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INVESTIGATION OF MODERN GEOLOGICAL PROCESSES IN HOLOCENE LACUSTRINE CARBONATES IN THE DANUBE–TISZA INTERFLUVE (HUNGARY)

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ABSTRACT

In the middle part of Hungary, lacustrine carbonate mud was deposited along the Danube valley and on the morphologically slightly elevated drift sand ridge east of the Danube in the Holocene. Beside similarities, the carbonates of the two regions display significant differences, as indicated by grain size distribution, mineralogical and gheocemical analyses. The authors propose that these differences are due to different palaeoenvironmental conditions, and to effects of subsequent soil formation. Investigation of the carbonate section reveals modern geological processes in detail.

Keywords: modern geochemical processes, lacustrine carbonate, carbonate, mineralogy and geochemistry

INTRODUCTION

The Danube–Tisza Interfluve is situated in the middle part of Hungary, between the Danube and Tisza rivers. The area is 180 km long and 120 km wide.

The Danube valley was formed by tectonical and erosional processes. It lies 90 to 100 m above sea level (elevation in this study is referred to the Baltic Sea). The valley is filled principally with gravel and coarse-grained sand, and the surface is covered by silt and, in local depressions, by peat. Before regulation of the Danube by training banks in the last century, the area was a 5 to 15 km wide flood plain (*Fig. 1 and 2*).

East of the Danube valley, a drift sand ridge is situated, extending for 70 to 80 km to the east. Its elevation is 100 to 150 m above sea level. It is covered by wind-blown sand and loess. In th Holocene, the prevailing wind formed northwest–southeast running rows of dunes across the area. The crest of these dunes is often as high as 10 to 20 m above the interdunes.

To the east, the drift sand ridge is bordered by the 10 to 15 km wide valley of the Tisza river. It is about 80 m above sea level, and is filled with fluvial sand and silt.

In the depressions among the drift sand dunes and in the Danube valley there are about 100 small natron lakes. Their length varies between 100 m and 6 km. Generally the water depth is only several tens of centimetres, and does not exceed 2 m even in more rainy periods. In the dry period of the last 10 years they totally desiccated. The distribution of Holocene lacustrine deposits clearly indicates the location and number of earlier lakes (*Fig. 1.*).

The summer temperature often exceeds 30°C in the Danube–Tisza Interfluve. Therefore, the water of the shallow lakes also warms up to 30°C. The groundwater-table

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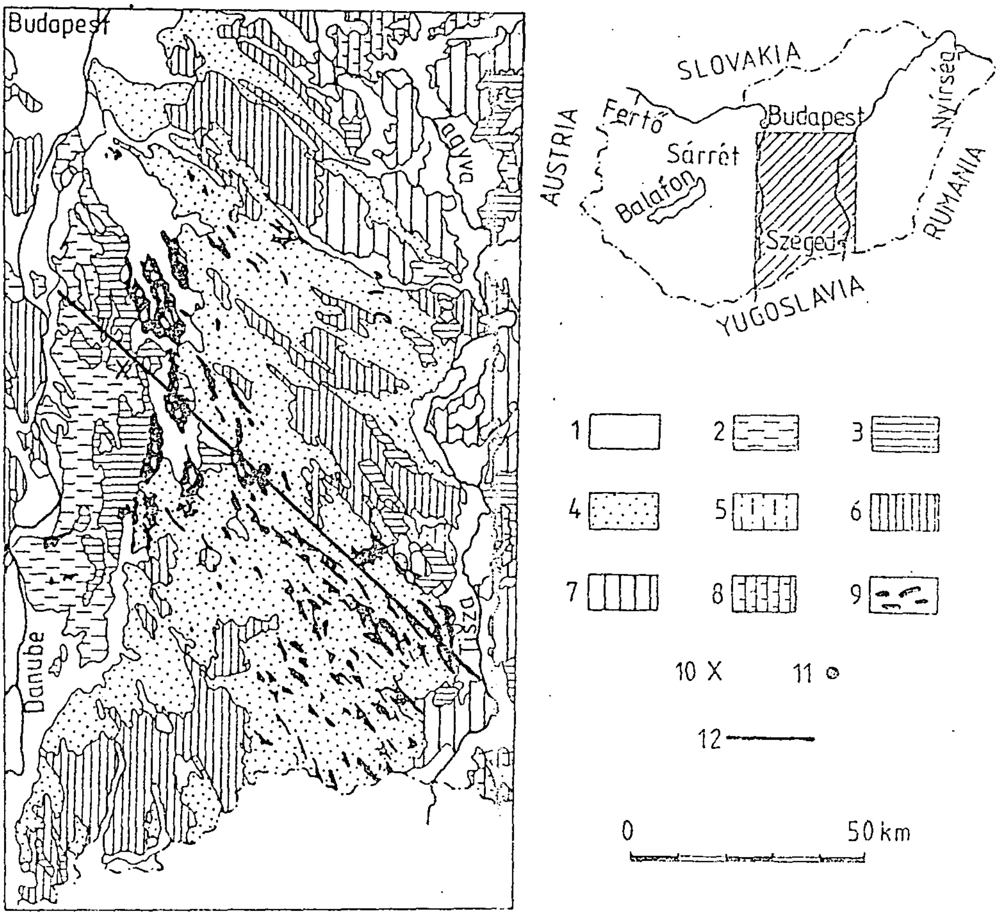

Fig. 1. Geological map of the Danube–Tisza Interfluve and the extension of the present and contemporaneous lacustrine depositional environments (carbonates). (From the map of Hungary on a scale of 1:300.000, K. BALOGH et al. 1956) 1: Alluvium, 2: Redeposited loess, 3: Sodic loess and clay, sand, 4: Wind-blown sand, 5: Loessy sand, 6: Typical loess, 7: Alluvial loess, 8: Clayey loess, 9: Lacustrine carbonate, 10: Kisrét lake, 11: Ródliszék lake, 12: Location of the model geological and geomorphological section of Fig. 2.

