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HOLOCENE ENVIRONMENT IN HUNGARY

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HOLOCENE ENVIRONMENT IN HUNGARY

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Edited by
MÁRTON PÉCSI
LÁSZLÓ KORDOS

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Technical editor:
Mrs. J. SIMONFAI

Revised by
Á. KISS
M. PÉCSI
Mrs. É. PÉCSI–DONÁTH

Translated by
O. TOMSCHEY
and the authors

Technical board:
K. EVERS, J. FÜLÖP, Mrs. ZS. KERESZTESI, Mrs. J. LÁNG, M. MOLNÁR,
J. NÉMETH, I. POÓR, Mrs. E. TARPAY

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ARCHAEOLOGY

PREFACE

Hungarian researchers of the Quaternary intend to contribute to the 12th congress of the International Quaternary Association in Ottawa, Canada, by the preparation of two volumes of papers. The present one is entitled *'Holocene environment in Hungary'* and published by the INQUA Hungarian National Committee with the support of the Geographical Research Institute Hungarian Academy of Sciences.

The authors of papers, who are geologists, geographers, geobotanists, ecologists and physicists, attempt to describe the paleoenvironmental changes in the territory of Hungary during the Holocene and, relying on recent data, to inform about the paleogeographical and ecological prehistory of the Carpathian basin or some of its typical areas.

Motivated by the recently declared principles of the INQUA, Holocene paleoenvironmental research has increasingly gained ground within Quaternary studies previously dominated by investigations of the Pleistocene. For this reason, the INQUA Hungarian National Committee acknowledged the need to publish a separate volume on the Pleistocene under the title 'Pleistocene environment in Hungary'.

The contributors and producers of both volumes dedicate their work to the 12th INQUA Congress.

Márton PÉCSI
president,
Hungarian National Committee
INQUA

László KORDOS
secretary,
Hungarian National Committee
INQUA

Budapest, April 1987

ENVIRONMENTAL CHANGES

M. Pécsi--L. Kordos (eds.)
Holocene environment in Hungary
Geographical Research Institute
Hungarian Academy of Sciences
Budapest, 1987

CLIMATIC AND ECOLOGICAL CHANGES IN HUNGARY DURING THE LAST 15,000 YEARS

L. KORDOS

ABSTRACT

Recurring and opposing climatic changes during the Pleistocene played a fundamental role in the evolution of the biosphere and, consequently, that of the natural environment. The system of the environmental development and the hierarchy of the interactions generated by the general warming period which started some 18,000-20,000 years B.P. are shown. It is the most suitable period for modellizing, within the human evolution, and its activity has brought about changes in the environment leading to basic modifications of the ecological balance of the Earth. Historical analysis of the elements of the natural environment, and of the interactions between nature and society offers general guidance for preparing longrange meteorological predictions and for lessening the consequences of catastrophic natural events.

* * *

INTRODUCTION

The last 15,000 years has had an utmost significance from the viewpoint of the evolution of mankind as well as of the development of the present environment. The Pleistocene Ice Age that can be characterized by the alternation of periods with decrease or rise in temperature has begun already two and a half million years ago. Within this Ice Age, some 18,000-20,000 years ago, near the last glacial culmination, i.e. Würm glaciation a still continuing cycle has begun. During the last 10,000-15,000 years a considerable rise in temperature took place all over the world the degree of which can be considered as that of an interglacial phase and our Holocene period is by all means its culmination.

The results presented here are in connection with the activity of the World Climate Programme. These are valid for both: Hungary and the continental areas of Middle Europe.

Conclusions concerning the history of climate based on palynology (ZÓLYOMI, B. 1958; JÁRAI-KOMLÓDI, M. 1969) were already well-known in Hungary before and later the so-called "vole-thermometer" and "Arvicola humidity" methods based on micromammals yielded data of similar value (KRETZOI, M. 1957; KORDOS, L. 1977b). More recently paleoclimate data measured by oxygen isotope method in the subsurface water samples of the Great Hungarian Plain dated also by radiocarbon method provided new important data (DEÁK, J. 1980; DEÁK, J. and KORDOS, L. 1980).

The results of these methods giving numeric climatic values can be well correlated with each other *(Fig. 1)*.

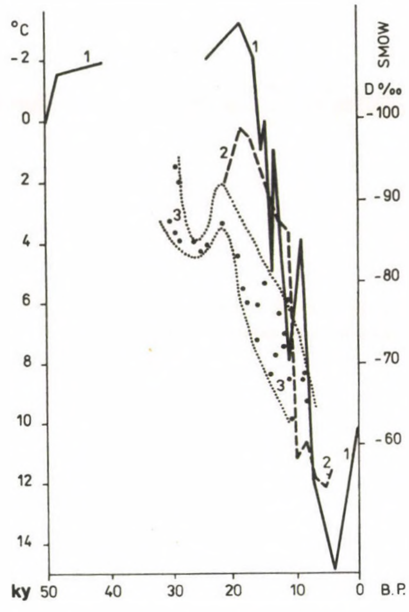

Fig. 1 Changes of temperature during the past 50,000 years in the territory of Hungary on the basis of pollen-analysis (1,), "vole thermometer" method (2), stable isotope of subsurface waters (3)

During Würm III glaciation 18,000 years ago, the average January temperature was -18 °C, the average July temperature was between +9 and 12 °C while average annual temperature was between 0,5 and 3 °C. After this period till 9,000-10,000 years B.P. a slow rise in temperature with minor climatic oscillations can be observed (KRETZOI, M. 1957). In the formation of the Holocene Interglacial the emergence of the Early Holocene

climatic optimum played a great role. In the Carpathian Basin this climatic optimum rose 7,000 and 8,000 years ago with an average July temperature of 18,8° C *(Fig. 2)*.
This optimum was followed by a cooling down till 3000 B.P. Then a still lasting oscillation has begun with several rises and decreases of temperature like the so-called "Little Ice Age" or "Little Optimum" which can be proved all over the Northern Hemisphere (KORDOS, L. 1977b). Changes in temperature were accompanied also by those in humidity conditions. Though during Würm III glaciation the climate was arid the quantity of precipitation which was necessary for subsoil waters must have fallen. Together with the temperature rise the humidity rose, too. For its degree, however, we have only relative data from the Holocene measured by the so-called "Arvicola humidity" *(Fig. 3)*. According to the distribution of values representing the frequency of Arvicola humidity maximum in the Carpathian Basin was till 8,500 and 7,000 B.P., and between 4,000 and 2,000 B.P., while minimum was between 5,000 and 4,000 B.P. and between 1,500 and 1,000 B.P. (KORDOS, L. 1977b). The climatic change caused basic transformations in the development

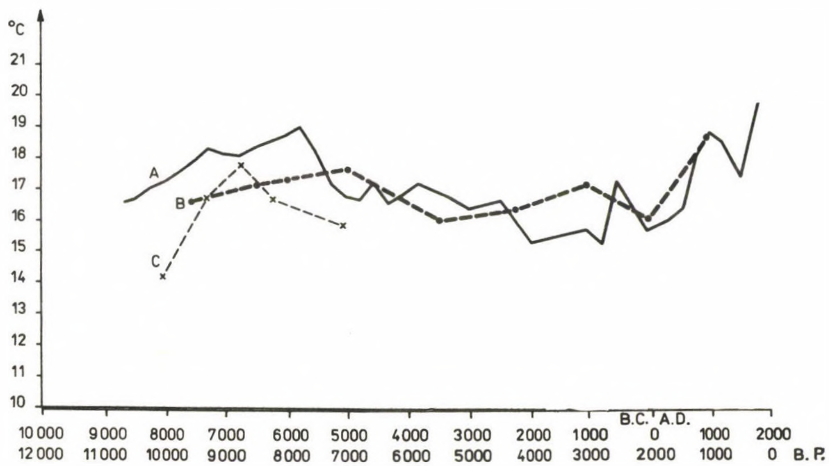

Fig. 2 Changes of average July temperature in the Holocene calculated by "vole thermometer" method

A = Hungary; B = Czechoslovakia; C = Frank Alb (BRD)

of both geomorphological and pedological conditions of Hun-Hungary's territory. Würm III glaciation with its arctic cool and cold climate was still a period of loess-formation, the so-called Tápiósüly Formation emerged then, but during the short humid period in 16,800 B.P. with rise in temperature already at Tápiósüly a humus level was developed (PÉCSI, M. 1977). Likewise, during the last glacial culmination of the Würm period, in certain areas of the Great Hungarian Plain, under the cold, arid climate, there was wind-blown sand movement, which produced characteristic sand formations (BORSY; Z. 1977). At the same time, the Danube decreased approximately to the half of its 40 per cent outlow factor because of the

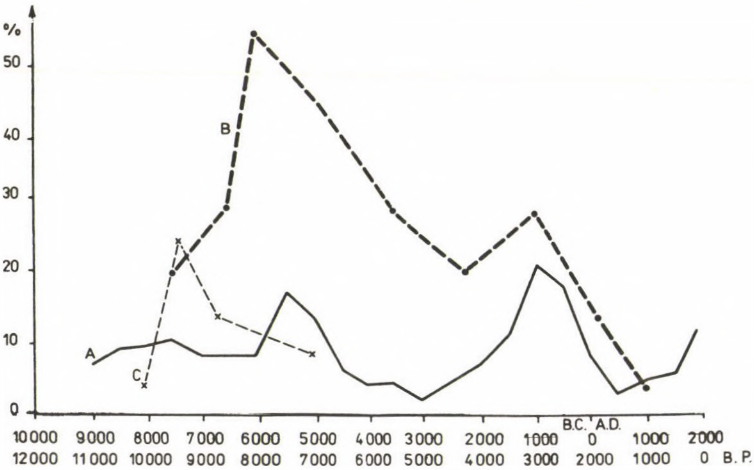

Fig. 3 Relative changes of annual humidity conditions in the Holocene measured with the aid of "Arvicola humidity" method
A = Hungary; B = Czechoslovakia; C = Frank Alb (BRD)

disconnection of the Alpine catchment area. Summer dry periods were interrupted by inundations caused by the coincidence of early summer thaw and precipitation maximum. These inundations transported a great quantity of debris. The valley-deepening activity of rivers started parallel with that rise of temperature immediately subsequent to the glacial (SOMOGYI, S. 1961).

During the last 10,000 years the changes in climate were not so significant. Alterations represented by oscillations of annual average temperature of a few degree and of humidity had, however, a considerable effect. This general trend of rise in temperature was favourable for soil formation, and during the climatic phases which included humid periods soil formation began. During the Holocene period 3-5 soil formation phases can be distinguished in Hungary. During arid periods between humid ones sand areas began to move again and the water-level of rivers had more extreme oscillations.

BIOLOGICAL EVENTS

The development of the vegetation of Holocene Interglacial is well-known on the basis of wide-scale palynological and anthracotomical researches (ZÓLYOMI, B. 1958; JÁRAI-KOMLÓDI, M. 1969; STIEBER, J. 1967). The evolution of vegetation began with a cold, arid loessic steppe and after the formation of pine and birch associations of subarctic taiga and forest it led to the deciduous forest vegetation indigeneous now here.

At the same time, there was a great change within the fauna, too. It was already well-known before that Upper Pleistocene big mammals like mammoth, wooley rhinoceros or cave bear didn't survive after the end of the Würm III glacial in Hungary. After the disappearance of the extinct and oppressed cold-bearing fauna, the animals that lived in pessimum till that time began to multiply in great quantities; while as an effect of the climatic change that made a new living space favourable for them, other animals immigrated. Thus, parallel with the rise in temperature a great part of the fauna had been altered; a new faunal wave has developed.

To illustrate this process we should like to review here the changes of vertebrate fauna of the Hungarian Uplands during the last 10,000 years.

The rise in temperature which took place during the present interglacial, stratigraphically called as Flandrian, had a great effect on the fauna and vegetation; the culmination of which was in the Holocene climatic optimum. At that time a very significant irreversible change took place in the succession of the organic nature, i.e. vegetation and fauna-types accomodated to the cold climate were replaced by modern thermophylous vegetation and fauna. With the complex biological examination of the Holocene sediments of Hungarian caves the development of organic environment influenced by the climatic changes could be directly observed because the different analyses were carried out on the material of the same sediments. According to palynological data the change of coniferous and

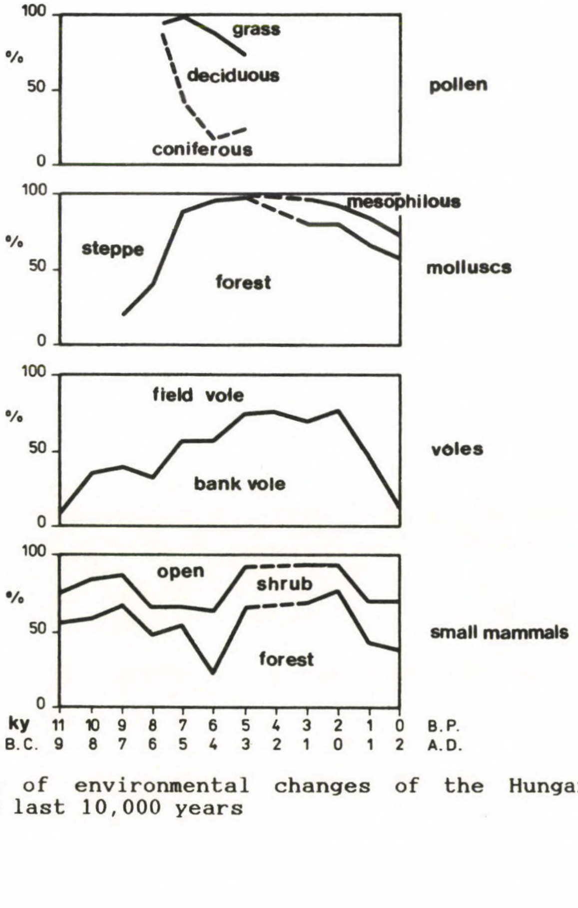

Fig. 4 Tendencies of environmental changes of the Hungarian Uplands during the last 10,000 years

deciduous vegetation already took place during the warm and humid period of the climatic optimum in 7,000-8,000 year B.P. The reconstruction of the ecological demands of vole species and other micromammals as well as of Molluscs yielded similar results *(Fig. 4)*. On the basis of Molluscs we could observe that together with the coniferous (deciduous change the predominance of steppe species was replaced by that of forest ones. Moreover, after the climatic optimum advancing to our times the ratio of mesophyl species and of those that prefer open areas was increasing (FÜKÖH, L. 1979). The change in the ratio of field vole and water vole gave the same results with the difference, however, that while the change of terrestrial Molluscan fauna followed almost immediately the vegetational change caused by the afforestation, vole species and other micromammals followed the transformation of the environment with a delay, i.e. of 1,000-2,000 years. The reason of this phenomenon is by all means the greater adaptible and enduring ability of mammals on the one hand, while it can be explained by the fact that the development of vertebrate fauna should be preceded by the accomplishment of the change in vegetation, on the other.

Summarizing the most important trends of environmental evolution caused by climatic changes which took place since the last glacial culmination it is clear that from the viewpoint of the World Climate Programme we have to put our questions already in a different way. That is, up to the present the simple recognition of qualitative connections, the mere registration of facts of environmental changing effects of the evidently extreme climatic conditions was quite enough.

KEY POINTS OF THE ENVIRONMENTAL EFFECTS

For the modelling of potential future climatic changes, catastrophe situations and their effects on the environment gained from data yielded by the past we have to get numerical quantitative relations. With the aid of climatic and environmental reconstructions for Hungary's territory obtained so far we try here to determine the climatic threshold values the effects of which resulted in changes in the organic and inorganic environment. So far we have been concerned only with general climatic changes of the past 10,000 years, but now we have to deal also with climatic oscillations of shorter duration and minor effect. Now, we can already establish the following: the climatic change taking place during the last 18,000 years had two culminations, i.e. Würm III glacial and Early Holocene climatic optimum. Between these two culminations 10,000-11,000 years had passed, meanwhile in morphological processes we can't observe unidirectional transformation but several periodic phenomena, like soil formation or sand-movement. Generally, we can establish that for the break of cold glacial loess formation an annual rise in temperature of 3-4 °C (from -0.5 to +3-4) and barely 1000 years were necessary. Above the humic loess formed during this period (Tápiósüly humic loess Nº 1) the new annual average temperature decrease of 2,0 °C for 1,000 years brought back loess formation again. The final stopping of loess formation went on together with the long significant rise in temperature with an annual average rise of 4-5 °C for several thousand years and with the increase of precipitation. Thus, after this period climatic conditions suitable for loess formation have not come about in Hungary. (According to the data of PÉCSI, M. 1977; and PÉCSI, M. et al. 1977).

In the realm of organic nature the transition from arctic climate to a warm temperate one was an irreversible change. According to palynological data, as a result of the 10,000-12,000 years, passed between the two climatic culminations and of the rise of annual average temperature by 10-11 °C the arctic continental mountain steppe and open, cold continental lowland steppe gradually transformed into thermophylous deciduous forest (JÁRAI-KOMLÓDI, M. 1971; 1973). From the viewpoint of paleobotany this transformation is divided into 9-10 units (phases). It can be established that for the development of a new phase, new quality, a change of annual average temperature of 1-2 °C and 1,000-2,000 years are necessary.

The evolution of the vertebrate fauna was also unidirectionally irreversible. In Hungary from the Würm III glacial period 43 mammal species are known so far. Till the beginning of the Holocene, during approximately 8,000 years, when there was a rise of 5-6 °C in the annual average temperature, 14 species disappeared; 6 of them extincted. The following significant rise in temperature, an annual average rise of 3-4 °C took place during the next 2,000-3,000 years. In this period a fauna adapted itself to cold climate has lost 8 species till the culmination of Early Holocene climatic optimum. It was not before that rise in temperature which took place at the beginning of the Holocene that the fauna diminished in this manner was first replaced by 6-7 new immigrant mammal species (KORDOS, L. 1977a; JÁNOSSY, D. 1979).

A significant completion of the fauna took place only during the climatic optimum when Hungarian mammal fauna increased by 15-16 new species. Thus, 10,000-12,000 years and a rise of 10-11 °C in annual average temperature were necessary to the process during which a completely new faunal type, a new wave developed *(Fig. 5)* with the exchange of about the half of the original nature animal stock.

The investigation of the effect of climatic change and climatic oscillations shorter than 10,000 years should be divided into two parts: different processes took place in extreme climatic culmination periods and different ones during transitional periods between the cold ones. Climatic culmination situations mean always a boundary in the development of the environment because usually a long time passes until the formation of the same climatic conditions. Würm III glacial with its loess formation and later with the stopping of this process is a climatic culmination. In the evolution of the living nature the character of the change that takes place in the culmination situtation depends on the condition of the succession, i.e. whether till the beginning of the succession reached its climax condition or not. If it reached - like it happened during Würm III glaciation - loosening of the developed association begins and with crossing of threshold values its irrevers-

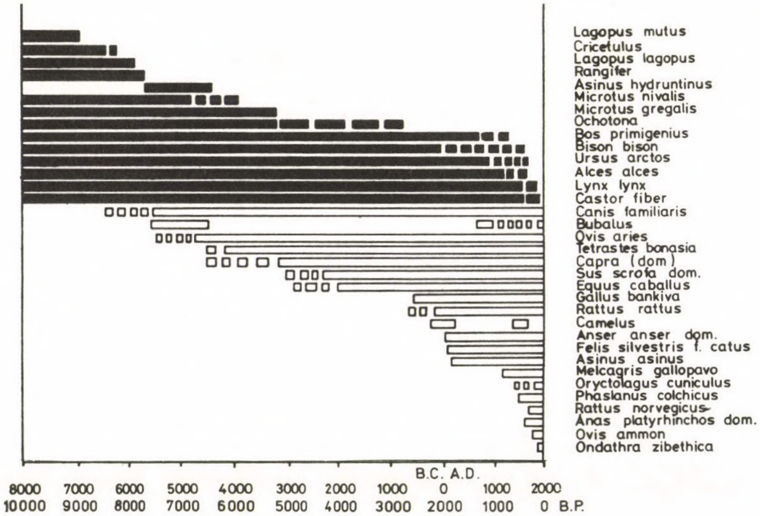

Fig. 5 Vertebrate animals extincted and disappeared (black) and appeared (light) during the Holocene in the Carpathian Basin

ible transformation begins. In this case an average annual rise of 3-4 °C in temperature during 2,000-3,000 years is necessary for the extinction of overspecialized species and for the immigration of species suitable for that. This rise in temperature also means that these above-mentioned animals cannot return to their previous area any more even during a later climatic deterioration.

In Hungary's territory during the Holocene climatic optimum an annual average rise of 1 °C in temperature and 1-1,5 thousands years were necessary for the completion of the "impoverished" Pleistocene vertebrate fauna. In longer periods between climatic culminations, climatic oscillations have an extraordinary environment-forming role. Small oscillations of temperature and of precipitation lasting for 500-1,000 years are enough to change significantly the surface development processes and to make alternation in the predominance relations of the organic nature.

According to paleontological data from Hungary, during the 1,000-2,000 years passed between the postglacial Alleröd and Dryas phases, the oscillation of the average annual temperature was 3-5 °C while according to the "vole thermometer" method it was only between 2-3 °C (JÁRAI-KOMLÓDI, M. 1969; KORDOS, L. 1977b). Early Holocene Preboreal afforestation was stopped by a rise of 1-2 °C in temperature, and desiccation during the Boreal period lasted only for 1,000 years. The few Hungarian evidences also show that oscillation of the average annual temperature and change of precipitation during only 1,000 years or even in a shorter period are quite enough for the rise of a significant and permanent alteration of surface development processes. At the same time, changes in the organic nature are characterized not by the apppearance and disappearance of new forms but by an areal expansion or regression together with the growth or decrease of individual number within species adapted to the changes of environmental conditions. At present the geological and paleontological investigations of 500 and 1,000 years accuracy at best are unsuitable for its reliable numerical measurement; now the only real possibility is to registrate tendencies.

In spite of our knowledge of several environmental evolutionary phenomena for the past few thousands years which can be traced back to climatic oscillations of considerably shorter length than the previous ones the threshold values of these phenomena are so inaccurate that it would be premature to evaluate them numerically. These minor oscillations lasted only a few hundred years or even for a few decades. All examples enumareted here to demonstrate the rise in temperature during the Holocene throw light upon the novelty that with the increase of the accuracy of paleontological and paleo-climatological investigations we have an even wider possibility to evaluate complex environmental evolutionary tendencies and their degree emerged as a consequence of climatic oscillations. Thus, in this respect we have to aim at the elaboration of model variations for the possible future types of climatic changes used for this work the examples of events already passed. With the aid of these model variations we can and have to take efficient precautionary and diminutive measures in course and efficiency (AMBRÓZY, P.--CZELNAI, R. and GÖTZ, G. 1977).

Our examples were taken so far from the natural environment untouched by human activity. Environmental evolution tendencies of the past 3,000-4,000 years and especially those of the last one thousand years are considerably and sometimes even basically influenced and altered by the increase of human activity.

THE HUMAN ACTIVITY: A NEW FACTOR

The evolution of Homo sapiens took place by all means in the period which preceded Würm III glaciation. His increase in individual number and later his determinative activity, however can be put only for the period after Würm III. To measure this process is an expressive method to compare the number of ancient settlements to the time passed during the periods in questions. During Upper Paleolithic, i.e. the period that preceded Würm III glaciation in Hungary 857 years were necessary for the emergence of a single settlement. From the last cold oscillation of the Würm till beginning of the Holocene (i.e. till 10,000 B.P.) the number of years decreased to 213 and then, till the Holocene climatic optimum it decreased to

145 years. The intensive population growth, the "demographic explosion" in Hungary's territory took place during the climatic optimum which coincided with the Neolithic. In that time in every 1,6 years one settlement was formed. According to the real data it means that from the approximately 2,500 years' period of the Neolithic approximately 1,500 settlements are known in Hungary's area. During the later Copper, Bronze and Iron Ages this settlement index varied between values 1.01-1.5 years/settlements (BÁCSKAY, E. 1976). If the past 1,000 years is compared to the number of present settlements we get the value of 3.0-3.3. Though population index is the result of a rough estimation it indicates undoubtedly that the considerable mass population of the Carpathian Basin coincided with the Holocene climatic optimum. The first peoples immigrated into the territory from the South and were influenced by the rise in temperature. In the territory of Hungary the population movement of east-west direction began only after the Neolithic during the climatic deterioration, with a decrease of 1.0-1.5 °C in annual average temperature during 2,000-3,000 years. Today in some cases the direct connection between population movements and climatic changes is already unambiguous fact. During the Classic Greek Period there was a significant rise in temperature all over Europe and later the Roman Ages coincided with a climatic oscillation that could be observed all over the world. The sea level was 2.5 m lower than today and this means 1,000 km^3 of water. The glaciers of this period, paleoclimatologically called as Roman Phase, were approximately twice longer than today. According to the meteorological records from the second century A.D. in Alexandria the precipitation was usual during the whole year except in August, while nowadays the area gets only winter rains. Roman agriculture covered the whole seaside area of Northern Africa. The period that followed the Roman phase having an utmost importance from the viewpoint of Hungarian Prehistory was generally warm and dry (FAIRBRIDGE, Rh.W. 1976). Thus, these climatic oscillations of 3,000-4,000 years duration still could strongly determine the migrations of human groups through the complicated economical and social relations. We can continue the enumeration of well-known examples of processes during which the effects of environmental changes influencing mankind can be observed. It seams to be more suitable, however, to reverse the question and detect the processes of human activity tending towards the alteration of climate, through the ages. In Hungary man started his first significant environmental transformation activity after his mass appearance and with the extension of agriculture after the climatic optimum. The "Neolithic Revolution" was a milestone not only from the ecological and social point of view but it was also the starting point of a new evolution of the environment as we are able to recognize this clearly now. The process of the significant alteration of the environment by man began with forest cleaning, with the agriculture and the extension of agriculture areas and with the building of dams. During Bronze and Iron Ages the constant large population stabilized agriculture areas, too. From Roman times on already a great number of artificial establishments are known which lead us to the well-known environment protecting problems of our age.

Among the effects of human activity which can modify the environment the change of climate can be taken seriously only from the beginning of this century, but the vegetation and fauna were already influenced by this activity several thousand years ago.

In Hungary, a good example for the irreversible change of the vegetation is the Aggtelek Karst (KORDOS, L. 1975). According to paleontological and recent phytogeographical investigations, mostly various forest associations existed here in the Early Holocene with smaller steppes on the rock (JAKUCS, P. 1954; KORDOS, L. 1978). The forest cleaning activity which began 6,000 years ago, in the Neolithic, and which was continuous through the Bronze and Iron Ages and strongly increased during Middle Ages made the soil eroded from the steep karstic hill-sides. The steppes on the rock extended and there was no possibility for the reforestation of karstic slopes. This barrenness produced by man's forest clearance and later by his shepherding activity immediately influenced the vertebrates living in this area; the original composition of species and their ratio were disturbed. Species preferring open areas became widespread and the Pleistocene species, that could have survived till that time as relics, extincted and the way became clear for the harmful hamsters and field voles appearing in great quantities.

Investigating the evolution of vertebrate fauna not only in a small area but in the whole territory of the Hungarian Uplands it is conspicous that the modern "warm" specific composition of the climate-determined faunal succession evolved during the Holocene climatic optimum and started on the natural way of its development to be a new faunal wave succeeding a Pleistocene cold fauna. This new vertebrate fauna is the proper original native stock of game which if adapted itself to the more and more stable climatic and vegetational conditions could survive by all means if human activity had not transformed it fundamentally. But this newly developed faunal wave was disturbed by human activity so it became "anthropogenic". In a situation without human appearance and activity the same development of environment could be experienced which we can observe in the interglacials. Human influence is double here, too, i.e. both biological and social.Man's appearance is a natural stage in the evolution of organic nature, his multiplication, "predominance" are mostly due to the new ecological conditions induced by climatic changes. Besides, by this time, man's intellectual ability reached the level at which he could actively protect himself against natural and environmental effects and to transform gradually nature and environment to be suitable for his demands. This ambivalence, the interaction system of natural and social factors can be painfully experienced in our time, too. Its character is highly similar to the mosaic evolution of organic nature, namely in certain characteristics (interaction systems) the artificial environment made by man can completely make independent itself from nature's influence. Nowadays, the best example of this phenomenon is the complex independent system of submarines or space ships. In other interaction systems the man--environment relation is almost as open as it used to be at the beginning of the Holocene. In spite of the high degree of some situation influences the connection between climate and vegetation is very close even nowadays. Human activity can balance the result of environmental factors only in a restricted sphere. This is the group of questions the investigation of which is aimed at by World Climate Programme.

In the course of historical analysis of the interaction system of environmental evolution and of human activity it seams reasonable for us to call the attention to the fact that the environment and nature conservation problems must not be setting out from the present situation. The nature conservation activity of our age is really a "save what one can" work while in environmental reconstructions the "let's avert catastrophe" attitude predominates. This is quite natural as regards the recently started conservation tasks but in the next phase a really efficient work could be carried out only with the increasing account of time factor together with the experience gained from the long-distance development of interaction systems. Beside the facts enumareted in this article to illustrate this train of thoughts it is worth mentioning that in the Aggtelek-Karst, declared as a National Park in 1985, the natural environment was fundamentally and irreversibly disturbed during the last more than 2,000 years. Similarly, in the area of the Hortobágy National Park not the natural environment, evolved in the Holocene, is conserved but the landscape that was later transformed by human activity mostly by water regulations. Nowadays this transformed landscape seems to be the ancient one for us.

As a conclusion we can say that the interaction system of climatic changes-environmental evolution-human activity can be interpreted properly only with regards to its 10,000-15,000 years history. All this mean a double task for the future. On the one hand, we have to increase the number of more accurate investigations of events that took place in the past and case situations have to be modelled with the aid of data (numerical if possible) using the possibilities given by modern technique, on the other. In this way mankind can prevent, diminish or predict possible disadvantageous changes in the condition of equilibrium of climate-organic and inorganic environment-human activity.

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ADDRESS OF AUTHOR:

László KORDOS

Hungarian Geological Institute
BUDAPEST Népstadion u. 14. H-1143

M. Pécsi--L. Kordos (eds.)
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RELATIONSHIP BETWEEN ENVIRONMENTAL CHANGES AND HUMAN IMPACT UNTIL THE 9TH CENTURY

S. SOMOGYI

ABSTRACT

In the Great Hungarian Plain, the vast lowland area within the Carpathian Basin, the hydrological conditions and terrain configuration that later became the scene of a series of changes in natural and social evolution till the end of the Pleistocene.
During the Late Pleistocene human settlements can be found on dry terrains covered by loess. The main occupation of the population of this period was big game hunting. In the Early Holocene these settlements were influenced by the inundations of rivers. During the period of the Körös culture animal husbandry and agriculture also appeared besides hunting, gathering and fishing.
During the Atlantic period of the Middle Holocene a radical change took place by the emergence of optimum natural conditions. The earlier population that had established modern culture, was replaced by several waves of new immigrants. Simultaneously with the spread of metallurgy, they began to utilize forests and oak groves on sandy soil. During the great climatic deterioration in the period following the Atlantic phase both abundance of water and heavy erosion was characteristic. Rivers had built their N° 1 terraces and the population left their near-water settlements. This process was followed by a new increase in the number of settlements that had already shown a decreasing tendency and from the Copper Ages on the main criterium of establishing settlements became self-defence. Late Holocene can be characterized by varied natural conditions similar to recent ones and till the period of the Hungarian Conquest of 895 AD by nomad shepherd's cultures.

* * *

The period of natural landscape in the Great Hungarian Plain free of social effects was over by the last glacial period's end (Pleistocene). The structural-morphological scheme of the large basin determining the recent conditions and filling the internal part of the Carpathian basin was more or less completed. The most conspicuous feature of this morphology has been represented by the fact that the subsiding basin surrounded by rising marginal mountains was dissected into units differing

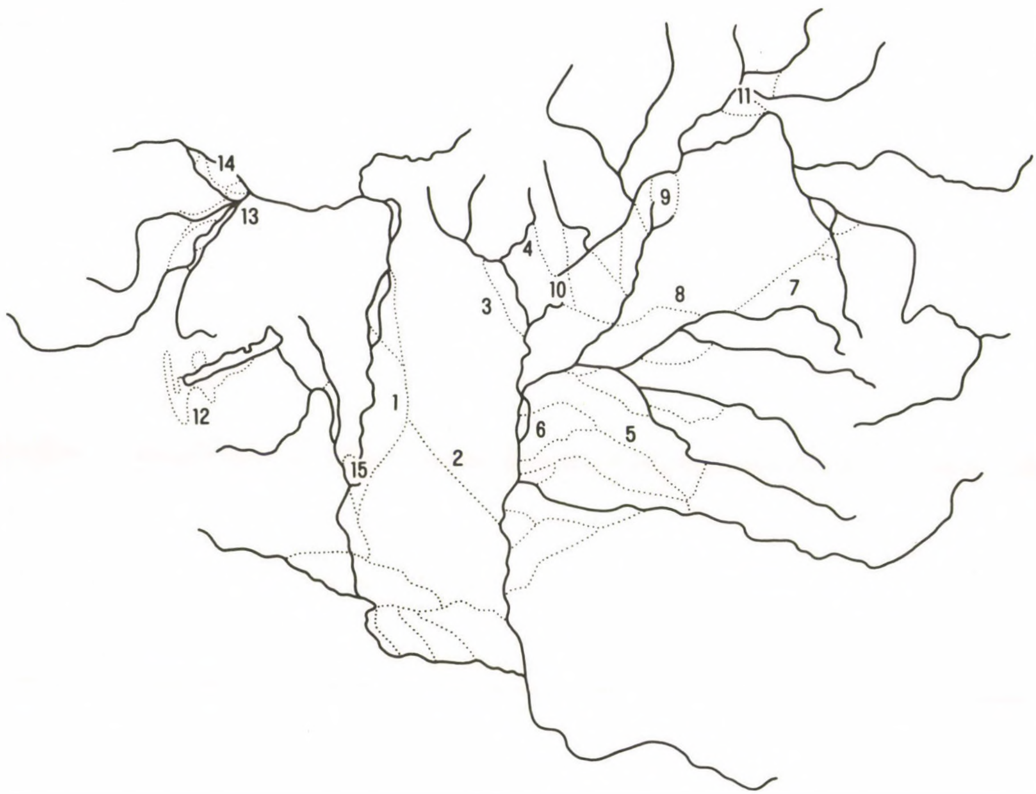

Fig. 1 River network in Hungary's territory at the end of Pleistocene and the main hydrographic changes during the Holocene

1 = Late Holocene side-valley of the Danube between the Danube and Tisza rivers; 2 = the last course of the Danube into the Tisza, (SÜMEGHY, J); 3 = contemporary estuary of the river Zagyva; 4 = contemporary lower reach of the river Tarna; 5 = beds of river Maros at the end of the Pleistocene; 6 = still existing remnants of Kurca and a paleo-stream in the Ér valley; 7 = The Ér valley, carrying away the floods of Szamos and later only those of the Kraszna after the Tisza had left; 8 = the course of Berettyó across the Nagy-Sárrét area before river regulation; 9-10 = the course of the floods of Tisza across the Hortobágy and the Nagykunság; 11 = the course of Tisza into the Bodrog valley; 12 = dimensional changes of the lake Balaton; 13 = changes in the confluence of Rába and Marcal; 14 = changes of river channels in the Szigeköz area; 15 = changes of river channels in the Sárköz area

in the intensity of movement. The more rapidly subsiding surface parts became the local base level of the river network (synclines) while the less rapidly subsiding or stagnant block displays eolian dust (sand) accumulation and loess formation.

The level changes of different degrees are best reflected by drainage. Its Late Pleistocene state is shown in *Fig. 1.* The most characteristic forms are the development of the Danube section south of Pest and the large and bend of the Tisza between Vásárosnamény-Csap and Tokaj in the northern part of the Great Hungarian Plain. The latter was produced by the subsidence of the Bodrogköz-Baktaköz-Borsod and Heves flood plains and by the uplift of the Nyírség in the late Late Pleistocene. Simultaneously, the large depression of the Körös environs was formed between the Fehér Körös and the recent Hortobágy-Berettyó line. Thus, the Great Hungarian Plain was dissected into former alluvial fans (Danube-Tisza Interfluve, Nyírség, Maros-Körös Interfluve), yound depressions (see above) and stagnant blocks of loess formation (Hajdúság, Bácska, Mezöföld). The river Tisza deviating from the Ér-Berettyó-Hármaskörös direction and flowing into the Vásárosnamény-Záhony-Tokaj-Csongrád section became the main river of the Great Hungarian Plain and not the peripheric Danube (SOMOGYI, S. 1961; BORSY, Z. and FÉLEGYHÁZI, E. 1982). This large-scale change of direction of the river affected (shortened or lengthening) the tributaries of the sections in question (Körös, Szamos, Bodrog, Sajó and Zala rivers).

UPPER PLEISTOCENE

This natural scene served as home for the inhabitants of the Great Hungrian Plain at the end of Pleistocene representing the Mousterien and Gravettien cultures. It is characteristic that all the prehistoric sites in the Great Plain were found under the loess cover, i.e. the dry surface of the given period.

