*Acta Mineralogica-Petrographica, Szeged, XXII/1, 73—86, 1975*

# GEOHISTORICAL EVOLUTION AND DOLOMITE SEDIMENTATION OF THE NATRON LAKES OF FÜLÖPHÁZA, KISKUNSÁG NATIONAL PARK, HUNGARY

B. MOLNÁR and I. M.-MURVAI

## INTRODUCTION

The origin of the natron lakes of the southern Great Plain of Hungary has been studied for more than a decade by a working team of geologists, biologists, hydrochemists and geographers. After the scientific elaboration of several natron lakes of the area, now a new research project concerning the natron lakes of Fülöpháza has been launched *(Fig. 1)*. The area of the lakes is a part of the Kiskunság National Park, very important geologically, being situated along the highest belt of the Danube-Tisza Interfluve's sand ridge, on its eastern side sloping towards the Tisza river, there, where wind-blown sands are still in motion, affected very little, if at all, by man's intervention.

The geological investigation of the Fülöpháza lakes has been aimed at contributing to the knowledge and understanding of the origin and evolution of the lakes and of the lacustrine sedimentary sequence deposited there.

## LATEST QUATERNARY HISTORY OF THE DANUBE-TISZA INTERFLUVE

The natron lakes of Fülöpháza occur on the wind-blown sand ridge of varied topography between the rivers Danube and Tisza. The territory of Hungary, consequently, that of the Danube-Tisza Interfluve as well, belonged, in the Pleistocene, to the periglacial climatic zone. Its evolution was controlled by two main faktors: on one hand, the alternation of markedly warm and cold phases due to the presence of the Pleistocene periglacial zone and the subsequent warmer climatic effects of the Holocene; on the other hand, the basin-shaping effect of tectonic movements controlling both the size and rate of accumulation and the particular sedimentary facies of the subareas.

Not every part of the Great Hungarian Plain did subside at the same rate in the Quaternary. For instance, the Danube seems to have flowed, up to the Günz-Mindel Interglacial, across the present-day Interfluve area diagonally towards the city of Szeged in the southeast [I. MIHÁLTZ, 1953; B. MOLNÁR, 1961, 1967, 1970, 1972, 1973; M. KRETZOI, E. KROLOPP, 1972; E. KROLOPP, 1970]. In the Günz-Mindel Interglacial, however, the Danube-Tisza Interfluve subsided at a lower rate compared to the adjacent areas; in fact, it may have uplifted a little. The present-day Danube valley, however, underwent a tectonic subsidence and this movement forced the Danube to abandon its diagonal course and occupy its present-day meridional valley.

Over the rest of the Pleistocene the Danube-Tisza Interfluve was not involved in fluviatile accumulation and a dry land topography developed on its surface.

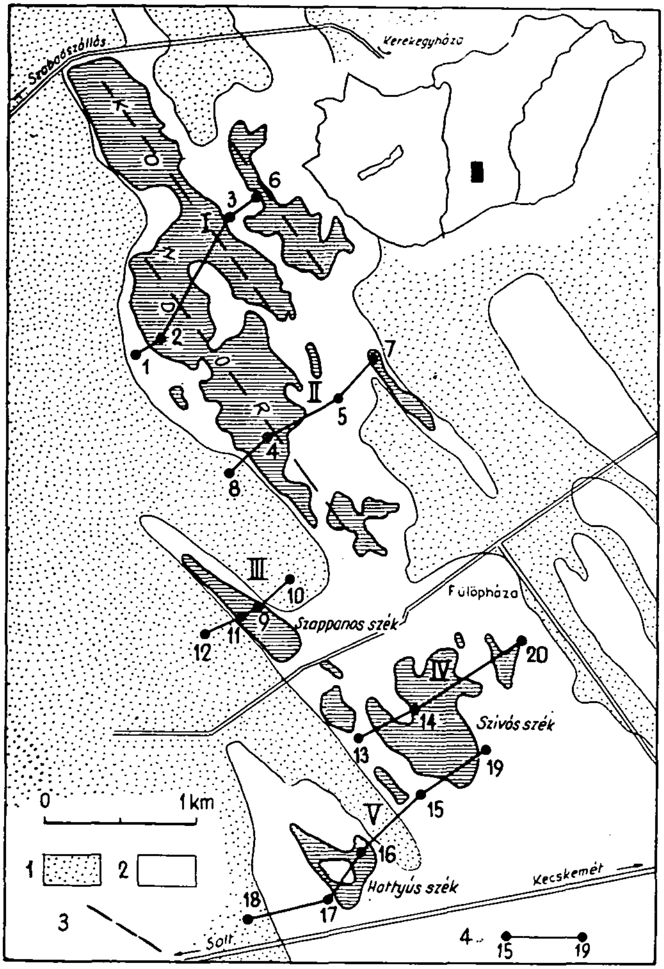

*Fig. 1.* Layout of the natron lakes of Fülöpháza with borehole dots and locations of geological profiles

*1.* Wind-blown sand area, *2.* Area filled up with lacustrial sediment, *3.* Axes of the one-time depressions of Lake Kondor, *4.* Locations of boreholes and geological sections

The westerly winds of the cold spells which introduced the glaciations blowed out sands from the flood-plain of the Danube depositing them as aeolian sands on the surface of the ridge. During the glaciations, loess was formed on the wind-blown sand surface. Alternating with wind-blown sand, loess attains 150 m thickness in some places in the middle part of the Danube-Tisza Interfluve, reaching up to the present-day surface [B. MOLNÁR, 1961]. Thus the surface of the Danube-Tisza Interfluve is covered predominantly by these formations.

In the Holocene the deposition of gravels, which had begun in Pleistocene time, continued in the Danube valley. In several places the surface of the gravel sheet was overlain by allochtonous loess, in other places, by peat accumulated in considerable thickness.

