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# First radiocarbon dated paleoecological data from the freshwater carbonates of the Danube-Tisza Interfluve

**Abstract:** The first radiocarbon dates available on the evolution of the freshwater carbonates of the Danube-Tisza Interfluve are presented in this work along with their possible uses to precisely date paleoecological and paleoenvironmental changes. This work also gives the basis of a comparative analysis of the Holocene radiocarbon-dated profile of Csólyospálos with other Hungarian radiocarbon-dated profiles of the same age (Bátorliget, the Sárrét, etc.) and the implementation of a detailed chronological and regional paleoenvironmental study. Furthermore, our findings clearly demonstrate the importance of radiocarbon analysis in the study of terminal Pleistocene and Holocene Hungarian sedimentary sequences for accurately dating and reconstructing the chronological order of paleoenvironmental changes as well as the evolution of the natural endowments plus the regional comparison of the various profiles.

**Keywords:** alkaline lake; dolomite; freshwater limestone; Csólyospálos village; Hungary

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## 1 Introduction

The first geological data available in the literature on the freshwater carbonates of the Danube-Tisza Interfluves (Fig. 1) come from the founder professor of the Department of Geology and Palaeontology at the University of Szeged, István Miháltz and his wife Mária Faragó [1]. After the identification of the freshwater carbonates, important paleontological and geological analysis and mapping work started on a cross-section of the freshwater lacustrine limestone and dolomite (Fig. 2a,b, 3) in the area of the Danube-Tisza Interfluves [2, 3]. According to the early earth science studies the most important stratigraphic section of the freshwater carbonate formation can be found in the area of the Csólyospálos village [4]. The geochemical and sedimentological data from the lacustrine limestone and dolomite section (Fig. 4) at Csólyospálos village suggest that this geological formation developed under a warm and dry climate phase during postglacial time [5] however there is currently no published radiocarbon or other isotope-geochemical data with which to support these hypotheses [6]. This paper presents new paleoecological and isotope-geochemical analyses on the origin of the freshwater carbonate monolith at Csólyospálos village and a resulting reconstruction of the paleoenvironmental conditions and chronological framework during deposition.

The very first sedimentological, geochemical, palynological and malacological examinations of the Danube-Tisa Interfluves were made in this freshwater limestone section [1, 2, 4, 5]. But during that time (between 1930 and 1990) the lacustrine and swamp formations werestarigraphically compared with the results of speleal vertebrate examinations. As a consequence, “cave” and “plain” investigative methods were developed in Holocene research in Hungary.

“Cave” and “Plain” methods make spatial stratigraphic correlations based on the presence of speleal vertebrate fossils [7–13]. Other subsidiary examinations included anthracological and malacological studies. Representatives of the “plain” method examined lacustrine and paludial sections by sedimentological, geochemical, palynological and malacological analyses [1, 2, 4, 5]. Biostratigraphical analyses were based on palynological examinations [14–17]. The development of the examined sections – amongst them the Csólyospálos section – was compared with the originally Scandinavian [18], but later Middle-

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**Figure 1:** Landscape of the Kiskunság and the Csólyospálos freshwater limestone exposure in 1936 (photo by Prof. István Miháltz).

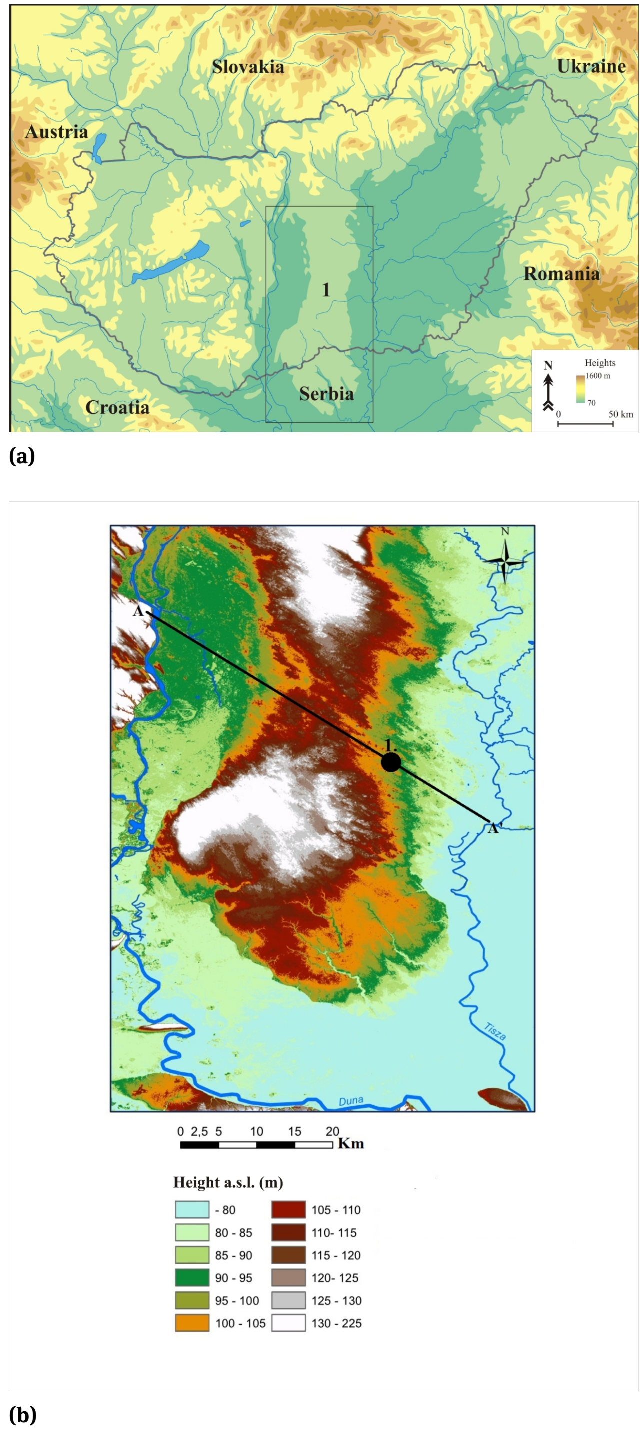



**Figure 2:** a) The location of Csólyospálos freshwater limestone exposure in the Carpathian Basin 1 = the area of Fig. 2b; b) The location of Csólyospálos freshwater limestone exposure in the Danube-Tisza Interfluve (DTM); A-A' line shows Fig. 3 cross section, the black dot is the location of the Csólyospálos profile.

European compatible pollen zones [19, 20], and resulted in the interpretation of chronological zones such as Late-Glacial, Preboreal, Boreal, Atlantic, Subatlantic and Subboreal.

