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Piroska Pazonyi, L² szlÄ Kordos, EnikĢMagyari, Elena Marinova, Levente FÍ kĢh, M² rton Venczel

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Pleistocene vertebrate faunas of the Süttő Travertine Complex (Hungary)

Piroska Pazonyi; László Kordos; Enikő Magyari;
Elena Marinova; Levente Fükőh; Márton Venczel

Abstract

Numerous fossil remains (vertebrates, molluscs and plants) were found in more than twenty sites of the Süttő Travertine Complex during the last 150 years. The majority of these remains were recovered from fissures of the travertine, but also from the travertine and an overlying loess-paleosol sequence. The aims of this study were to review the fossil content, to determine the stratigraphical positions of the various vertebrate faunas of Süttő and provide paleoecological interpretation of the periods on the basis of their faunas and floras. In addition, this paper describes new faunas and floras from the sites Süttő 16–20 and provides ^{14}C dates for Süttő 16.

On the basis of the new uranium series isotope and optical dating (OSL), the age of the travertine complex is Middle Pleistocene (235±21–314±45 ka, MIS 7–9), while the age of the loess-paleosol sequence in superposition of the travertine is Middle-Late Pleistocene (MIS 2–MIS 6). In contrast, the fossils of the travertine indicated an older, Pliocene–Early Pleistocene age. A fissure (Süttő 17) and a red clay layer (Süttő 19) contained mammal faunas of Early–Middle Pleistocene age. These results indicated the existence of older travertine in certain quarries (Hegyháti quarry, Cukor quarry).

Sedimentological and OSL data of well-dated layers of the loess-paleosol sequence (Süttő/LPS) at Süttő allowed a correlation with the layers of Süttő 6. The paleosol layer in the upper part of the sequence of Süttő 6, was correlated with a pedocomplex of the overlying loess-paleosol sequence, which was dated to MIS 5c (upper, dark soil) and MIS 5e (lower, reddish brown soil). The paleoecological analysis of the mammal and mollusc faunas supported the former interpretation of Novothny et al., inferring warm, dry climate during the sedimentation of the upper layers, and more humid climate for the lower layers). However, the fauna of the lower soil layer indicated cold climate, so an age of MIS 5d is suggested.

Dating of the fissure faunas is based on similarity studies. For some faunas, this method cannot be used, because of the low number of species. On the basis of the species compositions and former interpretations, these faunas originated mainly from sediments that were deposited under cold climatic conditions. Other fissure faunas

were dated by AMS ^{14}C (Süttő 16), or by correlation with soil layers of Süttő 6. According to these results, most of the fissure faunas can be correlated with different phases of MIS 5. However, there are a younger (MIS 2) and an older (Early–Middle Pleistocene) fissure fauna.

1. Introduction

The Süttő Travertine Complex (northern Hungary) was known in the geological literature as a series of paleontological sites for more than a century. The age of this complex was discussed by several authors since the middle of the 19th century (Hantken, 1861; Hauer, 1870; Hofmann, 1884; Liffa, 1907; Kormos, 1911, 1913, 1926; Schréter, 1953; Scheuer and Schweitzer, 1974; Jánossy, 1969, 1979; Brunnacker et al., 1980; Jánossy and Krolopp, 1981; Novothny et al., 2009, 2011; Kele, 2009; Sierralta et al., 2010).

To the authors' knowledge, Kormos (1926) was the first who identified vertebrate remains in the travertine and its fissures. His observation, that the age of the travertine's vertebrates is much older than the age of the fissure infill faunas, was a good take-off for later research. In addition to the vertebrate sites, he also described two archaeological sites from Süttő (Fleissig and Kormos, 1934). He suggested that the fauna of Süttő is not very similar to the mammalian faunas of Brasov and Püspökfürdő (Kormos, 1926), and that it is younger than those. He placed the fauna at the end of the preglacial interval characterised by Mediterranean climate (Kormos, 1926, Kretzoi, 1927). In contrast, Kretzoi (1927) suggested that the fauna of Süttő originated from the last interglacial fauna of Germany and Austria that migrated to this area when the ice front expanded southward in Scandinavia.

In the 1970s, Jánossy and Krolopp made excavations in this area and described several new faunas from travertine fissure infills and one unique fauna from the loess-paleosol sequence that covers it (Jánossy, 1969, 1979; Brunnacker et al., 1980; Jánossy and Krolopp, 1981). This site (Süttő 6) is the type locality of the Süttő Biochronological Phase (Kretzoi, 1953). In the 1980s, Kordos and Krolopp discovered and excavated some further sites in the quarries (Süttő 16–20), which are not published yet.

The aim of this study is to review the fossil content of the various sites of the Süttő Travertine Complex, their correlation an to describe the vertebrate and mollusc faunas, as well as the macrocharcoal-based floras of Süttő 16–20 and correlate them with the formerly discovered sites from Süttő and other Hungarian localities.

2. Geological setting

The town of Süttő is located in northern Hungary, about 60 km northwest of Budapest, close to the right bank of the river Danube (47º44.26' N, 18º26.87' E). The vertebrate sites of Süttő are located in the Diósvölgyi, Hegyháti, Új Haraszti and Pachl quarries on the northern slope of the Haraszt Hill in the Gerecse Hills, part of the West Hungarian Mountain Range (Fig. 1).

Süttő is one of the largest travertine deposits in the Gerecse Hills. The travertine covers an area of more than 1 km^2. The immediate bedrock of the travertine is Upper Pannonian gravel, sand and clay, which were correlated with the VIIth terrace of the river Danube by Pécsi et al. (1982). The minimum age of the terrace is Late Pliocene, based on the record of *Anancus arvernensis* and *Tapirus arvernensis* found in the travertine in superposition of the fluviatile sediments (Jánossy and Krolopp, 1981). The eroded surface of the travertine is covered by loose Upper Pleistocene eolian sediments: Riss-Würmian loess and Holocene topsoil. In the lower part of the loess section, a reddish paleosol horizon can be found, that developed during the last interglacial (Pécsi et al., 1982; Novothny et al., 2009, 2011). Petrographic description and interpretation of a site from the loess-paleosol sequence (Süttő 6) are in Table 1 (Brunnacker et al., 1980).

The fissures' infills also contain loess and paleosol layers, but red clay layers also occur. For example, the sequence of Süttő 16 is the following: red sandy loess, which was divided to three sublayers by visible remains ("csontos"– the lower layer wherein there are numerous bones (6); "marhás"– the middle layer wherein there are Bovidae remains (5); "eszközös" – the upper layer wherein there are tools (4)); soil, above the fissure, which was also divided into three sublayers on the basis of their colour ("legalsó" – the lightest lower layer (3); "sötét alatt középső" – the darker middle layer (2); "sötét talaj felső" – the darkest upper layer (1)) (Fig. 2). However, the sequence of Süttő 17 varies from the former one: the lower layer is red clay (17/C), and the upper one is sandy loess (17/L) (Fig. 3).

3. Material and methods

3.1. Fossil sites at Süttő

The known 20 fossil sites at Süttő (Fig. 1) are grouped into: (1) sites from the travertine; (2) sites from the loess-paleosol sequence (Table 2); and (3) sites from the fissures in the travertine (Table 3).

3.1.1. Non-numbered sites from the travertine

Fossils from the travertine have been found/recovered during mining, but they have never been collected systematically. These fossils, mainly vertebrates, often were found far from the quarry, mainly near renovation works of buildings, or in separated travertine blocks. Therefore, the exact location of these fossils is unknown. The exact provenance of fossils collected by Kormos or deposited earlier in his collection (see Kormos, 1926) is unknown. However, the localities of some vertebrate remains, which were found in the Hegyhát quarry (*Anancus arvernensis*, *Dicerorhinus* cf. *jeanvireti*, *Cervus* cf. *philisi*), and that of one fossil (*Cervus* cf. *ardei*), which is known from the top layer of Gazda quarry (Jánossy and Krolopp, 1981), are known.

The molluscan fauna of the travertines was identified exclusively on the basis of impressions and casts. Former lists of the malacofauna were revised by Krolopp (in Jánossy and Krolopp, 1981).

3.1.2. Sites from the loess-paleosol sequence (Süttő 5–6)

Süttő 6 is the most important site from the loess-paleosol sequence. It is situated in the northwestern corner of the Diósvölgyi quarry, about 210 m above sea level, in sandy loess (Fig. 1). The upper layers of this profile yielded fossils (vertebrates and molluscs, referred to site Süttő 5), but Jánossy started his excavation in 1973 from the paleosol horizon situated in the lower tier of the profile. He burrowed a 5 m deep, 1 m wide and 8 m long trench to the surface of the travertine. Except for the paleosol horizon, the loess seemed to be uniform sandy loess. He collected material per 20–50 cm and separated 13 layers (Jánossy, 1979; Brunnacker et al., 1980).

Süttő 6 is unique because, in contrast to other loess sites, of the co-occurrence of molluscs plus a significant volume of vertebrate remains in each layer (Table 2). This site is the type locality of the Süttő Biochronological Phase (Kretzoi, 1953; Jánossy, 1979).

3.1.3. Sites from fissures in the travertine

3.1.3.1. Kormos' sites (Süttő 1–2)

Kormos (1926) reported vertebrates from the fissures at first. However, the site of these vertebrates was not assigned exactly in his works. According to Jánossy (1969), Kormos collected his material from two places: Diósvölgy quarry (Süttő 1), and Pachl quarry (Süttő 2). In addition, he supposed Süttő 4/2 (Jánossy and Krolopp, 1981) is also related to one of Kormos' sites (Fig. 1, Table 3). Although the vertebrate fauna which was published by Kormos (1926) seems mixed, it is very important, because he noted small-sized carnivores, which have not been recorded from other sites of Süttő.

