Hungarian Geographical Bulletin 61 (2) (2012) 93–111.

Investigations of paleogeographic variations on the basis of the stratotype section of Viatovo at the Lower Danube

Éva KIS[1], Ferenc SCHWEITZER[1], László PALCSU[2], István FUTÓ[2]
János BALOGH[1] and Mária DI GLÉRIA[1]

Abstract

The Plio-Pleistocene changes of paleogeographic environment in the Lower Danube Basin were investigated with the involvement of new granulometric analytical methods. The loess-paleosol series at Viatovo (located 35 km to the SE from Russe, Bulgaria) provides a comprehensive archive of Pleistocene climate changes. Similarly to Moravian loess deposits, the investigated site situates in a corridor position between more glaciated terrains.

The completeness of horizontally-bedded loess and paleosoil layers makes it a particularly significant section in Central and Eastern Europe. With or new data, we would like to contribute to previous lithological, paleoenvironmental and chronological studies of the section.

The novelty in our study are the comparison and plotting of $\delta^{18}O$ values and our newly introduced indices (fineness grade: Fg and degree of weathering: Kd) together with traditional sedimentary parameters (Md, So, K, Sk). These values were competed with clay- and $CaCO_3$-content, and percentages of clay, silt, loess and sand. To the relative dating of the section, we have correlated our data with Marine Isotope Stages of the ODP-677 site. The series of the upper part of the section represent 100 ky cycles of Middle and Late Pleistocene climate changes.

These units are overlying the ca. 6 m thick red clay deposits and the lowermost sandy kaolinitic loess layer. The whole sequence is situated on Lower Cretaceous paleokarst system. The $\delta^{18}O$ values and other sedimentary parameters illustrate gradual decrease of temperature since the Pliocene.

The granulometric parameters suggest that pedogenic processes played also a dominant role during the formation of loess deposits. The clay and fine-silt content of the red clay, loess and paleosoil layers are also in the range of 65–90%. These loess deposits can be classified as "Mediterranean" loess.

An identified horizon with clay fragments in the upper part of the loess-paleosoil series can be employed as marker unit, and supports the correlation with other sections.

[1] Geographical Institute, Research Centre for Astronomy and Earth Sciences (Hungarian Academy of Sciences) H-1112 Budapest, Budaörsi út 45. E-mails: kis.eva@csfk.mta.hu; schweitzer.ferenc@csfk.mta.hu; balogh.janos@csfk.mta.hu; digleria.maria@csfk.mta.hu

[2] Institute of Nuclear Research of the Hungarian Academy of Sciences, H-4026 Debrecen, Bem tér 18/c, E-mails: palcsu@atomki.hu; futo@atomki.hu

The lower 3 paleosoils were formed under moister climate regimes, the more infiltered precipitation washed out the carbonates from these layers. The formation and evolution of river-terraces, denudation surfaces and valleys can also be observed well in the vicinity of the section.

Keywords: loess-paleosoil series, Pliocene, Pleistocene, paleogeographic environment, paleoclimate, granulometric parameters

Introduction

Loess-paleosol sequences are widely considered as the most important terrestrial records of Late Neogene and Pleistocene paleoenvironmental changes. Loess and loess-like deposits are covering extensive areas in Central and Eastern Europe, where after the regression (and desiccation) of the remnants of the Paratethys eolian processes played predominant role in sedimentation. The detailed granulometric analyses of accumulated dust material provide substantial information about changes in precipitation, in wind strength, in regional moisture balance and extent of dust source areas (Pye, K. 1987). Recent studies confirmed that windblown dust is an active component of the climate system, and can modify its elements by various ways (Pósfai, M. and Buseck, P.R. 2010; Varga, Gy. 2010).

Geographical setting and the environment of the Viatovo loess-paleosol sequence

The investigated section of Viatovo is located at the southern fringe of the Lower Danube Basin, approximately 35 km to the SE from Russe (*Figure 1, Photo 1*). It is situated between the Danube and the Balkan Mountains at the, so called Eastern Danubian Tableland. Due to the significant relief-energy of the area, it would be more proper to call it “hills”. The section is located at the eastern fringe of the River Beli Lom, at north-western part of the Ludogorie Hills. The average elevation of the region is 200–300 m asl.

