MORPHOGENESIS OF LAKE NAGYBÜDÖS AT SOLTVADKERT

by

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On the sand ridge of the Danube—Tisza Midregion there are many minor water bodies of permanent or intermittent character. Apart from a few exceptional cases, neither their genesis and evolution, nor their morphological and hydrographical properties have been satisfactorily cleared as yet, though a number of interesting problems have arisen in the course of their examination. Relevant investigations are necessary not only for contributing to the knowledge of their physicogeographical patterns, but also for economicogeographical and economic reasons. In fact, the utilization of these lakes (reed- and rush-harvesting, fish- and waterfowl breeding, inland-water storaging, establishment of holiday resorts, etc.) is feasible only if its preconditions are proved scientifically.

The detailed study of the lakes of the Danube—Tisza Midregion has been started by the author with one of the most peculiar permanent lakes known from sandy areas, i. e. with Lake Nagybüdös at Soltvadkert. Its genetical and morphological conditions to be discussed in the following are part-results of the author's work.

The environment of the lake

Lake Nagybüdös lies in county Bács-Kiskun, the north-western part of the Central Kiskunság, 3 km north of the village Soltvadkert. The basin of the lake is a shallow depression (110 to 115 m above the level of the Adriatic Sea), open to the west. It penetrates eastwards some 8 to 10 km deep into the surrounding, higher-seated reliefs. The monotonous landscape surrounding the lake is dissected by slightly elevated flat ridges and shallow depressions. In the latter at places there are waterlogged meadows, reeds, ephemeral stagnant pools. The terrain dips gently to the west, towards Kiskőrös and, some 5 km off the lake, its height is as little as 100 m a. A. S. Farther on, it grades into the plain of the Danube Riverine *(Fig. 1)*.

In the northern and eastern vicinity of the lake we find a sanddune area of varied surface relief lying, on the average, 115 to 120 m high a. A. S. It begins immediately on the eastern shore of the lake and, bordering east the depression around the lake, it becomes more and more elevated southwards, being continued by an intensively disintegrated blownsand area with scattered forest patches, where the sands locally are

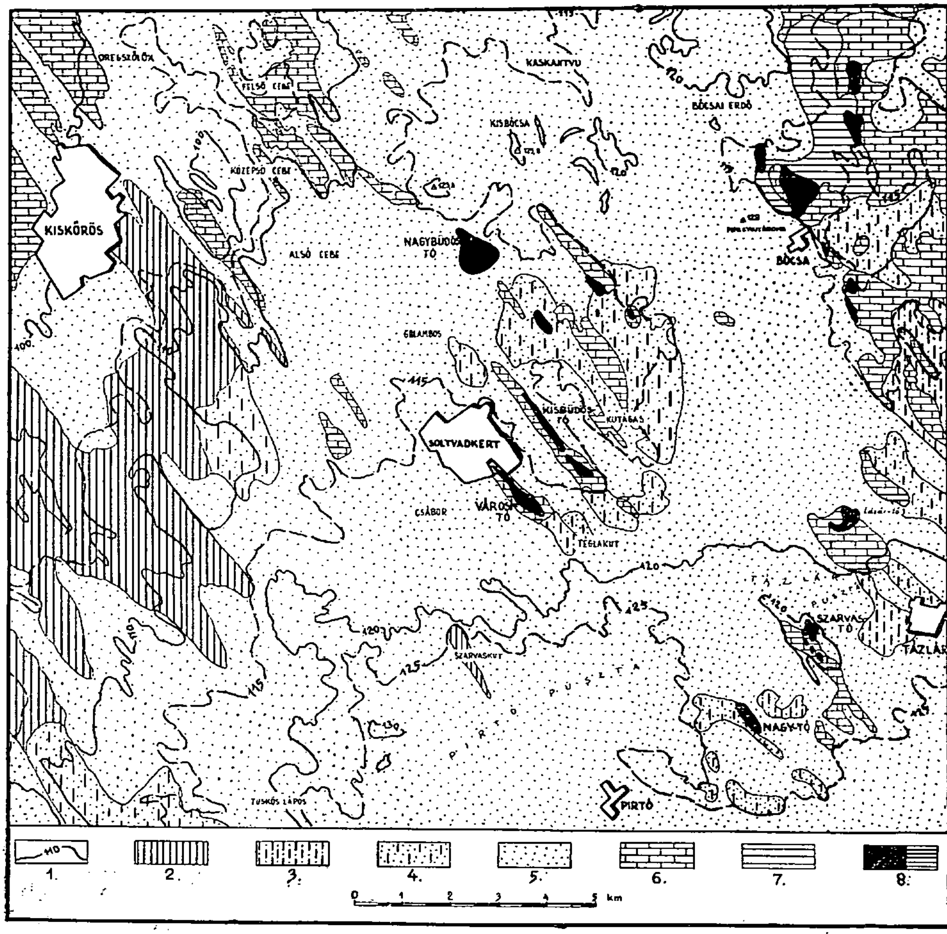

Fig. 1. Relief and geology of the region of Lake Nagybüdös.
1. — contour-line; 2. — loess; 3. — sandy loess; 4. — loessy sand; 5. — sand; 6. —calcareous silt; 7. — sodic soil; 8. — permanent lake; 9. -- periodic lake.

only half-bound. The relative height of the dunes is 3 to 15 m. The most prominent ones attain 125 to 128 m a. A. S. near the lake and 130 to 140 m a. A. S. south of Soltvadkert. The landscape goes on rising to S—SW and finds it continuation in the Bácska Sand Ridge including the highest elevation of the Danube—Tisza Midregion (Ólomhegy 174 m a. A. S.).