3.1.3.2. Jánossy's and Krolopp's sites (Süttő 3–4 and 7–15)

Jánossy and Krolopp found and excavated several sites between 1965 and 1974 (Jánossy, 1979; Jánossy and Krolopp, 1981). Some of them contain snail faunas only (Süttő 10, 11, 14 and 15), but in most cases they also found vertebrate remains (Fig. 1, Table 3).

3.1.3.3. Kordos' and Krolopp's sites (Süttő 16-20)

In the late eighties (1986–1988), Kordos and Krolopp collected five new faunas (sites 16–20) from the northern part of Hegyháti quarry (Müller quarry), Diósvölgyi quarry and New Haraszti quarry. These sites are mainly fissures (Süttő 16, 17, 18 and 20), but one (Süttő 19) is a fossiliferous, red clay layer in the travertine.

Süttő 16 is a fissure on the north wall of Hegyháti quarry (Fig. 1). Kordos and Krolopp found vertebrates, molluscs and charcoal in each layer (Table 4). To avoid referring to the original difficult names, the layers are numbered as shown in Figure 2, and henceforth this paper refers to these names (Süttő 16/1–6).

Süttő 17 is a fissure infill in Hegyháti quarry (Fig. 1), with two layers (Fig. 3, Table 4).

Süttő 18 is also a fissure infill in Hegyháti quarry (Fig. 1). Unfortunately from this fissure, only bone fragments were found.

Süttő 19 is a red clay layer in the southern wall of New Haraszti quarry (Fig. 1). This site has a poor vertebrate fauna (Table 4).

Süttő 20 is a fissure infill in Diósvölgyi quarry, near site Süttő 4 (Fig. 1). Some vertebrate remains and molluscs were found at this locality (Table 4).

Vertebrates (*Pliomys* sp., *Mimomys pusillus*) were found in the southern part of the area in Cukor quarry (Fig. 1). Cukor quarry is a small, disused quarry at higher elevation (260–270 m a.s.l.) than the other quarries. Its travertine is harder than other travertines from Süttő, with abundant calcite veins, dripstone fragments and reddish colour because of its red clay content. Probably this material originated from a cemented, red clay cave fill (Fig. 4).

3.2. Methods

3.2.1. Similarity study

For the correlation of the faunal assemblages, correlation measures were used. Percentage similarity is an index that measures the common part of two temporally consecutive or spatially adjacent communities and is calculated as follows (Krebs, 1989):

$P = \Sigma \text{ minimum } (p_{1i}, p_{2i})$;

where P is the percentage similarity between community 1 and community 2, p_{1i} is percentage of the i^{th} species of community 1, and p_{2i} is percentage of the i^{th} species of community 2.

3.2.2. AMS ^{14}C Dating

For this study, ^{14}C dates from two layers of Süttő 16 provide an independent age control. The measurements were done in ATOMKI (Debrecen, Hungary) by AMS.

3.2.3. Wood charcoal analysis

The material for wood charcoal analysis comes from handpicked visible concentrations of charcoal from layers 2-6 of Süttő 16 (Fig. 2). The wood charcoals were analysed under a reflected light microscope Zeiss Axiscope MAT, to 400X magnification. All fragments bigger that 5 mm (in total 46) were fractured in transversal, radial and tangential sections in order to observe the corresponding diagnostic anatomical features of the wood and to identify them. For identification, wood anatomical atlases (Greguss, 1955; Schweingruber, 1990) and a wood reference collection from Europe and West Asia were used. The determined charcoal specimens are given as absolute numbers in Table 4. Light microscope images made at Leuven University are displayed in Figure 6.

4. Results

4.1. Dating and correlation of faunas

4.1.1. Dating of the travertine

More than 50 travertine sites are known from the northern part of Gerecse Hill. These sites were found along a NE–SW line (Scheuer and Schweitzer, 1988). They were formed during the Pliocene (62%) and the Quaternary (32.8%), and the most dynamic interval of travertine formation within the Quaternary was in the Lower Pleistocene (Scheuer, 2002). However, the Pliocene travertines cannot be differentiated clearly from the Pleistocene travertines by their morphology and elevations in Gerecse Hill. In general, the older occurrences (older than the lower limit of the uranium-series dating method) are located above 250 m a.s.l., while the Middle Pleistocene travertines are situated between 250 and 150 m a.s.l. (Kele, 2009). In Scheuer and Schweitzer's (1981) opinion, the Middle Gerecse was the main drainage area in the Lower Pleistocene, and the travertine at Süttő formed at this time.

At the same time, new research (Kele, 2009; Sierralta et al., 2010) indicated a far younger, Middle Pleistocene age in the case of travertine at Süttő. Sierralta et al. (2010) published uranium-series ($^{230}Th/^{234}U$) dates of the travertine from two sections. On the basis of their examinations, the age of the travertine is mid- Pleistocene, ranging from 235 ± 21 to 314 ± 45 ka (296±22 ka at Új Haraszti quarry, 422±21 ka at Diósvölgyi quarry and 273±65 ka at Hegyháti quarry), that can be correlated with Marine Isotope Stages (MIS) 7–9. The age of the overlying loess-paleosol sequence was determined by OSL dating. Novothny et al. (2009, 2011) placed the formation of the loess sequence into MIS 2–6.

These results at first sight are in conflict with the paleontological data. Ranges of vertebrates from the travertine indicated a Pliocene–Lower Pleistocene age. However, Kele did not examine travertines from the northern part of Hegyháti quarry, from where fossils with exact location are known (see above). It is possible that the travertine of this part of Hegyháti quarry is older, as its elevation is not as high as in other parts.

The fauna of Süttő 17 also indicates an older age of the northern part of Hegyháti quarry. This fauna is very similar to that of the site Somssich-hegy 2 (Jánossy, 1983). Its age, based mainly on arvicolids (*Mimomys savini, Microtus pliocaenicus, Pliomys episcopalis, P. lenki, Microtus gregaloides)*, is at the boundary of the Lower to the Middle Pleistocene (about 800 ka). The fauna of Süttő 19 indicated an even older age (Lower Pleistocene). The new finds from the travertine of Cukor quarry (*Mimomys pusillus, Microtus pliocaenicus)*, its elevation and this travertine's differing appearance (pink, more compact and harder than the other travertines at Süttő) also suggests the existence of an older (Pliocene/Lower Pleistocene) travertine at Süttő.

4.1.2. Dating and correlation between the loess-paleosol sequence and Süttő 6

In previous years, several papers were published about a loess-paleosol sequence of Süttő (Süttő/LPS) (Novothny et al., 2009, 2011). The loess deposits are up to 20 m thick, and contain two greyish, laminated horizons, three brownish steppe-like soils and a thick pedocomplex including a dark brown chernozem-like paleosol and a reddish-brown paleosol (Novothny et al., 2011). Sedimentological studies and luminescence ages, mainly from the lower tiers of the section (Unit 14–16), are of importance.

This part of the section contains the pedocomplex (Unit 14–15, 1.5 m) and the lowest loess layer (Unit 16, 4 m). In the former literature about Süttő 6 (Brunnacker et al., 1980; Jánossy, 1979), the similarity of the two sections is apparent. Both of them are about 5 m thick, their top layers are paleosols, and both are underlain by loess. On the basis of their sedimentological descriptions (and vertebrate remains in case of Süttő 6), the units of the loess-paleosol section were correlated with the layers of Süttő 6 (Fig. 5).

At Süttő 6, there are five paleosol layers at the top of the section underlain by sandy loess layers. Based on their sedimentology and vertebrate material, the paleosol layers were divided in two parts. Layers 6/2–3 consist of a dark brown chernozem (1 m). Layers 6/4–5 are light reddish brown, chalk enriched horizons (C_c-horizon) (Jánossy, 1979; Brunnacker et al., 1980). The proportion of the steppe species is higher (61%), while the proportion of the forest species is lower (25%) in layers 6/2–3 than in layers 6/4–5 (56% steppe and 33% forest species) (Table 5). The mollusc fauna of this site also showed significant difference between layers 6/2–3 and 6/4–5. The molluscs of layers 6/2–3 indicated warm and dry climate (proportion of xerotherm species was 18% and cold indicator species are missing). In layers 6/4–5, the mollusc fauna indicated a slightly more humid, but rather dry and cold climate (proportion of cold indicator species was 40%) (Table 5).

These results can be correlated with Units 14–15 of the Süttő loess sequence (Novothny et al., 2011) and their paleoclimatic and environmental interpretations (warm, dry climate during the sedimentation of the upper layers, and more humid climate for the lower layers). Units 14-15 were dated at 93.7±21.1 ka and 106±13 ka/137±23 ka, respectively in the loess sequence. Layers 6/2–3 in Süttő 6 correspond with MIS 5c, while layers 6/4–5 correspond rather with MIS 5d than MIS 5e, because their fauna suggested rather cold climates. The lower loess layers were correlated with Unit 16 (MIS 6).

4.1.3. Dating and correlation of the fissures' faunas

Stratigraphic correlation of the fissure faunas is based on similarity studies. For some faunas, this method could not be used, because of the small number of species. On the basis of their species composition and former interpretations, these faunas originated mainly from sediments, which were deposited under cold climatic conditions (Süttő 4/1, 8/1, 8/3 and 13). However, some small faunas deposited under warmer climate (Süttő 4/2, 8/3 and 16/1) yielded insufficient material for analysis. Fauna of Süttő 3 is also poor, but this fauna was fairly well correlated with other faunas based on the appearance of an index fossil (*Dama* sp.).

