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GEOCHEMICAL INVESTIGATIONS OF THE DUNASZEKCSŐ LOESS-PALEOSOL SEQUENCE, SE TRANSDANUBIA, HUNGARY

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ABSTRACT

The paper discusses the relation between paleoclimate and geochemical characteristics of the loess-paleosol sequence of Dunaszekcső, Hungary. Geochemical properties of the sediments reflect the intensity of weathering and pedogenesis, thus five sediment types could be distinguished upon this basis. The *weakly weathered loess* formed under cold and arid climate, while the *weathered loess* accumulated during milder, more humid periods. The *strongly weathered loess*, overlying paleosols, shows intermediate character between loess and paleosol; its geochemical analysis indicates more intense weathering than in loess, but not intensive enough for soil formation. The Mende Upper and Basaharc Double paleosols were produced by strong pedogenesis, while the Basaharc Lower paleosol underwent the most advanced weathering and pedogenesis. Analyses of the geochemical character of different stratigraphic horizons allowed the reconstruction of paleoclimatic trends.

Keywords: younger loess, paleosols, geochemistry, carbonates, major components, trace elements, paleoclimate

INTRODUCTION

Quaternary sediments reflect the environmental influences that played crucial role in their development. The paleoenvironmental conditions determined the mineralogical composition and the distribution of chemical elements in loesses and in paleosols. Consequently, the changes of the mineralogical composition and geochemistry of sediments make possible the reconstruction of the dynamic changes of paleoclimate and environment.

As the climate becomes warmer and more humid, weathering and pedogenesis intensify. In warm-humid periods the solution of the carbonates increases, and so do the development of clay minerals, the accumulation of Fe_2O_3, Al_2O_3, and the enrichment of several main components and trace elements.

On the base of their lithological features, the loesses in Hungary can be divided into two well-distinguishable units: the "young loess" and the "old loess" series. The upper part of the young loess series is designated "Dunaújváros-Tápiósüly subseries", while the lower part is known as "Mende-Basaharc subseries" (PÉCSI 1975, 1985, 1993). The Dunaújváros-Tápiósüly subseries contains two humic horizons (h_1, h_2), while the two paleosol complexes (Mende Upper I and Mende Upper II; Basaharc Double I and Basaharc Double II) and one well-developed paleosol horizon of considerable thickness (Basaharc Lower) are interlayered in the Mende-Basaharc subseries (PÉCSI-SCHWEITZER 1995).

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Geochemistry of the loesses has been studied by a great number of scientists all over the world (GONG et al. 1987, LAUTRIDOU et al. 1984, PETROV et al. 1984, SCHNETGER 1992, TAYLOR et al. 1983). The young loess series of Hungary was investigated by PÉCSI-DONÁTH (1985). The relationship between geochemical character of loesses and paleoclimatic changes was revealed by WEN et al. (1985), LIU et al. (1995), and WEN et al. (1995).

According to previous investigations, the loesses of the area can be divided into three groups upon their geochemical and lithological composition: weakly weathered loess, weathered loess and strongly weathered loess (HUM and FÉNYES 1995, HUM 1997). As compared to weakly weathered loess, the weathered loess is characterized by higher TiO_2, Al_2O_3, Fe_2O_3, K_2O, Li, Cr, Zn, Rb, and lower CaO and Sr content, and its CaO/MgO and $(CaO+K_2O+Na_2O)/Al_2O_3$ ratios are lower, while the K_2O/Na_2O ratio is higher.

In this paper the geochemical investigation of the Dunaszekcső loess-paleosol section is discussed (*Fig. 1.*).

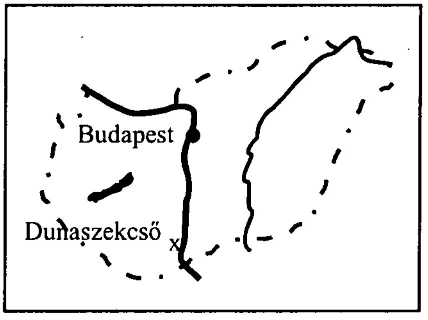

Fig. 1. Location map of the examined profile (x)