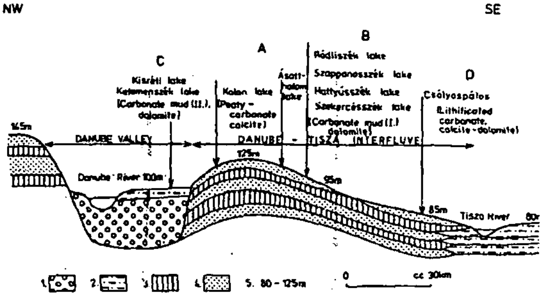

Fig. 2. Model geological and geomorphological section of the Danube–Tisza Interfluve region showing the distribution of lake types. Location of the section in Fig. 1. 1: Gravel, 2: Silt, 3: Loess, 4: Aeolian sand, 5: Elevation above sea level in metres

used to be 1 to 5 m below the surface, even coming to the surface in some depressions between the dunes. Due to the recent dry period, however, it has fallen to 3.to 8 m below the surface. Since in summer time several weeks may pass without precipitation, evaporation of the lake water is intense, and many of the lakes dry up by the end of August even in more humid periods.

The dissolved salt content of the groundwater around the lakes is as high as 500 to 2000 mg/l, in some places even 5000 mg/l. The lake water lost by evaporation is recharged primarily from groundwater, consequently, the total dissolved salt content of the lake water is high: 8000 to 70.000 mg/l. Though the dominant component is Na^+, the amount of Ca^{2+}, Mg^{2+}, and CHO_3^- is also significant. In summer the pH of the lake water is 9 to 11.

As we described elsewhere, high-Mg calcite is produced in these lakes mainly due to evaporation, and a vast portion of this carbonate turns into dolomite through early diagenetic processes (B. MOLNÁR 1980, 1990, B. MOLNÁR & SZÓNOKY 1973).

X-ray, and $\delta^{18}O$ and $\delta^{13}C$ analyses have shown that carbonate precipitation in the Danube valley took place in a different way than in the drift sand ridge (B. MOLNÁR & R. BOTZ 1994).

$\delta^{18}O_{PDB}$-values of the dolomite mud deposited in Ródliszék lake (type "B"), situated in the eastern slope of the drift sand ridge, vary between –3.45 and –0.1‰, while those of the Kisrét lake (type "C") in the Danube valley range from –5.6 to –3.5‰ (*Fig. 2. and 3.*).

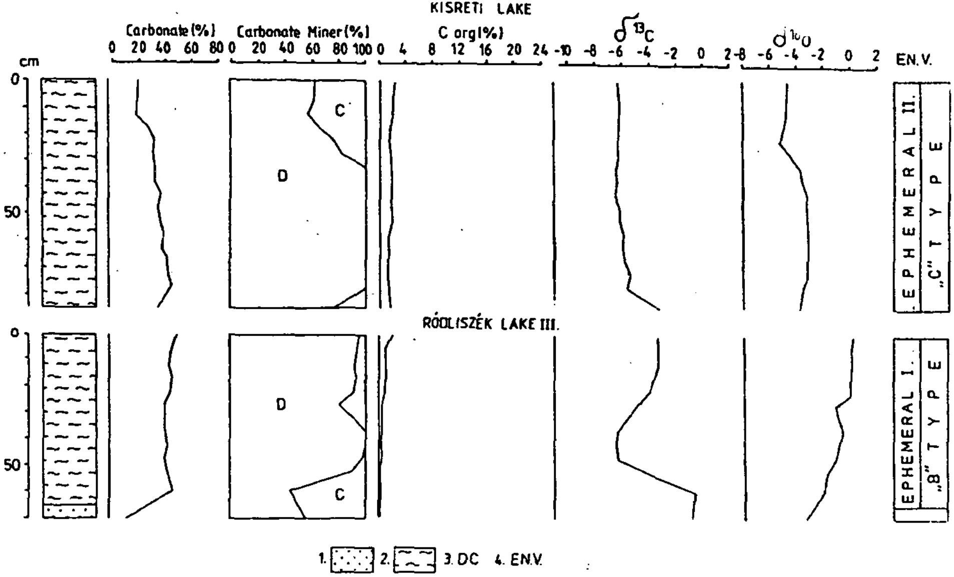

Fig. 3. Results of X-ray and isotope-geochemical analyses of the Kisrét lake and Ródliszék lake carbonate sections. 1: Aeolian sand, 2: Carbonate mud, 3: D=Dolomite, C=Calcite, 4: Depositional environment (B. MOLNÁR and R. BOTZ 1994)

We suggested that this difference is caused by different sources of recharge. Before the regulation of the Danube, lakes in the Danube valley were fed mainly by annual floods of the river. 85% of the water mass of the Danube in Hungary orginates from the Alps. $\delta^{18}O_{SMOW}$ value of the highland rainfall and melt at Vienna is –11.7‰ (D. RANK in J. DEÁK et al. 1972). In contrast, lakes in the drift sand ridge, having water supply from local rainfall and groundwater, have a $\delta^{18}O_{SMOW}$ value of –9.5‰ (J. DEÁK et al. 1992). This difference (–2.53‰ as expressed in terms of $\delta^{18}O_{PDB}$) is responsible in the first place for the –3.0 to –3.5 $\delta^{18}O_{PDB}$ disparity between lakes types "B" and "C", while other factors, like differences in isotopic composition of the local rainfall and groundwater, play a less significant role.

In geology, rock-forming processes are reconstructed from the final product. In our case, we have dolomite mud in both areas, but the generating processes and the conditions were fairly different. In our view, it is important to know these differences in detail, in order to be able to better understand genesis of fossil examples. In the Sedimentological Institute of the University of Heidelberg we had opportunity to carry out a comparative research, the results of which are discussed in this paper.

SELECTION AND SAMPLING OF THE DOLOMITE MUD SECTIONS

On the basis of earlier investigations, two carbonate sections were selected for further comparative study: the Kisrét lake section in Kiskunság National Park from the Danube valley, and the Ródliszék lake section from the drift sand ridge (*Fig. 1.*). Both sections were sampled in 5 cm intervals.

