PHYSICAL GEOGRAPHIC CONDITIONS OF THE NATRON LAKES OF THE "KISKUNSÁGI" NATIONAL PARK

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Geographical Position

The natron lakes of the "Kiskunsági" National park (later, KNP) are situated in the space between the Danube and Tisza in a part that belongs to the Danube valley system (the lakes of Kisrét, Zabszék and Kelemenszék).

The western boundary of the area is formed by the hydrographic system of Kígyós brook which, for that matter, organically fits into the genetic structure of the lakes. In like manner it is the Danube valley main channel that geographically marks off the area from the east (Fig. 1.). The extension of the above-mentioned lakes can well be railed off from the east by the Budapest—Kelebia railway line, while when trying to limit the area from the north and south we have to recur to micromorphological details. In these parts it is mostly the existing settlements (Szabadszállás on the north and Fülöpszállás on the south) that delimit the extension of the lake system.

In a regional geographic sense the approximately 10 km^2 large district of natron lakes lies in the western part of the structural rift valley of the Danube. The relief is that of a monotonous flat plainland with 93—94 metres at the lowest and 95—96 metres at the highest parts.

It was in this structural rift valley that in early days the Danube had drifted its Quaternary stream deposit. On the alluvial cone of the Danube the glacial spillways still exist in a clearly recognizable morphological form. The valley structure of Ancient Danube occupies a position in the medial line system of the southern part of the Great Hungarian Plain well known from literature (in the direction of Gyál and Hódmezővásárhely). To the south-west of this line basin slopes gradually upwards, while it rises rapidly to the north-east.

The "alpine, mountainy" rubble formed by the extreme weather condition of the Quaternary (glacial period) is traceable in the ancient alluvial deposit of the Danube. This deposit is a facies of a significantly sandier character. In the alluvial cone system of the Danube—Tisza space it is this composition that provides the matrix of the Würm wind-blown sand and loess.

In the glacial period of the Riss the Danube — dividing into several branches — flowed in the structural valley and deposited its river-sand mainly in this period. During the glacial dry, cold climate of the Würm the upper part of this deposit was exposed to the constructing and eroding activities of the wind, in a word to the formation of wind-blown sand.

The forwarding of stream deposit on the table-land had not ceased in the interglacial period of the Riss-Würm and not even in the first half of the Würm. The river shifted more and more to the west and it may be supposed that one of its main branches had occupied as early as the interglacial period the eastern margin of the present

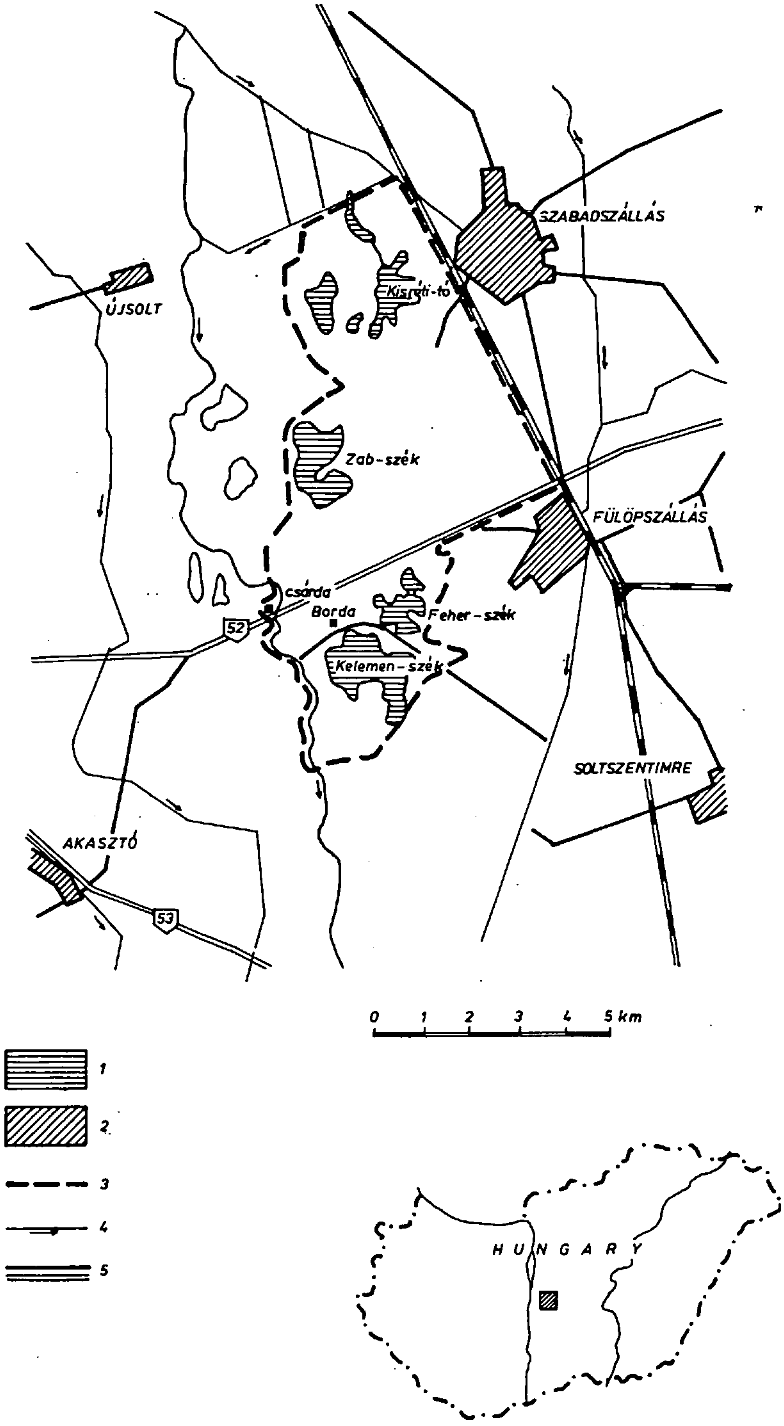

Fig. 1.

1. Preserved natron lakes
2. Settlement
7. No III area (zone) of the "Kiskunsági" National Park
4. Brook and channel
5. Highway

Danube valley. In spite of the new site of the basin the river went on constructing in the old valley flat. Even then the river carried a considerable amount of sand on the ridge, however, rough rubble deposited only in the southern area.

In the slowly shallowing ancient stream-beds a relatively significant quantity of fine-grain sand is being carried down, but even this process is gradually coming to an end, and in the desolate suckers and dune-embraced dips caustic sludge sand, loam and silty clay has gathered.

The Danube—Tisza Space Lakes in the Landscape

As it is commonly known on the deposit-plains made by the Danube, Tisza and their tributaries the number of natron lakes and seasonal inland waters is significant. While in the calciumrich deposit of the Danubian alluviãl cone system we find chalky, sodic, natron lakes and alkali soils, the deposit of Tisza is mainly characterized by "solonetz" type alkali soils on acid bottom lands of eruption origin.

It is mostly where the morphological conditions of the rerief were favourable that such lakes appeared. Thus it is ancient river valley bends, stagnant waters or terrain depressions without an outlet — blowout depressions — that form the basin of the lakes.

In the times before the regularization of inland waters and riverways natron lakes had existed in much larger numbers and extension than in our days. However, their present number is not small, either, and they line up in large numbers especially in the area betwen the Danube and Tisza. Despite the present regulation of inland waters in rainy springs this area of the Hungarian Plain is still a district of „a thousand lakes".

