PALAEOSOILS AS INDICATORS OF LOCAL PALAEOENVIRONMENTAL CHANGES

Mosaics from the Hungarian loess studies

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ABSTRACT

The loess palaeosoils are known for their palaeoclimatic significance and have also been used for regional stratigraphic correlations. In this paper, three important loess section sites were studied in the frame of an interdisciplinary approach. The soil-sedimentary sequences presented here cover the timespan between the MIS9 and MIS3. Basaharc is one of the key loess sections of the European loess belt. New sections allow for the description of so far unknown facies of the famous Basaharc Double (BD) and Basarharc Lower (BA) palaeosoils. Moreover, they indicate so far unknown sudden environmental changes during the development of the Upper Mende (MF) palaeosoil. The seven analysed sections of Verőce brickyard allowed the characterisation of the Last Interglacial palaeosoil in various landscape positions. The detailed investigations of the loess-palaeosoil series at Hévízgyörk suggest hiatuses which may have been hidden by a well-developed palaeosoil complex formed over multiple interglacial periods during the Late Middle Pleistocene. This research allows us to complement former knowledge by applying newly available research methods, to obtain new chronological data, and to highlight that soil characteristics of loess palaeosoils are not only influenced by climatic parameters, but also by geomorphological settings.

KEYWORDS

loess-palaeosoil sequences, climate changes, paleoenvironmental reconstruction, Hungary, Basaharc, Hévízgyörk, Verőce

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1. Introduction

In Hungary, the palaeosoils developed on loesses were mainly used for the correlation of distant profiles and for chronostratigraphic reasons, despite the fact that they also contain information about sedimentation rates, pedogenesis and erosion, and therefore about changes of the palaeoenvironment and palaeotopography (Horváth and Bradák 2014). Some of the recent studies of the Loess Research Group at the Department of Physical Geography at Eötvös Loránd University focus on the question how the palaeotopographical position influences palaeosoil formation and how this is visible in different outcrops. The purpose of this paper is to present some results concerning these questions.

Two of the selected sites, Basaharc and Verőce, are located in N-NW part of Hungary (Fig. 1a,b) along the River Danube. Hévízgyörk is located in the Gödöllő Hills, Central Hungary, to the East of Budapest on a terrace of the River Galga. Based on the presence of the Bag Tephra layer found at Basaharc and Hévízgyörk in the lowermost parts of the loess-palaeosoil sequences overlying fluvial sediments, the terrace of the Galga and the Danube rivers are considered to be coeval (Bradák et al., 2014, Horváth 2001; Horváth et al., 2019).

In the outcrops of the abandoned brickyard of Basaharc and Verőce, different palaeogeomorphological positions were revealed. This is in contrast with the case of Hévízgyörk, where only a wide section of the loess-palaeosoil sequence was explored. Former interdisciplinary studies point to the importance of erosion processes during or after the formation of the soil (Bradák et al., 2014; Csonka et al., 2019).

2. Methods

In addition to detailed documentation and the sampling of profiles, low field volumetric magnetic susceptibility (κlf) was determined during the field campaign. Frequency depended susceptibility (χfd) and the anisotropy of low field magnetic susceptibility (AMS) were measured in the laboratory. Samples were taken for granulometry, for bulk stable isotope, for geochemical research in 2 cm intervals, for palaeomagnetic (only from some outcrops) research, and for secondary carbonates analysis in 10 cm intervals.