The horizontally-bedded Lower and Upper Cretaceous, and Neogene sediments can also be found at the surface (*Photo 1*). The remnants of the Kimmeridge terrestrial basement situate in large depth (Dinev, L. and Misev, K. 1981). In the Eocene and Miocene the area was covered by different arms of the Paratethys (Bozukov, V. *et al.* 2009), and only the north-western parts of the region stayed terrestrial (Aleksiev, G. and Spiridov, H. 2002). In the Pliocene a brackish lake (Dacian Lake) was formed in the front of western Ludogorie, at the place of the ancient Miocene sea, and sand, clay marl and clay were deposited (Dinev, L. and Misev, K. 1981).

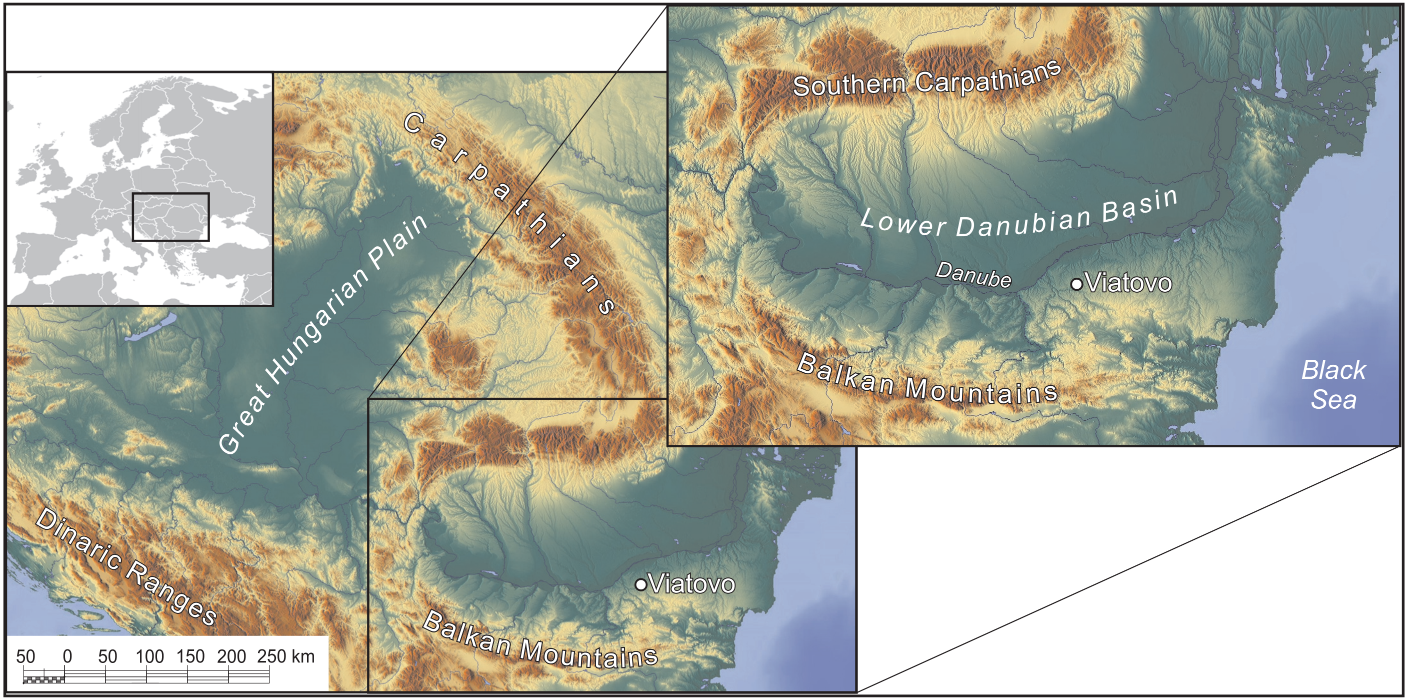

Fig. 1. Location of the investigated Viatovo loess section (Source of the digital elevation model: http://www.maps-for-free.com – Hans Braxmeier)

Photo 1. The sedimentary series of the Viatovo section (Photo by Kıs, É.).