ANALYTICAL METHODS

Sampling interval was 0.25 m in the section, but thinner layers were also sampled. The color of the sediments was determined after the Rock-Color Chart (1980). After the determination of grain-size distribution and carbonate content, we selected 27 samples for mineralogical and elementary analyses. The fraction under 71 µm has been analysed. X-ray measurements were used for determination of the mineral composition. The calcite/dolomite ratios were determined by the method of TENNANT-BERGER (1957). Determination of carbonate and clay minerals was promoted by thermoanalytical examinations. Inorganic carbon was removed with HCl, and then organic carbon content was determined by using LECO Carbon-Sulphur Determinator. For the determination of trace and major elements, destructive attack was performed by using $HF-HClO_4-HNO_3$ mixture in teflon bomb under high pressure. Al, Fe (total), Mn, Mg, Ca, Na, K, Li, Zn, and Sr were analysed by flame AAS (Perkin Elmer 4100). Cr, Rb, Ni, Co, Pb and Cu were measured by graphite-tube AAS (ZEISS). Si was measured by RFA, while Ti and P were analysed by spectrophotometry (using the Tiron-method and the molybdenum yellow method). Ba was measured by ICP-AES. The AAS measurements were checked by the results of RFA and ICP-AES measurements for several elements. All methods are described in HEINRICHS-HERRMANN (1990).