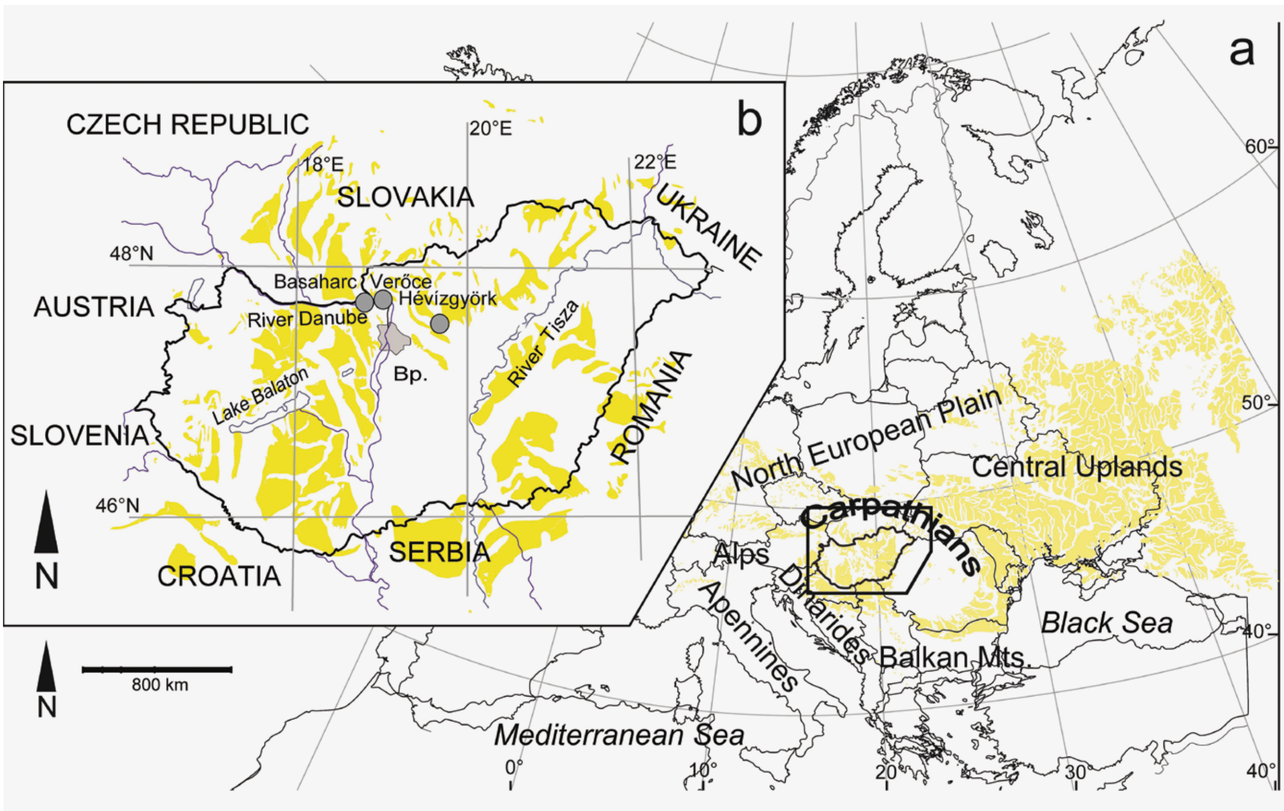

Figure 1. Distribution of loess sediments in Europe (a) and in Hungary with the location of the profile (b) (based on Haase et al., 2007 and Csonka et al. 2019).

The luminescence samples and the oriented samples for soil meso- and micromorphology were taken from selected horizons. [14]C-ages were measured from mollusc shells and charcoal. A detailed description of the applied methods is presented in previously published research papers (Bradák 2009; Bradák et al., 2014; Bradák and Kovács 2014; Barta 2014; Barta et al., 2018; Csonka et al., 2019; Novothny et al., 2010). Stable isotope investigations were carried out on the secondary carbonates, specifically on hypocoatings. For a more detailed characterisation of the palaeosoils, the Harden test was carried out, and the soil development index (SDI) and micromorphological soil development index (MISODI) were calculated (Bradák et al., 2014; Csonka et al., 2019).

3. Results and discussion

3.1. BASAHARC

One of the outcrops of the 20 m thick loess-palaeosoil series, covering a terrace surface of the River Danube, is at Basaharc in a former brickyard (Fig. 2). Three palaeosoils were identified from the classical sections situated in different parts of the brickyard. The Basaharc Double palaeosoil complex (BD1-2) and Basaharc Lower palaeosoil (BA) are important stratigraphic units in the Hungarian loess stratigraphy named after this site (Pécsi, 1965). Based on the luminescence ages and the presence of the 350 ka old Bag Tephra layer in the lowermost loess, the palaeosoils can be correlated with the marine isotope stages as follows: the uppermost, Mende Upper (MF1-2), palaeosoil complex developed during MIS5, the Basaharc Double palaeosoil developed during MIS7, and the Basaharc Lower palaeosoil developed during MIS9 (Frechen et al., 1997; Novothny et al., 2002; Novothny et al., 2009; Novothny et al., 2010; Thiel et al., 2014; Horváth et al., 2014). The reinvestigation of the classic profiles using the new methods proposed by our research group started two decades ago.

