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Special paleogeographic characteristics and changes in $\delta^{18}O$ values in Upper Pleistocene deposits of the Moravian Plateau

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Abstract

Our own new environment-discrimination proxies, which include beyond the traditional sedimentary parameters our newly introduced indices (fineness grade: F_g and degree of weathering: K_d), $\delta^{18}O$ values and stratigraphic data were used in our study to compare loess-paleosol sequences with the data of mid-latitude deep-sea sediments and ice cores from Greenland. By our data from the Červený kopec section completed with other surrounding sequences, we came to the conclusion that the section consists of the last glacial (Würm) and last interglacial (Riss/Würm) deposits.

The double paleosols equivalent with the MF_1 soils (according to the Hungarian loess terminology) can be found together only in some places. In most of the sections only some part of the complex remained (e.g. the chernozem soil in Dolní Věstonice with an age of 30.9 ky BP; the forest soil in Červený kopec – Bohunice-type culture: 40.2 ky BP). The MF_2 paleosol is situated in the lower part of the section and it was formed during the MIS 5 (Marine Isotope Stage).

Keywords: Quaternary, loess-paleosol series, paleoclimate, $\delta^{18}O$, granulometric parameters, demarcation of the layers, warming and cooling peaks, erosional gaps.

Introduction

The variations of the paleogeographic environment were investigated using sedimentological parameter values of samples from the northwestern fringe of the Carpathian Basin.

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We would like to contribute to the scientific studies of the environmental changes during the last 2 million years and to the understanding of the cooling and warming stages of the last major glaciation.

The Červený kopec (Red Hill) section *(photos 1* and *2)* was investigated in this paper due to its location in the so called "Moravian Gate". All of the variations of the North European and the Alpine glaciations could be examined in the outcrop. It is situated at the southeastern fringe of the Bohemian Massif, 50 kilometers to the one-time southernmost limit of the Pleistocene inland ice sheet and also close to the Danube and to the foreland of the glaciated Alps. The uplift of the area was caused by postglacial gradual crustal movements, so the height of the uppermost, fifth (V) river terrace is 280 m above sea level. The loess-covered terraces are the most reliable evidence of the uplifting.

The outcrop is situated on the uppermost two terraces of the terrace-system along the Svratka River *(photos 3, 4, 5).* The hiatuses are scarce, the location of the Brunhes/Matuyama paleomagnetic boundary and of the Jaramillo event is known in the series. It is important because the upper part of the long section of Krems is missing, and it consists almost only of loess-paleosol series older than B/M. In the course of the crustal movements in the last 700 thousand years vast amount of sediments were eroded. The generalized section from the series of the Krems site combined with the series of Červený kopec can be regarded the most complete loess-paleosol sequence in Central Europe.

The stratigraphic investigations of the Červený kopec section were conducted by Kukla, G.J. (1975); Fink, J. and Kukla, G.J. (1977); Smolíková, L. (1982); Zeman, A. (1992) and others. The loess-paleosol series is underlain by Lower Devonian red sandstone with high quartz-content, conglomerate and arcose *(Photo 6,* Demek, J. *et al.* 2005).

The arcose was formed from the weathering of the granite of the Lower Devonian Caledonian Mountains with high feldspar content (>25%), its thickness varies between 100 m to few thousand meters. The conglomerate is locally overlain by Miocene limestone (Smolíková, L. and Zeman, A. 1982). Above the pre-Quaternary strata fluvial river terraces (covered by Younger and Older Gravel) and loess-paleosol series can be found *(Photo 7).* The Younger and Older Gravel covers are gravelly sand layers, and ferretto-like soils were formed on them (Smolíková, L. and Zeman, A. 1982). These soils can be categorized in the same group as the terra rossae, the difference is only the bedrock, which is siliceous (e.g. gravel and sand) in the case of the ferretto soils. The soils directly superimposing the gravel and sand layers were formed *in situ*, its position is autochthonous. Our sample from the uppermost paleosol is also of this kind and above it recent chernozem-like soil has formed *(Photo 8).*

We have investigated the sediment series of the upper two steps of the Červený kopec section *(Photo 1).* The significant thickness of the section is due to its location between the Alpine and Fennoscandinavian glaciated

Photo 1. The outcrop of Červený kopec exposed on the V and IV terraces of the Svratka River (Photo by Kɪs, É.)

Photo 2. The environment of the outcrop at the eastern fringe of the Bohemian Massif *(Source:* Google Earth™)

Photo 3. Loess-paleosol series on the V terrace (the recent soil formed on a fossil pedogene horizon) (Photo by Kɪs, É.)