Radiocarbon analysis of the area, which would provide a more precise chronological framework has not previously been made. Nor has the area been defined in the context of "local vegetation zones" or "local environmental zones" [21]. This study presents radiocarbon-based chronological analyses used to correlate the chronological and paleoecological data to all of the Hungarian Late Glacial and Holocene sections [22] from 2002.

## 2 Material and methods

Radiocarbon measurements are of utmost importance in determining the chronological order of events dated to the end of the Quaternary, as the expansion of the individual faunal and floral communities and species is highly

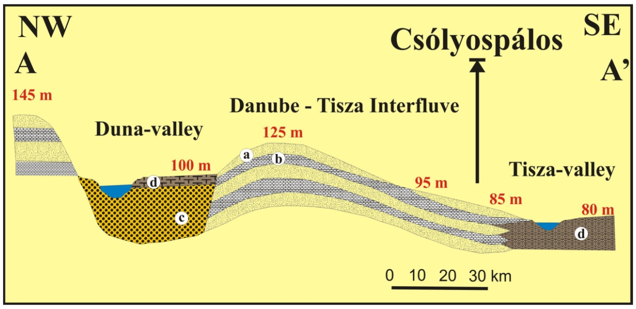



**Figure 3:** Cross-section of Csólyospálos exposure in the Danube-Tisza Interfluves along the A-A' line shown in Fig. 2b (*a – wind-blown sand, b – loessy sediments, c – alluvial sand and gravel, d – alluvial sediments*).

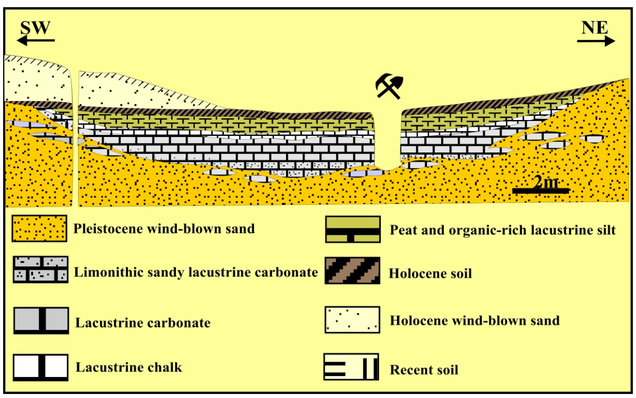



**Figure 4:** Geological cross-section of Csólyospálos exposure.

dependent on the environmental conditions, being a so-called "time-transgressive" phenomenon. Thus there is need for an independent control to use these as age markers. Radiocarbon measurements not only enable the establishment of a reliable chronology of the local floral and faunal transformations and the extension of local paleo-associations or ecozones, but also the comparative analysis of profiles lying at a distance from each other, and the delineation of spatial variation observed in floral and faunal transformations [21]. The importance of the application of this method in the Carpathian Basin lies in the fact that the evolution of the fauna, flora and the soils takes different pathways in different regions, because of the presence of a mosaic-like complexity at the macro-, meso- and micro level in the environment [41].

A part of the monolith section, where possible, was subjected to radiocarbon dating. These radiocarbon measurements were analysed in the Light Isotope Lab of the Nuclear Research Centre of the Hungarian Academy of Sciences in Debrecen [23].

Twenty g of cleaned mussel (*Pisidium*) and snail shells were retrieved from the samples for analysis. Because only those parts of the section yielding sufficient aragonite mussel shell and herbivore snail shell material could be analysed, only 6 samples from the 115 cm profile were used. The mussel and snail shell fragments were retrieved from the monolith of the freshwater carbonate via multiple freeze - thawing. The shell fragments then were boiled in distilled water and cleaned with diluted $H_2O$, before the analysis [24]. The physical parameters and experimentalsetup of radiocarbon measurements on mussel shells carbonates have been detailed previously [24].

The surface precipitates were removed by a treatment with diluted $H_2O_2$ [23]. It is important that some parts of the sequence were not applicable to get radiocarbon samples. Late Quaternary dated mollusc and charcoal samples from Hungarian sites had controversial results, i.e. younger ages in the lower parts of the sequences [38]. But these deviations could be phased out by using multiple measurements and comparisons [38]. Consequently, mollusc shells retrieved from freshwater carbonates and carbonate mud seem to be suitable for radiocarbon measurements. The resultant dates were calibrated using the CALIB700 software pack [39] available on the internet (Table 1). Resulting dates and isotope values aid inestablishing a more reliable and accurate chronology, determining the exact time of geological events and tcalculating sedimentation rates, as well as the characterization of the former sedimentary facies. Previous paleoecological findings are displayed on diagrams prepared by the Psimpoll software pack [40] and depths are substituted by BP years calculated from the sedimentation rates.

Grain-size analysis followed the Casagrande-type hydrometric method [42]. Lithostratigraphical description of the profiles followed the system of Troels-Smith [43]. Geochemical analyses and records of the geological profile have been published previously [4]. the results of Mária Miháltz-Faragó [2] were usedfor palynological examinations as well as malacological results [2] for paleobiological reconstruction of the freshwater limestone profile.

Samples for malacological analysis were dispersed in water and wet-sieved through 0.5 mm meshes after the freezing – heating mollusc shells separation process of the freshwater carbonate samples. After sieving, the mollusc shells were dried, sorted and identified under a stereo dissecting microscope at magnifications 6-50x. The shells were identified using keys of malacological and Quaternary malacological work [44–47]. Shells were classified into ecological and biogeographical groups based on the system published previously [48]. Relative frequencies of selected taxa and the ecological groups were plotted on diagrams.

**Table 1:** Radiocarbon data from the freshwater carbonate profile at Csólyospálos (presents $^{14}C$ age determinations along with $2\sigma$ ranges for calibrated ages obtained using Calib700).

| cm | uncal BP years | +/- | CAL BP years | CAL BC/AD years | Code | Troels-Smith |
|---|---|---|---|---|---|---|
| **30-40** | 3391 | 80 | 3453 - 3838 | 1504 - 1889 | Deb-2635 | Sh2Lc1 |
| **60-65** | 8040 | 200 | 8458 - 9431 | 6509 - 7482 | Deb-1067 | Lc4 |
| **70-75** | 8603 | 90 | 9456 - 9887 | 7507 - 7938 | Deb-3303 | Lc4 |
| **80-85** | 8747 | 70 | 9544 -10129 | 7922 - 8180 | Deb-3282 | Lc4 |
| **90-95** | 9237 | 80 | 10236-10642 | 8287 - 8693 | Deb-3290 | Lc4 |
| **110-115** | 10119 | 81 | 11350-12044 | 9401 - 10095 | Deb-3286 | Lc2Lf1Ga1 |

## 3 Experimental results and interpretations

According to the six mass radiocarbon dates, the calcareous sequence are estimated to have emerged between 12 000 and 8000 CAL YBP (Table 1), while the organic rich layers, relatively poor in carbonate (blackish-brown mud) are calculated to have been deposited after 4000 BP. The hard, highly consolidated type of freshwater carbonate is estimated have formed around 12 000 CAL YBP and between 8,000 and 8,500 BP. While according to the measured dates, the unconsolidated carbonate muds were precipitated between 8,500 and 3,400 CAL YBP (Table 1).