In the last couple of years, in the western part of the quarry, a new continuous profile was excavated and investigated using multi-proxy methods (Horváth et al., 2019). The ongoing studies clearly show the diverse development of coeval palaeosoils indicating different palaeoenvironments. The palaeosoils here are in a higher topographical position than the classic profiles. Even so, the MF1-2 palaeosoil is very weakly developed in this wall. It was identified using luminescence ages and appeared to have slightly higher values on the low field volumetric magnetic susceptibility (κlf) curve (Horváth et al., 2019). The presumption is that the pedogenesis could not keep up with the aggradation of the surface by the dust accumulation during MIS5, although the outcrop seems to be on a local hilltop position.

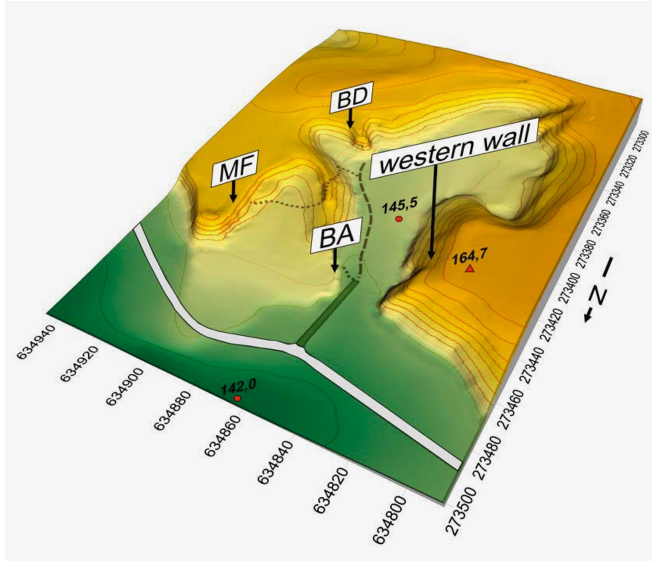

Figure 2. Digital elevation model of the Basaharc brickyard. Elevation (m a.s.l.), arrows show the positions of the loess-palaeosol sections; palaeosoils: MF – Mende Upper1-2, BD – Basaharc Double 1-2, BA – Basaharc Lower (based on Horváth et al., 2019).

Changes of the local palaeoenvironment were visible in two other parts of the abandoned brickyard as well. At the entrance of the quarry, below the BA palaeosoil, a hydromorphic environment can be observed based on the strong accumulation of Mn and Fe along the cracks and in the matrix in 4-5 m width. Most likely, there was a small fluvial channel which resulted in stagnated water appearing in the loess before the soil formation started. In the backyard of the quarry, a bigger sized fluvial channel is recognizable based on the layered soil material and the slightly layered loess with andesite blocks of 15-50 cm diameter. Below this reworked material a thick and strongly developed palaeosoil is located. Based on its topographical position, it is presumably the Basaharc Lower (BA) palaeosoil, which developed here in an environment with more water supply, possibly in a palaeovalley position. The layered material could be the result of a gully erosion, connected to the Palaeo-Danube after the development of the BA palaeosoil between MIS8 and MIS3. In the BA palaeosoil, a lighter horizon with low magnetic susceptibility (κlf) value suggests the presence of a period when the soil formation was subordinate relative to the sediment accumulation (Horváth et al., 2019).

3.2. VERŐCE

The abandoned brickyard of Verőce is situated on the foothills of the Börzsöny Mountains (the Visegrád Gorge) on the left bank of the River Danube. The seven investigated sections reveal a large panoply of palaeoenvironmental information. Firstly, the soil and sedimentary *characteristics* are witness to both interglacial and glacial climatic conditions. Additionally, the analysed sediments reveal that various depositional environments existed along the studied area and throughout time.

The fluvial-alluvial sediments of the Danube were covered by eolian and proluvial material. Based on the relative and numerical dating results, the sediment accumulation of this area started at the beginning of MIS6 or even at the end of MIS7 (Bradák et al., 2014; Barta et al., 2018). Four palaeosoils were identified in the sections, showing the climatic oscillations of the Late Pleistocene (Fig. 3).

A characteristic palaeosoil (P4) formed in MIS5e was identified from different sections (A, C, D, E) and three of its facies were characterised (Bradák et al., 2014).

Two loess outcrops at Verőce (profiles D and E) developed in a palaeovalley position, most likely in a former oxbow lake or a tributary valley connected to the Palaeo-Danube. Alluvial sediments in profile D are overlain by loess with an age of 132±7ka. The transition between them is gradual. The P4 palaeosoil is developed on this loess deposit.