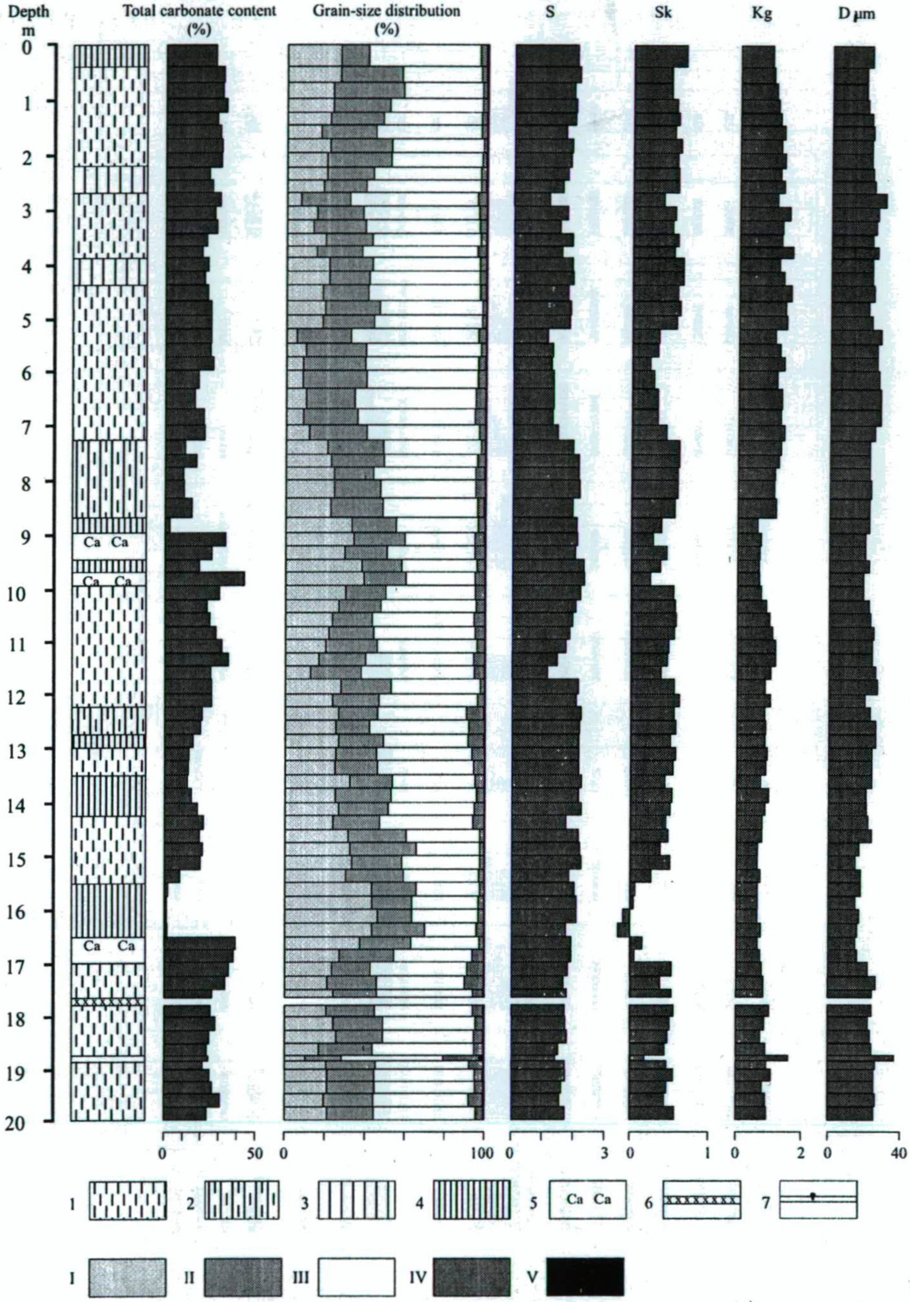

Fig. 2. Lithological profile and carbonate contents of the section
1 = loess; 2 = strongly weathered loess; 3 = humic horizon; 4 = paleosol; 5 = carbonate accumulation; 6 = The Bag Tephra; 7 = sandy layer
I = < 5 µm; II = 5 - 20 µm; III = 20 - 60 µm; IV = 60 - 100 µm; V = 100 - 200 µm; VI. = 200 < µm

