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TAXONOMIC STUDY OF OSTRACODS FROM THE EARLY HOLOCENE SEDIMENTS OF LAKE PEŢEA, NW ROMANIA

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Abstract:
The ostracod fossils are extremely important for the reconstruction of the prehistoric environment. This is also the case for lake environments (pH, carbonate content, isotope geochemistry, water depth, temperature, vegetation cover). In a lake of hydrothermal origin, such as Lake Peţea in the north-western part of Romania, it is of particular importance, as the lake has now dried up and a significant part of the endemic fauna has disappeared. The conclusions drawn from the Ostracoda remains, together with other taxa, could be of great help to local conservation efforts to restore the lake to its former state. Based on our results the following taxa were identified in the Early Holocene deposits of the lake: *Candona weltneri* var. *obtusa*, *Pseudocandona rostrata*, *Cypridopsis vidua*.

Key words: Ostracods, Lake Peţea, thermal water, Early Holocene.

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INTRODUCTION

The Ostracoda species, which are small, microscopic (0.3–7 mm) invertebrates, are one of the most widespread groups of crustaceans. They are widely distributed in all aquatic habitats, from thermal waters to cold springs, and are found in rivers, streams, lakes and canals (Külköylüoğlu *et al.*, 2018). Ostracods are excellent indicators of prehistory and have proven valuable in paleolimnology. They are very sensitive to environmental conditions, especially conductivity, pH and chemical composition. Their shells are readily fossilized and represent a major source of biogenic carbonate in continental environments (Laprida *et al.*, 2017). Despite this, freshwater ostracods are relatively understudied, and our knowledge of their habitat requirements is limited. Yet this could be important for several reasons: it could help us understand changes influenced by natural or human factors, provide past and present estimates of tree diversity, aid monitoring projects and conservation, help us understand the role of species in ecosystems, explain the geographic distribution patterns of species, etc. (Külköylüoğlu *et al.*, 2018).

Our samples come from a thermal lake sequence where three major stages were recognized in the lake evolution: eutrophic shallow lake, oligomesotrophic carbonate lake, and eutrophic thermal lake (Gulyás and Sümegi, 2023, 2024). Although the thermal lake sequence covers the entire Holocene, here we report some taxa from samples dated to the early Holocene alone. The reason is that a major low stand developed at the Holocene/Pleistocene boundary marking the transition into oligomesotrophic carbonate-rich lake. There is a shift in gastropods composition and this is the only horizon where shallow water chara remains appear (Benyó-Korcsmáros *et al.*, 2023). It should be noted, that ostracod identification is fundamentally difficult and studies from thermal lakes are poorly known.

LOCATION OF THE SITE AND STRATIGRAPHY

Lake Peţea (in Hungarian Püspökfürdő, in German: Bischofsbad, in Romanian Băile Episcopiei) is located in Bihor County, near Oradea, 9 km to the southeast, in the