In a taxonomic sense natron lakes do not appear as standing waters of a uniform character. A large number of them are shallow. Such lakes have already reached the stage of a swamp. With their surface completely covered by water vegetation they are becoming choked with mud. Natron waters are also extreme abodes populated by a specific living world that differs from other waters, even from salty waters of other countries.

The surface stagnant of the Hungarian Plain form a particular taxonomic group. We cab discern the deflated lake system of the sand-ridge in the area between the Danube and Tisza, the poligenetic system of the Tisza valley, the lake system of the stream-erosion basins of the loess-ridges beyond the Tisza.

Our area is situated in the western zone of the table-land netween the Danube and Tisza where the lakes were formed as a results of deflation.

As it is known the superficial deposit of the alluvial cone of the Danube—Tisza table-land accumulated and denudated in an aeolian way. The horizontal sand and loess-formations that can be traced on a large distance are peculiarly characteristic of the middle part of the table-land. Though the grains of sand found here do not bear the marks of a long distance eolithic drift that is to say the sand had originally been transported here by the strean of the river and later the wind transhaped and rebuilt it over and over again. These deflation configurations sunk into the sand deposit form the basins of the lakes. The most significant transformation of the surface took place in the last period of the Pleistocene when the dominating big configurations were shaped. It was in a north-west to south-east froove of the latter where the water surfaces that we can see in our days were settled.

The morphological state of the surface of the Pleistocene was further modified in the Holocene when in the hazel period a great reshaping took place. Basically, however, the basins of the lakes (deflation depressions) had already gained their shape in the Würm III period. The only changes that took place later were in the water-cover of the surface, e.g. the extension of the lakes was the largest in the cool oak-phase of the Holocene, and in the beach I, beech II phase a continuous decrease in the extensions of the water surfaces can be registered. In our days the extension of the lakes compared to the oak-phase is half as large and at the same time as a consequence of the formation of impermeable lake sediments (the accumulation of carbonate silt) the water balance and water-cover of the depressions became steady.

The lake deposit of the surface stagnant waters of the sand-ridges both beyond the Tisza and between the Danube and Tisza do well show the palaeogeographical conditions of the stagnant waters. The deposit material of natron lakes is a humous, strong-ly carbonated, sandy silt, caustic sludge and clay containing nonclassified rubble. This rather varied Holocene deposit formation has resulted in different hydrological conditions in different areas of the southern part of the plain. The more marked is the difference within the group of steady natron waters where beside the $Na^{=\mathrm{and}}$ HCO_3 ions setermining the type the quantity of other chemical components (CO^{--}, Cl^-. SO_4^-, K^+, Ca^{++}, Mg^{--}) in different natron waters can be very different, furthermore a hydrographic quality (the changing of the water-mass, the transparency of water, etc.) can also be of importance.

The increased carbonate concentration int the silt and water of the lakes can be explained by the fact that the lime of the higher parts of the environment was dissolved by the precipitation fallen and drifted towards the deflation depressions. The accumulated sodic water of the flats condensed the dissolved lime from the water of evaporating flats in form of minute grains and it is this residue that gives the characteristic caustic slud-ge of natron waters. If the condensation took place in the presence of grains of sand, the fine silt deposited on the grains of sand, and caustic sludge sand was formed. Sometimes the condensation of carbonate did not produce saparate grains, but the grains of sand were cemented together by the solid carbonate. In such case chalky sandstone-banks arose. In several places the condensation of lime was so strong that the grains of sand in the lime could not act as modifiers. In such cases limestone pro-ceeded.

Summary: the natron waters, natron lakes of the southern part of the Hungarian Plain form a perticular type of surface waters. Owing to the extreme climate of the plain these natron lakes have a characteristic hydrography. First of all they con-tain a fairly large concentration of dissolved salt (604,5—7. 124,2 mg/l) on account of which they can be classified as salty waters. Their salt content is first of all rich in Na^+ NCO^- ions, has a high pH value (7,5—10,5) and they are alkaline in character (MEGYERI, J. 1972).

The Morphologic Qualities of the Natron Lakes of the KNP

During the sourse of the morphologic survey of the terrain it was found that at an earlier time the lakes of Kisrét, Zabszék and Kelemenszék had been cotacted by a network of brooks as well as other drainage-systems. Man's remaking of nature,

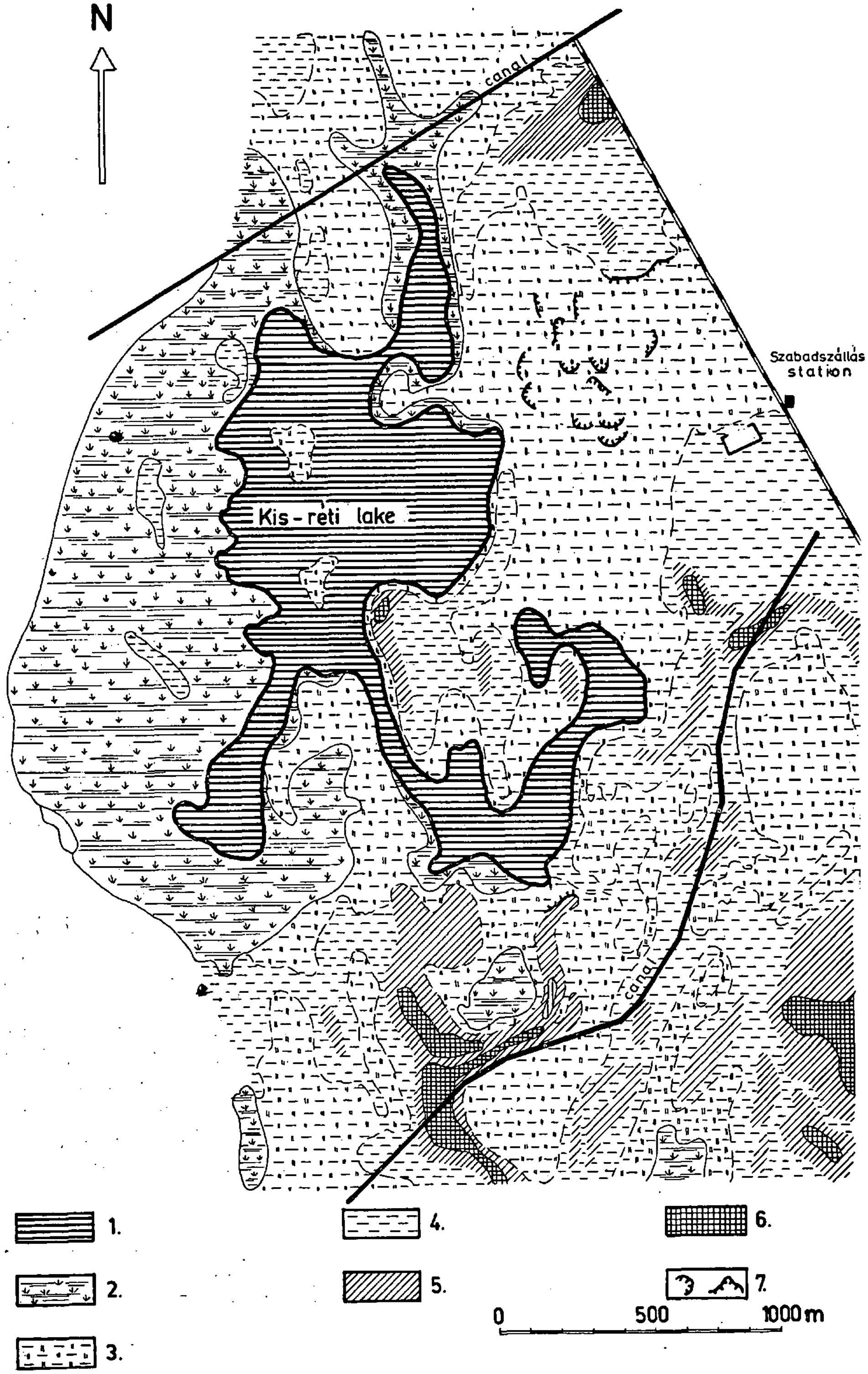

Fig. 2.