Predominant surface formations in the surroundings of the lake are little-grained blown sands of yellowish tint. The heavy mineral analyses [5] have shown their source material to have been Pleistocene fluviatile sands which had been removed by an eolian mechanism from the palaeochannels of the Danube. While depositing these sands, the predominant northwesterly winds of the Wurmian Glaciation arranged them into dunes like those occurring at present. Later, in the arid Hazel-nut phase of the Early Holocene — under conditions favourable for sand movement — the landscape forms of the blown-sand areas were renewed, re-arranged, but their surface features and areal extension are changing even today. Geological drillings have shown at many places [4] that the slowly advancing blown-sand blanket had buried younger surfaces (Holocene calcareous silts, humusbearing soil horizons, etc.). Following B. BULLA [1], we refer to these youngest, thin, redeposited sands as blanket sands. The advancing blanket sands were largely involved in the changes in the shape of our lake, too *(see geological section, Fig. 2.)*

South-east of Lake Nagybüdös there are Upper Pleistocene loessy sands of rather little extension, while in the depressions and in the areas of accreted pans Holocene lacustrine sediments and calcareous silts can be found. The so-called „Alföld" loesses of Wurmian age have only small, spot-like outcrops, but they can be shown to form several horizons both intercalating and underlying the blown-sand deposits. The thickness of these loess layers does not exceed 1,5—2 m. The layers are not continuous, as the loesses had fallen onto partly uneven blow-sand surfaces. Hence, their lenticular mode of occurrence is a syngenetic feature. On the other hand, at some places it may also be a post-depositional one due to removal by deflation.

According to B. MOLNÁR's investigations concerning the roundness of sand grains [5], the thickness of the eolian series is about 80 m at Soltvadkert, from where it increases to the E and decreases to the W. M. MUCSI could not detect any fluviatile sediment within the profiles of four artesian wells at Soltvadkert while tracing them from the surface to 100 m depth (personal communication). Thus, we may discard fluvial erosion from among the possible mechanisms of formation of the lake.

Our analyses suggest that the wind has played the decisive role in the morphogenesis of the landscape. The higher-seated, continuos patches of the blown-sand area are the result of *accumulation by wind,* deflation being responsible rather for some minor surface features there. However, on the less elevated surfaces, in the areas of pans (W and S—SE of the lake) it is the *effect of deflation* that prevails. The small drainless depressions trending NW—SE are also due primarily to the deflation work of the wind and result only in the second place from its damming, accumulating activity

Formation and development of the lake

As regards the formation of the lakes occurring on the sand ridge of the Danube—Tisza Midregion, we can find several interpretations in the literature.

J. CHOLNOKY [2] and SMAROGLAY [7] held the long, flat, level-bottom troughs of variable breadth with scattered natron lakes for deflation furrows.

According to B. BULLA [1], the numerous off-shoots of the Danube, building their alluvial fan, flowed in E—SE direction across the Danube—Tisza Miregion till the interglacial of the Upper Pleistocene. In his opinion, the blown sands derive from river wastes blown out by the winds from dying Danube channels, while the troughs with scattered natron lakes dissecting the surface of the alluvial fan represent in most cases uncompletely filled remnants of eroded channels buried due to wind action. M. Pécsi [6], E. Scherf and J. Sümeghy [9] advecate similar views.

P. Treitz [11] suggests that the trends of the pans and of the inland waters streaming in them are due to crustal movements (tectonics) that affected the region. We consider that this effect cannot by no means be of decisive importance in this case, since the block movements of the basement could not be effective in modelling the landscape, because of the thick loose clastic sediments (gravels, sands, silts, loesses) that have separated the basement from the surface. On the basis of his recent investigations, I. Miháltz affords only the assumption that some slight foldings may probably have some part in shaping the relief, and thus in the formation of pans and lakes, too (personal communication).

Concerning the above principal approaches expounded in the literature, we are of the opinion that one must not accept any uniform interpretation generalized for all the lakes of the sand ridge, as commonly not a single factor but several ones were involved in the formation of the depressions of these lakes and in that of the pans, i. e. they are the result of a complex mechanism. Accordingly, in the northern half of the sand ridge of he Danube—Tisza Midregion, where the alluvial fan of the Danube lies close to the surface, the pans may be even uncompletely filled remnants of palaeochannels. In the central and southern parts of the ridge, where the alluvial fan is covered by a thick eolian sheet, it is already the wind action that must have been largely responsible for morphogenesis. Nevertheless, there is some evidence suggesting that, owing to the recent upheaval of the region in the Holocene, the anastomosing streams of the troughs, flowing slowly to the SE, can also perform some modelling, erosive or accumulative functions, especially in periods of relatively more humid climate.

A decision as to the interpretation permitting a better approach to the processes responsible for the present morphological patterns, is possible only after a detailed analysis in each particular case. Therefore, we attempted to clear the genesis and age of Lake Nagybüdös, too, by means of multilateral, profound surveys.

First of all, 35 shallow geological boreholes were penetrated to 3—10 m depths around the lake, and 4 additional ones within the lake itself. Relying on the geological sections constructed from the information furnished by these boreholes as vell as on the morphological survey of the surface, the following conclusions as to the formation and development of Lake Nagybüdös can be drawn:

The lowest bed reached by the borer in the section asross the southern part of the lake is loess with fine-grained sands. It is subsequently overlain by little-grained sands, by loessy fine sands and by fine-sandy littlegrained sands. The latter are superposed, again, by loessy fine sands. These strata represent the Upper Pleistocene. The three loessy beds formed in the glaciations Wurmian I, II, III, respectively, while the intercalated layer of little-grained sands and fine-sandy little-grained sands represents blown sands redeposited here in the interglacial periods. The age of the beds was determined by relying upon the pollen analysis of borehole No 1 (in the lake), in the one hand, and upon correlations with a number of boreholes performed by I. Miháltz [4] in the Danube—Tisza Midregion, on the other. The Pleistocene beds reached by boring are all of eolian origin. During their deposition the relief was modelled by the alternating processes of deflation and eolian accumulation. This is evidenced, among others, by the varying thickness and lenticular shape of the beds.

