Joó 2003). All these together suggest a redox boundary at a depth of 2 meters.

The fourth factor (F4) includes Ti and Zr, i.e. the most conservative and immobile elements. Their uneven distribution along the section suggests the complete lack of chemical patent at the time of the construction.

**3.5. Results of the mineralogical analyses**

The mineralogical analysis of eight samples has been carried out following the geochemical tests. From the samples chosen for the X-ray examinations, on Figure 9 we present the spectra of two parameters. The chosen samples were taken from the Ap-horizon from a depth of 270 cm, and of 110 cm respectively – the latter having witnessed minor changes during the pedological and geochemical tests. Both samples contain kaolinite and illite, however, the intensity of both clay minerals is 1.5 times higher in the deeper sample than in the one representing the top of the culture-bearing layer. A group of swelling clay (smectites) has been found in the sample representing the palaeosoil, which is not present in the shallower sample.

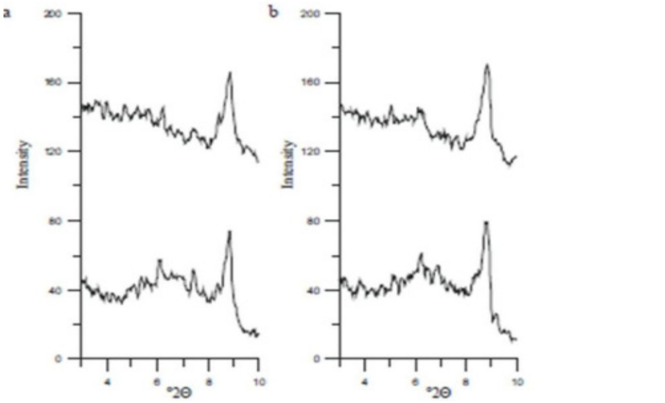



Figure 9. X-ray spectra of the mound's materials at 110 cm (a) and 270 cm (b), on sedimentated and expanded (offset by an intensity value of 100) samples

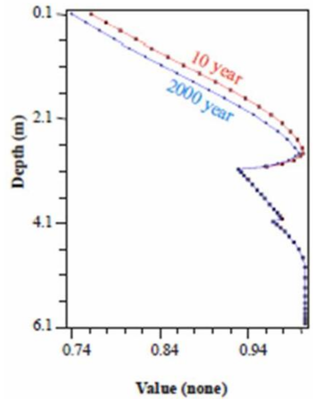



Figure 10. The 1D hydrodynamics model of the Csípő-mound (saturation curves)

**3.6. 1D hydrodynamic model**

In order to confirm our previous analyses, we have also drawn saturation curves for a 2000-year period with the VS2D/T software (Figure 10). The model, harmonised with the results of the other analyses, also indicates a perched water table in a depth of 150-250 cm, which also indicates the effect of swelling clay groups existing in the buried soil in a depth of 270 cm.

**4. DISCUSSION**

On the basis of the on-site macromorphological description and the various laboratory analyses the mound could be separated to a parent material, an ancient, buried soil profile, a cultural layer and to a modern, surface profile.

The modern soil profile on the mound is very similar to modern Chernozems with specific humus and $CaCO_3$ dynamics. The material of the so called cultural layer derives from the top layer of the surrounding territory. The buried soil can also be characterised as a Chernozem, according to its properties, such as declining total organic mater and humus in depth, $CaCO_3$ dynamics and colour. According to the pedological analysis, the former, ancient environment of the kurgan can be characterised as a warm, dry steppe environment. Traces of closed forest vegetation are not reflected in the soil properties, therefore it seems that forest vegetation can be excluded.

Salt-accumulation can be seen in a depth of 150-250 cm-s, which phenomena is underlined by the results of EC5, $Cl^-$, $NO_3^-$, $SO_4^{2-}$, $HCO_3^-$, $Na^+$, EC2.5 analysis types. An out-crop of the salt content appeared on the Southern side of the kurgan's surface (mantel). It can be easily seen in the form of an association patch (alkaline halophilic vegetation) atypical for steppe associations. Groundwater, transporting soluble salts, could not reach this height through regular capillary processes. The appearence of the salt effected area neither can be explained through leaching. In a depth of 270 cm-s, $K^+$ and $Mg^{2+}$ accumulation appears, which points on the fact that secondary clay minerals are present in higher content. It is underlined by the XRF analyses as well. The amount of kaolinite and illite increases at 250-300 cm-s – just in the buried paleosoil zone – and expanding clay minerals appear as well (smectite), which is underlined by the above mentioned fact of $K^+$ and $Mg^{2+}$ increase.