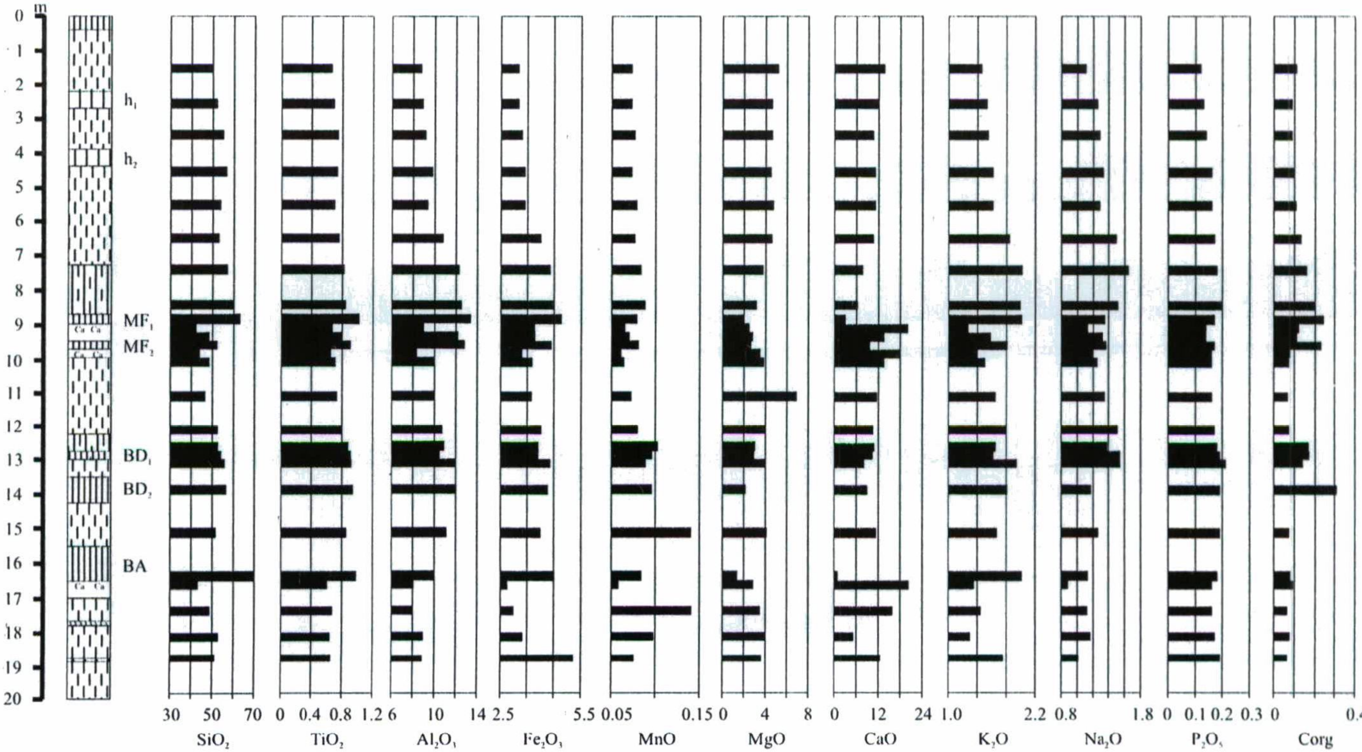

Fig. 3a. Distribution of major components (%) in the section

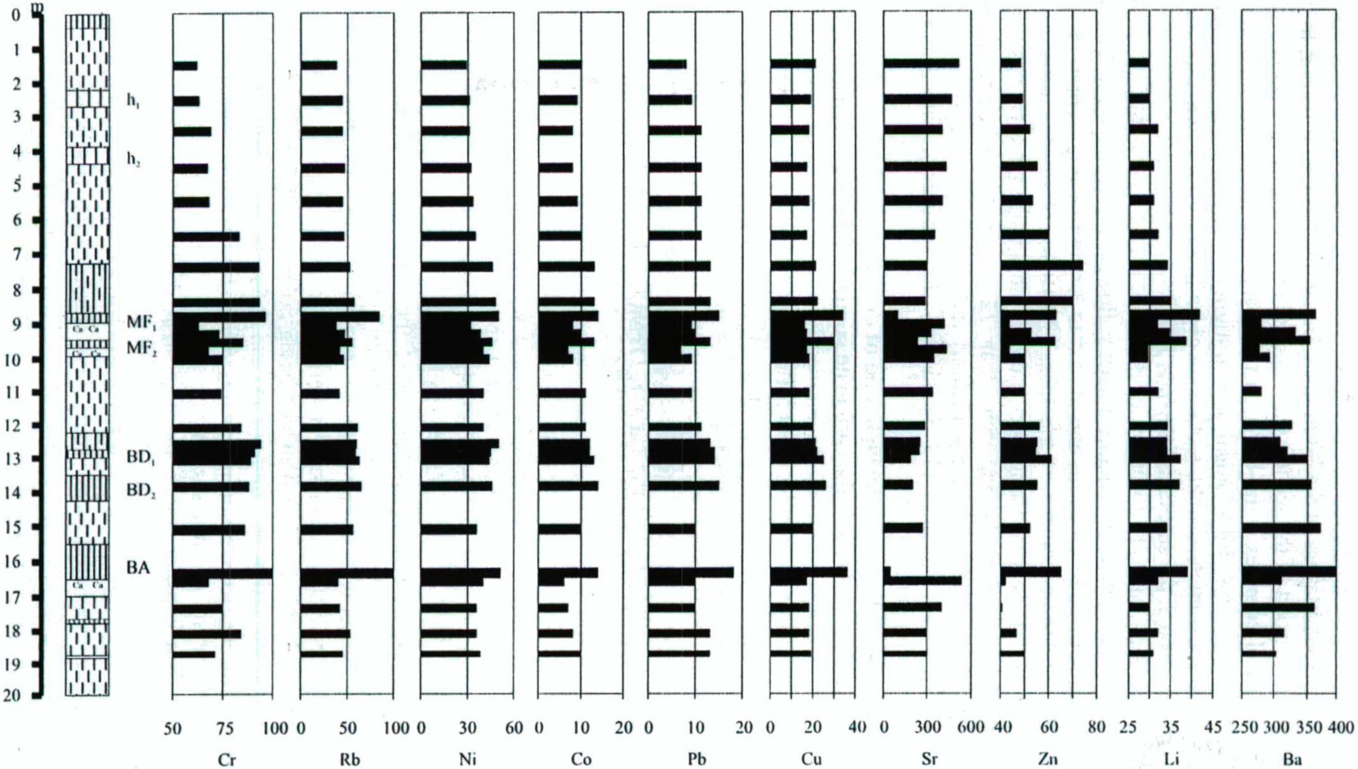

Fig. 3b. Distribution of trace elements (ppm) in the section

THE DUNASZEKCSŐ LOESS-PALEOSOL SEQUENCE

The nearly horizontal layers of the 20 m thick Dunaszekcső section belong to the young loess series. The upper part of the section was exposed by drilling, while – after reaching the Mende Felső paleosol complex – the lower part was sampled in the Semmelweis utca and Felszabadulás utca outcrops. Lithological and stratigraphic subdivision, carbonate content and sedimentological parameters of the section are given in *Fig. 2*. The evolutionary trends of chemical elements through the section is shown in *Fig. 3*.