With the help of the radiocarbon dates, the sedimentation rates were able to be calculated and utilized in determining the age of development for the individual layers within the profile (Fig. 5). As our work involved the analysis of samples deriving from the very same profile as the one discussed in l963, the chronological accordance and order of the formerly determined paleoecological results could be verified and updated.

From geological observations the high (over 60%) carbonate content can be traced in the freshwater limestone and dolomite formation even in the sandy bedrock (Fig. 6). Based on the mineral and higher carbonate content, the sandy bedrock is interpreted to have originated from the re-deposited alluvial sediments of the Danube River. The formation of Danube-Tisa Interfluves can be traced back to the Danube River [49], thus the Danube started to accumulate a huge alluvial fan in this area from the Early Pleistocene (Fig. 2a,b; Fig. 7). In the deserted and wind-blown sand covered Danube beds, due to the aeolian re-deposition of the alluvial sand, coves formed where the ground water could outcrop after the floods, and this is why solingene-topogene ponds formed in the study area. In one of these ponds, a carbonate rich lake system formed

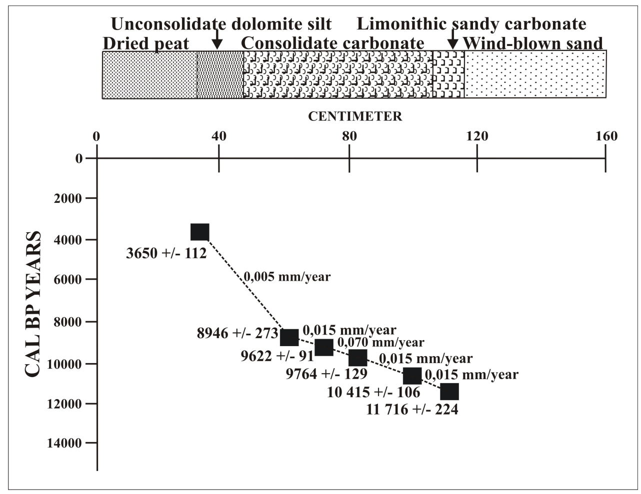



**Figure 5:** Chronological results of Csólyospálos profile and the accumulation rate.

in the area of Csólyospálos during the Late Pleistocene and Early Holocene.

The dominance of the Arbor Pollen (<40 %) indicates the presence of a forest steppe – steppe vegetation for the catchment area of the carbonate lake at Csólyospálos at the end of the Pleistocene, implying the mutual role of both the above mentioned factors in the preservation of a mesotrophic stage. Conversely, there is a sudden rise in the proportion of Arbor Pollens, deciduous trees and bushes around 10,200 and 10,500 CAL YBP, corresponding to the beginning of the Holocene, significantly exceeding the proportion of NAP (Arbor Pollen = 50-70 %) as shown by the pollen composition [2]. This transformation in the pollen composition is in good agreement and well-correlated with that observed in the profile of Bátorliget marshland at 10,200/10,500 CAL YBP, marked by a rapid increase in the proportions of taxa characteristics of oak woodland [50]. This state was preserved up till about 8500 CAL YBP. Consequently, while less intensive weathering must have characterized the area at the end of the Pleis-