Photo 4. The location of the terrace system (Photo by Kɪs, É.)

Photo 5. The view from the III terrace to the river valley. The B/M paleomagnetic boundary is located in the lower part of the terrace (Photo by Kɪs, É.)

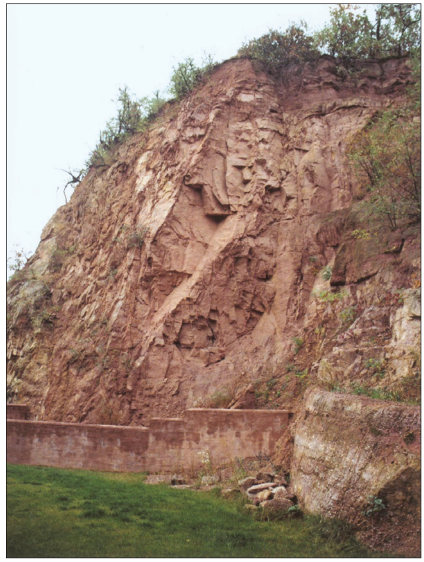

Photo 6. The underlying conglomerate derived from Devonian sandstone (Photo by Kɪs, É.)

Photo 7. The gravel and sand material of the V terrace (Photo by Kɪs, É.)

Photo 8. The uppermost loess layer of the outcrop (Photo by Kɪs, É.)

zones. During the glacial periods in the environs of the section three main wind directions have defined the eolian sedimentation: the westerlies in the east-west corridor along latitude 50°N, the north-westerly winds from the Fennoscandinavian ice sheet, and according to Rozycki, Sz. (1991) and Rousseau, D.D. *et al.* (2007) the Saharan dust from south was also relevant. This last conception about the role of the Saharan dust was confirmed by the studies of Varga, Gy. (2007, 2010, 2011).

The dust deposition was dominant under the cold continental climate of the glacial periods, while during the warm and moist interglacials pedogene processes played primary role. The section covers the last glacial-interglacial cycle (~125 ky; OXY Stage 5 – Kukla, G.J. and Cílek, V. 1996, ODP-677 record – Shackleton, N.J. *et al.* 1990, benthic $\delta^{18}O$, the B loess/paleosol cycle – Kukla, G.J. 1975).

The B subcycle contains three soil series (PK-I, PK-II., PK-III.; Demek, J. and Kukla, G.J. 1969). The investigated section comprises the uppermost strata of the sediments covering the V and IV terraces of the Svratka River. The study was especially important, because the section is almost complete and made up from *in situ* sediments. The surrounding deposits with the same age were formed from redeposited material. The section can be used as the upper part (B cycle) of the Central European general section. From the results of our studies, we can get a fairly good overview of the paleogeographic variations in the last 125 ky.

The lowest deposits (overlying the Miocene terrace gravels) are rather old; their formion could precede the Matuyama/Gauss paleomagnetic boundary. The B/M boundary and the Jaramillo event were reached by several drills (e.g. 830 and 831 by Zeman, A. 1992). The B/M can be found in the loess between the PC-Xa and the PC-X paleosols. The relatively complete sequence can be correlated well with other mid-latitude sections situated on terrace-systems uplifted by crustal movements in the foreground of large mountains (e.g. Tibet). In the case of Červený kopec five, while at Lanzhou six terraces build up the terrace system (Kukla, G.J. and Cílek, V. 1996).

Methods

In the course of the studies, we have compared the section of Červený kopec along the Middle Danube with the paleoclimatic data of the ice core GISP2 from Greenland. We have studied how to establish the cold-warm periods of the ice cores (estimated by isotope-stratigraphic methods) in the terrestrial sediments, and how to determine the limit of the Pleistocene glaciations.

The section was characterized by our own new environment-discrimination proxies, which include beyond the traditional sedimentary parameters our newly introduced indices (fineness grade: F_g and degree of weathering: K_d), and $\delta^{18}O$-values, which were not used in previous studies.

The curves of the measured and calculated values were plotted next to the section, so the data of each horizon can be promptly determined. The grain-size of the samples was measured using a Fritsch Analysette Microtec 22 laser grain-size analyzer in the Laboratory for Sediment and Soil Analysis in the Geographical Research Institute of the Hungarian Academy of Sciences (HAS). The oxygen-isotope ($\delta^{18}O$) values were determined in the Laboratory of Environmental Studies in the Institute of Nuclear Research (HAS) using a Thermo Finnigan Delta^{PLUS} XP stable isotope mass spectrometer.