On the Danube-Tisza Ridge, morphologically a land surface elevated 30 m high above the Danube valley floor and almost 40 m above the Tisza's alluvium, the predominant winds of NW—SE direction arranged, in the summer half-year, the windblown sands in NW—SE trending dune ranges, particularly so in the dry hazelnut phase of the Holocene when the ground-water table lay considerably deeper than today. Between the sand dunes NW—SE trending hollows developed corresponding to the wind direction predominating in summer. It is these hollows that enabled in the Danube-Tisza Interfluve area the development of shallow-water lakes, those of Fülöpháza inclusive *(Fig. 1)*. Most of the lakes extend in NW—SE direction corresponding-to the trend of the sand dune ranges.

## GEOLOGICAL FORMATION OF THE LAKES OF FÜLÖPHÁZA

The natron lakes of Fülöpháza too are situated in NW—SE trending hollows of wind-blown sand environment. Largest and of most permanent water cover of all the lakes is Lake Kondor, 3 to 4 km long and 1.0 to 1.5 km wide. The rest of the lakes are of substantially smaller size and it is only Lake Szappanosszék that does not dry out for a considerable length of time, just like it is the case with Lake Kondor. All lakes but Szappanosszék vary in size from season to season, the more so, their size is even dependent on rainfall, showing a swift increas in years of striking humidity. Morphologically, the Szappanosszék is bounded by such relatively higher wind-blown sand-dune ranges between which there are narrow hollows, so that the possibility for

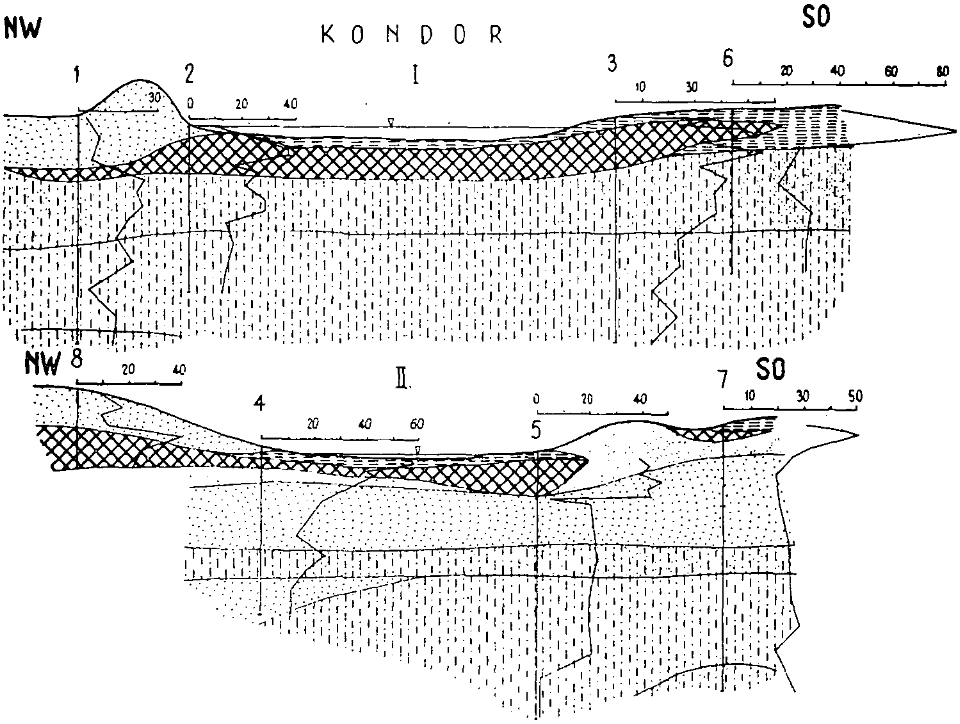

*Fig. 2.* Geological sections of Lake Kondor (For legend, see *Fig. 3.*)

changes in the size of the lake water table is rather restricted. Lakes Hattyússzék and Szívósszék run completely dry in the summer half-year.

The results of wind action there are indicated by the emplacement and shape of the depressions enclosing the lake-water bodies as well as by the intrusion of the sand dune ranges from northwestern direction into the hollows just mentioned (see *Fig. 1*).

In the neighbourhood of the lakes the authors carried out on-the-spot observations, then they collected rock samples. 5- to 10-m-deep holes were drilled into the ground in the vicinity of the lakes. The samples recovered were hydrometrically analyzed for grain size distribution, then the carbonate content in terms of $CaCO_3$ and, in some cases, the humus content of the camples were determined. In some boreholes the ground-water hit by drilling was sampled and the chemical composition of the water was compared with that of Lake Szappanosszék's water containing the highest quantity of dissolved solids.

On the basis of the results thus obtained, the geological map of the area was drafted and the lithological logs of the boreholes were grouped into geological sections *(Fig. 1—3)*.

The geological sections include three main sedimentary sequences over the depth range thus far penetrated.

*1.* The lower part of the sequences is constituted by predominantly Pleistocene fine-sandy loesses.

*2.* The fine-sandy loesses are overlain by a diversified development of sediments of coarser grain size in the majority of the places (fine to small sands).

*3.* This coarser sedimentary sequence, at Szappanosszék the loesses directly, is overlain by lacustrial sediment, mainly carbonate silt.

In the course of a detailed analysis of these sediments the following observations have been made.

(1) The oldest sediment reached by drilling in the survey area is fine-sandy loess. Its deepest subsurface position is in Section II of Lake Kondor, at 5 m or so, the position closest to the surface, at 2 m depth, being at Szappanosszék. The boreholes have penetrated the fine-sandy loess in 4 to 5 m thickness on the average. The largest thickness uncovered, 7 m, was in borehole Hattyússzék-18. The loess is fine-sandy throughout the area, the fine sand content showing a wide range of variation. Its grain size composition has been examplified by curves C and D in *Fig. 4*. As can be read off from these curves, the share of fine and small sands combined attains 30 to 35% on the average in the loess: a considerable quantity compared to the loess so far examined from the Danube-Tisza Interfluve area. The sorting of the loess is poorer than in other parts of the Interfluve.