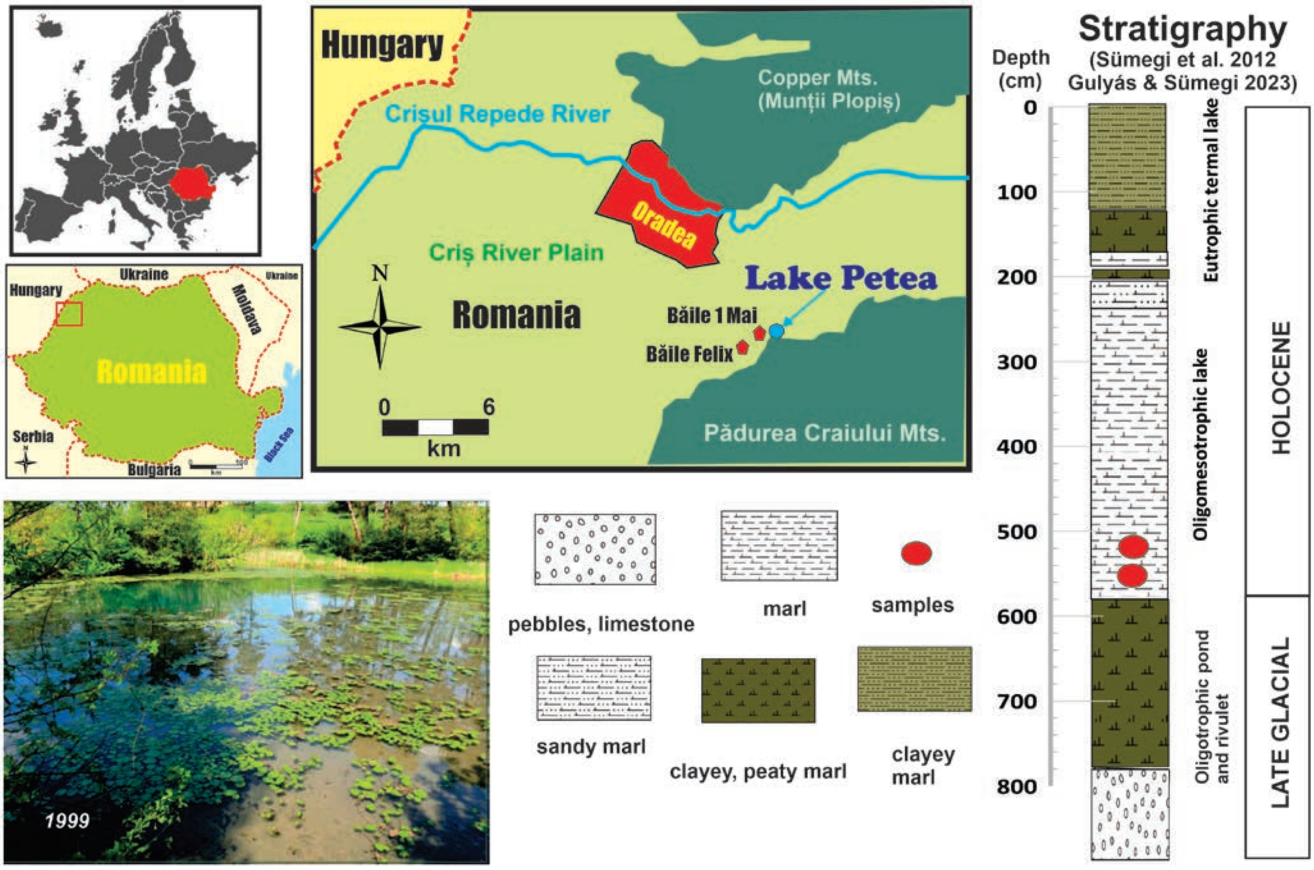

Fig. 1. Location of the study site of Lake Petea and a stratigraphic log of the lacustrine sequence with the position of samples for this study.

north-western part of Romania. It is a small and shallow thermal pond harboring a unique warm-water fauna, some of which are restricted there including the endemic gastropod *Microcolpia parreyssii parreysii* R.A. Philippi, 1847, the fish thermal Racovitza's rudd *Scardinius rakoviczai* G.J. Müller, 1958 and the Egyptian white water-lily *Nymphaea lotus* var. *thermalis* Linnaeus, 1753 (Sümegi *et al.*, 2012, 2014, 2018; Telcean and Cupsa, 2012; Sîrbu *et al.*, 2013; Neubauer *et al.*, 2014; Sîrbu and Benedek, 2016; Şerban and Grigoras, 2018; Benyó-Korcsmáros *et al.*, 2023; Gulyás and Sümegi, 2023, 2024). The lake is mentioned as early as the 18th century, but it has been known since ancient times and is one of the oldest known bathing places. Its popularity is because it is situated above a geothermal reservoir (Sîrbu *et al.*, 2013), and its waters are used to cure diseases such as rheumatism (Benyó-Korcsmáros *et al.*, 2023).

In the past the lake was much more extensive than today (Sümegi *et al.*, 2012, 2014, 2018; Neubauer *et al.*, 2014; Gulyás and Sümegi, 2023, 2024), and several studies of its evolutionary history have been published, based on detailed sediment and mollusk fauna studies, supplemented by palaeoecological interpretation. These studies have concluded that the evolution of the lake encompasses three main phases: oligotrophic shallow lake and thermal river, oligo-mesotrophic lake and highly eutrophic thermal lake (Gulyás and Sümegi, 2023, 2024). The pond is currently shallow on a much smaller scale, with a water depth of 2–3 m and a surface area of a few hundred square meters. Therefore, it is highly sensitive to changes, both natural and artificial (Gulyás and Sümegi, 2023, 2024). The geothermal effect is the determining factor for the lake, with temperatures between 20 and 30°C (Minta *et al.*, 2012).