Results

On the evaluation figure of the Červený kopec outcrop next to the section the following parameters were plotted: $CaCO_3$ content, $\delta^{18}O$ values, MIS values, sedimentary cycles, clay content, the different new and traditional sedimentary parameters and grain-size distribution values. With the comparison of these parameters with the $\delta^{18}O$ values of the ice cores from Greenland (GRIP/GISP2) we can make conclusions about the characteristics of the sediments and fairly reliable estimations about their age. All values of a given depth can be easily determined from the figure.

The following stratigraphic units were determined in the outcrop *(Figure 1, Photo 1):*

I. 9 soil horizons

– 1 B horizon of the recent soil *(Photo 3, 8)*

– 2 redeposited soils

– 6 paleosols – “Stillfried B” *(Photo 9, 10)* and “Stillfried A” *(photos 11* and *12)* pedocomplexes and the chernozem soil between them

II. 5 loess layers (Kiss, É. 2004, *photos 8, 9, 10*, and *12).*

The stratigraphic column of the Červený kopec section consist of loess and paleosol horizons of the last glacial-interglacial cycles (Würm glacial and Riss/Würm interglacial) from ~125 ky onward. The units based on its parameter values can be correlated with the similar sediments of the Stillfried *(Photos 13, 14, 15)* and the Dolní Věstonice (*Photos 16, 17)* sections.

The section of the last interglacial/glacial period lying on one of the most beautiful terrace-system of Central Europe is almost complete. The $\delta^{18}O$ values and sedimentary parameters of our own available loess-paleosol sections can be compared with the data of deep-sea sediments and ice cores.

The $\delta^{18}O$ values of the carbonates are reflecting the paleotemperature conditions during their formation. These were also affected by the waters from different sources (e.g. precipitation, the water removal due to desiccation