1. Constantly submerged area
2. Periodically submerged area
3. Soggy, sodic meadows
4. Sodic silt surfaces
5. Dry loess-silt surfaces (plough-land)
6. Loess-silt swells (elevations)
7. Sodic clay-pits

however, put an end to this connection and now an artificial inland drainagesystem links up the water districts. With this act the artificial character of the lakes has increased and the lakes became subject to man's managing activity. The once unbroken uniform area has two faces morphologically, we can distinguish between the Szabadszállás area and Fülöpszállás area.

In the Szabadszállás area between the water of Kígyós brook and the Budapest—Kelebia railway line we find several flat alkali dips. From among these two are of major importance, the lake of Kisrét having a steady water-cover and the periodically submerged lake of Zabszék. Both lake areas have relatively large parts that are periodically submerged only.

The Solt-Fülöpszállás highway can be considered as an artificial southern boundary of the Szabadszállás lake system. The flats lying to the south of this highway are generally referred to as the Fülöpszállás district of natron lakes and this area is mostly periodically submerged.

The lake of Kisrét (Fig. 2.) is a characteristic lake of the Szabadszállás sodic water system. The approximately 2 km wide and 3—3,5 km long stretch of water lies to the west of Szabadszállás. In shaping the present form of the lake early surface river-stream erosion played an important role.

Taking into consideration the stages of the development of the lake we can say that a large portion of it has the character of a swamp. Only one third of the approximately 6 km^2 extension surface is an open stretch of water. The average depth of the lake is small (0,8—1,0). The open stretch of water is surrounded by reeds and salt bulbrush water vegetation. Only the eastern sections of the shore are an exception where the beating of the waves has a strong shore-shaping effect for the water vegetation growing on the shore is missing here and steep-walled wavebuilt terraces have been formed.

Generally the open stretch of water is the deepest lying part of the relief, here the water-cover is stable even in the driest years. Much less certain is the stability of the water-cover in the reeds and salt bulbrush vegetation regions where in most years at the end of summer and in the beginning of autumn there is no water at all.

In the outer belt of the lake of Kisrét there is a lick of great extensions which at one time used to be the steadily submerged basin of the lake. This fact cab easily be proved with the structure and composition of the deposit close to the surface. The morphological features of the terrain in the lake system area also manifest that once there used to be higher elevations (residue of infusion loess) and swells mostly safe from flood. The swells in the eastern half of the lake system protrude as high as 1—1,5 m and gained their present shape as a result of river water erosion and stagnant water abrasion. The micromorphologic picture of the northern foreground of the lake system is of special interest. (Ürgehalmi balk) where the basin shapes of early water-streams that may haven been branches of the Kígyós broop riversystem are better emphasized.

In the water system of the lake of Zabszék the natural geographic picture is slightly different. This territory is a stagnint-water system sunk into a loess-ridge. The lake is not wider than 1 km and is 2 km long with sodic water and no significant water vegetation. The environment of the lake is a loess-ridge 1—2 meters above lake level and its aurface deposit is silty loess and sandy loess.

In the basin of the lake of Zabszék taken in the broader sense salt water vegetation is characteristic of the shore-zone, the vegetation coverage being the thickest in the southern part of the lake (Fig. 3.).

Morphologically the lake has an irregular crescent shape, since the Csordásszállási balk protrudes deep into the lake system in an east to west direction. This morphological formation refers to traces of an ancient river valley meander system. Naturally in the course of time the river bed was notably filled up with river and lake deposit. On the eastern border of the above lake system we find wave-built terrace sections in the shore which again appeared as a result of the beating of the waves. This morphological situation was brought forth by the dominating western, north-western winds. In those areas where the open surface of water is shadowed by the shore reeds, plant communities came about even in the eastern shore regions. The waving of the lake caused a shift of the silt in the basin of the lake, which is more emphasized in the eastern part of the lake.

On the 3 km^2 extension water system of the lake of Zabszék at an approximately 0,6—0,8 m mean water-level the salt concentration of the water-mass is fairly great. Though in summer the level of the water goes significantly down, the basin never dries up entirely. In earlier times the water area had a close contact with the present basin of Kígyós broop which can broved with the morphological features of the southern end of the lake basin. There was also surface overflow to the lake of Kelemenszék, which is demonstrated by the strongly silted dry branches of small basins.

The Fülöpszállás lake system is made up of the lakes of Kelemenszék and Fehérszék. These are solid flats of great extensions. Practically it is only a minor part of Kelemenszék that is steadily submerged. The water-coverage of Fehérszék can be called periodical sod during the course of the whole year it is not under water. At present the flats of Fehérszék and Kelemenszék collect the precipitate falling in the surrounding area. In an effort to systematically conduct and drain the waters here technical solutions were devised but their use contradicts to the protection of nature.

In the surroundings and inside the area of Fehérszék and Kelemenszék the upper layers of the soil are formed by either sand or silty sand. In many places this uppermost layer is sodic. As a matter of fact the permeability of the upper layers is spoiled by a 30—40 cm thick clayey, muddy layer found at the depth of approximately 1 metre. This is the reason why we need not be afraid of great seepage-losses in the Fülöpszállás reservoirs, unless later mistaken technical interventions — the breaking through of the impermeable layer — lead to such losses.

The measurements of seepage — clayey layers considered — have given a value pf 1,0—1,5 cm/day=0,01—0,015 m/m^2) day per one metre water column. The lake of Kelemenszék for the most part is a natron water with a basin having no shore and it is only periodically submerged (Fig. 4.). In its northern part there is a 2 km wide open stretch of water without vegetation and in the south the lake area ends in the shape of a triangle where a signifidant plant community grows (reeds, salt bulbrush). Here, too, along the eastern shore we find wave-built terraces as a result of abrasion. In a morphological sense Kelemenszék is separated from its alkali environment for the "Kiséri-ridge" on its eastern shore as well as the ridge of Kígyósér bordering the lake on the west separate the lake from its environment. At times of high underground water-level the position of the outstanding configurations of the relief do not obstruct the flowing of water from lake to lake.