The appearance of $Na^+$ derives from the parent material present the surrounding areas. It has been previously shown that the albite content of the loess material around the Hortobágy region is high. Weathering of the albit can be an explanation for the appearance of the kaolinite and smectite. In acid microenvironment albite reacts in two different ways, resulting both $Na^+$ and various clay minerals:

1. in case of moderate hydoreffect Al-hydrosilicates may form in more steps and paralelly $Na^+$ liberates.

$$4NaAlSi_3O_8 + 4H_2CO_3 + 18H_2O \leftrightarrow 4Na+ + 8H_2SiO_4 + Al+ 4HCO_3$$

2. in case of low and slow hydroeffect, if $Mg^{2+}$ is present smectites are produced

$$3NaAlSi_3O_8 + Mg^{2+} + 4H_2O \leftrightarrow 2Na0,5Al1,5Mg0,5Si_4O_{10}\ (OH_2) + +2Na+ + H_2SiO_4$$

In case of the studied burial mound, probably both processes were present. This can underline the presence of relatively high $Na^+$ content and the appearance of caolinite and smectite clay minerals.

Our first hypothesis that salinization is a result of the sodium content of the material used for constructing the structure (soils of the surroundings) could not be certified by the chemical analyses. The behaviour of the calcophilic elements (Cr, As) in the depth of 200 cm is periodical, but below it is chaotic. The mount of Fe and Mn shows stability in the same depth. All these may be the keysigns of a redox barried in the mentioned depth of the profile. This is underlined by the 1D hydrodynamic modell as well. However it can not be assumed that the groundwater rises several meters, which is inconceivable knowing the topography of the environment. It is more feasible that the expanding clay minerals in this depth create a hydrophobe layer and retain moister creating a kind of 'hanging' ground water level. This may cause the appearance of the redox stratum and barrier. Since the time of construction significant element movements appeared in the material of the mound body. As a result, the heterogenous geochemical profile evolved to homogenous zones separated by chemical barriers. The original geochemical pattern can only be seen in the distribution of Ti and Zr. On the basis of the geochemical distrbution of the elements it can be stated that the mound did not reach the so called steady state condition. In summary, we may reconstruct the former environment of the Csípő-mound as a dry and warm habitat, where steppe vegetation was the predominant type.

**REFERENCES**

[1.] Aleksandrovskii, A.L. 1996. Natural Environment as Seen in Soil. Eurasian Soil Science, Vol. 29., No. 3., 245-254.

[2.] Alexandrovskiy, A. L. 2000. Holocen development of soils in response to environmental changes: the Novosvobodnaya archaeological site, North Caucasus. Catena, Vol. 41., 237-248.

[3.] Barczi, A., Sümegi, P., Joó K. 2003. Adatok a Hortobágy paleoökológiai rekonstrukciójához a Csípő-halom talajtani és malakológiai vizsgálatai alapján. [Data to the palaeoecological reconstruction of the Hortobágy based on the pedological and malacological examination of the Csípő-halom kurgan] Földtani Közlöny 133/3., 421-431.

[4.] Barczi, A., Penksza, K., Joó, K. 2004. Research of soil-plant connections on kurgans in Hungary. Ekológia (Bratislava), Vol. 23., Supplement No. 1., 15-22.