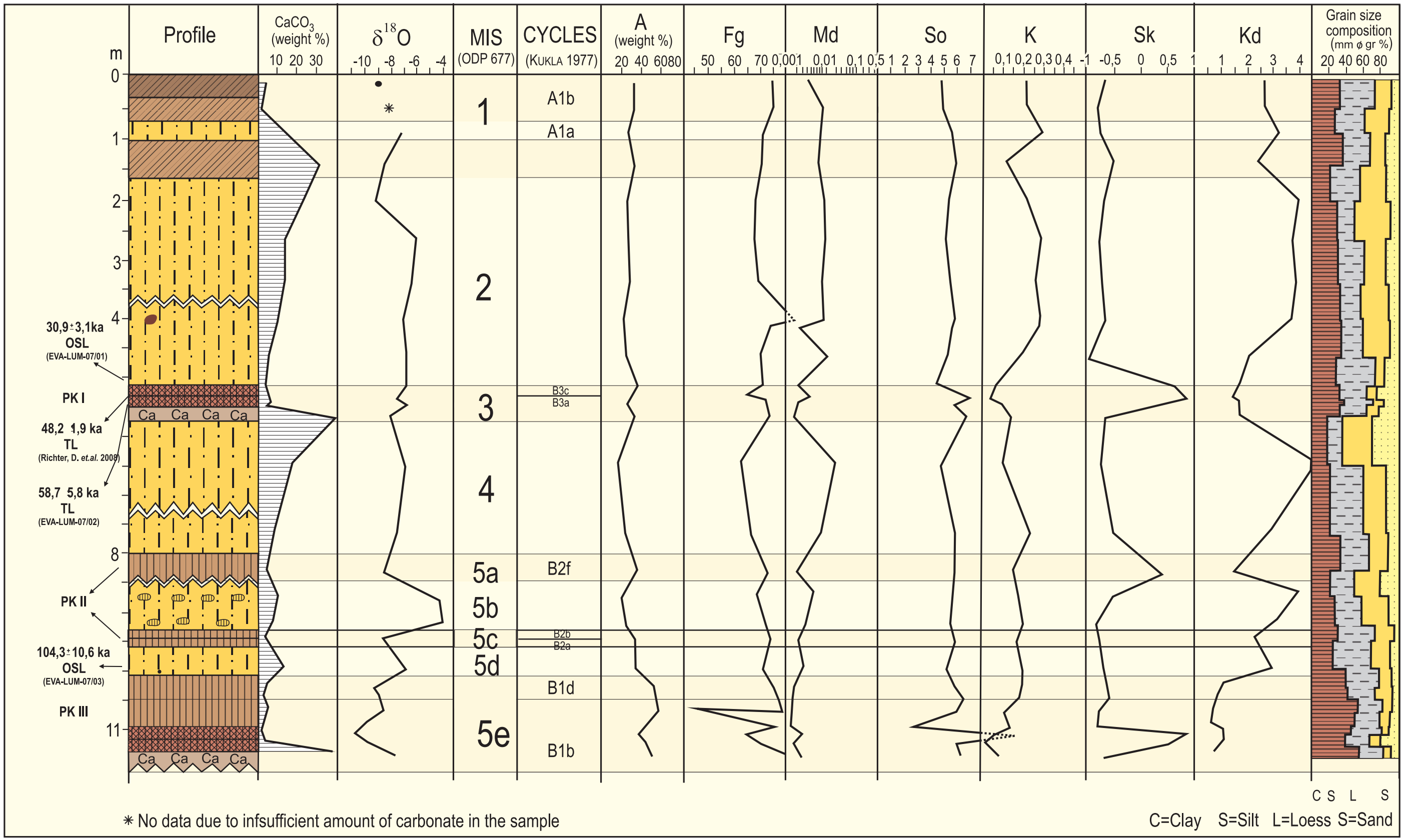

Fig. 1. Granulometric parameter values by samples from the Červený kopec section (Kis, É.). Stratigraphical analysis: Schweitzer, F., Kis, É., Balogh, J. and di Gleria, M. Oxygen isotope measurements: Futó, J. and Vodila, G. Granulometric analyses in 9 grain-size categories: di Gleria, M.

Photo 9. The II step on the IV terrace (Photo by Kɪs, É.)

Photo 10. The fossil soil of the II step (Photo by Kɪs, É.)

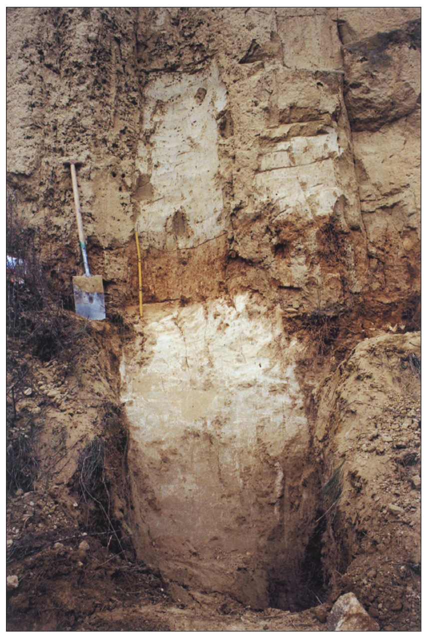

Photo 11. Loess layers between paleosols in the substrate of the I step (Photo by Kɪs, É.)

Photo 12. Fossil soil in the middle part of the I step (Photo by Kɪs, É.)

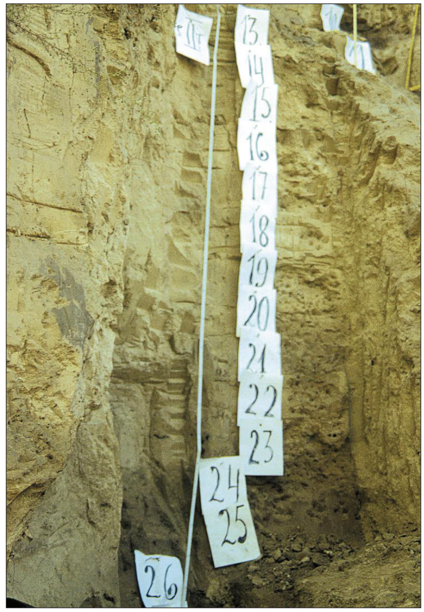

Photo 13. The Stillfried B pedocomplex (under the sample 22) in the Stillfried section (Photo by Kɪs, É.)

Photo 14. The triple PK-III pedocomplex in the Stillfried section (Photo by Kɪs, É.)

Photo 15. The lowest brown forest soil of the PK-III pedocomplex with krotovinas and traces of soli-fluctional processes in its lowermost part in the Stillfried section (Photo by Kɪs, É.)

Photo 16. The brown forest soil (lower) and the chernozem soil (upper) of the PK-III pedocomplex in the Dolní Věstonice section (Photo by Kɪs, É.)

Photo 17. The lowest part (R/W interglacial) of the PK-III pedocomplex and the underlying Riss loess in the Dolní Věstonice section (Photo by Kɪs, É.)

under warm climates – Deмény, A. *et al.* 2010). According to Kɪs, É. (2010) the series of Červený kopec consist of the last glacial (Würm) and last interglacial (Riss/Würm) deposits, based on their values. The maxima of the isotope curves represent the coldest climate (full glaciations), while the minimum values mean the warmest phases of the interglacial periods. Our oxygen-isotope curves agree especially well with the K_d index (degree of weathering), with the clay-content, with the $CaCO_3$ content, with the data of deep-sea sediments and ice cores. The concordant values of the ca. 10 parameters of the stratigraphic column allow to separate and compare the units, also those which were not visible to the naked eye.