The thickest loess-palaeosoil section has a higher elevation, in a so-called local hilltop position (profile C). Here, the P4 palaeosoil, attributed to the last Interglacial, is overlain by two succeeding palaeosoils formed during subsequent phases of MIS5. The luminescence age of the loess underlying the P4 palaeosoil is higher than that in profile D (202±11ka), which suggests the earlier onset of the dust accumulation on hilltops or high landscape positions and erosion in the alluvial position.

The P4 palaeosoil in profile D is well-developed and more than 2 m thick. It can be divided into a lower red, a middle brown, and an upper black horizon. The upper part of the brown horizon is characterised by slickenside phenomena and blocky soil structure. The black horizon was characterised by carbonate veins. The soil development index (SDI) is very high compared to those of the other P4 palaeosoils, most likely because of the great thickness due to the continuous pedogenesis during sediment accumulation. This palaeosoil formed during the MIS5e interglacial period under hydromorphic conditions (Bradák et al., 2014). The stable isotope investigations revealed signs of the effects of hydromorphic phenomena, implying significant evapotranspiration under dense vegetation cover (Barta et al., 2018).

The P4 palaeosoil in profile C is characterised by well-developed and separated, differentiated pedological horizons, the same as in profile D, but with a smaller thickness. Its SDI is lower than the SDI of P4 in the valley bottom position (in profile D). The stable isotope patterns

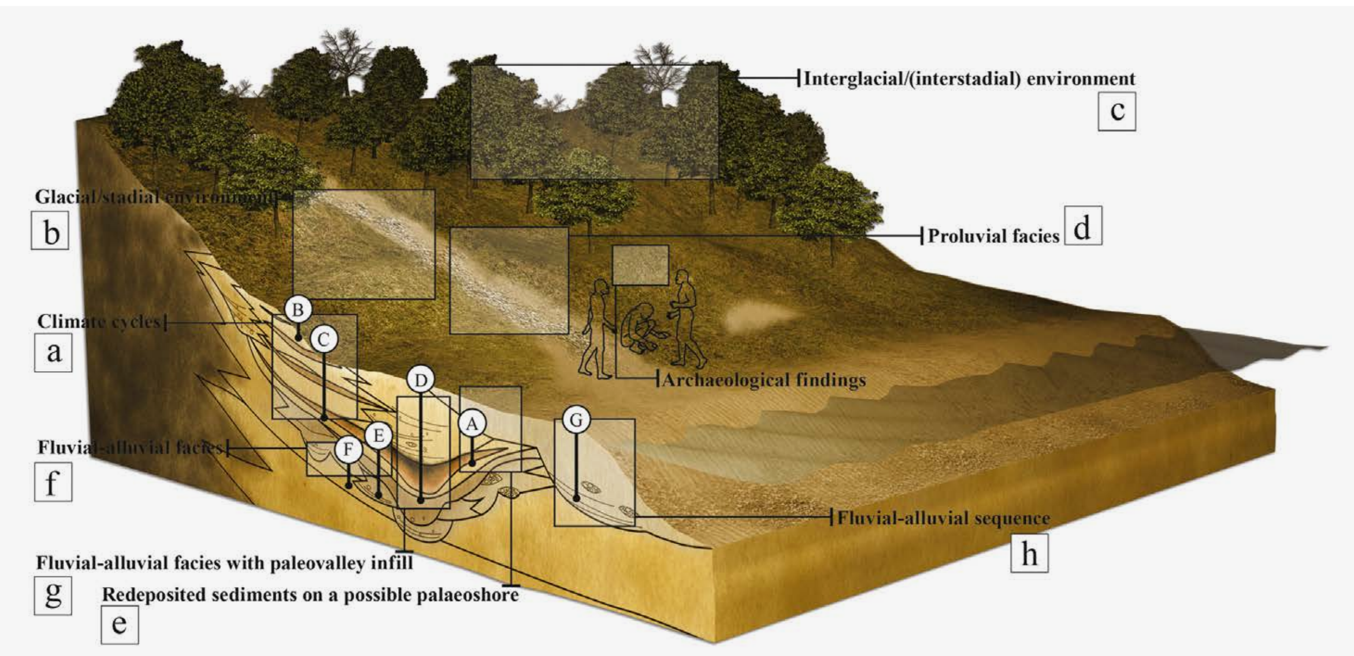

Figure 3. Summarised and idealised image of the palaeoenvironments that appeared around the Verőce brickyard during the Late Pleistocene period (based on Bradák et al., 2014).
A-G: studied profiles; a-c: reconstructed palaeoclimatic contexts; d-h: reconstructed depositional settings.