In the course of correlation studies, suitable faunas from the site Süttő 6 were compared with other mammalian faunas with similar ages (MIS 5), and with each other. Süttő 16 is, based on ^{14}C data, younger than the others, so this site was studied separately.

Similarity studies of small mammalian faunas showed strong connections between Süttö 6 and Süttő 3, 7/U and 9 (percentage similarity >60%). Between Süttö 6 and Süttő 7/L and 12A the percentage similarity is about 50%, whereas the site 12/B did not show correspondence with the site Süttő 6 (Table 6).

The mammalian faunas (including site 16) were divided into three groups: (1) proportion of steppe species is far higher (50–55%) than proportion of forest species (15–30%) (Süttő 9 and 16/2); (2) proportion of forest species is far higher (40–65%) than proportion of steppe species (16–40%) (Süttő 3 and 7/L) and (3) proportions of steppe and forest species are nearly equal (20–40%) (Süttő 7/U, 12/A, 16/3 and 16/5–6). These groups coincide with the results of comparison of the faunas. Within the first and second groups the percentage similarity values are about 60%, while in case of the third group, the values are about 50–55% (Table 7).

However, in the mollusc faunas there are slightly different groups. Most mollusc faunas indicated warm and dry climatic conditions (site 3, 9, 12/A and 12/B), whereas in sites 16 and 7/U they indicated cold and humid climates. The fauna of site 7/L, based on its mollusc fauna, arose in warm and humid circumstances (Table 7).

Based on these (mainly mollusc) results, faunas of Süttő 3, 9 and 12/A were correlated with Süttő 6/2–3 (although the site Süttő 9 also showed strong correlation with other faunas of the same region: Diósgyőr-Tapolca Caves (Hellebrandt et al, 1976), as well as Eger, Dobó-bástya (Kordos and Krolopp, 1980)). The result of this analysis showed cold and humid climatic conditions at Süttő 7/U, a site also well correlated with Süttő 6. Accordingly, this fauna was correlated with Süttő 6/4–5.

In the mammalian fauna of Süttö 7/L, the percentages of steppe and forest species are in contrast to values of Süttő 6. However, site 7/L was well correlated with Tarkő IV

(Jánossy, 1979) (MIS 5c). Beside this, the proportion of forest species is far higher (43%) than proportion of steppe species (17%) in the mammalian fauna of Tarkő IV, even as in the group 2 (Table 7). The mollusc fauna of Süttő 7/L also indicated a warm and humid climate. This result indicates that the age of these sites is probably not MIS 5c, which climate was warm and dry, but more likely MIS 5e.

Results of similarity study showed that mammalian fauna of site 12/B did not show strong correspondence with other faunas, although its similarity with the fauna of site 12/A is about 54%. However, its mollusc fauna indicated a more humid climate than site 12/A. The proportions of steppe (15%) and forest species (52%) in this fauna are similar to the Tar-kő IV, Süttő 3 and 7/L. Although the connections between the mammalian fauna of 12/B and these sites are fairly weak, they were tentatively correlated. The correlation results showed that all the mammalian faunas, which were deposited in warmer climate conditions, might be correlated with MIS 5.

4.1.4. Dating of Süttő 16

In order to obtain numerical ages for the floras of Süttő 16/3 and 16/6, 2 charcoal pieces were selected for AMS ^{14}C dating. For Süttő 16/3, the measurement was made on *Pinus* sp., while the other was on *Betula* sp. The results are as follows:

Süttő 16/3 (DeA-1319) — 12499±54 conv. BP (1σ); 15050–14590 cal BP (1σ), 14430–14350 cal BP (1σ);

Süttő 16/6 (DeA-1320) — 14079±63 conv. BP (1σ); 17340–17030 cal BP (1σ).

Three vertebrate (mainly mammal) cave localities (Peskő, Jankovich and Bivak Caves) are known from this period in Hungary. Comparing these with the mammalian fauna of Süttő 16, there is similarity with the sequence of Peskő Cave (Hír, 1991) only. This result was surprising, because the Bivak (Jánossy et al., 1957) and Jankovich Caves (Bácskay and Kordos, 1984) (Pilis and Gerecse Hills) are located very near to Süttő, whereas the Peskő Cave is in the Bükk Mountain. Based on Pazonyi (2006), the age of the top (yellow) layer of Bivak Cave is 15970±270 conv. BP, whereas the ages of Jankovich Cave are 11720±190 conv. BP (layer 7) and 12440±230 conv. BP (layer 8).

On the basis of the ^{14}C dates, the macrocharcoal assemblages of Süttő 16/4 postdate the last glacial maximum (LGM) and were likely deposited during the Oldest Dryas (late MIS 2). Overall, the layers of Süttő 16 are correlated with the top paleosol and loess layers of the loess- paleosol sequence (Unit 1–2) (Novothny et al., 2011) (Fig. 5).

4.2. Paleoecological analysis

According to their assumed ecological preferences, the mammalian community from the older (Pliocene/Lower Pleistocene) travertine, allude unequivocally to warm, humid climate and closed forest vegetation during its formation. Unfortunately, no vertebrate fossils have been recovered from the younger (Middle Pleistocene) travertine, but based on their Th/U ages and isotope geochemical ($\delta^{13}C$ and $\delta^{18}O$) results of Kele (2009), it was formed during the cold, but humid interval of MIS 7–9.

The mammalian and mollusc fauna of Süttő 6 and the sedimentological analysis of the loess-paleosol complex indicate warm/dry climate and steppe-like vegetation for layers 6/2–3 (MIS 5c), with colder and more humid climate during the formation of layers 6/4–5 (MIS 5d) (Table 5). The mammalian and mollusc faunas, in Süttő 3, 9 and 12/A indicate similar climatic conditions and vegetation as during the formation of Süttő 6/2–3. Süttő 7/U was formed under colder and humid circumstances, similar to Süttő 6/4–5 (Table 7).

Paleoecological analysis of the mammalian fauna of Süttő 16 also showed colder and humid climatic conditions (Table 8). The charcoal assemblages suggest the prevalence of boreal forest vegetation around the locality with birch (*Betula* sp.), pine (*Pinus* sp.), alder (*Alnus* sp.), spruce (*Picea* sp.) and larch (*Larix* sp.) (Fig. 6). Overall they suggest a cold continental climate during the terminal phase of MIS 2 (Oldest Dryas). The presence of spruce suggests that available moisture was relatively high (Rudner and Sümegi, 2001) in this period. Results of herpetological analysis of Süttő 16 also suggested cold and humid climate with parkland vegetation, in line with the results of the anthracological analysis. In contrast to this, the mammalian and mollusc fauna of Süttő 7/L indicated warm and humid climate and closed forest vegetation (Table 7).

In the mammalian fauna of site Süttő 17 (Early Biharian, MIS 22), the steppe species are dominant (60%), and the proportion of forest species is 40%. This result indicates probably steppe or parkland vegetation. This inference was supported by results of the herpetological analysis (dry, temperate climate, grassland vegetation).

On the basis of the results of the herpetological analysis, the fauna of site Süttő 19 (Late Villanyian–Early Biharian) was formed under warm (warmer than today), very dry (Mediterranean-like) climate and shrub-forest vegetation. The herpeto- and mollusc fauna of site Süttő 20 indicated temperate and humid climate and forest vegetation.

5. Conclusions

The data suggest the existence of older, Pliocene/Lower Pleistocene travertine deposits at Süttő in the north part of Hegyháti quarry and in Cukor quarry. These quarries have not yet been dated by U-Th. In addition to the vertebrates of the travertine, mammals of Süttő 17 and 19 also have signalled older ages.

The layers of Süttő 6 are correlated with parts of the loess-paleosol sequence (Units 14–16) (Novothny et al., 2011). Layers 6/2–3 are well correlated with Unit 14. In Novothny et al. and the authors' opinion, this unit corresponds to MIS 5c. This period was also correlated with some fissure faunas: Süttő 3, 9, 12A and probably 12/B (Fig. 7). According to Novothny et al.'s (2011) interpretation and based on the mammalian and snail faunas, it was a warm and dry period with steppe-like vegetation.

Other faunas showed strong connection to the site Süttő 9. Ringer and Moncel (2002) reviewed Taubachian tools from those layers of the Diósgyőr-Tapolca Cave with fossils (layers 4–5). The Taubachian culture is typical of MIS 5, so this data gave the age of the site. The mammalian fauna of Eger, Dobó-bástya is also correlated with MIS 5 (Pazonyi and Kordos, 2004).

Layers 6/4-5 of Süttő 6 are correlated with Unit 15 of the Süttő loess-paleosol complex. In Novothny et al.'s (2011) opinion, this unit corresponds to MIS 5e, but on the basis of the fauna it is suggested here to correspond to MIS 5d. In this period the climate was more humid than for Unit 14, but still rather dry and cold. The fissure fauna of Süttő 7/U is also correlated with this period. Layers 6/6–10 were correlated with Unit 16 (MIS 6) (Fig. 7).

Süttő 7/L, and the very similar Tarkő IV, are potential faunas of MIS 5e, which indicate warm, humid climate and closed forest vegetation.

Fauna of Süttő 17 is very similar to that of the site Somssich-hegy 2 (Jánossy, 1983), which is dated, mainly based on arvicolids, to the Early/Middle Pleistocene boundary. Süttő 16 is a younger site, correlated with Unit 1–2 of the loess-paleosol sequence (Novothny et al., 2011). Its age, based on the ^{14}C dating, is 17290–14300 cal BP (Fig. 7). Paleoecological analysis of its fauna and flora showed cold, humid climate and boreal parkland vegetation.