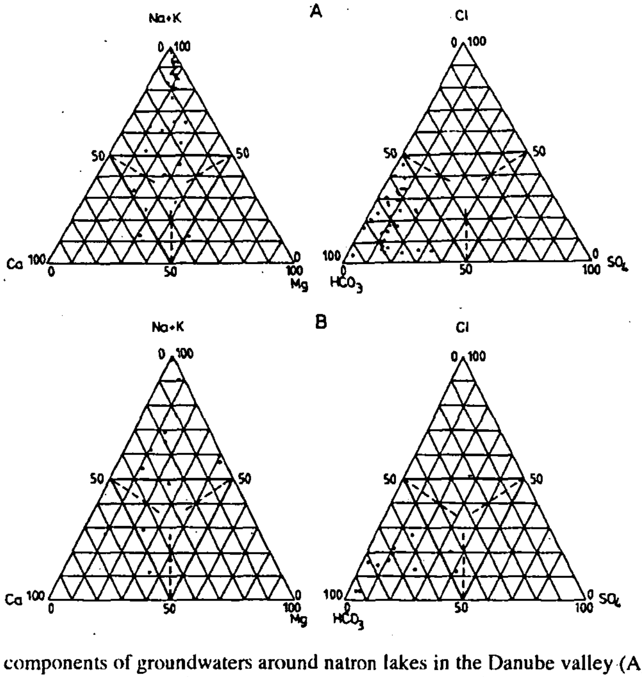

Fig. 4. Chemical components of groundwaters around natron lakes in the Danube valley (A) and in the drift sand ridge (B) (B. MOLNÁR and I. MURVAI 1975, B. MOLNÁR and L. KUTI 1978b)

Chemical composition of the groundwaters, as known from wells next to the lakes, is shown in *Fig. 4*. At the time of well drilling, in September 1974, the groundwater-table was 0.8 to 1.2 m below the surface at Kisrét lake. Its total dissolved salt content was 2000 mg/l averagely. The most important cation was sodium. Sodium was plotted together with potassium in the triangle diagram, the two averaging at 1000 mg/l. Calcium and magnesium was less, together was 10–15 mg/l. In the anions, hydrogencarbonate was dominating, while chloride and sulphate were less significant (B. MOLNÁR and L. KUTI 1978/b).

Chemical composition of groundwaters in Ródliszék area, like in the drift sand ridge in general, is more varied. Though the overall salt concentration is similar to that of the Kisrét area, the amount of sodium and potassium shows considerable scatter, while distribution of anions does not display any significant difference between the two regions (B. MOLNÁR and L. MURVAI 1975).

The Kisrét lake area is characterized by solonchak-solonetz type soils with a humus content of 0.3 to 1.75% (Gy. VÁRALLYAY 1967). Carbonate content of these alkaline soils is significant. In the B2 horizon, at about 20 to 30 cm depth, the maximum salt content of the soil is 6 to 35 mg equivalent. Due to alkalinity (pH = 9 to 10), the dissolved salt content consists mainly of sodium salts, such as Na_2Co_3 and $NaHCO_3$. Surface efflorescenses are rich in NaCl, too.

The drift sand ridge, including the Ródliszék area, is covered by various sorts of soils. Characteristic types are humic sandy soils and sandy regosoils. On lacustrine carbonates, meadow soils were formed, which in turn are replaced by solonchak-solonetz type soils in the southeastern part of the ridge (P. STEFANOVITS 1963). Consequently, changes in chemical features of the soils follow a mosaic-like pattern in the area.

RESULTS

The *Kisrét lake carbonate sequence* is underlain by slightly humic, grey, fine grained wind-blown sand. The lower part (0.75 to 1.05 m) of the carbonate section is light grey, followed by a light yellow (0.50 to 0.75 m) and another light grey (0.20 to 0.50 m) interval. The uppermost 0.2 m is slightly humic, and, consequently, darker grey again (Fig. 5. II). On the basis of hydrometrical and dry sieving analyses, characteristic grain size of the carbonate section down to 1.00 m is under 0.02 mm, that is, belongs to the clay and fine silt fractions. Minor modifications in grain size distribution are reflected by the colour of the rock. The uppermost – humic – part contains more coarse silt and sand than the directly underlying interval. Further parts relatively rich in coarse silt can be found at 0.5 m and at 0.75 to 1.00 m (*Fig. 5. III*).

The ratio of the material soluble in hydrochloric acid is 22% at the bottom of the underlying sand, and 30% at its top, i.e. right below the carbonate. Its maximum value in the carbonate section is 55%. At the interval of 0.75 to 0.85 m, being relatively abundant in fine- and coarse-grained silt, it decreases to 38 and 41%. Its low value (28%) between 0.00 and 0.20 m is probably due to the leaching effect of soil formation (*Fig. 5 IV*).

The mineralogocial composition of the carbonate was analysed by simultaneous thermoanalytical method (*Fig. 6, 7*). (We used a MOM Derivatograph Q-1500 instrument). 26% of the total carbonate was dolomite in the underlying sand (*Fig. 6. 1*). Ratio of dolomite in the total carbonate content of the 0.35 to 1.00 m interval was between 43 and 55% (*Fig. 6. 2–4, Fig. 7. 1*). In the uppermost 15 cm, its value decreases to 11 to 20%, as a consequence of soil formation. As we have pointed out above, the total portion