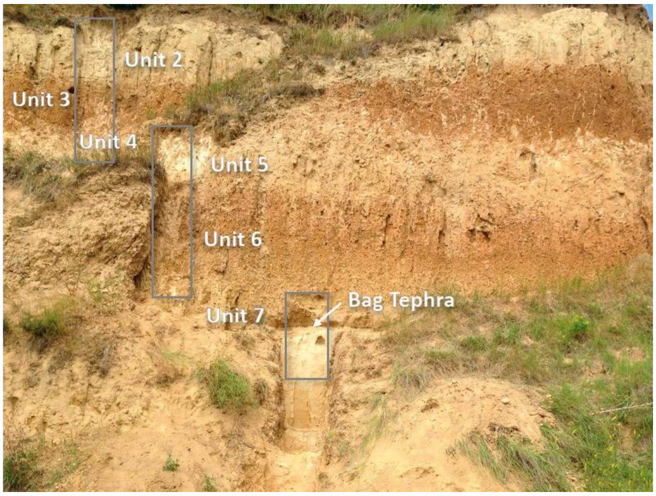

Figure 4. Loess-palaeosol sequence at Hévízgyörk (based on Csonka et al. 2019).

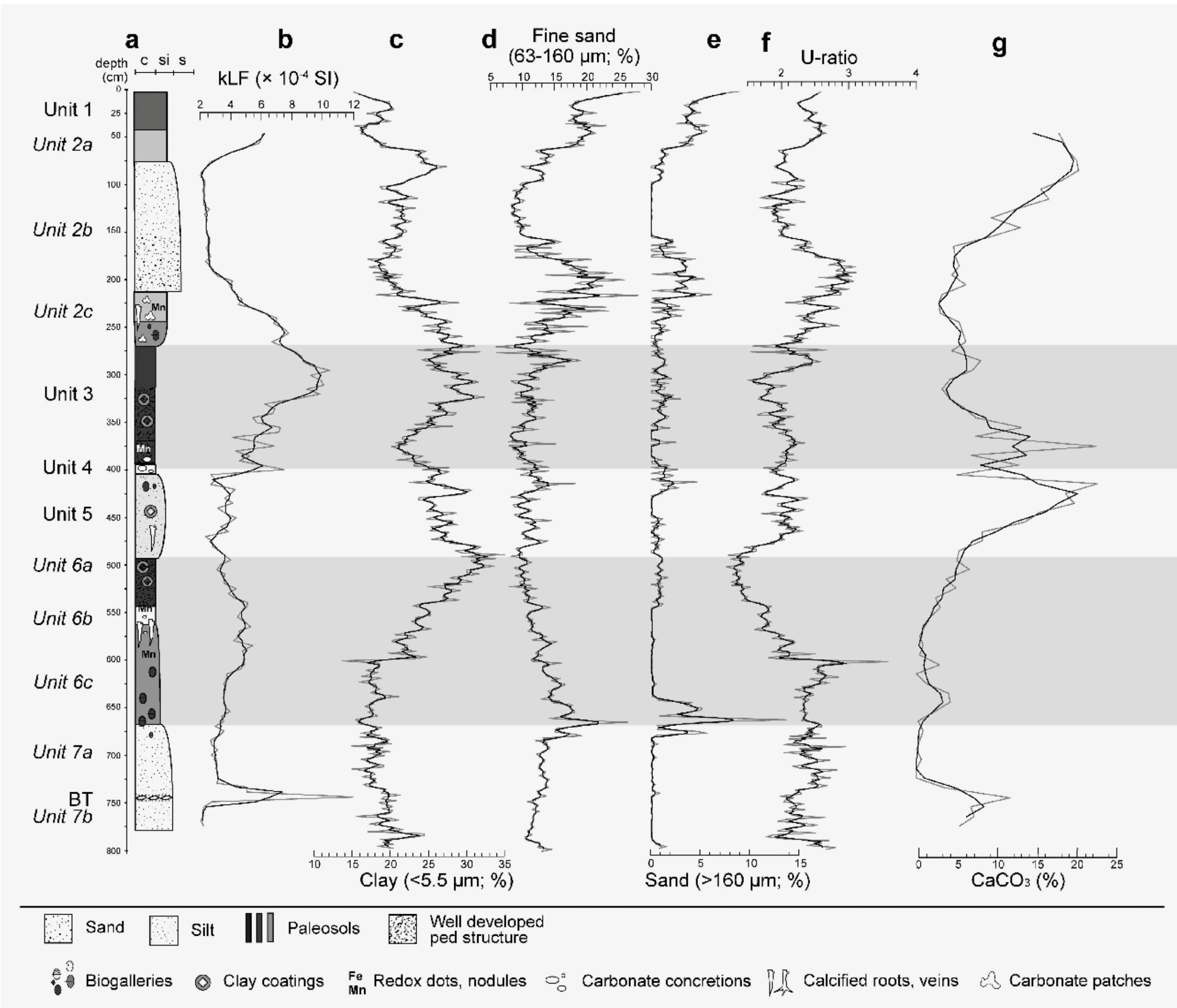

Figure 5. The results of the multi-proxy analysis of Hévízgyörk profile: a. studied section and its subdivision by Units; b. κLF curve/variations along the studied section; c. the clay content curve; d. fine sand; e) sand distribution; f. the U-ratio (44–16 µm/16–5 µm); g. bulk $CaCO_3$ distribution (Csonka et al. 2019).
The black curves represent the smoothed version (three member moving average) of the original dataset (grey line).

of hypocoatings from this palaeosoil can be used as palaeoclimate indicator because it developed primarily under climatic influence and therefore, it can be correlated with other profiles in hilltop position as well.

The thinnest P4 palaeosoil is in profile A. Although the pedogenetic horizons of the P4 palaeosoil were difficult to detect in the field, further analyses showed that several of its soil characteristics, such as the SDI value, are similar to the ones documented for the P4 palaeosoil situated on the hilltop position (profile C) (Bradák et al., 2014; Barta et al., 2018). In addition, its uppermost part is mixed with new sediments and covered by fine layered material, suggesting reworking. Sedimentation by run-off processes could be also observed. These signs of overland flow have been interpreted as indicators of higher precipitation in this palaeoslope position.

3.3. HÉVÍZGYÖRK

The section of the abandoned brickyard of Hévízgyörk contains only two fossil soils without a visible hiatus (Unit 3 and 6, Fig. 4). But, based on the presence of Bag Tephra (an important marker layer) and the so far documented palaeosoil sequence documented in the Hungarian loess stratigraphy, it was very likely that there had to be at least one missing palaeosoil.