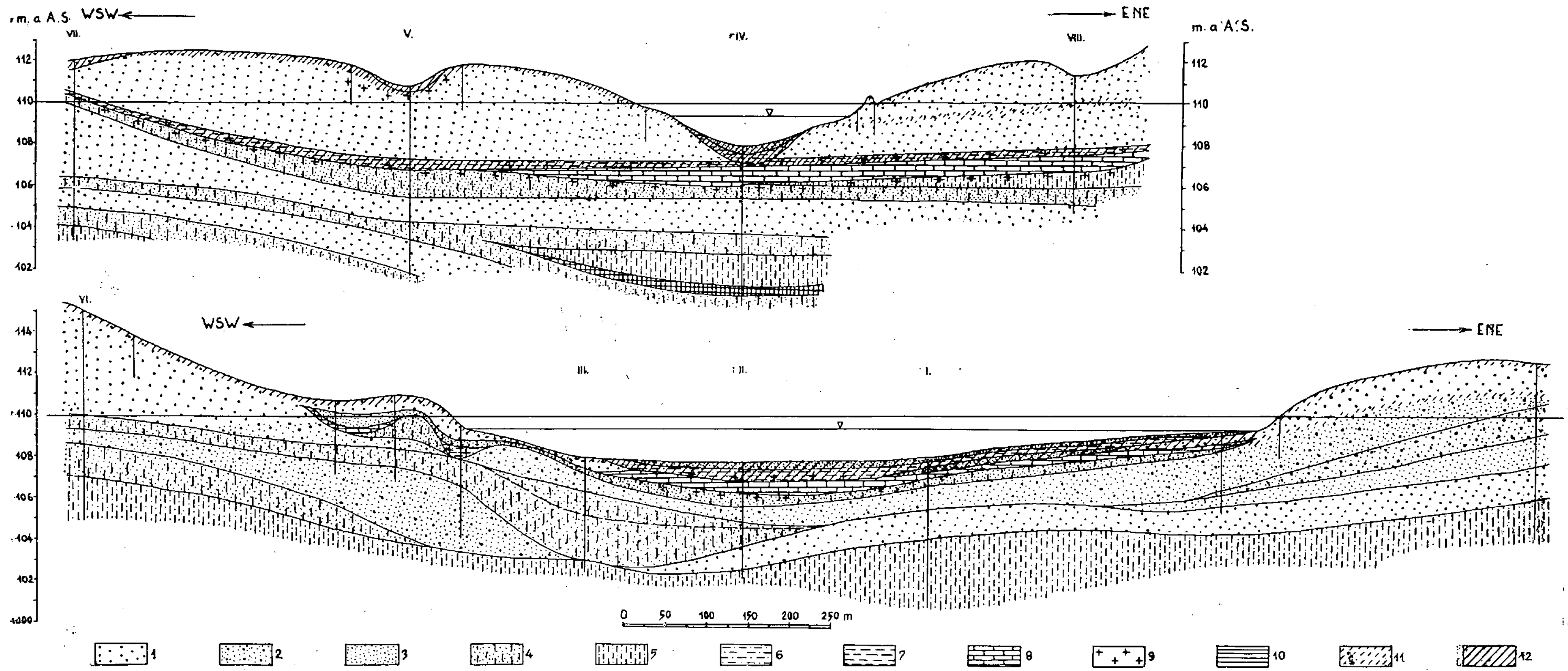

Fig. 2. Geological sections of Lake Nagybüdös. (J. Fehér—M. Mucsi)
1. — little-grained sands 0,1—0,2 mm Ø; 2. — fine sandy little-grained sands (0,05)—0,2 mm Ø; 3. — finegrained sands 0,05—0,1 mm Ø; 4. — loessy fine sands (O,02)—0,1 mm Ø; 5. — fine sandy loess 0,02—(0,1) mm Ø; 6. — fine sandy silt; 7. — silt; 8. — calcareous silt; 9. — deposits with a little calcareous silt; 10. — dry turf; 11. — a little humic strata; 12. — humic strata.

The sediments of the Early Holocene Pine-Birch phase have not been found in our boreholes, though it is quite possible that the fine-sandy loesses substrating the calcareous silts in borehole VIII. of the northern geological section were deposited that time (B. BULLA suggests the loesses of the Great Plain to have been formed in the Last Glaciation and the Pine-Birch phase) [1].

In the boreal Hazel-nut phase a warm and dry climate predominated in our region, too, so that the Great Plain was characterized by a scant grassy steppe vegetation void of trees. In our country this was the second period of extensive sand movement promoted by the arid climate and the scarce vegetation. Nevertheless, no sands dating from the Hazel-nut phase have been encountered in the area of Lake Nagybüdös, because *it is in this period that deflation excaved the area* as deep as the contemporaneous groundwater table, thus creating the „crib" of the later lake.

Towards the end of the Hazel-nut phase the climate became more and more humid and thus graded into the Atlantic Oak phase. The temperature changed hardly any. In spring, the most humid season of the year the shallow depression that existed here in the Hazel-nut phase was covered by water. This periodical water cover became later permanent. The ground-waters of the broader environs are likely to have also contributed to the water body; moreover, some recharge by surface waters may also have taken place. Since the substrate and the surrounding surfaces were made up of loessy formations, the waters that infiltrated into the depression from various directions may have exsolved much carbonate from those deposits. Because of the shallow character of the depression, the thin water body in it grew very warm in summer and evaporated for the most part. Owing to intensive evaporation, the water got supersaturated with hydrocarbonates (HCO_3). Thus, evaporation and the CO_2-absorbing activity of the plants that lived in the water gave rise to precipitation and deposition of calcareous silts. Accordingly, the calcareous silt layer attaining, as a rule, 60 to 80 cm in thickness was formed in this way under the boreal climate at the end of the Hazel-nut phase and in the Oak phase (between 8000 and 5000 years b. o. e.).