Wood charcoal and macrofossil assemblages dating to the Oldest Dryas are relatively scarce in the Carpathian Basin and adjoining areas. The Süttő 16 wood assemblage is in agreement with the indication in other sites: a parkland boreal landscape with increasing coverage of *Betula* in addition to *Pinus* species and *Picea abies* (e.g. Budapest-Csillaghegy, Balatonederics in Rudner and Sümegi 2001; Balatonederics in Juhász, 2007; Jakab, 2007), *Picea*, *Pinus cembra* and *Salix* (Poland, Damblon and Haesaerts, 1997; Haesaerts et al., 1998), and *Pinus cembra* and *Larix* (Slovak Tatra Mts, Jankovska and Pokorny, 2008; Kunes et al., 2008). Comparing the wood charcoal data with contemporaneous Transdanubian pollen records, the main difference concerns the scattered prevalence of relatively thermophilous temperate broad-leaved trees (*Corylus*, *Ulmus*, *Quercus*, *Fagus*) in several Oldest Dryas pollen records (e.g. Sárrét, Balatonederics, Mezőlak, Willis et al. 2000; Juhász and Szegvári, 2007; Juhász 2007), which, however, have not yet been confirmed by wood charcoal or macrofossils. The Süttő wood charcoal flora holds no evidence for their local occurrence either. Comparing the full glacial (LGM) woody cover of the Carpathian Basin with the Oldest Dryas (OD), the main difference is the increasing coverage of *Betula* during the OD that is in line with its increasing pollen frequency in several pollen records (Járai-Komlódi, 2003, Feurdean et al., 2007; Juhász and Szegvári, 2007), but otherwise the wood assemblages are similar. Notable is the abundance of *Picea* in Süttő 16 that seems typical for MIS 3-2 wood charcoal assemblages in the hilly area of Northern Transdanubia (Rudner and Sümegi, 2001). Mixed boreo-nemoral parkland forests were likely widespread in this region.

Based on former investigations (Pazonyi, 2004, 2006, 2011), in the Oldest Dryas the composition and the paleoecological features of the mammalian fauna also changed in the Carpathian Basin. The composition of fauna indicates warmer and wetter climate with more closed (forest-steppe) vegetation, but the area of tundra vegetation was probably significant (Pazonyi, 2004, 2011). These observations are in agreement with the paleoecological results of the current studies of the Süttő 16 fauna.

Earlier pollen and plant macrofossil studies in the Süttő 6 profile provided a relatively detailed picture of the last interglacial vegetation (Brunnacker et al., 1980). Pollen assemblages were studied in the MIS 5c and MIS 5d paleosols and the underlying loess horizons of Süttő 6, and yielded mainly entomophily herb rich pollen floras dominated by the Compositae subfamily Tubuliflorae. Brown paleosols likely dating to MIS 5c were abundant in *Juglans* pollen and contained fruits of *Celtis australis* and *Crataegus* sp. (Brunnacker et al., 1980). *Juglans* was considered secondary in the pollen assemblages. However, the association of these trees and shrubs suggests warm Sub-Mediterranean climate and at least partially forested landscape that agrees well with the fauna-based environmental inferences for this interglacial period. The reddish brown paleosol horizon was rich in *Vitis* seeds (both *V. vinifera* and *V. sylvestris*; Brunnacker et al., 1980) and inferred to liana rich forested environment probably near to a water body. These last interglacial botanical records are important additions to the Eemian floras of the Carpathian Basin, summarized by Járai-Komlódi (2003). The richest pollen and macroflora was described from the travertine deposits of Tata (19 km SW from Süttő; Vértes, 1964). Here, *Celtis* was also recorded in the warmest phase of the interglacial together with Cupressaceae, *Biota*, *Corylus*, *Cornus* and *Rhamnus*. Similar to this study's interpretation, Járai-Komlódi (2003) has inferred strong Mediterranean climatic influence in this period, but also emphasized the warm-microclimate of the area due to the presence of thermal springs. Brunnacker et al. (1980) made some important inferences regarding the MIS 6 (late Saalian glacial) steppe vegetation of Süttő as well. First of all, they argued that the absence of *Artemisia* and Chenopodiaceae pollen and the scarcity of Poaceae pollen in the loess deposit preclude the presence of periglacial sagebrush and grass steppes in this region unlike in Austria. Second, they argued that the high relative frequency of *Centranthus* sp., a typical Southern European drought-tolerant but warm-loving herb genus, suggests herb/forb rich warm steppe vegetation during MIS 6.

The composition of the Süttő 6 faunas and the current results is partly in agreement with these observations. All observations allude to warm and dry (Sub-Mediterranean) climate and steppe-like, but partially forested landscape, during MIS 5c (Süttő 6/2–3). Paleoecological interpretation of MIS 5d is unequivocal as well. There were more humid, but rather dry and cold climate and liana rich forested vegetation, probably near to a water body (Süttő 6/4–5). However, the current results do not support the former results. Mammalian and mollusc faunas of Süttő 6/6–10 (MIS 6) unequivocally indicate cold climate (*Microtus gregalis* was dominant in the mammalian fauna and *Dicrostonyx torquatus* also present; 68% of the mollusc fauna was oligothermic), so the former warm steppe hypothesis is untenable. Probably, there was cold, periglacial steppe in this region, but around the thermal springs, herb/forb rich warm steppe vegetation also was present.

Revision of the classical and studies of newly discovered vertebrate faunas from the Carpathian Basin allowed the reconstruction of an almost complete succession from the Late Saalian to the Early Weichselian (Pazonyi and Kordos, 2004):

Late Saalian–Eemian transition (MIS 6) — Type fauna Süttő 6, layers 6-10. The lowermost layer contains *Dicrostonyx* and *Lagopus muta* remains, while *Microtus* *gregalis* decreases and is replaced in predominance by *M. arvalis*. The current results completed this idea. The periglacial steppe was changed to warmer steppe vegetation in the surroundings of the thermal springs.

Eemian (MIS 5e) — Formerly, Süttő 6 layers 2–5 was considered the type fauna of this period. On the strength of the current results, these layers do not represented MIS 5e, but MIS 5d and MIS 5c. Instead of Süttő 6, the localities from the last interglacial are the karst fissure faunas of Süttő 7/L and Tarkő IV. These faunas are dominated by *Apodemus sylvaticus*, *Myodes glareolus*, glirids and insectivores, without any significant steppe and cool elements. Another locality from the Carpathian Basin is Por-lyuk at Jósvafő (Jánossy et al., 1973) which has a similar faunal character with a series of forest elements (*Myodes glareolus*, murids and glirids) in combination with some steppe taxa (*Spermophilus*, *Sicista*, *Spalax*, *Ochotona*).

Eemian–Weichselian transition (MIS 5d, MIS 5c) — This transition period is characterised, on the basis of current results, by most of the faunas of Süttő (Süttő 6/4–5, 7/U (MIS 5d); Süttő 3, 6/2–3, 9, 12/A (MIS 5c)), and several newly discovered faunas, as Horváti-lik at Uppony (Fükőh and Kordos, 1977, 1980; Pazonyi and Kordos, 2004), Eger Dobó-bástya (Kordos and Krolopp, 1980), Tatabánya Kálvária 4. (Kordos, 1994), Poros-lyuk at Répáshuta (Jánossy, 1979), and Bajót 3. rock-shelter 5a layer (Kordos, 1994). The faunas of these localities appear to fill the 25-30 ky gap between the end of the Eemian Süttő Phase (MIS 5e) and the Early Weichselian Varbó Phase (MIS 4) in Hungary.

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Figure captions

Fig. 1. Map showing location of Süttő in northern Hungary (Novothny et al., 2011) (left side), and the quarries of Süttő with numbers of vertebrate localities (right side). **A1** is an archaeological site (Süttő-Diósárok), **LPS** is the loess-paleosol sequence of Novothny et al. (2011).

Fig. 2. Section of site Süttő 16 with new layer numbers.

Fig. 3. Drawing of site Süttő 17. Fossils were found from the sand (17/S) and the red clay (17/C) layers.

Fig. 4. Travertine of the Cukor quarry with several vertebrate and mollusc fossils.

Fig. 5. Correlation of the loess profile at Süttő (Novothny et al., 2011) and the profile of site Süttő 6.

Fig. 6. Charcoals of site Süttő 16. **1.** *Betula* sp. ×5; **2.** *Betula* sp. ×10; **3.** *Picea/Larix* sp. ×20; **4.** *Picea/Larix* sp. ×20. Images were taken by Zeiss-InfinityX at Leuven University.

Fig. 7. Stratigraphic positions of sites of Süttő.

Table 1. Petrographic description and interpretation of site Süttő 6 (Brunnacker et al., 1980).

Table 2. Plants, vertebrate and mollusc faunas of site Süttő 6.

Table 3. Location, type of fossil deposit and paleontology of sites from the fissures in the travertine. **Dq** – Diósvölgyi quarry; **Pq** – Pachl quarry; **Hq** – Hegyháti quarry; **N–S** – orientation of the fissure.

Table 4. Fauna and flora of the new sites (Süttő 16–20).

Table 5. Results of the paleoecological analysis of site Süttő 6.

Table 6. Percentage similarity values of comparison between small mammal faunas of Süttő 6 and other fissures of travertine (percentage similarity values).

Table 7. Percentage of paleoecological groups of various sites from fissures in the travertine.