At loess-covered areas, the landscape was developed specially due to the typical properties of loess (permeability, porosity, friability, $CaCO_3$ content, vertical capillarity, etc. – Lóczy, D. 2008). As a consequence of the Pleistocene crustal movements and climate changes, rivers of the area were incised and 5–8 river terraces were formed. The thickness of the loess deposit is highest direct at the Danube, it is thinning toward the Fore Balkan and its material is altered gradually to loessial clay. At the bottom of the sequence, Lower Cretaceous paleokarst features can be found (*Photos 2* and *3*).

The series of red clays, the 7 loess and 6 paleosol deposits (*Photo 2*) were formed on the Pliocene denudation surface of the kaolinitic level (*Photo 4*) and at river terraces (Evlogiev, Y. 2006). According to Evlogiev (2006) the whole sedimentary series consist of 8 loess and 7 paleosol units at the Danube. At the area south from Russe, however, the dust sedimentation rate was lower, the layers are thinner and pedogenic processes were more intensive (Jordanova, D. and Petersen, N. 1999a,b). Therefore, the number of loess-paleosol units at Viatovo is less than in sections direct at Danube.

The loess-paleosol sequences represent comprehensively the climate changes at the Lower Danube Basin. The 100 ky cycles, loess deposition during glacials, and incision of river and soil formation in interglacial periods can be seen clearly at the *Photo 2*. The loess deposits are product of intensified glacial dust deposition.

Photo 2. Upper Pliocene and Pleistocene loess series deposited on denudated and karstified Lower Cretaceous limestone. – Paleomagnetic boundaries: B/M = Brunhes/Matuyama; J = Jaramillo; O = Olduvai (Photo by Kıs, É.).

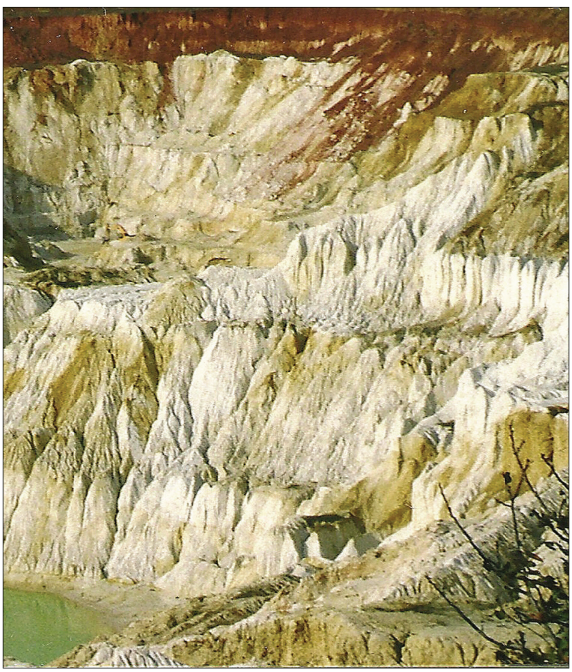

Photo 3. Specific denudation forms of the paleokarst system (Photo by Kıs, É.).

Photo 4. Pliocene denudation surface (Photo by Kis, É.).

The importance of the section was also confirmed by paleomagnetic and magnetostratigraphic analyses of Jordanova, D. (2008). The Brunhes/Matuyama (B/M) paleomagnetic boundary can be found in the lowermost loess layer (*Photo 5*), while two magnetozones were identified in the underlying red clay deposits, probably representing the Jaramillo and Olduvai paleomagnetic subchrons of Matuyama chron (*Photo 6*). The short-term events and the B/M reversal are very relevant stratigraphic markers (Jordanova, D. 2008). These markers can be used to correlate the East European loess deposits, which dust material is originated from different sources. The absence of numeric age data and correlative micro- and macrofauna also emphasise the importance of the paleomagnetic marker horizons.

The positions of major magnetic episodes in the surrounding regions were summarized by several workers (e.g. Jordanova, D. 2008). According to Tsatskin, A. *et al*. (2001), the B/M boundary can be found in Roxolany (at the western region of the Black Sea) between the 6th and 7th paleosols. This result was later confirmed by the measurements of Gendler, T.S. *et al*. (2006). The B/M reversal at Novaya Etuliya situates in the upper part of the 7th paleosol (Tsatskin, A. *et al.* 2001; Gendler, T.S. *et al*. 2006). The B/M reversal was also found at the foreland of the Eastern Carpathians in the section of Zahvizdja (Nawrocki, J. *et al.* 2002). Dodonov, A.E. (2006) found the B/M boundary in the 7th paleosol in a section at the northern coast of the Black Sea.