The extension of the calcareous silts suggests that the now narrow northern part of the lake was then still considerably wider than the southern part.

Hence, the ancestor of Lake Nagybüdös was formed approximately 6000 years before our era. However, as suggested by the study of geological formations and lacustrine sediments, the climate soon changed again and the phase Beech I of the subboreal stage set in. The amount of precipitations changed hardly any, but the climate became cooler. Evaporation diminished and so did the amount of calcareous silts precipitating from the diluted waters of the lake. Finally, precipitation ceased altogether.

The sub-Atlantic phase Beech II was already more abundant in precipitations, its climate was quite cool and humid. The water body of the lake grew and the lake reached its greatest extension at this time and its depth was also then the largest, as testified by our cross-section.

However, the configuration of the lake did not yet resemble much the current one. The northern part of the lake substrate which in the Oat phase had had still an elliptical outline grew in the Beech phase so wide that the contemporaneous western and eastern boundaries of the lake are altogether lacking in our bore profile. The largely humic, fine-sandy silt deposits of the Beech phase also evidence that the lake in the northern section was at least twice as broad as in the southern one. It may be supposed that the lake of that time had even drainage in NW direction into the Danube.

Since the beginning of historic times the climate of the region has become slightly warmer, drier, i. e. more continental than had been in the Beech phase. The thinning plant cover and human intervention such as grazing, logging, crop farming, etc, allowed the wind to re-disturb the sands, so that a new movement of blown sands from NW, W and NE, according to the direction of the strongest, prevalent winds, set in. The former configuration of the northern half of the lake changed due to these youngest blanket sands, as they led to a material filling of the NW and NE sectors of the depression, thus resulting in the present narrow shape of the lake on the N.

A map prepared at the end of the XVIIIth century permits to ascertain that in the last centuries the outline of the lake have not changed much. However, this map also shows that the surroundings of the lake that time represented still a barren landscape with very scarce vegetation. Forest was hardly available and only a thin grass cover and other scant sand vegetation may have occurred around the lake. The sand dunes of the region were still unbound or balf-bound. These conditions account undoubtedly for the rapid spread of the blanket sands and for the earlier intensive filling of the aforementioned parts of the lake. In the XIXth century the planting of vines and afforestation went on intensifying, the acreage of field crops grew, as a result of which the sands became bound. Since that time the rate of filling has diminished and the maps constructed in the last century show that the shape of the lake has not changed almost anything.

The above interpretation of the lake's morphogenesis is confirmed by the geological borings and sample analyses, by the knowledge of the wind conditions of the region and by the morphological observations alike.

The annual and mensual averages of the distribution of wind directions between 1921 and 1940 taken from the meteorological records of Kecskemét are illustrated by the diagrams of *Fig 3.* They indicate that in our region the prevalent wind direction in the winter half a year (month XII—V) is the NE one, and that in June it is outrivalled by the NW wind, though the frequency of both wind directions is still nearly the same. In summer most frequent are the north-westerly and westerly winds, while the distribution of wind directions in autumn can be regarded as rather uniform. Our lake lies some 45 km SW of Kecskemét. So here a greater frequency of the northerly winds may be reckoned with, because of the proximity of the Danube Valley. During the year the NE wind predominates for the longest time, yet as regards working capacity, the NW and

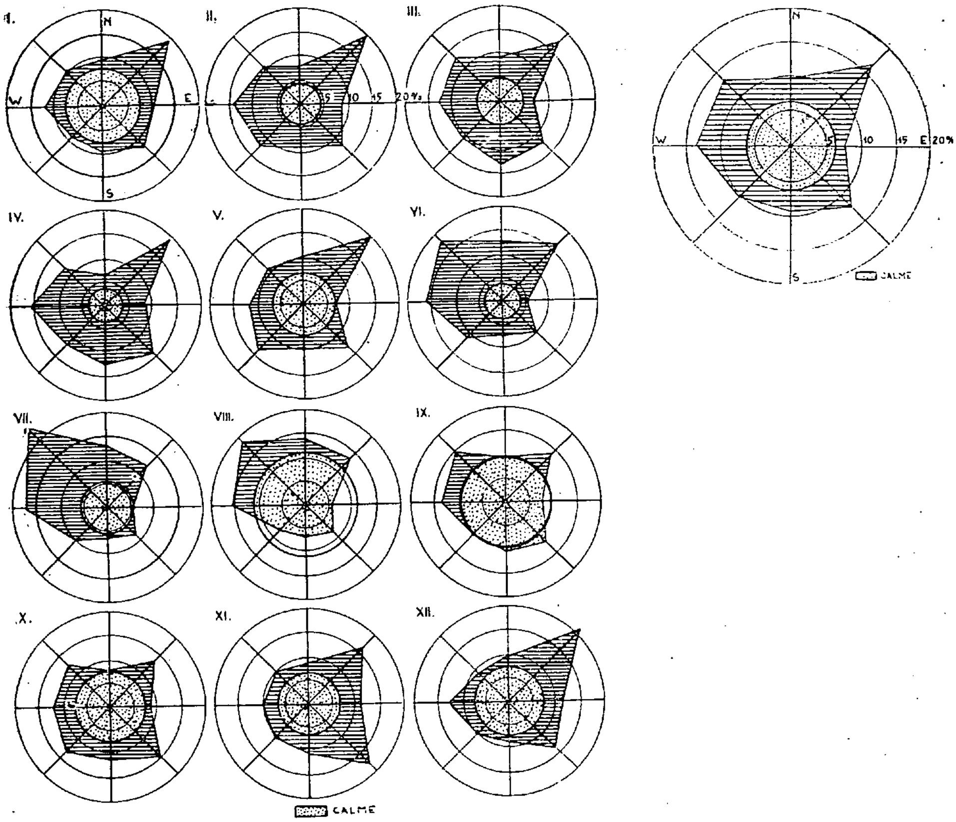

Fig. 3. Annual and mensual distribution of winds at Kecskemét (averages for 20 years).