In the shaping of the present form of the basin there was an important condition, namely that the lake basin lies in the delta of such brooks (Kígyósér, Kisér)

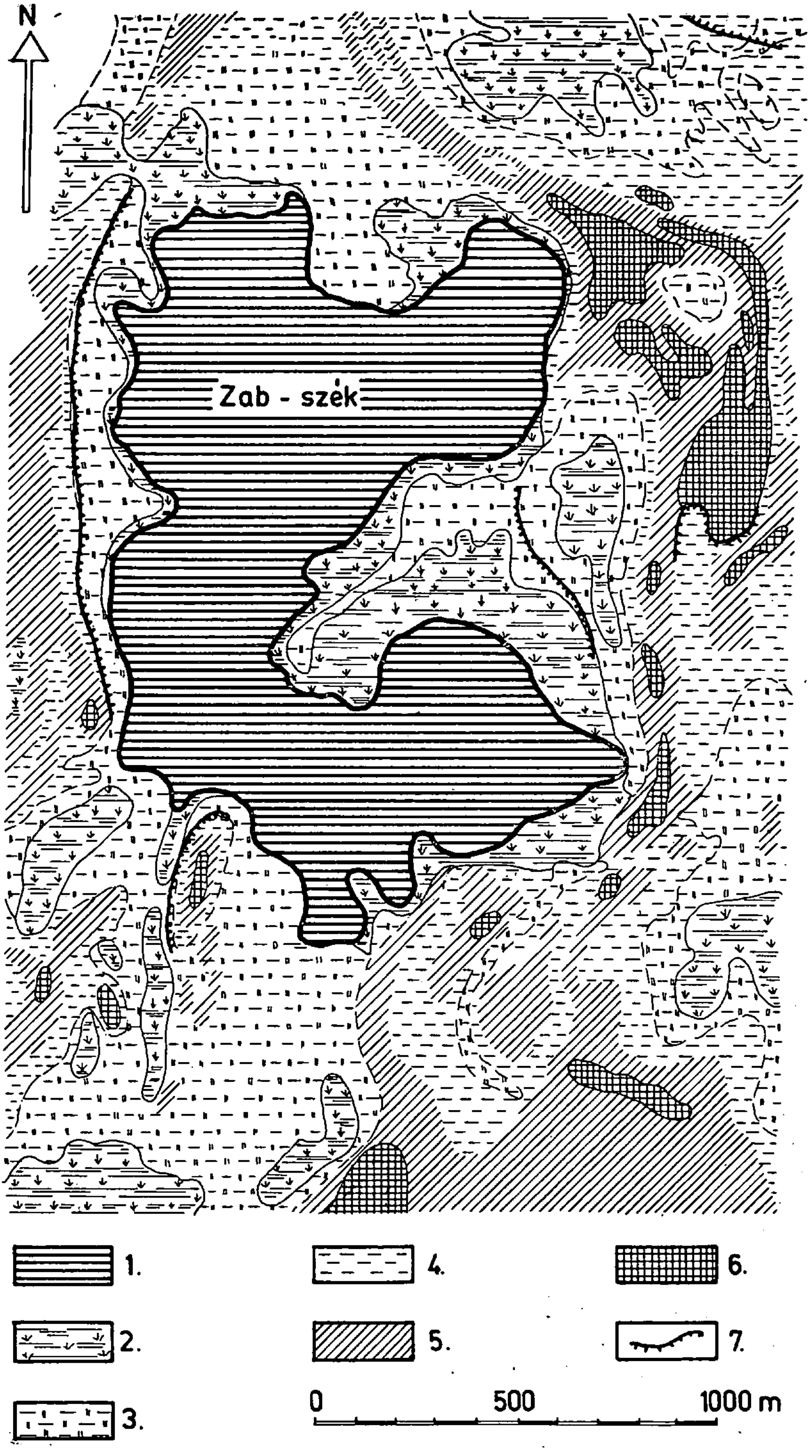

Fig. 3.

1. Constantly submerged area
2. Periodically submerged area
3. Soggy, sodic meadow
4. Sodic silt surface
5. Dry loess-silt surfaces (plough-land)
6. Loess-silt swells (elevations)
7. Abrasion-formed terraces

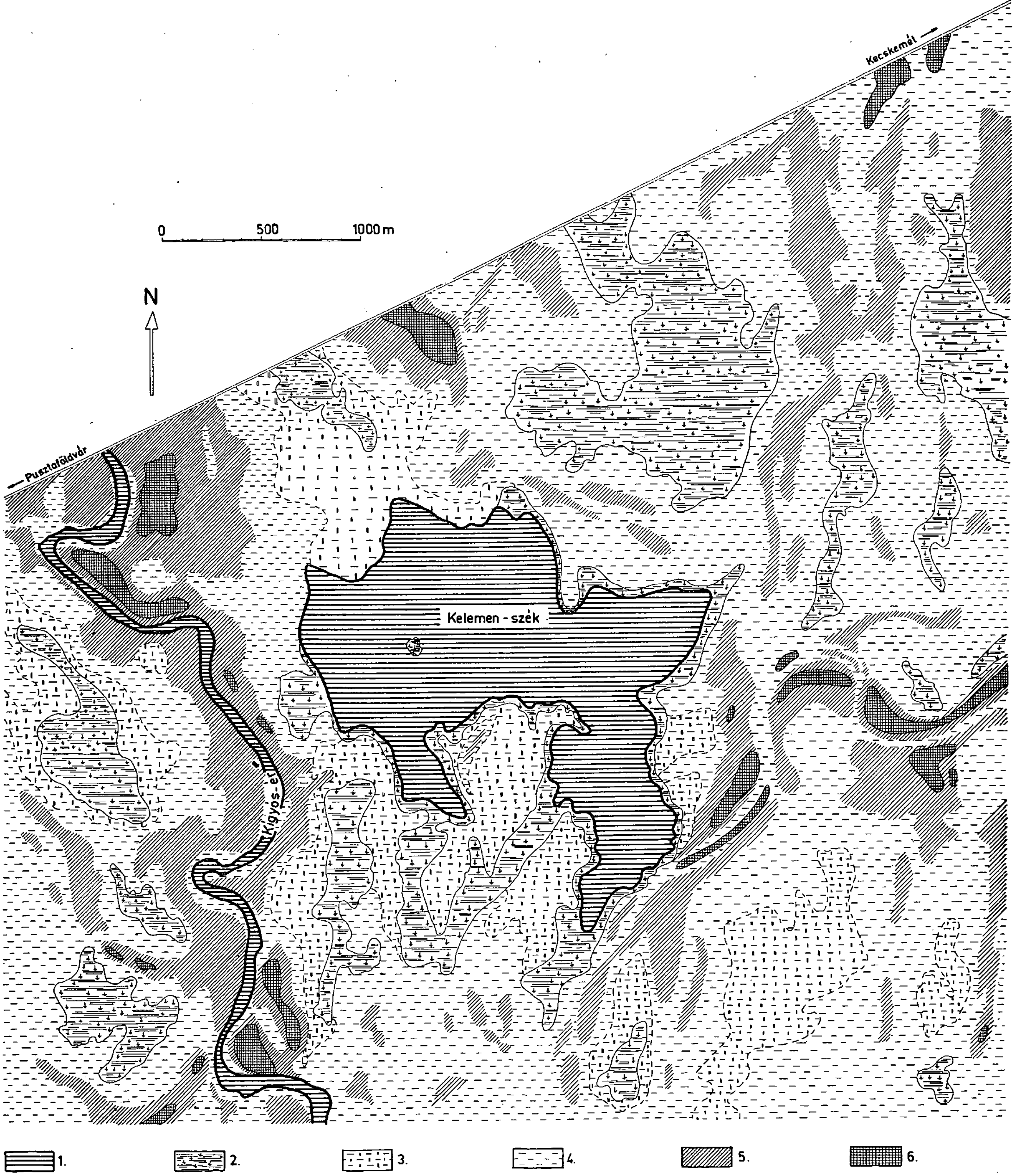

Fig. 4.