The lowermost loess unit (17 to 20 m) of the section is dusky yellow (5 Y 6/4) loess with carbonate nodules. The unit contains a dark yellowish orange (10 YR 6/6) limonitic, sandy loess layer (at 18.75 to 18.80 m) and the 1.5 to 3 cm thick Bag Tephra (at 17.75 m). Within the high carbonate content of the loess (24.10 to 33.35 %), dolomite prevails (between 68 and 74 %). Several Hungarian authors, including SZILÁRD (1983) and Pécsi (1993), assign the samples containing more than 22 weight % carbonate, to loess-like formations (horizons of carbonate accumulation) rather than to real loess. Others, like FÜCHTBAUER (1988) and HÄDRICH (1975), classify the sediments with 30 or even 40 weight % carbonate content as loess.

Another conspicuous feature is the high ratio of dolomite within the carbonate content. According to FÜCHTBAUER (1988), the carbonate content of the loess consists prevailingly of calcite, while dolomite occurs exceptionally only. Literature data show that calcite/dolomite ratio of loess samples from different parts of the world falls around 2:1 or 3:1 (HÄDRICH 1975, PYE 1983, TAYLOR et al. 1983, SCHNETGER 1992). In our loess samples, however, the calcite/dolomite ratio is 1:2 in average. High dolomite content in the young loess series of Hungary was registered by PÉCSI-DONÁTH (1985) and GEREI et al. (1985) as well.

The CaO/MgO ratio (2.31) and the $CaO+K_2O+Na_2O/Al_2O_3$ ratio (1.75 to 2.33) of the sediment are high, while the K_2O/Na_2O ratio (1.28 to 1.64) is low. As its carbonate content, geochemical ratios, and distributions of major components and trace elements indicate, the loess belongs to the weakly weathered group, and formed under arid and cold climate.

The overlying Basaharc Lower (BA) soil is a well-developed moderate (yellowish) brown (10 YR 5/4, 5 YR 4/4) paleosol (between 15.5 and 16.5 m). Carbonate content of the soil horizon is 1.36 to 1.81 %. The CaO/MgO and the $CaO+K_2O+Na_2O/Al_2O_3$ ratios are extremely low (0.71 and 0.42, respectively), while the K_2O/Na_2O ratio is high. As a result of intense weathering and pedogenesis, the amount of MgO, CaO, and Sr considerably decreased, while the concentration of SiO_2, TiO_2, Fe_2O_3, and K_2O significantly increased, as well as that of Li, Cr, Co, Ni, Cu, Zn, Rb, Pb, and Ba. The 0.5 m thick carbonate accumulation horizon, underlying the soil, displays as high carbonate content as 37.5 to 39.11 %, the bulk of which being dolomite (55 %). The CaO/MgO and $CaO+K_2O+Na_2O/Al_2O_3$ ratios are high (7.18 and 2.81, respectively). This horizon is characterized by a strong decrease in SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, Na_2O, and K_2O, and by an extreme increase in CaO and Sr content.

The overlying unit between 14.25 and 15.5 m is dusky yellow (5 Y 6/4) loess. Its carbonate content ranges from 8.64 to 20.11 %, dominated by dolomite (72 %). Though the CaO/MgO ratio is still high, the $CaO+K_2O+Na_2O/Al_2O_3$ and K_2O/Na_2O ratios indicate that it belongs to the weathered loess group. This classification is affirmed by the TiO_2, Al_2O_3, Fe_2O_3, MnO, Na_2O, K_2O, and P_2O_5 content of the sediment, all being higher than in weakly weathered loess. The weathered loess suffered more intense weathering and formed under more humid climate.