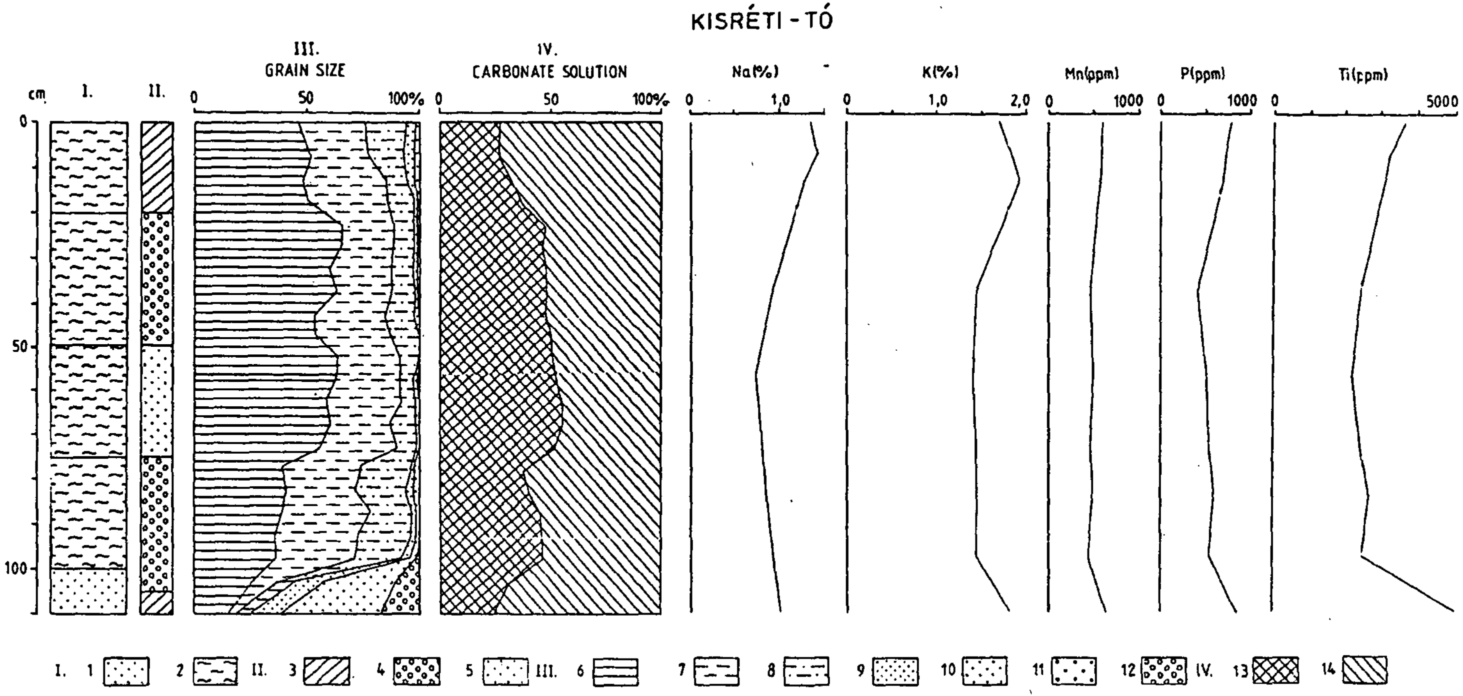

Fig. 5. Results of analyses of the Kisrét carbonate section. I. 1: Fine sand, 2: Carbonate, II. 3: Humic layers, 4: Darker grey, 5: Light grey, III. Grain size distribution, 6: Clay, 7: Fine silt, 8: Coarse silt, 9: Fine sand, 10: Small sand, 11: Medium sand, 12: Coarse sand IV. 13: Portion soluble in hydrochloride acid, 15: Portion insoluble in hydrochloride acid