Table 8. Percentage of paleoecological groups of Süttő 16.

layers of Süttő 6	**petrography**	**interpretation**
1	brown friable clay (with some travertine rubbles)	Bv-horizon of an interglacial brown soil (approx. 0.5 m)
2-3	humus, dark brownish gray friable clay	chernozem (humus zone, with the transition to layer 4) (approx. 1 m)
4	thin humus, light brown clay	chalk enriched horizon (C_c-horizon)
5	light yellowish gray loess, with lime-pseudomycelium	
6	light yellowish gray loess, with a little lime-pseudomycelium	
7	light yellowish gray loess	bedrock
8-13	pale yellowish gray loess	

	Süttő 6/0	Süttő 6/1	Süttő 6/2-3	Süttő 6/4-5	Süttő 6/6-10	Süttő 6/12	Süttő 6/13
plant macrofossils							
Celtis sp.		+	+				
Celtis cf. *australis*			+	+			
Vitis silvestris			+				
Vitis cf. *vinifera*				+			
wood charcoal indet.			+				
pollen (%)*							
Juglans			70		3		
Compositae Subfam. Tubuliflorae Type A	70		10		15		5
Compositae Subfam. Tubuliflorae Type B	15		5		2		
Compositae Subfam. Tubuliflorae			3		24		5
Artemisia	2		3				
Compositae Subfam. Liguliflorae	8		3		60		10
Centranthus sp.			4		30	99	85
Chenopodiaceae			1		2		1
Caryophyllaceae			3				
Cruciferae	1						
Labiatae	1						
Mentha type	2						
Polemoniaceae							
Rosaceae			2				
Ranunculaceae			2				
Umbelliferae	1		2				1
Plantago sp.							
Poaceae			1		1		3
Pinus	0.1		0.6			0.3	
Tilia			0.2		0.3		
Quercus			1.3				
Alnus					0.3		
Carpinus					0.3	0.3	
mammals							
Talpa europaea			10				
Sorex araneus			6	2	2		
Crocidura leucodon group				1			
Crocidura cf. *suaveolens*			1				
Sicista cf. *subtilis*			2	2			
Spalax leucodon			3				
Allocricetus bursae					3		
Spermophilus citelloides			10	3			
Glis glis			2	1			

	Süttő 6/0	**Süttő 6/1**	**Süttő 6/2-3**	**Süttő 6/4-5**	**Süttő 6/6-10**	**Süttő 6/12**	**Süttő 6/13**
Dryomys nitedula			1				
Mus sp.			1				
Apodemus sylvaticus			13	6			
Arvicola terrestris			2		1		
Microtus (Terricola) subterraneus			3				
Lagurus cf. *lagurus*				1			
Microtus arvalis			57	17	9		
Microtus gregalis				1	50		
Myodes sp.			6	5	4		
Dicrostonyx torquatus					1		
Mustela putorius					1		
Dama sp.			1				
molluscs							
Succinea oblonga				96	318		
Cochlicopa lubrica				1			
Columella columella				16	329		
Granaria frumentum			305	120	5		
Truncatellina cylindrica			4				
Chondrina clienta			16				
Pupilla triplicata			12	10	31		
Pupilla sterri				3	67		
Pupilla muscorum				15	103		
Orcula doliolum			1				
Vallonia costata			51	38	184		
Vallonia tenuilabris				90	121		
Chondrula tridens			20	6			
Cochlodina laminata			79		1		
Iphigena plicatula			64	7			
Clausilia dubia			1	19	9		
Clausilia pumila			58	7			
Laciniaria plicata			60	4			
Clausiliidae indet.			894	50			
Discus ruderatus			1				
Discus rotundatus			8	4			
Punctum pygmaeum			2				
Vitrea crystallina	7	1					
Vitrea contracta		2					
Oxychilus inopinatus	1						
Aegopinella minor	2	4					
Euconulus fulvus		20	109				
Phenacolimax annularis	2	2					
Limax cf. *maximus*	8	1					
Limacidae indet.	134	7	3				
Bradybaena fruticum	1						
Helicella hungarica	24	12	5				
Trichia hispida		15	35				

	Süttő 6/0	Süttő 6/1	Süttő 6/2-3	Süttő 6/4-5	Süttő 6/6-10	Süttő 6/12	Süttő 6/13
Trichia striolata		8	259				
Trichia sp. iuv. (*hispida+striolata*)			1274				
Helicidae indet.	37						
Perforatella incarnata	5						
Euomphalia strigella	22						
Helicodonta obvulata	6						
Helix pomatia	12	1					
Cepaea vindobonensis	28	7					
Arianta arbustorum			143				

*note that pollen percentages are approximate vaules read from pollen diagram

	Süttő 3	**Süttő 4/1**	**Süttő 4/2**	**Süttő 5**	**Süttő 7/L**	**Süttő 7/M**	**Süttő 7/U**	**Süttő 8/1**	**Süttő 8/2**	**Süttő 8/3**	**Süttő 9**	**Süttő 12/A**	**Süttő 12/B**	**Süttő 13**
location	Pq	Dq	Dq	Dq	Dq	Dq	Dq	Dq	Dq	Dq	Hq	Dq	Dq	Dq
geological information	N–S	-	-	loess	soil	-	loess	-	-	-	-	-	-	-
plants														
Celtis sp.	*		*		*		*				*			
Crataegus sp.	*													
cf. *Salix*											1			
Pinus											2			
Coniferous indet.											1			
vertebrates														
Amphibia indet.											*			
Bufo sp.													1	
Anura			6		90		3	4	1			16		
Lacertilia indet.					25		1	1						
Lacerta sp.	1										*			
Ophidia indet.	13	2	6		52		2				*	100	40	
Anguis sp.												1		
Limosa limosa					1									
Testudo cf. *graeca*	10										*			
Perdix perdix											1			
Passeriformis indet.											1			
Aves indet.					23		7					3	1	
Chiroptera indet.	15				1		1					*	10	
Rhinolophus ferrumequinum											*			
Rhinolophus cf. *hipposideros*											*			
Myotis cf. *daubentoni*											*			
Myotis capaccini											*			
Myotis mystacinus											*			
Myotis bechsteini											*			
Myotis dasycneme											*			
Myotis sp.											*			
Eptesicus nilssonii											3			
Eptesicus sp.											*			
Plecotus auritus											*			
Talpa europaea		1			26		1	8		3	2	14	2	
Sorex araneus					8		2	6			2			
Sorex minutus					15		1				1	1		
Crocidura leucodon group					2						3	5	1	
Crocidura cf. *suaveolens*	1		1										6	
Neomys fodiens									1					
Erinaceus sp.					1						1			
Sicista aff. *betulina*											2			
Sicista cf. *subtilis*					6		1							
Spalax cf. *leucodon*					4						4	2	2	
Cricetus cricetus											6			
Cricetulus sp.									1			1		
Spermophilus citelloides					4		2		5					
Glis glis			2		19							1		
Driomys nitedula					1									

	Süttő 3	Süttő 4/1	Süttő 4/2	Süttő 5	Süttő 7/L	Süttő 7/M	Süttő 7/U	Süttő 8/1	Süttő 8/2	Süttő 8/3	Süttő 9	Süttő 12/A	Süttő 12/B	Süttő 13
Mus sp.											1			
Mus cf. *musculus*					3									
Apodemus sylvaticus	5	1	2		107		5			1	2	9	6	
Arvicola terrestris					3		1	1			2	1		
Microtus (Terricola) subterraneus			2		8					1		1		
Microtus (Stenocranius) gregaloides							1			1				
Lagurus cf. *lagurus*					1				1		3	2	1	
Microtus arvalis	8				38		5			1	32	11	2	
Microtus nivalis					1								1	
Microtus oeconomus							1				8	1		
Microtus gregalis					1		1				1	3	2	
Microtus sp.		5												
Myodes glareolus										2		2	1	
Myodes sp.	3				58		1				6			
Ochotona pusilla					3		1					6	2	
Lepus aff. *praetimidus*					2		1				4	5	1	
Ursus arctos					5									
Canis lupus														1
Mustela cf. *nivalis*					2									
Sus scrofa					2									
Equus sp. (smaller)											2			
Equus sp. (larger)														1
Dama sp.	*				3									
Capreolus capreolus					5									
Cervus elaphus											3			1
Bos sive *Bison*					1						3			
cf. *Coelodonta antiquitatis*														1
molluscs														
Cochlicopa lubrica			3							2				
Cochlicopa lubricella			*							2				
Succinea oblonga			6	158		*		22	16		29	1	3	
Cochlicopa lubrica						3	2		*		4	1		
Cochlicopa lubricella					1	1					*			
Columella edentula												4	3	
Columella columella			2						*					
Granaria frumentum			10		37	103	6	*	3	*	259	40	14	
Vertigo pusilla										2				
Vertigo alpestris					2	1	5	8		*	1		1	
Truncatellina cylindrica					2	5						2		
Truncatellina callicratis												2		
Chondrina clienta					*	1								
Pupilla triplicata			5	3	9	2	1	2	2	1	12	25	12	
Pupilla sterri			2	2	*	1					7	11	13	
Pupilla muscorum				141			1	3	2	3	25	7	1	
Orcula dolium			1				*	1	*		1		*	
Orcula doliolum					3	2			*					
Vallonia pulchella			2								258	33	13	
Vallonia costata			18		65	146	9	9	4	80	245	35	25	