W winds are of the greatest importance, as suggested by the following table.

Table: Percentage distribution of wind directions acording to their force (Kecskemét)

Force °B	N	NE	E	SE	S	SW	W	NW
1—2	10	12	10	11	16	9	17	15
3—5	9	14	6	6	9	6	27	23
≧ 6	7	*19*	4	1	1	2	*32*	*34*

The values 34 p. c., 32 p. c. and 19 p. c. of winds with a strength of 6° B and more, occurring during the year, prove that the NW, W and NE winds are not only the most frequent, but also the strongest. However, as regards working capacity, i. e. surface modelling, destruction and sand movement, the NW and W winds are of decisive importance partly because the stronger winds blow mostly from these directions, and partly because these winds are most frequent in the driest season (months VII, VIII, IX) when the dry sands can be most easily moved. The landscape-modelling function of the NE winds prevailing in the winter half a year is more limited, as the winds are weaker and the surface is protected in winter by snow cover, too. (Duration of snow cover is 35—45 days a year, its average thickness being 6—7 cm.)

In brief, we can state that examination of the present wind conditions confirms our conclusions deduced from the geological and morphological evidence suggesting the lake's substrate to have been sculptured by all three predominant winds.

Morphological charakterization of the lake

Lake Nagybüdös resembles a drop narrowing to NW and growing wider in its S part. Its major axis diverges westwards by 52° from the northern direction, so that it coincides with the approximately north-western strike of the Danube—Tisza depressions such as lakes, moors, and marshy pools. Their axes usually form 25—63° angles with the northern direction. If we compute the average value for the strike angles of these depressions, the result will be 45°, which means that the average strike is exactly NE—SE.

At mean stages (KÖV) the shape and extension of the lake bottom and of the water surface are determined by the following data:

The lake is 1300 m long; its major axis being 1162 m. The minor axis is 962 m long and forms a 75° angle with the major one. The projection of the minor axis normal to the major one is 935 m. These data do not considerably change either at high (NV), or at low stages (KV). Striking changes occur in cases of floods (LNV) and in those of unusually strong ebbs (LKV). Therefore, Lake Nagybüdös can be considered as permanent.

The depth conditions of the lake are shown on the batymetric map inserted into this paper (Fig. 4). The average depth is 1,08 m; the largest depth at mean stage varies between 160 and 170 m. The height of the deepest part of the lake above the Adriatic Sea is 107,40 to 107,50 m. This is at the same time the deepest spot of the region.

The shape of the lake bottom allows to draw conclusions as to the last stage in the lake's development as well as to the current trend of evolution. The bottom sections (Fig. 5) clearly show the flat and even surface of the bottom, the deviation between the slope angle of the western and eastern beaches and the asymmetry between the subaquatic slope of the bottom and the two shore belts. These are not too great differences, but are conspicuous and morphologically motivated. So, for example, in the three northern bottom sections the deepest part of the lake is situated not in the middle, but in the eastern half of the lake.

Nota bene, the steepest beaches are to be found also here. This is due to the intensive filling action of the NW and NE winds. In fact, the advance of the blanket sands was the quickest on this shore and on the opposite, western one.

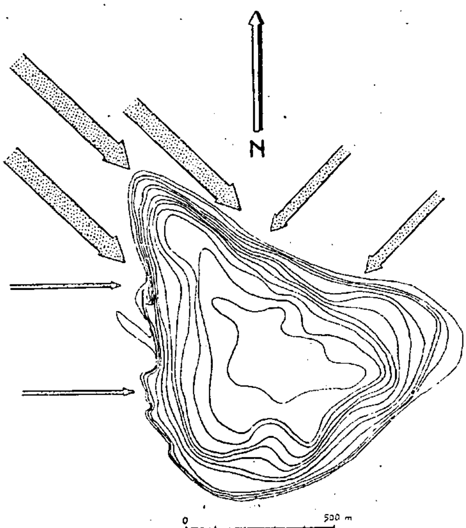

Fig. 4. Isobaths of Lake Nagybüdös (for 20 centimetre) and main wind directions affecting sand movement.

Conspicuous is the presence on the eastern shore (sections 6, 7, 8) of a wide, gently or scarcely sloping shoal, situated within the reach of the low-stage waters. In this connection it is worth of mention that the E part of the lake has been overgrown with dense reeds, bulrush, etc. The situation was otherwise the same in the XVIIIth century, too, as testified by the map mentioned earlier. The widest portion of the reeds, however, lies at the aforementioned places what obviously have had some part in the modelling of the shallower bottom portion which has been filled at a quicker pace. The presence of dense, high reeds keeps in check the water movement, the waves. Consequently, they protect the beach — which is rather high and steep here — against abrasion. At the same time, they provide some protection against the westerly winds, too.

The flat, almost level bottom surface of the lake's depression is the result of former deflation. In the Hazel-nut phase deflation blow out the sands from the contemporaneous depression as deep as the ground-water table or close to it. Since that time the following sediments have been deposited in the lake: calcareous silts overlain by dark, humic, sandy ones. The source materials of the latter have been primarily dusts, fine sands, etc. transported in eolian way and fallen from the air into the lake. This material is evenly filling the depression up to date. Lake