Unfortunately, human intervention has had disastrous consequences for the lake and its wildlife. The proximity and accessibility of the thermal waters has allowed the creation of resorts, spas, villas, guesthouses and hotels (Sîrbu *et al.*, 2013). This was particularly the case in the early 1990s. This had several consequences. Initially, the lake started to shrink, and the temperature decreased (Neubauer *et al.*, 2014), and subsequently, on 13 December 2011, the underwater thermal spring feeding Lake Peţea stopped working, as confirmed by a diving team called to investigate (Sîrbu *et al.*, 2013). Therefore, the Tării Crisurilor Museum decided to collect endemic fish and snail species and attempted to breed them in aquariums. Unfortunately, this did not help (Gulyás and Sümegi, 2023, 2024). Due to overexploitation (Şerban and Grigoras, 2018), the area practically dried up in 2014 and the breeding program was no longer funded (Gulyás and Sümegi, 2023), and the three species mentioned above disappeared from the reserve. *M. parreyssii parreysii* initially "only" disappeared from the natural environment and then disappeared permanently, all in less than a decade, while the invasive bivalve *Sinanodonta woodiana* Férussac, A. (1827) survived the desiccation due to its hardiness (Sîrbu and Benedek, 2016).

In terms of lithostratigraphy at the beginning of the lacustrine sequence, a coarse silty clayey lake mud is followed by lacustrine carbonate mud (Fig. 1). Its bottom part is composed of a layer of pebbles. It is topped by a gravel layer, above which, in the Late Glacial, it passes into a greyish, greenish-yellow lake layer with high carbonate content and significant water-soluble Ca, Mg ions, already indicating the end of the glacial period. The swamping, increased organic matter content, eutrophication and rising water temperatures of the thermal lake are dated around 5 500 cal BP (Sümegi *et al.*, 2012, 2014, 2018; Gulyás and Sümegi, 2023, 2024).

MATERIAL AND METHODS

Our samples derive from depths of 520 and 540 cm corresponding to the period of a major low stand dated between 11.2 and 10.5 ky cal BP; i.e. the Early Holocene (Gulyás and Sümegi, 2023, 2024).

Sample preparation

Naturally, one can deviate from above, they are not obligatory, everyone may choose own tools. The small size plastic storage is for keeping safe the samples permanently, in one of the 2 petri dish you can put materials not yet tested, in the other one you can put the documented samples. The thin brush and the dissecting needle have very important role. By wetting the brush, fragile patterns can be moved safely from one place to another, while the dissecting needle allows you to move the patterns with great precision. You can even use a sharpened loop stick instead, or other means of orienting the shells.

The material from two samples was placed in two separate Eppendorf tubes. The samples were named PF-26 and PF-27. As the first step, the content of Eppendorf tube has to be poured into the petri dish, and after that with our wet, thin brush touch carefully the surface of the carapace taking advantage of the surface tension, then put it in slide/another petri dish. First, check the place of the putting down with the smallest, 40x magnifying of the microscope, and then change the turret containing the objectives to bigger, at least 100× enlargement. For seeing the most important identification attributes in transmitted light, according to my experience it needs at least such high magnification (160 or 200), but higher also can be a good option. The next step is the patterns have to be oriented in horizontal way. This move is not vital, but it highly makes the work easier. This is when the dissecting needle is needed, which must be handled with extreme care, as the thin, fragile shells can be easily damaged, or virtually pop off the table. After positioning our sample and we are fully conscious of identification stamps those what we needs, the specimen can be identified and recorded by camera. If we feel that we do not have more business with that pattern anymore, then it must be put into another petri dish to indicate that we are done. So, this is the model of the process that we have done. Let's never forget that in Ostracods it is not a clever move to consider only one attribute, but all their combination can give the most reliable diagnosis (Victor and Fernando, 1981). The selected samples were not cleaned by using ultrasonic bath due to the small and fragile state of the carapace.

RESULTS

A significant part of the samples was not suitable for identification due to insufficient preservation (Fig. 2).