Photo 5. The Brunhes/Matuyama paleomagnetic reversal can be found in the lowermost loess unit (Photo by Kis, É.).

Photo 6. Two paleomagnetic events were identified in the red clay deposits, according to Jordanova, D. (2008) these are probably the Jaramillo (J) and Olduvai (O) subchrons (Photo by Kis, É.).

Eolian origin of loess in the Lower Danube Basin

Based on geomorphic and sedimentary observations, Fotakieva, E. and Minkov, M. (1966) and Minkov, M. (1968) were the first, who identified the eolian origin of loess in Bulgaria. According to their findings (blanket-like deposition of loess, southerly tilt of uplands, gradually thinning of loess deposits into southern direction, the presence of buried paleosols, angular bedding of some layers, etc.) are the proves of wind-blown origin.

Other evidences of eolian origin of loessial deposits in the Lower Danube Basin were summarized and completed with new results by Evlogiev, Y. (2007). As it was identified at several loess regions, grain-size of the loess material is decreasing gradually from the deflation area, when transport energy of wind reduces with increasing distance from the source area. It was also recognized in the case of the Lower Danube loess, where grain-size is changing from north to south and also from east to west. According to Evlogiev (2007) the well expressed directions of loess winnowing also confirms the eolian origin. The major dust source areas of the investigated section could be the alluvium of the Paleo-Danube (with its tributaries), the fine-grained unconsolidated material of the Dacian Basin and also the shelf region of the Black Sea. The stratigraphic differences of loess sections in the region are the results of the various, relief determined location of dust transport corridors. Therefore, Evlogiev (2007) differentiated five loess regions: Northeast, Yantra-Vit, Vit-Ogosta, Ogosta-Lom and the Black Sea region. The main dust transporting directions are NW–SE and NE–SW, at Viatovo both of them can be assumed.

Similarly to other old loess-paleosol sequences from Hungary, Tajikistan and China, the enhanced deposition of dust material started after the formation of the eolian red clay deposits (Kovács, J. *et al.* 2008, 2011; Varga, Gy. 2007, 2011). The accumulation of the material of the lowermost loess layers started around the Plio-Pleistocene boundary (~2.6 Ma BP) or even before this date. The oldest deposits can be found on the coastal part of the Dacian Basin (Evlogiev, Y. 2007). Similar depositional environments existed throughout the Late Neogene and the Pleistocene in Central Europe (Schweitzer, F. and Szöőr, Gy. 1997; Schweitzer, F. 2000).

Methods

A unified method of comparative grain-size analysis has been elaborated for the analysis of Quaternary sediments and this laid the foundations of an exact characterization and comparability of these deposits by the classification of loess regions (Kis, É. 2003; Schweitzer, F. and Kis, É. 2003). This method was tested in Hungary and applied exclusively by the author for the investigation into Quaternary deposits (loess and loess-like sequences) (Kis, É. 1992, 2001).

Through the evaluation of the results an opportunity has opened to acquire abundant information in a rapid way on the evolution history of the study area, including:

– the paleoenvironmental conditions during the deposition of the loess material;

– the subsequent changes taking place in the geographical environment;

– the climatic fluctuations over the past ca. 3 million years, including the ice ages;

– warming maxima and cooling minima of temperature during the Quaternary;

– sedimentary differences among the profiles of various loess regions based on the findings of the analyses.

Values of each parameter (index) as environmental indicator are gained by the application of analogous methods, so they are to be considered a correct and reliable source for the comparative analysis of profiles within a given region and between different regions, and for drawing conclusions on their paleogeography.

Quaternary sediments are characterized using the above method and an attempt is made to draw conclusions on changes in the rate of sedimentation and to establish local correlations between horizons with similar characteristics. Traditional sedimentological parameters (*So, K, Sk, Md*) were applied together with two indices introduced in Hungary recently: *Fg* (fineness grade) and *Kd* (degree of weathering), and with $CaCO_3$ content and percentage of clay, silt, loess and sand fractions. Organic matter content and pH values were also involved in the analysis.