1. Constantly submerged area
2. Periodically submerged area
3. Soggy, sodic meadow
4. Sodic silt surface
5. Dry loess-silt surfaces (plough-land)
6. Loess-silt swells (elevations)

that had once carried larger water-masses. The large variety of deposits close to the surface also seem to support this view.

The extension of the open sheet of water is nearly 3 km^2 with 0,5 m mean depth. As a consequence of intense evaporation this mass of water entirely disappears in the middle of summer. Holding no water the salty basin dries up, gets cracked and polygonal soil form-patterns appear that so characteristic of alkali soils.

After summer showers the water of the regenerating lake quickly softens the concentrated salty silt and the opal-milk-white sodic lake comes to life again. In the dically submerged areas the water vegetation stagnates but suffers a lot on account of the dryness of the surface.

The northern, north-eastern shore of the basin is generally flat, while on the opposite shore sharp terraces, seats and bars of 20—40 centimetre's height can be found.

Under the wave-beating influence of the ruling north, nort-western wind a strong delevelling can occur, which may eventually shift the water away to hundreds of metres. Consequently it is mainly on the southern, south-eastern shore that the large variety of formations characteristic of sodic lake areas can be studied.

The uppermost sodic level is the sodic seat. Since it has a steep form, it protrudes considerably from its surroundings. However, we can only find sodic seats with structural alkalis, the seat incorporating the "A" level and the "B" upper level of the soil. As an effect of the soda the soil is rather tough and compact.

The second sodic level is the sodic slant or slope. The difference in level between the erosion basis and the sodic seat being slight the angle of gradient of the slope is very small. Its soil is highly resistant, protected by vegetation, erosion in the area is slight, so the surface decays very slowly but demonstrably with receding erosion.

These sodic flats are very extensive but they form a transition of a small angle of gradient between the bottom of the slope and the lake basin. It is here that the material worn off the seat is accumulated. The deepest part of natron lakes is the basin. It can be well distinguished even in the case of a dried out lake for the basin, compared to the paler seat and slope is darker. This is partly because this is the part that is submerged for the longest period of time and partly because owing to the imperfectly disintegrating vegetation this portion of the lake has a living vegetation even in summer and is green, opposite to the completely parched vegetation of the above levels.

The Hydrogeographical Features of the Lakes

The natron lakes of the Hungarian Plain — as it is commonly known — belong the greater part to the group of astatic waters. There are only a very few exceptions that have a considerable water, supply throughout the year. Large is the number of those lakes which in some drier years lose their water for the summer period. The depth of the latter practically coincides with the value of evaporation per year (0,8—1,4 m). Another group is formed by those lakes that lose their water for several months every summer. In different lake systems the climate of the water and the microclimate of the environment may be different, however, the changing of the water-mass does not cause significant climatic differences, unless the water completely evaporates.

The natron lakes of the KNP are qualified analogous with the above-described lake areas except for the lake of Kisrét, the latter being steadily submerged with water. A notable part of the lake does not dry up in extreme summers, either, the reason of which is the artificial supply of water and its hydrogeographical qualities. Contrarily the lake of Zabszék completely dries out in extremely dry summers, while the lake of Kelemenszék does so every summer.

During our alkalization research programme carried out on the ridge between the Danube and Tisza it was established that the phenomenon of alkalization is widely experienced in the Danube valley as well as in the border regions of its ridge. A primary reason for this is the easily dissolvable high concentration of salt $NaHCO_3$ and $NaCO_3$) in the deposit close to the surface. Literature related to alkalization emphasizes already as early as the turn of the century the importacne of hydrogeological factors, but it also notes that the salt accumulating processes of stagnant waters are also among the primarily important factors. Modern genetic soil research as well as the complex survey of the Alkali Research Work Team of the SZAB have considerably contributed to the elucidation of alkalization in the region and also to its natural factors.

As is well known palaeohraphically the Danube was the most important factor of the area. Beginning from the end of the Pliocene through the Pleistocene-Hlocene period with the building up of a large alluvial cone, then with the gradual changes in the character of the basin a regional palaeohydrographie area with an indented, cut up relief was formed until the inland drainage began. A significantly sodic part of the area is the territory of the KNP III. The alluvial deposit of the Danube is made up of carbonate rocks of varied thckness, layering and grain-composition. These — for the most part stream-water deposits — form the basic material of the upper soil-layer and the matrix of the Danube valley. The thickness of these layers is approximately as much as 50—100 m. Regionally it is this deposit that forms the material of certain underground, water collecting areas (natron lakes and their environment), the upper layers of which — as is known — do not constitute a unified type of deposit.

In the Danube valley owing to the very small slope of gradient in a 40 km long and 6—10 km wide area (Apaj—Kunszentmiklós—Fülöpszállás line) the flow of underground water slows down a great deal, the surface waters belonging here accumulate, pile up, and stagnant underground waters arise. This stagnant underground water — especially in such regions where because of its shallow position there is a chance for increased evaporation — is cocentrating with the sodium hydrocarbonate content becoming very significant. According to this in the Danube valley there in often a close negative correlation between the level and salt content of underground water. Below a few metres' layer of higher salt content unterground water we usually find less salty waters.

The mean shallowness of underground water in the Danube valley is 1—3 metres generally. On the large flate in the neighbourhood of Kunszentmiklós, Fülöpszállás and Szabadszállás it is 1—2 metres, in the areas adjacent to this it is 2—3 metres, it is 3—4 metres along the Danube bank and 3—5 metres under the brinks of the ridge. The so called critical underground water level is around 2 metres, but it reaches 2—3 metres on the border of the ridge which refers to a significant flow of underground water towards the Danube valley.

It is characteristic of the underground water condition of the Danube valley and the Danube valley ridge that the largest fluctuations of the underground water mirror can be found in the riverside regions where it reaches the value of 6—7 metres. Proceeding to the east the extent of the fluctuation is gradually lessehing as low as 2 metres, but even this level is relatively high in the named areas, so it leads to the appearance of inland waters.

As to the general state of underground water in the area its level always rises gradually in winter beginning from the previous autumn. The rise is generally sespended in April, when — if there is considerable thaw — it lasts as long as the middle of August. The underground water level considerably falls already in August in the Fülöpszállás region where its volume is 0,8—1,5 metres. The culminating water levels caused by the spring thaw in the Fülöpszállás—Szabadszállás area are accompanied by a sudden fall of the underground water level from the east to the west. Later this quick fall in the water level (underground water level falls as much as 80—100 cm/km) slow gown in the area of the Danube valley main channel and the Kígyósér system. Near Kígyósér the underground water hardly has a fall (3—20 cm/km) and this condition is very favourable for the process of alkalization.

The measurements of seepage with measuring tubes (VITUKI 1963) suggest that the natural fall of underground water in the Fülöpszállás—Szabadszállás region is small and we can hardly ever speak of a natural flow of underground water in this region. According to Darcy's law the actual speed of progress of underground water — reduced with the free volume — is no more than 1—1,5t cm/day.

The climate of the area also notably affecte the underground water level. Being continental, the weather greatly favours the evaporation processes. The average annual precipitation of the area is 550—600 mm, which is significantly surpassed by the potential evapotranspiration of 680—700 mm. The annual water shortage is 125—1250 mm here, which is especially strongly felt in the summer months. The evaporation in the summer period of the open stretches of water (continentality lessening on the surface) reaches an approx. 500 mm value. The monthly totals of open stretch surface evaporation are as follows: 84 mm in May, 91 mm in June, 147 mm in July, 106 mm in August, 57 mm in September and around 35 mm in October. From these high evaporation values we can see that the process of surface evaporation may be an important factor in alkalization.