The last glacial (Würm III) culminated in Europe about 18,000 B.P. At that time cold-dry climate predominated in the area of the Great Hungarian Plain, with monotonous loess tundra (Danube-Tisza Interfluve, Tiszántúl and Mezöföld), woody and shrub tundra (in the Danube flood plain). In the subsequent millennia gradual amelioration took place in the climate, the cold loess steppes became forested with pine and alder, and in the flood plains the forests with willow an alder associations predominated. Nevertheless, this warming up was followed by temperature falls interrupted by smaller warming up periods. The transitional period ended at about 10,000 B.P. At that time the thermophilous trees (Tilia, Quercus, Ulmus) appeared, the aqueous flood plains were covered by unbroken fenwoods with Salix, Populus and Alnus.

The composition of vegetation reflected these conditions also in the Hungarian Upper Paleolithic sites. E.g. at Ságvár, 18,600 B.P. the Pinus cembra predominated with a frequency of 90%, subordinately Larix and Picea occurred with a frequency of 5%. At Madaras of Bácska the proportion of Pinus cembra is

53%, further Pinus silvestris (15%), other pines (30%) and Betula (2%) could be found. At the site Arka (Hernád valley), at about 17,000 B.P. the Pinus silvestris had a frequency of 90%, and Pinus cembra and Picea were also present (10%) (STIEBER, J. 1967).

Under these conditions hunting was the basic occupation of the primitive society. The remains of the hunted animals reflect the frequency of occurrence of the herbivorous large mammals, too.

EARLY HOLOCENE

After a short Pre-Boreal transition starting in about 10,000 B.P. (characterized by the cutting of terrace IIa in the non-subsiding regions) the warmest and driest phase of the Holocene, i.e. the Boreal followed (9,600-7,300 B.P.). In the Great Hungarian Plain continental sand and loess steppes existed in the drier part, and in the margins of flood plains sodaic steppes were found. In the somewhat more humid landscapes initially pine-woods, later mixed oak-forest steppes were characteristic (JÁRAI-KOMLÓDI, M. 1966; SOMOGYI,S. 1965). The Mesolithic findings of Szekszárd-Palánk that settled on sand dunes are closely related to this period.

At the end of this period, the first Neolithic culture, the Körös Culture appeared in the territory of the Great Hungarian Plain. In addition to the hunting-fishing-plant-gathering, the people of the Körös Culture commenced the stock-farming and agriculture (7,500-6,200 B.P.). Thus, though only locally, this people started to affect and transform the environment according to the social needs. Concerning its setting, the people of the Körös Culture lived between the name-giving rivers and the Tisza flood plains. Here the first settlements producing cereals in the region can be found (Gyálarét 7,140 B.P., Hódmezövásárhely-Kotac-part 6,500 B.P., Dévaványa-Katalszeg 6,420 B.P., Tarnabod 6,330 B.P.; BALASSA, I. 1973).

MIDDLE HOLOCENE

Economic life reached this revolutionary evolution phase in the Atlantic phase of more humid climate than that of the preceding Boreal phase (7,000-5,000 B.P.). Under the warm oceanic climate, often called the climatic optimum of Holocene, mixed oak forest steppes developed in the territory of the present Great Hungarian Plain, accompained by the large marshes of the constantly humid areas. The lower horizons of flood plains were covered by soft-wood gallery forests, the higher-situated ones by forests with Ulmus, Fraxinus and Quercus. The previously drier sand and loess steppes were also afforested. Nevertheless, these could be afforested if certain areas of this region would not be occupied by the groups subsequent to the Körös Culture. However, the population of the Tisza and Bükk Cultures of linear pottery of the present Great Hungarian Plain had practiced, on a regional scale, the stock-breeding and the ancient forms of agriculture. Due to this fact, the afforestation of the loess plateaus in the present Great Hungarian Plain, during the Atlantic phase, the development of forest steppes was hampered, mostly did not developed. On the contrary, however in the sandy ridges of the Danube-Tisza Interfluve where no findings of culture of different ages could be found, afforestation could proceed with different types of sandy oak-woods.

In the present Great Hungarian Plain, at about the end of the Atlantic oak-phase (5,400 B.P.) the first cultures of the Copper Age appeared. Their habits similar to that of the preceding cultures, changed when at about 5,000 B.P. the mild-humid climatic phase was replaced by a cool-humid climatic period, i.e. the Sub-Boreal 'beech' phase (5,000-2,600 B.P.).

LATE HOLOCENE

In this climatic phase the spreading of beech requiring balanced climatic conditions progressed, and not only in the marginal mid-mountains but also in the northern areas of the present Great Hungarian Plain (SIMON, T. 1957). In the forested surfaces the chernozem soils of the Boreal phase were gradually transformed into forest soils.

Though the temperature of this phase did not reach that of the Atlantic period its humidity was greater. Thus, in South-eastern Europe this phase is the humidity optimum and the flourishing time of the lowland forests and marshes of the Holocene. The overall abundance in waters is also reflected by the rivers erosions. The dendrochronological data provided by BECKER, B. and FRENZEL, B. (1977) for this period, not only indicate remarkable deforestation but also the fact that the oak trunks buried in the Danube's alluvium reached the maximum thickness. This resulted in the modification in the valley-forming activity of rivers. The period of the Boreal filling was characterized by accumulation of the material of terraces Nº 1. In the Atlantic phase gigantic bends developed along the Danube and Tisza (see e.g. the ox-bow lakes in the Nagykunság). The increasing quantity of precipitation enforced the rivers to cut the landscape. Consequently, except for the subsiding basins the rivers cut the valley floors filled during the Boreal and formed Terrace I, the height of which is usually 3 to 6 m higher than the mean water table and in case of Danube even higher (PÉCSI, M. 1959; SOMOGYI, S. 1962). The floods and the rising groundwater table of this climatic phase, considerably modifying the water table fluctuations, forced the peoples of the first Copper Culture to remove from the former water-side Neolithic settlements. This can be the reason why, contrary to the previous period, initially the number of settlements decreased and the habitats of Copper Age lie in higher areas. The same and/or similar results were obtained in the Tiszazug (KALICZ, N. 1957) and in the Balaton Highland (ZÓLYOMI, B. 1980).

The progress of forests was hampered by the stock-breeding and agriculture of the population of the present Great Hungarian Plain in the Copper Age and since 4,000 B.P. in the Bronze Age, especially in the loess plateaus and sand-free alluvial fans, also in the Sub-Boreal. Thus, botanists believe the vegetation of the "Great Hungarian Plain" steppes to be not of climatic origin but as a product of social effects. In the pollen spectra of vegetation sites of that period pollen of cereals appears in large amounts indicating the fact that the local agricultural activity of the Neolithic became regural in the Copper Age and this process increased further during the Bronze Age. Thus, the steppe, preserving the anthropogenic effects, also preserved the steppe type flora. Consequently, the nature transforming role of society, though on a primitive level, can be reckoned from the beach phase of the Late Holocene Sub-Boreal.

At the end of this phase the purposeful selection of sites for human settlement in the Copper and Bronze ages, i.e. those at natural water or margins of flood plains, became characteristic. While in the Neolithic the possibility of the choice of the sites corresponding to the primitive way of life was at hand, since the Copper Age the search for protection against natural elements (see the rise of floods) became also characteristic. It is reflected by moving to the higher-situated parts of the marginal flood plains. Since the turn of the Copper-Bronze Age, on the eve of the agressive and marauding tribal wars, seeking for defensible sites became also an important aspect. That is why the settlements of agricultural and stock-breeding communities can be found enclosed by marshes and bogs and, at some places, on periodically flooded islands and water-side dunes. Some of these water-side settlements survived a sequence of cultures, and were filled due to the wastes coming from the inhabitants (e.g. Laposhalom of Tószeg, Mágori-halom of Vésztö). The first fortified settlements derive also from this age.

The gradual inundation of some previously flood-free settlements was caused not only by the rise of flood levels, but also by the continuation of the level change of the marginal depressions. Though their size did not exceed 10 to 20 based on the height differences of the II/a Danube terraces, this process considerably modified the local hydrographic conditions of the areas in question. One main period of level changes was in the Early Holocene, and the second period took place in the Late Holocene (PÉCSI, M. 1959; SCHMIDT, E.R.--ZÓLYOMI, B. 1940; SOMOGYI, S. 1973).

In Hungary the end of the Sub-Boreal beech phase more or less coincided with the disappearance of the Bronze Age cultures. This period was followed by the Sub-Atlantic phase from the climatical, and the Iron Age from the historical points of view. In both respects, the approach to the recent conditions was characteristic. Climate became somewhat drier. Thus, beeches became restricted also in the "Great Hunarian Plain" except for the northeastern part. The climate could have been favourable for oak-woods but these were deforested by man, especially in the loessic regions and the developing nomad stock-breeding also restricted the possibilities. Among the grass types the domesticated plants became predominant, but weeds were also wide-spread. In harmony with climate, in the driest parts of the "Great Hungarian Plain", the forest steppes would have disappeared, the agriculturally used steppes began to develop in the form mentioned by writen documents from that period (see e.g. Priscos report on the visit in Attila's court).

During the dessication period the erosion activity of rivers prevailed in the middle courses in the "Great Hungarian Plain" instead of the cutting-character of rivers in the Sub-Boreal, and this means, the alternation of meandering-cutting and filling types. So, in case of low-water, the terraces I that filled in the Early Holocene Boreal and cut in the Late Holocene Sub-Boreal are undercut. The floods inundating terraces I, and locally terraces II/a, caused erosion also at these sites. As a result of meandering, beside the water courses, several stagnant waters, naturally cut-off meanders developed that, under the favourable climate, became the scenery of flourishing aguatic vegetation and extension of the marshes.

The climatic fluctuations can be also determined by the genesis of different soil types. During the Boreal phase the formation of chernozem soils was predominant. In the Atlantic and Sub-Boreal phases when afforestation progressed, the brown forest soils became predominant. The deforestations in the Sub-Atlantic period not only hampered the further extension but promoted, artificially, the dynamism of chernozem formation The sites of deforested areas are fairly well indicated by the chernozem brown forest soil, the structure of which preserved that of the brown forest soil, but its A-horizon became gradually humified. Nevertheless, this type occurred in greater areas only in centuries AD, especially near the margins of the "Great Hungarian Plain".

The impact of climatic changes is reflected also by the fluctuation of areal distribution of sodaic soils, i.e. by the most characteristic soil type of the present Great Hungarian Plain. The dry Boreal enhanced their spread. At the same time, the humidity of the Atlantic and Sub-Boreal phases exercised their leaching and areal restriction. In the Sub-Atlantic period the solonchak soils (surficial soda soils) occurred in areas without outlets, the structural solonetz soils could not spread over greater areas due to the frequent floods (SOMOGYI, S. 1965).

Deforestations reaching over the sand-areas led to the renewed movement of the sand cover. In the Boreal, the climatic conditions enhanced this process. In the given period this process was restricted to smaller areas. The formation of sand coats can be put to this time.

When studying the extension of primitive cultures in the "Great Hungarian Plain", it is clear that different peoples invaded the territory of the "Great Hungarian Plain" in an alternating manner. The only culture predominating everywhere in the country was the Zók Culture of the Early Bronze Age. Cultures that were restricted only to the "Great Hungarian

Plain" occurred in greater numbers: the Late Neolithic Tisza Culture, the Bodrogkeresztúr Culture of the Middle Copper Age or the Vatya Culture of the Middle Bronze Age. In case of these typical cultures of the "Great Hungarian Plain" the relation between the natural conditions and the way of life can be demonstrated.

This areal differentation continued also in the Iron Age (since 2800 B.P.) when in the "Great Hungarian Plain" the Mezöcsát Culture emerged, and somewhat later the Halstatt Culture evolved in Transdanubia. The equestrian nomads of Mezöcsát invaded also the Mezöföld already lying in East-Transdanubia. In the "Great Hungarian Plain" the Mezöcsát Culture was replaced by the Scythians. Since that time, the cultures replacing each other in the "Great Hungarian Plain" can be bound to different populations. At the same time, Transdanubia eyewitnessed the rule of Illyrians to the Danube being the borderline. In the "Great Hungarian Plain" the Sarmatians and then the Roman conquerors occupied the same region. During this period the way of life of people in the "Great Hungarian Plain" and in Transdanubia was different till the end of the Roman regime. In case of the large animal breeding nomads living in the "Great Hungarian Plain" land cultivation was only a supplementary activity. On the contrary, however, in case of Pannonians, and their successors land cultivation dominated. The population here attained highly developed civilisation (stone buildings, aqueducts, constant road network). The large Roman cultural centre in Eastern Transdanubia, close to the recent Székesfehérvár, along the river Sárvíz was called Gorsium (Tác). The archeological findings unambiguously prove maturity of civil life at that time. Eastward, further spread of the Roman culture was sharply cut by the Danube that had been reinforced by the fortress-chain of more than five-hundred years.

Nevertheless, the Sarmatians east of the Danube were not only simple stock breeding nomads. The first large-scale intervention in the "Great Hungarian Plain"'s hydrography can be attributed to them: the creation of the so-called Csörsz-árok. The extended (perhaps) fortification is, by all means, the result of a highly organized joint human work. The Sarmatians' impact can be seen in the hydrography of the landscape in question: the river Tarna flows, recently, between Tarnabod and Zaránk, and the Gyöngyös creek between Visznek and Jászárokszállás (FODOR, F. 1942).

The control of waters is proved by written documents and maps. Nevertheless, the primitive maps and sketches deriving from the first century A.D. are, of course, rather unreliable. It cannot be accidental, however, that in the atlas drawn by the famous cartographer Ptolemy the river network that differs from the present one always coincides with the hydrographically changed one. (See *Fig. 1*, constructed on the basic of geological and geomorphological data.) E.g. on page IV the Tisza flows at the Nyírség-margin of the Rétköz, and on page V. the curvature of the Paks bend of the Danube is greater. The mouth of river Sió is situated in the Bogyiszló-bend of the Danube near Tolna. The large ox-bow lakes in the south were, in fact, river beds in the lower course of the Hármas-Körös. The river Maros met the Tisza through its southern mouth, i.e. through the river Aranka. The river Bega met the Danube, together with the river Temes. On page IX, however, the river Bega joined alone, without the Temes. The Fehér-Körös alone joined previously united Berettyó-Sebes-Körös river assemblage. These data alone prove the uncertainties of Ptolemy's map, but also prove that these hydrographic regions of uncertain shape all coincide with the later marginal depressions. Nevertheless, this uncertain hydrographic state lasted till the period of waterway regulation (FRÖCHLICH, R. 1885), e.g. the uncertain direction of the Ér-valley, or the hydrographic situation in the Hortobágy.

Subsequently to the Roman Rule the Huns introduced again the nomad way of life in the "Great Hungarian Plain" and, in this manners with the subsequent nations of the migration (Osthrogots, Longobards, Gepids) stock-breeding also predominated. The same was the situation during the Avar's reign lasting for two and a half centuries. Following the Avars the areal-national distribution became uncertain in the "Great Hungarian Plain". For the moment it is not clear how far the agricultural sites of Slavs extended eastwards through the Transdanubian Uplands. In case of the "Great Hungarian Plain" we only know that up to Csongrád the Tisza Valley was controlled by Bulgarian tribes, i.e. they succeeded in the region the equestrian nomad people. It is, however, rather questionable that the great number of Avar settlements represent a continuous period, even in its details. It is probable that, subsequently to the Avar population, a hiatus existed concerning both the population and way of life and this gap ended only after the conquest of Hungarians.

Finally, the presence of a surficial microform, characterizing Hungary and the sites of the former nomad, shephard nations, the hillocks should be also mentioned. In the Great Hungarian Plain the monotony of the lowland is interrupted except for the sandy areas and alluvial fans, by these hillocks of various sizes, of 10 to 100 m radius and of 5 to 15 m relative height. Since most of these contained archeological finds, on archeological bases they are considered to be graves or Kurgans. Anyhow, these people were nomads.

As to recent view, these are rather different in their role and areal distribution. They always follow former on recent water courses except for alluvial fans and sandy areas.

As to their role, the hillocks, in a broad sense, can be classified into three groups. The first group represents the hillocks formed by the riverbank dunes, point bars and natural levees. All these can be found by the turns of former meandering water-courses although probably the water course is lacking now. In the Neolithic peoples of the first cultures settled in the "Great Hungarian Plain" moved to sites above the mean water table. The culture of the peculiar, circular (tell) settlements, developed on them, considerably increased their height. This was the situation especially in cases, when from the Neolithic to conquering Hungarians, the unbroken sequence of different cultures was superimposed (e.g. the Mágori-hillock of Vésztö, near the Sebes-Körös).

The second group includes the tumuli. It was characteristic not only of the nomadic people to bury the corpses (probably mainly the head of clans) under earth and stone hillocks of different sizes. The first nation of this type appeared in the Bronze age. The second tumulus culture is bound to the first part of the Iron Age and its remains can be found mainly in Transdanubia. The greatest nations using tumuli for funerals were the Scythians and Sarmatians in the "Great Hungarian Plain".

Hillocks occurring in groups (e.g. in the environs of Vaskút or Ágota) are of special interest. These are considered to mark the camping ground of nomadic peoples.

Finally, there are examples that the previously inhabited hillocks were later used and tumuli, or the previously formed tumulus serves as settlements for the subsequent peoples. The latest hillocks remained from the Hun period. These establishments requiring enormous earthwork are not only records of the communal work of the ancient societies but serve also as evidence of man's ability to control and transform nature (TARICZKY, E. 1892; KOZMA, B. 1910; GYÖRFFY, I. 1921; HARMATTA, J. 1950; PÁRDUCZ, M. 1941, 1959; SOMOGYI, S. 1971).

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ADDRESS OF AUTHOR:

Sándor SOMOGYI

Geographical Research Institute
Hungarian Academy of Sciences

BUDAPEST Népköztársaság útja 62. H-1062

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POSTGLACIAL CLIMATE AND VEGETATION HISTORY IN HUNGARY

M. JÁRAI-KOMLÓDI

ABSTRACT

The vegetation changes during the Holocene in the territory of Hungary had the same basic features that were characteristic of Middle Europe. Differences can be observed in case of conifers and in the composition of herbaceousplants. The present paper tries to summarize the history of vegetation in Hungary, the occurrence of characteristic plant species, their dominance relations and different biotopes. The study is extended also by paleoclimatological data (July, January and annual average temperature) obtained through palynological investigations. This paper also includes the manner of the formation of steppe, culture-steppe as well as that of the characteristic features of its vegetation. In the end of study it is proved that, before anthropogenic influences, at least 85 per cent of the given territory was covered by primeval deciduous forests, mostly by oak. Today forests cover hardly 17 per cent of the area and only 9 per cent of them can be regarded as the reminder of the primeval vegetation.

* * *

The climate and vegetation history of the Postglacial can be fairly well followed by means of pollen analysis in Hungary (JÁRAI-KOMLÓDI, M. 1966, 1968, 1969, 1985; ZÓLYOMI, B. 1936, 1952, 1980).

In Central Europe the history of Holocene forestation was the same, concerning at least the predominance of deciduous trees (birch, hazel, oak and beech, *Fig. 1* and 2). Nevertheless the role of conifers and the refinements of vegetational changes, e.g. the composition of the herbaceous vegetation are usually different.

PRE-BOREAL

In Europe, since the Pre-Boreal, the disintegration of the Scandinavian ice-sheet, its withdrawal and general warming up started. The extension of the Pinus silvestris and Betula pendula forests is characteristic all over in Europe. On the sandy soils of North and West Europe, mainly the Pinus silvestris, while in the clayey soils of Northern Europe mainly the Betula are predominant. In the Central European forests other deciduous trees also occur, like the Populus tremula, Ulmus, Quercus and Corylus. On the higher mountains, i.e. in the Carpathians and Alps, spruce-predominated taiga forests, and above them dwarf birch-shrubs (Betula nana) were also grown.

During the Pre-Boreal the climate in Hungary's territory was rather cold, dry and subarctic character. In the Hungarian Uplands beside steppes and birch-pine forests, the deciduous tree species sporadically also occurred in the Pinus silvestris taiga forests. In the open grassy spots a vegetation probably similar to the recent saxigenous grasses with Sesleria could exist. Maybe the native Pinus silvestris pinewoods of Fenyőfő at the margin of the Bakony Mountains and the cranberry-birch forest of Uzsa are the remnants of these forests.

At the same time, in the Great Hungarian Plain a birch-predominated forest-steppe could exist that resembled to the forest-steppe, south of the West-Siberian pine-birch taiga, though cannot be completely compared with it. The West-Siberian birch-predominated forest-steppes consist mainly of "small-leaved" deciduous trees, i.e. first of all Betula, then to a lesser extent of Salix and Populus species, in the forests of the Great Hungarian Plain "broad-leaved" deciduous trees, e.g. Tilia, Quercus, Ulmus, Acer, Alnus and Fraxinus can be also found (10.5% of total AP). In the treeless spots of the forest-steppe regions the previous vegetation also changed in the territory of the Great Hungarian Plain. The loess steppes of the glacials remained but their floristic composition gradually changed: Artemisia, Chenopodiaceae and the Late-Glacial heliophytes became subordinate, some of them e.g. Ephedra and Armeria became extinct and grasses became predominating. This vegetation could be transitional phase between the former Late-Glacial cold steppe and the subsequent steppe meadows with xerothermal vegetation (e.g. Stipa, Festuca) of the Boreal. In the already dry and cold climate the fenwoods and gallery forests could not be significant though according to the results of pollen analyses, the stagnant waters became more abundant in water-milfoils (Myriophyllum sp) and in sporadically occurring reedmace, reed and bur-reed (Typha, Phragmites, Sparangium) in the off-shore zones.

In the area of the Great Hungarian Plain the mean temperature of July could be +18 °C, that of January -2 °C and the annual mean temperature +8 °C - +9° C.

BOREAL

In the subsequent phase, i.e. in the Boreal the warming up continued and the quantity of precipitation decreased all over Europe. In the extremely dry areas climatic xerothermal steppes existed. In the mountainous pine-birch forests hazel

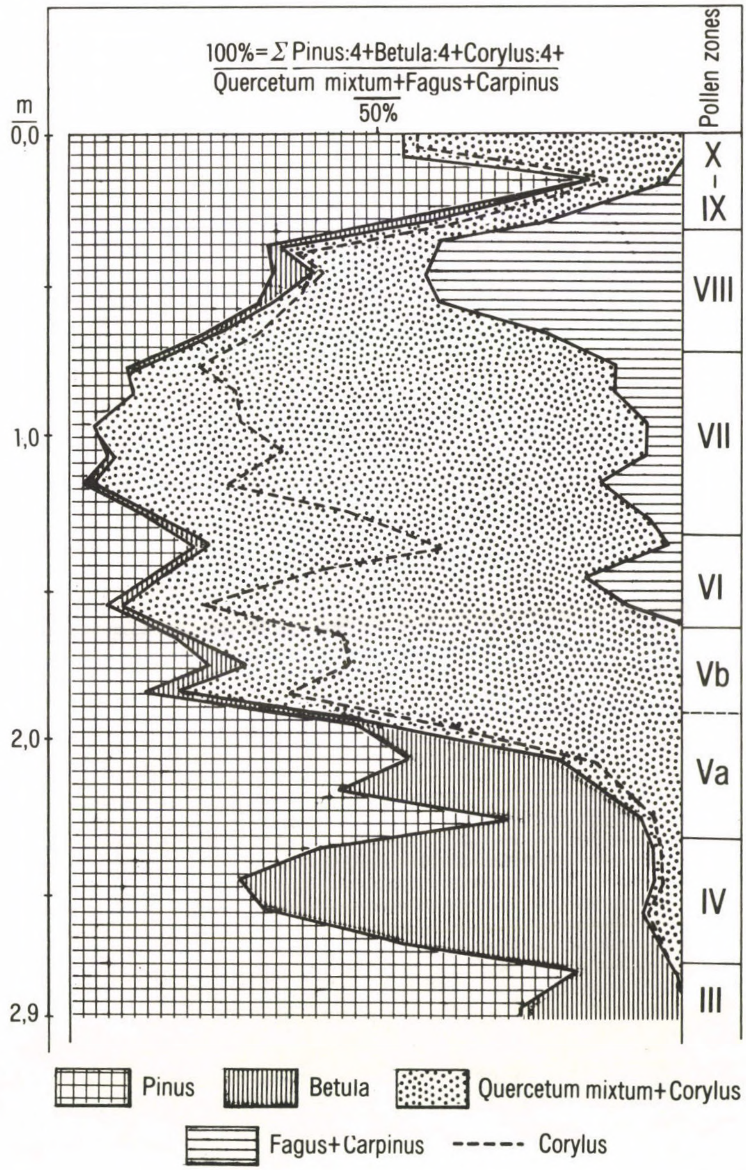

Fig. 1 Areal diagram of forest development in the Holocene, based on pollen analysis (JÁRAI-KOMLÓDI, M. 1968)

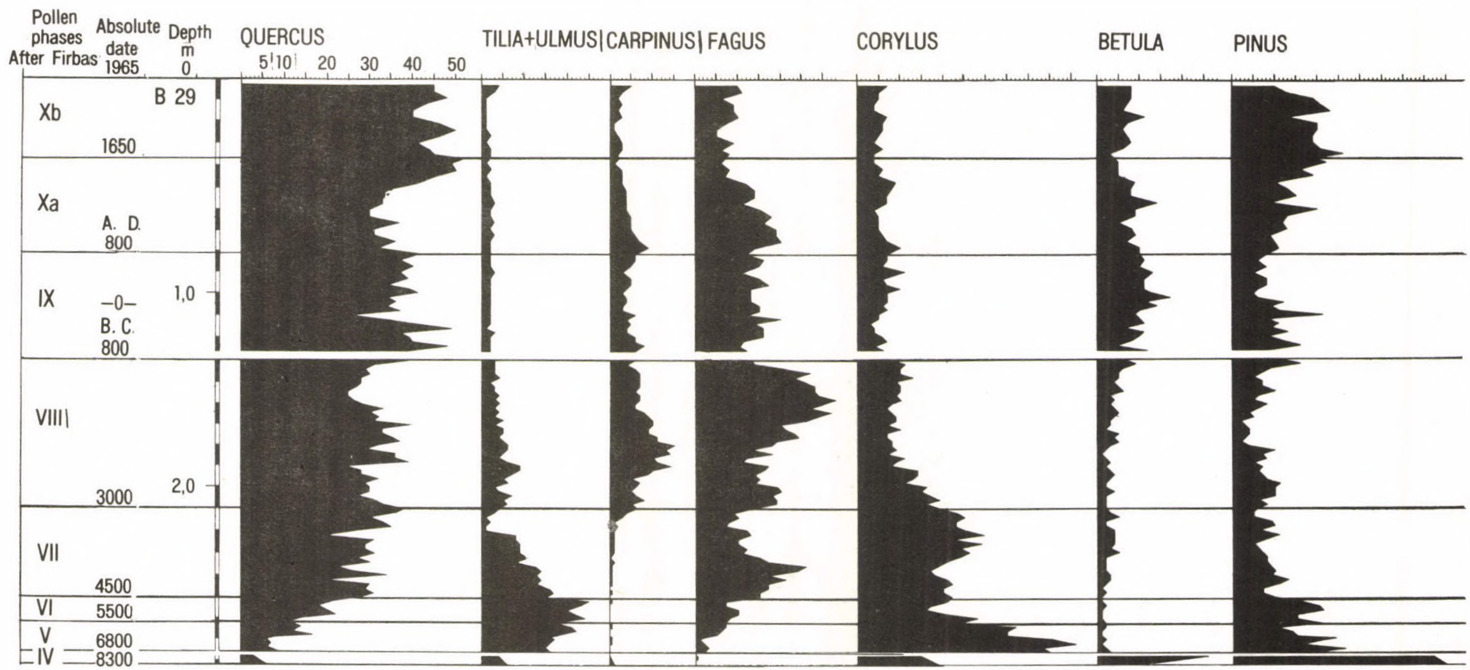

Fig. 2 Pollen diagram showing the Holocene forest development (Lake Balaton) After ZÓLYOMI, B. 1980

became more abundant and when the climate became warmer the birch decreased and first the pine later the deciduous forests predominated (Ulmus, Quercus) in many localities with abundant hazel-shrubs. In Hungary a warmer and drier climate predominated at this time than in Pre-Boreal, and the mean temperature in January was also higher with +1 °C - +2 °C than even today. This was unfavourable for forestation, especially in the Great Hungarian Plain.

This region was partly deforested, and on the loess and sand soils were covered by natural steppes, warm-dry continental steppe-meadows, but at its margins, as well as in the sand ridges close to rivers, the forest-steppes were preserved. In the early phase of the Boreal this might be forest-steppe of Pinus silvestris with Quercus, Tilia and Corylus (similar association has been recently found in Ukraine). Later the deciduous trees supplanted the pines and mixed-oak forest steppes emerged. (The pollen of Carpinus appears first in the strata of the Great Hungarian Plain at that time). The autochtonous pine forests living on the acidic gravelly soils of Western Transdanubia are still preserved from the early phase of this period. As to our pollen-analytical investigations (JÁRAI-KOMLÓDI, M. 1968) in the Boreal the hazel had been less characteristic in the Great Hungarian Plain region that it was presumed before. It seems to be probable that the warm dry climate had an unfavourable impact the spreading of the mesophilous hazel, and the contemporaneously extending deciduous trees could also restrict its extension, not like in Western Europe.

Deciduous trees became more abundant since the beginning of the Boreal in the pine forests of the Hungarian Uplands, finally the pine forests are supplanted by the mixed oak forests (with Ulmus, Tilia, Fraxinus, Acer and Corylus). Forests alternated with climatic xerothermal steppe-meadows also in the mountains that in the valleys of the Carpathians reached also the Picea-zone.

The smaller stagnant waters, as well as the shallow parts of Lake Balaton became marshes. The aquatic plants became impoverished, but in the greater waters in general more thermophilous species e.g. Nymphaeaceae occurred due to the warmer climate. The gallery forests with Salix and Populus are less significant and the Alnus-forests with fern-rich underwood (Thelypteris palustris) became important only at the end of the Boreal. The Boreal was the most critical phase in the Holocene concerning the preservation of the marshy and rock vegetation relics of glacial origin. Many species became extinct obviously since the number of protected microclimatic spots and of the wet-cool bogs was considerably reduced. Luckily enough at Bátorliget in the Nyírség, the glacial plants were able to survive through the dry warming-up climate of the Boreal, and could be preserved to our days.

This period eyewitnessed also the immigration and extension of the Pontian Central-Asian species, though the more psychrophilous Eurasian continental steppe plants, e.g. Eurotia ceratoides and Kochia prostrata belonging to Chenopodiaceae or the Artemisia species could immigrate onto the previous Late-Glacial loess steppes, as well. The grassland vegetation on karstic slopes developed from the low-mountain sub-Alpine rock grasses, and especially the "steppe" vegetation on continental rocky slopes were very wide-spread. The grassy vegetation descending from the limestone and dolomite rock slopes was mixed with the elements of karst scrub forest and grasses immigrating from the Sub-Mediterranean. Flora exchange of similar character, but not of the same extent, procedeed like the mixing of the arctic flora migrated to south and of the Alpine flora descended from the Alps producing the arctic-alpine flora assemblages.

The recent forest-steppes on sandy soil of the Danube-Tisza Interfluve as well as the loess steppe-meadows restricted to roadsides and borderlands (Békés, Nagykunság, Kalocsa, Dunaföldvár, Balatonkenese); the oak forests with tartare maple (Acer tatarica) on loess soil in the margin of the Great Hungarian Plain (Kerecsend); the grassy "steppes" on slopes of the Hungarian Uplands preserved by all means the landscape of the Boreal, with some rare endemic species, i.e. Pulsatilla hungarica, Adonis transsylvanicus, Centaurea sadleriana, and with surviving-plants on loess, i.e. Salvia mutans, Sternbergia colchiciflora, Crambe tataria and Scilla autumnalis.

The wind-blown sand of widest area originated from the dried-up river-beds developed in that time in Hungary. In the periodically inundated areas the climate of the Boreal and the intense groundwater evaporation largely contributed to the accumulation of salt in the soils. The first larger salt effected soils and the related vegetation could emerge at that time, and the immigration of the halophytic vegetation, e.g. the endemic Aster tripolium ssp.pannonicus, Sueda pannonica and the Puccinellia pannonica, already extinct, is related to this period.

From the points of view of vegetation history perhaps the events taking place during the Boreal and Atlantic seem to be most interesting for explaining the origin of steppe culture-steppe in Hungary. In certain localities of the Great Hungarian Plain first of all in the internal loess ridges, in the sand-spots, and salt effected soils, the true climatic steppe could exist in the Boreal. The last natural scenery of the Great Hungarian Plain, i.e. the forest-steppe developed in the Atlantic. Nevertheless, it is widely accepted and this impression is also supported by touristic information that the true climatic steppe is still one of main features' Hungary's. Just on the contrary, SOÓ pointed out the origin of the Hungarian steppe already at the beginning of our century and stated that the Great Hungarian Plain, moreover the southern-southeastern slopes of the Hungarian Uplands have belonged to the climatic forest-steppe zone, thus the recent tree-less regions in Hungary were not climatic steppes but culture-steppes generated by the deforestation of the original forest-steppes (SOÓ, R. 1931).

All the primeval landscapes and relic plants, discovered in the subsequent decades, and also the megafossils and pollen analytical results supported this statement.

Consequently, the recent steppe is of different origin than the Boreal steppe, since it had been formed and maintained by anthropogenic factors till present. Deforestations, accompained by the historic events, e.g. the great migrations, the Mongol invasion and the Turkish reign as well as the improper regulation of water-ways and drainage resulted the recent culture-steppe.

In the deforested region the wind removed the sand, the inter-dune sites became marshy due to the raised groundwater table since the end of Sub-Boreal, further modified due to the salts produced by the regulations of waterways and draining of the last century. Under the climatic conditions characteristic of the forest-steppes, no forest could evolve on the blown-sands and salt effected soils. The fertile loess soils were transformed into ploughlands everywhere from the Sub-Atlantic.

So, disregarding of some relic landscape spots, the Great Hungarian Plain as a whole is a cultivated landscape and culture-steppe ("puszta") that bears an anthropogenic origin but its vegetation derives at least in part from the former climatic steppes, from the steppe-spots of forest steppes and from the grassland vegetation on rocky slopes of the Hungarian Uplands. This flora is partly preserved by the relic landscapes, and by edaphic steppe spots.

ATLANTIC

The Atlantic phase is called the climatic optimum of the Holocene since the more rainy but still warm and balanced climate affected optimally the forest development and the immigration of Mediterranean and Sub-Mediterranean species. This is proved by the appearance of some species, also in Hungary's territory e.g. Vitis sp., Hedera sp., and Ilex sp. determined by pollen analyses (JÁRAI-KOMLÓDI, M. 1968, 1985). Forests spread northwards and on the mountains over higher levels all over Europe. In the lowlands the deciduous trees (mainly the oak, elm and linden-tree) became more abundant on the expense of pine forests. In the higher mountains Fagus, Carpinus and mainly the Picea showed progress, in the Tatra Mountains the Abies alba occurred.

Hungary's territory was strongly forested. The major part the Hungarian Uplands covered by unbroken oak probably Quercus cerris. Q. pubescens forests in which sporadic Carpinus and Fagus admixtures were found. In several regions, e.g. in the Balaton Highland *(Fig. 2)* remarkable beech-forests existed already in first half of the Atlantic phase (ZÓLYOMI, B. 1980). The open plant communities of the xerothermal slopes of mountains, i.e. the mosaic assemblage consisting of Carex humilis, Festuca rupicola and of Quercus puescens scrub forest could develop also at the same time. These belong to the forest-steppe-zone, together with the landscape of the Great Hungarian Plain.

The climatic steppes of the Great Hungarian Plain were also forested to a great extent. The last natural landscape of the region developed at that time, i.e. the mixed-oak forest-steppe, the steppe spots of which could be locally important on some loess ridges. The forest-steppe alternating with steppe-meadows could be Quercus robur-forest with Festuca rupicola on loess soils. While on the deep, more wet sand soils Quercus robur forests with Convallaria majalis and hazel-shrubs were found. As to the palynological investigations, the hazel was of the same significance in the Great Hungarian Plain especially in the second half of the Atlantic, as in the Boreal. The Atlantic climate was optimal for it, its greater extension was restricted only be the deciduous forests. Locally, the Quercus robur forests were closed. In these forests Carpinus and Fagus could occur, Hedera climbed the trees and Ilex grew among the shrubs. The pine-birch forests practically disappeared.

Under the rainy climate the marshy and gallery forests with Alnus were wide-spread, in the latter Vitis silvestris abounded. In the pollen diagrams the Alnus was predominant first in this phase. In the stagnant waters, preserved meanders and interdune depressions, rich marshy and bog vegetation existed. The Ophris sp. and Orchis sp, that are now protected relics, could immigrate from the south to the region's bogs at that time. It can be palynologically proved that the vegetation of stagnant waters was more abundant in species as compared to the Boreal, e.g. the Nymphoides sp., the Sagittaria sp. and the Alisma sp. also occurred.

In the forested steppes the grasses and Boreal steppe species were substituted by dicotyledonous forest species and by shrubs (Viburnum sp., Lugustrum, sp.).

The climate of the Atlantic phase could be reconstructed first of all on the basis of the presence of Vitis, Hedera, Viscum and Ilex (the latter is missing from the recent flora) demonstrated by palynological studies. The mean temperatures of July and January could be +25 °C and +5 °C, respectively,- the annual mean temperature can be put to cca. +16 °C.