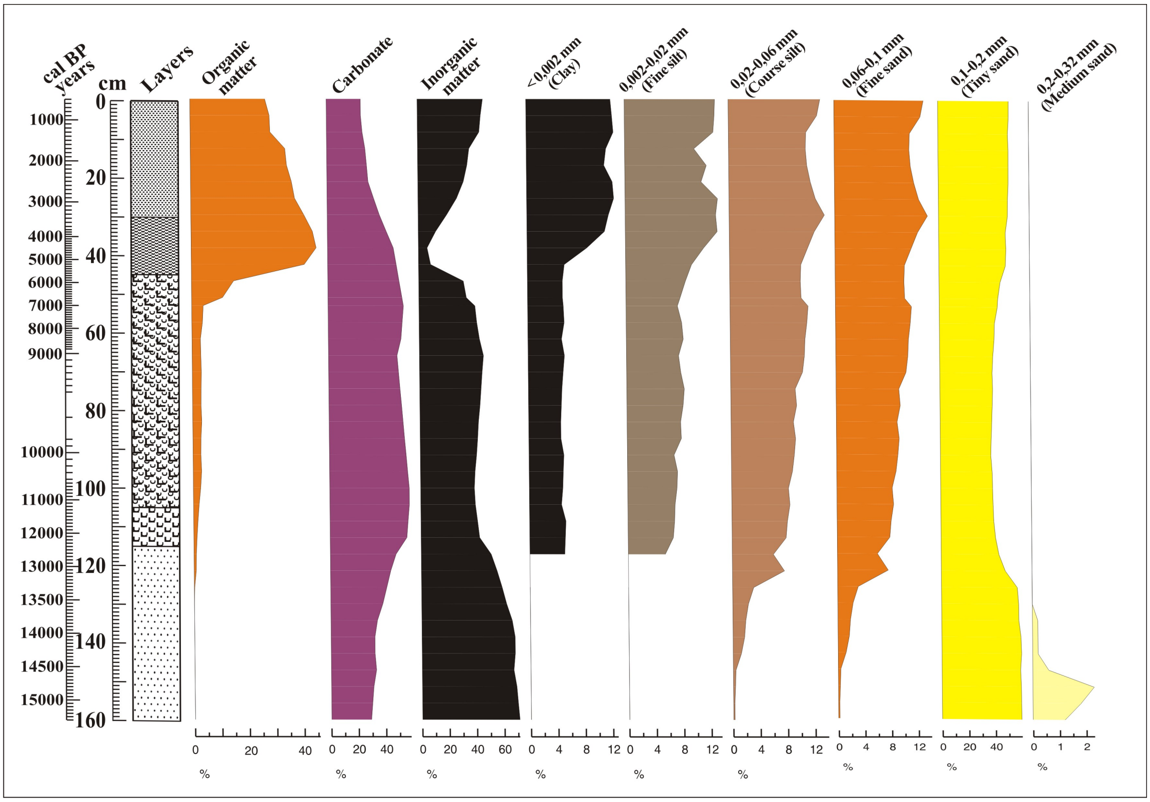



**Figure 6:** Results of sedimentological analyses on Csólyospálos section (for stratigraphic legends, see Fig. 5).

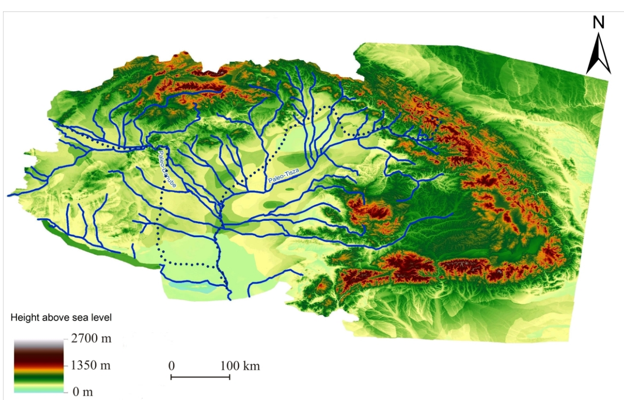



**Figure 7:** The river system in the Carpathian Basin and the location of the Paleo-Danube River.

tocene, the bush vegetation cover must have hampered the emergence of large-scale weathering in the vicinity of the lake during the beginning of the Holocene.

The pollen data from the freshwater carbonate layers of the geological profile of Csólyospálos (Fig. 8) suggest that the recent Pannonian forest steppe formed during the last phase of the Pleistocene in the study area. At the beginning of the $20^{th}$ century in the Carpathian Basin, the centre of the Great Hungarian Plain climate probably favoured the forest-steppe, which can be showed using the CRU TS 1.2 database [51], according to the Holdridge modified life zone system [52] (Fig. 9). This type of forest steppe (cool temperate subhumid forest steppe) and its forming climatic conditions [52] coupled with late spring, early summer and late autumn precipitation maxima [53], and late summer droughts, probably played an important role for formation of freshwater limestone in this area.

Based on the comparative analysis of radiocarbon dating and the revised malacological data, the following paleoenvironmental transformations and evolution have been reconstructed for the area of Csólyospálos, for the time-period captured within the layers of the studied freshwater carbonate profile. Precipitation of freshwater carbonates are interpreted to have initiated as early as the Pleistocene/Holocene boundary (late glacial/postglacial transition zone) and not during the Boreal phase as it had been formerly assumed [2]. This is evidenced by the common presence of the faunal elements *Valvata pulchella*, *Bithynia leachi*, *B. tentaculata*, *Cepaea vindobonensis*, highly characteristic transition malacofaunas, between the Pleistocene and Holocene in Hungary [54].

The newly emerged pond or lake was characterized by fluctuating water coverage and depth as well as chemistry. This is shown by the relatively same proportions at