The definition of carapace/valves was based on the work of Meisch (2000), Horne et. al. (2002), Gobert (2011–2012), Karanovic (2012), Krzyminska and Namiotko (2013). In our opinion, the samples contain at least three species belonging to the genera *Candona*, *Pseudocandona* and *Cypridopsis*. The main considerations were basically the shape, adductor muscle scars, size, shells surface.

TAXONOMY

Within Crustacea, these genuses are representatives of the four orders of Ostracoda in the order Podocopida (Karanovic, 2012).

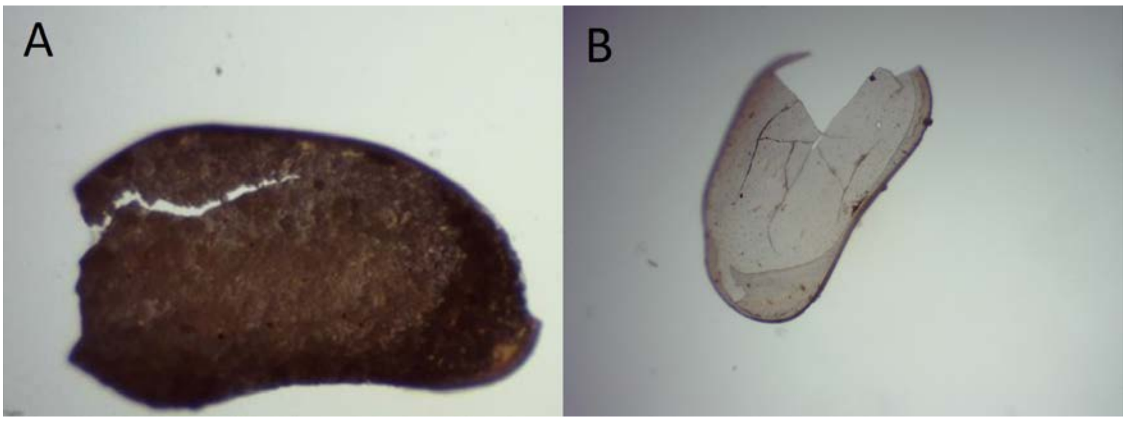

Fig. 2. Broken and sediment-filled shells unfit for identification. A and B – fractured shells, magnification of 100x (A) and magnification of 40x (B), (photo by Bóni).

Superfamily Cypridoidea
Family Candonidae
Subfamily Candoninae
Genus *Candona*
Species *Candona weltneri* var. *obtusa*
Superfamily Cypridoidea

The shell can be very small (0.3 mm) or considerably larger (8 mm), although the latter is quite rare. Their shape, like the overlapping of the turtles, is variable, with both the right and left turtle overlapping. The level of calcification is weak. The adductor muscle scars show a characteristic pattern, consisting essentially of a row of three scars in front of a fourth scar. This superfamily includes the families Cyprididae and Candonidae (Meisch, 2000; Horne et. al., 2002; Karanovic, 2012).

Family Candonidae

Members of the family are characterised by an extreme variation in the shape and structure of the shell, which varies in size from 0.4 to 1.5 mm. The surface may be smooth or decorated to varying degrees. The central muscle scars consist of an elongated scar with an anterior row of three scars and a posterior row of two scars. The family is considered to be essentially cosmopolitan. The inner lamella and the fused zone can be either wide or narrow (Meisch, 2000; Karanovic, 2012).

The adductor muscle scars gave acceptable point of references for starting identification but should be added, they alone are a necessary but not sufficient basis for identification. In addition, the shape, marginal pore channels, etc. are important, but a definite determination can only be made by examining the soft parts.

Subfamily Candoninae

The subfamily is characterised by the varied shape of the valves and the fact that the left valve overlaps ventrally with the right valve. The muscle scar consists of six central elements of approximately similar size. The vast majority of its members are adapted to a digging, crawling lifestyle. Their swimming ability has declined and they prefer to live in bottom mud, but several species also occur in shallow water (Meisch, 2000; Karanovic, 2012).

It should be noted that many species of the genera *Candona* and *Pseudocandona*, among others, are very similar in terms of shell outline. The same is true for the shell structure.