By these parameters, the differentiation of forest and chernozem soils is quite good. We can affirm the opinion of Vaʟoch, K. (1996) who has stated that the two parts (the upper chernozem and lower forest soil) of paleosols equivalent with our MF_1 soils can be found together only in some places (e.g. Stillfried).

In most of the sections only one part of the complex remained (e.g. the chernozem soil in Dolní Věstonice with an age of 30,9 ky BP; the forest soil in Červený kopec – Bohunice-type culture: 40,2 ky BP). According to Vaʟoch,

K. (1996), the lack of the lower part of the "Stillfried B" soils is peculiar in flat terrains, while the absence of the upper part is typical on the more differentiated areas, where the chernozem soil was eroded during the uplift. Richter, D. *et al.* 2009 have explained the ~10 ky hiatus within the MF_1 soil also with erosion, and the TL age of the lower soil is 48.2±1.9 ky, its OSL age is 58.7±5.8 ky (EVA-LUM-07/02), the OSL age of the loess above the upper soil is 30.9±3.1 ka (EVA-LUM-07/01). The MF_2 soil in the Červený kopec section is similar; its upper chernozem soil was formed during the glacial, while the lower forest soil belongs to the R/W interglacial. According to Gábris, Gy. (2006), the MF2 soils in Hungary were formed in the last interglacial.

Based on our results, the Červený kopec section represents nobly the regional characteristics of the Late Pleistocene loess deposits.

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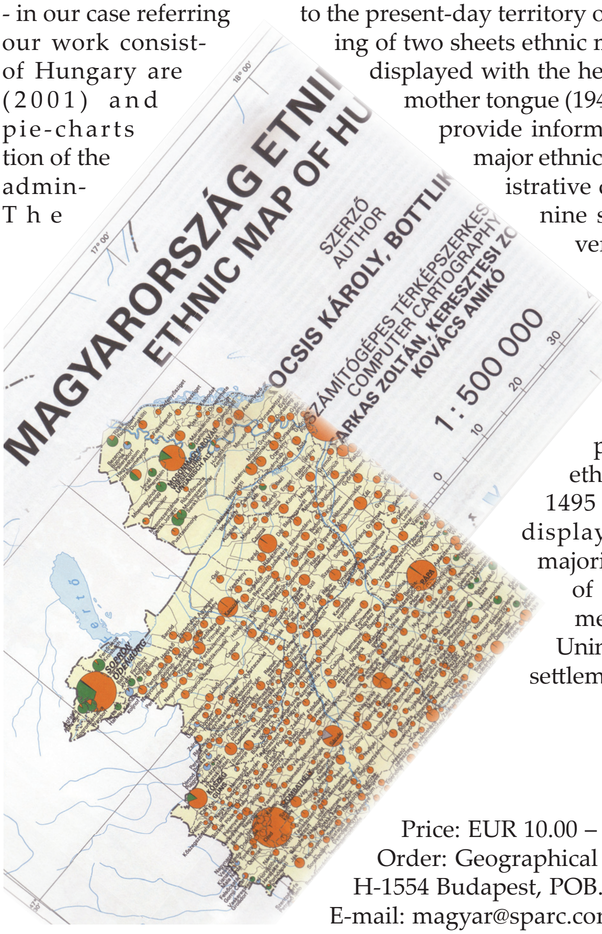
The latest (eighth) piece of ethnic map series of the Carpathian Basin was an attempt to draft the changes that have taken place in the ethnic structure during the past five hundred years as well as to display its present state with the help of ethnic maps and a chart - in our case referring to the present-day territory of Hungary. On the front pages of our work consisting of two sheets ethnic maps of the present-day territory of Hungary are displayed with the help of pie-charts, based on ethnic (2001) and mother tongue (1941) data. Population-proportional pie-charts provide information on the territorial distribution of the major ethnic groups and on the contemporary administrative division. The nine supplementary maps on the reverse show the lingual-ethnic composition of the present-day territory of Hungary in 1495, 1715, 1784, 1880, 1910, 1930, 1941, 1990 and 2001 respectively. The chart here explores the quantitative and proportional changes of the main ethnic groups' population between 1495 and 2001. The series of maps displays absolute or relative ethnic majorities only in the inhabited areas of the settlements which had been mentioned in the source referred. Uninhabited areas with no permanent settlements are shown as blank spots.



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