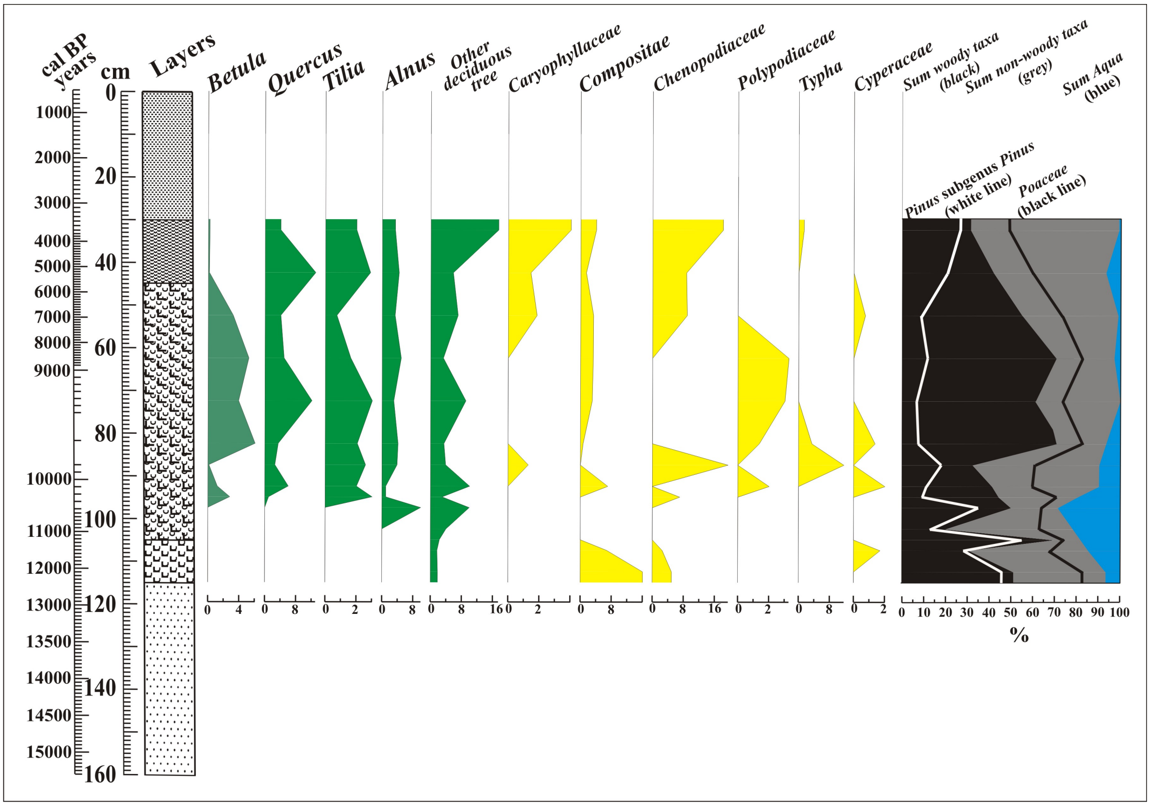



**Figure 8:** Results of palynological examinations at Csólyospálos section (for stratigraphic legends, see Fig. 5).

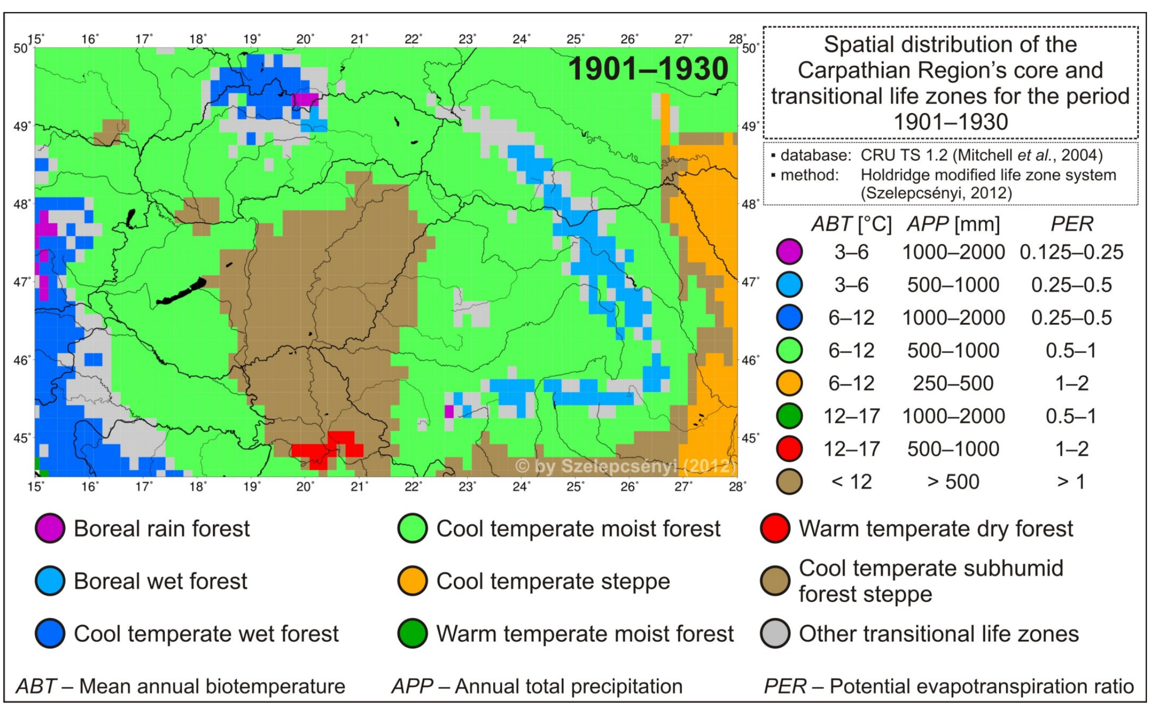



**Figure 9:** The environmental background of carbonated sediments in the Kiskunság; spatial distribution of the Carpathian Region's core and transitional life zones for the beginning of 20th century based on the Holdridge modified life zone system [51], using the CRU TS 1.2 database [52].

12 000-8500 CAL YBP of the species *Valvata pulchella* and *Bihynia leachi*, preferring deeper and colder waters, that of *Valvata piscinalis* preferring moving waters and generally inhabiting the wave zone of ponds, lakes or rivers and creeks, those of *Lymnaea peregra* f. *ovata*, *Bithynia tentaculata* preferring warm waters and finally the species *Lymnaea truncalula*, *Anisus spirorbis* tolerating shallow and alkaline waters. In our view, water level fluctuations must have been unusually high in the lake at the end of the Pleistocene, beginning of the Holocene (Fig. 10a)

During the spring, marking the opening of the growth season, the lake must have harboured relatively cold waters of a depth of approximately 3 meters, which could have dropped even below 1 m during the summer. However, this drop in the lake level has never been accompanied by a proliferation in primary production, thus the lake must have been characterized by a mesotrophic state. This fact on the other hand implies either the presence of stable vegetation around the lake preventing stronger soil erosion, or the lack of an intensive soil formation in the vicinity of the lake.

There is a significant transformation in the mollusc fauna at 9,500 CAL YBP as shown by $^{14}C$ dates. The proportions of Holarctic elements suffered a significant decrease accompanied by a rise in the dominance of the Palearctic elements and the retreat of the Northern European cold-resistant *Valvata pulchella*. The firm presence of *Valvata piscinalis,* preferring oxygen-rich deep waters, between 10,500 and 6,000 CAL YBP shows the possibility of a drop in the water level as an underlying factor of these transformations. Rather the alterations must have involved the water temperatures as shown by the retreat of the cold-resistant *Bihynia leachi* and the presence of *Lymnaea peregra* f. *ovata* preferring warmer waters. All these alterations desirable in the mollusc fauna imply a gradual warming up of the aquatic habitat, because the mean temperatures of the growth season at the end of the Pleistocene, beginning of the Holocene must have continued to rise, eventually reaching a mean July value of 22°C as is characteristic today.

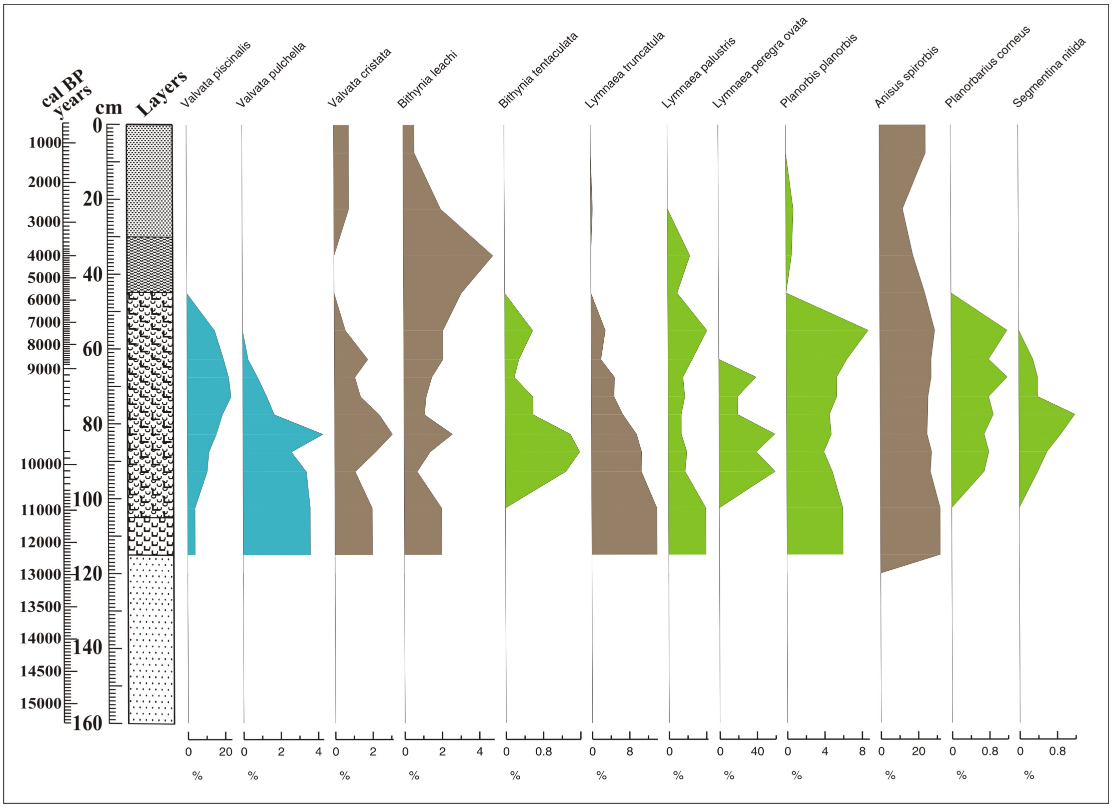
There is a marked change in aquatic life at around 5000-6000 CAL YBP with the complete disappearance of the taxa *Valvata piscinalis*, *Bithynia tentaculata*, *Planorbarius corneus*, *Pisidium* and a significant drop of *Planorbis planorbis* in the profile. Not only did the species preferring moving waters experience a population retreat, but also the species preferring significant water coverage as well, regardless of dwelling in still or moving waters (Fig. 10a).