	Süttő 3	Süttő 4/1	Süttő 4/2	Süttő 5	Süttő 7/L	Süttő 7/M	Süttő 7/U	Süttő 8/1	Süttő 8/2	Süttő 8/3	Süttő 9	Süttő 12/A	Süttő 12/B	Süttő 13
Vallonia tenuilabris			3	2	3	26	70	35	18	1	12	11	11	
Acanthinula aculeata			3									2	1	
Chondrula tridens	39		5		*	*	1	*			479	22	10	
Pyramidula rupestris						2								
Cochlodina laminata					3	12	4		1	12	1	1	1	
Iphigena plicatula					31	286	38		6	180		1	1	
Iphigena ventricosa						1								
Clausilia dubia			1		1	3	4	28	9		22	1		
Clausilia pumila					1	8	25	6	3	2	2			
Laciniaria plicata			1		10	145	15	1	3	54	1			
Neostyriaca cf. *corynodes*			2											
Clausiliidae indet.			4		*	*	*	16		359	19	4	1	
Discus ruderatus						5	10	15	1		28			
Discus rotundatus					10	16	2		1	65		2	3	
Punctum pygmaeum			1		1						1	4		
Aegopis verticillus					*									
Vitrea crystallina			2		2			1	1		5			
Vitrea subrimata					1							8	10	
Vitrea contracta												10	7	
Oxychilus draparnaudi					1	13	1					12	20	
Oxychilus inopinatus			1		2	11	1					11	8	
Aegopinella minor					3	6	4			*	1	9	7	
Nesovitrea hammonis					1		1	1	1		18			
Zonitidae indet.			1			11						66	30	
Euconulus fulvus			1								1	1		
Vitrina pellucida					3	1								
Phenacolimax annularis			3		4	5				*	45	7	2	
Semilimax semilimax							1	1			1			
Limax cf. *maximus*						25				15	24	4	6	
Limacidae indet.			1		22	99	18	1	11	28	41	33	9	
Bradybaena fruticum											4		1	
Helicopsis striata	24				*	13	2		2	2	390	72	23	
Thricia unidentata					1							2	1	
Trichia hispida			5	143		1	2	5	7		58			
Trichia striolata												1	1	
Helicidae indet.			2		5	1		4			10	12		
Perforatella bidentata											3			
Monachoides incarnata					6	28	*	1		*		10	1	
Monachoides umbrosa						1								
Euomphalia strigella					2	8	1	1	1	11		2		
Helicodonta obvulata					6	29	4		*	1		15	7	
Soosia diodonta												2		
Helix pomatia					1	2	1		*	*		2		
Cepaea vindobonensis	1				1	6	*			*	17	6	2	
Arianta arbustorum				2					3		8	1		

	Süttő 16/6	**Süttő 16/5**	**Süttő 16/4**	**Süttő 16/3**	**Süttő 16/2**	**Süttő 16/1**	**Süttő 17/C**	**Süttő 17/S**	**Süttő 19**	**Süttő 20**
plants										
Betula	3		16							
cf. *Alnus*			1							
Pinus			7	3						
cf. *Pinus*					1					
cf. *Picea*			2							
Larix/Picea			1	1						
Coniferous indet.				1	1					
vertebrates										
Osteichthyes indet.	1									
Limax		1								
Bufo bufo	2		2		1					
Bufo cf. *viridis*							2			
Bufo sp.		1								
Rana cf. *arvalis*	1									
Rana cf. *temporaria*					1					
Rana sp. 1			1		1					
Rana sp. 2			1							
Pelobates cf. *fuscus*					2					
Pelobates sp.							1	1		
Pseudopus cf. *pannonicus*									*	
Hierophis cf. *viridiflavus*									*	
cf. *Zamenis longissimus*										1
Anura	3	4	1							
Lacertilia indet.				6	1					
Lacerta sp.	8		6		25					
Lacerta cf. *agilis*		6								
Natrix sp.					5					
Coronella sp.					2					
Vipera sp.		5	2		2					1
Aves indet.				6	12					
Chiroptera indet.	1			1			7	5	1	
Talpa europaea	9	6	7	4	9		1	2		
Sorex araneus	11	10	13	4	15		2			
Sorex minutus	1	1	1	3				1		
Beremendia fissidens									2	
Sicista sp.					9					
Spalax cf. *leucodon*									1	
Cricetus cricetus	1	1	1		2	2	1	1		
Allocricetus sp.								1		
Sciurus vulgaris							1			
Spermophilus citellus								1		
Apodemus sylvaticus		1			1					
Arvicola terrestris	3	3	6	4	4	2				
Microtus (Stenocranius) gregaloides							5	3		
Lagurus cf. *lagurus*			1							
Microtus arvalis	13	10	9	9	36					
Microtus arvalinus							1			

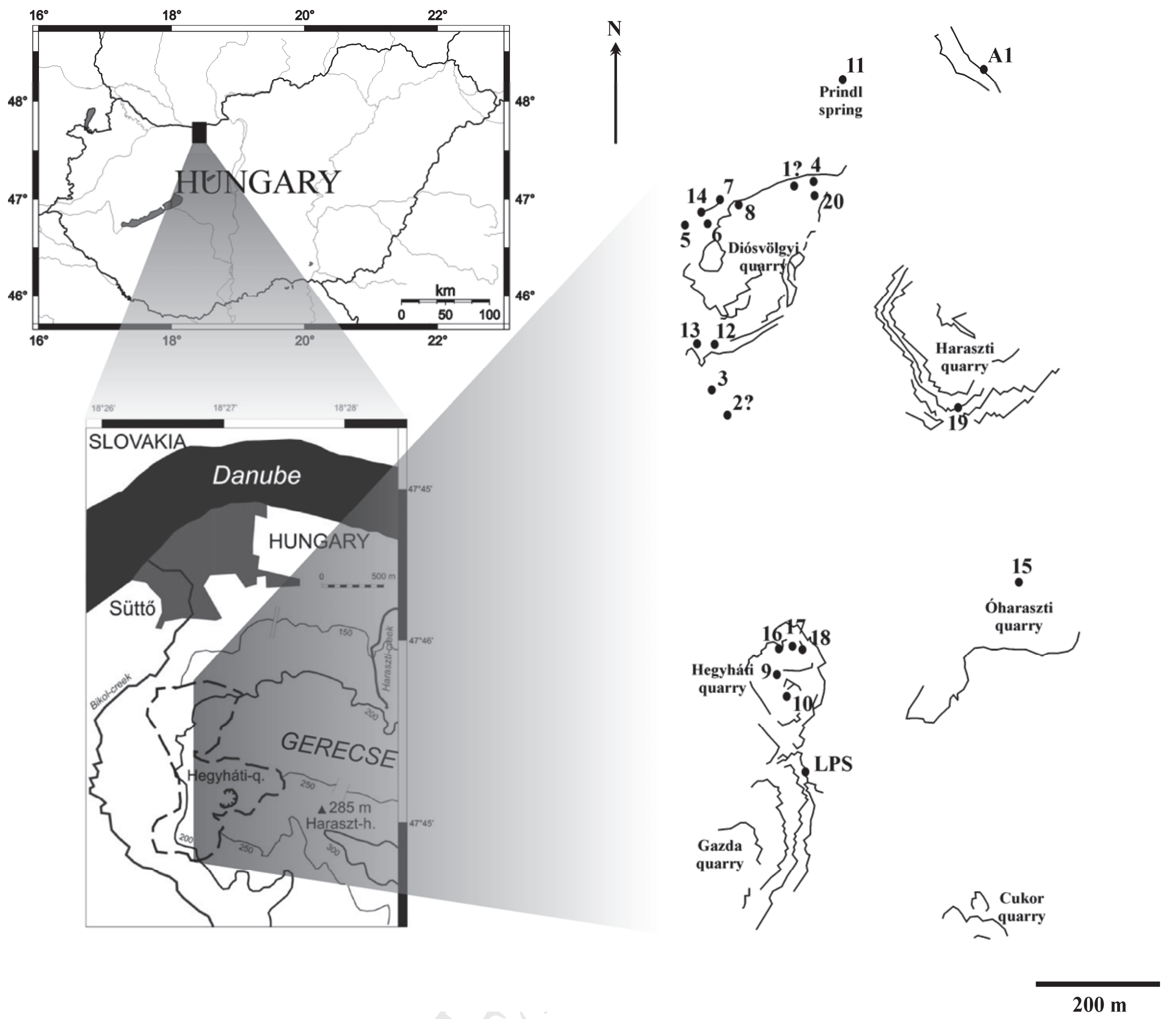
	Süttő 16/6	Süttő 16/5	Süttő 16/4	Süttő 16/3	Süttő 16/2	Süttő 16/1	Süttő 17/C	Süttő 17/S	Süttő 19	Süttő 20
Microtus gregalis	4	1		2	6		2			
Mimomys savini							1			
Mimomys pusillus									1	
Mimomys pitymyoides							1			
Pliomys episcopalis							2	2		
Pliomys lenki							1			
Microtus pliocaenicus							1	1		
Myodes glareolus	13	4	13	9	8	1				
Lepus sp.				1			2	1	1	
Mustela putorius					1		1			
Martes sp.	1				1					
Meles meles			1					1		
Vulpes vulpes						1				
Capreolus capreolus					1					
Bos sive *Bison*		1								
molluscs										
Cochlicopa lubrica										1
Cochlicopa lubrica					1					
Granaria frumentum	4									1
Vertigo alpestris				1						
Pupilla triplicata	1									
Pupilla muscorum	3	1		4						1
Vallonia costata	9		2	1	7					2
Vallonia tenuilabris	3									1
Chondrula tridens							1			
Clausilia dubia	5						2			1
Clausilia pumila	2		2				1			1
Clausiliidae indet.		2		2	3					3
Discus ruderatus										1
Nesovitrea hammonis				1						
Euconulus fulvus	1									
Helicopsis striata	1									
Trichia hispida	4									1
Helicidae indet.				1			*			
Arianta arbustorum										1