Fineness grade (*Fg*) serves for an exact separation of horizons from each other and the reconstruction of paleotopography. Increasing or decreasing values of *Fg* are indicative of the source area of the parent material of loess, wind direction and speed during transport. The *Kd* index can be used to determine the degree of weathering, to point out extreme warming and cooling events. Traditional parameters provide additional information such as sorting (*So*) on the origin of the sediment material, kurtosis (*K*) is helpful for the sharp separation between loess and sand, asymmetry (*Sk*) orientates in the identification of regions of accumulation and denudation.

Of the newly adopted indices fineness grade shows maximum values in soils and minima in sands. Knowing these values soils horizons become recognizable while those finer than the average represent young loess and considerable finer ones represent silt intercalations. *Fg* values are used for an exact denomination of sediments, delimitation of the boundary of layers, their trend to increase or decrease refer to grain-size to refine or coarsen so they can be used for distinguishing between old and young loess varieties, revealing alterations within paleosols, correlating between loess and paleosol horizons.

The *Kd* index is represented by minimum values in soils and maxima in loess (and by figures slightly above minimum in sands). Apart from being useful for the identification and demarcation of sediments, its maxima is suitable for pointing out the traces of extreme cooling events within loess sequences (their exact depth can be identified within a given loess layer) and minimum values refer to warming maxima inside soils (exact depth within the soil horizon).

By the sorting (*So*) values, conclusions can be drawn on the origin of parent material (*So*<2.5: eolian; *So* = 2.5–3.5: fluvial; *So*>3.5: pedogenesis). The sorting values also support the distinction of young and old loess deposits, with higher values in the case of the older ones. According to Trask, P.D. (1932) *So* index values below 2.5 represent poorly sorted sediments, normal sorting is around 3 and well-sorted deposits show values above 4.5.

The asymmetry (*Sk*) values provide information on the accumulation of material and allow us to distinguish in-situ and redeposited slope sediments. Higher values refer to the highest accumulation rates of the parent material. Together with the kurtosis index, it is useful for the identification of hidden bimodal and trimodal redeposited sediments. They allow us to distinguish between sands and loess on the one hand and clays and silt on the other, and to separate areas of accumulation from those of denudation. Using this parameter more phases of sedimentation can be identified than by other methods.

Kurtosis (*K*) values support the determination of layer boundaries. The extremes indicate the mixing of loess with soil, referring to boundaries of loess and soils sharply. The laboratory analysis of the collected samples have been made in the Laboratory for Sediment and Soil Analysis in the Geographical Research Institute of the Hungarian Academy of Sciences (HAS). The grain-size distribution of the samples was measured using a Fritsch Analysette Microtec 22 laser grain-size analyser.

Oxygen stable isotope ratios of the loess samples were measured in the Laboratory of Environmental Studies in the Institute of Nuclear Research (HAS) by a Thermo Finnigan Delta Plus XP isotope ratio mass spectrometer using the GasBench sample preparation device. Depending on the carbonate content of the sample, 1–20 mg of each sample was measured in vials with septa. Headspace gases were purged by high purity (5.0) He gas, then 100% concentrated phosphoric acid is added to convert carbonates to carbon-dioxide which is lead to the mass spectrometer. Oxygen isotope ratios are published in the conventional delta (δ) values in permils, relative to the VPDB standard.

Results

The section (*Photo 7*) consists of horizontally-bedded (*Photo 8*) deposits, which represent almost the whole Pliocene and Pleistocene paleogeographic (climate,

Photo 7. The ~100 ky cycles of the loess-paleosoil formation at the upper part of the section (Photo by Kis, É.).