All the above are due to the fact that at the time of loess formation the area must have been, like it is the case at present, morphologically more diversified as compared to the rest of the Danube-Tisza Interfluve. The surface of wind-blown sands underneath was duned, so that the finer fraction of the wind-blown sands has been admixed to the loess. That the land surface had a varied relief at the time of loess deposition is evidenced by the fine-sandy layer reached in the loess in a number of places, *e.g.* in borehole Nr. 1 of Section I of Lake Kondor, borehole Nr. 7, Section II, and borehole Nr. 17, Section V, Hattyússzék. These fine-sandy beds testify to convex landforms, while the dark grey silts of 16.0% humus content with plenty of gastropod shell remnants, deposited on a water-covered loess surface and now recovered by borehole Nr. 15 or Nr. 18, Section V, Hattyússzék, in fact, the carbonate silt underneath, are evidences of concave surface landforms *(Fig. 2, 3)*.

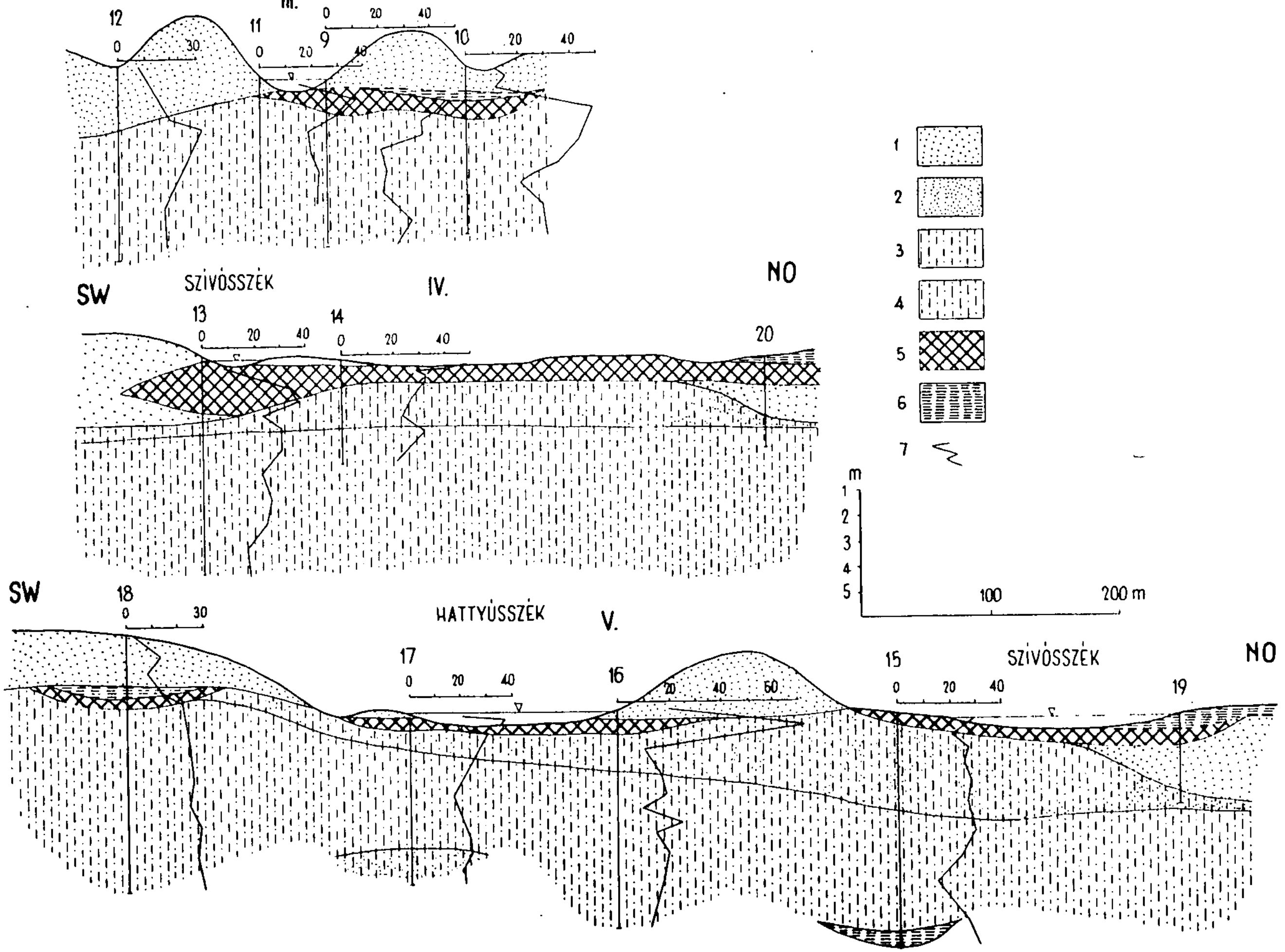

*Fig. 3.* Geological sections of the Szappanosszék, Szívósszék and Hattyússzék
*1.* Small-grained wind-blown sand (0.1—0.2 mm), 2. Fine sand (0.06—0.01 mm), *3.* Loessic fine sand (0.02—0.1 mm), *4.* Fine sandy loess (0.02—0.1 mm), *5.* Carbonate silt, *6.* Heavily humic, unsorted silt (0.005—0.1 mm), *7.* Carbonate %.

The fine-sandy loesses are of porous structure and because of their position below the ground-water table, where reduction processes are in action already, they are of grey colour in the majority of the places.