High resolution multi-proxy studies were carried out in the last couple of years by our research group in order to discover these missing units. In the lower part of the upper palaeosoil (Unit 3) a strong secondary carbonate accumulation appeared along vertical cracks which suggested the polygenetic development of this palaeosoil. This hypothesis was confirmed by the results of further investigations. The low field volumetric magnetic susceptibility (κlf) curve indicated a strong pedogenesis with at least two periods in the upper palaeosoil. In addition, these soils are characterised by a higher clay and $CaCO_3$ content than the other units (Fig. 5). The simultaneous presence of the clay coating and secondary carbonate accumulations and the absence of the humiferous surface horizon are most probably related to the combined effect of eolian and/or water triggered erosion processes and of the passage from a leaching to a non-leaching environment during the long evolution of this sequence. Furthermore, it is possible that a lower loess sedimentation rate occurred during the cold phases in this landscape position. Preliminary luminescence results confirmed an important hiatus between the upper part (84±5ka) and the lower part (>243ka) of this palaeosoil (Unit 3), therefore, the two parts formed in different interglacial periods (Csonka et al., 2019; Novothny et al., 2019). Based on the luminescence age of the uppermost loess unit (35±4ka) another hiatus is detectable above this palaeosoil.

4. Conclusions

The development of the palaeosoils was strongly influenced by the climate, but the local palaeoenvironment had a great influence on it as well. The sites presented here provide a great opportunity to investigate coeval palaeosoils in different geomorphological positions and therefore recognise the distinct balance among pedogenesis-erosion-sediment accumulation. At Verőce, the local top, the palaeovalley and the palaeoslope landscape positions were clearly characterised by different soil features of the same P4 palaeosoil. At Basaharc, various environments and geomorphological processes were described as well. It was possible to detect unconformities in the Hévízgyörk profile by using a multiproxy analysis.