Conversely, there is a sudden increase in the proportions of marshland dwellers and littoral forms, especially that of the Euro-Siberian, more precisely European and Western Asian, cold-resistant *Succinea oblonga*. There is a simultaneous growth in the number of the European - Western Asian *Bradybaena fruticum* dwelling in gallery forests and preferring a milder climate. Surprisingly, the littoral and marshland-dweller *Carychium minimum* experienced a retreat at ca. 5000-6000 YBP (Fig. 10a). Parallel with the decrease of the proportions of Palearctic elements, there is a significant increase in the ratio of European and Siberian, or more precisely European and Western Asian elements. There is a coeval rise in the proportions of forest-steppe- and forest-steppe - dwellers. All these sometimes contradictory changes are related to an intensification of erosion, a significant drop in the water level, and a rapid shoaling and silting-up of the sedimentary basin. Thus the terrestrial forms must have been transported into the sedimentary basin as a result of this intensified soil erosion.

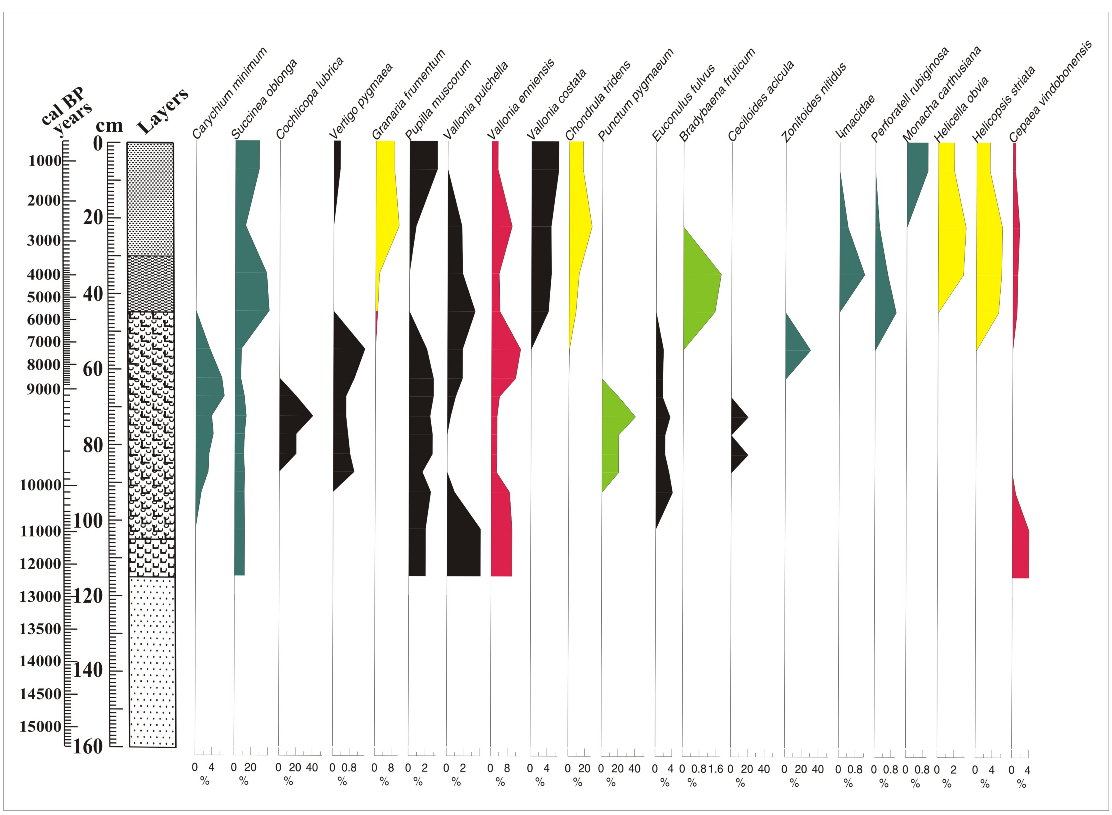
On the other hand, the concomitant growth in the open habitat preferring mollusc, such as steppe-, forest-steppe-, forest-dweller and littoral species appears to be related to the emergence of either a complex vegetation displaying mosaic-like patterning in the surroundings of the lake, or a special hydroseries made up of littoral swamp- gallery forest and sandy forest-steppe and steppe elements (Fig. 8, 10b, 11 and 12). The latter being in accordance with the spatial and temporal fluctuations of the groundwater table. From around 8000 CAL YBP the original extension of these hydroseries-induced vegetation mosaics must have undergone a gradual transformation, as shown by the gradual increase in the dominance of mesophylous, xerophylous terrestrial elements towards the surface in the profile most likely reflecting the emergence and expansion of open-vegetation habitats (Fig. 8, 10b, 11 and 12).

There is persistent, intensified erosion in the area from around 7000-5500 CAL YBP (5000-3500 BC years). This was the time when several groups engaged in active agricultural production, settled [55] here from the last phase of the Neolithic to the Copper Age [56]. These productive cultural groups must have induced significant alterations in the vegetation [57] around Csólyospálos, creating extensive open areas to supply their stocks with sufficient pasturelands [58].

This assumption is clearly justified by the observed pollen composition displaying a gradual transformation from dominance of deciduous Arbor Pollens (APs) in the Early Holocene to an advent of Non-Arbor Pollens (NAPs) from above 7000 CAL YBP (5000 cal BC), the last phase of the Neolithic in the profile (Fig. 12). The change of the malacofauna composition suggests that the local environ-




(a)




(b)

**Figure 10:** a) Malacological results of the section 1: dominance changes of freshwater species (for stratigraphic legends, see Fig. 5); b) Malacological results of the section 2: dominance changes of terrestrial species (for stratigraphic legends, see Fig. 5.