The carbonate content of the fine-sandy loesses is considerable in all but a few samples, averaging between 25 and 30%. In some cases, however, particularly there,

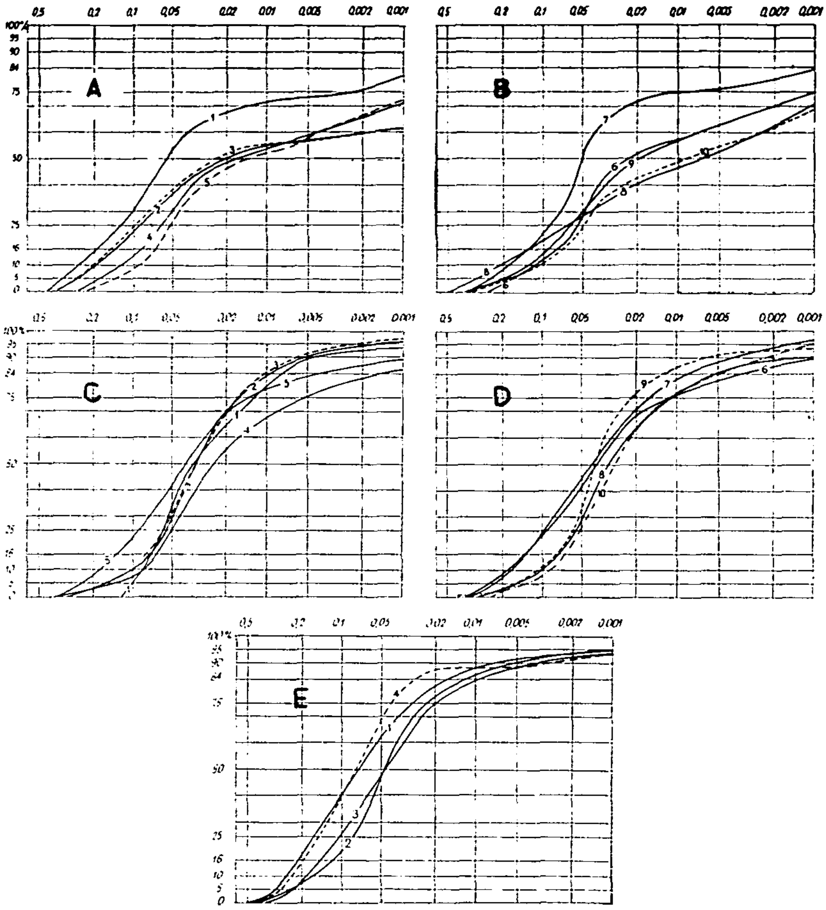

*Fig. 4.* Curves of grain size composition types of major types of sediment deriving from the area of the natron lakes of Fülöpháza, with the carbonate content of the samples

A—B Granulometric curves of carbonate silt samples
1) Lake Kondor, borehole No. 1 2.0—2.5 m (26.0%)
2) Lake Kondor, borehole No. 2 0.5—1.0 m (36.4%)
3) Lake Kondor, borehole No. 2 1.0—1.3 m (36.4%)
4) Lake Kondor, Borehole No. 3 0.3—0.4 m (50.0%)
5) Lake Kondor, borehole No. 3 0.4—0.5 m (48.0%)
6) Lake Kondor, borehole No. 3 0.5—0.6 m (57.0%)
7) Lake Kondor, borehole No. 3 1.0—1.5 m (50.0%)
8) Lake Kondor, borehole No. 6 0.6—0.8 m (72.0%)
9) Lake Kondor, borehole No. 4 0.4—0.5 m (56,5%)
10) Lake Kondor, borehole No. 5 0.2—0.4 m (65.5%)

where overlain by a carbonate silt layer, the loess is even richer in carbonate (*Fig. 3,* Section III, borehole Nr. 11, *Fig. 4,* D). At the last-mentioned occurrence, the part ex-solved from the carbonate silt layer has been accumulated by downward-migrating waters.

(2) In all places, excepting Section III, Szappanosszék, the fine-sandy loesses are overlain first by loessic fine sands grading into unconsolidated, smallgrained, wind-blown sands.

Within the survey area examined, the thickness of the loessic fine sands varies between 0.5 and 2.8 m, that of the small-grained sands between 1.0 and 3.5 m. The average thickness is, accordingly, 2.6 to 6.0 m or so.

The fine- to small sand content of the loessic fine sands attains, or even exceeds, 50%. Consequently, the finer fraction too is represented in substantial quantity in them (*Fig. 4,* E).

The predominant fraction of the small-grained wind-blown sands is between 0.1 and 0.2 mm. In the wind-blown sand area lying west of the lakes, however, interbedded wind-blown sand lenses of 0.4 to 0.8 mm predominant grain size, heavily rounded, of dull surface, can frequently be encountered.

The loessic fine sands largely vary in carbonate content, this variation being primarily dependent on the availability of carbonate silt above them. If there is any, the carbonate content attains even 25 to 30%, if not, it is as low as 15% or so.

As shown by earlier examinations of heavy minerals, the sands occurring here have been deflated from the flood-plain of the Danube in the west, thus being of Danubian origin [B. MOLNÁR, 1961].

It is characteristic of the loessic fine sands that they lie parallel to the fine sandy loess layer, growing thicker to varying extent and not pinching out over considerable distances and showing an upward increase in grain size.

The small wind-blown sand is arranged in dunes and accordingly the greatest thickness of the sand layer can always be measured in the vertical plane traceable from the top of the dune downwards. The wind-blown sand will often pinch out.

(3) The youngest sediment of the area is represented by lacustrial carbonate silt and palustrial silt. According to composition and origin, the carbonate silts can be split up into three groups:

*a)* The lower part of the carbonate silt derives from waters infiltrating deepwards and percolating across beds of higher carbonate content atop. This makes

---

C—D Granulometric curves of fine sandy loess
1) Lake Kondor, borehole No. 1 6.0—7.0 m (5.0%)
2) Szappanosszék, borehole No. 12 2.5—3.0 m (32.7%)
3) Szappanosszék, borehole No. 12 3.0—3.5 m (28.6%)
4) Szappanosszék, borehole No. 11 1.0—1.5 m (31.4%)
5) Szappanosszék, borehole No. 11 1.5—2.5 m (19.0%)
6) Szappanosszék, borehole No. 9 1.5—2.0 m (36,4%)
7) Szappanosszék, borehole No. 9 3.0—4.0 m (23.0%)
8) Szappanosszék, borehole No. 9 5.0—6.0 m (34.1%)
9) Hattyússzék, borehole No. 18 3.0—5.0 m (25.4%)
10) Hattyússzék, borehole No. 18 9.0—10.0 m (30.4%)

E: Granulometric curves of fine sands
1) Lake Kondor, borehole No. 1 4.0—5.0 m (14.5%)
2) Lake Kondor, borehole No. 2 3.5—4.0 m (15.0%)
3) Lake Kondor, borehole No. 6 2.0—2.5 m (20.4%)
4) Szívósszék, borehole No. 14 0.0—0.5 m (25.0%)

up 30% or even more of the total thickness of the carbonate silt; thus being about 0.3 to 0.4 m thick, though largely varying in thickness even within one and the same lens. In other Interfluve natron lakes studied earlier this thickness was more considerable. For instance, in the case of Lake Kerek of Bugac it attained 0.6 to 0.8 m [B. MOLNÁR, M. SZÓNOKY 1974].