SUB-BOREAL

About 5000 years ago the Sub-Boreal commenced with some deterioration of the climate. This is proved by the disappearance of pollen of the thermophylous Vitis and Ilex. The climate became cooler again and it favoured the closing of forests, the extension of mountainous tree species (Fagus, Carpinus, Picea) and the spreading of boggy-marshy vegetation.

In the Central-European mountains the forest-forming Carpinus, Fagus, Picea and Abies showed rapid extension. The latter is mixed with Fagus in Western, and with Picea in Eastern Europe. Northwards it did not reach the Fagus, but only the Quercus zone; in the Tatra Mountains it is widespread. Picea extended west- and southwards from the Eastern Alps and the Carpathians.

In the Central European lowland areas the Fagus is mixed southwards with Quercus and Pinus silvestris northwards with Abies, then with Picea, Carpinus spread from the east. In Europe all the recently forest-forming species existed (in Hungary the forests are closed).

In the Hungarian Uplands the hornbeam-oak mixed forests and the beech forests extended. The continuous Fagus zone evolved. Fagus could get to the scree-bearing rock-forests of the northern slopes at that time forming the recent beech forests on rocky slopes with Sesleira sp. In the cool-wet climate the calciphobe oak-forests, beeches and Quercus cerris forests of the low-mountains were spread on the acidifying soils ZÓLYOMI presumed (1936) fir-forests, too.

According to palynological data, the forests closed also in the margin of the Great Hungarian Plain. In its central region forest-steppe with oak-woods existed but with differing composition. The most characteristic association here could be the Quercus robur forests with Convallaria, as well as the oak-woods mixed with Carpinus and Fagus. The two latters descended from the mountains, together with their accompanying species.

In the course of the Post-Glacial the forestation and the boggy areas were mostly expanded and the abundance of Fagus was the highest here at the time. The complete forestation could be hampered only by the boggy areas and pastoral and agrarian people who pursued remarkable deforestation activity.

Some protected forests of the Bereg-Szatmár lowland, of the Bodrogköz and Kiskunság can be regarded as relics of beeches, and of hornbeam-oak mixed forests descended from the mountains to the Great Hungarian Plain (e.g. the Hosszúerdö at Sárospatak, the Közös-forest of Beregdaróc).

Under the cool, wet climate the food-plain willow-groves, aspen-groves, the gallery forests with Quercus, Fraxinus and Ulmus, the fenwoods with Alnus and Fraxinus, the bog and marsh meadows flourished and reached their maximum postglacial extension. These forests protected a part of species that descended from the mountains at that time, e.g. Majanthemum bifolium, Asarum europaeum, Lamium galeobdolon, Pulmonaria officinalis (JÁRAI-KOMLÓDI, M. 1958).

Since the end of the Sub-Boreal the anthropogenic effects accelerated. The pasturing and agrarian people, as well as the historic events exerted ever greater impact on the primeval vegetation. It is also proved by the appearance of cereals and weeds, e.g. Centaurea cf.cyanus, Plantago cf.lanceolata, Polygonum cf.aviculare, Rumex sp. (JÁRAI-KOMLÓDI, M. 1968). Pollen of Triticum monococcum occurs sporadically from the Atlantic (about 6000 B.P.) but its quantity is significant only from the end of the Sub-Boreal, the period roughly corresponding to the middle of the Bronze Age (cca. 3000 B.P.); it can be, en masse pointed ored only in the Recent period. Nevertheless, the historical events are also reflected: subsequently to the Hungarian conquest (896) the cereal pollen show increasing tendency then, under the Turkish reign (1526-1686), the pollen quantity decreases obviously due to the recession of agriculture. In the mud strate of Lake Balaton the presence of rye and maize can be proved since the Bronze Age (3900 B.P.) and since 1650, respectively. Among the domesticated plants the nut has been present since the Roman ages (380 A.D.) in ever increasing quantities (ZÓLYOMI, B. 1980, see *Fig. 2)*.

In the territory of the Great Hungarian Plain the slow artificial restriction of the primeval forest steppe vegetation growing on both sand and loess soils began due to the anthropogenic landscape-forming effects. The deforested regions were substituted partly by steppe vegetation, on sandy soils partly the sand was removed by the wind, and large wind-blown sand regions developed in the Danube-Tisza Interfluve (Dabas, Kunpeszér, Fülöpháza, Bugac, Jánoshalma). Loess steppes were transformed into croplands and the original native vegetation could be preserved only in smaller spots, on the narrow bands of borderlands and bluffs (see Boreal). During the Sub-Boreal period the natural landscape of the Great Hungarian Plain has irrevocably developed to a cultural landscape.

SUB-ATLANTIC

No remarkable changes took place in Hungary's climate and vegetation in the Sub-Atlantic following the Sub-Boreal; these conditions were rather similar to those of our days. Climate became somewhat more unfavourable, became drier, but remained cool. In the mountains the oak-woods and beeches, in the Great Hungarian Plain being the westernmost occurrence of the East-European large forest-steppe zone, the oak forest-steppes constitute the natural vegetation. Except for its Northern part the beech withdrew from the Great Hungarian Plain; and the hornbeam became also subordinate. The mixed autochtonous coniferous woods living in Western Transdanubia, close to the Alps, belong to the Central European coniferous woods.

Man has conquered ever more land from nature. The regulation of waterways, started in the 18th century, has become increasingly intense. This period was followed by the use of fertilizers and insecticides on the ploughlands, the mechanized sylviculture and management of water supplies, the extended live-stock breeding, the fixation of blown-sands, the amelioration of salt effected soils, the plantation of allochtonous species and import of adventive weeds have contributed to form of Hungary's present landscape.

Except for some original landscapes and relic plants that preserved the ancient features of vegetation, most of our mountains is characterized by cultivated forests, and nearly the whole Great Hungarian Plain by the culture-steppe. In our days, the original vegetation is restricted to about one-tenth the country's area.

Before the environment-transforming activity of man about 85% of the country's area was covered by ancient deciduous forests, mainly by oak-woods. Nowadays, forests cover about 17% of the area only 9% can be regarded as remains of the native vegetation. The rest is artificially planted, strongly transformed and deteriorated forest (cca. 160 000 ha). In Hungary about 410 000 ha is protected (1980).

The preserved autochtonous, of wild vegetation has become endangered during the last fifty, or rather twenty years due to the global environmental damages. As far as we know, in Hungary 19 autochtonous species disappeared and the extinction of 26 species has been forecasted. This is more than 2% of the total flora (2148 species) and 600 species (28%) is endangered, and would require protection. At present, about 370 species are regarded as species to be protected (CSAPODI, I. 1982).

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ADDRESS OF AUTHOR:

Magda JÁRAI-KOMLÓDI

Eötvös Lóránd University
Department of Plant Taxonomy
BUDAPEST Kun Béla tér 2. H-1083

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EVOLUTION OF THE MOLLUSCA FAUNA OF THE HUNGARIAN UPLANDS IN THE HOLOCENE

L. FÜKÖH

ABSTRACT

In Hungary the karstic area of the Hungarian Uplands is most suitable to study the Holocene terrestrial Gastropod fauna. The great number of caves, found in the region preserved the fauna of the recent about ten-thousand years as natural traps. The malacological material found in the sediments can be not only fairly well correlated with the contemporaneous vertebrate and pollen material but provides the possibility of comparing it with the fauna deriving from other areas of the Hungarian Upland. Based on the biostratigraphic, biometric and zoogeographic investigation of the Holocene fauna of Hungary, four phase can be distinguished within the Holocene (Table 1), that can be parallelled first of all with the evolution of vegetation.

* * *

In Hungary, the most appropriate locality for the investigation of the Holocene terrestrial Mollusca fauna is the karstic low-mountain region. Numerous caves and rock shelters served as natural traps for accumulating the fauna and flora of the environment and the traces of anthropogeneous activity. This versatile deposit made possible detailed fauna-analyses that can be well correlated.

CHARACTERIZATION OF THE SUCCESSION PHASES

Steppe fauna of the open areas (Boreal)

These Early Holocene faunal assemblages can be best characterized by KROLOPP's (1973) statement observing the disappearance of the species *Vallonia tenuilabris, Columella columella,* *Pupilla sterri*, typical for cold Pleistocene climate, after the last cold peak of the glacial, followed by, in great masses, not new species, but ones already present in the fauna in a subordinate role, breaking forth due to the new climatic factors and resultant changes in dominance ratios.

These changes in the dominance relations are reflected also by the faunas of the Horváti-hole (FÜKÖH, L. 1983), Kölyuk II cave (FÜKÖH, L.--KROLOPP, E. 1985), Csúnya-valley Rock shelter Nº 1 (FÜKÖH, L.--KROLOPP, E. 1984), and the Muflon-cave (FÜKÖH, L.--KROLOPP, E. 1982-1983), yielding Early Holocene assemblages, that can be characterized by the dominance of species preferring an open-area environment. Beside the dominance of the species *Vallonia costata*, preferring open spaces of karstic shrub vegetation, presence of cliff-steppe species like *Granaria frumentum*, *Chondrula tridens* can be demonstrated. In some places, the species *Chondrina clienta*, living at rocky areas, as well as the xerotherm *Cochlicopa lubricella* occur, as accessory elements.

The quantitative analysis of the dominance relations, within the faunal assemblages outlined shows a 30-80% relative frequency of the species preferring open-area (shrub vegetation, cliff-steppe). The variability of 50% is determined by local subassociations as well as microclimatic parameters.

The conclusions drawn from the examination of the Mollusca-fauna are supported also by palynological investigations. In Early Holocene assemblages (Kölyuk II cave), pollen of the species Pinus silvestris, Betula, Tilia and, dominantly, Graminae were found.

Formation of the "closed forest" fauna (Atlantic)

In sediments overlying the Early Holocene strata, the composition of the fauna is considerably changing. According to the characteristic faunal assemblages, e.g. that of the Kölyuk II cave, Muflon-cave, Rejtek I Rock shelter, Csúnya-valley I Rock shelter (FÜKÖH, L. 1978; FÜKÖH, L.--KROLOPP, E. 1982-83; FÜKÖH, L. 1979, 1980), the relative frequency values of species preferring open area decrease, not reaching the value of 30%. The members of the closed forest fauna predominate: species of the family Clausiliidae, *Orcula dolium*, *Helicodonta obvoluta*, *Acanthinula aculeata*, *Acicula polita*, live in coat of mosses *Carychium minimum*, *Vallonia pulchella*, *Isognomostoma isognomostoma*, *Daudebardia rufa*, *Daudebardia brevipes*.
The change in vegetation determining the faunal change is reflected also by palynological evidence; pollen of the Fraxinus, Alnus, Salix, Quercus and Corylus appear in the sediments. The individual number ratio of the species *Vallonia costata*, predominant in the previous fauna, decreases.

Formation of the secondary forest-steppe vegetation (Sub-Boreal)

After the sediments containing the fauna characteristic of the closed forest vegetation we find again strata with a fauna similar to that of the Early Holocene. In the fauna of the Nagyoldali-shaft, located in the Aggtelek Karst territory (FÜKÖH, L. 1978, 1979), the ratio of the species preferring open spaces increases again, their relative frequency surpassing the 30% frequency limit. The increase in the number of species *Granaria frumentum*, *Chondrula tridens*, *Pyramidula rupestris* refers to the more open-area vegetation of the territory again. The closed forest vegetation of the preceding period is changed to forest-steppe vegetation. This short phase is followed by a further forestation period.

The phase second of the formation of the closed forest vegetation (Sub-Atlantic)

On basis of the Mollusca fauna the youngest sediments of the Holocene yielded the records of a closed forest vegetation again. The fauna originating from the Kisköhát-shaft sediments (FÜKÖH, L. 1981) are predominated by species preferring wet, warm climate (LOŽEK, V. 1965): *Acicula polita*, *Vertigo pusilla*, *Discus rotundatus*, *Perforatella incarnata*, *Isognomostoma isognomostoma*, *Clausilia pumila*, *Laciniaria turgida* etc.

Besides an 80% frequency of the forest species, we can report on the complete lack of the species preferring the open-space vegetation; only the presence of the groove-forest species can be found: *Aegopinella minor*, *Helicigona faustina*, *Helix pomatia*.

INDIRECT PROOFS OF THE SUCCESSION PROCESS

In the course of the investigation of the malacological material the possibility for discussing the above changes from an other angle emerged.

Zoo-geographical studies

The progress of zoo-geographical research in Hungary enables us to track the changes witnessed in the Holocene (BÁBA, K. 1982; FÜKÖH, L. 1983; BÁBA, K.--FÜKÖH, L. 1984).

The examinations, performed so far, indicate that in the older sediments (Boreal), the species characteristic of the continental centres are frequent (*Vallonia costata*, *Vertigo alpestris*, *Cocnlicopa lubrica*, *Euomphalia strigella*, *Bradybaena fruticum*, *Discus ruderatus*, *Columella edentula* etc.), while in the younger sediments (from the Atlanticum on), we can observe an expansion of the Mediterranean elements. (*Isognomostoma isognomostoma*, *Laciniaria plicata*, *Laciniaria biplicata*, *Orcula dolium*, *Vitrea contracta*, *V. crystallina*, *V. diaphana*, *Truncatellina claustralis*, *Truncatellina cylindrica*) (FÜKÖH, L.--GERA, I.--KÖRMENDY, Á. 1985). This change coincides with the formation of the closed forest vegetation and the mass occurrence of species characteristic of the closed forest vegetation.

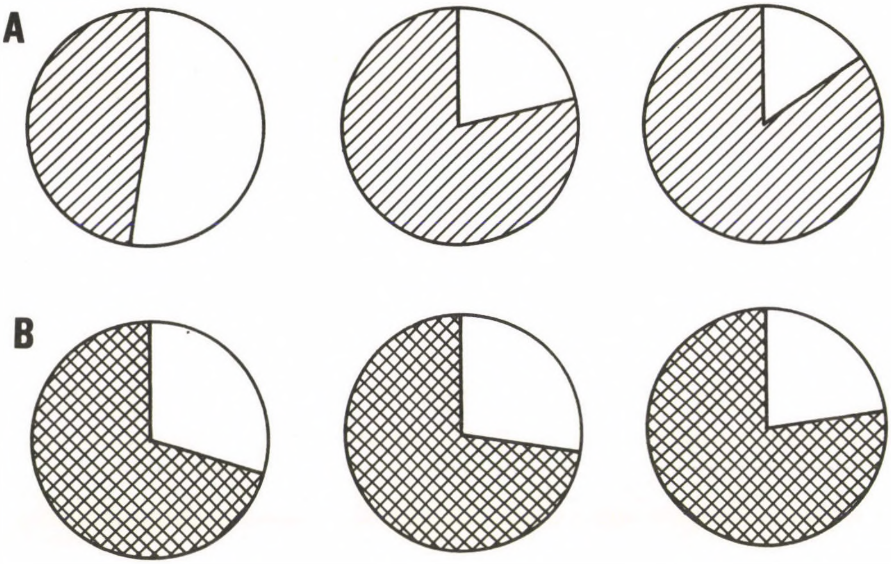

Fig. 1 Presentation of the fauna succession by ecological and zoo-geographical methods (Bükk-Mts., Csúnya-valley)

A: based on ecological investigations (individual number frequency).

From left to right: change in the ratio of forestal elements (marked) during the Boreal, Atlantic and recent period

B: based on zoo-geographical investigation (taxon number frequency).

From left to right: relative frequency of the species of the Sub-Atlantic fauna center (area marked), during the Boreal, Atlantic and recent period

Biometrical investigations

In the Uppony-Canyon as well as in the environs of the Horváti-hole, it was possible to observe the ecological parameters together with that of the recent fauna (FÜKÖH, L. 1980). As a result, it could be demonstrated that a difference of 2,6°C and of 10% rel. humidity can lead not only to the change of fauna, but is of decisive effect on the metric characteristics of the snails, as well (DOMOKOS, T.--FÜKÖH, L. 1984). This recognition led to the biometrical investigation of the Holocene fauna. Considering the aspects of preservation, the individual number and ideal dimensions, the biometrical study of the species *Granaria frumentum* was performed.

The results corroborated the hypotheses, i.e. the changes in dimension coincide with the most important climatic change during the Holocene, that is with the Boreal/Atlantic border.

CHANGES OF THE NATURAL SUCCESSION. ANTHROPOGENIC EFFECTS

While investigating the Hungarian Uplands cave assemblages, we came across the traces of people inhabiting the area in prehistoric times (herd, pottery, bone and stone tools). In the course of the faunistical study of the sediments containing also traces of human activity, we could study its impact on the way of natural succession *(Fig. 1).* In the cave Kölyuk II and the rock shelter Rejtek I, we found the remains of the Neolithic man. In the sediments of this layer, the fauna indicated by the general climate ought to have been characteristic of the faunal assemblage of the "closed forest". And still, the fauna abounds in elements characteristic mainly of open spaces *(Vallonia costata, Granaria frumentum).* The reason for this phenomenon is that Neolithic man deforested the region, and thus influenced the microclimate by altering the vegetation and altering, indirectly, the composition of the Mollusca-fauna, as well. This phenomenon should be considered to proceed in an increasing manner towards our days. After the Bronze Age the intensive agricultural production resulted in a considerably transformed environment. In the course of historical development, the scope of such activities are increasing, thus in our days it is practically impossible to demonstrate clear (unaltered) assemblages. This fact is also added to the factors necessitating the study of the Holocene faunas, because in order to improve the efficiency of environment protection, we can utilize the data obtained from a 10,000 - year prespective.

CONCLUSIONS

The data accumulated during the past 15 years serve as a proper basis for the refinement of the Holocene faunal evolution outlined before (FÜKÖH, L. 1980) as well as for their supplementation with recent studies of new investigation approach (zoo-geography, biometry).

The Holocene Mollusca-fauna, known today, is known in aprox. 2/3 part from regions of the Hungarian Uplands, comprising the freshwater species, as well. The great taxon number and individual number enable us to discover the basic laws of the faunal changes and to outline the faunal succession, offering a basis for the elaboration of a new method for the division of the period following the Ice Age.

The way of the faunal evolution can be compared to the succession processes of the regions to the north of our country

Table 1 The succession of the Hungarian terrestrial Mollusca-fauna during the Holocene

Age B.P.	Malacological characters	Vegetational aspects
1000	In natural assemblages, the number of forest elements increase again, with predominance of species typical for wet, warm climate: Acicula polita, Vertigo pusilla, Carychium tridentatum, Orcula dolium Granaria frumentum - minimum	The number of natural, original assemblages decrease, the anthropogenic transformation of the environment increases
2000		
3000	Beside the predominance of the species of "closed forests" the species characteristic of open spaces and steppe increase: Granaria frumentum, Chondrula tridens, Pyramidula rupestris	The "closed deciduous forest" remains as ruling element, but - as compared to the preceding period - the ratio of open spaces increase. At some places, the people of the Bronze Age change significantly the natural vegetation by the agricultural activity.
4000		
5000 6000	The faunal assemblage changes significantly, species preferring open spaces and steppe are subordinate. In natural assemblages, the members of the closed forest fauna predominate: Clausiliidae, Truncatellina claustralis, Orcula dolium, Vallonia pulchella, Oxychilus orientalis, Oxychilus depressus, Daudebardia rufa, Daudebardia brevipes, Vitrea diaphana, Vitrea contracta. Their relative frequency is over 70%. Vallonia costata - minimum	Formation of closed deciduous forests. Open spaces, cliff steppe decrease. Bush vegetation is changed by forest. Palynological studies indicate the predominance of deciduous forest: Quercus, Fraxinus, Alnus, Salix, Corylus and Gramineae. First signs of anthropogenic interference.
7000		
8000 9000	Disappearance of Pleistocene elements: Pupilla sterri, Vallonia tenuilabris Increase of the species preferring open space and steppe: Granaria frumentum, Cochlicopa lubricella, Chondrina clienta, Chondrula tridens Vallonia costata maximum	The forest zones of the Late Pleistocene are substituted by more open karstic bush-forests. Palynological investigations indicated the frequency of Gramineae, offering a basis for supposing extended cliff-steppes
10,000		

in the mountinous regions of Czechoslovakia (LOŽEK, V. 1982). We can see from the comparison, that though the scale and the actual species characteristic of different phases can be different, as it is obvious from the different climatic and geomorphological endowments of the two regions, the most important trends in the evolution of the species show the same directions. We can suppose, that the potentials are given for a unified biostratigraphy to be elaborated for the Central European region for the subdivision of the Holocene.

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ADDRESS OF AUTHOR:

Levente FÜKÖH

Mátra Museum
GYÖNGYÖS Kossuth u. 40. H-3200

FLUVIAL AND LAKE DEVELOPMENT

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PALEOHYDROGRAPHIC CHANGES IN THE BODROG-TISZA INTERFLUVE (NE HUNGARY) IN THE PAST 20,000 YEARS BASED ON PALYNOLOGICAL STUDIES AND ^{14}C DATING

É. CSONGOR and E. FÉLEGYHÁZI

ABSTRACT

The morphological and hydrographical conditions of the Bodrog-Tisza Interfluve Bodrogköz - in the NE part of the Great Hungarian Plain has been subjected to essential changes during the past 20,000 years.
A lot of abandoned riverbeds can be observed in the area. The ages of the majority of them were determined by palynological and radiometrical methods. From the results it can be concluded that these beds belonged earlier to the river Tisza. In the area S of the Karcsa brook two lines of abandoned riverbeds can be observed running NE-SW direction, and from the E to the W two other lines of beds can be found.
Concerning their ages, the Eastern line of beds proved to be the oldest. ^{14}C and pollen analyses show that it became abandoned at the end of Upper Pleniglacial. The further lines of beds from the E to the W were abandoned at the Late Glacial, in the Atlantic, and Sub-Boreal stages, respectively. The river Tisza occupied its present place during the Sub-Atlantic.

* * *

INTRODUCTION

The most important phases of the evolution in the NE part of the "Great Hungarian Plain" can be explained fairly accurately throughout the thirty years of research. Some questions remained, however, unclarified regarding the evolution of the watercourse system on the margin of the "Great Hungarian Plain" at the end of the Upper Pleniglacial and Holocene periods.

The Bodrog-Tisza Interfluve (Bodrogköz) is one of the depressions near the Nyírség region, where, during the period, concerned the morphological and hydrographical conditions underwent by significant changes. The Interfluve, located in the region of the Zemplén Mountains, Nyírség and Rétköz, is bordered by the river Bodrog on the W, the Tisza on the S and E, and the Latorca on the N *(Fig. 1)*.

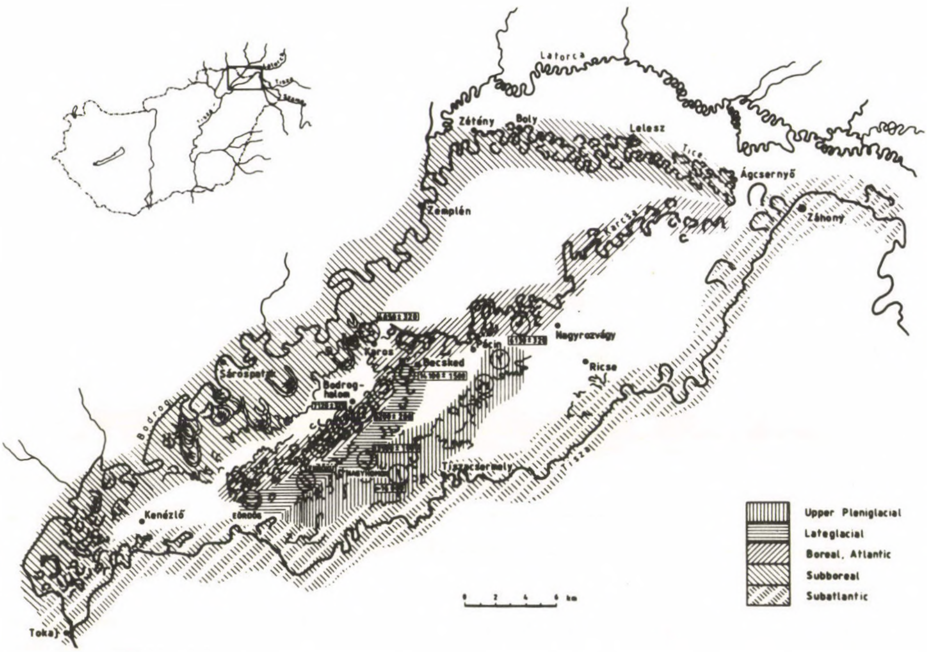

Fig. 1 The changes of the bed of the river Tisza in the Bodrog-Tisza Interfluve during the past 20,000 years.

The ages of charred plant remains found in the bottom layers of the abandoned beds are determined by 14C dating in Cal BP years.

A really confused type abandoned riverbed network can be found in the area enclosed by the three rivers. Among the best preserved ones is the bed of the Tisza, running along the northern part of the region, from the great Tisza bend at Záhony towards Zemplén, in WNW direction.

The Karcsa-brook, along the Hungarian-Czechoslovakian frontier, is also a former bed of the Tisza.

Two lines of abandoned river beds, running NE-SW direction can be found between the sand isles, in the area S of the Karcsa brook. They divide the local region into eastern, central and western parts. The length and width of the meanders of the beds increase from E to W.

The eastern series of beds, running southwards, from the line between the villages Nagyrozvágy and Pácin, is composed of abandoned beds hardly noticeable on the surface and consist of narrow, slightly bent, short reaches.

In the western series of beds, S of the Becsked-Karos line, bends with larger curves can be observed. As to their dimensions, they can be compared to the meanders and oxbow lakes of the Karcsa brook, and the youngest oxbow lakes of the Tisza.

The largest oxbow lakes of the Bodrog-Tisza Interfluve, best visible in aerial photos, evolved on the left bank of the Bodrog. These accompanied by a belt of banks, are similar, in size, to the oxbow lakes of the Tisza, W of the town Tokaj, and the abandoned Tisza beds in the Hortobágy plain.

Former beds of the Tisza and Karcsa were regarded as abandoned Tisza beds already by earlier investigators (BORSY, Z. 1953).

Previously, no accurate data were available concerning the abandoned beds in the Interfluve, and through stratigraphical methods approximate data were obtained only for the Karcsa. Since 1978 several boreholes have been sunk in all the important beds for obtaining appropriate samples for both palynological and possibly, ^{14}C dating. The aim of these examinations were to determine that which abandoned bed had belonged to which river, and in which period. Dating of the abandoned beds was important in other aspects as well. A naturally built levee runs along each, more significant, abandoned riverbed. The badly drained depressions between them actually served as sediment accumulating areas. In order to date the deposits, knowledge of the ages of these beds is of decisive importance.

In the next section, on the basis of new palynological data and ^{14}C datings, an account is given of the hydrographical changes taking place in the Bodrog-Tisza Interfluve since the Upper Pleniglacial period.

From earlier investigations it is well known that in the Pleistocene a huge alluvial fan was built up in the NE part of the Plain by the rivers running from the NE Carpathians and N Transylvania (TRENKO, Gy. 1909; SÜMEGHY, J. 1944; BORSY, Z. 1953, 1969). In the Interfluve marked accretional activity was performed by the smaller watercourses from the Zemplén Mts, and mainly by the rivers flowing southwards from the N Carpathians: the Tapoly, Ondava and Laborc. In the Nyírség, primarily the depositional work of the Tisza and Szamos was considerable. According to recent finds, the Tisza and Szamos abandoned the Nyírség area of the alluvial fan during the Würm glacial, and shifted their course towards the southern margin of the region, to the E of the Ér valley (BORSY, Z.-FÉLEGYHÁZI, E. 1982). The Tapoly, the Ondava and, possibly, the Laborc may have for a time, continued their course across the Bodrog-Tisza Interfluve, in towards the Nyírség *(Fig. 2)*.

The network of watercourses, outlined above, was subject to considerable changes around the middle of the Upper Pleniglacial period, for the areas on the edge of the Nyírség began to sink. Since this depression was significant mostly on the Bereg Plain, in the Bodrog-Tisza Interfluve, the Tisza was forced to abandon the Ér valley and took its course in the NW direction. When passing through the Huszt gate, the Tisza,

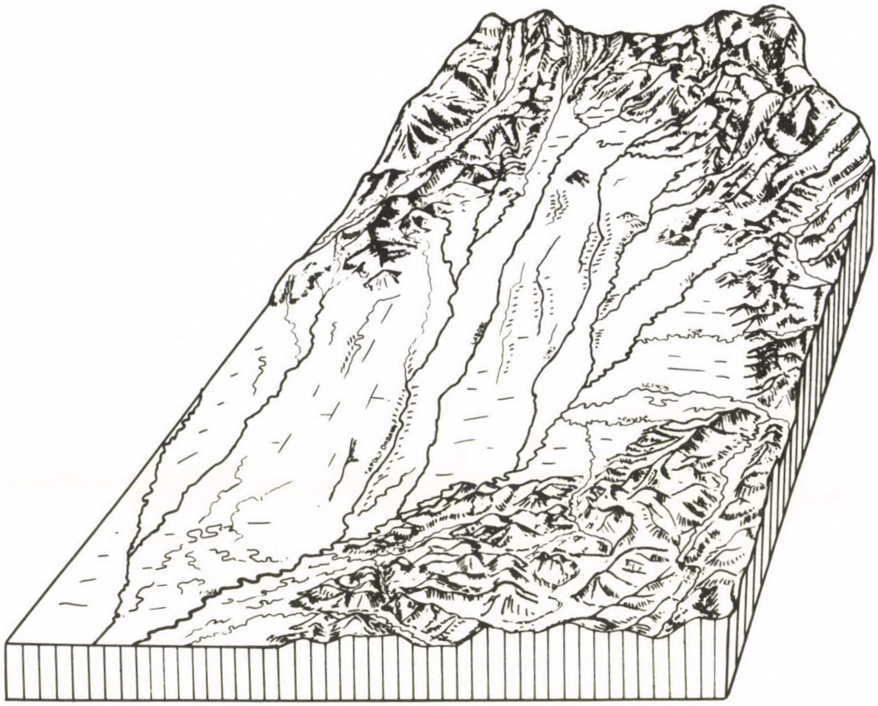

Fig. 2 Network of rivers in the first half of the Upper Pleniglacial

on arriving at the area of the Interfluve, full of sand dunes, crossed the course of the previously southbound waterways. It took up the Latorca, Ondava and Tapoly and, be means of its sideling erosional activity, exerted a considerable surface-forming work already in that period.

DISCUSSION

Present investigations and the stratigraphic data obtained from the abandoned beds suggest that the Tisza appeared in the Bodrog-Tisza Interfluve about 18,000-20,000 years ago, i.e. several earlier than it was previously assumed (SÜMEGHY, J. 1944; BORSY, Z. 1953).

From the "earliest" abandoned bed of the Tisza only some smaller parts have remained, since later, in the course of the meandering, when the material of the flood basin was re-agglomerated over a large area, the Tisza destroyed most of its previous bed.

The earliest reaches of the abandoned riverbed could be found only now, in the present investigations in the area E and S of Pácin, as well as W of Tiszacsermely *(Fig. 1)*.

The recent drillings in the eastern part of Pácin, reached the bottom of the one-time bed of the Tisza, at a depth of 620 cm. After the Tisza had abandoned this flow direction, a nearly 2 m thick layer of silt was deposited in the bed and these proved to be barren from the pollen analytical point of view. Taking into account the age of the overlying layers, that had good pollen conservation capacity, the previously mentioned silt is to be regarded as of *Upper Pleniglacial*. The silty sand deposited at the depth of 460-410 cm, was found also in cases of pollen analysis of samples from the Late Glacial, and that of the depth of 410-310 cm of Pre-Boreal age. From the Boreal phase the bed might have frequently got dry and the local sediments became unsuitable for pollen conservation.

In the southern part of Pácin, the coarse sand of the bottom of the bed was reached at a depth of 9 m. Overlying that, there are *Upper Pleniglacial* silty sand and silt, on which, between the depth of 520 m and 290 cm, Late Glacial and Preboreal sediments were deposited, as proved also by palynological examination. It is obvious that the filling up of the bed was fast, especially in the early phase. From the Boreal phase, however, only 290 cm of sediment has been deposited in the riverbed.

W of Tiszacsermely *Upper Pleniglacial* sediments were accumulated in the 8 m deep bed, at a level of 6.2 m from the bottom. A sediment layer, deposited in the Late Glacial, is above this, up to 500 cm. The sandy silt contained pollen as far as 500-400 cm from the surface. At the depth of 400-370 cm charred plant remains were exposed. Their ages by ^{14}C determination are 7,160 ± 320 years B.P. (Deb-487). This value agrees with the results of the palynological examinations. These latter data prove that the layer in the depth of 400-370 cm originates from the early Atlantic phase *(Fig. 3)*.

As indicated by the results obtained from boreholes, the Tisza abandoned the above-mentioned flow direction as early as the second half of the Upper Pleniglacial period and, taking its course W of Pácin, turned between the villages Becsked and Karos first southwards then south-westwards *(Fig. 1)*. The Tisza kept to this line until the *Late Glacial*. The abandoned beds and oxbow lakes found near Becsked, Nagyhomok, Csengökút and Eördög hamlet are filled up to a thickness of 5.5-9.0 m. The bottom layers are, unequivocally *Late Glacial* as shown by ^{14}C and palynological dating. The ^{14}C dating of the charred plant remains found at the village Becsked, in the bottom layer of the abandoned bed, at the depth of 850-810 cm indicates 14,100 ± 1500 years B.P. (Deb-482). At the village Nagyhomok further charred plant remains were found at the depth of 525-510 cm, the ^{14}C data indicated an age of 13,900 ± 1000 years B.P. *(/Deb-456/ Fig. 1)*.

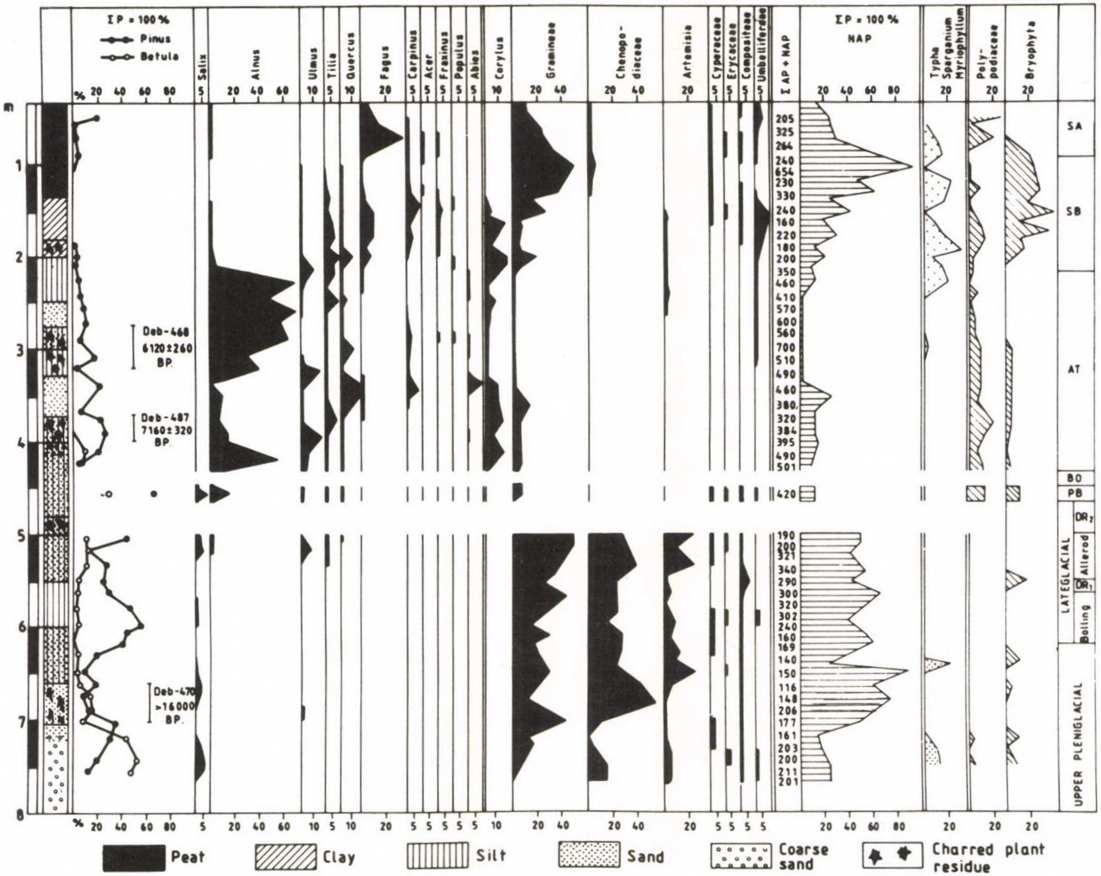

Fig. 3 Pollen diagram of the abandoned riverbed west of Tiszacsermely. The data are calibrated ^{14}C dates in years B.P. of charred plant remains

The ^{14}C data, corresponding to the results of the palynological examinations. Although the quantity of charred plant remains exposed at Csengökút and at Eördög hamlet was not sufficient for ^{14}C dating, from the pollen analysis of the bottom layer samples of these beds it can be established that the Tisza abandoned these courses already in the *Late Glacial*.

After the *Late Glacial* stage the Tisza, passing through the area between Becsked and Karos, turned south-westwards. In this region, a large number of abandoned reaches, oxbow lakes can be found, that actually form a network of abandoned beds in the zone of the Bodrog-Tisza Interfluve *(Fig. 1)*.