TREITZ, HERKE, SZEKRÉNYI and many others also found evaporation processes to be of decisive importance. According to latest literature (ROHRINGER, SZABOLCS and JASSÓ, VÁRALLYAI) and the findings of research the alkali soils of the Danube valley were not engedered by the evaporation of surface waters, they were rather influenced by the salty, sodic underground waters. Where the underground water is in dynamic connection with the river and the flow of the underground water quickens up in the deposit system, there the accumulation of extremely concentrated salt is less likely. This phenomenon is well demonstrated by the three natron lakes of the KNP (Kisrét, Zabszék, Kelemenszék). Since the lake of Kisrét is sunk into the deposit of earlier river basins and taps the deposit, it can be seen that influenced by a dynamic supply of water its water balance is stable and the salt concentration of its stock is smaller. On the other hand the lakes of Zabszék and Kelemenszék are situated in sites with stagnant underground water supply; where the stock of water is determined by the changes of the ever-low underground water level and by surface precipitation.

The extreme fluctuation of the water-stock of the lakes is in strong correlation with the precipitation factor of the weather. Consequently in some years there is an abundance, in others a bad shortage of water. The extreme fluctuation of the water-stock is rather rhytmical than periodical. E.g. the abundant inland water stock of 1970 was caused by the rainy weather of the years 1969/70, when in the Kelemenszék lake system there was a surplus of approx. 800.000 m^3 of water. At the same time in the years 1962/68 the slight precipitation caused a shortage of tho same extent. The given data well show the extremities of the water balance of the lakes as well as the periodical character of the lakes. Essential changes can be seen in the water balance of the Kelemenszék lake. It has a water collecting area of about 10 km^2 and as a consequence of its 840 mm annual open water evaporation and 540 mm precipitation only the lake is dried out for a long period of the year. Since sodic waters primarily feed on precipitation and only secondarily on underground water, the distribution of precipitation in time is an important factor in the changing of the water level. In this regard in wet seasons, when there is a balance beween evaporation and precipitation the surface area of Kelemenszék lake is approx. 4 km^2. In order to preserve this state of the lake in times of massive evaporation and drier weather a significant stock of water (250 000 m /year) is to be supplied. With this artificial supply of water we can provide for the avifauna at least a "puddle" character of the lake. This supply of water can come from the "fehérszéki" water-basin which can store one million m^3 of water (BUZÁTZKY GY., — Dr. ZSUFA I. 1976). Since the water supplied is of similar chemical composition, the character of the natron lake is only sligthly modified. Thus the resulting Hydrological situation is favourable. Any water supplied from the KNP main channel would deteriorate the quality of the water of the lake.

Besides the above the changes in quality of the water of Kelemenszék are strongly influenced by the fact that the supply of water comes primarily from precipitation. When talking about the stability of the water level of the lake wehave to bear in mind the fact that the precipitation falling directly on the surface of the water raises the level in a degree depending on the height of the precipitation. So in times of rich summer showers we can count on an 8—10 cm rise in the level which corresponds to 80—100 mm precipitation per day (or perhaps in a few years). This often leads to a situation when the extension of the lake immensely grows and the whole water-collecting area is submerged with a shallow water-cover. Because of the impermeable character of the deposit close to the surface there is only a minimal drainage of water down to the depths. E.g. below the 20 cm thick silty layer of the lake basin there is a layer of impermeable clay of compact structure, and this layer isolates the surface water from the low-lying underground water level. No such hiydrographic situation is seen in the areas of Zabszék and Kisréti lake. Here the lowpositioner underground water has an important role in the formation of sodic waters.3

The Climatic Features of the Natron Lakes in the KNP III

Our area — part of the plain along the Danube — owing to its north-south direction in the Danube valley has climatic features partly different from the characteristic plainland climate of other parts of the Hungarian Plain. There is a striking difference in temperature and the quantity of sunshine and precipitation. This region has a warm dry climate that is unfavourably supplied with water, ehere a hot summer and the scarce rain causes an annual average water shortage of 150 mm.

As we have already pointed out the extreme continental weather of the area has a strong effect on the natron lakes. For the greater part our lakes are astatic sodic waters where the microclimatic and hydroclimatic features are varied. The shallow sodic lakes may entirely dry out in very dry summers, but in rainy years their extensions grow considerably. This extreme changing of the surface of sodic waters takes place in a warm, temperature, continental or as it is called "plainland" climate. The temperature of the air and the distribution of precipitation in time and space is rather capricious. It is here that the yearly mean temperature in both positive and negative direction shows the greatest amplitude in the country. The mean temperature of the hottest summer month is +22—23 °C while that of the coldest winter month is —2, —3 °C. This means an average 25 °C yearly swing, but in summer sometimes the air warms up to +39—40 C and in winter it cools down to —29, —30 °C occassionally. The very hot days followed by relatively cold nights. The greatest amount of illumination in both time and energy was observed here, since heat losses owing to emission are the greatest here daily, but also throughout the year. The year is divided into a wet-cold and a dry-warm period. In winter and spring evaporation is slight, but very significant in summer and autumn. Summers often bring 2—4 weeks of drought. The annual precipitate is between 500—600 mm, which is very little and the distribution of the precipitation is also very uneven.

The above-mentioned features greatly affect the stagnant waters and their closer environment. The heat energy of the summer period causes quantitative and qualitative changes in the climate of the lake and also with their biocenosis. Especially great are the changes that take place in the water balance and hydrological conditions of the lakes. As a consequence of the intense evaporation the loss of water is so great in summer that the precipitation of the season cannot make up for it.

In the course of our research it was shown that the volume of the precipitation falling into the lake compensates only about 63% of the annually evaporated watermass. Comparing the evaporation and the annual quantity of precipitation the water balance shifts to the negative side. In the lakes of the southern plain owing to the different values of evaporation and precipitation there is a 70—120 mm shortage of water in the summer period. This meand a 0,5—1,0 m yearly fluctuation of the water level. Serious water losses occur in the period between the middle of June and the middle of October and they seriously affect water life and other natural processes. To give a short example: with the evaporation of water the salt concentration increases as well as the quantity of suspenden load enlarges. In the case of lakes shallower than 1 metre — where usually a complete evaporation takes place — the sodic watel microfauna was still significant even when the concentration leapt up from 2500 mg/r to 40,000 mg/l. With deeper lakes, however, where evaporation is not cimplete only a growth of 2,5—5000 mg/l was observed.

The nation of climatic conditions of sodic lakes seems a bit elaborated for the first sight since when talking about the weather we usually mean both the climateo the air-space and the ground surface, Climate is a set of climatic conditions dominating in a given area and at the same time it is a set of those aerial phenomena and processes that have ever occurred there and are very likely to occur in the future, too.

Surface waters may be subject to the aerial climate in a meteorological sense, however, from the point of view of their living world water areas have a specific climate of their own. This climate is partly characterized by specific water features (alkalinity, dissolved salts, gases, pH, electric conductivity etc.) and partly by such as correspond to certain factors of the air-space (temperature, light, dynamic conditions, O_2, CO_2 pollution etc.).