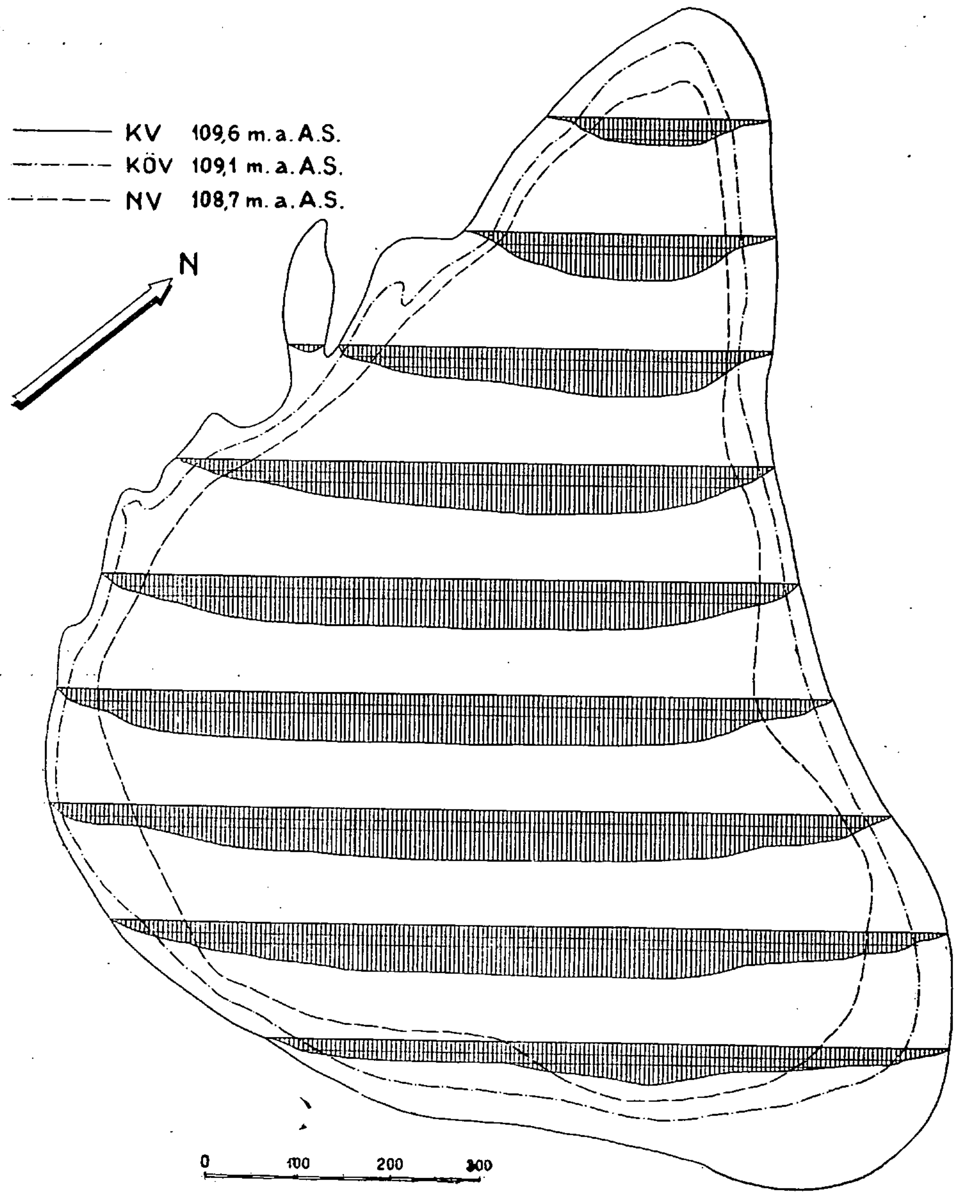

Fig. 5. Cross-sections of the lake bottom.
KV — The low water-level, KÖV — The mean water-level, NV — The high water-level.

bottom is covered in varying thickness by this loose silt layer. The thinnest silt layer is encountered in front of the western and southern shores (0—5 cm), where the bottom is made up of sands for the most part. This can be explained by the fact that on the W shore it is the NW and W winds, while on the S shore it is the waves that bring much sand into the lake. The second reason — and, in our opinion, this is the more important one — is that for several decades before Liberation people used to bathe on the W shore, while since Liberation they prefer to do so on the S one. In summer water and mud are constantly disturbed. The stirred-up mud cannot be deposited in situ, as the currents carry it away to other, more quiet bottom tracts, where it finally settles. In summer 1963 we observed that in a warm Sunday — when some two thousand persons were bathing in the lake — the water was troubled so much that it remained quite turbid and preserved its grey colour for several days. It could clear, though not perfectly, only by the end of the following week when it was disturbed again. Therefore, the thickest mud layer is found in the central part of the lake and near the reeds.

The mud of the lake is very loose, finegrained. In wet state its colour is greyishblack, in dry state dark brownish-grey. Its granulometric composition is remarkable for the lack of sorting and shows the following pattern: The coarsest constituents are little-grained sands, but there are fine sands, loesses, silts and calcareous silts, too. The high carbonate content (about 30 p. c.) is accounted for by the fraction having a grain size smaller than 0,02 mm which represents about one-third of the mud, as suggested by our measurements. The dried mud sample shows a high degree of binding because of its very high humus content. When disturbed, the lacustrine mud effervesces due to the release of hydrogen sulphide, and the samples taken on such occasions smell strongly of hydrogen sulphide. Obviously, this smell is responsible for the very name of the lake.

In the course of the morphological examination of the lake shore we have constructed the relief sections of two peculiar shore types (*Fig. 6*). Of these, particularly the section of the flat southern shore is worth mentioning, where the building and destructing work of waves generated by the NW and NE winds can be clearly seen. As a matter of course, the waves breaking in the shallow water and running over the flat beach are able to bring about only minor forms. However, the observation of the behaviour of waves rendered easier to determine the low, mean and high stages of the lake.