The infiltrating, carbonate-rich solution impregnated the basal, fine to small sands or, at Szappanosszék, the loess, and it was primarily the pores of the rock that were filled up by the precipitated carbonate matter. The transition upward into the middle member is without any remarkable or sharp limit. The carbonate content is largely variable, usually 25 to 50% or so, being heavily dependent on the quantity of water migrating deepward and laterally, a quantity remarkably controlled and influenced by the morphology of the land surface. The lower member is distinguished from the middle one by the higher amount of the fraction insoluble in hydrochloric acid, too. Its insoluble residue consists primarily of fine to small sands or, at Szappanosszék, of a material corresponding in grain size to the loess fraction.

b. The middle part of the carbonate silt attains as a rule 50 to 60% of the total carbonate silt thickness, being 0.6 to 0.8 m thick.

Because of the increasing precipitation of carbonate here, the carbonate content is often as high as 70 to 80%. Although it does not always attain this figure, it is above 50% in the majority of the cases, however. The composition of the insoluble residue is similar to that of the lower part, but its quantity is considerably smaller. When dry, this sediment is white to greyish-white and of loose structure. Its composition and characteristics were shown in detail, and its distribution in the Interfluve area described, in earlier works [I. MIHÁLTZ, M. FARAGÓ, 1946; M. MUCSI, 1963; B. MOLNÁR, 1970, 1971; B. MOLNÁR, M. SZÓNOKY, 1974]. As shown by the *X*-ray diffraction results of P. KRIVÁN and E. NEMECZ, the carbonate silts of the Danube-Tisza Interfluve were identified as being of lime and dolomite composition [in P. KRIVÁN 1953]. The carbonate silt contains molluscs only quite unfrequently, and even if so, the forms available represent only one or two species.

c. The upper member of the carbonate silt accounts for 10 to 15% of the total carbonate silt thickness, i.e. 0.1 to 0.2 m. Its carbonate content is lower than that of the middle part, being similar to that of the lower one, hence 25 to 50% or so. Characteristically enough, it is laid down in those parts of the natron lakes which are water-covered for the longest span of time. The difference from the lower and middle members consists in that the clay content in its insoluble residue is higher than in the other two members. The result is that the sediment is heavily cracked upon dessication, the cracks penetrating to a depth of 6—8 cm.

In the plotted geological profiles the subdivisions of the carbonate silt have been omitted for technical reasons, so that the carbonate silt bed shown on the profils includes all three members just quoted *(Fig. 2, 3)*. As can be readily seen on the profiles, the carbonate content extends beyond the present-day boundary of the lakes. Moreover, there are such buried carbonate silt lenses which are not interconnected with the carbonate silt of the lakes (*Fig. 3*, borehole 18). Since carbonate silt is deposited only at permanent water coverage, the extension of the lakes must have been other than today, several minor lakes having been buried by wind-blown sands in the meantime.

Examples on the grain composition of the carbonate silt have been shown in curves A—B of *Fig. 4*. It is evident that every sample contains sands in considerable, but subequal, quantity. Their fine silt and clay fraction, however, shows a much wider fluctuation (0.002 mm ∅ >). Notably, the quantity of the fine fraction in the carbonate silt depends on the value of the carbonate content in it and on whether the upper, more argillaceous, part or the two other members have been sampled.

d. In those points of the lakes, where the vegetation is or was more lush compared to the rest, *e.g.* in the reed-grown zones, 0.1 to 0.3 m of heavily peaty-earthy, ill-sorted sandy silts, rich in gastropodes, can be found. Such a layer occurs, *e.g.*, in profiles I and II of Lake Kondor *(Fig. 2)* and in boreholes 10 of profile III and borehole 15 of profile V. This layer contains lacustrial deposits and a mixture of fine and small-garined sands blown by the wind into the lake ,combined. This accounts for the poor sorting, too.

## GEOHISTORICAL HISTORY OF THE NATRON LAKES OF FÜLÖPHÁZA AND DEPOSITION OF SEDIMENTS IN THEM

It is generally agreed on that the uppermost loess horizon reached by drilling in the Danube-Tisza Interfluve represents the end of the Pleistocene, i.e. the Würm III glaciation. As shown in the above, the loess of the Fülöpháza region is represented by fine sands grading upwards into loessic fine sands in the majority of the places. Similar latest Pleistocene sequences were observed in a number of places by I. MIHÁLTZ and L. MOLDVAY [in I. MIHÁLTZ, 1953] as well. As already pointed out, the loess matter could have been deposited and generated on a surface of varied topography and morphology.

Accordingly, the sedimentary sequence overlying the fine sandy loess or the loessic fine sand is already of Holocene age. The chronology of the deposition of the Danube-Tisza Interfluve's Holocene sequence is well-known thank to contributions by I. MIHÁLTZ, M. M-FARAGÓ [1964], B. ZÓLYOMI [1953], A. HORVÁTH, S. ANTALFI [1954], M. MUCSI [1963, 1965, 1966], M. M.-FARAGÓ [1966, 1969], M. ANDÓ, M. MUCSI [1967]. They too believe that the fine sandy loess and loessic fine sand of the Fülöpháza region developed in the late glacial phase and that the sedimentary sequence overlying it represents the post-glacial period already.