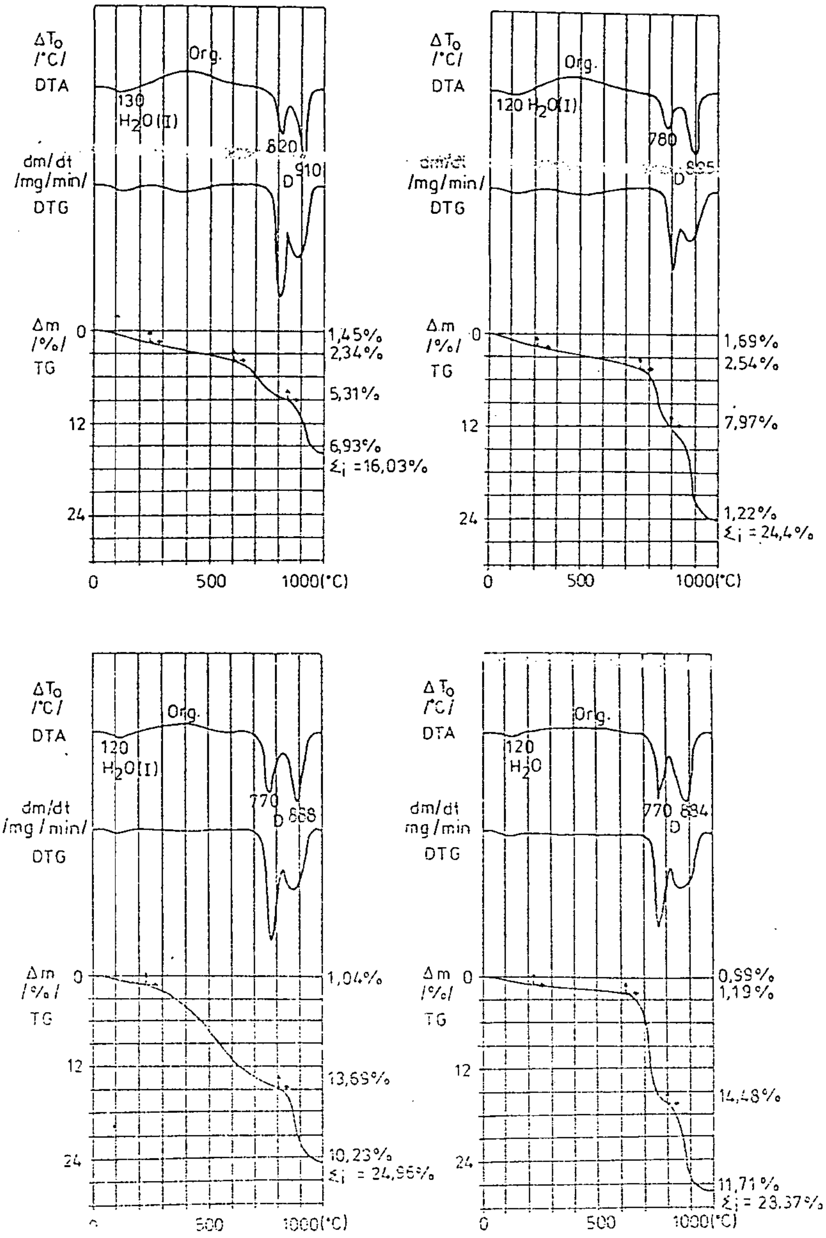

Fig. 6. Thermal analyses of the Kisrét carbonate samples. 1: 1.05–1.10 m, 2: 0.80–0.85 m, 3: 0.70–0.75 m, 4: 0.55–0.60 m. H_2O (I): adsorbed water content, Org.: Decomposition of organic material, P: pyrite, Mg: magnesite, D: dolomite, K: calcite, Σ i: Total amount of material lost by reaction, expressed as percentage of the initial test material. Thermograms were determined in air, with a heating rate of 10 °C per minute. The initial amount of test material in the chindholder varied between 500 and 900 mg.

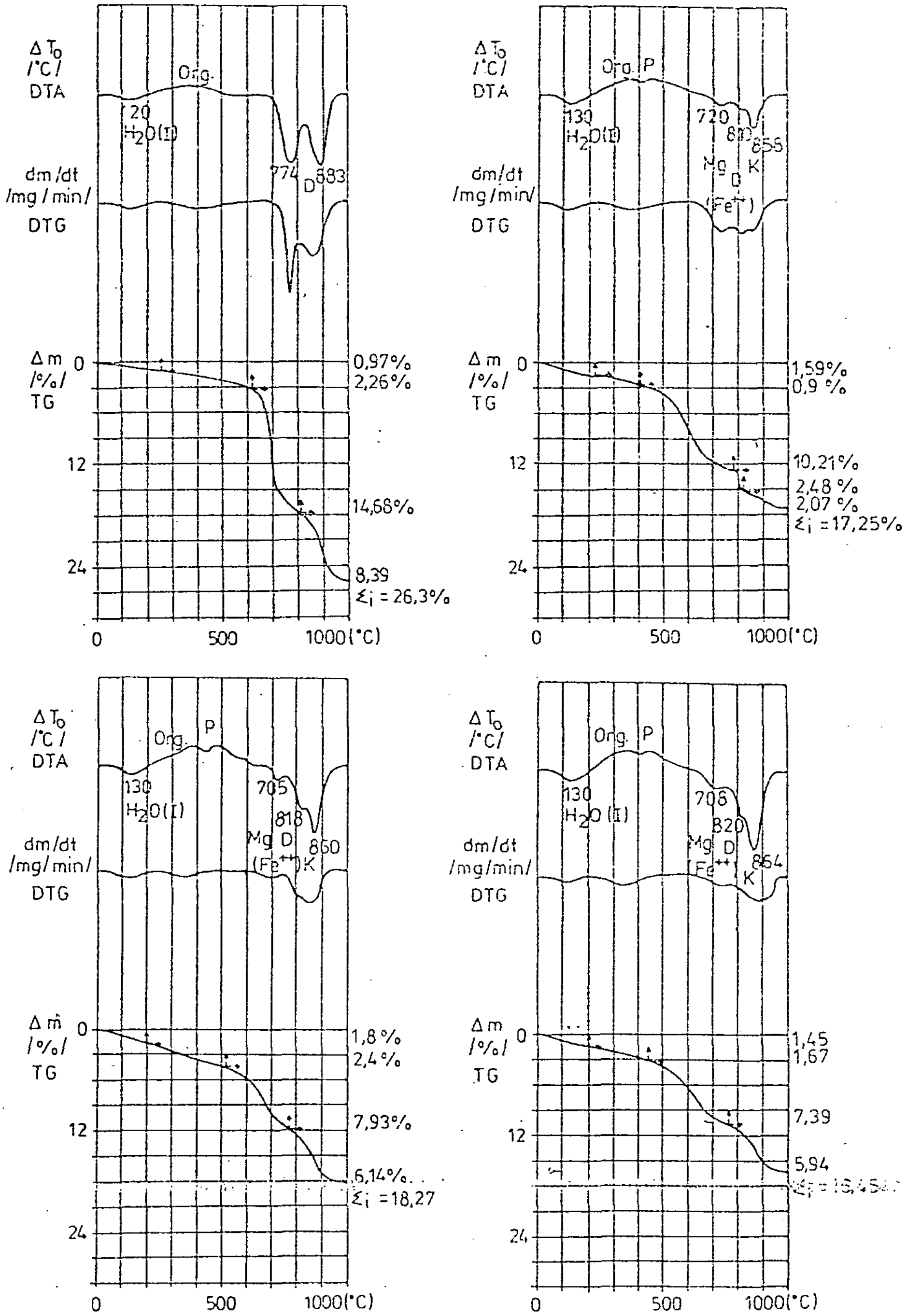

Fig. 7. Thermal analyses of the Kisrét carbonate samples. 1: 0.35–0.40 m, 2: 0.10–0.15 m, 3: 0.05–0.10 m, 4: 0.00–0.05 m. (For legend, see Fig. 6.)

soluble in hydrochloric acid, i. e. the total amount of acid soluble carbonate is also small here. Beside the dolomite-calcite double peak, an additional endothermic peak was recorded in these samples between 705 and 720 °C in the D.T.A. curve. This peak may be attributed to the presence of illite. A several percent illite content of the samples had been justified by X-ray diffraction. It is more probable, however, that the three-peak pattern indicates presence of dolomites with different state of order (B. MOLNÁR and R. BOTZ 1994) (*Fig. 7. 2–4*). Gy. SZÖŐR et al. (1992) suggested that the three peaks show synchronous presence of three phases, namely calcite, dolomite, and magnesite, and prove incorporation of Fe^{2+}. In our case, meteoric water could cause dedolomitization, and precipitation and incorporation of iron.

The Na, K and Mn content of the samples was determined by instrument Perkin Elmer 4100 AAS, while concentration of P and Ti was measured by spectrophotometer (Milton Roy Company Spectronic 1201). Characteristic changes in concentration of these elements are as follows.