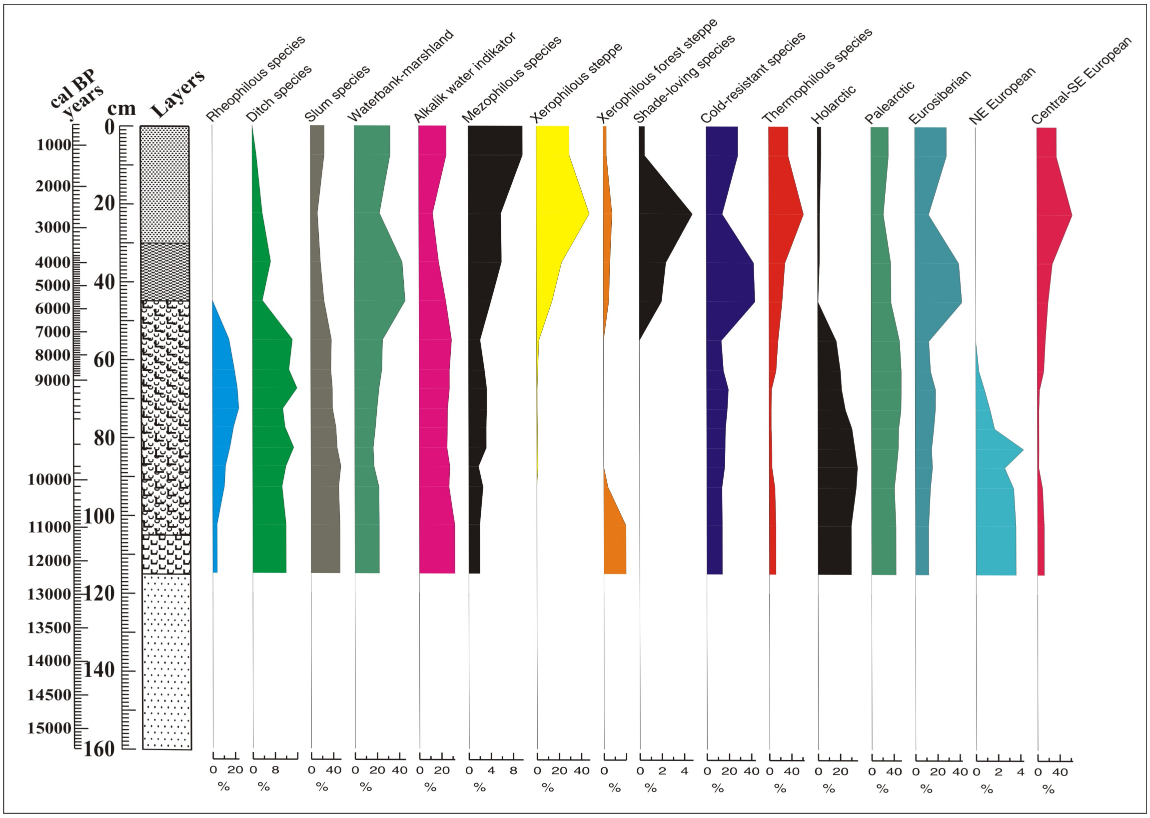



**Figure 11:** Malacological results of the section 3: dominance changes of paleoecological groups (for stratigraphic legends, see Fig. 5).

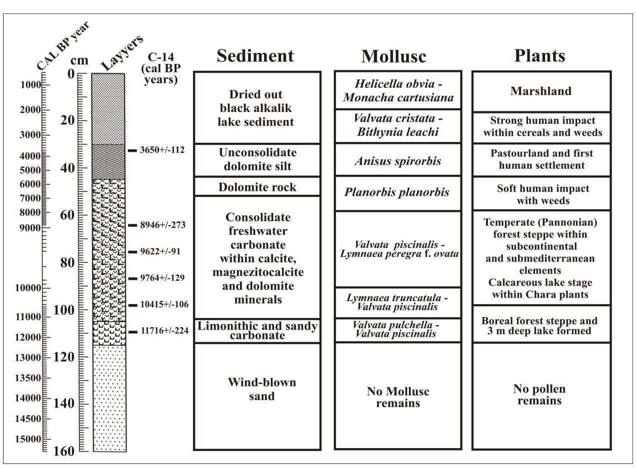



**Figure 12:** Consolidated results of chronological and paleoecological analyses at Csólyospálos.

ment transformed slowly during the Late Neolithic and Copper Ages.

As inferred from the composition of the malacofauna at Csólyospálos a colder climatic phase must have developed around 3300 CAL YBP (1300 cal BC), as seen in the drop of the average temperatures of the growth season and the mean July paleotemperatures to a level lower than that observed between 10,000 and 7,000 CAL YBP (22°C). The dominant population of the cold-resistant mollusc species marks the development of another significant cooling in the profile at the end of the Cosiderian Periode (Middle Bronze Age – 3800-3400 CAL YBP). This paleotemperature change may be evident in otherHungarian profiles as well [61, 62].

Conversely, as the composition of the mollusc fauna and that of the pollen grains imply, a rather strong human influence must have emerged in the vicinity of Csólyospálos, and the whole Danube-Tisza Interfluves during the second half of the Bronze Age [63]. These paleoenvironmental findings correspond to those of archeological investigations in the area, according to which, a highly developed network of settlements emerged in the area of the Danube-Tisza Interfluves, harbouring numerous populations and characterized by on-mound settlement (so-called "tell") centres during the second half of the Bronze Age [62–64].

The above mentioned composition of the malacofauna and the vegetation must have been preserved till around the end of the Bronze Age (3300 cal BP = 1300 BC). Afterwards, the Late Bronze Age and the beginning of the Iron Age marked a gradual decrease of the Eurosiberian, cold-resistant forms, primarily those of marshland-dwellers and littoral elements, accompanied by the gradual advent of the mesophylous and xerophylous taxa like those of *Granaria frumentum*, *Pupilla muscorum, Chondrula tridens, Helicopsis striata*. It was not only the mollusc fauna that underwent a significant transformation, but the facies of the sedimentary sequences as well, which accumulated in the lacustrine sedimentary basin (Fig. 8, 10b, 11 and 12).

The precipitation of calcareous mud ceased completely at the end of the Bronze Age and was replaced by the deposition of organic-rich, eutrophic lacustrine mud as observabed in the pollen composition. Although there is a significant rise in the ratio of Arbor Pollens, this must be unequivocally attributed to the in-wash of pine pollen grains into the analysed basin from distant areas. Such an intensive increase in the number of pine pollen grains, with the lack of the other Arbor Pollens is attributed to intensive deforestation during the Iron Age. In particular the second half of the Iron Age witnessed the emergence and spreading of the Mezőcsát, Scythian and Celtic cultures utilizing advanced iron tools and engaged in more intensive and organized forms of agricultural production, as well as that of the Roman Empire [65]. Thus changes in the pollen composition appear to complement the resulting radiocarbon dates from the section.