	Süttő 6/2-3	**Süttő 6/4-5**
mammals		
Microtus arvalis	48.305	43.59
Sicista cf. *subtilis*	1.6949	5.1282
Spalax leucodon	2.5424	
Spermophilus citelloides	8.4746	7.6923
steppe species (%)	**61.017**	**56.41**
Crocidura leucodon group		2.5641
Crocidura cf. *suaveolens*	0.8475	
Glis glis	1.6949	2.5641
Dryomys nitedula	0.8475	
Mus sp.	0.8475	
Apodemus sylvaticus	11.017	15.385
Myodes sp.	5.0847	12.821
Dama sp.	0.8475	
forest species (%)	**21.186**	**33.333**
molluscs		
Chondrula tridens	1.0735	1.0601
Cochlicopa lubrica		0.1767
Granaria frumentum	16.371	21.201
Pupilla triplicata	0.6441	1.7668
Euconulus fulvus		3.5336
xerophilous species (%)	**18.089**	**27.739**
Vallonia costata	2.7375	6.7138
Clausilia dubia	0.0537	3.3569
Clausilia pumila	3.1133	1.2367
Discus ruderatus	0.0537	
hygrophilous species (%)	**5.9581**	**11.307**
Pupilla sterri		0.53
Pupilla muscorum		2.6502
Succinea oblonga		16.961
Vallonia tenuilabris		15.901
Trichia hispida		2.6502
Trichia striolata		1.4134
oligotherm species (%)	**0**	**40.106**
Laciniaria plicata	3.2206	0.7067
Aegopinella minor	0.1074	0.7067
Phenacolimax annularis	0.1074	0.3534
Cepaea vindobonensis	1.503	1.2367
thermophilous species (%)	**4.9383**	**3.0035**

	Süttő 6/2-3	Süttő 6/4-5
Süttő 3	56.949	68.205
Süttő 7/L	49.67	50.38
Süttő 7/U	60.023	62.587
Süttő 9	60.26	61.71
Süttő 12/A	51.57	49
Süttő 12/B	35.36	35.58

	Süttő 3	Süttő 7/L	Süttő 7/U	Süttő 9	Süttő 12/A	Süttő 12/B
small mammals						
Sicista cf. *subtilis*		1.961	4.545			
Spalax cf. *leucodon*		1.307		5.263	3.704	8.333
Cricetus cricetus				7.895		
Cricetulus sp.					1.852	
Spermophilus citelloides		1.307	9.091			
Microtus arvalis	47.06	12.42	22.73	42.11	20.37	8.333
steppe species (%)	**47.06**	**16.99**	**36.36**	**55.26**	**25.93**	**16.67**
Crocidura leucodon group		0.654		3.947	9.259	4.167
Crocidura cf. *suaveolens*	5.882					25
Glis glis		6.209			1.852	
Driomys nitedula		0.327				
Mus sp.				1.316		
Mus cf. *musculus*		0.98				
Apodemus sylvaticus	29.41	34.97	22.73	2.632	16.67	25
Myodes glareolus	17.65	18.95	4.545	7.895	3.704	4.167
forest species (%)	**52.94**	**62.09**	**27.27**	**15.79**	**31.48**	**58.33**
molluscs						
Cochlicopa lubrica			0.873	0.197	0.202	
Granaria frumentum		15.42	2.62	12.75	8.081	5.645
Pupilla triplicata		3.75	0.437	0.591	5.051	4.839
Chondrula tridens	60.94		0.437	23.57	4.444	4.032
Euconulus fulvus				0.049	0.202	
Helicopsis striata	37.5		0.873	19.19	14.55	9.274
xerophilous species (%)	**98.44**	**19.17**	**5.24**	**56.35**	**32.53**	**23.79**
Vallonia costata		27.08	3.93	12.06	7.071	10.08
Clausilia dubia		0.417	1.747	1.083	0.202	
Clausilia pumila		0.417	10.92	0.098		
Discus ruderatus			4.367	1.378		
Nesovitrea hammonis		0.417	0.437	0.886		
Arianta arbustorum				0.394	0.202	
hygrophilous species (%)	**0**	**28.33**	**21.4**	**15.9**	**7.475**	**10.08**
Succinea oblonga				1.427	0.202	1.21
Pupilla sterri				0.344	2.222	5.242
Pupilla muscorum			0.437	1.23	1.414	0.403
Vallonia tenuilabris		1.25	30.57	0.591	2.222	4.435
Trichia hispida			0.873	2.854		
Trichia striolata					0.202	0.403
oligotherm species (%)	**0**	**1.25**	**31.88**	**6.447**	**6.263**	**11.69**
Acanthinula aculeata					0.404	0.403
Laciniaria plicata		4.167	6.55	0.049		
Aegopis verticillus						
Aegopinella minor		1.25	1.747	0.049	1.818	2.823
Phenacolimax annularis		1.667		2.215	1.414	0.806
Soosia diodonta					0.404	
Cepaea vindobonensis	1.563	0.417		0.837	1.212	0.806
thermophilous species (%)	**1.563**	**7.5**	**8.297**	**3.15**	**5.253**	**4.839**