The sand, underlying the carbonate section, contains 0.98% Na in feldspars. In the lower half of the carbonate section its amount decreases to 0.73%, and from 0.55 m to the surface it shows a rising trend. A sharp increase was recorded between 0.00 and 0.15 m, due to the solonchak-solonetz type of soil. Concentration of Na is as high as 1.26 to 1.37% here (the latter value belongs to the sample representing the 0.05–0.10 interval) (*Fig. 5*).

K content of the basal sand, also due to feldspars, is 1.8%. It remains steady (1.4 to 1.5%) in the interval of 0.35–1.00 m, while in the uppermost 15 cm, in the soil formation horizon, it displays an increase, similarly to the curve of Na, and reaches 1.73–1.94%.

A similar trend is shown by the concentration of Mn. It is 628 ppm in the underlying sand, varies between 439 and 497 ppm in the interval 0.35 to 1.00 m, and rises to 580 to 586 ppm in the upper 35 cm.

This trend is more pronounced in concentration of P. It is 830 ppm in the basal sand, 401 to 584 ppm in the lower two third of the carbonate section, and 692 to 772 ppm in the uppermost 15 cm.

Concentration of Ti is 5150 ppm in the sand, 2257 to 2715 ppm in the interval between 0.35 and 1.00 m, and 3135 to 3675 ppm in the interval between 0.00 and 0.15 m. Though the Ti concentration curve shows more fluctuations than the others, a basic trend common to the distribution of all these elements can be recognized.

Based on the concentration curves, the section can be subdivided to three parts: the basal sand, the 0.35 to 1.00 m interval, and the uppermost 0.35 m right below the surface.

The *Ródliszék carbonate section* is 0.6 thick, and it is also underlain by fine-grained wind-blown sand. This sand, as well as the lower half of the carbonate section, is light grey in the 0.30 to 0.80 m interval. The 0.00 to 0.30 m interval slightly humic, and darker grey (*Fig. 8 II*).

Predominant grain size in the basal sand is 0.10 to 0.20 mm. It is continuosly decreasing towards the carbonate layer. In the lowermost sample of the carbonate (0.55 to 0.60 m) the ratio of coarse silt and finer material together reaches 60%. This value falls to 38% in the overlying 0.50 to 0.55 m interval. From 0.50 m to 0.15 m the amount of finer fractions is steadily increasing, while in the uppermost 10 cm the ratio of coarse-grained silt is increasing at the expenses of the finer fractions (*Fig. 8 III*).

The ratio of the material soluble in hydrochloric acid is 18% in the basal sand, and it increases upwards. Its maximum value is 48% at the finest-grained 0.55 to 0.60 m interval. In other parts of the carbonate it changes between 36 and 44%. A slight deveease to 36% was measured right below the surface (*Fig. 8 IV*).

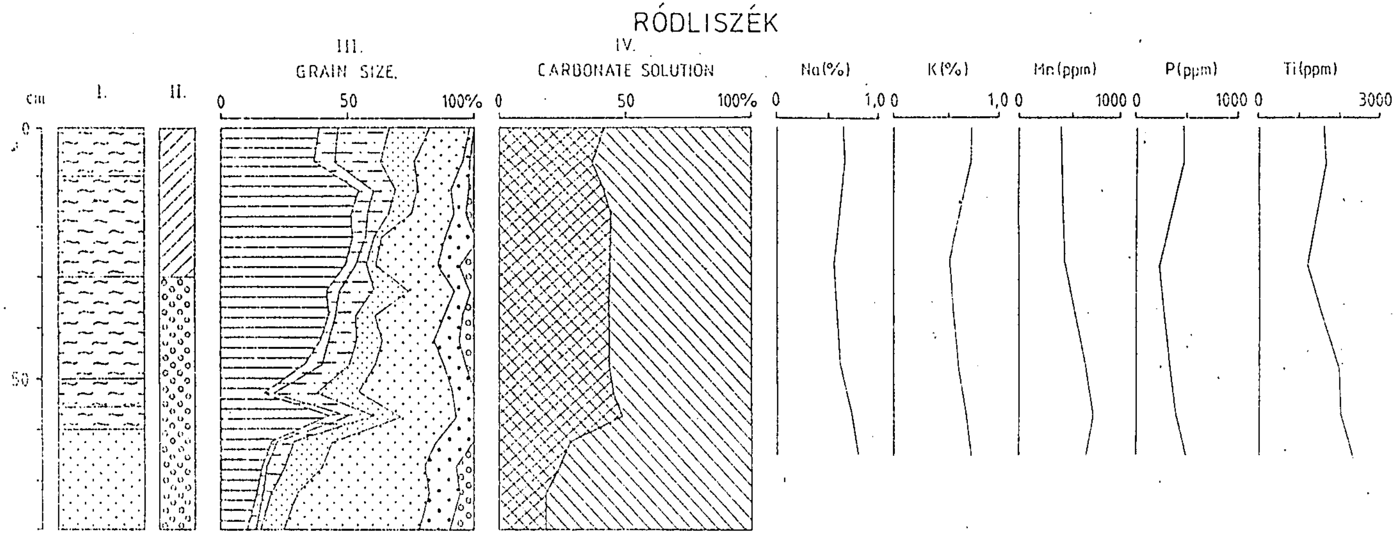

Fig. 8. Results of analyses of the Ródliszék carbonate section. For legend, see Fig. 5.