Beside the territorial distribution of heat energy the duration of sunshine is also an important factor with the climatic conditions of the lakes. Transparency — as a characteristic feature of waters — is of great importance with lightabsorption. The waters of the area between the Danube and Tisza fall into two groups from the poin of view of transparency and transillumination:

1. Relatively well transilluminated lakes: their chief characteristic is transparancy over 200 mm (based on SCHELL spe cimen of writing), their depth is 1—2 metres or above. The colour of the water is light, borwnish, yellowish-green. Their underground water supply is very small in summer, surface contribution is scarce if any. The shore is generally covered by higherclass association, while the surface of the water is covered by pondweed communities. A hogh-class water fauna is also characteristic of this kind of lake.

2. Morr or less transilluminated lakes: their chief characteristic is transparency over 200 mm and more than 1 metre's depth. The colour of the watef is light (greyish-white, turbid). The supply of water is partly periodical, the flow of underground water is slow, surface water contribution is minimal. In summer the water of the lakes completely evaporate, their basin is covered by thick alkali silt. High-class plant communities are unimprotant in this type of water.

As shown by our research the measure of transparency changes in the course of the year. In simmer months transparency leassens to the half if compared to the winter period. It is the more so with less transilluminated lakes. Transparency is closely related to the climate of the water, especially to its temperature. In the changing temperature of the water we can observe the reciprocal effect on the conditions of the transparency of the water. Therefore under the influence of the water climate the transparency of a given lake changes significantly during the period of illumination in a single day. For example with less transilluminated lakes[1]the energy of light disperses in the upper thin layer of water, so this layer is of a higher temperature. With relatively well transilluminated but shallow lakes the lower layers of the water are warmer than the upper ones in the period of their warming up (the morning hours), since the active level at this time is the lake basin. This phenomenon leads to the acceleration of the vertical levelling convection of heat. With this turbulent movement the floating load of the water increases which, in turn, lessens transparency that is the deep penetration of light. This condition leads to the higher temperature of surface water level. So the change in light transmission plays an important role in the temperature of the lakes.

In the case of the lakes in the KNP area it was found that owing to the relatively small extension of the area there is no significant difference in the amount of light energy reaching the surfaces of different lakes. The warming up and coeling down of the lakes takes place in almost the same way. In winter stagnint waters in temprerate climatic regions usually freeze, shallow waters often freeze to the basin. The average thickniss of ice is 10—20 cm, but sometimes it reaches 30—40 cm. The first freeze usually comes at the end of November or the beginning of December. However, sometimes ice appears as early as October. Thaw begins in the second half of February and the beginning of March, but in extreme cases it may shift to the end of March or the beginning of April.

Ice formation on the lakes is influenced by several natural factors. First it is lakes without vegetation or scarce vegetation that freeze. Where the vegetation (reeds, bulbrush stc.) is thick, ice formation is normally 7—10 day delayed. In such cases ice formation does nit begin along the shore but on the contact line of the vegetation and the open water. It is especially noteworthy that sometimes the shore is void of ice because of the underground current reaching it. At this time in the ice-covered water-mass a stratification of heat occurs. This stratification in our lakes takes place between —0 °C and —4 °C. Water temperature is usually +4 °C near the basin while it is around 0 °C right underneath the ice. The colder and less dense water is above and the warmes and denser water is down in the deep. This inverse stratification can be observed in every lake.

As soon as ice disappears in spring the whole water volume starts slowly warming up. The warming up takes, place mainly by heat absorption from the air-space. Heat absorption can be quickened up to a great extent by the wind, since air motion promoting the turbulence of water may come tobe a major factor with relatively shallow waters.

In spring our lakes rapidly warm up thans to the intense energy illumination and heat absoprtion from the air. The warmind up generally affects the whole volume of water, since in spring air motion conditions are a factor of increased importance.' By means of turbulance an intense circulation of the water begins between surface and bottom.

The most important changes from the point of view of the microclimate of the environment and the climate of the water area are experienced in the summer period. With the water volume considerably changing a specific situation appears in the climate of the waters that reinforces the conditions of alkalization. In summer water temperature lessens if we go downwards from the surface and this phenomenon may lead to differences in the stratification of heat with lakes of different types. In the case of less pure, so called "badly transilluminated" lakes the upper layer of the water warms up relatively well in times of summer illumination. In thickened alkali puddles the difference in temperature between surface and bottom (10 cm thick water layer) may well be 5—8 °C. In the stratification of relatively well transilluminated and deeper (1,2—2,0 m) lakes the difference between surface and bottom is not as great as in shallow waters that are non-transparent, turbid. In the stratification of heat of these waters there are three zones: from the surface to the depth of 0,5 m, then between 0,5—1,0 m and from 1 m to the bottom. The upper zone sensitively reacts to daily temperature changes, the middle layer can be considered an isotherm zone from the point of view of heat-stratification and in the lowest layer temperature lessens with the depth. The water temperature in tihis region is a function of the warmind up or cooling down of a longer period of time and not a single day.

In spring as a result of significant heat illumination as well as heat absorption from the air our lakes warm up fairly quickly. In summer and autumn the water temperature of the surface is usually higher than the daily mean temperature if the air, while maximum water temperature is normally lower than maximum air temperature. Surface water temperature is generally 3—5 °C below maximum air temperature. In case of warm aerial advection even a 7—8 °C difference may occour. In a microclimatic sense the water volume of the lake and the contacting air are in active interaction. The degree of interaction is high in times of summer illumination. So e.g. in the air-space above the lakes the temperature of the macroclimate falls notably.

The daily amplitude of air temperature above the lakes is generally 2—3 °C less, which is a result of the slow warming up of the water volume and the good heat-preserving capacity of the water. On natron lakes and in their shore regions the difference caused by the heat economy of the water is strongly felt in the period of cooing down (at sunslet anad nitght). However, radiation values do not definitely diminish when moving away from the lake since the shore environment is made up of different substrata. It is sand-dunes and low-lying sites that cool down most. In sommer during the cooling down period the latter become the reservoirs of cool air-masses. The cool air-masses that originate in higher-lying areas flow down towards the depressions, so in the shore-strip of the lakes a mixing zone with strong condensation (formation of micro-precipitate) comes into being. Therefore here frequent dews and local fogformation are observed. The microclimate[1]of the shore zone varies according to the circulation of the air-masses of the water and the dry ground region; whichever is in the foreground it determines the microclimate of the shore. Those regions where in the environment of the lake there is higher-class vegetation (wood, reeds) are exceptions to this. Here local air motion is modified by the wind protection of the stock.

Where in the surroundings of the lakes the vegetation is relatively scarce, air motion is much more free and the is a closer contact between the microclimate of the water and the dry region. During the period of warming up the heat and moisture content of the air above the vegetation-free silt-surface of the shore-strip equalizes as a result of free air motion. In calm periods of intense illumination the testraining influence of the water-masses is felt, of course, moving away to a 100 metre's distance from the shore this influence is not felt. This practically means that the temperature and the air moisture features of the sandy surfaces in the neighbourhood of the lakes show an extremely continental character. In Windy weather the climatic effect of the dry wind-blown sand areas dominates even in the shore regions of the lake.

In the summer illumination period resulting from the slow warming up of the water frequent inverse heat-stratification occurs in the air space above the water. Above the lakes the warming up is generally moderating. The fall in the temperature of the air is not in proportion with the breadth of the waterlayer, that[1]is the change in both time and space of the air temperature above the lakes of different depths is about the same.