The palaeosoils developed in a higher landscape position (such as local plateaus or intervalley ridges) are suitable for the determination of the intensity (the strength) of the interglacial and interstadial periods, and can be used as a basis for the interregional correlation. Other geomorphological positions (slopes and valley bottoms) were more sensitive to the local changes, therefore they carry information about the development of their local environment.

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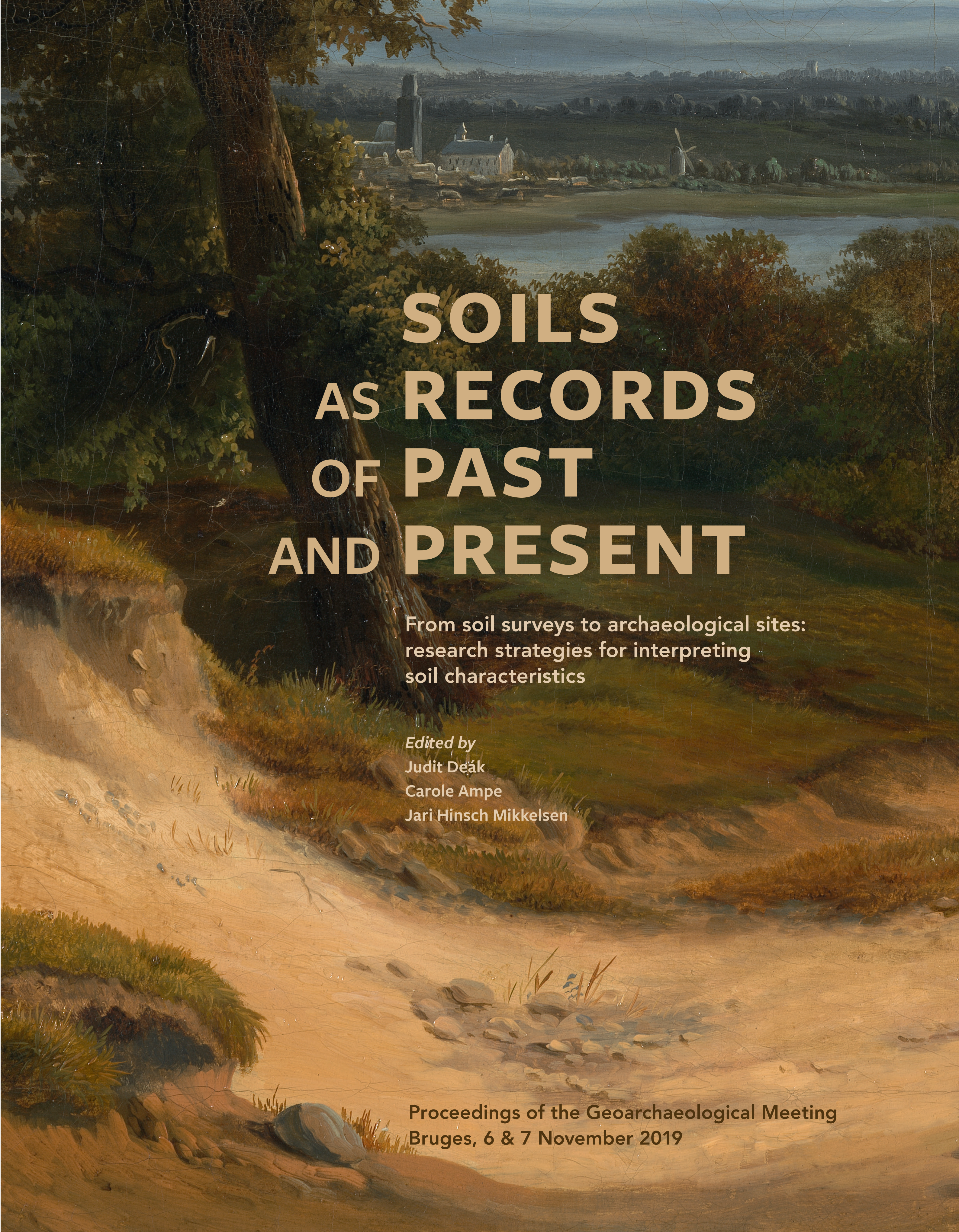

SOILS AS RECORDS OF PAST AND PRESENT

From soil surveys to archaeological sites: research strategies for interpreting soil characteristics

Edited by
Judit Deák
Carole Ampe
Jari Hinsch Mikkelsen

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