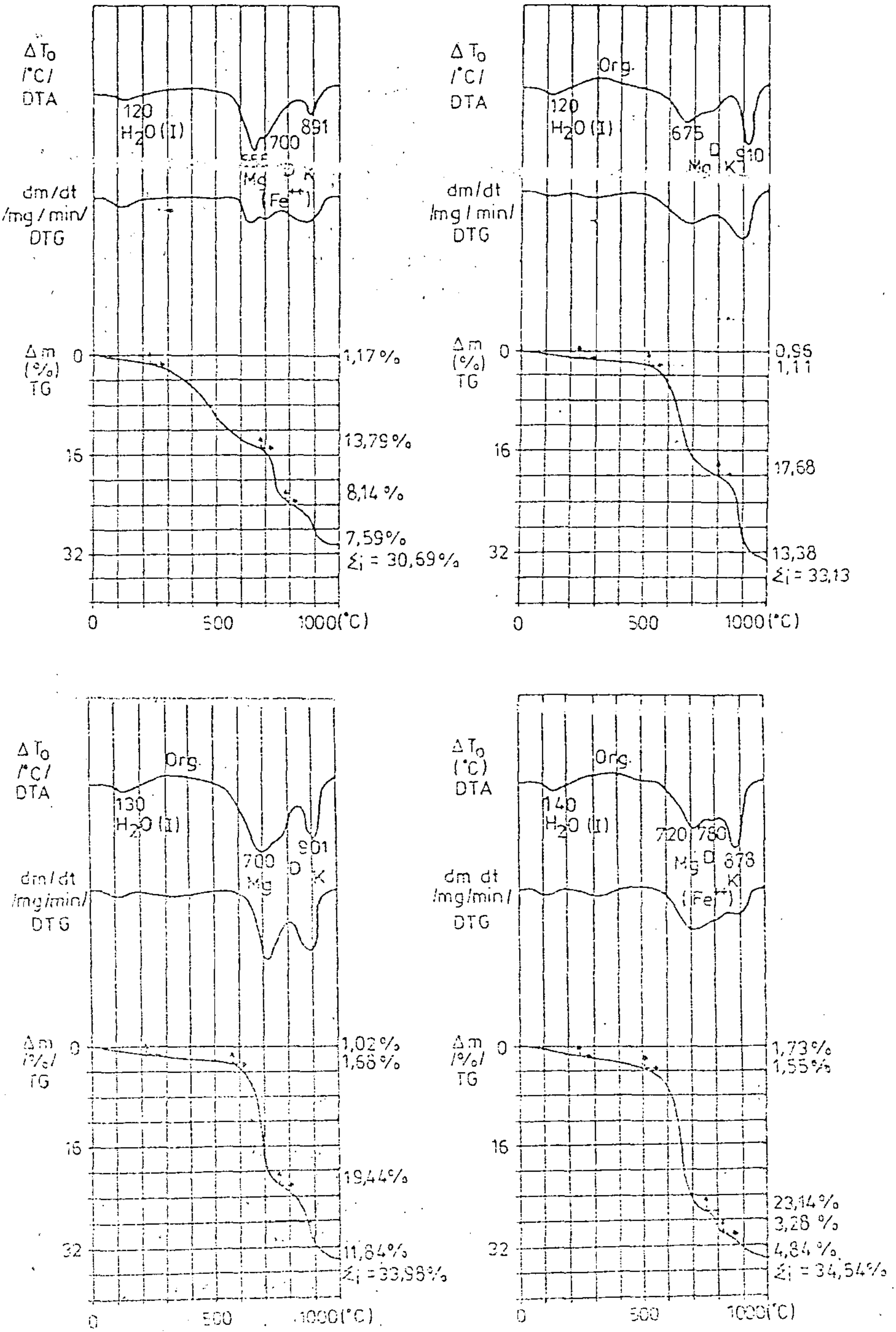

Fig. 9. Thermal analyses of the Ródliszék carbonate samples. 1: 0.60–0.65 m, 2: 0.55–0.60 m, 3: 0.45–0.50 m, 4: 0.25–0.30 m. (For legend, see Fig. 6.)

Thermal analysis of the basal sand samples indicates that its carbonate content consists of dolomite (*Fig. 9. 1*). Similar mineralogical composition was observed in the sample representing the 0.55 to 0.60 m interval of the carbonate layer (*Fig. 9. 2*). Even more definite indication of dolomite was recorded by a double dolomite peak of the D.T.A. curve in the sample from between 0.45 and 0.50 m (*Fig. 9. 3*). Similarly to the Kisrét section, the D.T.A. curve shows an additional third peak along with the calcite and dolomite peaks in samples from the uppermost 30 cm. The third peak was recorded between 693 and 720 °C. We think that this pattern, missing in the deeper parts of the section, is due to dedolomitization and consequent formation of differently ordered lattices and hybrid carbonate minerals (*Fig. 9. 4, and Fig. 10. 1–2*).

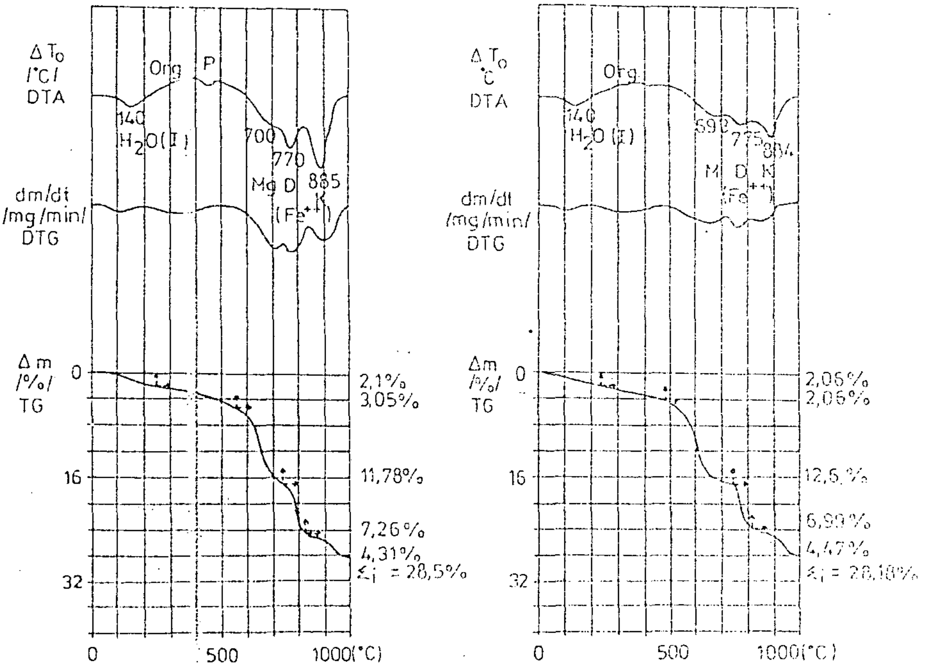

Fig. 10. Thermal analyses of the Ródliszék carbonate samples. 1: 0.05–0.10 m, 2: 0.00–0.05 m. (For legend, see Fig. 6.)