On the basis of pollen grains and gastropodal fauna the afore-mentioned authors have subdivided the post-glacial period into the following stages: birch-pine, hazelnut, oak and beech. These stages correspond to FIRBAS's IVth to IXth climatico-vegetational phases [FIRBAS, F. 1949].

According to the above, the fine sandy loess and loessic fine sand uncovered at the base of the profiles must have been deposited during the Würm III glaciation. The wind-blown sand sequence overlying the loessic fine sand thus began in the birch-pine stage. Some of the lakes, e.g. the Szappanosszék, the NW part of Lake Kondor and the Hattyússzék, existed at the beginning of the Holocene already. Notably, the carbonate silt in these directly overlies the loessic fine sands or the fine sandy loess. In other cases, *e.g.* in that of the SE part of Lake Kondor, it was formed probably later, in the place of a depression that had existed in the hazelnut stage already, in the first half of the more humid oak stage.

The difference between the two parts of Lake Kondor is due to the fact that the presentday configuration of the lake was shaped by the fusion of two or three parallel depressions. This is evident from *Fig. 1,* too. The formation of similar, so-called H-shaped, lakes was already mentioned by F. SMAROGLAY [1939]. According to that author, in cases like that the dune range between two adjacent depressions is broken through and a communication is established between them. In the present case Lake Kondor was brought about by three parallel depressions. Accordingly, the flats in this lake type are formed at different times and under different circumstances, hence their dissimilar basement and bottom morphology.

Understanding of the mechanism of lacustrial carbonate silt deposition and precipitation has been greatly enhanced by earlier investigations by A. Horváth [1950], P. Kriván [1953], T. Nógrádi [1956], Zs. Dvihally [1970], J. Szépfalusi [1970] and A. Richnovszky [1970]. Complementing their results and taking into consideration the geological processes and circumstances, we can explain the origin and deposition of the carbonate silt in the following way.

The lakes are recharged by meteoric waters and ground-water flowing toward local depressions. Particularly, the recharging effect of ground-water is of importance. The precipitations falling into the lakes of the Danube-Tisza Interfluve and the waters getting from surface watercourses into the lake are less in quantity than the annual rate of evaporation. Thus the excess of water seems to derive from the ground-water resources [M. Andó, 1964].

The sand of Danubian origin making up the basement of the lakes and the loess contain $CaCO_3$ in considerable quantities. As a result of weathering during soil genesis the ground-water flowing towards the lakes will exsolve from the aforementioned sediments those components, i.a. $Ca^{++}$ and $Mg^{++}$, and transport them into the Lakes.

The chemical composition of ground-water sampled from a few boreholes has been examined. The results are shown in Table 1. As evident from the tabulation, the ground-water in the vicinity of the lakes contains significant quantities, 700 to 4000 milligrams per litre, of dissolved salts. Of these, $Ca^{++}$ is present in a quantity of 16 to 160 mg/l, $Mg^{++}$ in 8 to 150 mg/l. Similarly important are $Na^+$, $HCO_3^-$ and $H_2SiO_3$ and in some cases $CO_3^{--}$ as well. Thus, the ground-water flowing towards the lakes is already a water containing a considerable amount of dissolved solids.

The characteristics of the water reaching the lake develop under diversified circumstances. The Danube-Tisza Interfluve is characterized by an unevenly distributed annual rainfall of 500 to 600 mm. The mean temperature in July does not exceed 22 °C, the maximum of the July average during 50 years in turn is not higher than 25 °C. Sometimes, a high temperature is coupled with droughts keeping on for several weeks. The water body of the Fülöpháza lakes is scarcely a couple of decimetres thick, so their surface area is disproportionately large compared to their volume of water, hence the intensive evaporation in the lakes. The waters are markedly alkaline, their pH in summer being above 9, often reaching even 10, moreover 11, in value.

The fluctuation of lake-water temperature is considerable even within considerably short spans of time, viz. diurnally. Naturally, under such circumstances large-scale chemical changes from season to season, or even diurnally, can be observed in the waters, both in respect of the quantity of the dissolved salts and the ionic balance equation in them.

Nevertheless, a general feature typical of the waters is their high dissolved solids content. Water samples recovered from Lake Szappanosszék simultaneously with the sampling of boreholes, in July 1972, were analyzed (Table 1). It can be seen from the results that the total dissolved solids content of the water of the lake is higher than 15 thousand mg/l. According to Zs. Dvihally [1970] and J. Szépfalusi [1970], however, it can exceed even 25 thousand mg/l in exceptional cases.

Most of the Interfluve lakes, including those of Fülöpháza, will lose their natron nature in winter, when they contain carbonates and their pH value and alkalinity will considerably decrease, too. In winter time the decline of assimilation by plants and the predominance of dissimilation as well as the contribution of autumn and winter precipitations lead to an accumulation of $CO_2$ in such a high quantity in the water that the rate of $CaCO_3$ precipitation is gradually diminished, as $CaCO_3$ is transformed into calcium hydrocarbonate according to the following reaction equation:

$$CaCO_2+H_2CO_3 \rightleftharpoons Ca(HCO_3)_2.$$

Because of the increase of free $CO_2$ during winter the $Ca^{++}$ getting into the lake and deriving from the ground-water will remain in the form of solution and a part of the carbonate silt deposited earlier on the bottom of the lake will be dissolved so that the quantity of $Ca^{++}$ can increase to tenfold the summer time figure. Whereas in summer the carbonate and hydrocarbonate content of most of the water is quasi equivalent to the quantity of $Na^{++}$, in winter a considerable part of $Ca^{++}$ is fixed to $Ca^{++}$. In spring time the quantity of assimilating organisms will increase again. So first the free and then the equilibrial $CO_2$ is consumed and the chemical equilibrium established in winter will be upset. Under the effect of warming up, the evaporation of water increases, provoking an increase of the concentration of dissolved salts including $Ca^{++}$ and $Mg^{++}$, though the value of the solubility product of $Ca^{++}$ and $Mg^{++}$ does not increase proportionately. This process will reduce the solubility of $CO_2$ as well. With the reduction of $CO_2$ and the increase of pH, $CaCO_3$ and $CaMg(CO_3)_2$ will gradually precipitate from lake water and thus the $Ca^{++}$ and $Mg^{++}$ content of the water will decrease. After the total loss of free and equilibrial $CO_2$ the plants making photosynthesis will consume the half-fixed $CO_2$ reserves of $NaHCO_3$, so calcium carbonate will precipitate from the lake water and gradually increase in it, while the $Ca^{++}$ and $Mg^{++}$ content will decrease and the pH and alkalinity value increase. In summer, on account of the increasing light conditions, the intensity of light is so high that dissimilation gets predominant as soon as the optimum is exceeded. In such cases, the entire process will set in inversely.