[5.] Barczi, A., M.Tóth, T., Csanádi, A., Sümegi, P., Czinkota I. 2006a. Reconstruction of the paleo-environment and soil evolution of the Csípő-halom kurgan, Hungary. Quaternary International, Vol. 156-157 (2006), 49-59.
[6.] Barczi A., Golyeva A.A., Pető Á. 2006b. Additional data on the paleoenvironmental reconstruction of the Lyukas-mound based on biomorphic and pedological analysis. Bulletin of the Szent István University, 51-71.
[7.] Birks, H.J B., Birks H H. 1980. Quaternary Palaeoecology. E. Arnold Press, London
[8.] Bodrogközy, Gy. 1980. Szikes puszták és növénytakarójuk. [Alkaline „puszta"-s and their vegetation] A Békés Megyei Múzeumok Közleményei. 6. pp. 29-50.
[9.] Borsy Z. 1989. Az Alföld hordalékkúpjainak negyedidőszaki fejlődéstörténete. [Quaternary evolution of the alluvial cone of the Great Hungarian Plain] Földrajzi Értesítő, 38. (3-4), 211-224.
[10.] Buzás, I. (ed.) 1988. Talaj- és agrokémiai vizsgálati módszerkönyv 2. [Methods of soil and agrochemical analyses 2.]. Budapest, Mezőgazdasági Kiadó
[11.] Crutzen, P.J., Stoermer, E. F. 2000. The "Anthropocene". Global Change Newsletter. 41, 12-13.
[12.] Crutzen, P.J. 2002. Geology of mankind. Nature, 415, 23.
[13.] Ecsedy, I. 1979b. The people of the pit-grave kurgans in Eastern Hungary. Fontes Archaeologici Hungariae, Akadémiai Kiadó, Bp., pp. 148
[14.] Finnern, H. (ed.) 1994. Bodenkundliche Kartieranleitung. 4. verbesserte und erweiterte Auflage. Hannover, pp. 392
[15.] Fűköh, L., Krolopp, E. 1983. Holocene lacustrian fauna from Sárrét in County Fehér, Hungary. Abstract of the Eight International Malacological Congress Budapest 1983, Hungary, p. 41.
[16.] Füleky, Gy. 2001. Soils of the Bronze Age tell at Százhalombatta. Proceedings of the 1st International Conference on Soils and Archaeology, Százhalombatta. Környezetkímélő Agrokémiáért Alapítvány, pp. 149-152.
[17.] Járainé Komlódi, M. 1997. A legutóbbi, azaz holocén beerdősödés flóratörténetéből. [Vegetation history of the newest, so Holocene forestation] Botanikai Közlemények, 84, 3-15.
[18.] Joó, K. 2003. Adatok a Csípő-halom flórájához és vegetációjához. [Data on the flora and vegetation of the Csípő-halom kurgan] Tájökológiai Lapok. I.(1.), 87-95.
[19.] Joó, K., Barczi, A. 2001. Halomsírok, határhalmok, lakódombok: a kunhalmok. [Burial mounds, border mounds, living mounds: the Cumanian mounds] A Földgömb, 19.(4), 22-30.
[20.] Lovász, Gy. (2002): A holocén felszínfejlődési folyamatok rekonstrukciója Magyarországon.[Reconstruction of Holocene surface evolution of Hungary] Földrajzi Értesítő, LI.(1-2.), 31-39.
[21.] Kovácsné, G., Salamon, F. (ed.) (1976): Hortobágy a nomád pusztától a Nemzeti Parkig. [Hortbágy: from nomad „puszta" to National Park] Natura Kiadó, Bp., pp. 351
[22.] Magyari, E., Jakab, G., Rudner, E., Sümegi, P. 1999. Palynological and plant macrofossil data on Late Pleistocen short term climatic osscilations in North-East Hungary. Acta Palaeobotanica, Supplement 2, 491-502.
[23.] Marosi, S., Somogyi, S. (eds.) 1990. Magyarország kistájainak katasztere I. [Cadastre of Hungary's geographical microregions] Budapest, MTA Földrajztudományi Kutató Intézet.
[24.] Molnár, M., Joó K., Barczi, A., Szántó Zs., Futó, I., Palcsu L., Rinyu L. 2004. Dating of total soil organic matter used in kurgan studies. Radiocarbon, 46(1), 413-419.
[25.] Nyilas, F. I., Sümegi, P. 1991. The Mollusc fauna of Hortobágy at the end of the Pleistocene (Würm 3) and in the Holocene. Proc. 10th Intern. Malacol. Congr. (Tübingen 1989), pp. 481-486.
[26.] Pécsi, M. (ed.) 1969. A tiszai Alföld. Magyarország tájföldrajza. [The Great Hungarian Plain at the Tisza. Landscape geography of Hungary] Budapest, Akadémiai Kiadó
[27.] Somogyi, S. 1964. A szikes talajok képződésének földrajzi tényezői Magyarországon. [Geographical factors of alkaline soil evolution in Hungary] Földrajzi Közlemények, XII.(88), 219-244.
[28.] Somogyi, S. 1988. A magyar honfoglalás földrajzi környezete. [Geographical setting of the Hungarian Conquest] Magyar Tudomány, 88/11., 863-869.
[29.] Soó, R. 1929. Die Vegetation und Entstehnung der ungarischen Puszta. J. Ecology 17, 329-350.
[30.] Soó R. 1965. Növényföldrajz. [Plant geography] Tankönyvkiadó, Budapest
[31.] Stefanovits, P., Filep, Gy., Füleky, Gy. 1999. Talajtan.[Soil science] Mezőgazda kiadó,
[32.] Budapest, pp. 470
[33.] Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, G., van der Plicht, J., Spurk, M. 1998. INTCAL98 radiocarbon age calibration, 24,000–0 cal BP. Radiocarbon, 4.(3), 1041–1083.
[34.] Sümegi P. 1998. Ember és környezet kapcsolata a Kárpát-medencében az elmúlt 15000 év során. [The relation between mankind and environment int he Carpathian Basin int he last 15000 years] Panniculus 3, 367-395.