The large number of abandoned beds indicate that the Tisza kept its course for a long time. This view is confirmed by the results gained from the boreholes, sunk in the riverbed NE of Pácin, between Becsked and Karos, in the Bodroghalom region, W of Nagyhomok and NE of Kenézlö.

According to ^{14}C dating the age of the Karcsa oxbow lake, NE of Pácin was cut off 6,130 ± 320 years (Deb-172 and Deb-201) ago, in the middle of the *Atlantic stage* (CSONGOR, É.-FÉLEGYHÁZI, E.--SZABÓ, I. 1982). At Bodroghalom, in the sandy sediment, overlying the bottom of the traverse of charred plant remains of ages of 7,120 + 320 years (Deb-479) could be found. At Magasorom, S of Bodroghalom, the age of the charred plant remains found at depths of 550-530 cm, and 400-380 cm of the deposit overlying the bottom, were found the same, 6200± 280 years of age (Deb-484 and Deb-483), and this indicates a fast rate of filling. No charred plant remains were found in the boreholes sunk in other abandoned beds and oxbow lakes. The palynological examinations, however, prove that in these beds there has been no actual watercourse since the middle of the Atlantic stage. This, at the same time, indicates that in the first part of the *Atlantic stage* the Tisza abandoned this part of the Interfluve and flowed from Ágcsernyö through Lelesz, Boly, Zétény towards Zemplén. The Tisza, however, preserved the traces of this course, showing well-developed meanders. The number of oxbow lakes, along the bed, suggests that the Tisza flowed in this bed for a longer period. The results of the drillings performed by the Bratislava Geographical Institute of the Slovakian Academy of Sciences (personal communication) suggest that the Tisza abandoned this part of the Interfluve as early as the *Sub-Boreal stage*.

Also, while flowing in the bed of the present-day Tice, by gathering waters of the courses coming from N of the village Zemplén, the Tisza formed large meanders at the Zemplén Mountains. On the alluvial plain on the left bank of Bodrog, E, SE and S of Sárospatak, the large oxbow lakes that have been greatly filled up since, can be seen.

Since the *Sub-Boreal stage* the Tisza abandoned the N and E part of the Interfluve and changed its course towards the present southern part of the region joining the river Bodrog at Tokaj. This, at the same time, means that from this time on it was only the Bodrog that ran at the foot of the Zemplén Mountains.

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ADDRESS OF AUTHORS:

Éva CSONGOR

ATOMKI
(Institute of Nuclear Research
of the Hungarian Academy of Sciences
DEBRECEN Bem tér 18/c. H-4001

Enikö FÉLEGYHÁZI

Kossuth Lajos University
Institute of Geography
DEBRECEN Egyetem tér 1. H-4010

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Hungarian Academy of Sciences
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RESULTS OF RECENT INVESTIGATIONS OF THE LAKE BALATON DEPOSITS

T. CSERNY

ABSTRACT

The history of investigation of the Lake Balaton deposits were reviewed and the recent studies carried out by the Hungarian Geological Institute between 1981 and 1985 are summarized.
Launched in 1981, the project was aimed at the understanding of the genesis process and the history of the lake, at an exact determination of the changes in its sedimentation, at studying the still-active sedimentation processes and diagenesis in their full complexity and assessing the Holocene lacustrine deposits by using key section approach.
In 1981-1982 a total of 16 boreholes were put down to a depth of 1.7-4.7 m, mainly in the Balatonfüred-Siófok subbasin. Six of these boreholes cut through the Holocene deposits in full and stopped in the Upper Pannonian. The recovered drill samples were analyzed for soil-physical, organic and inorganic geochemical, X-ray and DTA characteristic and palynologically.

* * *

The Hungarian Geological Institute planned to carry out investigations of the deposits of Lake Balaton during the 6th five-year plan. Having determined the natural trends of sedimentation the changes followed as a result of artificial factors, can be studied.

RECENT INVESTIGATIONS

The investigation of the lake deposits, in modern sense, was led by LÓCZY, L. Ser. (1913). To study the lacustrine sediments and the basement 17 boreholes of 8-15 m depth were deepened in the years 1894-1896 *(Fig. 1, 1-17)*. Based on the sequences of boreholes and on other observations the history of evolution of the lake was outlined.

Boreholes for studying the lake sediments were drilled later in 1948, partly along the shore, partly in the central area of the lake *(Fig. 1, 18-22)*. In 1961, for the study of the siltation of Lake Balaton a team was organized under the guidance of VITUKI (Scientific Research Institute for Water Management), the team included representatives of 22 institutions in 1963-1964. In 1964-1965 16 boreholes were drilled by the vibration instrument, developed by VITUKI *(Fig. 1, 23-28)*. The report, published in 1966, containing the results of the complex investigations included 9 papers (SZESZTAY, L. et al. 1966).

Based on surficial samples, MÜLLER, G. reported sedimentological data on the lake sediment (MÜLLER, G. 1970). In 1972 sediment samples were collected in 6 localities *(Fig. 1, 39-44)* and mineralogical, geochemical, oxygen-isotopic analyses were carried out on the mostly carbonate sediments (MÜLLER, G.--WAGNER, F. 1978) and in the samples taken from the upper

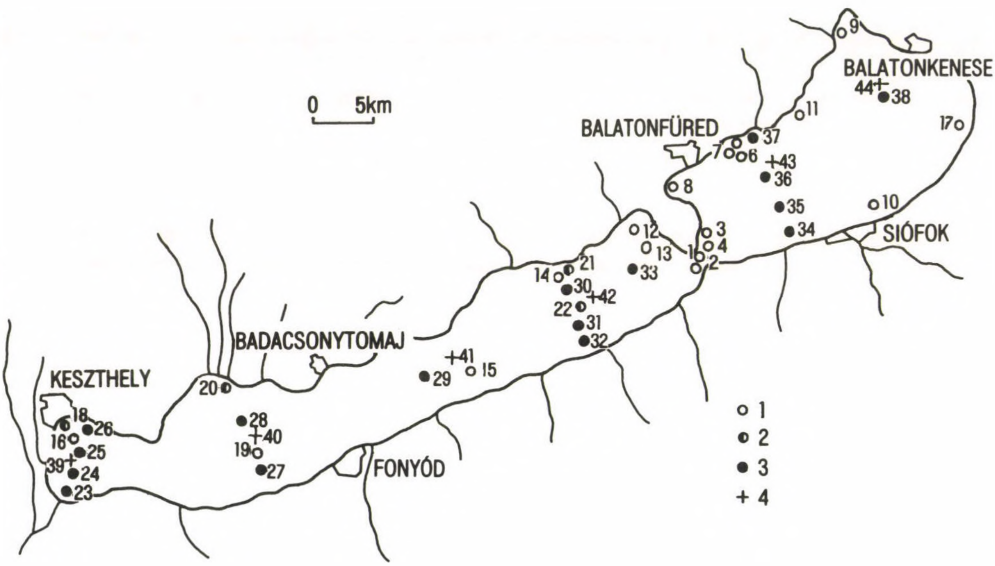

Fig. 1 Borehole sites (sampling points) drilled in the course of earlier investigations

1 = L. LÓCZY's boreholes: 1-17 (1894-1895); 2 = in 1948, 18-Keszthely VII, 19-Szigliget-Fonyód III, 20-Szigliget V, 21-Akali-Szemes II, 22-Akali I and Ia; 3 = VITUKI team, Nº 23-38 (in 1964-1965); 4 = G. MÜLLER, Nº 39-44 (in 1972)

15-20 cm of the sediments the organic carbon, the total nitrogen content, the easily soluble phosphate concentration, and total carbonate content were determined.

RESULTS OF THE HUNGARIAN GEOLOGICAL INSTITUTE (1981-1985)

Investigations were carried out along sections parallel with the lake axis, and perpendicular to it, by means of boreholes. Investigations aimed at the determination of the physical, chemical, mineralogical-petrological and sedimentological characteristics of the sediments, as well as, based on the pollen and diatome analyses, at the determination of the age and facies of the sediments. In the course of interpretation we tried to analyze the formation conditions of the lake sediments and the temporal changes of sedimentation, with regard to biostratigraphic, environmental-geological and sedimentological aspects. Along the sections 16.8 m was drilled in 1981, and 26.12 m in 1982 by eight-eight boreholes *(Fig. 2)*. Out of the 16 boreholes 14 was drilled in the Siófok-Balatonfüred subbasin, while two in that of the Akali-Balatonszemes subbasin.

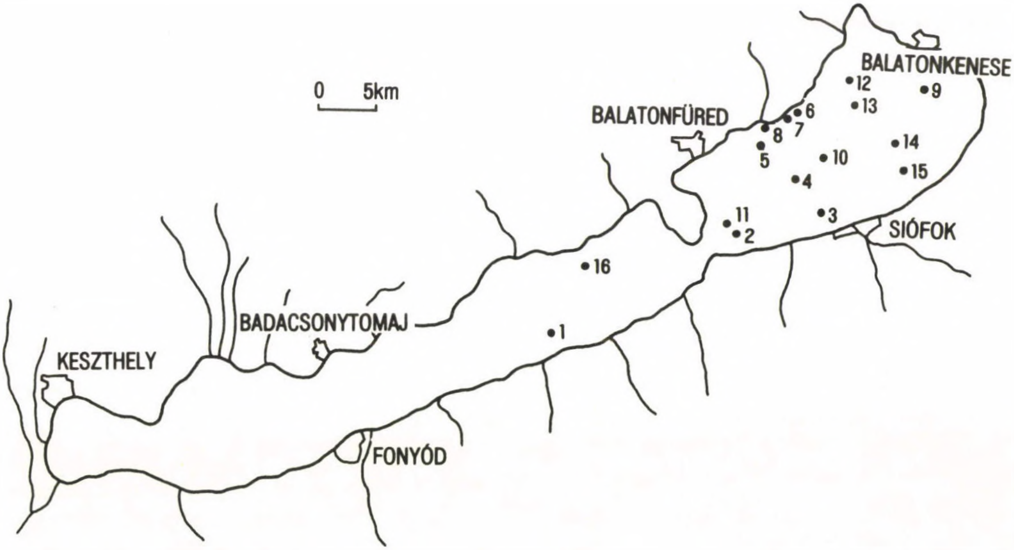

Fig. 2 Site of boreholes drilled within the frame of the recent project (Nº 1-16)

The Hungarian Geological Institute has carried out engineering-geological mapping in the period 1966-1979 on scale 1:10,000, and during 1983-1988 on scale 1:50,000 (BOROS, J. et al., 1980; CSERNY, T.--RAINCSÁK-KOSÁRY, Zs. 1984). On behalf of the Central-Transdanubian Water Management Authority the Engineering Geological Department of the Hungarian Geological Institute analyzed the samples from the bed and bed-surface between 1978 and 1980.

The Research Institute for Lymnology of the Hungarian Academy of Sciences at Tihany carried out the mapping on scale 1:10,000 of the open water table. Sampling density was 7-8 points/sq.km. From the samples the determinations of the physical parameters (grain size composition, water content, bulk and specific density, plasticity), that of the mineralogical-petrological and geochemical features, of the organic carbon content were carried out. Besides only in case of the samples of 1982 palynological and malacological investigations were performed at the Analytical Department of the Hungarian Geological Institute and at the Laboratory for Engineering Geology in Balatonfüred. Boreholes drilled in 1982 and stopped in or close to the Upper Pannonian could be palynologically divided.

Strata conditions and physical parameters

The grain size composition of the Holocene formations explored by the boreholes was nearly the same in all boreholes, i.e. argillaceous silt (10 to 30% argillite and 0 to 20% sand contents). Exceptions are boreholes 11 and more or less 14. In these boreholes fine-sandy silt was found (with 5 to 15% argillite and 40 to 70% fine-sand contents). The difference is caused by the fact that borehole 11 lies close to the Tihany Strait, borehole 14 lies in the line of intense water flow, thus instead of the finer pelitic sediments somewhat coarser psammitic ones were deposited. The Holocene argillitic silt (mud) and the fine-sandy silt are light-grey, become darker downwards, and contain greenish-grey and dark-grey strips. The bulk densitiy of sediments increases downwards, in case of argillitic silts from 1.1 g/cm^3 to 1.4 g/cm^3, in that of the silty fine-sands from 1.7 g/cm^3 to 2.0 g/cm^3. Their specific weight varies between 2.2 and 2.3 g/cm^3. The natural moisture content of the argillitic varieties is about 60%, that of the fine-sandy silts between 30 and 40%.

Based on Casagrande-test, the plasticity index of the argillitic rocks varies between 30 and 55%. The presence of fine-sands decreased this value to 10-20%, practically independently of the method applied. According to Hungarian Standards the sediments were qualified as clays and muds, respectively. Nevertheless, due to their high carbonate contents the correct terms are: clay-marl, lime-marl and lime-mud. The relatively high plasticity index is due to clay minerals present in the sediments (their proportion varying between 10 and 25%). The consistency index of the formations refers to their state. Since these values are negative, the sediments are "very soft" and contain much water. Downwards the sediments transform into "soft" state.

Summing up the results on physical parameters it can be stated that in the boreholes two vertically, characteristically differing formation types are found. The boundary between the two types is found in the last 0.1-1.0 m thick section and it coincides with the Upper Pannonian-Quaternary boundary. This is proved by the bulk density, the moisture content and the consistency index.

Within the Quaternary sediments also two types can be distinguished in harmony with the physical parameters, i.e. an argillaceous silt (clay, mud) and a silty fine-sand (sand-silt). The differences within the Holocene sediments can be traced back to the sedimentation conditions (quiet or flowing waters).

MINERALOGICAL INVESTIGATIONS

Thermal and X-ray diffractometric analyses

Thermal analyses were performed by a MOM derivatograph, the X-ray diffractometric analyses were carried out by a Phillips powder diffraction instrument.

Based on the parallel investigations the following conclusions can be drawn:

in the Holocene lacustrine sediments detrital minerals (quartz, potash-feldspar, plagioclase), clay minerals (montmorillonite, illite, muscovite, chlorite), carbonates (calcite, Mg-calcite, dolomite, protodolomite) as well as pyrite and organic matter can be found. As for the quantities and frequency the carbonates, quartz, muscovite and chlorite are most characteristic. As compared to the previous samples, the quantity of clay minerals is subordinate (between 10 and 25%). The quantitative and compositional changes of carbonates fairly well reflect the process of sedimentation. Thus, the quantities of calcite, dolomite and total carbonate, as well as the Ca/Mg ratio of magnesiocalcites were demonstrated for each boreholes. The diagrams show that

- in each boreholes, in their total length, the Holocene sediments are of high carbonate content (30 to 70%);
- in the magnesiocalcite of the sediments the Ca/Mg ratio gradually decreases as a function of depth (the Mg-enrichment may be a result of climatic changes);
- the Holocene-Upper Pannonian sediment boundary can be drawn in the boreholes where Mg-calcite disappears and only "pure" calcite and dolomite are present. This boundary is indicated by increase in the quantities of quartz, feldspar and muscovite, as well as by the decrease in that of montmorrillonite.

Results of the chemical analysis

The suitable methods were designed and the analyses were also carried out in the Hungarian Geological Institute. Selective dissolution, adsorbed and structural water determination, and carbonate determinations, expressed in CO_2 percentages, of the samples were performed, and the results were evaluated.

In the course of selective dissolution, the Ca, Mg, Na and the main rock-constituents were dissolved and determined by AAS. The quantity of the Ca and Mg ions shows a uniform distribution in the Holocene sequence, while at the Pannonian-Holocene boundary the quantity of water-soluble calcium increases. The Ca/Mg molar ratio shows a definite trend as a function of depth: in the Holocene sequences this value gradually increases from 0.6 to 1.0, in the Pannonian sediments the value varies around 2.0. The Ca/Mg molar ratio of recent sediments in the water of Lake Balaton is 0.4.

The relative value of the exchangeable ions can be satisfactorily evaluated (the concentration of Ca or Mg exchanged by Ba, divided by the sum of the water-soluble and exchangeable ion concentrations, and expressed in percents).

When demonstrating the relative values of exchangeable ions as a function of depth two phenomena are worth of mentioning.

- In the Holocene sequence smaller-greater minima and maxima alternate and this alternation can be identified in all boreholes. In the freshwaters Ca is bound to hydrogencarbonates in the solutions, due to the carbonic acid, the quantity of which is controlled by the water temperature. Thus, the alkali-metal content bound to clay minerals reflect also the former climatic conditions. Consequently, the maxima of the exchangeable ions relate to waters, more abundant in hydrogencarbonate and carbonic acid (i.e. to colder water), and the minima refer to warmer water.
- In some boreholes (9, 15, 16) the Holocene-Pannonian boundary is marked by a negative peak. This means that the ion-exchange capacity of clay minerals irreversibly decreased, i.e. the area became terrestrial in the Pleistocene. During this period a soil cover of 0.4-0.5 m emerged.

The absorbed water content of sediments was determined by drying, the carbondioxide content of carbonates by gas-volumetry, the structurally bound water quantity by measuring the ignition loss. The values, expressed in percentages and shown as a function of depth, reflect the following:

- The trend of the absorbed and structurally bound water is the same in all boreholes, the Holocene-Pannonian boundary is marked by a large and steep step,
- The carbonate content shows sharp change not only at the Holocene-Pannonian boundary, but also within the Holocene, where trhee phases can be distinguished. In borehole 11 repeated redeposition can be observed that can be attributed to the strong water flows in the Tihany Strait.

ORGANIC GEOCHEMICAL STUDIES

Among the bituminological analyses the Soxhlet extraction (bitumen %), the IR study of bitumens and asphalthene separation, and the organic carbon content determinations were performed. Analyses and evaluation of the results were also carried out.

The quantity of the chloroform-soluble bitumen first increases and reaches a maximum between 2.5 and 3.5 m (0.10 %), and then downwards, it decreases and shows minima close to the bottom (0.02 to 0.03 %).

During the extraction process different quantities of elementary sulfur were dissolved from the samples. The maxima of the exsolved bitumen, and the large quantities of elementary sulfur at the same places, proved by the intense activity of sulfate-reducing bacteria, can be explained by the very slow sedimentation, or by the high, dissolved salt rate of content of the water.

The change in the quantity of organic carbon shows similar picture also as a function of depth: between 2.0 and 3.5 m considerable amounts of organic matter accumulated from the water.

Based on the IR spectra, the lower aquatic organisms predominante in the organic matter with minor terrestrial organic matter content.

PALYNOLOGICAL INVESTIGATION

Palynological analyses were also carried out. Results of the evaluation were suitable to determine the predominating temperature during sedimentation period, in addition ot the determination of pollen species (see the next article).

CONCLUSION

1. Among the boreholes drilled in the Balatonfüred-Siófok subbasin those of Nº 9, 10, 11, 14 and 15 traversed the Holocene lacustrine sediments and reached Upper Pannonian formations. No Pleistocene lacustrine sediment could be found in the boreholes. The Holocene lacustrine sediments are represented by clay-marls, clays, marls and lime-marl muds. In the boreholes the bands consisting of rounded quartz and phyllite as well as of carbonates, found at the boundary of the Holocene and Upper Pannonian formations may derive from the Late Würm, immediately preceding the lacustrine sedimentation, from the erosion of the rocks of the Balaton Upland. In borehole Nº 16, peat-band and large amounts of molluscs shell fragments can be found at the Holocene - Upper Pannonian boundary.

2. The Holocene - Upper Pannonian boundaries, determined macroscopically, were also verified by palynological results, and by the organic and inorganic geochemical analyses. As for the X-ray and DTA analyses, the quantity of magnesiocalcite

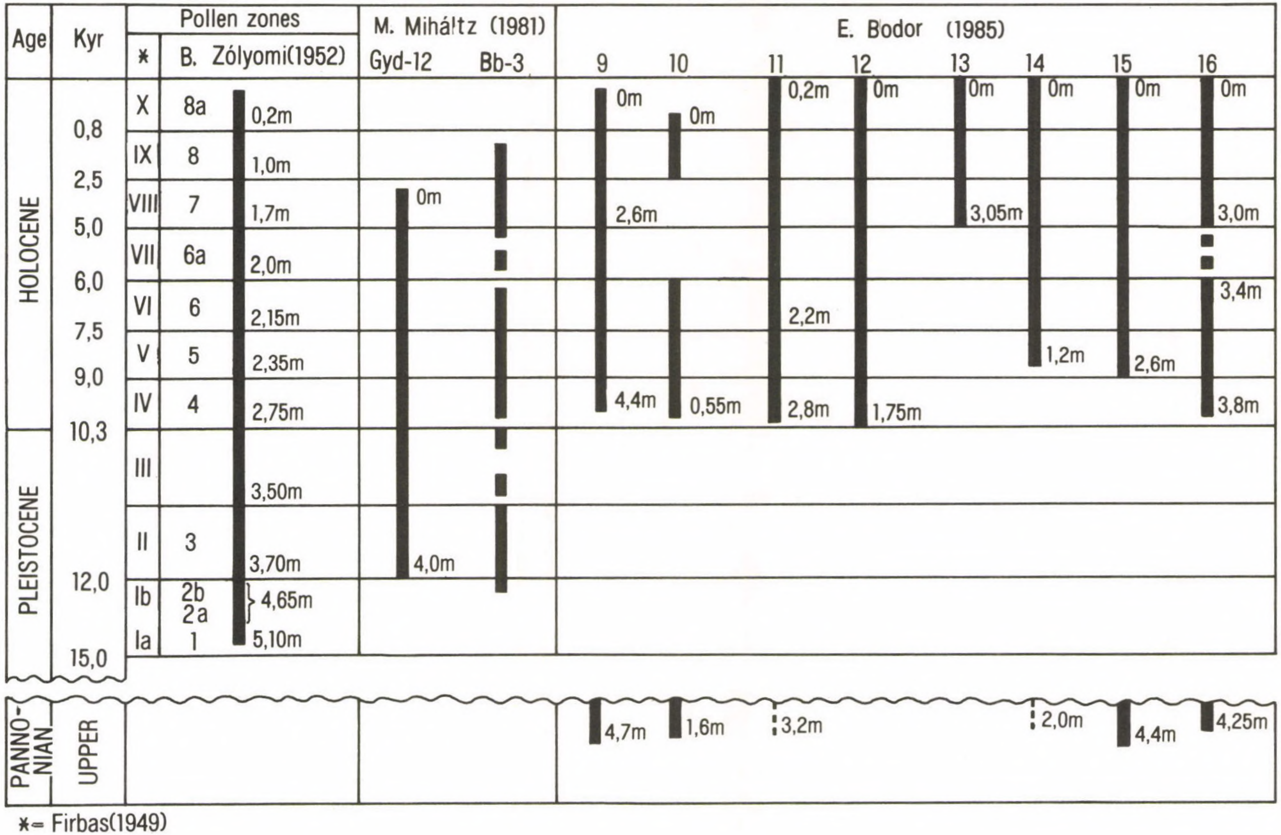

Fig. 3 Correlation of the boreholes deepened into Lake Balaton in 1982

in the sediments gradually decreases down to the Holocene - Upper Pannonian boundary and disappears in the Upper Pannonian. At the boundary the organic carbon and the choroform-soluble bitumen show minima. The carbonate content is 2-3 times higher in the Holocene samples. At the boundary the water-soluble Ca quantity increases and a negative peak occurs in the relative quantities of exchangeable Ca and Mg.

3. Based on palynological data, information was also obtained on the Holocene climate:

- The cool climate of Early Holocene (pine-birch vegetation period) is indicated by the sudden change of the carbonate content, by the high organic matter content and the minimum of relative quantities of the exchangeable Ca an Mg (10,300-9.000 B.P.) ions.
- The Boreal climate and low water table level of the lake in the hazel vegetation period (9,000-7,500 B.P.) is indicated by peat formation.
- Pollen analyses refer to the Atlantic stage in the borehole section between 2.0 and 3.5 m, the highest water table level of Lake Balaton can be presumed in that period. Organic geochemical analyses revealed the precipitation of elementary sulfur. Two maxima and one minimum were found in the relative quantities of exchangeable Ca and Mg (2.2 to 2.6 m, 2.95-3.35 m and 2.6-2.85 m, respectively).

In the Szigliget (ZÓLYOMI, B. 1962) and Keszthely Bays, as well as in the boreholes drilled at Gyenesdiás and Balatonboglár (MIHÁLTZ-FARAGÓ, M. 1979, 1983). Late Glacial strata (15,000 B.P.) could be also found. The age of the earliest pollen association found in the boreholes drilled in 1981-1982 is postglacial pine-birch (10,300 B.P.). Consequently, the coverage by water of the subbasins of Lake Balaton is younger when moving eastwards, i.e. the Keszthely Bay was inundated by about 5,000 years earlier than the Balatonfüred-Siófok subbasin.

4. Based on the knowledge of the data, obtained from sediment thicknesses, and the time interval needed for their accumulation, the sedimentation rate can be determined. The available data from the sequences of boreholes sunk in flow regions (boreholes 11, 10, 15) suggest that the sedimentation rate could be 1.5 to 3 mm/10 years, and 4 to 6 mm/10 years in the quiet areas (boreholes 9, 13, 16). These averages are valid for the total length of the boreholes; the values are higher in the Late Holocene than in the Early Holocene. This fact can be explained by the looser structure of the sediments.

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ADDRESS OF AUTHOR:

Tibor CSERNY
Hungarian Geological Institute
BUDAPEST Népstadion út 14. H-1143

M. Pécsi--L. Kordos (eds.)
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Geographical Research Institute
Hungarian Academy of Sciences
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FORMATION OF THE LAKE BALATON PALYNOLOGICAL ASPECTS

E. BODOR

ABSTRACT

In the course of the investigations of Lake Balaton boreholes have been recently deepened into the bottom of the Lake between Balatonakali and Balatonkenese. The material, thus obtained were analyzed also palynologically.
The material yielded, among others, a sporomorpha association characteristic of the Upper Pannonian and Holocene. During the Upper Pannonian the area was covered by marshy vegetation, and none of the boreholes yielded Pleistocene sporomorpha associations. Upper Pannonian sediments were followed by Holocene ones. These latter sediments cover a period lasting from the Early Holocene Pinus--Betula phase till a period of forest exploitation in the Late Holocene. Therefore, in the area mentioned above, the lake was formed during the Pinus--Betula vegetation phase.
There were periods when the Northern and the Southern shores were connected by landstripes. Their existence is proved by hiatuses in the sequence of the boreholes.
Based on our data, together with those obtained from the boreholes deepened into the bed in the Szigliget and Keszthely bays of the Lake, it can be seen that the present bed of the Lake Balaton had formed only gradually, from the West towards Northeast.
The sequence of boreholes sunk int he Lake Hévíz was also investigated. This sequence also yielded Upper Pannonian and Holocene sporomorpha-associations. Here, however, the Upper Pannonian sediments were covered by Late Holocene layers and not by Early Holocene ones, verifying the different tectonic origin of the two lake bed areas.

* * *

Palynological investigations of the sediment sequence of the boreholes drilled in the Balaton Basin were carried out by ZÓLYOMI, B. (1952), MIHÁLTZ-FARAGÓ, M. (1981). ZÓLYOMI demonstrated that the formation of Lake Balaton can be assigned, in this region, to the last glacial period. MIHÁLTZ-FARAGÓ studied Pleistocene and Holocene sediments in the vicinity of the Keszthely Bay. Recently, within the actual-geological investigations of Lake Balaton boreholes were drilled between Balatonakali and Balatonkenese.

Palynological studies were also performed in these boreholes sequence, and sporomorph associations, characteristic of the Upper Pannonian and Holocene, were found. In this phase of the Upper Pannonian, the region was covered by marshy vegetation *(Fig. 1)*.

In the section the Upper Pannonian was followed by Holocene sediments. These had started by the Early Holocene pine-birch vegetation phase (10,000 B.P.), and were finished by the phase of utilized forests in the Late Holocene.

Thus, in these areas the formation of the Lake can be assigned to the pine-birch period.

At the beginning of the pine-birch period the bed was covered, periodically, with shallow water and this is proved by the Pannonian sporomorph material, redeposited in the terrestrial phase. The history of evolution of the Lake can be traced to the period of constant water coverage and is the following:

The Pinus-Betula (pine-birch-tree) predominance was replaced by that of Corylus, and in the Late Holocene, during the period of mixed deciduous forests, the vegetation preferring the deep water environment became predominant. The water table level of the Lake reached its maximal height in the period of Fagus-forests.

The pollen spectra taken from the topmost layers of lake-basin boreholes indicated the presence of forests that thinned due to agricultural activity and the shallow water conditions returned again.

At the same time, two boreholes, deepened in the Lake-Hévíz, were also studied in order to determine whether the two lakes formed and developed simultaneously or not.

Though the sections of the two boreholes Upper Pannonian sporomorph accociation could be also identified, the Holocene formations continued with the Fagus-predominating Late Holocene sediments and not with the Early Holocene formations. Consequently, the formation of Lake Hévíz took place later than that of Lake Balaton. This fact proves the different tectonic origin of the two beds.

MORPHOGENETIC AND STRATIGRAPHIC RELATIONS

By means of the dense sampling, i.e. by 20 cm, we had the possibility to reconstruct the morphogenesis of the bed of Lake Balaton from the Late Holocene up to the Recent.

The morphological changes of the bed clearly show that there were periods in the lake's life when subaerial areas emerged between the northern and southern shores. In the section of borehole Nº 10 the rise of the basement occurred in the period of the predominance of the Fagus forests and it is reflected by hiatus in the sequence. It can be assumed that at that time the area represented an uplifted erosion surface. Based on the sequences of the northern and southern shores,

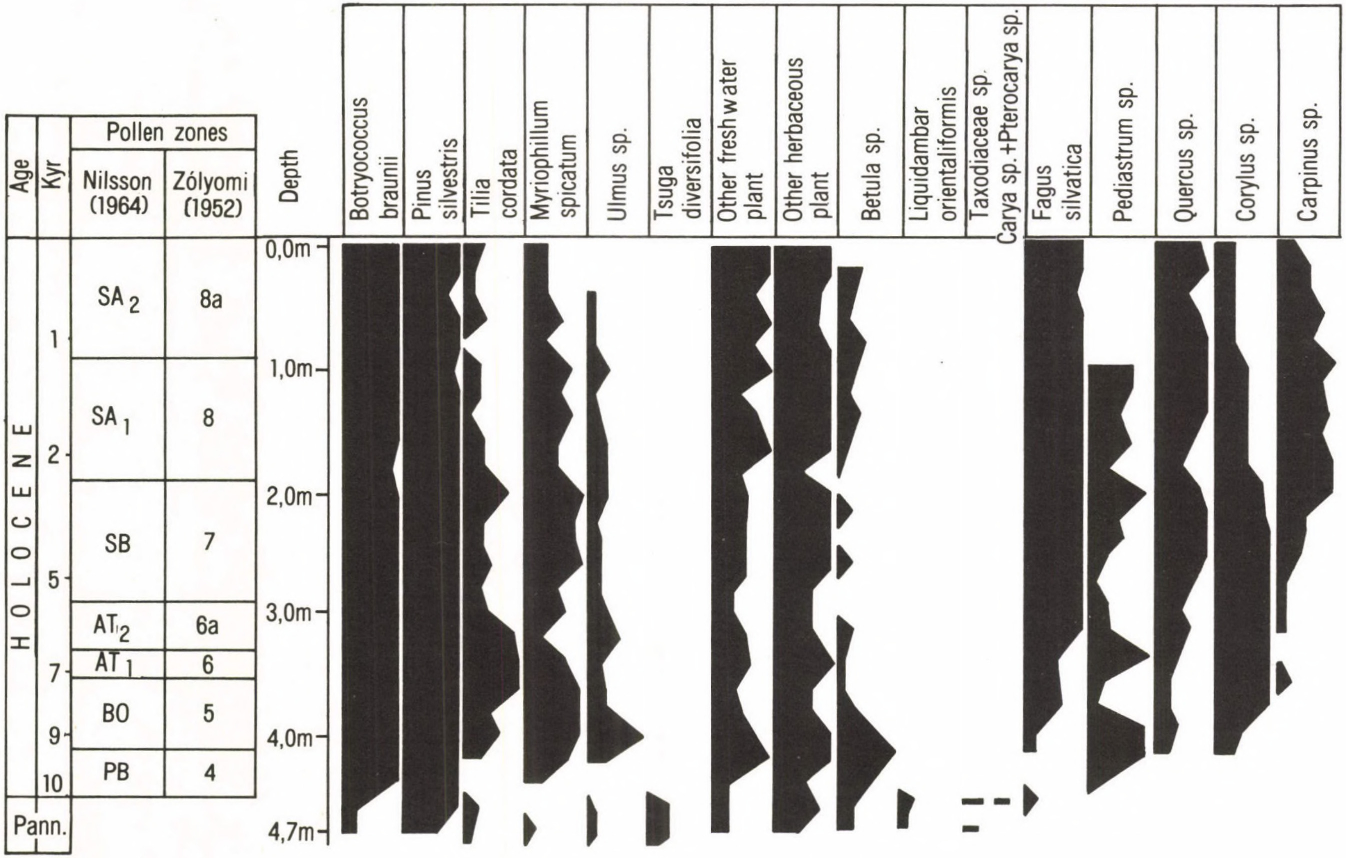

Fig. 1 Palynological diagram of borehole № 9

these subaerial connections (i.e. land-bridges) were already mentioned by SÜMEGHY, J. (1952). Our palynological investigations, proving the validity of these observations, can be summarized as follow:

1. In boreholes Nº 9, 10, 11, 15 and 16, Upper Pannonian sediments were found at the bed's base.

2. No Pleistocene sporomorph association was found in the boreholes.

3. Accordingly, it can be concluded that in this region the formation of the Lake could take place in the initial period of the Early Holocene Pinus-Betula vegetation phase.

4. In the sections the latest fossil sporomorph associations disappeared the phase utilized forest vegetation.

5. When comparing our data with those obtained earlier by ZÓLYOMI and FARAGÓ-MIHÁLTZ from the Szigliget and Keszthely Bays, according to which in this region the formation of the Lake Balaton can be assigned to the Würm III (15,000 years B.P.) the conclusion can be drawn that the formation of the recent bed of Lake Balaton proceeded gradually from west to the northeast. About a 5,000 years interval seems to exist between the formation of the bed of the Keszthely Bay and that of the Balatonkenese section.

6. The formation of Lake Balaton and Lake Hévíz is not contemporaneous and does not belong to the same tectonic unit.

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ADDRESS OF AUTHOR:

Elvira BODOR

Hungarian Geological Institute
BUDAPEST Népstadion u. 14. H-1143

STUDIES OF THE KISKUNSÁG NATIONAL PARK

GEOLOGICAL ASPECTS OF NATURE CONSERVATION IN THE KISKUNSÁG NATIONAL PARK

B. MOLNÁR and L. KUTI

ABSTRACT

The Kiskunság National Park is covered mostly by wind-blown sand. As shown by boreholes however, wind-blown sand is coupled with less permeable loess that plays important role in its constitution. Along with these two eolian sediment types there is lacustrine carbonates, overwhelmingly calcite mud and early-diagenetic dolomite mud that were in formed ponds filling up the flats between sand-dunes. The lastly mentioned deposit is, when wet, a completely impervious formation.
In the area the static groundwater level varies between 0 and 6 m in depth, and the position of the groundwater table is quite unstable. On the map plotted on the basis of the absolute values of the groundwater level as compared to sea level, two major (NE-SW and NW-SE) and two minor directions of groundwater flow can be indentified. In the region this topography, geological setting and groundwater resources produced varied vegetation.
Having determined the geological setting and geohistorical evolution, the drilling of chekc-wells for monitoring the variation of the groundwaer level were proposed.

* * *

INTRODUCTION

The Kiskunság National Park (KNP) lies in the Danube-Tisza interfluvial region within the Carpathian Basin *(Fig. 1, A)*.

The KNP is not a contiguous territory, but a so-called mosaic-park consisting of six subregions *(Fig. 1, B)*. Its surface area covers a total of 31,529 hectares, 23,066 ha of which have become, since 1979, a Biosphere Reserve under the auspices of UNESCO's MAB (Man and Biosphere) project.