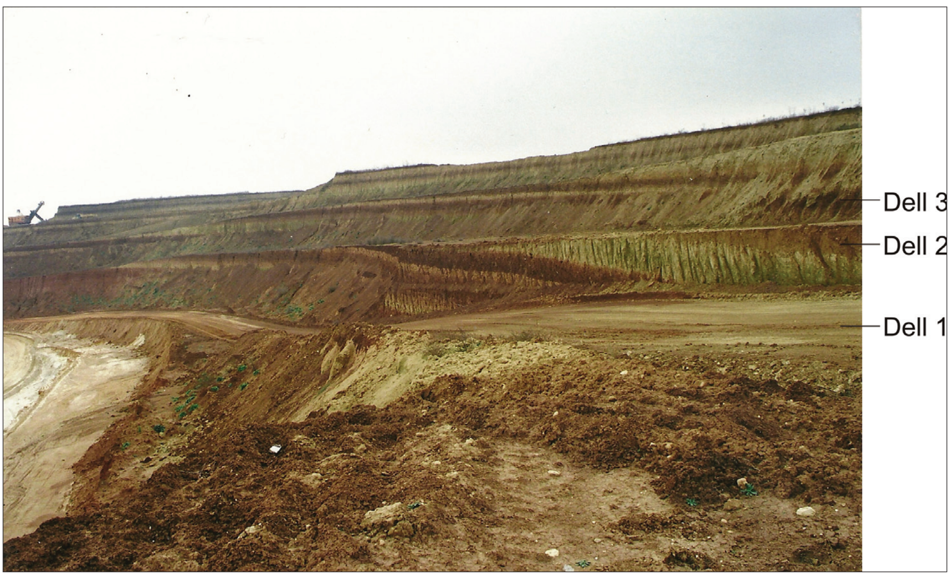

Photo 8. System of dells filled with loess and paleosoils, and soil erosion forms (Photo by Kis, É.).

relief and hydrology) evolution of the region. Therefore, it is an excellent archive of the paleoclimatic and paleoenvironmental changes of the last ca. 3 million years. The presented photos and results of the joint evaluation of granulometric and sedimentary parameters allow us to get more detailed information on these changes.

The upper section of the outcrop is a series of Middle and Late Pleistocene loess and paleosol units lying on river terraces. Similarly to other loess sections, this sequence represents the ~100 ky cyclic variations of Brunes paleomagnetic chron (Varga, Gy. 2011). The Brunhes/Matuyama paleomaegnetic reversal can be found in the lowermost loess layer (Jordanova, D. 2008). The thick loess and the distinct paleosol units illustrate gradual cooling and longer depositional periods of the Middle and Late Pleistocene climate.

The loess-paleosol sequence is overlying the ca. 6 m thick red (or reddish) clay series and the remnants of Lower Cretaceous paleokarst system. According to Jordanova (2008) two paleomagnetic episodes were identified in the red clay deposits; these are probably the Jaramillo and Olduvai subchrons. The recognition of the old, Pliocene loess under the reddish clay units is especially important, since evidences of loess formation before 2.6 Ma BP are considerably rare. Based on the stratigraphic position, the material of these loess layers were deposited before the Matuyama/Gauss paleomagnetic reversal.

To identify and distinguish different stratigraphic units, we compared the $\delta^{18}O$ values and our newly introduced indices (fineness grade: *Fg* and degree of weathering: *Kd*) together with the traditional sedimentary parameters (*Md, So, K, Sk*). These values were completed with clay- and $CaCO_3$-content, and the percentages of clay, silt, loess and sand. To the relative dating of the section, we have correlated our data with the Marine Isotope Stages of the ODP-677 site. The following stratigraphic units were determined and sampled:

I. 6 soil horizons
– 5 paleosols (*Photo 9*)
– 1 multiple red clay series (*Photos 13* and *14*)
II. 4 loess layers (*Photos 9–12*).

A horizon with clay fragments can be found above the third paleosol unit. According to recent evidences, this marker horizon was formed under continental climate during the heavy rainfalls following the warm-arid episodes. The surface of bare clayey soils at the deflation area could easily desiccate and fall apart to larger blocks. Similar markers were identified in the sections of Stillfried and the Dolní Věstonice (Kis, É. 2004; Schweitzer, F. and Kis, É. 2006).

The sampled section of Viatovo consists of 4 loess and 6 paleosoil layers, 1 multiple red clay complex and the lowermost sandy loess with kaolinitic interbeddings (*Figure 2*). The $\delta^{18}O$ values of the samples suggest a gradual

Photo 9. Paleosols at the southern part of the site (Photo by Kis, É.).