In bright, calm summer-weather the maximum temperature above the water is felt about 2—3 hours later. This is a consenquence of the slower warming up of the water and the contacting air-space. As a local phenomenon it causes a slight local circulation of air between the water surface and the shore region which may result in the higher moisture content of the air in the shore zone. The microclimate of the shore zone varies in accordance with the circulation of the air between water and ground, and in other it varies according to the climatic features of the dry ground surface.

Lower-class water vegetation is also a factor of the temperature of sodic waters. Water vegetation can greatly influence the vertical and horizontal distribution of water temperature. Water temperature tests show that the dense surface or rooted seaweed communities at the depth of 20—30 cm turns into an active surface owing to illumination and this layer is warmer than the temperature above it. Under the influence of intense warming up a so called "springing layer" is formed, which changes the regular order of the heat-stratification of the water. In comparison with such parts where there is no seaweed community, in dense seaweed communities we can observe a 5—6 °C difference in water temperature at the depth of 20 cm.

The heat-stratification modified by the seaweed community may have other interactions as well. E.g. with the upper water level significantly warming up the turbulent mixing may lessen. In summer, in the case of high water temperature the latter may lead to a great shortage of oxygen, the accumulation of organic gases and other pernicious effects related to this.

In the air-space of the south plain lakes the temperature swing of the macroclimate greatly moderates. Above the water of the lakes the daily amplitude of air temperature is generally small (2—3 °C), which is due to the slow warming up and the good heat-preserving capacity of the water-masses. The effect of heat-presevation shows best in the cooling period, in the afternoon and at night as reflected by the heat-radiation values. The values of radiation minimum, however, do not diminish unanimously when moving away from the lakes since they are modofied by the different substrata. There is a common phenomenon that the cold air-masses of higher regions occupy the depressions of the lakes. At this a time a mixing zone is formed in the shore-stretch, where there is a strong process of condensation. As we found in the shore zone in the summer period there is a frequent formation of dewe, but also of local fog in cooler weather. The latter has a detrimental effect on the shore vegetation e.g. the rusty disease of the leaves of plants, etc.

In the period of cooling down the heat-stratification of the air is of normal distribution. Temperature inversion here — as we find it on dry ground — does not occur. Owing to the differences in cooling down the air above the water is relatively warmer than above the dry parts of the relief. As a consenquence a local circulation strats between the colt and warm air-masses. Right after sunset this phenomenon causes a secondary warming up (minor maximum) in the air-space of the environment of the lake.

During the day owing to the slow warming up of the water inversion frequently occurs in the air-space above the water. The same phenomenon was observed above the wet silt-surface of drying lakes. Research at the lake of Kelemenszék in bright, calm, sunny weather showed that above the wet alkali silt there is a heat-stratification similar to that above stagnant waters. On the other hand in the immediate neighhourhood (50 m) above the surface of dry alkali soil the air temperature and the distribution of the gradient was normal.

On a wet, sodic silt-surface the tedree of warmth is moderate, the daily fluctuation of temperature diminishes. Seven days after the complete drying out of the basin the heat-stratification is of even distribution. This also proves that periodical lakes in a climatic sense lose the character of a lake. Above stable waters warming up is more moderate, but the fall in the air temperature is not in proportion with the thickness of the water-layer, that is the change in both time and space of the air temperature above lakes of different depths is about the same.

As a result of general air motion as well as circulations arising from differences in local temperatures the climate of the air-space above the water gets in close contact with the climate of the shore zone. The circulation-caused interaction can be very well seen in the conditions of air temperature and air moisture. The microclimate of the shore zone depending on which air-mass gets into the foreground in the course of the circulation — the air-mass of the water of that of the groundcorresponde the climatic features of the water space or the dry ground respectively. An exception to this are those regions where the higher-class vegetation (wood, reeds) provides protection against air motion.

Reeds as a prticular plant community of the shore has a peculiar microclimate in spite of the interactions between the lake and the dry ground. In connection with the freezing of a lake we have already pointed out the role of reeds as a modifier of microclimate. In summer we have to differentiate between the reeds standing in the dry and the reeds standing in water, since they have a different climate. E.g. in submerged thick reeds in sunny weather thermal inversion becomes steady. Opposite to this in dried out redds in the warming period heat-stratification is normal. The climatic difference here not caused by the presence of water, but by the differences in the illumination conditions. In the reeds of the dried out area together with the drying of the foliage the conditions of illumination change as compared to reeds communities still standing and vegetating in water. In a dry area the active surface is at the bottom of the vegetation while in water it is at the upper third of the vegetation-stock. In the lower of the latter as a consequence of the shadowing effect of the foliage the extent of illumination notably diminishes and because of the constant shadowing effect this layer warms up less. The temperature of the water can never equalize in a horizontal sense since convection is strongly obctructed by the thick vegetation. So warming up takes place only by way of heat absoption from the air. In the dense vegetation air motion decreases to 0 m/sec. so even this process slows down. As a consequence the temperature of the water surface here is 4—5 °C lower than that of the 10 cm thick air layer above the water, while above open sheets of water this difference is only 2—3 °C.

In spite of the low temperature of the bottom in the upper levels of the reeds the temperature is relytively high and here rapid changes in temperature occur. The active level in this case is not one single level, since the energy of the sun is distributed in a larger cross-section of the stock and the warming up of these interactions the upper layers are warmer, but at night the middle zone of the vegetation is the coldest.

In summer when the sun is high in the sky in the dry basin reeds illumination reaches as deep as the basin so the highest temperature is characteristic of the lower part of the stock. But it is also here where the lowest temperature are taken. From a microclimatic point of view we can speak of the heat-stratification of the air with two types of the smae kind of vegetation. If compared to submerged reeds the reeds of dried out basins do not show a great difference either from the point of view of air moisture or temperature. When examining the climatic conditions of a lake reeds are of great interest not only because they have a specific microclimate of their own, but — since they take up a fairly wide stretch in the shore zone of south plain lakes — also because they play an important part in the modification of the air circulation of the lakes, in the changing of the conditions of evaporation and they are of major importance for water wildlife (e.g. shelter of water-birds, protection against heat and illumination, stc.).

In vegetation-free areas in the environment of natron lakes — where ait motion is free — there is a close interaction between the microclimate of the water and the dry surface. In the daily warming up period on the vegetation-free wet ailt-surfaces of the shore strip the effect of the surrounding dry area is felt in the distribution of heat and moisture of the air. In the period of cooling down in calm eather the effect of the water is stronger. Here as a result of free air motion the temperature and the stratification of air moisture equylizes in the air levels and the dry surface climatic character strengthens. In calm weather with strong illumination, however, the temperating effect of the water-masses is greater, while moving away from the water it is smaller.

The different surface rock material of the environment of the lake has also a strong effect on the microclimate. Above dry sandy areas in sunny summer days heat distribution can be very extreme. Moving away no further than 20—25 m from the water in the day we find a high temperature and a low moisture content of the air. The moderating effect of the water can only be felt in the period of cooling down (in the afternoon and at night)[1]but this phenomenon rapidly ceases to be when moving away from the water. E.g. above sandy and loess surfaces at a 100 m distance from the lake the daily changes in temperature and air moisture content show an extremely continental character, i.e. the effect of the mass of water upon its shore environment is of minor importance.

The chamical features or the water are in strong correlation with the climate of the lakes. We have found that these features are primarily functions of the supply of water evaporation, two factors significantly affecting the conditions of condensation. These phenomena will be expounded in a future work.

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