However, the presence of the taxa *Monacha cartusiana* and *Helicella obvia* are significant in the profile and in sections younger than the Bronze Age both stratigraphically and chronologically as well. According to previous malacological studies, lacking radiocarbon analysis and dates, the representatives of the species *Helicella obvia* must have appeared in the Carpathian Basin as early as the Bronze Age [66]. Conversely, malacological studies linked to archaeological excavations put the first appearance of this taxa in the basin into the final phase of the Iron Age and the opening phase of the Imperial Period [67] According to our findings at the Csólyospálos site, this species must have appeared after the Bronze Age but before the Imperial Age in the study area. Conversely, the other immigrant form of *Monacha cartusiana* appeared in a younger horizon, dated around the opening of the Imperial Period. A similar stratigraphic position of this species may have been evidenced in the marginal littoral profile of the marshland at Bátorliget as well [68].

# 4 Discussion and summarized results

According to the detailed radiocarbon analyses, the accumulation of carbonate sediments in the lacustrine basin of Csólyospálos must have initiated between 11,000 and 12,000 CAL YBP in relatively deep and cold waters, although as implied by the composition of the malacofauna, the water temperatures and the extension of water coverage may have undergone significant changes during this period (Fig. 12).

It must be noted here that according to several researchers mollusc shells are not suitable for radiocarbon analysis yielding incorrect dates compared to charcoals retrieved from the same layer [25–27]. The main reason for this is the presence of carbonate in the substrate, which yields significant amount of inactive carbon. These can be then either built into the mollusc shells, or precipitated on the surface of the shells [28–30]. Conversely, several scientists used radiocarbon dates determined from mollusc shells in their works, sometimes verified by and compared with dates retrieved from charcoals of the same horizon [31–34]. Radiocarbon dates determined from charcoal and mollusc shells from the same sediment layers tended to display minimal difference (between 300 and 80 years) for samples aged between 11,000 and 30,000 $^{14}$C yr BP [35]. In order to minimize or eliminate the bias derived from the presence of inactive carbonates, only herbivorous gastropod shells [36, 37] primarily those of herbivore Molluscs and bivalve *Pisidium* have been utilized in this study, in accordance with the proposal of Richard Preece [35].

The development of the lake system shows the fractionally increased ground water level owing to the climatic changes and floods and this is why the accumulation of lacustrine carbonated sediments started. Changes in the temperature, the evapotranspiration and the precipitation amount indicate changes in the Late Glacial vegetation. Deciduous trees and shrubs containing coniferous vegetation and temperate steppe vegetation developed in the centre part of the Carpathian Basin, beginning with boreal type followed by temperate steppe of Pannonian type. In line with this, the nature of biogeochemical substrate circulation and weathering radically changed Ca and Mg rich carbonate deposition in the Late Glacial pond at Csólyospálos.

By about 10,500 CAL YBP, the terrestrial habitat had been highly altered, accompanied by a similar large-scale change in the aquatic habitat by about 9500 CAL YBP. These alterations are characterized by an expansion of plants dwelling in deciduous woodlands, and an increase in the water temperatures, reaching values similar to those observable during the summer today, in the majority of the growth season. As shown by the composition of the mollusc fauna, a special hydroseries corresponding to the spatial and temporal fluctuations of the groundwater table as well as variations in the morphology must have emerged, starting off from the littoral part of the pond, and made up of littoral swamp- gallery forest-sandy forest-steppe-and steppe elements.

In parallel with this, significant changes occurred in the Csólyospálos travertine and dolomite section. Most importantly, the lake water became more alkaline, it salinized as a result of the increase of dissolved alkalis, and its Mg content considerably increased due to the Danube alluvium and bedrock.

These geochemical and hydrochemical characteristics intensified even more at the beginning of the Holocene, when in the centre of the Carpathian Basin a warming greater than the maximum temperatures observed today occurred. As a consequence, the mixed leaved taiga forest steppe with Scots pines transformed, and the Pannonian forest steppe type within Submediterranean–subcontinental taxa emerged. In the territory of the Csólyospálos sedimentary basin, at the beginning of the Holocene, under the temperature conditions of about 10,500 years ago, strongly evaporitic lakes formed, in which the necessary Mg/Ca ratio for chemically formed dolomite mud could rhythmically develop at the end of summer, beginning of autumn [4].

Due to their carbon dioxide deprivation, the algae in these lakes, including charophytes, could also play a major role in the formation of carbonate mud with high magnesium content [3]. In the lakes of Kiskunság, along with the high dissolved Mg content and carbon dioxide entrapment, the saline, alkaline dissolved salt content could constitute an important factor of the precipitation of dolomite mud. So chemical and biological factors both played role in the accumulation of dolomite mud.

Since the end of Copper Age, 5000 CAL YBP (3000 YBC), solidified travertine and dolomite were replaced with loosely structured dolomite mud and sparsely calcite-dominated lime mud developed until 3300 CAL YBP (1300 YBC) in between the Copper Age and the last phase of the Bronze Age. It seems that from the end of the Copper Age, due to increased precipitation and the gradual decrease in temperature, the lakes of Csólyospálos did not dry out, and as a result, meadow conditions did not emerge, and rock solidification did not occur. In the loose dolomite mud layer, based on gradually increasing organic matter content, at the end of the Copper Age, there were likely considerable human impacts in the catchment area of the sedimentary basin of the Csólyospálos lake.

Late Copper and Early and Middle Bronze Age communities settled in the Kiskunság area. The settling and farming of productive farming cultures and the increased precipitation would have initiated soil-erosion and thus progressively changed the accumulation area.

Precipitation of calcareous formations must have continued as long as the end of the Bronze Age, but the facies and composition of the sediments accumulated suffered a gradual transformation.

The transformation of Csólyospálos pond occurred at the end of the Bronze Age. At this time, the white alkalization and carbonate stage has ended because of the choking up processes, after which the black alkalization process started in which carbonated sediment accumulation did not occur. This black alkalic lake sediment suffered pedogenetic effects owing to the ground water level-regulation in the past 130-150 years.

The accumulation of carbonated sediments in the Kiskunság has global correlatives, but in Europe this is a unique recent depositional feature. The freshwater dolomite formation is interpreted to have formed through a unique combination of local geological, biological, hydrological and climatic factors. It is interpreated that the cessation of formation of freshwater carbonates is due more to increased direct anthropogenic impacts than the changing of environmental factors (increased precipitation). It is unique that the recent freshwater carbonate accumulation areas of the Kiskunság has been extremely sensitive to human impacts. For that very reason the increased natural protection of the area is essential: can this process, which started at the end of the Late Glacial (approx. 12,000 years) and is unique in Europe, subsist for posterity?

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