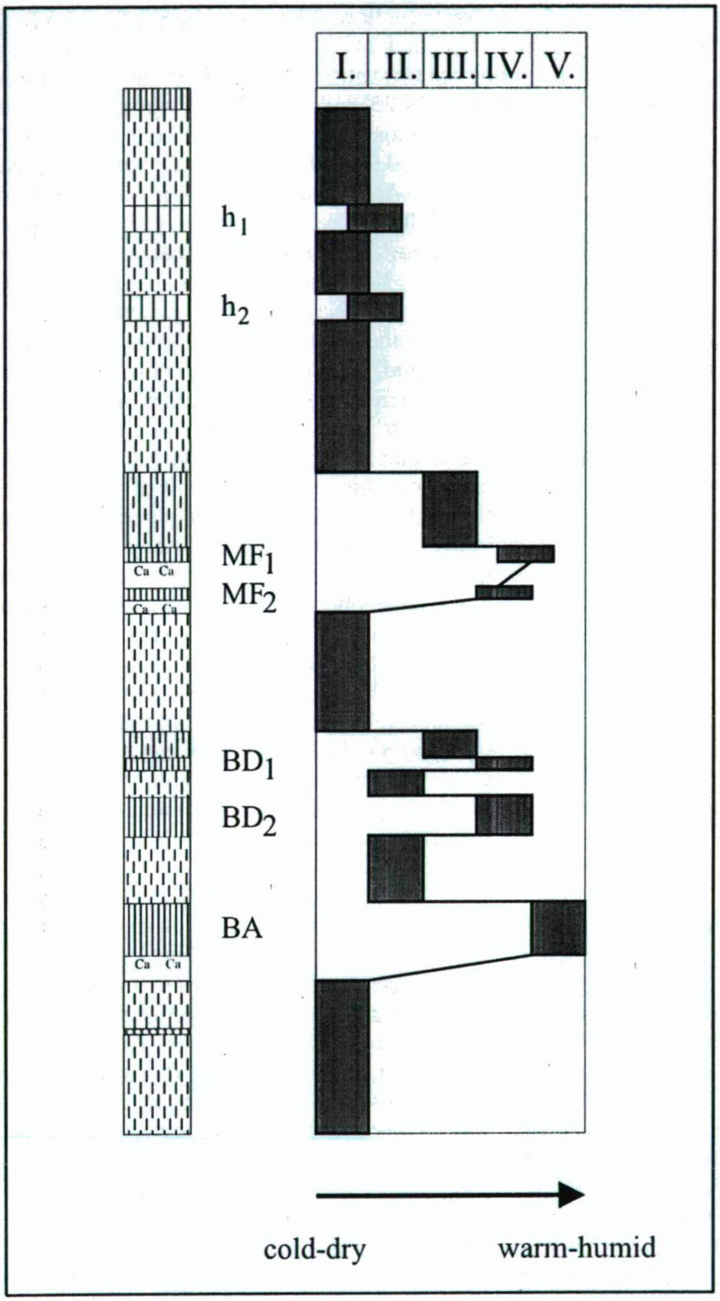

Fig. 4. The evolutionary trends of paleoclimate and intensity of weathering in the young loess series in southeastern Transdanubia as reconstructed from the geochemical analyses of the Dunaszekcső section. I. = weakly weathered loess; II. = weathered loess; III. = strongly weathered loess; IV. = MF and BD soil complexes; V. = BA soil complex

The following unit is the moderate (yellowish) brown (10 YR 5/4, 5 YR 4/4) Basaharc Double (BD) paleosol between 12.75 and 14.25 m. The lower member of the soil complex – Basaharc Double II – is a moderate brown (5 YR 4/4) chernozem-like forest steppe soil (PÉCSI-SCHWEITZER 1995) between 14.25 and 13.50 m. Carbonate content of the soil horizon is 12.73 to 17.09 %, most of which being calcite (73 %). The $CaO+K_2O+Na_2O/Al_2O_3$ ratio is low (0.98), the K_2O/Na_2O ratio is high (1.55). As compared to loess, the amount of TiO_2, Al_2O_3, Fe_2O_3, K_2O, Li, Co, Ni, Cu, and Pb shows higher values, while concentration of alkaline earthes decreases. Between BD II and BD I soils there is a loess layer (from 13.00 to 13.50 m), the carbonate content of which is 13 to 14 %, being mainly dolomite (68 %). On the base of its CaO/MgO (2.01), $CaO+K_2O+Na_2O/Al_2O_3$ (0.95), and K_2O/Na_2O (1.26) ratios and its elementary composition, this layer also belongs to the weathered loess group. Consequently, it was formed during a relatively mild period, when the weathering processes were more intensive than in typical cold and arid periods of loess formation. The moderate yellowish brown (10 YR 5/4) BD I soil (12.75 to 13.00 m) contains 16.12 % carbonate with a balanced calcite/dolomite ratio (the calcite is slightly more: 54 %). According to the oxide ratios and to the elementary composition, this soil is the result of a slightly less intensive pedogenesis than the lower member of the soil complex. The paleoclimatic conditions did not allow the formation of a well-developed soil horizons in these cases.