According to investigations by P. KRIVÁN [1953], the character of the chemical processes taking place in the lakes is influenced, beside the foregoing, by other physical (reduction of pressure and wave action) and chemical factors, such as the actual morphological position of the lakes, as well.

Precipitation of carbonate silt in an alkaline environment is indicated by the poverty of the gastropodal fauna represented, in a low number of specimens, by some species comparatively insensitive to alkalinity [A. HORVÁTH, 1950; M. MUCSI, 1963; A. RICHNOVSZKY, 1970].

The geological result of this phenomenon consists in the fact that $Ca^{++}$ and $Mg^{++}$ introduced every year into the lake will repeatedly precipitate as $CaCO_3$ and $CaMg(CO_3)_2$ and then settle as a layer of carbonate silt on the bottom of the lake.

As shown in the foregoing, the carbonate silt bed of Fülöpháza can be subdivided, on the basis of origin and composition, into three parts.

According to M. M.-FARAGÓ [1966, 1969], the middle member containing the highest percentage of carbonate was deposited at the end of the dry hazelnut stage of the Holocene and the first half of the oak stage.

The upper part less rich in carbonate, but richer in clay was accumulated in the subsequent period, *i.e.* from the second half of the oak stage to the present-day beech stage. The lower carbonate and higher clay content of the latter is accounted for by the relatively higher humidity of the present-day climate compared to that of the oak stage. Notably, compared to the hazelnut and oak stages, a lower amount of carbonate can precipitate under present-day climate. The lower part of the carbonate silt precipitated from downward-migrating waters after the time of deposition of the two members overlying it.

It is interesting that the dolomite fraction of the carbonate silt is brought about partly as a result of syndiagenetic precipitation of a synsedimentary deposit. Deposits of similar type are known to occur in alkaline seas of high salt concentration and natroncontaining lakes of deserts. This genetic mechanism of dolomite was dealt with in detail by H. E. Usdowski [1967, 1968]. According to his results, the transformation of calcium carbonate into dolomite may be enhanced or even provoked by the syngenetic substitution of $Mg^{++}$ for $Ca^{++}$. This is the so-called early diagenetic dolomitization that can even be increased by the exposure of still not completely consolidated sediments to subaerial conditions. At the Fülöpháza lakes, on account of the dessication of the lakes, carbonate silt often happens to be exposed to daylight. Accordingly, in some cases, this also can provoke some dolomitization.

A considerable part of the carbonate silt has been buried by wind-blown sand of Holocene origin. Owing to burial, the area of the lakes varied at a swift rate. For this reason, the extension of the carbonate silt does never reflect the one-time extent of the lake, but other changing development.

Because of the evaporation of the capillarilylifted, saline ground-water in deeper patches in the neighbourhood of the lakes and of the waning surface water of the lakes, it is mainly $NaHCO_3$ and $Na_2CO_3$ soluble in water that are concentrated and precipitated. In these places calcareous, sodaic soils of solontchak-solonets type are formed. At renewed rainfall a part of the soda, often segregating even at the surface, is washed by rainwater into the lake, thus increasing its alkalinity.

This is how the precipitation of lime, dolomite and natron soda brings about that peculiar geological environment in the vicinity of Fülöpháza, Danube-Tisza Interfluve, whose peculiar present-day appearance as well as its Holocene history are good and sound reasons and arguments accounting for the conservation of the area and for its inclusion in the Kiskunság National Park.

## CONCLUSION

1. The neighbourhood of the natron lakes of Fülöpháza, Kiskunság, National Park, Hungary, is a wind-blown sand area. The lakes were formed in early Holocene time in depressions between ranges of wind-blown sand of NW—SE orientation brought about by predominant winds. Their base is made up of latest Pleistocene loess or earliest Holocene wind-blown sand.

2. The area has a continental climate with a very hot summer temperature and a high frequency of droughts without any precipitation for several weeks. In this environment, on account of heavy evaporation, the dissolved salts are largely concentrated in the scarcely a couple of decimetres of lake water thickness, a process further enhanced by recharging ground-water flow.

3. Under the influence of various factors (vegetation. rapid changes in temperature, wave action, etc.) calcium carbonate and dolomite are still being precipitated even today from this lake water of high salt concentration and alkalinity.

4. In the deeper patches in the neighbourhood of the lakes, capillarily-lifted, saline groundwater will evaporate, thus leading to the formation of calcareous, sodaic soils of solontchak-solonets type. Meteoric water will introduce a part of the subaerially-segregated soda into the lakes, thereby increasing their alkalinity.

# REFERENCES

ANDÓ, M. [1964]: Geomorphologische und Hydrographische Charakterisierung des Kunfehérsees und seiner Umgebung. — Acta Geogr., Acta Univ. Szegediensis **5**.

ANDÓ, M., MUCSI, M. [1967]: Klimarithmen im Donau—Theiss—Zwischenstromland. — Acta Geogr., Acta Univ. Szegediensis **7**, 1—6, pp. 44—53.

DVIHALLY, Zs. [1970]: Die Dynamik der chemischen und optischen Veränderungen in den ungarischen Natron (Szik) Gewässern. — Hidrológiai Tájékoztató **10**, pp. 130—132.

FIRBAS, F. [1949]: Spät- und Nacheiszeitliche Waldgeschichte Mittel-Europas nördlich der Alpen. — Fischer Verlag, Jena, p. 480.