The shape of the Na content curve across the Ródliszék section is very similar to that of the Kisrét section, but the values are smaller. Na concentration in the basal sand is 0.79%. It steadily goes down to 0.55% in the 0.25 to 0.30 m sample, than continuously increases to 0.67% and 0.64% in samples 0.05 to 0.10 and 0.00 to 0.05, respectively.

The Ródliszék section, just like the Kisrét one, is more abundant in K than in Na. The differences between the concentration of the two elements, however, are less significant here. The ratio of K in the sand is 0.85%. It is steadily decreasing to 0.60% in the sample representing the 0.25 to 0.30 m interval, then increasing to 0.74% at the surface.

Mn content of the sand is 656 ppm. It has a maximum value of 716 ppm at the bottom of the carbonate layer, then it is steadily decreasing to 408 ppm at the surface. Unlike in Kisrét section, Mn concentration does not rise near the surface.

The amount of P in the basal sand is 453 ppm, in the lower part of the carbonate layer (0.45 to 0.60 m) is 337 to 395 ppm. It goes down to 227 ppm in sample 0.25 to 0.30 m, than steadily increases to 460 and 496 ppm in the 0.00 to 0.10 m interval. While in the Kisrét section the values are greater and the maximum value is in the sand, the greatest value in the Ródliszék section is recorded in the carbonate right above the sand.

Maximum concentration of Ti (2300 ppm) was observed in the sand. At the bottom of the carbonate layer it is 1977 ppm, and falls to 1195 ppm in 0.25–0.30 m of the section. From 0.25 m to the surface it increases to 1600 and 1670 ppm, In the Kisrét section the amount of Ti was much more significant, and the near-surface increase of concentration was more definite.

COMPARISON OF THE KISRÉT AND RÓDLISZÉK CARBONATE SECTIONS

Both sections are underlain by fine-grained sand. We know from earlier investigations that the Kisrét sand is mixed fluvial and aeolian sand (B. MOLNÁR and L. KUTI 1978a). The Ródliszék carbonate was deposited on wind-blown sand.

Though both sections are dominated by light colours, the Kisrét carbonate is more varied in this respect, having a light yellow interval beside the grey ones. According to earlier investigations, the light yellow colour is due to higher concentration of iron (B. MOLNÁR and R. BOTZ 1994). The near-surface part of both sections is slightly humic.

The grain size distribution is more uniform in the Kisrét section. The amount of sand increases near the surface in both sections. The overall sand content of the Ródliszék section, however, is considerably higher. It has palaeogeographical reasons: the Ródliszék area was a drift sand region even during the deposition of the carbonate, and the wind blew more sand in the lake.

Consequently, the acid soluble part of the Kisrét carbonate is greater. Soil formation is at a more advanced state in Kisrét section, thus the fine fraction of the residue insoluble in hydrochloric acid contains clay minerals, the identification of which has not been done yet.

As to mineralogical composition, the carbonate mud in the basal sand layers is dolomite. This dolomite probably satured the underlying sand layers right after its precipitation from the lake water. The carbonate section itself is also composed of dolomite. The Kisrét material has a more perfect dolimite structure, or crystallinity, than the Ródliszék material. The D.T.A. curve of the latter displays the first endothermic peak at about 675 to 700 °C, instead of the standard 780 to 810 °C. Earlier X-ray diffraction analyses of these samples, however, had unambigously proved the dolomite structure (B. MOLNÁR and R. BOTZ, 1994). This shift of the characteristic peak is due to the extremely high sodium carbonate content of the water from which the dolomite precipitated, and may be related to different crystal grain size. In contrast, the Kisrét lake, receiving the bulk of its input from the Danube, witnessed less dramatic evaporation, therefore its water was less saline, and provided more favourable conditions for crystal formation and growth. This explanation seems to be justified by results of $d^{18}O$ analyses; its less negative values in Ródliszék samples indicate more significant effects of evaporation (B. MOLNÁR and R. BOTZ 1994) (*Fig. 3*).

In the D.T.A curves of both sections, triple endothermic peaks were recorded instead of the characteristic double dolomite peaks in near-surface samples. This phenomenon can be a consequence of dedolomitization caused by rainwater, and formation of a secondary carbonate paragenesis with differences in state of order, grain size, and iron content.

Concentration of Na and K are higher in the Kisrét section than in the Ródliszék one. Changes in the amount of these elements follow a similar pattern. Concentration of Mn, unlike in the Ródliszék section, increases near the surface in the Kisrét sequence. Maximum values of P concentration were recorded in the basal sand in Kisrét, and in the overlying carbonate in Ródliszék. In adddition, the overall amount of P is greater in Kisrét. Minimum values of P in Kisrét were observed in the sample representing the interval 0.35 to 0.40 m, while in Ródliszék it was in 0.25 to 0.30 m. The latter sample contains not only the minimum value of P, but the less Na, K and Ti as well; these elements were probably leached from this horizon of the Ródliszék section.

In summary, despite of their different thickness, the two sections display very similar patterns: They both can be divided three correlable parts, as a consequence of nearly identical geological and genetical processes. They have differences, however, in grain size distribution, in details of carbonate association, in the hydrochloride acid soluble part, and in concentration and distribution of some elements. These differences are due to the drift sand environment of the Ródliszék lake, and to different sources of water supply; the Ródliszék lake was fed by groundwater and precipitation, while, as indicated by geochemical facies analysis, the Kisrét lake was fed primarily by the Danube, and only a much less significant amount of its water came from precipitation and groundwater.

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