	Süttő 16/6	Süttő 16/5	Süttő 16/4	Süttő 16/3	Süttő 16/2
small mammals					
Sicista sp.					10
Cricetus cricetus	1.818	2.632	1.923		2.222
Microtus arvalis	23.64	26.32	17.31	25.71	40
steppe species (%)	**25.45**	**28.95**	**19.23**	**25.71**	**52.22**
Apodemus sylvaticus		2.632			1.111
Myodes glareolus	23.64	10.53	25	25.71	8.889
forest species (%)	**23.64**	**13.16**	**25**	**25.71**	**10**
molluscs					
Cochlicopa lubrica					9.091
Granaria frumentum	12.12				
Pupilla triplicata	3.03				
Euconulus fulvus	3.03				
Helicopsis striata	3.03				
xerophilous species (%)	**21.21**	**0**	**0**	**0**	**9.091**
Vallonia costata	27.27		50	10	63.64
Clausilia dubia	15.15				
Clausilia pumila	6.061		50		
Nesovitrea hammonis				10	
hygrophilous species (%)	**48.48**	**0**	**100**	**20**	**63.64**
Pupilla muscorum	9.091	33.33		40	
Vallonia tenuilabris	9.091				
Trichia hispida	12.12				
oligotherm species (%)	**30.3**	**33.33**	**0**	**40**	**0**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18°
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22°
48°
47°
46°
HUNGARY
km
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18°26'
18°27'
18°28'
SLOVAKIA
Danube
HUNGARY
Süttő
0 500 m
GERECSE
Hegyháti-q.
285 m
Haraszt-h.
47°45'
47°46'
Bikol-creek
Haraszti-creek
150
200
250
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Prindl
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1?
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6
Diósvölgyi
quarry
13
12
3
2?
Haraszti
quarry
19
15
Óharaszti
quarry
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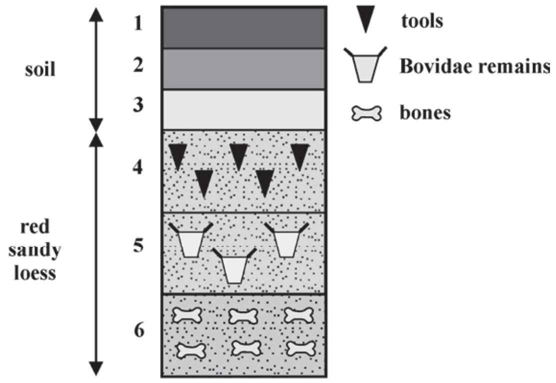
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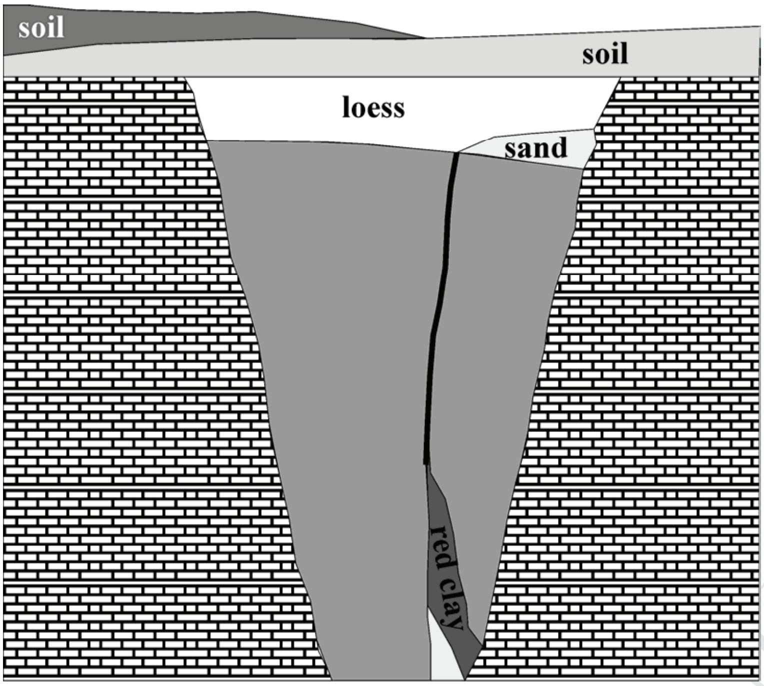
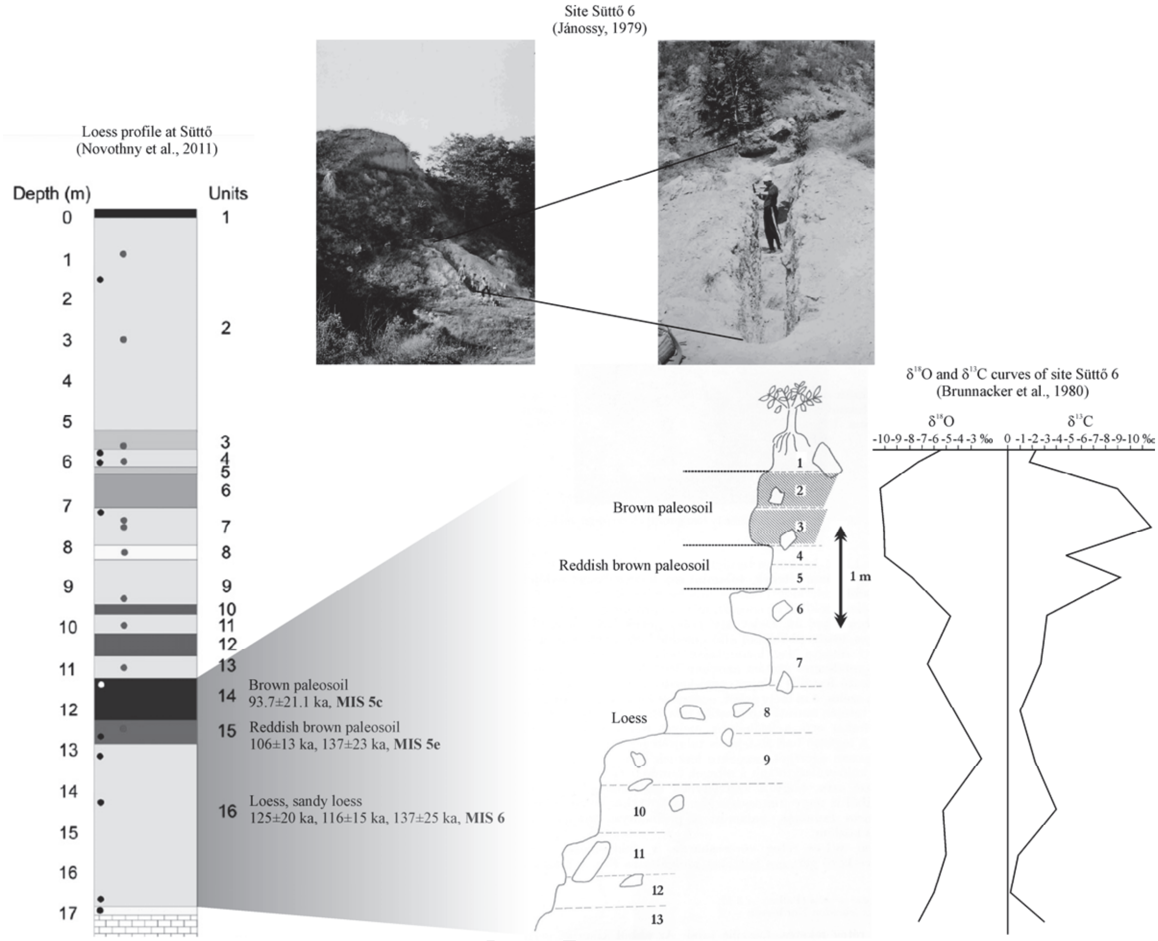
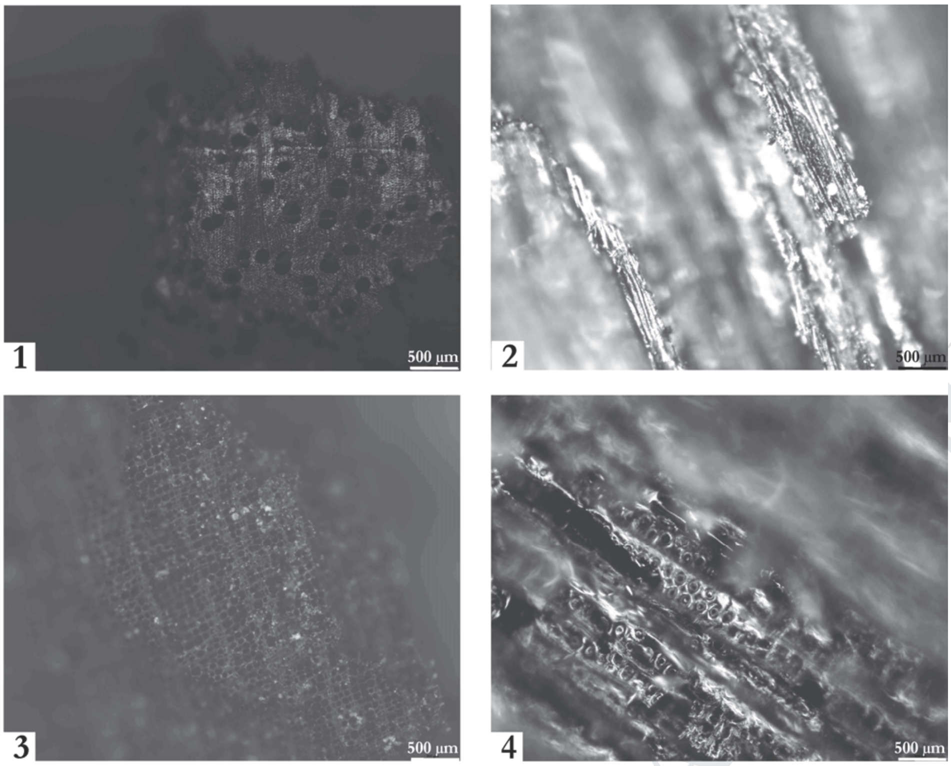
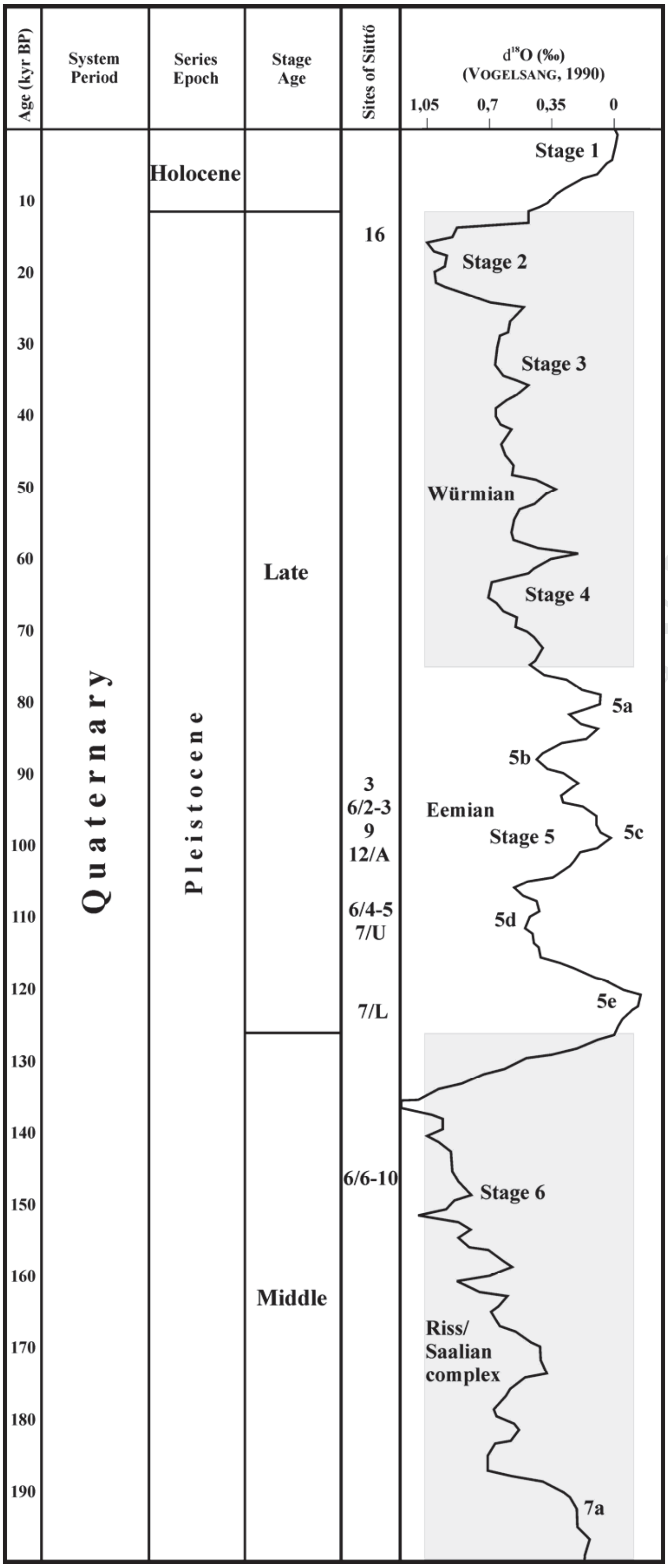
2
3
4
5
6
soil
red sandy loess
tools
Bovidae remains
bones


soil
soil
loess
sand
red clay



Site Süttő 6
(Jánossy, 1979)
Loess profile at Süttő
(Novothny et al., 2011)
Depth (m)
Units
Brown paleosoil
93.7±21.1 ka, MIS 5c
Reddish brown paleosoil
106±13 ka, 137±23 ka, MIS 5e
Loess, sandy loess
125±20 ka, 116±15 ka, 137±25 ka, MIS 6
Brown paleosoil
Reddish brown paleosoil
1 m
Loess
δ18O and δ13C curves of site Süttő 6
(Brunnacker et al., 1980)
δ18O
δ13C


1
500 µm
2
500 µm
3
500 µm
4
500 µm



Age (kyr BP)
System Period
Series Epoch
Stage Age
Sites of Süttő
d18O (‰) (VOGELSANG, 1990)
1,05
0,7
0,35
0
Stage 1
Holocene
10
16
Stage 2
20
30
Stage 3
40
50
Würmian
60
Late
Stage 4
70
Quaternary
Pleistocene
80
5a
5b
90
3
6/2-3
9
12/A
Eemian
Stage 5
5c
100
110
6/4-5
7/U
5d
120
7/L
5e
130
140
6/6-10
Stage 6
150
160
Middle
170
Riss/
Saalian
complex
180
190
7a