For this reason, in the Park's operation, devoted to active nature conservancy, the research and training directives of UNESCO aimed at serving the interests of universal science and education have to be kept also in mind. Thus, the gates

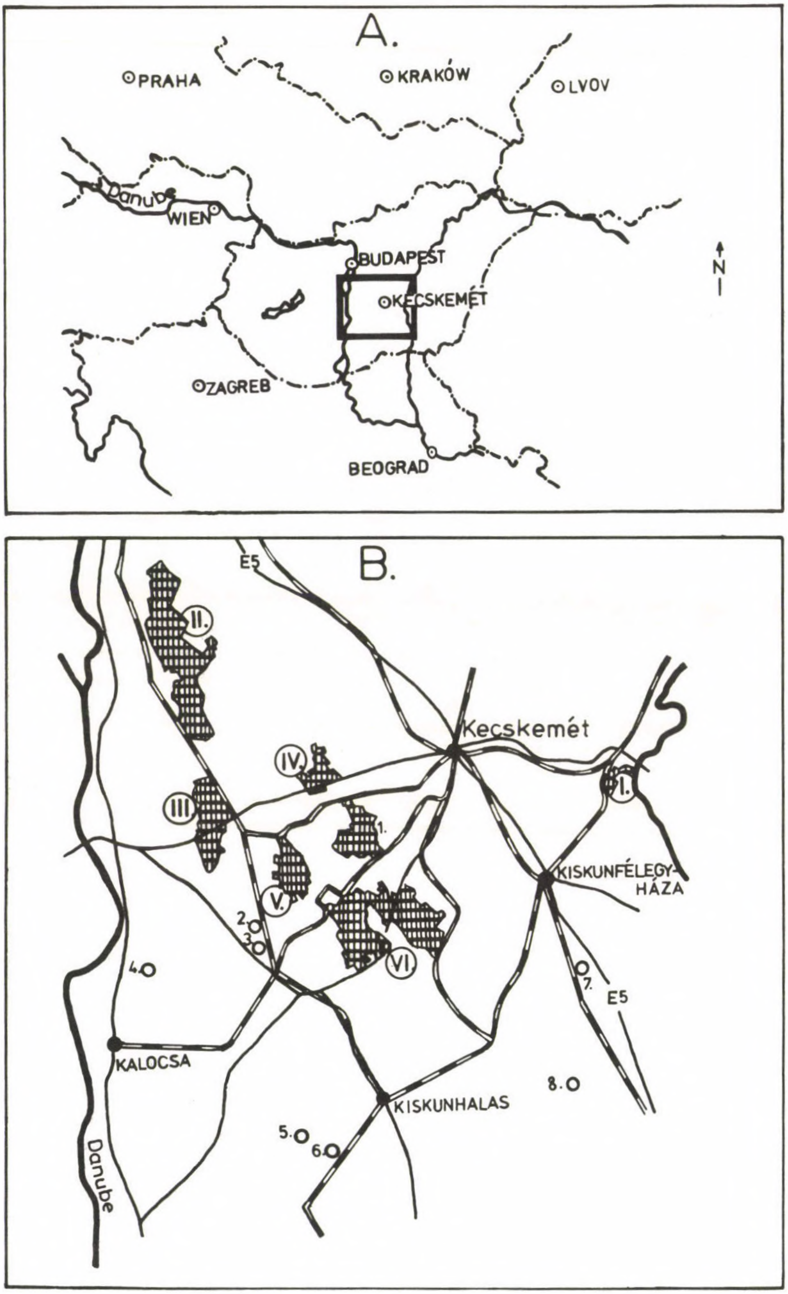

Fig. 1 The Kiskunság National Park in the Carpathian Basin (A), and in Hungary (B)

B: I-VI. Parts of the Kiskunság National Park,
1-8: Landscape conservation districts and nature conservation areas

of KNP have been opened to the outside world and a constantly increasing number of foreign nature conservancy experts visit the area.

In the present-day area of KNP geological investigations were performed already prior to the establishment of the Park. At that time the sand-dunes and the natron lakes at Fülöpháza were studied in detail *(Fig. 1, B, Area IV)* (MOLNÁR, B.--MURVAI, I. 1975), with an emphasis mainly on the natron lakes. Since 1961 regular local observations and laboratory analyses were carried out, with the participation of hydrochemists, biologists and physical geographers. The team work has enhanced also the geological research. Several results were achieved that geology was able to interpret and assess only by comparing them with results of experts of other fields. Results of this kind included data concerning early diagenetic dolomite formation in the ponds. The joint interpretation of ground- and lakewater-chemistry data, the comparison of the paleontological results with the recent fauna and flora, etc. were important, too. In this way, in case of molluscs, the results obtained from subfossil forms enabled us to follow the continuity of the fauna or the changes in it, respectively.

After establishing the KNP, scientific research work was conducted first under the auspices of the Hungarian Academy of Sciences and then with the support given by the Hungarian National Environmental and Nature Conservancy Office. First the natron lakes of Kiskunság *(Fig. 2, B, Area III)* (MOLNÁR, B.--KUTI, L. 1978ab) and the Kolon Lake *(Area V)* (MOLNÁR, B.-IVÁNYOSI, A.--FÉNYES, J. 1983) were studied, and then the Orgovány Landscape Conservation District *(Area I)* was investigated (MOLNÁR, B.--KUTI, L. 1983). In the course of this work the special problems of nature conservation were also taken into consideration. Previously, nature conservation was restricted to the conservation of the bios. In the KNP, however, it is just the conservation of inanimate nature that is very important in many cases. In the area in question modern wind-blown sand accumulation and lacustrine early diagenetic dolomitization are evaluated from the point of view of nature conservation, as well.

In the relation of man and nature there are factors that may change the natural environment and that are still hardly possible to assess at present. It is important to achieve a most complete understanding of these factors by exploring the KNP area also geologically, in order to conserve the natural environment at least in its present state or possibly to help restoring its original condition.

Over a considerable part of the KNP area highly permeable wind-blown sands cover the surface or, in the river valleys, the earlier flood-plain is exposed. Natron lakes, occurring in a number of places and often having a high pH (9-11), are characterized by high dissolved amounts of solid (5,000 to 70,000 mg/l) and sodium content. Frequent seasonal or, in many cases, even diurnal changes in these factors have brought about a quite significant bios. Thus, the geological, morphological, physico-chemical and biological characteristics of the natron

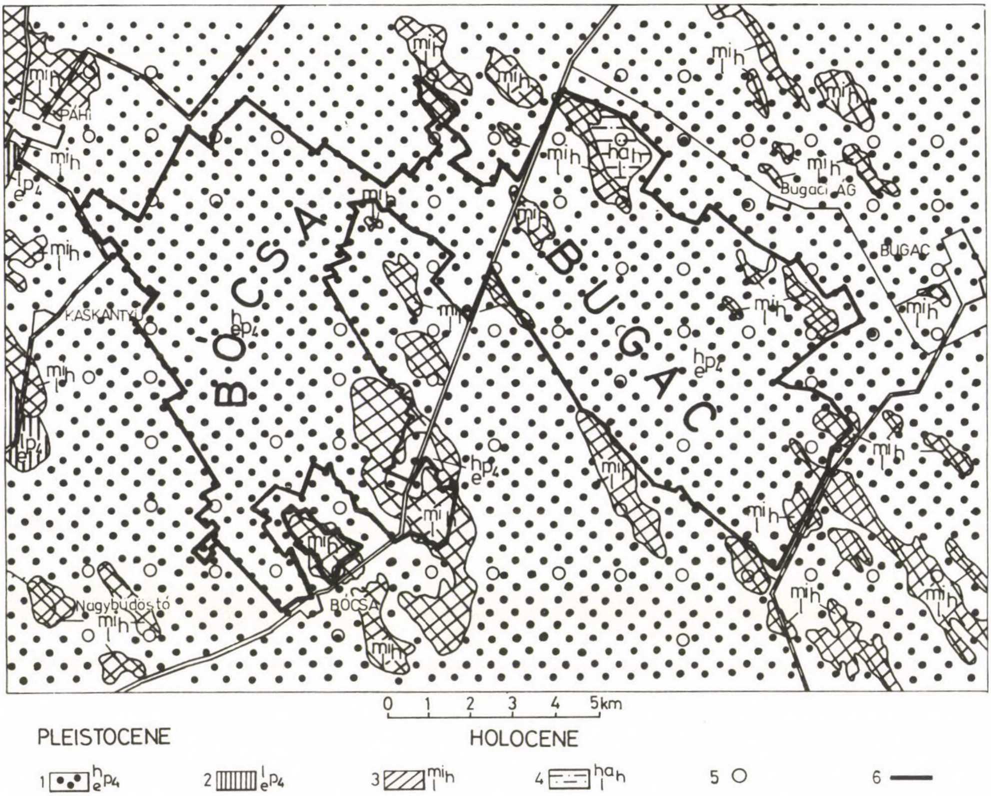

Fig. 2 Surface geology of the Bócsa-Bugac area and its surroundings

1 = wind blown sand; 2 = loess (1-2 Pleistocene); 3 = carbonate mud; 4 = lacustrine, humic, poorly sorted silt (3-4 Holocene); 5 = locations of boreholes spaced at rather great distances from each other; 6 = boundary of the Bócsa-Bugac area

lakes have resulted in a particular type of sedimentation the understanding of which will enhance, beside a better knowledge of the region, also the discovery of the general rules of lacustrine sedimentation.

Our aim is to make the interested Hungarian and foreign scientists to be familiar with the natural values of the area in question, by relying on their comprehensive knowledge. This goal has justified the investigations in the KNP, too.

Between 1981-1985, on the basis of a contract with the Hungarian National Environmental and Nature Conservancy Office, the Department of Geology and Paleontology of the József Attila University (Szeged) investigated the Bócsa-Bugac area of KNP *(Fig. 1, B, VI)*. The Department had undertaken to carry out a sedimentological and hydrogeological survey of the area, to study and assess its geological and hydrogeological features, and to carry out an exhaustive paleontological study of the formations building up the area. These studies, were aimed at evaluation of the history of deposition of the sediments constilating the area and at the reconstruction of the geohistory of the natron lakes in it. The present paper attempts to delineate the geological setting and geohistory history of the Bócsa-Bugac area. Two papers summarize the investigations of natron lakes in the subarea, and the paleoecological investigation of the fossil material recovered from boreholes, respectively.

GEOLOGICAL SETTING

The Bócsa-Bugac Nature Conservation Area covers a total area of 10,880 hectares, being one of the largest units of KNP. It includes two, i.e. the Bócsa and the Bugac sand-dune ranges of NW-SE direction. The nature conservation area is also adjusted to the orientation of these two dune-ranges *(Fig. 2)*. The western part (Bócsa) has an average width of 4.5 km and length of 10.5 km; the eastern part (Bugac) is 5.7 km wide and 15 km long. In the north the two zones are connected by a belt of hardly more than 0.5 km in lenght.

The geomorphologically highest part, with an altitude of 120 m a.s.l., is situated in the axis of dunes, the lowest surfaces, at 100 m a.s.l. or less, are the foot of the dunes. A relative relief of some 10-15 m within a distance of a few tens of km is common here too, as reflected quite clearly by the sections shown below. A varied substratum is covered by semi-desert grassland and remains of pedunculate oak woods. Between the two sand-dune ranges there are alkaline sag-depressions. In the eolian furrows of a length of several 100 m, the semi-desertic grassy area, boggy-swampy flats and minor natron lakes have developed.

The geological formations of the area have largely controlled the morphology and the substratum, affecting, at the same time, the resulting vegetation and partly also the fauna. The position of permeable and impermeable layers controls the hydrogeological features of the area. These data must be taken into consideration by engineers when determining the track of artifical canals required for local water control. This is why altogether 152 boreholes of 10 or nearly 10 m depth were sunk with a spacing of 1.5 km or, in the natron lake area, with that of 150-200 m, in order to investigate the position of the geological formations in the Bócsa-Bugac area of KNP and the area immediately adjacent to and hydrogeologically interrelated with it. From the areas between boreholes surface rock samples were collected.

The material, thus collected, was analyzed in laboratory. The analyses and tests included the determination of the grain size reflecting the physical state. This made possible the identification of the lithologies involved, and the establishment of a typology for the geological formations present in the studies area *(Fig. 2)*. In addition, we analyzed the samples for carbonate content and, in several cases, especially in peat samples, for organic content. The changes in colour reflect the alteration of the soil and the carbonate accumulations. Samples from modern carbonate mud layers were analyzed by differential thermal (DTA), derivate thermal gravimetric (DTG) and thermogravimetric (TG) techniques for the identification of the carbonate minerals. From these results only the mineralogical-petrographical results are discussed now. The detailed analytical results, including also the hydrochemical data, were summarized by J. FÉNYES and L. KUTI (1986).

Based on the analytical results the geological map of the study area, scale 1:100,000 was prepared. On this map four essential geological formations are plotted.

a) Most common is the wind-blown sand overwhelmingly with a grain size of 0.1-0.2 mm. Medium-grained (0.2-0.5 mm Ø) and fine grained (0.06-0.1 mm Ø) sands also occur. On the map for technical reasons, the categories of wind-blown sands have not been distinguished since there is no substantial difference in terms of permeability between them *(Fig. 2)*.

b) The second most widely distributed rock type is the carbonate mud. As it is known from earlier (MOLNÁR, B.--MURVAI, I.--HEGYI-PAKÓ, J. 1976; MOLNÁR, B. 1979ab; MOLNÁR, B.--SZÓNOKY, M.--KOVÁCS, S. 1980) and more recent sources, the carbonate mud varies in composition from calcite through calcareous dolomite mud to dolomotide mud and, from ferruginous dolomite to magnesite respectively.

The geological map shows quite distinctly that carbonate muds occur always in patches of NW-SE orientation, coinciding with the sag-depressions between the dune-rows reflecting the prevailing wind direction. Because of the high position of the groundwater table and the impermeability of the carbonate mud, ephemeral alkaline (natron) lakes of shallow water attaining scarcely one dm or, even in the humid periods, just a few dm in depth have emerged.

c) In the N part of the area, in one of the depressions, humic, poorly sorted sandy silt occurs (with a predominant grain size of 0.02-0.1 mm Ø) in an extension that can be shown even on a synoptic map.

d) S of Páhi and Kaskantyú villages, at some distance W of the conservation area, there are two patches of fine-sandy loess. As it will be evident from the discussion of the geological sections, the loess continues farther E under the surface, playing substantially more significant role as compared to its surface extension. Hydrogeologically, the loess is a very important product, since due to its great extension and poorer permeability, it largely reduces the rate of the infiltrattion of precipitation waters that have passed through the overlying wind-blown sands and so it exerts some influence even upon the plants that grow on the sands. This proves the importance of the understanding, together with the surface formations, of the buried geological formations as well.

The regularities determining the position of buried formations in space can be best studied in geological sections. That is why six geological sections were plotted running in W-E and N-S direction accross the Bócsa-Bugac area. When plotting the closer-spaced boreholes were also marked *(Fig. 3)*. These sections expose the formations involved, in accordance with the adapted depth of drilling, down to 10 m *(Figs. 4-5)*.

At the base usually loess or wind-blown sand appears. The eolian origin of the loess and the wind-blown sand is proved by also the fossil content (TÓTH, Á.--MOLNÁR, B. 1986). Unlike in case of the map, the various types of wind-blown sand are figured on the profiles in more detail.

In section I of northernmost position the uppermost 10 thick layer m consists, predominantly, of wind-blown sand and its different varieties. Loess, if any, occurs only in the E part of the section. On the contrary in section IV, exposing the central part of the area, under the wind-blown sand of 5-8 m average thickness the loess is consistently present all along the section.

Otherwise, the loess widely varies in thickness. In section III, even the thickest part of the upper loess horizon scarcely reaches the 1-2 m thickness. In section V, however, drilling has exposed it in a thickness of 8 m. The fact that the presence of loess and wind-blown sand is only partly coinciding in surface morphology, is easily observable. Between boreholes 6/1 and 5/2 both surfaces are convex, while the surface of the wind-blown sand is concave. Moreover, in the last-quoted borehole that was sunk in a morphologically deeper-situated area, the loess is persistent up to the overlying lacustrine deposit, the wind-blown sand is, thus, absent.

As it is proved also by the other sections, loess and wind-blown sand alternate both vertically and horizontally. Both types of sediment layers grow often very thick, to become then quite thin and to pinch out only in the end. In several places, e.g. in sections III and IV, the loess includes minor wind-blown sand lenses, and in Profile II, the loess is even divided into two parts by the intervening wind-blown sand.

In Profiles III, V and VI, there is a 2-3 m thick peat lens within the loess.

It is rather interesting in borehole 8/2 of section VI that there is some carbonate mud below the peat lens. In the sag-depressions, between the dune-rows overlying the eolian loess and wind-blown sand, lacustrine deposits can be very often found. Their facies is proved both by the earlier observations and by the fossils recovered from this site (MOLNÁR, B.--SZÓNOKY, M. 1974; MOLNÁR, B. 1979; MOLNÁR, B.--SZÓNOKY, M.--KOVÁCS, S. 1980). The overwhelming bulk of this deposit consists of carbonate muds that are of different mineral composition, as mentioned above. The carbonate muds attain a maximum of 1 m in thickness. The fact that the edges of carbonate muds are laterally buried by wind-blown sand is an important factor. The sand must have been blown out by the winds from the neighbouring wind-blown sand area. The carbonate muds are repeatedly overlain by a thin, lacustrine, humic, poorly sorted sandy silt. In borehole 8/3 of section VI a thin peat lens appears at the surface.

Thus, the conclusion can be drawn that the geological setting is much more complicated than the surface of the study area indicates it. The extension of the loess is considerably wider than it visible in outcrop. Consequently, the last men-

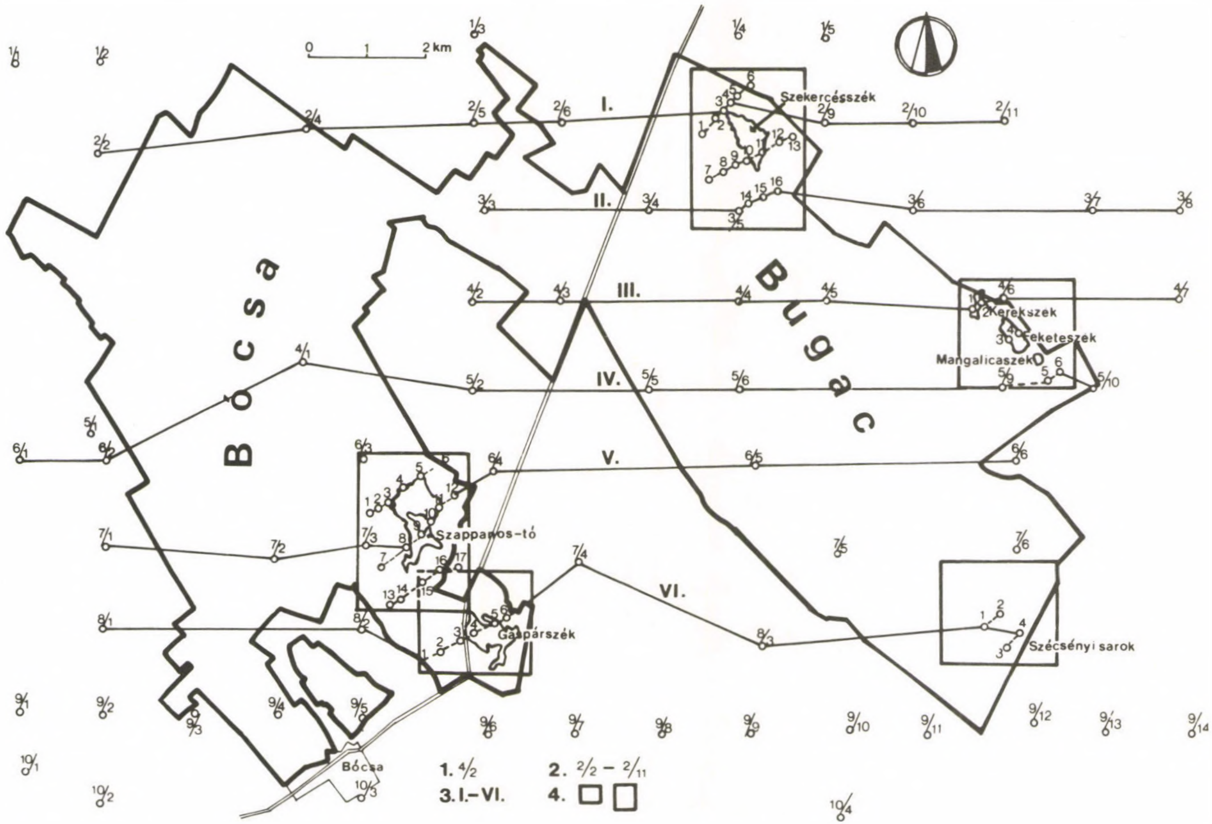

Fig. 3 Location of geological sections from the Bócsa-Bugac area

1 = 4/2. Location and number of borehole/s/; 2 = 2/2-2/11 Geological section line; 3 = I-IV Number of geological sections; 4. Areas outlined by a square and a parallelepipedon indicate and area selected for more scrutinized study of the lacustrine features

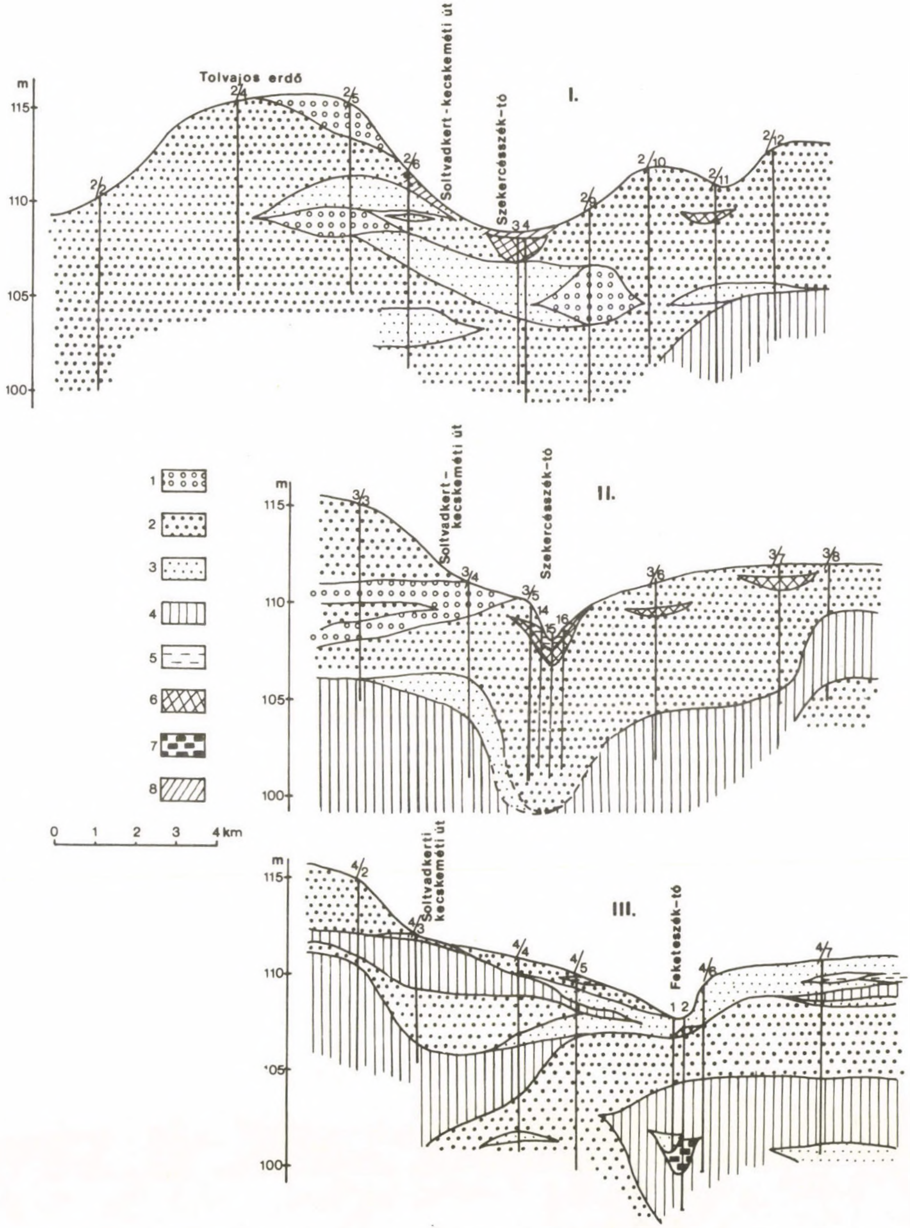

Fig. 4 Geological sections I-III

1 = Medium-grained wind-blown sand (0.2-0.5 mm ∅); 2 = Small-grained wind-blown sand (0.1-0.2 mm ∅); 3 = Fine-grained wind-blown sand (0.06-0.1 mm ∅); 4 = Loess (1-4 Pleistocene); 5 = Lacustrine, humic, poorly sorted silt (0.02-0.1 mm ∅); 6 = Carbonate mud (5-6 Holocene); 7 = Peat (Pleistocene-Holocene); 8 = Humus on the surface

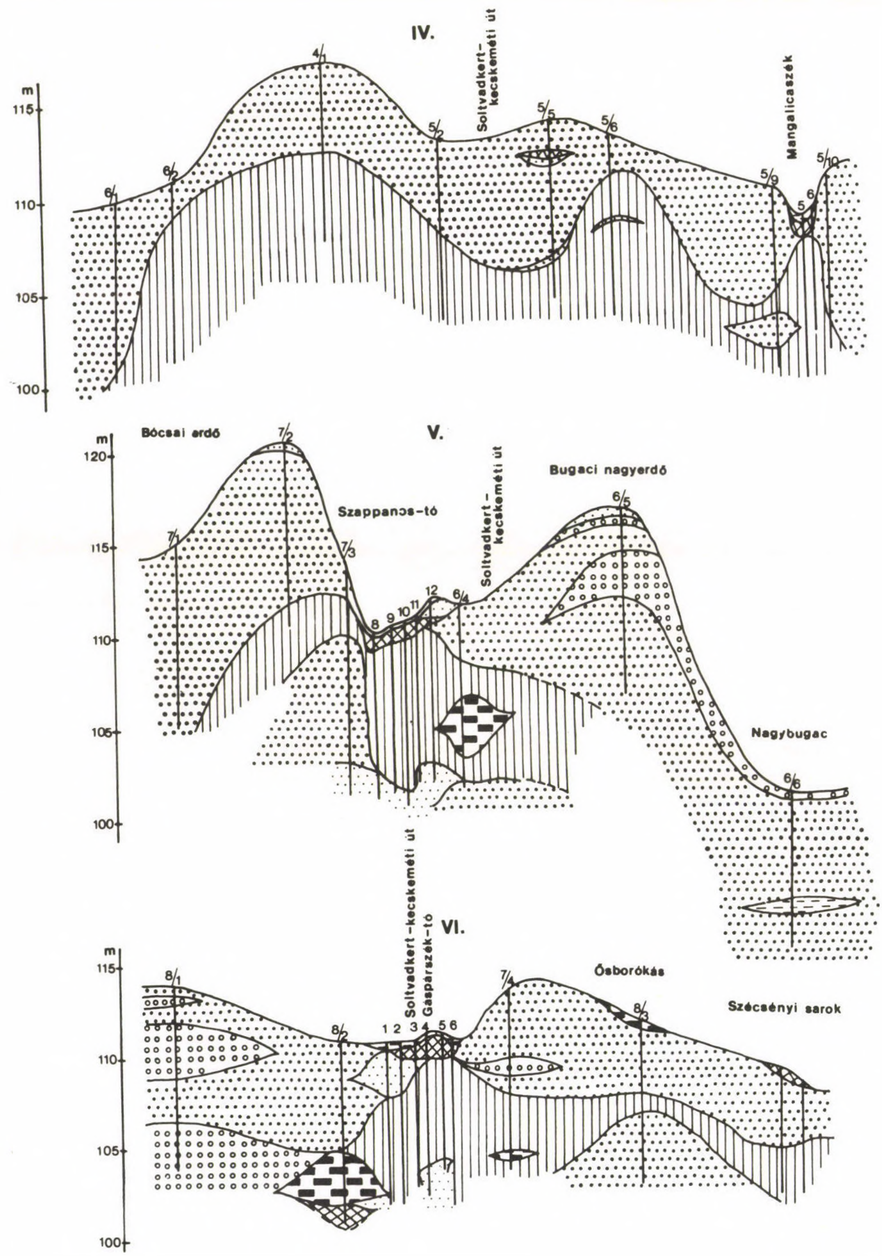

Fig. 5 Geological sections IV-VI
(For explanations, see Fig. 4)

tioned poorly permeable formation plays an important role in controlling the hydrogeological regime of the study area. The carbonate mud, appearing in morphologically deeper-situated areas, and completely impervious when wet is more widely distributed than its surface occurrence. Thus, it is logical that today, in more humid periods, exactly in these places there is a water cover or natron lakes occur *(Figs. 3-5)*.

GROUNDWATER REGIME

When drilling, the hydrostatic level of the (phreatic) groundwater was measured and then, on the basis of the results, a map showing the depth of the groundwater table in the study area was plotted *(Fig. 6)*.

The groundwater level varied at depths between 0 and 6 m. The greatest average depth was registered in the morphologically highest-situated, wind-blown-sand-dotted Bócsa-Bugac area. The lowest figure, 0-1 m, was obtained for the NE foot of the Bugac sand-dunes, the Szekercésszék lake and outside the KNP area N and S of Páhi, however, lying closest to the KNP, the highest-situated groundwater table occurs between Nagybüdöstó and Bócsa villages. In a large part of the study area the groundwater table is between 2 and 4 m. The surface of the groundwater table conforms in a more equilibrated way with the changes in the relief.

The position of the groundwater table was converted into absolute values as referred to sea level and the resulting data have been used in plotting the map of groundwater table altitude *(Fig. 7)*.

Hydrogeologically this is important because on the map the directions of groundwater flow taking place under the present-day surface can be delineated.

The results are partly in conformity with the surface morphology. The lowest altitude of the groundwater table, below 100 m, is found in the W and E parts of the study area. The highest position of the groundwater table is observed on the W and E sides of the Bócsa-Bugac sand-dune rows or, especially, close to their axis.

Thus, two distinct directions of groundwater flow can be delineated on the map. This is in harmony with the fact that the N-S oriented watershed of the Danube-Tisza interfluvial sand ridge passes exactly accross this area. One of the flow directions is NE-SW, running from the N part of the study area towards Páhi and Kaskantyú villages.

The other direction runs from the NW to the SE, i.e. from Soltvadkerti Street, Kecskemét towards Bugac village. This flow direction is intersected by a rather considerably deep, artificial canal already in operation, the Nagybugac Canal. To prevent any substantial reduction by canal drainage of the groundwater level, the canal can be operated only on a locks-controlled base. Unless such a regime is adapted, the natural groundwater regime will enormously change, and the groundwater level, under hydrostatic pressure due to the marked relative relief

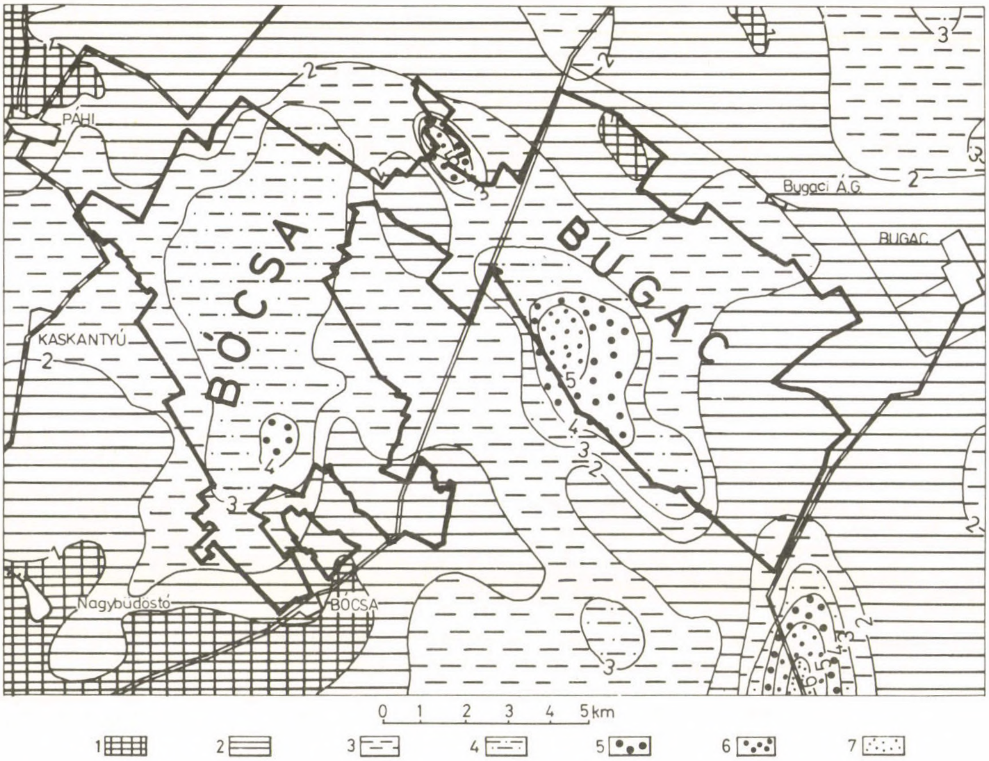

Fig. 6 Depths under the surface of the phreatic groundwater table in the Bócsa-Bugac area

1 = 0-1 m; 2 = 1-2 m; 3 = 2-3 m; 4 = 3-4 m; 5 = 4-5 m; 6 = 5-6 m; 7 = > 6 m

as it is, will be strongly reduced. Its operation under locks-controlled conditions, however, is very advantageous, as strikingly high groundwater levels that may recur from time to time can thus be kept control.

Along with the two main groundwater flow directions two less important ones can also be identified. Situated between the main directions, these secondary directions are subparallel to the Kecskemét-Soltvadkert highway, running from the N to S *(Fig. 7)*.

GEOLOGICAL HISTORY

The geological history of the study area, considering the exposed sections and the groundwater regime just presented, can be outlined as follows.

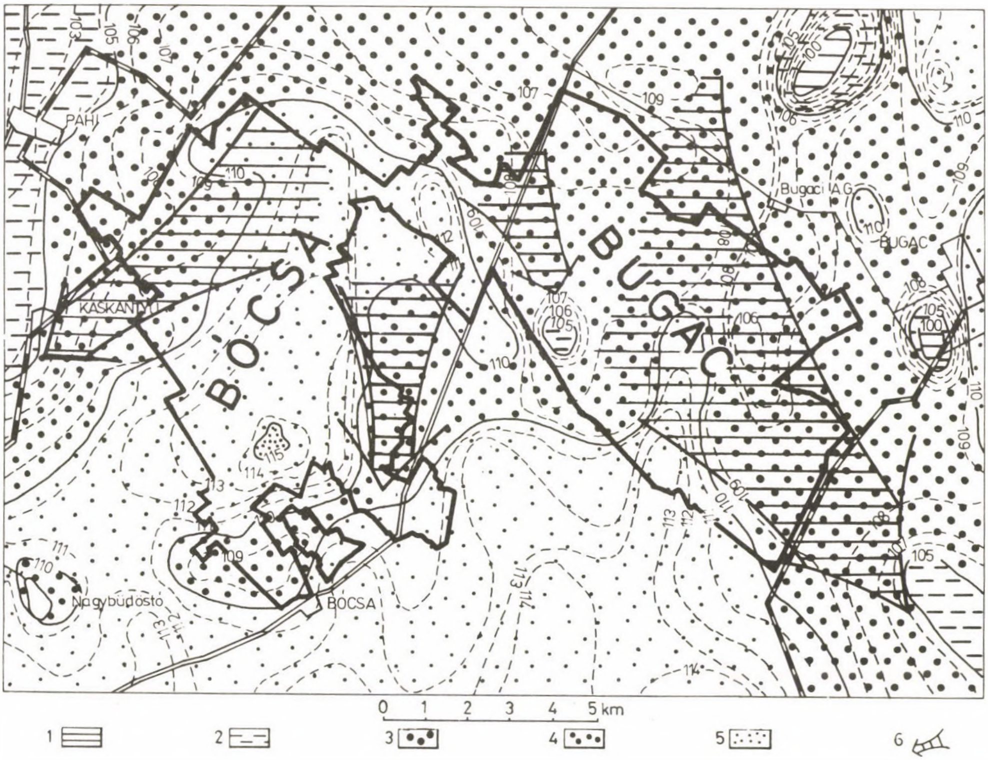

Fig. 7 Altitude of the groundwater table in the Bócsa-Bugac area as referred to sea level

1 = < 100 m; 2 = 100-105 m; 3. 105-110 m; 4. > 110 m; 5 = > 115.m; 6 = Directions of groundwater flow

It is accepted that the uppermost fine-sandy loess horizon of the Danube-Tisza Interfluve was formed during the last Pleistocen glacial. It provides an important clue to a better understanding of the geological history of the study area. Loess is apparently present in most places. In the central part of the area it occurs divided into two parts, by intercalated wind-blown sand. The lower boundary and the surface of the loess is not level, but undulate. This means that during the last glacial the paleomorphology was rather rough with a 10 to 15 m difference in altitude even within a very short distance; the same is the case at present. The frequent pinching-out of the loess from wind-blown sand suggests a morphology similar to the present-day pattern. The deposition of fine-sandy loess, and especially the wind-blown sand accumulation, were associated with a period when the groundwater table used to be relatively deeper, i.e. with a rather dry period.

In the loess, as shown above, there is a repetition of peat layers. An obvious explanation for this phenomenon is that when the groundwater (phreatic groundwater table) under pressure rises a little in the morphologically deeper-situated parts, getting above the ground surface, it will enhance, together with the meteoric waters, a temporary growth of a hydrophilous vegetation leading to peat formation. Peat is observed to be formed in several places on the wind-blown sand surface of the Ridge even at present (MOLNÁR, B.--SZÓNOKY, M. 1974; FÉNYES, J. 1983).

The carbonate below the peaty layer in section VI means that during the last glacial the climate was rather diversified in the study area. I.e. the carbonat mud could be deposited and accumulated only during the comparatively short dry periods (MOLNÁR, B. 1971).

After the end of loess deposition wind blown sands went on accumulating and the process grew even stronger, so that new wind-blown sand layer was laid down on the undulate loess surface. How active the wind-blown sand movement was is reflected by its considerable thickness, sometimes exceeding even 10 m.