The next layer is a light brown (5 YR 6/5) strongly weathered loess (between 12.25 and 12.75 m). Its carbonate content changes between 20.01 and 21.37 %, 58 % of which being calcite. Both the elementary composition and the oxide ratios indicate strong weathering. The pedogenesis, however, was too weak to form a soil.

The overlying layer is a dusky yellow (5 Y 6/4) weakly weathered loess (12.25 to 9.95 m). It is characterized by high carbonate, and particularly by high dolomite content (25.92 to 31.98 % and 62 to 88 %, respectively). The CaO/MgO and $CaO+K_2O+Na_2O/Al_2O_3$ ratios are high, the K_2O/Na_2O ratio is low, and the major components as well as the trace elements indicate that this sediment belongs to the weakly weathered loess group. It was formed in a cold and arid period, offering favourable conditions for loess accumulation.

The following Mende Upper (MF) soil complex (8.75 to 9.95 m) consists of two chernozem-like forest steppe soils. The moderate brown (5 YR 5/4) lower paleosol horizon (MF II, between 9.55 and 9.75 m) contains 19.20 % carbonate, mainly calcite (61%). The CaO/MgO, $CaO+K_2O+Na_2O/Al_2O_3$, and K_2O/Na_2O ratios (3.62, 1.01, and 1.32, respectively) also indicate a low intensity pedogenesis. The highest carbonate values of the whole outcrop were measured in the carbonate accumulation horizon underlying this soil: 43.66 %, 52 % of which is calcite, the rest being dolomite. The upper member of the soil complex is the Mende Upper I horizon (8.75 to 9.05 m). Its carbonate content is low: 2.72 %. The calcite/dolomite ratio is close to 1 (46 % calcite, 54 % dolomite). The CaO/MgO ratio (1.51) and the $CaO+K_2O+Na_2O/Al_2O_3$ ratio are low, while the K_2O/Na_2O ratio is high. Beside the high content of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, K_2O, Corg and low amount of MgO, CaO, and Sr, the high concentration of several trace elements, such as Li, Cr, Co, Ni, Cu, Zn, Rb, Pb, and Ba also indicates high-intensity pedogenesis. The Mende Upper I and Mende Upper II soil horizons are separated by a carbonate accumulation zone (9.05 to 9.55 m), with a carbonate content of 25.92 to 33.65 %. Within the carbonate content, the ratio of calcite ranges from 65 to 68 %.

The unit overlying the Mende Upper soil complex is a 1.5 m thick, strongly weathered, clayey, moderate yellowish brown (10 YR 5/4) loess. Its carbonate content changes between 10.00 and 17.73 %, with a dolomite ratio of 74 to 77 %. The CaO/MgO ratio of the sediment is low (1.96 to 1.99), as well as the $CaO+K_2O+Na_2O/Al_2O_3$ ratio (0.77 to 0.90), while its content of Al_2O_3, Fe_2O_3, MnO, K_2O, and P_2O_5 is high. The overall geochemical character of this layer indicates intense weathering and relatively mild paleoclimate, though paleosol formation did not take place.

The overlying layer, between 4.40 and 7.25 m, is dusky yellow (5 Y 6/4) loess. Its carbonate content ranges from 16.37 to 26.83 %, the dolomite being 63 to 80 % of the total. The CaO/MgO and the $CaO+K_2O+Na_2O/Al_2O_3$ ratios are high (2.31 to 2.52 and 1.27 to 1.49, respectively), while the K_2O/Na_2O ratio is low. According to these ratios and to the amount of major components as well as that of the trace elements, this layer belongs to the weakly weathered loess group, thus it formed under cold and arid paleoclimate.