Species *Candona weltneri* Hartwig, 1899 var. *obtusa*
(Fig. 3)

The shell is wide when viewed from the dorsal side, which is greater than 1/3 of the length. Two forms of *C. weltneri* are known: *C. weltneri* var. *weltneri* and *C. weltneri* var. *obtusa*, the main difference between which is the shape of the shell and ecological tolerance. Females are elongated (forma weltneri) or stocky (forma obtusa) in lateral view,

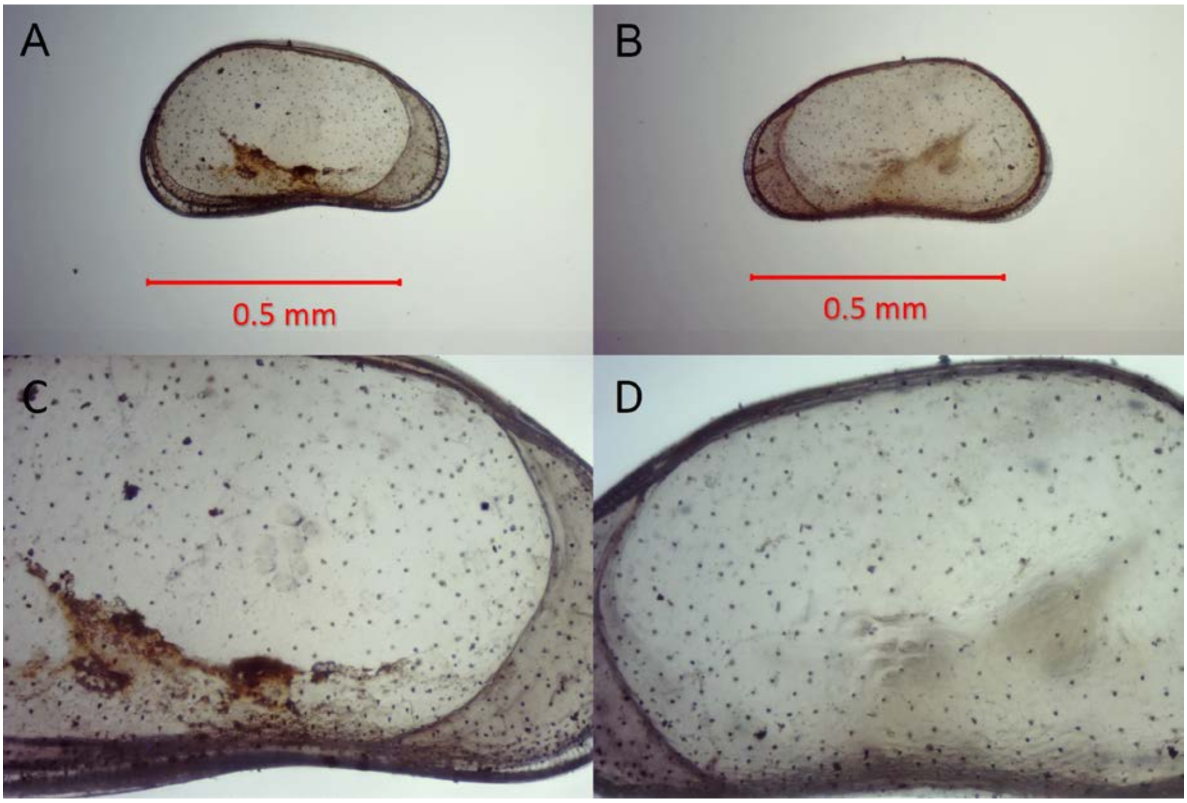

Fig. 3. A–D. Side view of the shell of Candona weltneri var. obtusa. (C–D) The adductor muscles scars are clearly visible on both sides (photo by Bóni).

with maximum height at 2/3 of the length of the shell. The ventral margin is almost straight. Females range in size from 1.13 to 1.21 mm, males are slightly larger (1.18–1.31 mm) (Meisch, 2000; Krzyminska and Namiotko, 2013).

Genus *Pseudocandona*

The carapace is rarely elongated when viewed from the side, mostly short. In adults, the shell surface may be smooth or perforated. The left valve overlaps the right valve ventrally (Meisch, 2000).

Species*Pseudocandona rostrata* Brady et Norman, 1889
(Fig. 4)

They range in size from 0.9 mm to 1.2 mm and in height from 0.5 to 0.7 mm. The dorsal part is straight and then slopes steeply towards the anterior part, the ventral margin is distinctly concave, its height is greatest behind the middle of the total length, not much more than half the length. The left shell overlaps the right at both ends of the shell. The shell surface of adults is smooth (Meisch, 2000; Krzyminska and Namiotko, 2013).