Photo 10. Loess and paleosol layers with clay fragments at the surface of the paleosol (Photo by Kis, É.).

Photo 11. $CaCO_3$ concretions, ca. 5 cm in diameter (in the foreground), eroded from the prismatic paleosol (Photo by Kis, É.).

Photo 12. Old loess deposits with notable carbonate concretions at the right-hand side of the section (Photo by Kis, É.).

Photo 13. Pliocene denudation deposit between the kaolin and the red clay horizons (in the middle) (Photo by Kis, É.).

Photo 14. Multiple red clay strata and yellowish, loessial Pliocene denudation deposits in the lower right corner (Photo by Kɪs, É.).

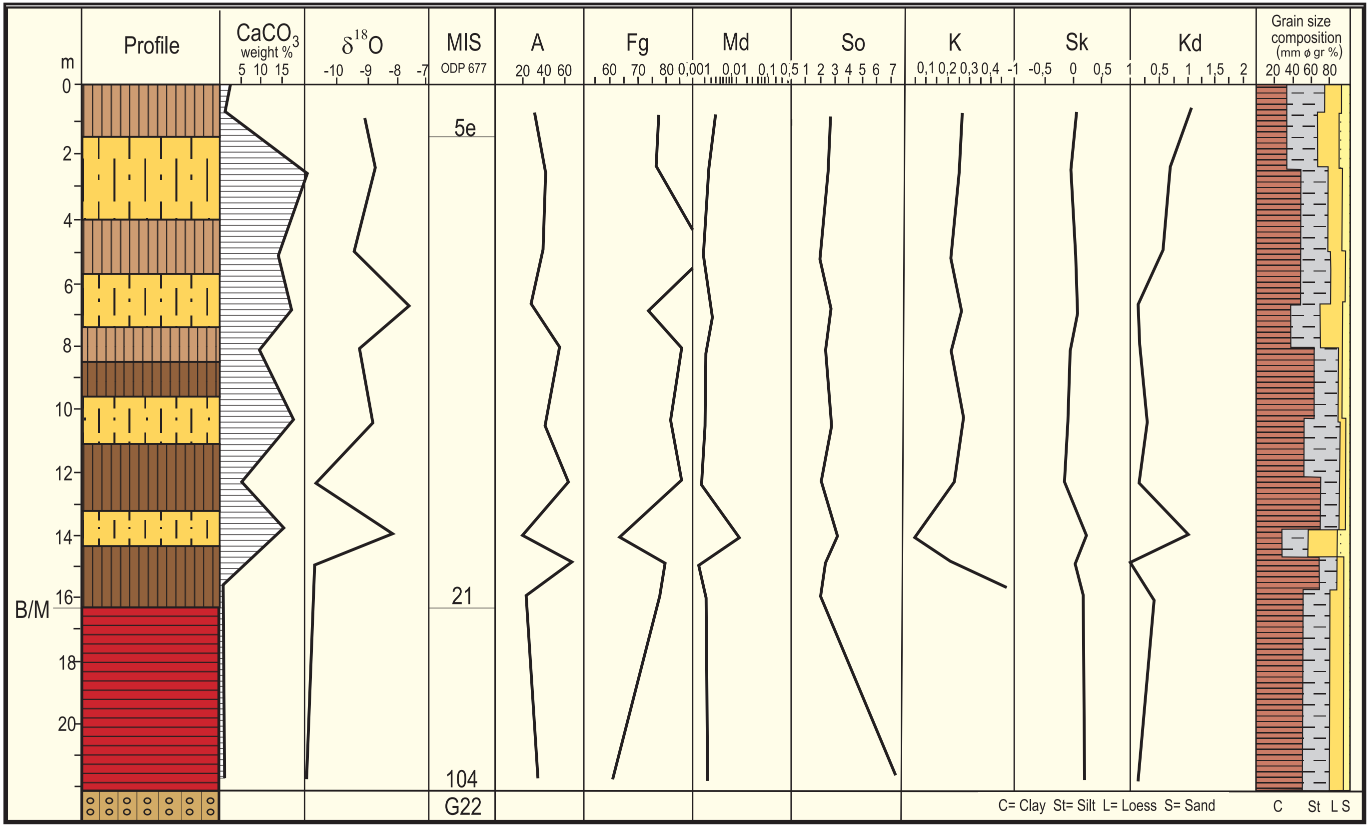

Fig. 2. Granulometric parameter values by samples from the Viatovo section (Kis, É.). Stratigraphical analysis: Kis, É., Schweitzer, F., Balogh, J. and di Gleria, M. Oxygen isotope measurements: Futó, J. and Vodila, G. Granulometric analyses in 9 grain-size categories: di Gleria, M.