Between 3.95 and 4.40 m, the 2nd humic loess horizon (h_2) of the Dunaújváros-Tápiósüly subseries was identified. Since this horizon is a result of very weak pedogenesis, its carbonate content (23.64 to 21.83 %) and other geochemical features are not unlike those of loesses. Another dusky yellow (5 Y 6/4) weakly weathered loess follows between 0.40 and 3.95 m. The loess is characterized by high (20.46 to 33.65 %) carbonate content, dominated by dolomite (61-72 %). The CaO/MgO and $CaO+K_2O+Na_2O/Al_2O_3$ ratios are high (2.61 and 1.83, respectively), while the K_2O/Na_2O ratio is low (1.31).

Between 2.15 and 2.65 m, the loess unit contains the 1st humic loess horizon (h_1), resulting from weak weathering processes.

CONCLUSIONS

On the base of their mineralogical and chemical composition, determined by paleoclimatic conditions, it is possible to make distinction between loess and paleosol types that suffered different degree of weathering and pedogenesis.

As weathering and pedogenesis intensify, the grain size distribution significantly shifts towards the finer fractions at the expense of the silt fraction. At the same time the carbonate content decreases; it is high in weakly weathered loess, but has been nearly entirely dissolved from well-developed paleosols. Along with the decrease in carbonate content, the originally low calcite/dolomite ratio (1:2) of the loess significantly changes and increases to 2:1 to 3:1 in paleosols, the overall carbonate content of which being very low.

Due to weathering and pedogenesis, the CaO, MgO, and Sr content of the sediments decreases, while the amount of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, Na_2O, K_2O, P_2O_5, and Li, Cr, Co, Ni, Cu, Zn, Rb, Pb, and Ba increases. When weathering intensifies, the CaO/MgO and $CaO+K_2O+Na_2O/Al_2O_3$ ratios fall, and the K_2O/Na_2O ratio keeps growing. On the base of geochemical properties, groups of different origin can be established.

The *weakly weathered loess* formed under cold and arid climate. This is the group the least affected by weathering. The *weathered loess* was deposited under milder and more humid conditions, thus weathering did influence its formation. More intense weathering, however, led to the formation of *strongly weathered loess*, which can be interpreted as humic loess or embryonary soil as well. In these cases, however, pedogenesis was not strong enough to develop real soil horizon. The strongly weathered loess displays intermediate geochemical and developmental character between loess and paleosol. The Mende Upper and Basaharc Double soil complexes were formed by strong pedogenesis under mild and humid climate. The Basaharc Lower paleosol witnesses the most intense pedogenesis and weathering, and is associated with even warmer and more humid paleoclimate than the Mende Upper and Basaharc Double soil complexes.

Geochemical investigation of loess-paleosol series renders reconstruction of paleoclimatic trends possible. The loess underlying the Basaharc Lower paleosol represents the weakly weathered loess group. The cold period, favourable for loess accumulation, was interrupted by a warm, humid period, resulting in the formation of the Basaharc Lower soil horizon. The overlying weathered loess was deposited during a period characterized by cooling down. Geochemical data from the two chernozem-like forest steppe soil horizons of the following Basaharc Double soil complex argue for the same degree of pedogenesis. The weathered loess interlayered between the Basaharc Double I and Basaharc Double II soil horizons indicates that the cooling down between the two mild and humid periods forming the soils was not significant. The soil complex is overlain by strongly weathered loess, indicating graduate cooling in the profile. When the climate became cold and dry again, weakly weathered loess accumulated. During the following mild and humid period, two chernozem-like forest steppe soil horizons formed (Mende Upper soil complex). The upper horizon of the complex (Mende Upper I) suffered more intense weathering than the lower one (Mende Upper II). Again, the paleosol complex is overlain by strongly weathered loess, formed under cooler, still mild climate. The overlying weakly weathered loess hallmarks the last cold and arid period, which was interrupted by two milder intervals, as indicated by two humic loess horizons (h_1 and h_2) (*Fig. 4.*).

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