Superfamily Cypridoidea
Family Cyprididae
Subfamily Cypridopsinae

Genus *Cypridopsis*
Species *Cypridopsis vidua*
Family Cyprididae

The members of the family range in length from 0.3 to 7 mm, with great variation in shell shape and structure. Their surface is generally smooth, possibly with varying degrees of ornamentation. The edges of the shells are smooth but may also be slightly carved. The calcified inner lamella and the fused zone may be either wide or narrow. Marginal pore channels may be sparse or numerous (Meisch, 2000; Karanovic, 2012).

Subfamily Cypridopsinae

In members of this subfamily, the left valve overlaps ventrally with the right valve or vice versa. Their shells are small, ranging from 0.3 to 0.9 mm. The fused marginal zone is rather wide in those parts where the concrescence curves inwards (mouth area) (Meisch, 2000; Karanovic, 2012).

Genus *Cypridopsis*

The shell is ovoid in both lateral and dorsal view, with a height and width nearly equal to half the length. The left side of the shell overlaps the right side ventrally and is slightly longer. The posterior margin of the left valve is well developed (Meisch, 2000).

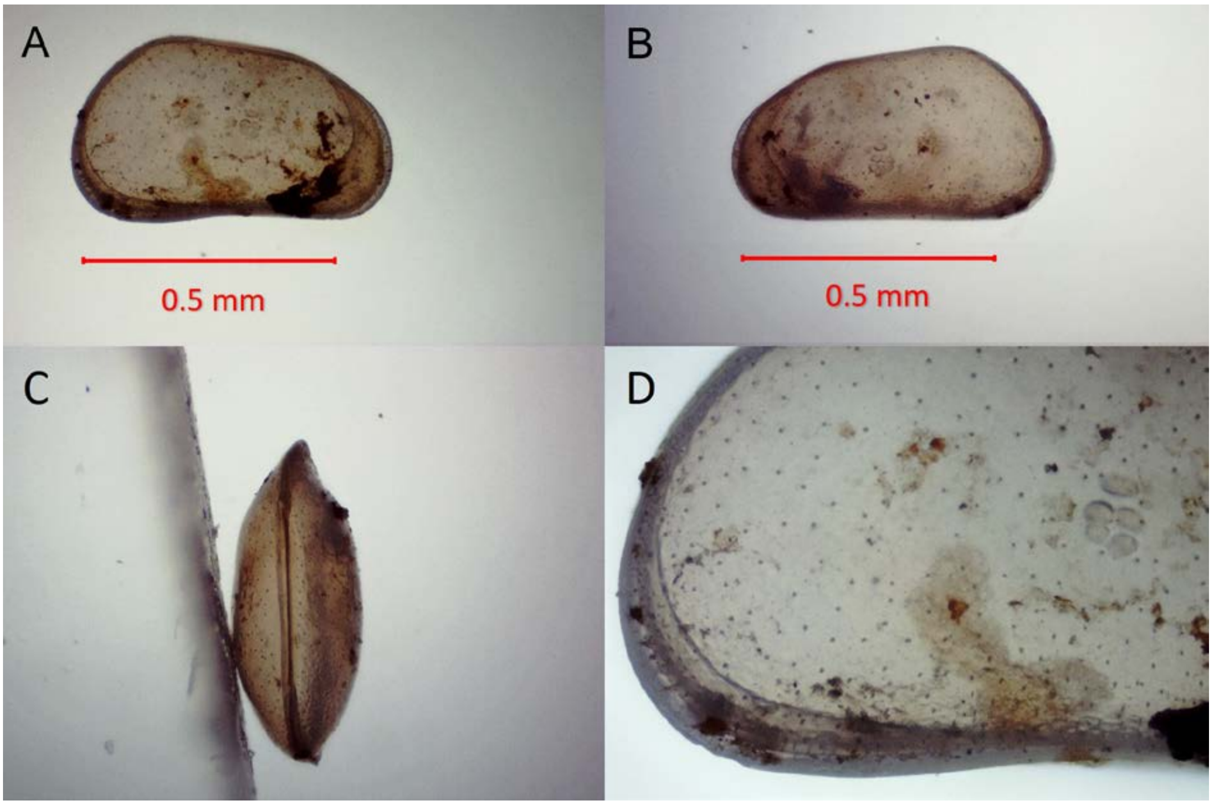

Fig. 4. Pseudocandona rostrata: A–B – lateral view, the difference between the two valves is clearly visible on the ventral side, C – dorsal view, the overlapping of the turtles is clearly visible, D – the adductor muscle scars (photo by Bóni).