[35.] Sümegi, P., Kozák, J., Magyari, E., Tóth, Cs. 1998. A Szakáld-Testhalmi bronzkori tell geoarcheológiai vizsgálata. [Geoarchaeological examination of the Bronze Age tel lat Szakáld-Testhalom] Acta Geographica, Geologica et Meteorologica Debrecina, 34, 165-180.

[36.] Sümegi, P., Krolopp, E., Rudner, E. 2002. Negyedidőszak végi őskörnyezeti változások a Kárpát-medencében térben és időben.[Palaeoecological changes in time and space at the end of the Quaternary int he Carpathian Basin] Földtani Közlöny, 132., 5-22.

[37.] Szabolcs I., Várallyay, Gy., Mélyvölgyi, J. 1978. Az újszentmargitai talajok és a táj ökológiája. [Ecology of soils and the landscape of Újszentmargita] Agrokémia és Talajtan, Tom. 27., No. 1-2., 1-30.

[38.] Székely, Gy. 1984. Magyarország története. [History of Hungary] Előzmények és magyar történet 1242-ig. Akadémiai Kiadó, Budapest, p. pp. 49-68.

[39.] Szöőr, Gy., Sümegi, P., Balázs, É. 1991. Sedimentological and geochemical analysis of Upper Pleistocene paleosols of the Hajdúság region, Hungary. In: Pécsi, M., Schweitzer, F. (eds), Quaternary environment in Hungary. Studies in Geography in Hungary, 26. Akadémiai Kiadó, Budapest, pp. 47-59.

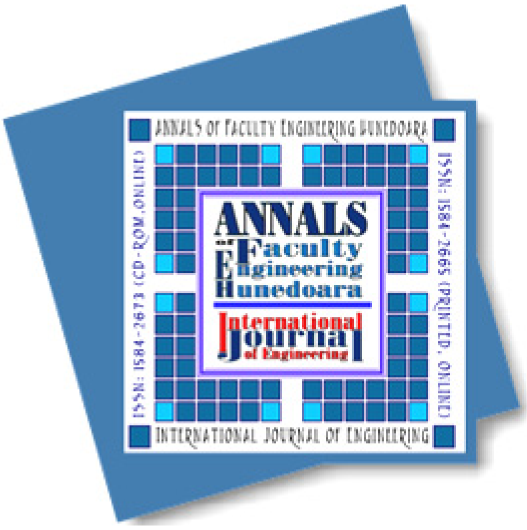
[40.] Tóth, A. (ed.) 1999. Kunhalmok. [Kurgans] Alföldkutatásért Alapítvány Kiadványa, Kisújszállás, pp. 77

[41.] UNESCO, 1999. http://whc.unesco.org/sites/474rev.htm

[42.] Várallyay, Gy., Láng, I. 2000. A talaj kettős funkciója: természeti erőforrás és termőhely. [The double function of soils: natural resource and place of production] A Debreceni Egyetem „Honoris Causa" cím átadása alkalmából megtartott előadás, Debrecen, p. 5-7.

[43.] Willis, K.J., Braun, M., Sümegi, P. Tóth, A. 1997. Does soil change cause vegetation change or vica versa? A temporal perspective from Hungary. Ecology, 78(3), 740-750.

[44.] Willis, K. J., Sümegi, P., Braun, M., Keith, D.B., Tóth, A. 1998. Prehistoric land degradation in Hungary: who, how and why? Antiquity 72, 101-113.


ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering