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Holocene paleoclimatic and paleohydrological changes in the Sárrét basin, NW Hungary

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ABSTRACT – *According to detailed sedimentological and paleontological analyses carried out on samples taken from the Sárrét–Nádasdladány core-profile, a complete environmental history of a neotectonic depression was drawn. The sequence is composed of fluvial-lacustrine and marshland deposits which started to accumulate during the Late Glacial and culminated at the beginning of the Holocene. The highly characteristic changes in the biofacies were linked to changes in the lithofacies within this sequence. A transition in the dominance of moving water species, observable initially in lacustrine species preferring well-lit, well-oxygenated conditions was observed. Eventually, the littoral and eutrophic lacustrine species, as well as marsh-dwellers, became dominant in the profile, marking the emergence of uniform peat land in the Sárrét Basin.*

IZVLEČEK – *S pomočjo sedimentoloških in paleontoloških analiz vzorcev iz vrtine Sárrét-Nádasdladány lahko sestavimo popolno okoljsko zgodovino te neotektonske depresije. Zaporedje sestavljajo rečni, jezerski in močvirski depoziti, ki se začnejo v poznem glacialu in se nadaljujejo v začetek holocena. Zelo značilne spremembe v fosilnih zbirih lahko povežemo s spremembami v sedimentaciji. Na začetku prevladujejo vrste, ki živijo v tekoči vodi, te pa kasneje zamenjajo vrste, ki živijo v jezeru, v dobro osvetljenih vodah z dovolj kisika. Kasneje postanejo pogostejše obalne in evtrofične kot tudi močvirske vrste, ki zaznamujejo nastanek šote v kotlini Sárrét.*

KEY WORDS – *paleohydrology; paleoecology; mollusks; Holocene; Sárrét*

Introduction

Quaternary geological and malacological investigations in the neotectonic basin of the Sárrét started as early as the beginning of the 20th century (*Kormos 1909*). The region, with an area of approximately 120km^2 located at the interface of the Mezőföld and the Transdanubian Mid-Mountains, occupies a neotectonic basin (*Lóczy 1913; Cserny 2000*) with a NE-SW trend which developed at the end of the Quarternary (*Dömsödi 1977*) and infilled with Quaternary deposits of great thickness. Although a large portion of the peat was destroyed, compacted and suffered pedogenesis as a result of drainage (from 1825 onwards), according to the quarter-malacological investigations initiated by Tivadar Kormos (*1909*), Holocene deposits of great thickness are still preserved in the area under investigation.

The region of the Sárrét came into the focus of Hungarian paleo-environmental and stratigraphic research via the detailed quarter-malacological investigations carried out by Endre Krolopp and Levente Fűköh from the 1970s onwards (*Fűköh-Krolopp 1986; Fűköh 1977; Krolopp 1972*). Furthermore, corings with continuous undisturbed samples in the area near Nádasladány and Sárkeszi in the Sárrét region (Fig. 1), and the sedimentological, isotope-geochemical, geochemical, pollen analytical and quarter-malacological investigations carried out as part of a Hungarian-British Joint Scientific Cooperation in 1995, meant a major breakthrough in the stratigraphic and paleo-environmental study of the area (*Willis et al. 1996; Cserny 2000*). The findings of the detailed chronological, lithostratigraphical and biostratigraphical analyses of these core samples are presented in this paper.

Material and methods

Sampling was carried out with the help of a Livingstone piston corer, following the so- called 'overlapping' method. Cores were halved lengthwise after having been transported to the lab, to suit the needs of different analytical approaches. The terminology and symbols of Troels-Smith (*Troels-Smith 1955*), internationally accepted for unconsolidated sediments, were used to describe the lithology.

Radiocarbon measurements were carried out on 7 samples derived from the peat layers, the inwashed charcoals and flue-ash horizons in the Light Isotope Laboratory of the Nuclear Research Center at the Hungarian Academy of Sciences in Debrecen. The methodology and techniques presented in Hertelendi et al. (*1989*) were followed for the digestion and measurements. In addition, these 3 samples were analyzed with AMS in the Isotope Laboratory of Oxford University (*Willis 1997*). Radiocarbon dates were utilized to determine the lithostratigraphy and chronological units with the help of the results of geochemical, pollen analytical and malacological analyses. They were also utilized to determine the rate of deposition in the sedimentary basin (Fig. 2).

The results of pollen analysis were used as input in comparative biostratigraphy. In order to gain an expansive picture of the paleo-environment, pollen data published earlier by Katherine Jane Willis (*Willis 1997*) have been utilized.

Samples collected from layers between 8–12cm were washed through a mesh screen for mollusks. The work of Sümegi and Krolopp (*2002*), Meijer (*1985*), Ložek (*1964*) was utilized to determine and put the species into paleo-ecological groups according to their temperature tolerance, recent biogeographic affinity and distribution, as well as their humidity and vegetation cover preferences. Both the dominance values of the species found and the ratio of paleo-ecological and recent biogeographical groups, along with the results of the radiocarbon measurements and the lithostratigraphy, were depicted on graphs with Psimpoll software (*Bennett 1992*).

Lithological and lithostratigraphical findings

Three major lithostratigraphic units were identified in the undisturbed, continuous core of the 398cm deep borehole (Fig. 2). The first unit, located between depths of 398 and 268cm, is made up of alternating layers of fine laminated silt, gravelly sand and sandy gravel. According to the radiocarbon data, the development of these silty intercalations must have taken place between 13 000–11 000 BP, at the end of the Pleistocene.

The next sedimentary unit is located between depths of 268 and 164cm. This horizon is composed of white, grayish-white, calcareous muds, with a carbonate content ranging between 80–90%. The majority of the carbonates are derived from biomicritic pellets secreted by the Chara vegetation and calcareous oogonia. This sequence must have been deposited in a relatively shallow, well-lit lacustrine system, with eutrophic conditions prevailing at the bottom. This lacustrine phase, characterized by the deposition of calcareous marls, must have existed between 11 000 and 9000 BP in the area.

From a depth of 164cm, there is a sudden decrease in the carbonate content, accompanied by a prominent increase in the organic content. The distribution of organic matter is not homogenous and by no means dispersed, but resembles a downward flame-like structure made up of the remnants of peat fern (*Thelypteris palustris*). All this points to the emergence of individual floating mats, which must have

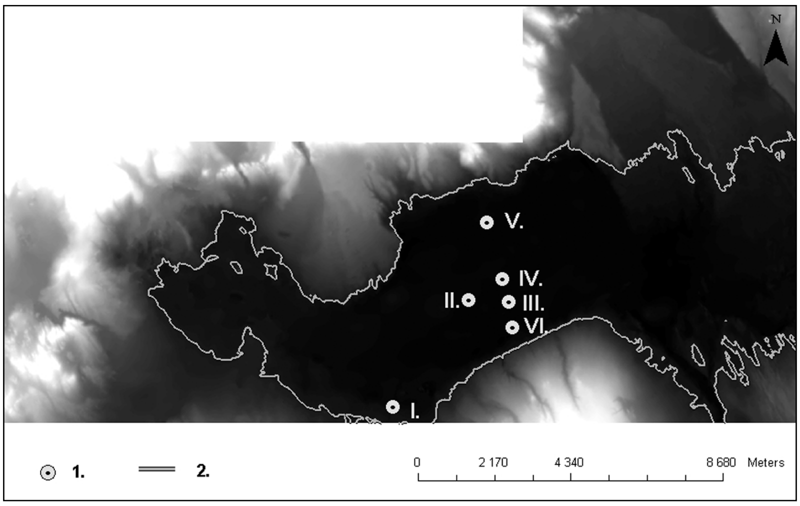

Fig. 1. The area of the Sárrét catchment basin, with the Sárrét-Nádasdladány borehole (I.) marked.

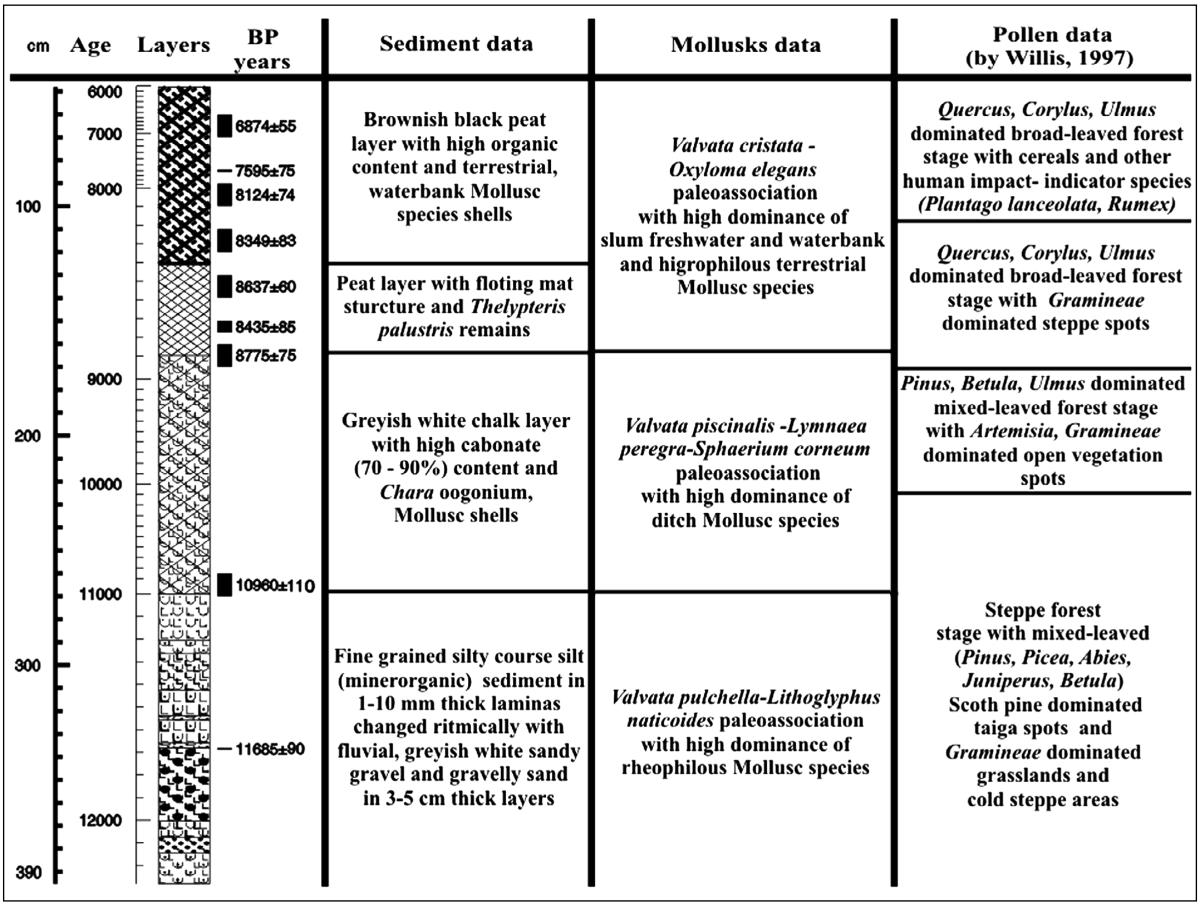

Fig. 2. Palaeo-ecological results of the Sárrét–Nádasdladány I core sequence.

united and closed within a period of 100–200 years. A recent analogy for the development of such floating mats is known from Lake Velencei, situated NE of the area of the Sárrét (*Balogh 2000*).

No samples were taken from the surface down to a depth of 48cm and no radiocarbon measurements were taken for this part of the profile. The emergence of floating mats can be placed between 8500–8700 BP, while the development of a unified closed peat horizon must be younger than 8500 BP. Peat formation must have been quite significant even at 6500 BP as well, according to the radiocarbon data.

The results of malacological analysis

Some 4785 specimens belonging to 41 species have come to light from the core. Three major malacological zones have been identified with the help of statistical analyses on the data (Fig. 2.).

The first zone is located between depths of 398 and 270cm. According to sedimentation rates, this horizon must have developed between 13 000–11 000 BP. The ratio of species with a preference for moving water habitats is above 50% in this horizon (*e.g.: Valvata psicinalis, Lithoglyphus naticoides, Pisidium amnicum, Unio cf. crassus*). Specimens of the Boreal *Gyraulus riparius* and *Valvata pulchella* have come to light from this part of the profile alone. One of the major characteristics of this horizon is the collective appearance of aquatic species expanding during the colder phases of the Pleistocene, becoming restricted at the beginning of the Holocene (*Valvata pulchella, Bithynia leachi, Gyraulus riparius*), and the aquatic species starting their expansion during the Holocene (*Lithoglyphus naticoides, Bithynia tentaculata*). This collective appearance of mollusks preferring milder climatic and colder climatic periods at the end of the Pleistocene and the beginning of the Holocene can be regarded as one of the most characteristic features of the Quarternary malacofauna of the Carpathian basin. (*Willis et al. 1995; Sümegi 2004*). Fauna of the same age and composition have been identified from the areas of the Tapolca basin, the Jászság, the bedrock horizon of the Vörös marshland of Császártöltés, and the sandpit of Tószeg (*Hertelendi et al. 1993*). On the basis of these fauna horizons, we may assign the collective appearance of the species *Valvata pulchella* and *Lithoglyphus naticoides* between 12 000–9000 BP in the Carpathian Basin.

The results of the pollen analysis from the malacological samples (*Willis 1997*) also seem to corroborate the findings of the radiocarbon measurements (Fig. 2).

The neotectonic depression of the Sárrét was surrounded by gallery, forest-like, forest-steppe taiga, characterized by a dominance of birch (*Betula*) mixing with conifers of common pine (*Pinus silvestris*), spruce (*Picea*), fir (*Abies*), juniper (*Juniperus*) and grasses (*Graminea*), carices (*Cyperaceae*) at the time. Although regarding the extension of the sedimentary basin of the Sárrét (80–120 km^2) (*Jacobson-Bradshaw 1981*), we may assume that the pollen composition of the profile reflects the composition of the vegetation on a wider, regional scale (Mezőföld, Bakonyalja, Bakony) and not only the adjacent marginal vegetation of the depression.

The second malacological horizon is located between depths of 270–167cm. The majority of species with a moving-water habitat preference, like *Valvata pulchella, Gyraulus riparius, Lithoglyphus naticoides, Lymnaea stagnalis, Pisidium amnicum, Unio cf. crassus*, became restricted. On the other hand, the rheophilous species *Valvata piscinalis* managed to survive. Moreover, there was a significant increase in the proportion of this latter species, which has become a prevailing element of this local malacological zone. However, it must be noted that there was a definite decrease in the size of the specimens collected from the calcareous muds compared to those from the preceding zone. According to data and observations on the recent malacofauna, as well as the Quaternary malacofauna deriving from several profiles in the Nyírség and Lake Balaton, the gastropod species *Valvata piscinalis* successfully copes with environmental transformations like that from a fluvial to a lacustrine habitat, surviving in the littoral surf zone, where moving water supplies a sufficient amount of dissolved oxygen. It is in this malacological zone that the species *Lymnaea peregra* (*f. ovata*), *Physa fontinalis, Gyraulus albus, Sphaerium corneum,* and *Bithynia tentaculata* appear and gradually become dominant. Besides these strong changes in the aqueous fauna, the amphibic species *Carychium minimum* and *Succineas* also show up in this horizon. All these changes seem to imply the development of a relatively shallow, 1–3m deep, well-lit, but eutrophication at the bottom lacustrine environment, characterized by mild water temperatures and alkaline pH during the growth season in the area under investigation. The higher ratio of littoral elements implies the proximity of our sampled profile to a singular littoral surf zone.

The analyzed biological zone must have emerged between 11 000 and 9000 BP. That is, the End-Pleistocene, Early Holocene mesotrophic lake phase must have emerged as early as 11 000 BP in the Sárrét depression, and this correlates well with the developmental history of the sub-basins of the neotectonic depression of Lake Balaton (Tapolca Basin, Kis-Balaton) and the ponds located at the Danube-Tisza Interfluve (*Cserny-Nagy-Bodor 2000*). This calcareous mud horizon of Sárrét yielded some harpoons assumed to be of Mesolithic Age, according to archeological data (*Marosi 1935; 1936a; 1936b; Nemeskéri 1948; Makkay 1970*). Thus the calcareous muds identified in the Nádasladány borehole may be correlated with a period of the Mesolithic.

According to palynological data, there was also significant change in the composition of the vegetation parallel with the emergence of this malacological horizon (*Willis 1997*). There was a shift in the advance of deciduous trees, in contrast to the formerly dominant conifers, namely birch (*Betula*), oak (*Quercus*), elm (*Ulmus*), and hornbeam (*Carpinus*). Nevertheless, the ratio of common pine (*Pinus silvestris*) remained significant. This latter factor might be strongly related to the ability of the Sárrét sedimentary basins to act as a regional pollen trap in the area. Thus pollen from the common pine woodlands, being extensive in the Bakony Mts. at the beginning of the Holocene, might also have been transported into and accumulated in the sedimentary basin of the Sárrét from greater distances. To put it another way: the basin must have preserved pollens originating from several regions characterized by different natural endowments and highly varying plant paleoassociations (coniferous remnant woodlands, the cooler basins and valleys of the Bakony Mts., deciduous woodlands, the Bakony Mts. including the foothill area, open loess and dolomite steppe areas, the dolomite cliffs of the foothill area of the Bakony, with high relief, the area of the Mezőföld).

There was a complete turnover in the malacofauna at the final stage of calcareous mud deposition and the initiation of peat formation in the area of Sárrét-Nádasladány. Species with a moving water habitat preference completely disappeared, giving way to the extensive, Holarctic still water species. The gastropod *Valvata cristata* is the dominant form in this part of the profile. However, species preferring a well-lit, well-oxygenated lacustrine habitat (*Physa fontinalis, Lymnaea peregra f. ovata, Sphaerium corneum*) also completely disappeared when peat formation began. The increase in the proportions of marsh-dwellers (*Acroloxus lacustris, Planorbis planorbis, Anisus leucostoma*), and the littoral, amphibic *Succinea*s (*Succinea oblonga, Oxyloma elegans*) indicate a change in the environment and lithology. The malacological data are in close correlation with changes in the sedimentary layers, the emergence of floating mats and the appearance of a wet, terrestrial-like habitat wedged into the lacustrine environment. Such island-like patches of floating mats was observed on the Nagy-Mohos floating mat of Kállósemjén at the end of the 1980s. According to the findings of investigations on the recent malacofauna, the underwater areas of the floating mats are inhabited by the gastropod species of *Valvata cristata, Planorbis planorbis* and *Anisus*es. While the surfaces located above the water such as wet reed, ferny and bulrush areas are populated by *Succinea*s and *Carychium minimum* in large quantities, the composition of the malacofauna of the recent floating mats of Kállósemjén is highly similar to that of the floating mat phase observed in the borehole of Sárrét–Nádasdladány.

According to radiocarbon data, peat formation, resulting in a transformation of the lacustrine environment, began around 9000 BP in the area under investigation, being active even at 6000 BP. Peat formation must have continued even after that. However, because of the presence of mixed, disturbed layers, no samples were taken from the surface to a depth of 48cm.

The composition of pollens also underwent a sharp and strong change at the beginning of peat formation, with a sudden increase in the proportions of fern (*Pteridophyta*), and grass (*Gramineae*) pollens, including water plants (*e.g.* float-grass – *Glyceria*). All these changes are closely linked to the development and evolution of floating mats in the area. The inwash and transportation of pollens of local flowering plants into the basin was dominant during this time, as reflected in the composition of pollens and spores. The question is, however, what might have caused the transformation of the basin from a regional pollen trap into a local one? It seems that the conditions favoring pollen entrapment must have changed in the basin as a result of the development of floating mats also changing the entrapment capacity. According to investigations carried out, this horizon can be characterized by the quickest rate of deposition. The underlying factor must have been the rapid horizontal and vertical growth and expansion of floating mats. According to the analyses of plant remains, the majority of the spores within this horizon come from peat fern (*Thelypteris palustris*), one of the most important floral elements in floating mats. As a result of the relatively rapid growth in the local vegetation, and the rapid accumulation and deposition of their spores, along with rapid sedimentation, prevented the large-scale accumulation of regional, distant pollens transported into the basin. These pollens appear only subsequently in the profile in this horizon.

Following the development of floating mats, the rate of deposition decreased, accompanied by a stall in peat formation increasing the pollen entrapment ability of the Sárrét sedimentary basin and enabling the entrapment of regional pollens as well. As a result of this, larger amounts of pollen from oak (*Quercus*), elm (*Ulmus*) hazel (*Corylus*), and grasses (*Gramineae*) could have accumulated. According to the pollen composition, a mixing of pollens deriving from a forest steppe or closed woodland existing in the neighborhood in a milder phase (with a transportation direction from the Bakony and Vértes Mts.) and an open steppe area (Mezőföld, loess steppes) was identified. The early appearance of cereal pollens in the Sárrét-Nádasdladány section (6000 calBC) seems to be in good agreement with the appearance of the Early Neolithic communities and the emergence of productive societies in the Carpathian basin (*Hertelendi et al. 1998*).

Summary

According to the detailed sedimentological and palaeoontological analyses carried out on samples taken from the Sárrét–Nádasdladány core-profile, a complete environmental history of a neotectonic depression have been drawn. The sequence is composed of fluvial-lacustrine and marshland deposits which started to accumulate during the Late Glacial. Paleo-associations determined with the help of malacological data form a line of successions, with the first fluvial phase appearing as early as 13 000–11 000 BP. The infant neotectonic depression characterized by fluvial conditions must have been surrounded by open, gallery-like mixed taiga vegetation. At a greater distance, a more open, cold, continental forested steppe covering the loess and dolomite surfaces can be reconstructed.

Around 11 000 BP the depression was inundated, resulting in the emergence of a well-lit, but eutrophication at the bottom lacustrine environment, characterized by a water depth of 3m in the deepest parts of the depression. There was a change in the vegetation around the depression at about 10 000 uncalBP, characterized by the emergence of deciduous woodland in the area. A substantial amount of pollen grains from the pinewoods surviving in the cold relict spots in more distant, mountainous regions, accumulated during the Early Holocene. The lake was surrounded by extensive cattail and reedbeds, as well as sedge tussocks, at the time fringed by hardwood and softwood gallery forests and deciduous woodland. These conditions survived for some one thousand years, suggesting that the rate of infilling (0.31 mm/year) roughly equalled that of the rate of subsidence (11 000–9000 uncalBP).

The infilling of the basin intensified between 9000–6500 uncal BP, with the sedimentation rate exceeding 0.8 mm/year. There is a marked change in the pollen composition here, characterized by the appearance of taxa indicating arable farming and stockbreeding. The close correlation between the appearance of taxa reflecting a production economy, and the acceleration of the sedimentation rate, most certainly indicate the presence of human settlements around Lake Sárrét during the Early Neolithic, resulting in increased erosion rates. As a result of human activities, paludification of the lake was accelerated, and from 6500 uncalBP onwards led to the emergence of stable marshland with floating mats.

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