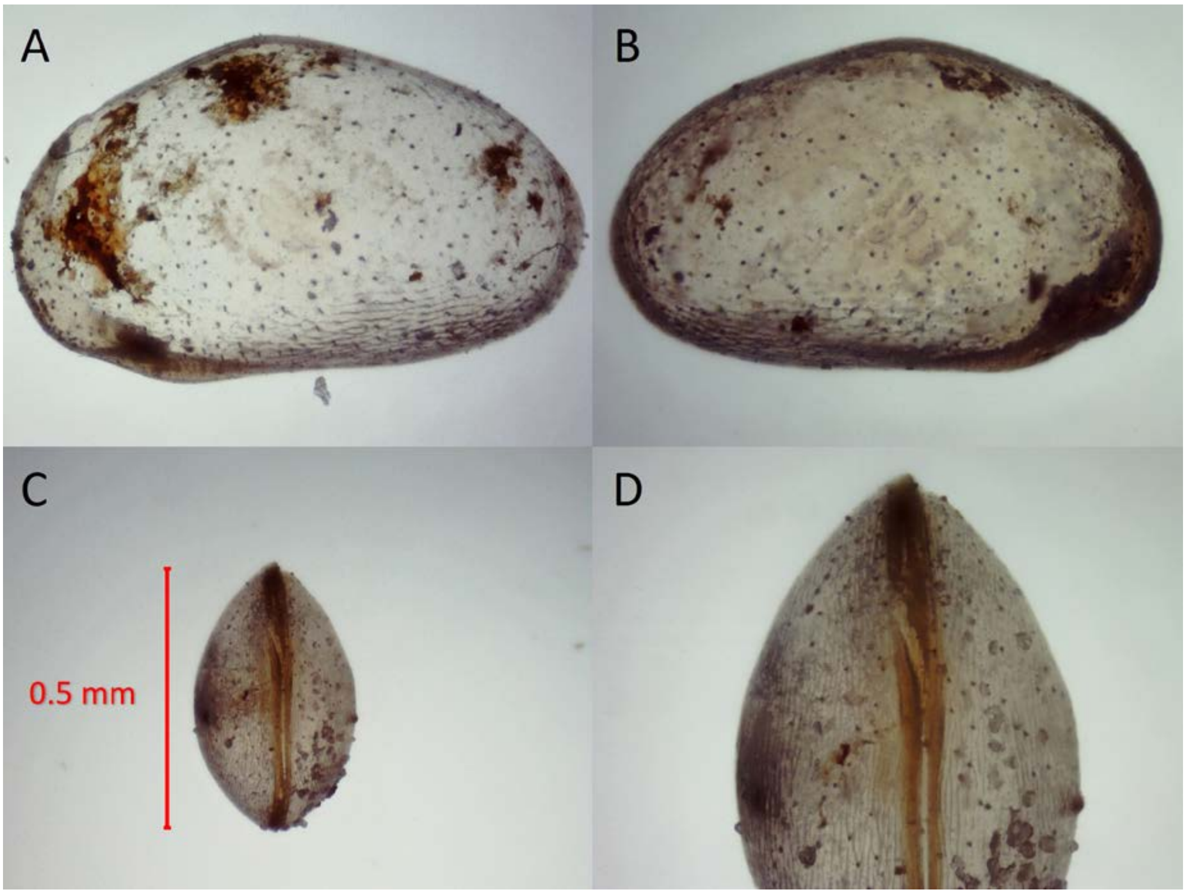

Fig. 5. Cypridopsis vidua: A–B – outlines of the left and right valve are nearly similar, C–D – with the degree of overlap between the two valves being less striking than in other taxa (photo by Bóni).