decrease of the temperature during the warming phases of the deposition. The relationship between the oxygen isotopes and the paleotemperature is complicated, and it is controlled by several additional environmental factors (e.g. regional moisture sources, amount and $\delta^{18}O$ values of meteoric water, seasonality – Demény, A. *et al.* 2010). However, the main changes of the temperature are properly archived in the oxygen isotopic composition of pedogenic carbonates. Peaks of the isotope curve illustrate different temperature regimes.

The correlation of stratigraphic units to the Atlantic deep-water deposits of ODP677 site (Shackleton, N.J. *et al.* 1990) confirmed the suggested ages of the layers. The paleosoils (S_1–S_6) correspond to the odd numbered units of ODP677 as far as the Stage 21, the red clay deposits were formed after the Stage 104, while the age of the lowermost sandy loess can be correlated to the stages between 104 and G22.

According to the granulometric studies, proportion of silt fraction is very low, while the amount of clay is particularly high (27.5–75.5%) in all stratigraphic units, also in the loess layers (except the lowest loess deposit – 6.4%). The pedogenic processes played important role also during the glacial periods. This might be influenced by the climate modification effect of the nearby (~100–120 km) Black Sea.

The carbonate content of the units is also diverse. The $CaCO_3$ values are 8.76–15.43% in the upper 3 paleosoils, while these values are changing between 5% and 7.09% in the lower 3 soils.

These values show us that the older soils were formed under a moister climate, and the carbonate content was reduced due to the more infiltrated rainwater. Jordanova, D. and Petersen, N. (1999a,b) reported similar conclusions on the depositional environment. The organic content varies between 0.11% and 0.86%, with higher values in red clays, also confirming the above explained establishments. All other sedimentary parameters can be easily determined from the curves plotted next to the section on the evaluation figure.

Conclusions

The paleoenvironmental and paleoclimatic changes of the Lower Danube Basin are well represented in the compiled general section. The detected granulometric variations and sedimentary parameters provide information on the climatic and environmental fluctuations and conditions that prevailed during the deposition of the last 3 million years. All of these changes can be directly read from the evaluation figure. The curves of the measured and counted values were plotted next to the section, so the data of each horizon can be promptly determined.

Due to the same methodology, the results can be compared to the conclusions of previous studies from the region. Through these comparisons, new proofs can be found for the correlation heretofore based upon the description of the profiles, sampling and subsequently laboratory analyses.

Acknowledgement: The study and the measurements were supported by Hungarian Scientific Research Fund (OTKA K63814).

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Geography in Visegrad and Neighbour Countries

Regional Socio-Economic Processes in Central and Eastern Europe – 20 Years in Transition and 2 Years in Global Economic Crisis

Edited by
Ágnes Erőss and Dávid Karácsonyi

Geographical Research Institute Hungarian Academy of Sciences
Budapest, 2011. 169 p.

During the last twenty years the erstwhile Soviet bloc countries in Central and Eastern Europe (CEE) have taken distinct routes in post-socialist development, wherein the national trends and internal regional processes proved to be in deep contrast. Responses to the challenges of the global economic crisis also varied, repeatedly brought to the surface long existing regional issues, structural problems and ethnic conflicts. Human geographers are divided in the assessment of the shifts that occurred during the past twenty years and the exchange of experience is vital for finding adequate answers to the new challenges. In order to provide a forum for discussion the Geographical Research Institute Hungarian Academy of Sciences with the generous support of the International Visegrad Fund Small Grant Programme organized a conference in order to induce the revival of contact between the institutes of geography of Visegrad Countries and their Western and Eastern neighbours. Present volume is a selection of presentations aiming to provide a deeper insight in socio-economic processes and their interpretation from geographical aspects taking place in the broader region of CEE countries.