With the climate turning warmer in the Holocene, a more copious supply of precipitation arrived, too. As a result, the groundwater table rose and minor lakes were formed in the sag-depressions. In the lakes, just like among the present under circumstances, similar carbonate mud was deposited. The wind-blown sand movement continued, as it is proved by the buried carbonate mud layers. This was responsible for the fact that areas that once lay in a deep position are now overlain, in several cases, by high-perched sand-dunes section II, boreholes 3/6, 3/7). As earlier results indicate, changes in the composition of carbonate muds are also climatic indicators. Calcite is typical of dry periods, dolomite is indicative of periods of extreme drought, reflecting such microclimates of the micro-environments involved.

The lakes continuously changed their surface area. Their birth, growth and desiccation are proved, among others, by the appearance of dark, humified, lacustrine, poorly sorted, sandy silts.

Thus, the conclusion can be drawn that the prevailing micro-environments always played an important role in the study area. The morphological difference of the relief frequently produced different sedimentary environments. Eolian and lacustrine sedimentation may have alternated within one and the same area. It was as a result of the combined effect of these phenomena that the present-day geological and biological pattern has developed, a pattern that enabled the study area to become, with its conserved natural riches, a part of KNP.

NATURE CONSERVATION: OBSERVATIONS AND PROPOSALS

Our decades of geological research in the Danube-Tisza Interfluve have enabled us to carry out a great number of time-dependent observations, as well. The extension of water cover of the Danube-Tisza Interfluve's natron lakes, including the Bócsa-Bugac lakes, is determined by the prevailing position of the phreatic groundwater table. For example, at higher position of the ground water table in the late 1970's there was some water in the lakes, too. Because of the droughts of recent years, however, the groundwater table has sunk deeper and deeper, so the water cover has disappeared from Bócsa-Bugac lakes. Accordingly, the lacustrine carbonate deposition has been also missing. As proved by paleoecological investigations, the earlier history of the lakes was also characterized by periodical changes.

The prevailing position of the groundwater table affects not only the lakes themselves, but the vegetation of the study area, as well. The vegetation of the sag-depressions between the dune-rows depends on the depth of the groundwater table, too. In addition, the quality of vegetation is controlled by the higher position of the groundwater table in the spring. Its impact is certainly felt even sharper by the plants during lasting droughts or, for that matter, during protracted humidity periods. In case of a deeper-situated groundwater table a vegetation less exigent of humidity appears, while at a high position of the groundwater table the case is just the contrary. Naturally, this does not apply to tree vegetation.

The physical pattern of the study area is rendered rather diversified and vivid by the rough relief and the presence of impervious or less impervious layers under a rather complex surface. Thus, it follows, that it is impossible to determine the basic features of the study area unless based on long-term observations. A full picture can be obtained only by comparing the results of measurements carried out at high position of the groundwater table with the results recorded at low groundwater. That is why proposals for the construction of checkwells for the observation of changes in ground-water level have been submitted. The original idea was to locate the checkwells at the tops of the sand-dunes and in the sag-depressions between them. Subsequently, a series of checkwells to be located in NW-SE direction at the E foot of the Bugac sand-dune row was to be constructed, in addition to the former ones. The measurement of the groundwater level in the wells ought to be performed weekly, or a continuous automatic registration ought to be provided for.

It would be also useful to check continuously the changes in the chemical composition of the groundwater based on sampling to be performed at least once every month. Probably, because of the upward groundwater flow and the high capillary action due to hydrostatic pressure and the resulting higher rate of evaporation, the total dissolved solid content of the groundwater, at the E foot of the dunerow, is very high, up to 20,000 mg/l, and it is substantially lower, an average of 2,000-5,000 mg/l or so, elsewhere in the study area (FÉNYES, J.--KUTI, L. 1986). The recorded data would provide information on the water supply of the substratum, while the chemical analyses would shed light on the seasonal changes in the composition of the groundwater.

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ADDRESS OF AUTHORS:

Béla MOLNÁR

József Attila University
Department of Geology
SZEGED Táncsics M. u. 2. H-6701

László KUTI

Hungarian Geological Institute
BUDAPEST Népstadion u. 14. H- 1143

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GEOLOGICAL HISTORY OF THE PONDS IN THE KISKUNSÁG NATIONAL PARK

J. FÉNYES and L. KUTI

ABSTRACT

Among wind-blown sand dunes in the Kiskunság National Park lakes of great geological interest can be also found. This is why the present study attempts to describe their origin and geological history.
74 boreholes of 10 m depth were deepened to explore the pond area. After laboratory processing of the material, recovered from the boreholes, geological profiles were plotted. As shown by these profiles, the boreholes indicated loess or wind-blown sand at the base. The pond sediments are superimposed on the former, represented mostly by carbonate muds and humic, poorly sorted silts.
On the basis of the level of groundwater table, measured in the boreholes, the position of the phreatic groundwater table in the studied area could be assessed as varying between 1.0 and 3.5 m.
As shown by the groundwater analysis, in the neighbourhood of the ponds, the total salt content (total of dissolved solids) is very high, 20,842 mg/l, dropping to 625 mg/l farther away from the pond area. The dissolved solids are dominated by the cations of sodium, calcium and magnesium and the anions of hydrogen carbonate are predominant. Sulphates and chlorides occur in much smaller quantities.
In the composition of carbonate muds, together with calcite and dolomite, Mg-containing calcite, ferroginous dolomite and magnesite play an important role. Magnesite was observed only in layers of the morphologically deepest position, where the water coverage had lasted for the longest time, and the Mg/Ca ratio of the lakewater was extremely high due to evaporation. In the carbonate muds, the most frequent carbonate mineral was dolomite and its iron-contaminated variety, respectively. In case of the studied ponds the dolomites are of early diagenetic origin. No purely calcitic carbonate mud could be identified, two or more carbonate minerals having always been observed to occur jointly. The variability trends in the quantitative and qualitative features of the carbonate minerals were studied both laterelly and vertically and, from the results, geohistorical conclusions were drawn.

* * *

INTRODUCTION

In sag-depressions, between wind-blown sand dunes in the Danube-Tisza Interfluve, on or near the surface, numerous carbonate formations can be found. Groundwater movement and lacustrine carbonate precipitation in local intermittent water bodies, in sag-depressions, played a role in the formation carbonates. The carbonate layers, as a rule, are of little lateral extension, being frequently covered by eolian deposits. Studies by MIHÁLTZ, J.--FARAGÓ, M. (1946), KRIVÁN, P. (1953) and MOLNÁR, B. (1970) greatly promoted the geological understanding of the young lacustrine deposits of the Danube-Tisza Interfluve. Although their surface occurrence and extension had been already known in the course of mapping in the Great Hungarian Plain, relatively little was known about their sedimentological, and mineralogical-petrographical features, and genetic circumstances.

The preparation of the surface geological map, scale 1:100,000, and the series of geological profiles from the same area played important role in the outlining and understanding of the one-time ponds of the Bócsa-Bugac area (MOLNÁR, B.--KUTI, L. 1986).

The investigation was aimes at the geological interpretation of the lacustrine sedimentary sequences and elucidation of the geological history of the ponds in order to determine the differences between the one-time and the present conditions. An additional purpose was to carry out detailed derivatographic and X-ray analyses of the lacustrine deposits for the assessment of the mineral composition of the carbonate muds both qualitatively, and quantitatevely, and on the basis of the obtained results, to achieve a more exact portrayal of the contemporaneous lacustrine sedimentation conditions.

THE PHYSIOGRAPHY OF THE POND AREA

In the area between Bócsa and Bugac villages there are seven depressions of varying size *(Fig. 1)*. Among them the Nº 2 and Nº 3 ponds situate between different dune-rows, whereas the ponds of Nº 5, Nº 4 and Nº 6 lie in one and the same row of dunes. The ponds cover small areas, even the largest of them had been originally smaller then 10 km^2.

49 boreholes of 10 m or nearly 10 m depth were put down in the lake areas and their immediate neighbourhood. Drilling was performed by the Lowland Department of the Hungarian Geological Institute. After preliminary studies, 25 more boreholes were drilled later, in addition, at the Gáspárszék pond.

On the basis of the boreholes 12 geological profiles of NE-SW direction were plotted. The most typical of these are presented here *(Fig. 1, A--E, Fig. 2, A--C, Fig. 3, A--D)*.

ANALYSIS OF LACUSTRINE CARBONATE MUDS

Lacustrine dolomitization and, particularly, dolomite accumulation in modern lakes have come, during the past two decades, into the centre of interest. Many of the environmental factors, necessary for carbonate formation are already well-known. The

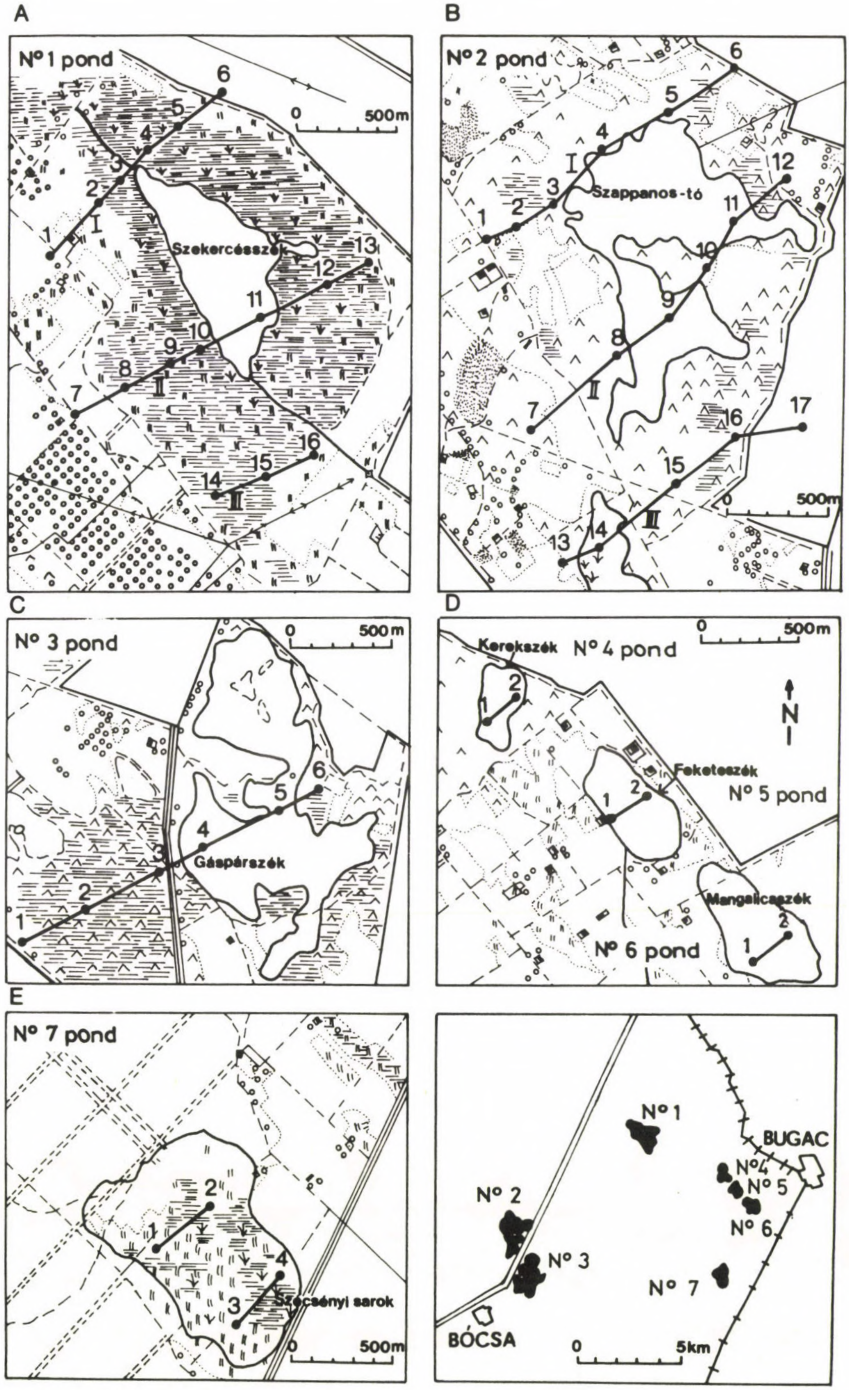

Fig. 1 The Bócsa-Bugac ponds with borehole sites and geological profiles

A-E = studied ponds; 4 = borehole location; III. geological profile number

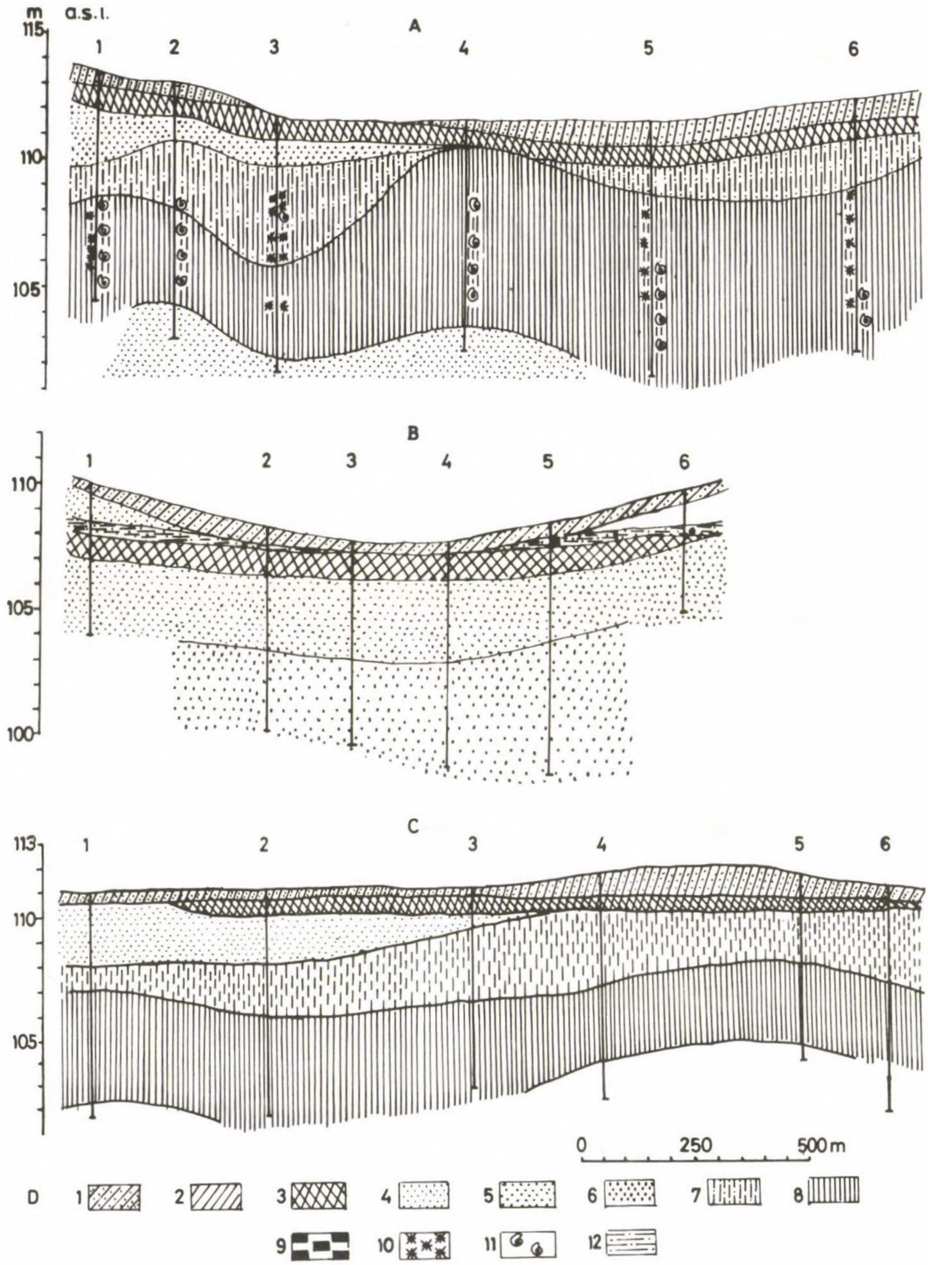

Fig. 2 Geological sections between ponds A-B-C (Szappanos I; Szekerceszék I, and Gáspárszék)
1-6 = borehole locations; D1 = humified wind-blown sand layer; 2 = humic layer; 3 = carbonate mud; 4 = fine-grained; 5 = small-grained; 6 = medium-grained wind-blown sand; 7 = fine-grained loess; 8 = typical loess; 9 = peaty layer; 10 = layer with plant remains; 12 = lacustrine, unsorted sandy silt

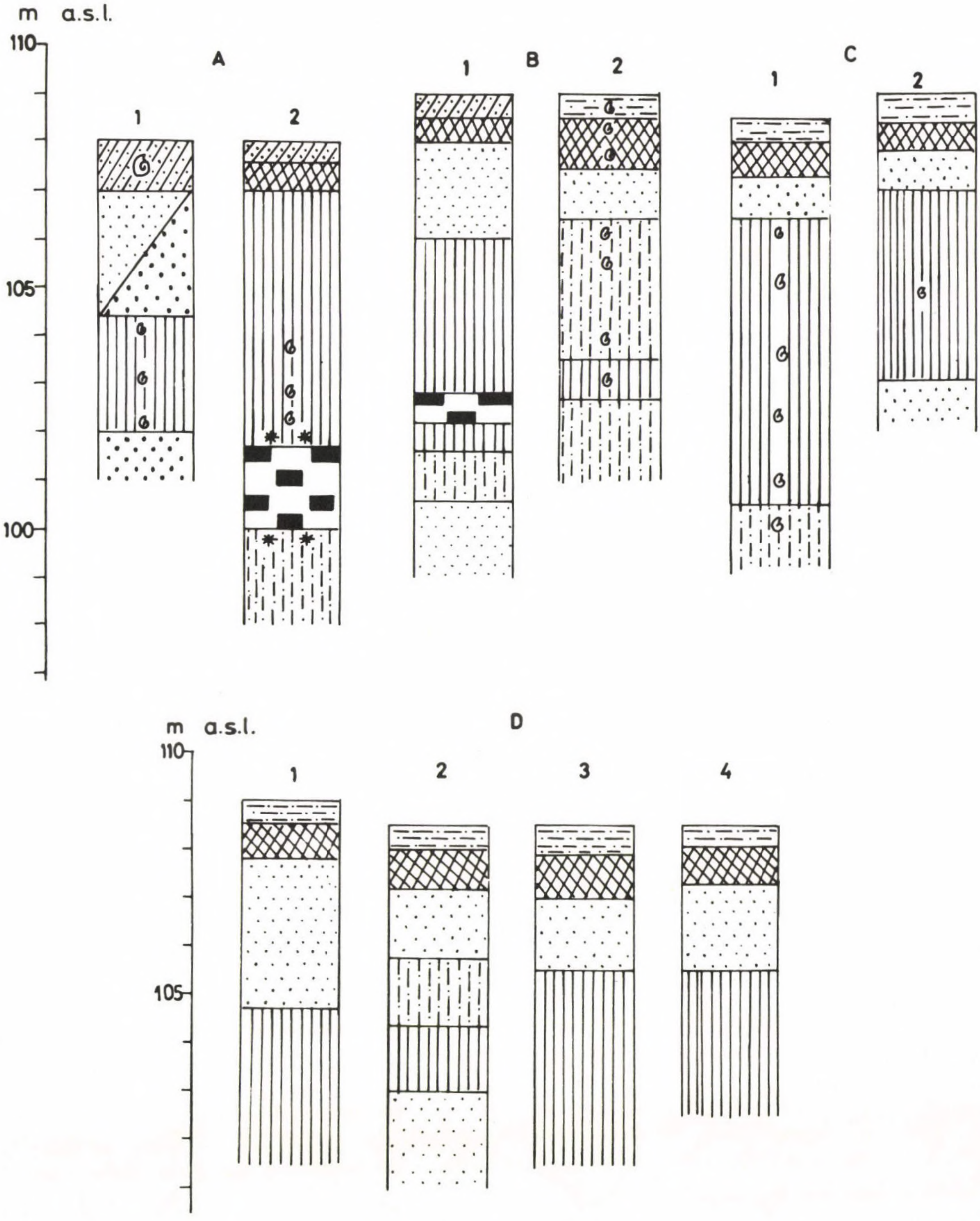

Fig. 3 Borehole logs from Kerekszék (A), Feketeszék (B), Mangalicaszék (C) and Szécsényi-sarok (D)
For the legend of sediment types see Fig. 2

removal of CO_2 from the water, the evaporation, the rise in temperature, the decrease of the partial CO_2 pressure, etc. may serve as example.

For an assessment of the sedimentation conditions of the Bócsa-Bugac lakes and for a reconstruction of the geohistory of the lakes, the qualitative and quantitative analyses of the carbonate minerals are essential. That is why, by using Q-1500 D instrument, derivatographic analyses of more than 300, overwhelmingly carbonate mud, samples were performed. The analyses were extended to the deposits that underlie the lacustrine carbonate muds, and to the underlying them. The quantitative and qualitative determinations of the individual mineral types were made more complete by X-ray analytical techniques.

The underlying beds of Nº 1 pond contain an average of about 15-20% dolomite or ferruginous dolomite. Also in the lacustrine carbonate muds dolomite is the most important carbonate mineral. In borehole 1 the upper part of the carbonate muds is constituted by calcite. Calcite is most common in the humic, poorly sorted silts, its amount in borehole 1 reached 55%. In boreholes 4 and 16, it was associated with magnesite and its relative value showed a gradual increase upwards *(Fig. 4)*. Magnesite is limited to the lacustrine deposits, particularly to the carbonate muds. It either shows a gradual increase upwards *(Fig. 4, borehole 11)*, or its maximum is reached in the middle part of the carbonate mud layers *(Fig. 4, boreholes 4 and 16)*. In the upper part of the carbonate muds of borehole 16 the amount of magnesite is as high as 50%.

In the underlying loess of the Nº 2 lake is dolomite the predominant carbonate mineral. Calcite is restricted either to the upper part of the carbonate muds or to the overlying wind-blown sand, but its value does not exceed 10%. In the whole sequence dolomite and ferruginous dolomite are the most frequent carbonate minerals *(Fig. 5)*. Along with the two carbonate minerals, magnesite here is also restricted to the top of the carbonate muds, mainly in the axial line of the lake. Its maximum is 21%, in borehole 9.

In the underlying beds of Nº 3 pond, Nº 4 pond, Nº 5 pond, Nº 6 pond and Nº 7 pond also the dolomite is predominant *(Fig. 5, D-E)*. As far as the carbonate minerals of the carbonate muds are concerned, the picture, however, is much more varied than it has hitherto been the case. The carbonate muds of Nº 3 pond are predominated by dolomite, those of Nº 5 pond are, at the base, by dolomite or ferruginous dolomite, and are higher up the profile replaced by calcite (in quantity of 70%), those of Nº 6 pond are also overwhelmingly calcite (32%). In the

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Fig. 4 (1) = Borehole number; α = lower part of carbonate mud; β = middle part of carbonate mud; γ= upper part of carbonate mud. I.percentages of total carbonate and other components (quartz, feldspar, etc.) as calculated by the proper reaction equations on the basis of the derivatographic TG and DTG curves of the samples, II. relative percentages of carbonate minerals; a = total carbonate; b = other components; c = magnesite; d = calcite; e = dolomite; f = ferruginous dolomite

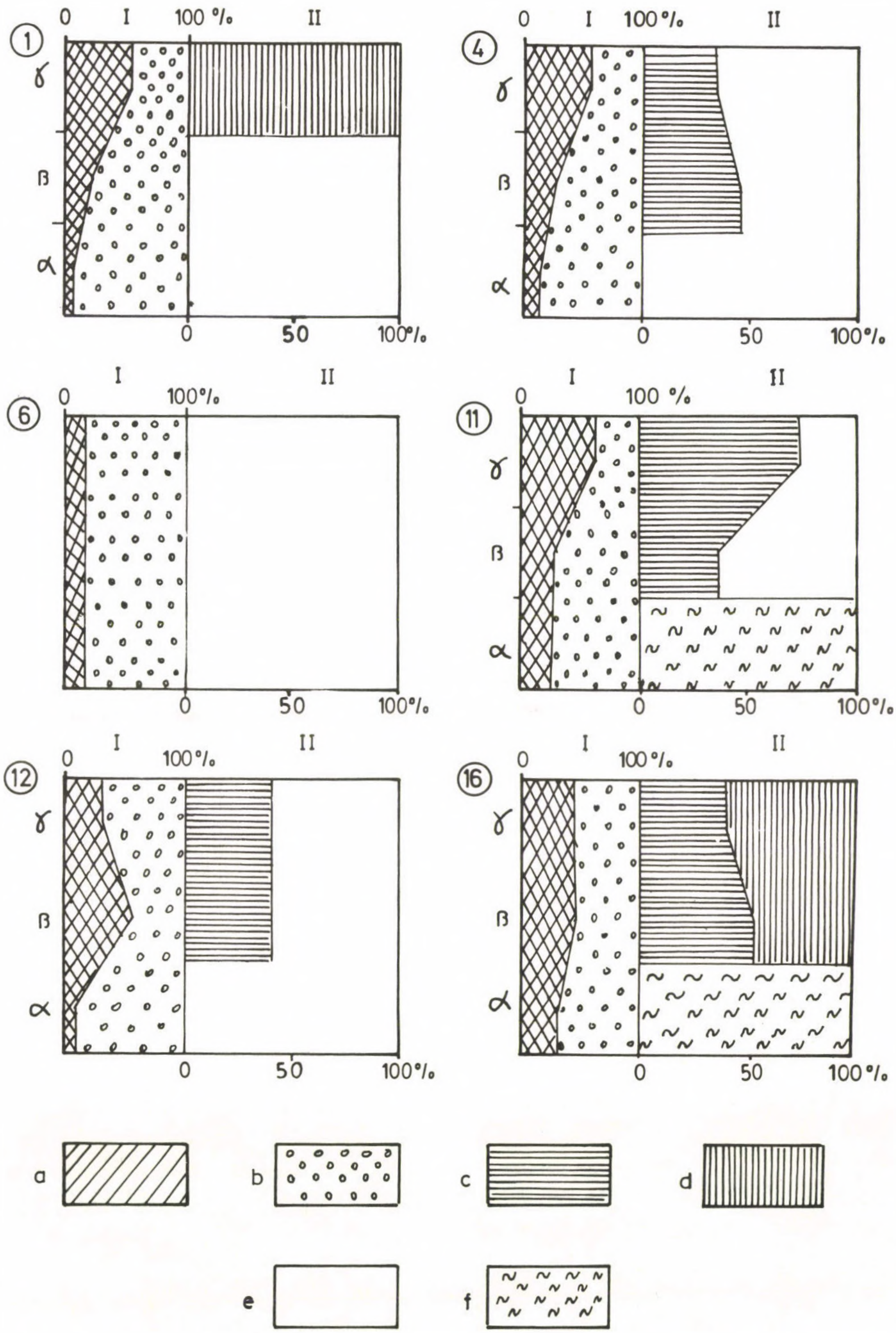

Fig. 4 Mineral composition of the carbonate muds of Szekerceszék pond

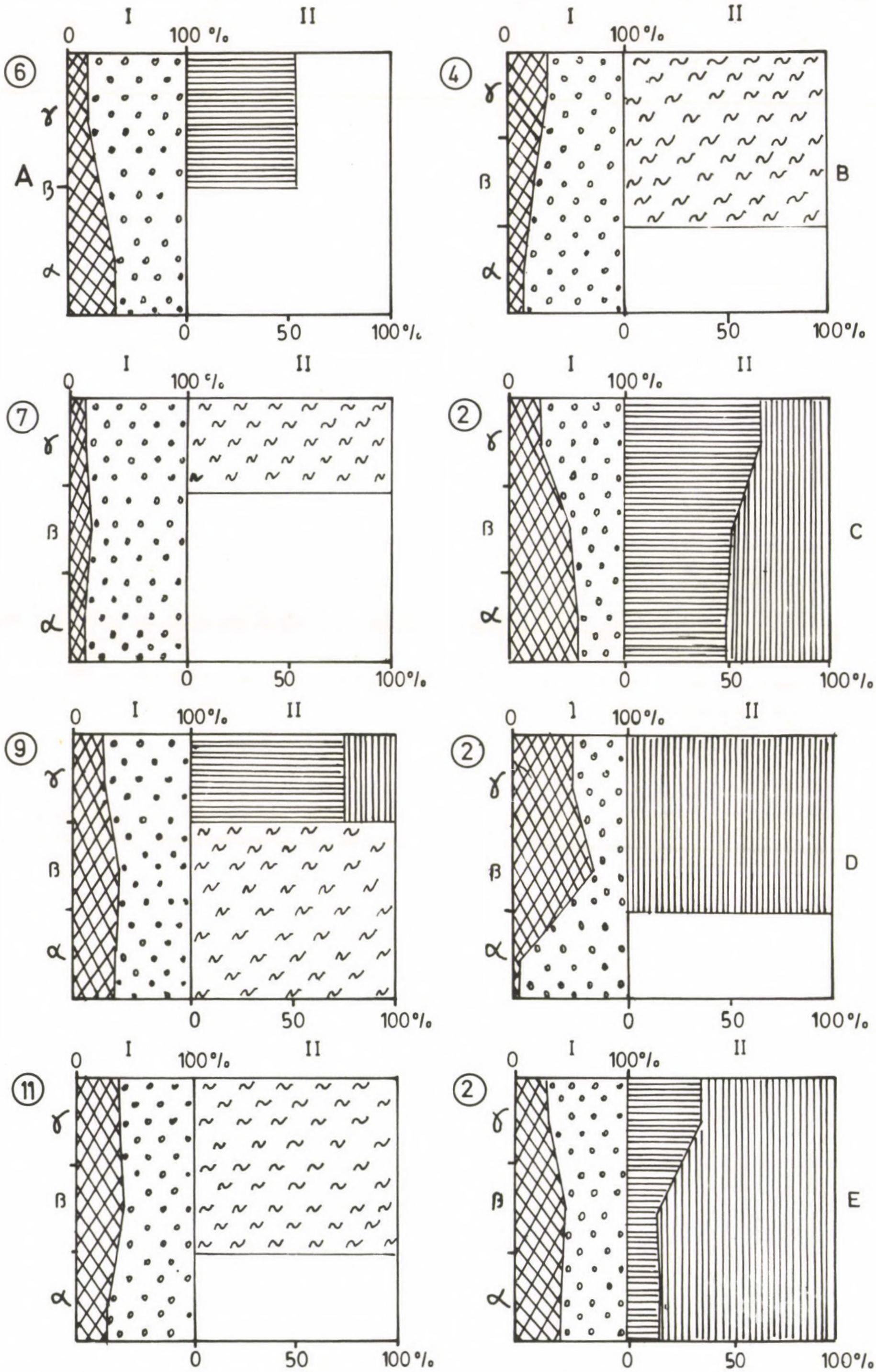

Fig. 5 Mineral composition of carbonate muds from Szappanosszék (A), Gáspárszék (B), Kerekszék (C), Feketeszék (D) and Mangalicaszék (E)

middle or at the top of the carbonate mud layer of Nº6 pond and borehole Nº 3 pond 3, magnesite appears. At Nº 4 pond, the relative value of magnesite, as compared to calcite, shows and upward increase, but its absolute value drops, on due to a decrease in total carbonate content, from 31% to mere 18%.

The X-ray results agreed with the qualitative and quantitative derivatographic determinations. At the same time, because of the high sensitivity and resolution power of the X-ray technique, the presence of calcite and magnesite (1-5%) could be also detected in the samples, in which the thermoanalytical results had identified only dolomite. As shown by the X-ray analyses, calcite appeared most frequently in the form of Mg-calcite. The reflexion of dolomite suggested the presence of a regular, well-ordered dolomite lattice, though a fairly ordered or disordered dolomite lattice could be frequently identified, too.

GEOLOGICAL HISTORY

The Bócsa-Bugac lakes were recharged here both by rainwater and by groundwater infiltrating along the slope towards the centre of the depression. Their water depth could have never been too great. The shortage of water, due to considerable evaporation, was compensated by a recharge from the groundwater resources. According to geological and morphological evidence the total amount of dissolved solids and the chemical composition of the groundwater, when the lacustrine sediments were deposited may have been similar to the present-day figures. Thus, the cations and the hydrogen carbonate needed for carbonate precipitation were available in a concentrated form in the infiltrating groundwater. The escape of free CO_2 was one of the prerequisites for carbonate precipitation. This is accounted for by vegetal assimilation only to a smaller extent since becasue of the high pH, 8-10, of the water, the organic content of the carbonate muds is due to the very low absence of vegetation. Consequently, the effect, we have to reckon with, is rather the influence of evaporation.

Wind-blown sand was transported into the carbonate muds by the winds from the area of the neighbouring sand dunes. Thus, to the carbonate muds some detrital components were added. Therefore the total carbonate content of the carbonate muds could never exceed 70%, the less so, for the same reason, even very low values may also occur.

The precipitation of carbonate mud was a periodical process. Precipitation and re-dissolution alternated dynamically, so that the precipitation outscored re-dissolution. The primary carbonate mineral was calcite and Mg-rich calcite. In case of proper Mg/Ca ratio, the interstitial water, largely depending on the cations of the groundwater, caused early diagenetic dolomitization. Secondary, and in situ, dolomitization is proved by the fact that dolomite is always accompanied by some calcite and sometimes even magnesite. On the basis of microscopic results the carbonate minerals must have segregated most frequenty as calcidolomite crystals of 1-3 µm size - an indication, suggesting that the crystallization process was rapid. Larger, 10-100 µm carbonate crystals also occur. All these phenomena suggest changes in the conditions and rate of precipitation. For the precipitation of dolomite and, particularly, of magnesite in the upper part of the carbonate mud layers, a high Mg/Ca ratio is necessary. Its prerequisites became increasingly available with the silting-up of the lake and the reduction of its water cover, as well as with an increase in the rate of evaporation. An upward increase in Mg-carbonate content is always observed in the deepest point of what used to be a lake. This is quite obvious for the water coverage of these places may have lasted for the longest time. The extremely high ($<$40) Mg/Ca ratio necessary for magnesite segregation seems to have evolved here owing to evaporation and concentration.

The Mg/Ca ratio in the embayments, that got periodically disintegrated, could be different and other environmental factors may have differred, too. Thus, many different microenvironments may have evolved in space and time.

The question is when the lakes were formed. The rock underlying the lacustrine deposit is not a good aquifuge. Consequently, the lakes must have been formed in the more humid period of the Holocene, when the groundwater table level was higher. The carbonate muds, that initially segregated, already represented a more impervious layer, so the lacustrine sedimentation could go on even in drier periods.

The chemical composition of the lakewater and particularly its considerable Mg content, indicated by the presence of dolomite and magnesite, did not permit the appearance of a mollusc fauna. Where the lacustrine carbonate sediment is over - whelmingly $CaCO_3$-containing, and where food was available, this biotope could be also populated by molluscs, as it was in case of the Nº 5 pond lake.

The rapid silting-up replenishment may have been provoked by the fact that, unlike observed in other lakes of the Danube-Tisza Interfluve (Kolon lake, Kerek lake), the formation of carbonate mud was not followed by formation of peat (FÉNYES, J. 1983).

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ADDRESS OF AUTHORS:

József FÉNYES

József Attila University
Department of Geology
SZEGED Táncsics M. u. 2. H-6701

László KUTI

Hungarian Geological Institute
BUDAPEST Népstadion u. 14. H-1143

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A PALEOECOLOGICAL STUDY OF THE LACUSTRINE DEPOSITS OF THE KISKUNSÁG NATIONAL PARK

Á. TÓTH and B. MOLNÁR

ABSTRACT

In heavily alkaline lakewaters of high total dissolved solid content the Mollusca fauna is rather poor and, consequently, an ecologically evaluable amount of molluscs can be expected only after decantation of a great number of core samples. To explore Bócsa-Bugac natron lakes of the Kiskunság National Park, boreholes were sunk into their bottom sediment and the Mollusca fauna recovered from the core samples was evaluated. The base of the lake bottom is constituted by loess, fine-sandy loess and fine- to small-grained wind-blown sand. As lacustrine sediment, carbonate muds were precipitated from the lakewater and it was then overlain by lacustrine, humic, unsorted silt. Winds frequently blew eolian sands out of the surface of the adjacent, topographically higher-situated areas. The rich gastropod fauna of the Pleistocene loess testifies to a cold climate and a wet local biotope. The fauna of the wind-blown sand shows a substantial change as compared to the former one. It is rather poor, the species are indicate a warm, often arid climatic spell. Consequently, the enclosing sedimentary sequence must have been deposited already in Holocene. The carbonate mud of calcitic composition contains thermophilous species of a wide range of ecological endurance in a low number of individuals, and a comparatively high number of species. If the carbonate muds are of dolomite or magnesite composition, they contain no fauna. This difference can be attributed to the chemical composition of the lakewater. The lacustrine, humic, unsorted silts are rich both in individuals and in species of molluscs. The fauna includes alternately either subaerial or aquatic species in the particular lakes studied. The differences are always due to changes the contemporary in water coverage. At the margin of the lacustrine deposit, the wind-blown sands contain a similar fauna though the number of individuals decreased, as compared to the preceding case.

* * *

INTRODUCTION

The geological setting and history of the Bócsa-Bugac area of the Kiskunság National Park were discussed by MOLNÁR, B.--KUTI,

L. (1986). The origin and geohistory of the local lakes and the sedimentological features of the lacustrine beds were studied by FÉNYES, J.--KUTI, L. (1986).