Section „B" of Fig. 6 shows three abrasion levels manifesting themselves by section breaks on the gently-sloping beach. Level „a" at mean water stage is situated at a distance of 6,10 to 6,25 m from the water boundary. Here a level difference of 11 cm occurs over 15 cm distance. This abrasion level is scoured by the breaking waves at high stages in spring time. Beneath it, within the belt ranging from 3 m to 6,10 m off the water border, the beach slopes hardly any (at 3,10 m), and the gradient is 18 cm here. At high stages the regressing waves scour,

* Nagybüdös means „strongly-stinking" in Hungarian.

remove the rock of this belt. The second break appears at the mark „b", and the mean stage coincides with the point of inflexion of this more inclined beach section. The next to follow is a wide, flat, underwater escarpment which used to be exundated at low water stages only. This breaks at mark „c" and passes into the scarcely-sloping lake bottom,

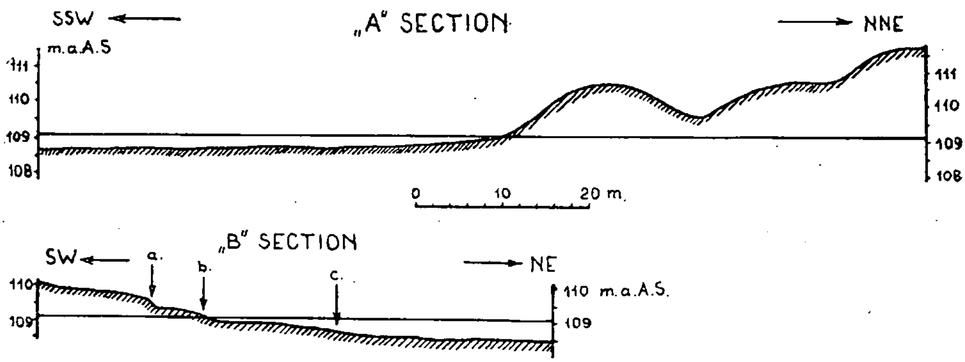

Fig. 6. Sections along the shores of Lake Nagybüdös.

the gradient of level „c" being even smaller than that of the former. Here between 13 m and 20 m distance from the water border the gradient is only 20 cm, but the following 20 m section has even smaller gradient: 5 cm.

In section „A" of the E shore we cannot find such abrasion levels, as the shore is surrounded by a wide belt of reeds which protect the beach at any water stage against the destructing or building effect of the waves. The slope of the beach is considerably steeper here, because the shore continues with a dune landscape, while the bottom slopes even less than on the S.

The water amount of the lake

It varies within a wide range and so does the water level. Water stage observations and the morphological study of the lake bottom furnished following information on the mean, high and low stages of the lake:

At mean stage the water table lies at 109,10 m a. A. S. In such cases the maximum depth of the lake is 1,60 m. In terms of annual level oscillations the high stage (NV) appears in spring and is likely to range from about 109,50 to 109,60 m a. A. S. At this time the water depth in the deepest part of the lake reaches about 2,10 m. The lowest stage (KV) sets in in autumn, with approximately 108,70 to 108,75 m a. A. S., the water being 1,20 m deep at this time. Hence, the annual oscillation of the water level averages some 80 to 90 cm.

Because of the shallow-dish shape of the lake basin the changes in the water level are associated with considerable changes in the surface area and in the volume of the water body. The lake's water reserves are 473 thousand m^3 at low stage, 1,153 thousand m^3 at high stage, and 720 thousand m^3 at mean stage. The data on surface area and water amount corresponding to various water-gauge readings are illustrated by the combined graph of water-table area and water volume *(Fig. 7).*

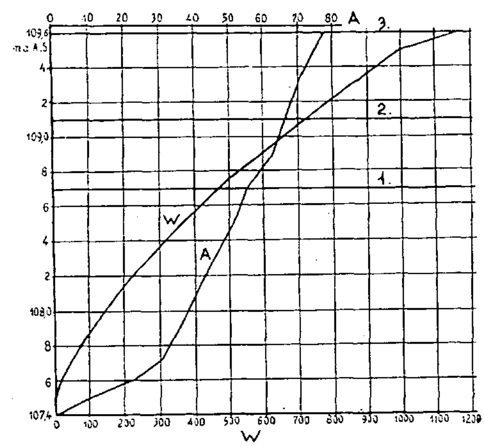

Fig. 7. Relationship between the surface area and the volume of the lake's water body.
A — The water-table area of the lake (ha); W — The water volume (thousand m^3); 1. — The low water-level (KV); 2. — The mean water-level (KÖV); 3. — The high water-level (NV).

At the lowest stage the area of the water table is very restricted. For instance, in August 1952 the water area shrank to 0,2—0,3 squ. km. and only the deepest portion of the depression was covered by some muddy water. This corresponds approximately to a water stage of 107,70 m a. A. S. (LKV). The highest water stage of the lake (LNV) was observed in 1940 when it overflowed its shores and, joining the inland waters which concentrated here, it inundated large areas. The height of the flood level may have reached 111,00 a. A. S. This flood resulted from the joint effect of the abundant precipitations of the preceding years, the extremely cold winter of 1939/40, the amount of precipitations of 1940 — which was the largest in this century — and the also otherwise very high ground-water table. In fact, the soil saturated with water could not absorb the waters that accumulated on the surface. Owing to the rising water-table which in the depressions surged up, to the inland waters which streamed here from the direction of Slotvadkert, and to the meteorologic waters falling into the lake, the water level of Lake Nagybüdös rose by some 2 m above the mean stage Consequently, the lake extended, inundated the near-by scattered farmsteads, and the lowerseated areas of the region got covered by water.

Accordingly, considering the annual behaviour of temperature, evaporation and precipitation, the waters of the lake exhibit a regular, though moderate, annual oscillation. However, within the scope of a longer period there are striking anomalies, even though seldom. This ought to be ascribed to the extreme, continental nature of the climate and to the close interconnection of the lake's waters with the ground-water. In average years, it is the latter that secures equilibrium, but in exceptional cases it provokes anomalies, too.

In our region the many years' average of precipitations is 579 mm, the evaporation of the open water table reaches, on the average, 698 mm a year (average value of evaporationgauge readings multiplied by the coefficient of correction 0,77) [10]. Surface water influx or drainage are insignificant. So the water balance of the lake would be negative and the lake ought to dry out soon owing to the annual water loss of 120 mm. Nevertheless, this cannot take place, as the infiltration of ground-waters moving easily in the loose, sandy substrate recharges the loss. Our observations have shown that the ground-water table is inclined towards the lake during the major part of the year (average inclination being 0,5 to 5,0‰). The water surface of the lake can thus be assumed as an open ground-water table, the oscillation of which is intensified by the precipitations falling directly into the lake and by evaporation; on the other hand, it is attenuated by the infiltrating ground-waters. Therefore, the lake bears a permanent character.