HORVÁTH, A. [1950]: Mollusca-Fauna das Fehérsees nahe der Szeged. — Ann. Biol. Univ. Szegediensis **1**.

HORVÁTH, A., ANTALFI, S. [1954]: Malakologische Studie über die oberen Pleistozän-Schichten im Süden zwischen Donau—Theiss. — Ann. Biol. Univ. Hungariae **2**, pp. 417—428.

KOMLÓDI, M. [1966]: Quaternary Climatic Changes and Vegetational History of the Great Hungarian Plain. I — Botanikai Közl., **53**, 3, pp. 191—201.

KOMLÓDI, M. [1969]: Quaternary Climatic Changes and Vegetational History of the Great Hungarian Plain. II — Botanikai Közl., **56**, 1, pp. 43—55.

KRETZOI, M., KROLOPP, E. [1972]: Oberpliozäne und Quartäre Stratigraphie des Alföld (Grosse Ungarische Tiefebene) aufgrund paläontologischer Angaben. — Földr. Értesítő **21**, 2—3, pp. 133—158.

KRIVÁN, P. [1953]: Die Bildung der Karbonatsedimente im Zwischengebiet von Donau und Theiss. — Acta Geol. Hung., **2**, 1—2, pp. 91—108.

KROLOPP, E. [1970]: Őslénytani adatok a Nagyalföld pleisztocén és felsőpliocén rétegek sztratigráfiájához. — Őslénytani Viták **14**, pp. 5—43.

M. FARAGÓ M. [1966]: A soltvadkerti Petőfi-tó rétegeinek kronológiája palinológiai vizsgálatok alapján. — Őslénytani Viták **6**, pp. 59—63.

M.-FARAGÓ, M. [1969]: Über die Erforschung der sodahaltigen Seen im Süden der Grossen Ungarischen Tiefebene und deren Ergebnisse. — Hidrol. Tájékoztató **9**, pp. 128—130.

M. FARAGÓ, M. , MUCSI, M. [1971]: Geologische Entwicklungsgeschichte von Natronteichen auf Grund Palynologische Untersuchungen. — Acta Geogr., Acta Univ. Szegediensis **11**, 1—7, pp. 93—101.

MIHÁLTZ, I. [1953]: Le lévé geologique de la partie meridionale de l'entre-deux-fleuves Danube—Tisza. — Magya. Áll. Földt. Int. Évi Jel., **1950**, pp. 111—143.

MIHÁLTZ, I., M.-FARAGÓ, M. [1964]: A Duna—Tisza-közi édesvizi mészkőképződmények. — Az Alföldi Tud. Int. Évk., **1**, 1944—45, Szeged, pp. 371—384.

MOLNÁR, B. [1961]: Die Verbreitung der äolischen Bildungen an der Oberfläche und untertags im Zwischenstromland von Donau und Theiss. — Földtani Közl, **91**, 3, pp. 300—315.

MOLNÁR, B. [1967]: Rhythmen der Pleistozän-Auffüllung des südlichen Teils der Grossen Ungarischen Tiefebene und ihre hydrogeologische Bedeutung. — Hidrol. Közl., **47**, 12, pp. 537—552.

MOLNÁR, B. [1970]: Pliocene and Pleistocene Lithofacies of the Great Hungarian Plain. — Acta Geol. Hung., **14**, pp. 445—457.

MOLNÁR, B. [1971]: Entstehungsgeschichte der Sodaseen im Süd-Alföld (Ungarn). — Aus den Sitzungsberichten der Österr. Akademie der Wissenschaften Mathem.-naturw. Kl., Abt. I, **179**, 8—10, Wien, pp. 183—191.

MOLNÁR, B. [1972]: A Nagyalföld negyedkori üledék-komplexumának genetikája. (Manuscript) Szeged, p. 1—305.

MOLNÁR, B. [1973]: Latest Tertiary and Quaternary Sedimentary Accumulation cycles of the Great Hungarian Plain. — Földtani Közl., **103**, 3—4, pp. 294—310.

MOLNÁR, B., SZÓNOKY, M. [1974]: On the Origin and Geohistorical Evolution of the Natron Lakes of the Bugac Region . — (Manuscript) Szeged.

MUCSI, M. [1963]: Examen de la stratigraphie fine des formations carbonatées d'eau douce du Kiskunság (Hongrie Centrale) — Földtani Közl., **93**, 3, pp. 373—386.

MUCSI, M. [1965]: Geologische Verhältnisse des Soltvadkerter Petőfi-Sees. — Földtani Közl., **95**, 2, pp. 240—248.

MUCSI, M. [1966]: Die geologischen Verhältnisse des Petőfi-Sees von Soltvadkert II — Földtani Közl., **96**, 4, pp. 453—459.

NÓGRÁDI, T. [1956]: Limnologische Untersuchungen an Natrongewässern der ungarischen Tiefebene. — Hidrológiai Közl., **36**, 2, pp. 130—137.

SMAROGLAY, F. [1939]: Natron Seen von Bugac. — Budapest.

SZÉPFALUSI, J. [1970]: Die chemische Untersuchung der Soda-Teiche der Ungarischen Südebene. — Hidrológiai Tájékoztató **10**, pp. 132—134.

USDOWSKI, H. E. [1967]: Die Genese von Dolomit in Sedimenten. — Berlin — Heidelberg — New York, pp. 1—95.

USDOWSKI, H. E. [1968]: The Formation of Dolomite in Sediments. — in: MÜLLER, G.—FRIEDMAN G. M.: Recent Developments in Carbonate Sedimentology in Central Europe. — Berlin—Heidelberg—New York, pp. 1—255.

ZÓLYOMI, B. [1953]: Die Entwicklungsgeschichte der Vegetation Ungarn seit dem letzten Interglacial — Acta Biol. Acad. Sci. Hung., 4, pp. 367—413.

*Manuscript received, June 20, 1975*

DR. BÉLA MOLNÁR
MRS. I. MOLNÁR—MURVAI
Institute of Geology and Palaeontology
Attila József University
H-6722 Szeged, Egyetem u. 2—6.
Hungary