As it was found, the uppermost ten metres of the geological column of the study area are constituted, as listed from the base to the top, overwhelmingly by loess, fine-sandy loess and fine- and small-grained wind-blown sand. In the morphological depressions, the former deposits are overlain by carbonate muds as lacustrine sediment varying in mineral composition from calcite through dolomite and ferruginous dolomite up to magnesite. The carbonate muds are often covered by lacustrine, unsorted silt. Finally, the lacustrine deposits on the lakesides are overlain by small-grained, humified wind-blown sand.

The origin of the observed sediment types is unseparable from the particular climatic conditions. The loess is connected to a cold climate, the wind-blown sand is to an arid one. The calcite from the lacustrine carbonate muds is also bound to an arid climate with summer droughts. The dolomite and magnesite, in turn, are associated with extremely dry summer periods (MOLNÁR, B. 1985). The listed sediment types differ also in depositional environment. Loess and wind-blown sand were deposited subaerially, the carbonate muds and the lacustrine, unsorted silts were formed in lakewater.

During the sedimentological analysis of the material, it could be clearly seen that the drilling material contained also some molluscs. Thus, the idea occurred that the faunal composition might reflect these relationships, too. The question arose, whether the fossil content would agree with the sedimentological results and whether it would make also possible to draw further geohistoric conclusions. Since the most diversified geohistoric picture was expected in the lake area, the studies on molluscs were concentrated also to geological sections containing lacustrine facies *(Fig. 1)*.

The study of the mollusc fauna of Quaternary formations was rather neglected for a long time and this was due, among others, to the unproper sampling method that resulted in a mixing of the fauna. Its introduction had been delayed by the sporadical character and the low amount of the collected material and by the unproper method of its evaluation (LOZEK, V. 1964). It is known that if the principle of actualism is critically applied, the study of the Quaternary mollusc fauna will provide possibilities for a historical analysis of the faunal pattern. And this, in turn, will contribute to the determination of the genetic circumstances of the enclosing deposits.

EXAMINATION OF THE MOLLUSCA FAUNA

In three relatively larger and four comparatively smaller lakes areas, 370 samples from a total of 42 boreholes were selected for fauna investigations. Unfortunately, 258 samples contained no fauna. In the course of the work 11,993 individuals of 49 species were recovered *(Table 1)*. From each sample

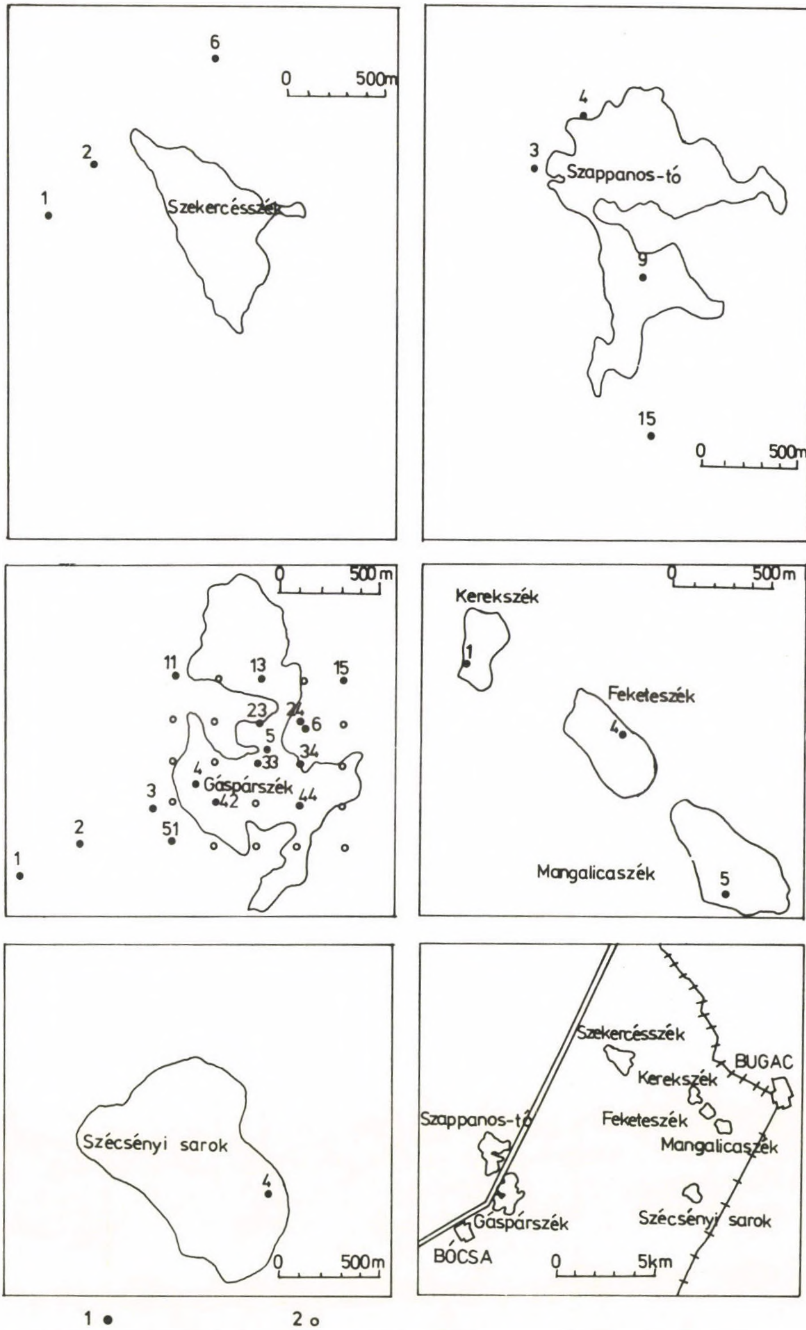


Fig. 1 Situation of the Bócsa-Bugac lakes and location of the paleontologically studied boreholes
1 = boreholes with fauna; 2 = boreholes without fauna

Table 1 Molluscs from the lacustrine core samples of Bócsa-Bugac, Kiskunság National Park

Age	sediment type	number of samples washed for fauna	number of fauna-less and fauna-bearing samples		total number of specimens	sample/number of specimen	number of species
Holocene	Surface humic small grained,' wind-blown sand	35	28	7	300	9	11
	lacustrine humic bed-sorted silt,	10	2	8	3000	300	21
	lacustrine car-bonate mud	113	97	16	648	6	30
	small-grained wind-blown sand	55	52	3	410	8	11
	fine-grained wind-blown sand	8	7	1	35	5	7
Pleisto-cene	fine-sandy loess	56	39	17	600	11	35
	loess	93	33	60	7000	75	47
	total	370	258	112	11993	59	49

300-400 g of material was washed through a sieve of 0.8 mm mesh, so that even small size specimens could be included in the study.

31 of the total of 42 boreholes were drilled in the Gáspár-szék lake and 15 of these contained no fauna. The fauna was not equally present in the different sediment types. The loess and the lacustrine, humic, unsorted silt with their mollusc specimens of 75 and 300 respectively per one sample were by far the richest of all. The wind-blown sand and the carbonate mud with their 5-9 specimens per sample, in turn, may be considered to be poor.

In the wind-blown sand the number of species are much less varying between 21 and 47 *(Table 1)* than observed in the other sediment types.

The striking value of the number of specimens obtained for the loess and the lacustrine, unsorted, humic silt may be connected to a more favourable paleobiotope. The Pleistocene loess was deposited during a cold period when climate was less unstable than in case of the Holocene sequences and that cold climate must have provided a favourable habitat for the molluscs. As pointed out by FÉNYES, J.--KUTI, L. (1986), the carbonate mineral of the lacustrine, humic and poorly sorted silt is overwhelmingly of calcitic composition. Studies by MÜLLER, G.--IRION, G.--FÖRSTNER, U. (1980) and MOLNÁR, B. (1985) provided reassuring evidence, according to which calcite is precipitated from lakewater having a higher pH and higher total dissolved solid content than it is the case with dolomite and magnesite. Such an environment is more advantageous for molluscs, too, and this accounts for the occurrence of a greater number of specimens in the calcitic, humic and unsorted silt. The lower number of specimens observed in other sediment types can be explained by a less favourable biotope. A term of transition regarding the number of specimens upwards in the geological column is represented between the previous sediment types by the fine- and small-grained wind-blown sands. The wind-blown sand surface, extremely dry in the summer as it used to be, did not encourage the proliferation of molluscs, so they were strongly reduced in number of specimens.

As shown by FÉNYES, J.--KUTI, L. (1986), the carbonate muds widely vary in composition, calcite being accompained by considerable amounts of dolomite, with ferruginous dolomite and magnesite in it. As suggested by MOLNÁR, B. (1980, 1985), the latter does not precipitate from lakewater, unless the pH and the amount of total dissolved solids of the lakewater rise considerably. Thus, a pH of 11 and a total of 40,000-50,000 mg/l of dissolved solids must have discouraged the growth of molluscs. That was why 97 of the 113 carbonate mud samples were free of fauna and only a total of 16 samples contained some fossils. Their amount, however, did not exceed an average of 6 individuals per sample.

The small-grained humic wind-blown sand covering the surface was deposited in an arid environment similar to that responsible for the wind-blown sand underlying the lacustrine deposits. So it is poor in fauna, too.

The number of species and specimens did not always change simultaneously. The lowest number of species was present in

Table 2 Mollusc fauna and ecological groups of the fauna from the core samples of the Bócsa-Bugac Lake and of its environs, Kiskunság National Park

I. Aquatic species	
ecological demand	species belonging of the ecological group
V_1 thermophylous species requiring constant coverage by water	Planorbis planorbis (L.) Limnaea stagnalis (L) Limnaea palustris (O.F.MÜLL) Planorbarius corneus (L.) Gyraulus albus (SHEP.) Bythynia leachi (SHEP.)
V_2 species tolerant to periodical water coverage	Valvata cristata O.F.MÜLL. Armiger crista (L.) Gyraulus riparius (WEST.) Pisidium sp. Bathyomphalus contortus (L.) Segmentina nitida (O.F.MÜLL.) Valvata pulchella STUD. Physa fontinalis (L.) Anisus spirorbis (L.) Anisus septemgyratus (ROSS) Anisus leucostoma (MILLET) Anisus vortex (L.) Aplexa hypnorum (L.) Galba truncatula (O.F.MÜLL.) Radix peregra (O.F.MÜLL.)

II. Terrestrial species	
ecological demand	species belonging of the ecological group
SZ_1 species of shore requiring humidity	Succinea elegans RISSO Succinea oblonga DRAP Carychium minimum O.F.MÜLL. Succinea putris (L)
SZ_2 species requiring less humidity	Zonitoides nitidus (O.F.MÜLL.) Euconulus fulvus (O.F.MÜLL.) Cochlicopa lubrica (O.F.MÜLL.) Limax sp. Vitrea crystallina (O.F. MÜLL.)
SZ_3 thermophylous terrestrial species	Vallonia enniensis (GRED.) Vallonia pulchella (O.F.MÜLL.) Vertigo antivertigo (DRAP.) Vertigo anggustior (JEFFR.) Monachoides rubiginosa (A.SCHMIDT) Nesovitrea hammonis (STRÖM)
SZ_4 species of high ecological tolerance	Pupilla muscorum (L.) Vallonia costata (O.F.MÜLL.) Vertigo pygmaea (DRAP.) Punctum pygmaeum (DRAP.) Clausilia sp.
SZ_5 xerothermal species	Abida frumentum (DRAP.) chondrula tridens (O.F.MÜLL.)

III. Loess species	
L_1 species tolerant to humidity and cold	Trichia hispida (L.) Vertigo substriata (JEFFR.)
L_2 species tolerant to drought and cold	Columella columella (G.MARTENS) Columella edentula (DRAP.) Vertigo parcedentata (A.BRAUN) Discus ruderatus (FERUSS)

the wind-blown sand sediment types. Loess, fine-sandy loess, carbonate mud and lacustrine unsorted silt were substantially richer in species. The high number of species (30), of the carbonate mud containing just a few specimens in particularly interesting. In this case, a lot of species seem to have been able to endure the given environment, but their representatives are present in a restricted number of specimens only.

From the Danube-Tisza Interfluve, along with natron lakes, the peaty lakes were also examined. As compared to the present-day results, the deposits of the peaty lakes excelled with their substantially higher number of specimens. In contrast with the figure of 49 counted here, the number of species there was as high as 70 (MOLNÁR, B.--IVÁNYOS SZABÓ, A.--FÉNYES, J. 1979; FÉNYES, 1983).

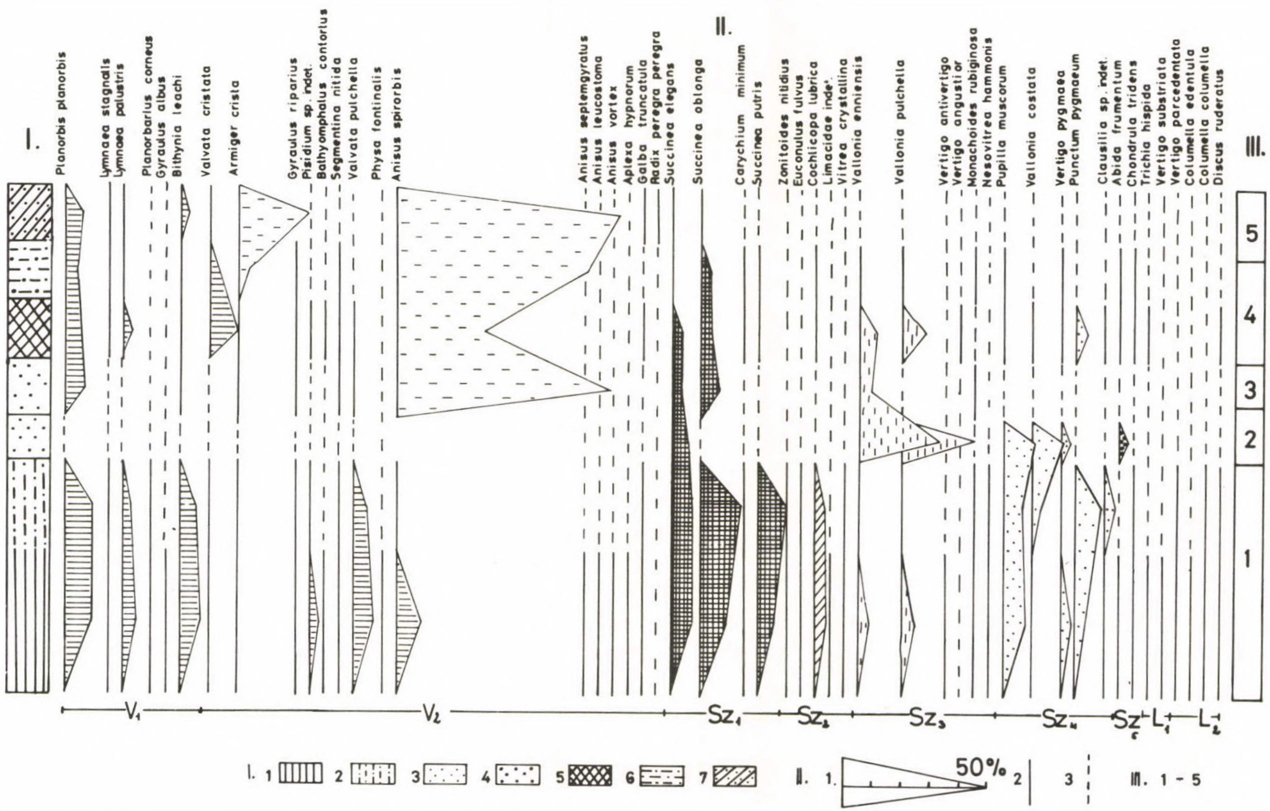
The observed speices have been divided into subaerial (SZ) and aquatic, humidity-demanding (V) ecological groups based on their environmental needs and endurance. The subaerial species, according to their increasing tolerance of drought, have been further subdivided into five subgroups (SZ_1 - SZ_5), the hydrophilous (humidity-demanding) species into further two subgroups (V_1 - V_2). Species occurring only in loess (L) have been considered to represent a separate group and divided into two subgroups (L_1 – L_2) in terms of their ecological needs *(Table 2)*.

Naturally, the ecological groups do not represent rigid limits; many species represent transitions between the distinguished groups. For this reason, after the determination of species and specimen numbers, the results were plotted graphically according to sediment types as a function of depth *(Fig. 2)*. Because of the frequent occurrence of species of high ecological endurance, when evaluating the paleobiotope the variation of an assemblage of several species was always taken into consideration (LOŽEK, V. 1964; KROLOPP, E. 1967, 1973). If, in a lacustrine environment, we wanted to reconstruct the water coverage or the variation of any other special factor, we should concentrate on checking the trend of variation in the composition of a group. In such cases, even at smaller shifts in the amounts, changes in the circumstances of sedimentation may suggested. As it is known from earlier studies, that molluscs are sensitive indicators, reflecting the changes in any environment (MOLNÁR, B.--KROLOPP, E. 1978).

In *Fig. 2* the percentage occurrence of species belonging to groups of different ecological demand is shown for each particular sediment type. For technical reasons, the species present in 2.5% are indicated by solid line on the figure. If any of the species was absent in a sediment type, it is represented by a dash-line.

On the basis of the percentage occurrence of the species and their abundance curves, respectively, five faunal intervals could be distinguished *(Fig. 2, III, 1-5)*.

1. The first interval falls to the period of loess and fine-sandy loess deposition. The faunas of this interval, and particularly that of the loess deposition period are characterized by nearly identical percentages of the species involved. A characteristic feature of the fauna, as a whole, is that



<u>Fig. 2</u> Mollusca fauna of the Bócsa-Bugac area

I 1 = Loess; 2 = fine-sandy loess; 3 = fine-grained wind-blown sand; 4 = small-grained wind-blown sand; 5 = carbonate mud; 6 = lacustrine, humic, unsorted silt; 7 = subaerial, humic, small-grained wind-blown sand; II The different species present, and their ecological groups ($V_1 - V_2$)= aquatic, $Sz_1 - Sz_2$= subaerial, $L_1 - L_2$= loess-dwelling species) 1 = 50%,; 2 = 2.5% or less; 3 = Interval with no species; III 1-5 = Faunal intervals the aquatic speices are in majority. The thermophilous, subaerial forms, in turn are present in a somewhat lower percentage. Species that are typical only of loessic sediment forms labelled L_1- L_2, are present, too.

Higher upwards in the geological column the number of specimens, decreases in the fine-sandy loess and percentage values of the individual species also show a decreasing trend. This is the case for instance with Pisidium sp. and Anisus spirorbis among the aquatic forms, and with Vallonia enniensis, Vallonia pulchella and Vertigo pygmaea from among their subaerial counterparts. Some groups completely disappear, e.g. the remaining Anisus forms or Trichida hispida and Columella columella become restricted to the loess and to cold-resisting species. At the same time, a transition is indicated towards the overlying wind-blown sand by fact that the role of some species, e.g. Vallonia costata, became more significant than had hitherto been the case.

As reflected by the fauna as a whole, the conclusion can be drawn that during the deposition of the loess and the fine-sandy loess, the climate must have been cold and relatively humid locally.

2. The second faunal interval falls to the period of fine-grained wind-blown sand deposition. In this interval there is a decrease in the number of specimens and the aquatic forms disappear completely. Of the subaerial forms, it is especially the thermophilous Vallonia eniennsis and Vallonia pulchella that were present in significant percentages, 27 and 25%, respectively, though the shares of Pupilla muscorum and Vertigo pygmaea also increase. Naturally, the loess-dwelling forms do not occur anymore. Consequently, when the fine-grained wind-blown sand accumulated, the climate was already arid.

3. The third interval corresponds to the deposition of small-grained wind-blown sand. In this period the fauna was somewhat richer both in species and in specimens as compared to the preceding interval, yet it still can be said to have been rather poor. Of the 11 species present, Anisus spirorbis, with 74% is, by far, the most important. Of the aquatic forms Planorbis planorbis is still significant. Of the subaerial forms, two hydrophilous, riparian species (SZ_1) and one less humidity-oxigent species attain a figure of more than 2.5%.

This faunal composition shows a transition between wind-blown sand deposition and alkaline lacustrine sedimentation. In springtime, the study area seems to have been covered already by less water. In the late summers and autumns, however, the water may have disappeared due to evaporation and so wind-blown sand could be deposited.

4. The fourth interval coincides overwhelmingly with the period of carbonate deposition. The number of specimens is invariably very low, but then sudden leap in the number of species to 30 a phenomenon obviously due to the appearence of water, followed. A rapidly changing biotope is suggested by the fact that four aquatic and four subaerial species each exceeded 2.5%. The same proposal is confirmed by the presence of Punctum pygmaea (SZ_4), a species of high ecological tolerance.

The humic lacustrine, unsorted silt, overlying the carbonate muds shows, as far as its fauna is concerned, a transition between the carbonate muds and the wind-blown sands overlying them and thus it reflects the slow change in the biotope, as well.

5. The fifth interval is related to the deposition of the humic, small-grained wind-blown sands covering the surface. Its lower part is still made up of humic, lacustrine unsorted silts that are rich both in the number of specimens and in the number of species. In the wind-blown sands, however, both are strongly reduced. Here, curiously enough, the aquatic, hydrophilous forms predominate, while the subaerial ones play a subordinate role. The wind-blown sands were introduced into these depressions by the winds from the surrounding higher situated surfaces, so the depressions could still provide the moisture that was required for the life of molluscs.

EXAMINATION OF THE MOLLUSCA FAUNA OF DIFFERENT LAKES

The identical sediment types of all boreholes and their fauna, respectively, were presented above. Although this approach could show the most spectacular changes in the biotope, it was not extended to local divergencies. That is why the variation of molluscs in different lakes was separately studied, i.e. local characteristics of single lakes, could be also investigated. Here the Gáspárszék and Feketeszék lakes will be discussed in detail. The deposits of these lakes were relatively rich in fauna.

Fig. 3 illustrates the changes in the number of specimens and species. In these lakes the loess is more complicated than in case of the other lakes and the lake deposits are more simple in lithology. In the Gáspárszék lake the loess overlies wind-blown sands, in the Feketeszék it is superimposed on fine-sandy loess. As shown by MOLNÁR, B.--KUTI, L. (1986) and FÉNYES J.--KUTI, L. (1986), the wind-blown sands underlying the loess are virtually sand lenses that divide the loess into two parts. The lacustrine, humic, unsorted silts are present only in the Gáspárszék, but are absent in the Feketeszék.

The fauna of the loess is rich in individuals and species in both lakes. In the Gáspárszék lake the fauna disappears from the small-grained wind-blown sands overlying the loess and it does not reappear anymore even higher up in the section. In the Feketeszék lake there is also a decrease in the number of species and specimens. Contrary to the Gáspárszék lake, however, the fauna does not dissapear either in the carbonate mud or in the lacustrine, humic unsorted silts, but it reaches, as far as the number of specimens is concerned, a figure that is even higher than that in the loess. Although the number of species is lower than in case of the loess, it comes quite close to that figure. The difference is caused by the fact that the carbonate mud of the Gáspárszék is dolomite and magnesite, and that of the Feketeszék, in turn, is composed, together with the carbonate, of the lacustrine, humic, unsorted silt, overwhelmingly of calcite. As already pointed out, during the deposition of the latter the lower pH of the lakewater

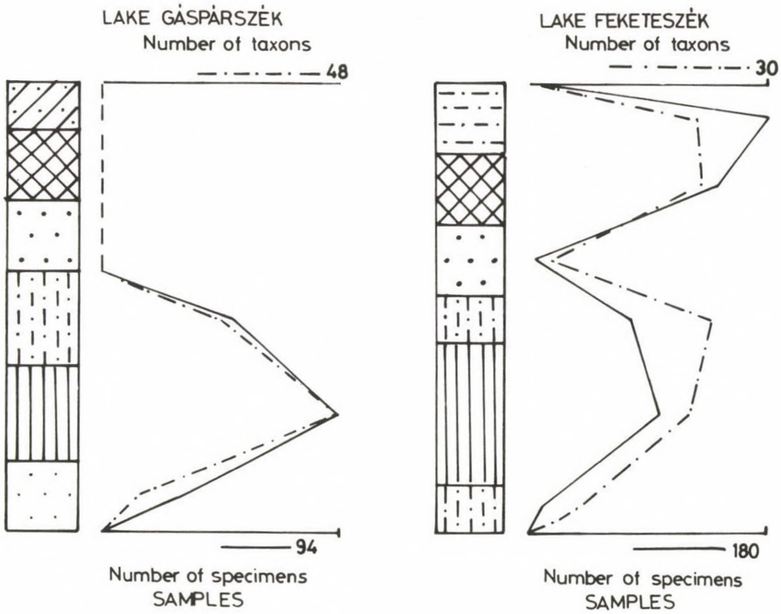


Fig. 3 Number of specimens per sample and number of species found in the Gáspárszék and Feketeszék lakes

and its lower total dissolved solid content provided an environment that was more favourable for molluscs than it used to be with the lakewater of extremely high pH and total dissolved solid content that prevailed when dolomite and magnesite were precipitated.

In the Gáspárszék lake three faunal intervals could be distinguished *(Fig. 4)*.

1. The faunal pattern of the fine-grained wind-blown sands of the first faunal interval corresponds to the second interval of the cumulative fossiliferous sequence. Here the subaerial species predominate, too.

2. The loess and fine-sandy loess of the second interval are identical, in character, with the first interval of the cumulative sequence. Aquatic and subaerial species also predominate here.

3. The third interval is characterized by the total lack of fauna.

The faunal history of the Feketeszék, similarly to the cumulative fossiliferous sequence, can be split up into five intervals *(Fig. 5)*.

1. The fine-sandy loess of the first interval differs from the fine-sandy loess of the cumulative fossiliferous sequnce: here only aquatic species are present.

2. The fauna of the loess and fine-sandy loess of the second faunal interval is nearly identical with the first interval of the cumulative fossilisferous sequence. The species are

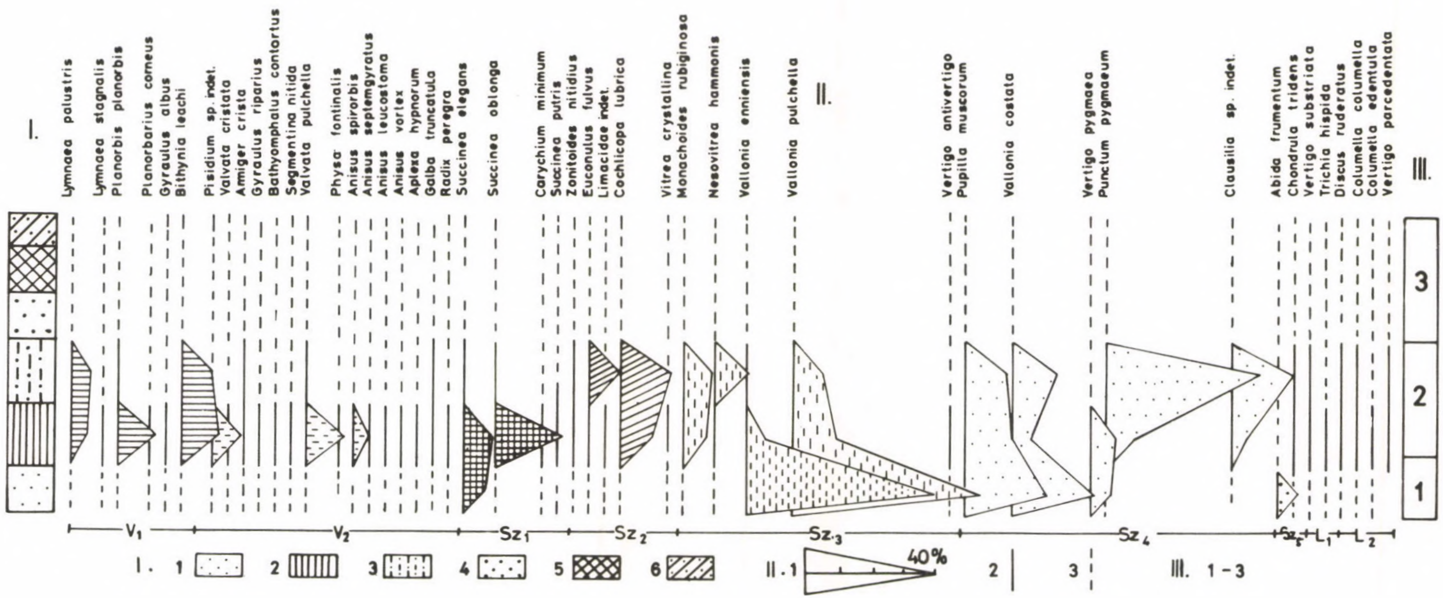


Fig. 4 Mollusca fauna of the Gáspárszék lake deposits
(For explanations, see Fig. 2)

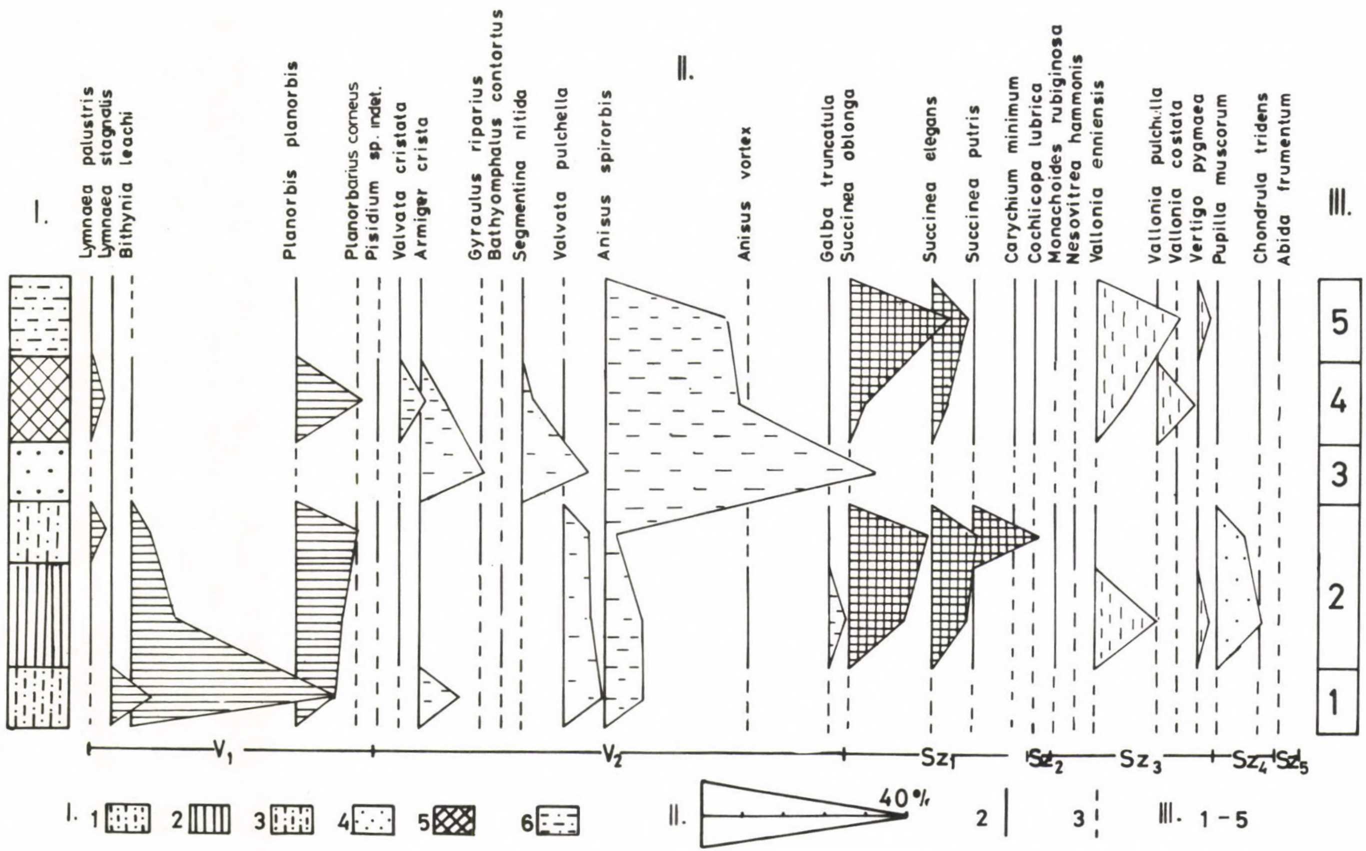


Fig. 5 Mollusca fauna of the Feketeszék lake deposits
(For explanations, see Fig. 2)

represented in similar percentages, and these, though divergent in the loess and the fine-sandy silt, show a similar trend.

3. The third interval corresponds to the fauna of the small-grained wind-blown sand. In conformity with the strikingly high percentage of *Anisus spirorbis* in the third interval of the cumulative fossiliferous sequence, this is the most frequent species here. In the deposits of the Feketeszék lake, however, specimens of *Armiger crista* and *Segmentina nitida* are presented in considerable amounts. The subaerial species, however, are almost completely absent. In the Feketeszék lake the small-grained sands must have been deposited in a depression where the waterlogged flats provided a biotope for aquatic molluscs.

4. The fourth interval can be related to carbonate muds and shows a composition corresponding nearly to that of the lower interval of the cumulative fossiliferous sequence.

5. The fifth interval took place during the earlier part of the fifth interval of the cumulative fossiliferous sequence. Here the humic wind-blown sand is absent. In the Feketeszék the role of the subaerial forms is more significant in the unsorted lacustrine silts. Together with Succinea oblonga and *Succinea elegans* there are also other forms here, i.e. *Vallonia enniensis* and *Vertigo pygmaea.* These also played important roles meaning that at the time of silt deposition here the hot climate was predominant.

The Szekercés lake deposits are very poor in fauna. At the base of the lacustrine deposit wind-blown sand can be found that, like the carbonate muds, is unfossiliferous. Only the unsorted lacustrine silt contains some fossils, mainly aquatic forms. The loess of the Szappanos lake shows a fauna that corresponds to the previous one, but its lacustrine deposit was found to be completely unfossiliferous.

GEOLOGICAL HISTORY OF THE STUDY AREA AS REFLECTED BY THE MOLLUSC RECORD

1. When the loess was deposited in the latest Pleistocene the study area was a cold, but not too dry terrain. As indicated, quite convicingly, by the Mollusca fauna of the wind-blown sand lenses intercalated within the loess, the warming-up of the climate was due to an alternation of cold and hot phases. The fauna of the fine-sandy loess marks a climate that must have been somewhat drier than that of the period of loess formation, but was still cold. This is indicated by the higher percentage of subaerial forms, as compared to the loess, and by the persistence of loess dwelling forms (L_2).

2. The deposition of fine sands upon the loess marked an essential change in the biotope. The wind-blown sand contains only poor fauna with subaerial species (SZ_3 - a group of thermophilous forms, SZ_4 - one of the species of high ecological tolerance). The loess-dwelling gastropods had disappeared. Consequently, this sediment must have been deposited already in the Holocene.

3. The small-grained wind-blown sand overlying the fine sands contains both aquatic and subaerial species. This was probably the period when the sand-dune ranges, and the sag-depressions in between, were formed. With a rise in the position of the groundwater table, these depressions could be filled up with water, resulting in the appearance of lakes. The aquatic species in the wind-blown sands testify to periodical inundation of the sag-depressions in the more humid seasons. The water amounts involved, however, were not sufficient for the precipitation of carbonate.

4. During the deposition of the carbonate muds, overlying the small-grained wind-blown sands, the chemical character of the water must have had a crucial effect on the fauna. If dolomite and magnesite were segregated from an extremely alkaline water of high dissolved solid content, the resulting sediment does not contain molluscs. In case of lower pH and lower amount of dissolved solids, when calcite is precipitated, aquatic and subaerial forms are found in number of specimens and a high number of species.

5. In the lacustrine, unsorted, humic silts the number of specimens is strikingly high, and the sediment is rich also in species. Similarly to the phenomenon, observed in connection with the carbonate mud, the difference from subarea to subarea is considerable also here. The rapid changes here, during the period of deposition, are proved by the presence of sites where the deposit is dominated by aquatic forms, and also by the existence of the sites, where the subaerial forms predominate. The sediment seems to have been deposited in a period when dessiccations and inundations alternated several times, but when the dessiccation trend was prevailing. Moreover, in the Gáspár-szék lake, this type of deposit did not form at all.

6. Finally, the small-grained, humic wind-blown sands reflect a period when in the spring, with still-existing water pools in the sags, eolian sands were blown from the neighbouring, high-perched surfaces into the sag-depressions. If the surface was completely dry, as in case of the Gáspárszék, the fauna is absent; if the surface was wet, the resulting sediment contains predominantly aquatic species.

Consequently, the faunal succession reflects fairly well the succession of changes in the biotope. During the Holocene the water coverage and dessiccation changed very rapidly both in space and time even in juxtaposed lakes, very similarly to the situation at present. The extension of water coverage was highly dependent on the prevailing position of the phreatic groundwater table, while this latter was controlled by the rate of precipitation. These changes can be also followed through the divergencies of the fauna.

The results of faunal investigations are in harmony with the sedimentological results (MOLNÁR, B.--KUTI, L. 1986 and FÉNYES, J.--KUTI, L. 1986). These, however, have made possible even finer distinctions than those provided by the sedimentological investigations.