On the contrary, the extreme values of the lake's water level are provoked by a succession of unusually humid and cool years, on the one hand, and by that of years with unusually warm droughty summer, on the other. In humid periods the abundant precipitations falling into the lake and the lake rising ground-water table provoke floods. The dry periods, in turn, are accompained by a striking ebb, owing to scant precipitations, to material evaporation and to the sinking of the ground-water table.

The vicissitudes of the climate in this region are well illustrated by WALTER's climatic diagrams, showing the variation of temperature and rainfall *(Fig. 8)*. WALTER's diagram represents the mensual temperature and rainfall averages in such a way that 3 mm of precipitation corresponds to 1° C. Consequently, T:P = 1:3. On the diagram the area cut off by the precipitation curve below the line of temperature represents a droughty period (horizontale hachure). If the two climatic elements are plotted also according to the ratio T:P = 1:2, (raster), the strictly arid. droughty period will also be indicated. Diagram 1 illustrating the average conditions has been plotted on the basis of many years' averages. Diagrams 2 and 3 indicate the driest period within the time span studied (1902—1960) and its driest (droughty) year. Diagrams 4 and 5 show the most humid period within the same time span, precisely the behaviour of temperature and precipitations in 1940, year most abundant in rainfall. These diagrams clearly show the main climatic factors causing the rare anomalies of the lake's water level.

The results of our investigations can be summarized as follows:

Lake Nagybüdös is a shallow depression brought about by deflation in the Hazel-nut phase. Ephemeral or permanent water cover can be

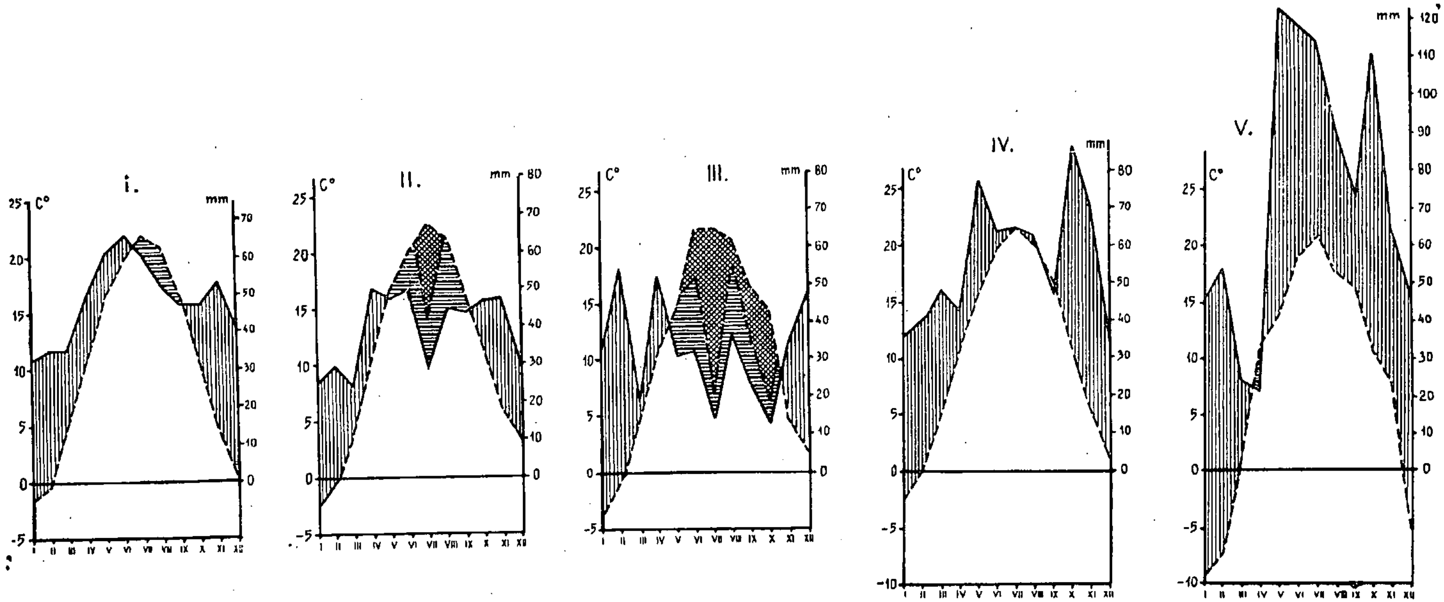

Fig. 8. WALTER's climatic diagrams for Soltvadkert.
№ I. — The mean temperature 10,5 C°, the mean rainfall 578 mm (averages for 60 years, 1900—1969). № II. — A dry period (1928—1935). № III. — The driest (droughty) year (1935. The mean yearly emperature 10,7 C°, the mean yearly rainfall 394 mm. № IV. — A humid period (1936—1944). № V. — The most rainy year (1940). The mean yearly temperature 8,1 C°, the mean yearly rainfall 882 mm.

reckoned with from that time on. The later changes in the lake's size and shape and its present pattern have been brought about by eolian accumulation, by the advance of the most recent, Late Holocene blanket sands as well as by accretion and damming. This latter process has been slackened by human intervention, by the transformation of the surrounding landscape and by the binding of blown sands.

Our drainless lake is fed chiefly by the meteorologic waters falling into it, while the great loss caused by evaporation is recharged by ground-water infiltration. The ground-water can to some extent reduce the water-level oscillations of the lake. However, if weather is unusually humid or too dry for several years, the ground-water may provoke striking water-level anomalies in the lake.

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