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ADDRESS OF AUTHORS:

Ágnes TÓTH
József Attila University
Department of Geology
SZEGED Táncsics M. u. 2. H-6701

Béla MOLNÁR
József Attila University
Department of Geology
SZEGED Táncsics M. u. 2. H-6701

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NEW RESULTS OF RADIOCARBON DATING OF ARCHAEOLOGICAL FINDS IN HUNGARY

I. BOGNÁR-KUTZIÁN and É. CSONGOR

ABSTRACT

The present paper discusses radiocarbon dating of 22 finds from the Neolithic and Copper Ages. These investigations were carried out by a team dealing with the chronological problems of Holocene prehistory in Hungary by applying archaeological and independent physical methods, respectively. The applied methods and techniques are described, and the significance of measuring bone samples is emphasized. This is followed by the discussion of results. The majority of ^{14}C dates of 18 human tubular bones and 4 charcoal samples are in accordance with their archaeological datings based on relative chronology. Moreover, the stratigraphical position of two superposed burials agree with their radiocarbon dates.

* * *

INTRODUCTION

Specialists of the Archaeological, Nuclear, Isotopes and Central Chemical Research Institutes of the Hungarian Academy of Sciences, and of the Geophysical Department of the Eötvös Loránd University formed a team with the aim to contribute to a more exact determination of the "absolute" chronology of the Holocene periods of prehistory in Hungary by using independent dating methods. L. BENKÖ takes part in the work with thermoluminescent (BENKÖ, L. 1976, 1977, 1983, 1985), P. MÁRTON with archaeomagnetic (MÁRTON, P. 1984), A. ROCKENBAUER and P. SIMON with electron spin resonance datings. In this paper results of radiocarbon determinations, stratigraphical and relative chronological examinations, and also the systematization and archaeological evaluation of various dating results are given (BOGNÁR-KUTZIÁN, I. 1983, 1985; CSONGOR, É. 1985; CSONGOR, É.--HERTELENDI, E. 1981; CSONGOR, É. et al. 1982, 1983).

One of the main purposes of our investigations is to make possible the comparison of the results achieved by independent physical dating methods as well as their checking by each other, and with the archaeological chronologies. Further aims are to fill in the time gaps in prehistoric chronology and, as far as possible, to replace the single datings by a series of measurements.

METHODS

Formerly, the chronometric datings of prehistoric finds in Hungary could be realized by applying ^{14}C age determination methods only in foreign laboratories (first of all in Berlin, then in Groningen, London, Frankfurt/Main, Tucson and San Diego-La Jolla). The material of the samples was wood, charcoal and other plant remains, i.e. materials for the preservation of which the conditions were not always favourable. Consequently, we were cut off from datings of the most important finds, even from whole periods or cultures, fairly frequently. Since wood remains are usually scarce in graves, the ^{14}C dating of them is missing. Their closed find assemblages, however, provide rich sources for relative chronology. This is one of the reasons why radiocarbon analyses carried out on human bones, suitable for direct dating of find associations, are of great importance.

The other reason is, that since bone samples are suitable for examinations by electron spin resonance method, too, they provide the possibility to compare directly the results derived from the same skeleton by applying two different methods. At the same time, pottery of the same grave can be also dated by using the thermoluminescent method. Results of the TL and ESR are, however, comparable only with radiocarbon years converted to calendar years.

Thus, for this study samples, not merely suitable for the three independent physical examinations and in satisfactory quantity for repeated analyses were needed, but they also had to meet the archaeological requirements, such as the authenticity of the excavation, the availability of the find material and the observations, the adequate relative chronology supported by stratigraphy and topography, moreover closed find units in large quantities in a given site for series of dating.

Considering all these criteria, the cemetery at Tiszapolgár-Basatanya, as the object of the first experiments was selected (BOGNÁR-KUTZIÁN, I. 1963). Furthermore, the choice was motivated by other factors, too. The two cultures in the cemetery, the Early Copper Age Tiszapolgár and Middle Copper Age Bodrogkeresztúr ones had no ^{14}C dates, due to the lack of carbonaceous samples, thus only cross datings were possible (BOGNÁR-KUTZIÁN, I. 1963, 1972). One Neolithic burial preceding the cemetery, was also unearthed at Basatanya, so a third period could be involved in the investigations. The indisputable connections of skeletons and pottery, just like direct links between the different vessels found in the individual graves provided a most appropriate series of samples for comparison of ^{14}C, ESR and TL datings.

Neither the cemetery yielded charcoal samples suitable for radiocarbon dating, nor could be such samples obtained from other sites of the Tiszapolgár and Bodrogkeresztúr cultures for the comparison of the dates of the two different materials. For this purpose the components of the Neolithic samples were suitable: the find spot of one pair of samples is the same (Deb-408 bone and -450 charcoal), while dates of the remaining three charcoal samples (Deb-396, 413 and -417) can be compared with bone samples of similar ages (Deb-473, -474 and -357) but from diverse find spots. Charcoal and bone are the most important types of archaeological materials for ^{14}C datings while about 1400 archaeological samples of various dating materials were evaluated statistically from different sites in Europe (EVIN, J. 1983). Though the number of the dated bone samples is about only half of that of the charcoal samples, the reliability of the ^{14}C dates of the bone material is higher than that of the charcoal. In case of bones the higher reliability has two main reasons; due to the short lifetime of a bone, the age is always contemporary with the archaeological event, and the tubular bones provided samples of less significant contamination. In dates of charcoal material, however, systematic errors may exist due to differences in age between the time of growth of the wood and the time of the event when it was used. An other source of error may be if the charcoal pieces are not homogeneous. Most reliable dates can be expected by selecting homogeneous, uncontaminated sample material of large-sized bone or charcoal, and less reliable are the dates from small pieces.

The original sample can be contaminated in the surrounding environment by some carbonaceous material of inappropriate age. A charcoal sample lying in the soil might be penetrated by rootlets, or contaminated by humic substances or carbonates. To remove the mechanical contamination of charcoal samples ultrasound treatment was applied first. Then the rootlets, etc. were selected by handpicking. Thereafter the sample was chemically pretreated, removing the carbonate contaminants by acid and the humic acids by alkali extractions. Finally, the charcoal samples were acidified and dried. The bone samples were treated according to the Longin method to extract the collagen fraction of the bone (LONGIN, 1970; CSONGOR, É. et al. 1983). Only tubular bones were selected to reduce the possibility of contamination.

After the chemical pretreatment the carbon content of the sample was combusted to produce carbon dioxide gas; the gas was then converted to methane (CSONGOR, É. et al. 1982). The ^{14}C activity of the sample was measured in proportional counter filled with the methane (CSONGOR, É.--HERTELENDI, E. 1981).

The measured sample activities were compared with 95 percent of the activity an oxalic acid sample provided by the National Bureau of Standards. The conventional ^{14}C ages in BP years (see, Antiquity 1972, Vol. 46,265) were calculated with the conventional (Libby) ^{14}C half-life of 5568 years and reference year of AD 1950. The error is ±1 standard deviation based on the counting statistics.

By radiocarbon dating the conventional ^{14}C ages of archaeological samples are measured in bp years. These dates are based on the assumption that the atmospheric ^{14}C level was constant in the past. However, past atmospheric ^{14}C level varied in time, and the conventional radiocabon ages deviate from calendar years BP. This deviation can be determined when the same tree rings were dated dendrochronologically in calendar years and their radiocarbon dates in bp years were measured. More than one thousand measurements were carried out to construct the calibration curves and calibration tables for correcting ^{14}C dates during the last 8000 years, respectively (SUESS, H.E. 1970; DAMON, P.E. et al. 1972; RALPH, E.K. et al. 1973; CLARK, R.M. 1975; KLEIN, J. et al. 1982; PEARSON, G. W. et al. 1983). The various calibration curves agree in general trend, their differences depend on the statistical smoothing of the curve, on the precision of the measurements, and on the way how the errors of measurements and calibration are taken into account.

The calibration measurements were carried out first on Bristlecone Pine grown in the USA. The measurements were repeated, with a high precision, on Irish oak, and the comparison of the calibration concluded that the corrections are the same world-wide (for different tree species and at different altitude).

RESULTS

In this study dates measured in the radiocarbon laboratory in Debrecen, are published together with their calibrated dates concerning the Early and the Late Neolithic and also the Early and the Middle Copper Ages. They are summarized in the *Table*. The MASCA calibration (RALPH, E. K. et al. 1973) was used for the calibration of the conventional ^{14}C dates. All samples are of tubular human bones, except for four charcoal ones (Deb-396,413,417 and 450).

Table

Sample number	^{14}C dates	Calibrated dates	
	bp	BP	BC
Deb-473	7100 ± 230	7910 ± 250	5960 ± 250
Deb-396	7050 ± 200	7860 ± 220	5810 ± 220
Deb-413	6960 ± 220	7830 ± 250	5880 ± 250
Deb-408	6580 ± 180	7490 ± 200	5540 ± 200
Deb-474	6430 ± 220	7230 ± 240	5280 ± 240
Deb-450	6240 ± 190	7110 ± 210	5160 ± 210
Deb-357	5980 ± 200	6860 ± 220	4910 ± 220
Deb-416	5600 ± 180	6370 ± 200	4420 ± 200
Deb-464	5460 ± 170	6270 ± 190	4320 ± 190

Sample number	^{14}C dates	Calibrated dates	
	bp	BP	BC
Deb-417	5400 ± 180	6210 ± 200	4260 ± 200
Deb-361	5350 ± 190	6160 ± 210	4210 ± 210
Deb-355	5220 ± 220	5960 ± 220	4010 ± 220
Deb-481	5210 ± 170	5950 ± 190	4000 ± 190
Deb-354	5090 ± 190	5840 ± 210	3890 ± 210
Deb-349	5060 ± 170	5810 ± 190	3860 ± 190
Deb-348	5020 ± 180	5750 ± 200	3800 ± 200
Deb-465	5020 ± 170	5750 ± 190	3800 ± 190
Deb-350	5010 ± 180	5720 ± 200	3770 ± 200
Deb-214	4980 ± 140	5710 ± 160	3760 ± 160
Deb-122	4850 ± 150	5545 ± 170	3595 ± 170
Deb-428	4240 ± 180	4760 ± 200	2810 ± 200
Deb-441	4090 ± 180	4520 ± 200	2570 ± 200

Archaeological data of the samples of the Table in relative chronological order

EARLY NEOLITHIC AGE

Deb-473	Körös culture	Szajol-Felsöföld (Szolnok-county) 1976, P. RACZKY's excavation square 5, pit 3 (skeleton Nº 2)
Deb-474	Körös culture	The same site and excavation "house" (skeleton Nº 3)
Deb-396	Körös culture	Szarvas-56 (Békés county) 1981, J. MAKKAY's excavation trench I
Deb-413	Körös culture	Szakmár-Kisülés (Bács county) 1978, I. BOGNÁR-KUTZIÁN and A. HORVÁTH's excavation square XXIV, depression a,
Deb-408	Körös culture	Endröd-6 (Békés county) 1982, J. MAKKAY's excavation square I (skeleton Nº 1)
Deb-450	Körös culture	The same site and excavation square I, depth 120-170 cm

LATE NEOLITHIC AGE

Deb-357	Tiszapolgár-Basatanya grave Nº 84 (BOGNÁR-KUTZIÁN, I. 1963)
Deb-417	Bodrogzsadány-Akasztószer (Borsod-Abauj-Zemplén county) 1983, I. BOGNÁR-KUTZIÁN and J. MAKKAY's excavation square IX, pit a, above the ashy layer

Samples of the Early and Middle Copper Age come from the cemetery at Tiszapolgár-Basatanya. Though the cemetery was already published (BOGNÁR-KUTZIÁN, I. 1963), yet for sake of immediate orientation we indicate the relative age and the grave numbers from which the samples have been collected.

EARLY COPPER AGE

Deb-361	Tiszapolgár culture	grave Nº 5
Deb-416	Tiszapolgár culture	grave Nº 12
Deb-348	Tiszapolgár culture	grave Nº 23
Deb-349	Tiszapolgár culture	grave Nº 28
Deb-354	Tiszapolgár culture	grave Nº 54
Deb-464	Tiszapolgár culture	grave Nº 61

MIDDLE COPPER AGE

Deb-350	Bodrogkeresztúr culture	grave Nº 41
Deb-214	Bodrogkeresztúr culture	grave Nº 44
Deb-481	Bodrogkeresztúr culture	grave Nº 59
Deb-428	Bodrogkeresztúr culture	grave Nº 85
Deb-122 Deb-465	Bodrogkeresztúr culture	grave Nº 101, dual burial: skeleton A skeleton B
Deb-355	Bodrogkeresztúr culture	grave Nº 120
Deb-441	Bodrogkeresztúr culture	grave Nº 133

DISCUSSION

As the present paper gives a review of the results of analyses, still going on, a final evaluation would seem to be inconsiderate. That's why we shall hint only at some results and some problems to be solved.

We would like to mention that the dates in the Table do not refer to the whole duration of the examined periods, i.e. for the Early and the Late Neolithic and the Early and Middle Copper Ages, they are only of informative value.

The 22 dates, discussed here, coincide with the relative chronological order given by the archaeological methods except for three ones (Deb-417, -355 and -481). They are in good accordance with dates of other foreign laboratories, at least in case of Early and Late Neolithic samples. Concerning the Copper Age, there are no published datings from either the Tiszapolgár or the Bodrogkeresztúr cultures.

In accordance with the expectations, the ages of the Körös-culture are the oldest, the longer time intervals between them agree with the persumed long life of the culture. The time, however, elapsed between the burials of two dead at the Szajol site, as suggested by the achieved dates, seems to be too long. The difference between the most probable datings of the bone and charcoal samples from Endröd-6 site is within the error limits.

The datings of the bone sample from the grave 84 at Tiszapolgár-Basatanya and the charcoal sample from pit IX/a at Bodrogzsadány-Akasztószer are not enough to draw conclusions concerning the duration of the Late Neolithic. The former grave can be separated from the Copper Age on the basis of its rite, grave goods and topographic situation (lying on the edge of the early part of the cemetery), and can be considered earlier. The radiocarbon dates of the grave coincides with those expected for the beginning of the Late Neolithic (see the earliest dwelling layer, house F at Csöszhalom, - QUITTA, H. and KOHL, G. 1969:5940±100 bp, Bln-513). The age of the Bodrogzsadány sample is around the expected lowest value (see Csöszhalom house A, the latest dwelling layer, QUITTA, H. and KOHL, G. 1969, 5575 ± 100 bp, Bln-509). So the latest Neolithic datings indicate an overlapping with the beginning of the Basatanya cemetery that, considering the possible time intervals is no more than touching and is still not convincing as the earliest graves of the cemetery belong to the phase B of the Tiszapolgár culture (BOGNÁR-KUTZIÁN, I. 1972).

It means that the cemetery was started according to the datings with the burials of the Tiszapolgár culture and closed by those of the Bodrogkeresztúr culture. The same historic order is testified by artifacts, burial rites, and stratigraphical data of the graves, and also the main directions of the trend the topographical situation agrees (BOGNÁR-KUTZIÁN I. 1963).

The most probable datings of the Early and Middle Copper Age graves unearthed in superposition are

MCA grave 59 = 5210 ± 170 bp

ECA grave 61 = 5460 ± 170 bp

so they agree with the stratigraphic positions.

From the skeletons of the cemetery so far dated the 59 and 120 graves of Bodrogkeresztúr culture are older while the 85 and 133 graves are younger than expected.

The ^{14}C ages of graves 59 and 120 are also situated higher than those of graves 54, 28, and 23 of the Tiszapolgár culture according to the most probable dates, though they stay within the possible time interval around 5000 bp to which most of the measured samples of the cemetery belong.

CONCLUSIONS

The above ^{14}C dates clearly support our earlier asssumption, i.e. the graves of transitional character can be interpreted as belonging to the Tiszapolgár population and gradually adopted to the Bodrogkeresztúr culture. Consequently, the transition is not a separate period but a complex of traits reflected by the artifacts and burial rites emerging after the appearance of the Bodrogkeresztúr culture, i.e. in the Middle Copper Age (BOGNÁR-KUTZIÁN, I. 1963).

The radiocarbon ages of graves 85 and 133 are lower than expected. They differ, however, only in the most probable dates, still they are much later than the other Middle Copper Age graves of the cemetery, and also those datings, which, due to the milk jug of grave 133 (BOGNÁR-KUTZIÁN, I. 1963,-pl. CXII.14) are also be considered. This jug connects the grave - through salcuta IV - with the Lasinja culture, and the ^{14}C dates of the latter are significantly higher (4890 ± 80 bp, Bln-501 and 4780 ± 80 bp Bln-500, QUITTA, H. and KOHL, G. 1969). Grave 133 together with some other burials of the cemetery indicate the beginning of the phase B of Bodrogkeresztúr culture according to typological and topographic evidences, and at the same time the coming abandonment of the cemetery (BOGNÁR-KUTZIÁN, I. 1963, 1969, 1972).

We also have to hint at the divergence between the ^{14}C datings of the two skeletons of the dual burial Nº 101, which, however, can be concieved only between the most probable dates, disappearing in the time interval of the possible datings.

It can be concluded that the radiocarbon datings are in good agreement with the following archaeological results: /a/ The Körös culture is the earliest Neolithic culture in Hungary and /b/ had a long life; /c/ in the Copper Age the Tiszapolgár culture precedes the Bodrogkeresztúr one; the sequence of dating of the Tiszapolgár-Basatanya cemetery allows even a more thorough analys: /d/ the Late Neolithic grave precedes the Copper Age cemetery, which /e/ starts in the Early Copper Age, /f/ carried on with the phase A of the Bodrogkeresztúr culture without /g/ a break between the populations of the two cultures and at last /h/ closing with the phase B of the Bodrogkeresztúr culture; /i/ the ^{14}C dating gives a chronological order in accordance with the stratigraphic evidences.

The reasons of the low ^{14}C dates of graves 85 and 133 are, nevertheless, to be cleared up.

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ADDRESS OF AUTHORS:

Ida BOGNÁR-KUTZIÁN

Archaeological Institute
of the Hungarian Academy of Sciences
BUDAPEST I. Uri u. 49. H-1250

Éva CSONGOR

Institute of Nuclear Research
of the Hungarian Academy of Sciences
DEBRECEN Bem tér 18/c. H-4001

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A COMPARATIVE STUDY OF INDEPENDENT DATING RESULTS OBTAINED FROM PREHISTORIC SAMPLES

I. BOGNÁR-KUTZIÁN

ABSTRACT

Datings obtained by ^{14}C, TL and ESR methods are compared with each other and with the archaeological relative chronology. The examinations were carried out by physicists L. BENKÖ, É. CSONGOR, A. ROCKENBAUER and P. SIMON. All samples were taken from seven burials of a cemetery started in the Early Copper Age and left in the Middle Copper Age.
Though agreements and deviations equally occur in the most probable years of the closed find units but they predominantly remain within the error limits. According to the most probable dates the graves were buried in the first third of the 4th millennium BC.
The results arrived at by the three independent physical methods are consistent and correspond to the expectations of the archaeology as well.

* * *

INTRODUCTION

Recently, a few datings obtained by the radiocarbon, thermoluminescence and electron spin resonance methods, respectively, have been first compared with an archaeological chronology based on stratigraphy, topographic data and typology (BOGNÁR-KUTZIÁN, I. 1985). During that study, datings with the three physical techniques were available only for one burial (Nº 120), while two additional graves (12 and 23) were dated with the radiocarbon and thermoluminescence methods respectively. Meanwhile these serial investigations have continued and they are being still undertaken currently. Following the request of the Editor of this volume some preliminary conclusions will be discussed.

The examinations are being carried out by a team. É. CSONGOR (Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen) is in charge of the radiocarbon dating. The methodology and the results presented here have already been published (CSONGOR, É. et al., 1983; CSONGOR, É. 1985; BOGNÁR-KUTZIÁN, I.--CSONGOR, É. 1987). Datings with the thermoluminescence methods were provided by L. BENKÖ (Institute of Isotopes of the Hungarian Academy of Sciences, Budapest). Details of his methodology as well as some of the results are available in the literature (BENKÖ, L. 1983, 1985; BENKÖ, L.--BOGNÁR-KUTZIÁN, I. 1987). The rest of the results were presented at international conferences (Tallin, 1986; Cambridge 1987). All but one (BOGNÁR-KUTZIÁN, I. 1985) electron spin resonance datings by A. ROCKENBAUER and P. SIMON (Centreal Research Institute for Chemistry of the Hungarian Academy of Sciences, Budapest) are unpublished. These results could be included in this study by courtesy of the authors.

Comparisons are based on datings of samples from the cemetery at Tiszapolgár-Basatanya. This site (BOGNÁR-KUTZIÁN, I. 1963) is particularly suitable for serial examinations using a variety of dating methods. At the same time, these datings fill a gap on the chronology of Holocene prehistory. Advantages of this site were discussed previously (BOGNÁR-KUTZIÁN, I. 1985; BOGNÁR-KUTZIÁN, I.--CSONGOR, É. 1987). In this Copper Age cemetery 13 graves were dated by the radiocarbon, 15 with the thermoluminescence and 11 with the electron spin resonance methods. Of these burials those seven are compared where all three techniques were applied.

For the purposes of the radiocarbon and electron spin resonance datings bone samples were consistently taken from the same skeletal parts (humeri and tibiae) in each burial. Pottery samples subjected to the thermoluminescence analysis originate from the same graves.

The seven find assemblages shown in *Table 1* each represent a grave from the Copper Age cemetery. Graves 5, 23 and 61 belong to the B/ phase of the Early Copper Age Tiszapolgár Culture. Graves 85, 101, 120 and 133 come from the Middle Copper Age. The first three represent the A/ phase of the Bodrogkeresztúr Culture, while grave 133 may be assigned to phase B/ of the culture due to its Hunyadi-halom (Salcuta IV) typological characteritics.

All dates in the table measured with the radiocarbon methods are given in bp years (see, Antiquity 1972, Vol. 46, 265) and are converted in calibrated dates (BP) as well. This adjustment was carried out using the calibration curve published by RALPH, E.K. et al. (1973). Half-life calculations were made with 5568. Estimated errors of the ESR datings are 10% or more. Error assesment of the TL measurements was done as proposed by J.M. AITKEN (1976).

In case of several TL samples representing the same grave mean values of the measurements were used to facilitate comparison. Such results are distinguished by an asterisk.

Table 1

Grave number	^{14}C		TL	ESR
	bp	BP	BP	BP about + 10%
5	5350 + 190	6160 ± 210	*6392 ± 50, ± 531	6072
23	5020 ± 180	5750 ± 210	*6518 ± 79, ± 561	6821
61	5460 ± 170	6270 ± 190	5691 ± -, ± 526	5738
85	4240 ± 180	4760 ± 200	6307 ± -, ± 585	5594
101 skeleton A	4850 ± 150	5545 ± 170	6055 ± -, ± 595	6267
101 skeleton B	5020 ± 170	5750 ± 190		
120	5220 ± 220	5960 ± 220	*5795 ± 178, ± 488	6003
133	4090 ± 180	4520 ± 200	5177 ± -, ± 802	5796

The mean value for grave 5 was calculated from dates of a storage jar (6380 BP ; BOGNÁR-KUTZIÁN, I. 1963; Plate X:1, Inv. Nº of the Hungarian National Museum: 52.95.29.) and a deep bowl 6471 BP; op. cit. Pl.X:8, Inv. Nº 52.95.34).

The mean value for grave 23 is based on two samples of a cooking pot (6447 and 6605 BP respectively; op. cit. Pl. XXX:8, Inv. Nº 53.1.55). Date obtained for the storage jar (op. cit. Pl. XXX:7, Inv. Nº 53.1.56) in the same grave provided an unreasonably high value (8005 BP), and was discarded as such at present.

Finally the mean date for grave 120 was obtained from the measurements of a large and a smaller flower-pot like vase (op. cit. Pl. CVI:5 and 6, Inv. Nº 53.35.114 and 116) and fragments of a milk jug (op. cit. Pl. CVI:8, Inv. Nº 53.35.113.). These individual dates were 6115, 5785 and 5500 BP respectively.

Both skeletons in grave 101 were measured with the 14C method. However, their mean date has not been tabulated since ESR dating is available only for skeleton A.

Thus every grave display lower values in terms of radiocarbon years by either the TL or the ESR datings, that is why only calibrated years were used for the purposes of comparison.

DISCUSSION

According to the most likely dates, even calibrated radiocarbon years are later than the values obtained by TL, graves 61 being an exception. Most of the ^{14}C calibrated years are lower than the ESR dates as well, however, there are two exceptions (grave 61 and skeleton A from grave 101) in this regard.

The seven graves provide no firm information on the possible ranking of methods in terms of the highest and lowest values of most likely dates. Actually, ^{14}C dates seem to be the lowest, while the TL and ESR values are distributed proportionally between each other.

Most likely dates obtained from the three different kinds of dating are in good accordance in the case of grave 120, and are similarly consistent for grave 5 as well. In both cases ^{14}C and ESR dates coincide particularly well, while a similar correspondence of TL and ESR values may be observed at grave 61.

On the other hand, consistent dates were calculated within the limits of errors of all methods. For grave 85, the ^{14}C value, however, is lower than the time intervals obtained by TL and ESR methods. One should remember, however, that in case of ESR the estimated error may be beyond the 10% limit. The situation is slightly better in case of grave 133, because its ^{14}C date meets the lowest value of the unusually long time interval defined using the TL method, and is lower only than the 10% error estimated for ESR. It is important to point out that the data of these two burials provided outstandingly low values even in terms of ^{14}C years (BOGNÁR-KUTZIÁN, I.--CSONGOR, É. 1987).

In this comparison one should not ignor the fact that ^{14}C dates may somewhat be increased by two factors: the 5730 years half-life adds 3% to the value (AITKEN, M.J. 1974) and modification in the same direction is caused by the new calibration curve (PEARSON, G. W. et al., 1986). The latter effects the majority of datings, among others, those of graves 85 and 133.

Four of the cemetery's graves were suitable for the comparison between the directly observed stratigraphic data and datings obtained by the three physical methods. One pair of these graves was measured both by ^{14}C and TL, and one of the burials was dated with the ESR method as well. The other pair of graves, which was close to the first one both in topographic terms and relative age, was investigated by ESR measurements. The dates obtained are shown in *Table 2.*

Table 2

Grave number	^{14}C bp	^{14}C BP	TL BP	ESR BP about 10%
59	5210 ± 170	5950 ± 190	5747 ± -, ± 520	
61	5460 ± 170	6270 ± 190	5691 ± -, ± 526	5738
57				5301
56				5274

Grave 59 from the Middle Copper Age (Bodrogkeresztúr Culture) was dug on top of Grave 61, an Early Copper Age burial (Tiszapolgár Culture). Their position is shown in *Fig. 1.*

According to the most likely dates, ^{14}C measurements support their stratigraphic position. On the other hand, TL dates provided contradictory results. The samples for measurements were taken out of vessels marked with asterisks in *Fig. 1.* However, this contradiction is only apparent, since the date obtained for the top grave is only 56 years more than that of the lower one with error limits of 520 and 526 years.

According to the most likely dates resulting from the ^{14}C measurements, there was a 320 years difference between the two burials which is much more than the expected value. However this difference is exceeded by ± 190 years.

^{14}C and TL datings of the two graves are in accordance with each other within the limits of errors and the same holds true for the ^{14}C and ESR datings of grave 61 as well.

In case of the other superposition *(Fig. 2)* grave 57 with transitional characteristics and Middle Copper Age traits was placed above grave 56 of the Early Copper Age.
According to the ESR measurements the two graves essentially are of the same age *(Table 2).* Comparing these results with the TL date of the 59/61 pair of graves the following similarities can be observed: in both cases the superposed graves had similar ages, further on the TL and the ESR showed a reversed situation than the stratigraphical position. However, the contradiction occuring between the ages of the single pair of graves also falls within the range of error limits.

Finally, a comparison of ^{14}C and ESR dates obtained for grave 84 deserves attention. This burial did not belong to the cemetery, although its topographic position on the west-southwestern edge of the cemetery may have been misleading if its funeral rite and grave furniture did not point unambigously to the Late Neolithic Age (BOGNÁR-KUTZIÁN, I. 1963). The calibrated ^{14}C date for this grave

6860 ± 220 BP

is higher than all the values obtained for the Copper Age burials in the cemetery and is in a good correspondence with the ESR date of the skeleton:

6788 ± c. 10% BP

On the basis of ESR measurements, however, there is an even earlier Copper Age burial in the cemetery (grave 23: 6821 BP). The difference between these two burials is no more than 33 years on the basis of the most likely dates. Actually, this latter date is disproportionally high among the other graves subjected to ESR measurements. TL dating of grave 23 is also the highest, even if the unexplained outstanding 8005 BP date of the storage jar is not considered in the mean value of this grave *(Table 1).*

Consequently the results are in a good accordance regarding the means of dates indicated in *Table 1.* The ^{14}C dates are the lowest, the TL dates are the highest, while the ESR values stand closer to the TL than to the ^{14}C. The discrepancy comes insignificant, keeping in mind both the error limits and the

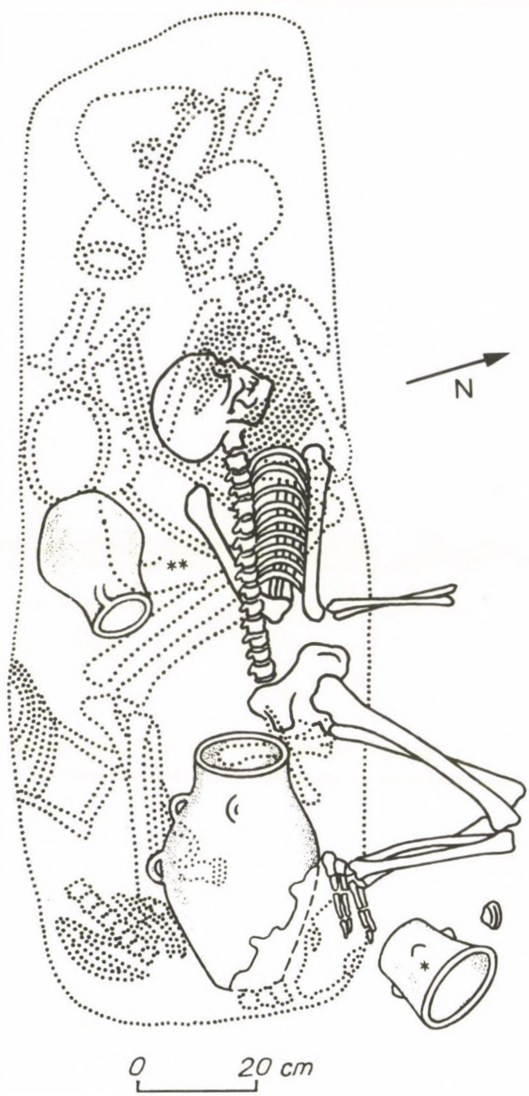

Fig. 1 Superposed graves 59 and 61 at Tiszapolgár-Basatanya

two factors increasing the ^{14}C dates i.e. 5730 half-life and the new calibration.

In the first column of *Table 1* the burials follow the sequence of the archaeological relative chronology. The mean dates of the first three Early Copper Age burials do not only

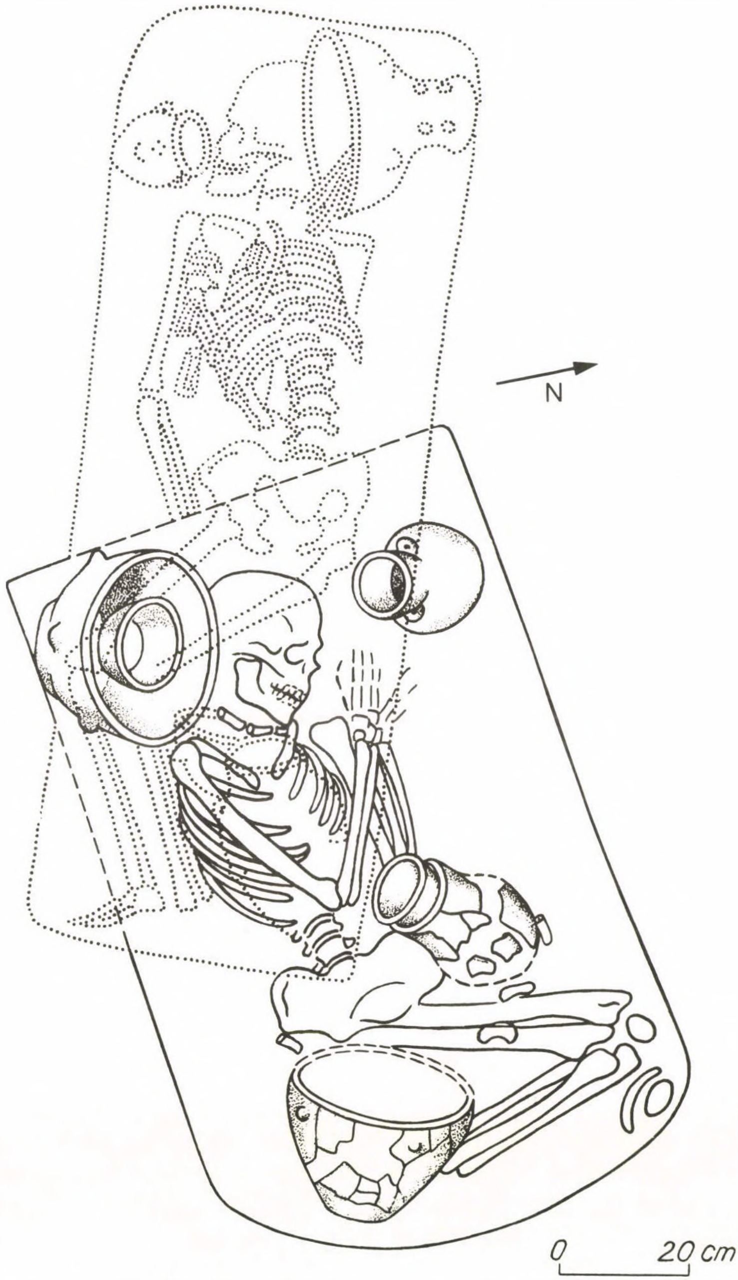

Fig. 2 Superposed graves 56 and 57 at Tiszapolgár-Basatanya

stand close to one another but are earlier than the mean of the four Middle Copper Age burials of the same column. Namely they are in agreement with the archaeological relative chronology. The age of the seven burials calculated from their mean values is c. 5600 BP by radiocarbon, c. 5900 ESR and c. 60,000 BP by TL dating.

It has to be stressed repeatedly that the preliminary assemptions are based on the dates mentioned above excluding those spreads which have already occurred on the dating of other samples and will surely be expected (see: BOGNÁR-KUTZIÁN, I.--CSONGOR, É. 1987; BENKÖ, L.--BOGNÁR-KUTZIÁN, I. 1987).

As far as I know there is no published data that would enable the comparison of datings obtained by the three independent physical methods. So far only the results of ^{14}C and TL methods were compared, anyhow the relation of the datings of the two methods is not unambiguously clarified.

In case of the Ib layer of the Early Aegean Neolithic at Anza in Macedonia, four TL datings resulted 400-800 years higher values than six ^{14}C datings (GIMBUTAS, M. 1976). The ^{14}C dating of two Late Neolithic samples from Franchthi Cave in Greece surpass the TL years with an even larger time interval (JACOBSON, Th.W. 1973).

The best agreement between the two kinds of dating is provided by Quanterness on mainland Orkney excavated by C. RENFREW. The mean of ^{14}C datings carried out on samples from the femur and tibia of a skeleton from stratum 5 of the chambered cairn is scarcely higher than the TL dates of pot sherds of the cairn and the entrance passage (FLEMING, S. 1979). The slight difference between them is significantly under the error limits.

Similarly favourable relation can be observed between the datings of samples from level 1 of the Neolithic settlement at Hacilar in Turkey (FLEMING, S. 1979).

Although the dating mean by ^{14}C at Myrtos in Crete is higher than the results obtained by TL methods, the discrepancy anyhow stays far under the error limits of the latter (FLEMING, S. 1979).

In case of a sample pair from pit 414 in Hienheim (Germany) the ^{14}C dating is much higher than the TL value (MODDERMAN,.P. J.R. 1977), still it stays inside the limits of error. The time interval calculated from ^{14}C datings for the time span of Hienheim and the earlier Linear Pottery site at Bylany (Czechoslovakia) cover the relevant TL time interval inside the limits of error (FLEMING, S. 1979).

Recently a consistency became known between ^{14}C and TL results dating the layers at Besiktepe, representing early Troy I (WAGNER; G.A. et al., 1986).

CONCLUSIONS

Dates obtained by independent physical methods show discrepancy among single measurements just like among certain burials regarding within methods and among them, however they are consistent on their mean values. According to the mean of the discussed seven burials they can be dated to the first third of the 4th millenium BC. Within this the TL and ESR dates in complete agreement refer to the first century of the millennium. The obtained results remarkably meet the requirements.

The evaluation of the results can be considered only preliminarly because of the relatively few dates. The team research is carried on with refining the methods, increasing the dates as far as possible on the basis of sequence analyses and extension the chronology obtained to the entire Holocene prehistory of Hungary.

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ADDRESS OF AUTHOR:

Ida BOGNÁR-KUTZIÁN

Archaeological Institute
of the Hungarian Academy of Sciences
Budapest Úri u. 49. H-1250

Készült a Magyar Tudományos Akadémia Földrajztudományi
Kutató Intézetének házi sokszorositóján. A kiadásért felel:
Dr.Pécsi Márton intézeti igazgató. Példányszám: 600