Species *Cypridopsis vidua* O.F. Müller, 1776
(Fig. 5)

The length of the shell ranges from 0.4 to 0.7 mm and the height from 0.3 to 0.5 mm (Krzyminska and Namiotko, 2013). According to another source, Meisch (2000), the carapace is extremely variable in size and shape, being approximately ovoid, usually half a mm long. The dorsal area may be slightly or strongly curved, the front rounded or pointed. Its surface is basically smooth, rarely covered with shallow pits, which are weakly marked. The left valve overlaps the right one (Gobert, 2011–2012).

CHARACTERISTICS OF THE SPECIES

Candona weltneri var. *obtusa*

It prefers lacustric environments (lakes, marshes, backwaters) and is found in both permanent and temporary waters The most favored areas along lakes are the littoral regions, but it is also found in the profundal region, but in much smaller numbers. The two sexes are always found together. Its distribution is typical of the Palaearctic and Nearctic regions. (Krzyminska and Namiotko, 2013).

Ecological characteristics:
- preferring cold waters (oligothermophilic)
- occurring in turbulent littoral waters of lakes and/or sometimes in flowing water (oligorheophilic)
- mainly occurring at 18–72 mg Ca/L. or mainly occurring at calcium concentrations higher than 72 mg/L. (meso- to polytitanophilic)
- limited to freshwater (Meisch, 2000)

Cypridopsis vidua Müller, 1776

It is a cosmopolitan species and one of the most common ostracod species, occurring in the Palaearctic, Nearctic, Afrotropical, Neotropical and Pacific regions. Although it is found in a wide range of aquatic habitats, it prefers stagnant aquatic environments such as the littoral zone of (fish) ponds, springs, where there is abundant vegetation and shade. It is particularly common where dense stands of Chara fragilis are present, as the plants provide protection from predators as well as food (periphyton). It tolerates low salinity increases (up to 8‰), but is less tolerant of poor oxygenation (Karanovic, 2012; Krzyminska and Namiotko, 2013). It is an active swimmer, surface form.

Ecological characteristics:
– preferring warm waters (politermofil)
– occurring frequently in flowing waters with various velocities (mezorheofil)
– occurring indifferently in all three Ca-ranges (titanoeuryplastikus)
– fitofil
– oligohalofil (Meisch, 2000; Gobert, 2011–2012)

Pseudocandona rostrata

This spceies is widespread in Europe and Asia (Palaearctic and Nearctic regions), but rare in the Southern Hemisphere. It is most commonly found in permanent or temporary lacustric waters (up to 17 m depth), including in the coastal zone, and less frequently from streams, springs and springs, but has also been detected in near-surface groundwater. It tolerates salinity increases up to 5%. In seasonal waters, eggs, juveniles and adults survive the summer in dry mud (Meisch, 2000; Krzyminska and Namiotko, 2013).

Ecological characteristics:
– species linked to permanently cold waters (cold stenothermal)
– rheotolerant
– főként 0–18 mg Ca/L-nél fordul elő (oligotitanophilic)
– between 0.5–5‰ (oligohalophilic)
– stygophilic (Gobert, 2011–2012)

CONCLUSIONS

In relation to the Ostracoda, an important question was to what extent the palaeohydrological relationships reconstructed by previous malacofaunal and Chara studies are reflected or complemented by the Ostracoda data. Compared to the Characeae, the Ostracoda species occur both in lacustrine environments and permanent and intermittent waters, with their most typical habitat being marshy environments. In pond environments, they prefer the coastal zone. Based on our results, the Ostracod fauna clearly represents the current phase of the lake environment. In addition, it can be reported that conclusions drawn from the Chara and Ostracods remains can complement each other well, and where is it possible, it is worthwhile consider the possibility of documenting them.

As with the malacofauna, the girogonit and the ostracod shell remains play an important role in the reconstruction of the hydrological characteristics (pH, water depth, flow, carbonate content, isotope geochemistry-water chemistry and temperature) of the former lake habitats. The carapaces of ostracod were collected from early Holocene layer of the Lake Peţea. The investigated remains originated from the Mesolithic level of the lake, so providing information about the hydrology of the lake for this period. These remains come from the 520–540 cm range of the section. According to the data of the sediments, a marked low water level was indicated in this lake section between 11 700 and 10 200 cal BP (Gulyás and Sümegi 2023). The identified ostracods can be found in shallow lacustric environment, but like the charophytes, they prefer the smaller, sheltered areas as well. In general, they occupied depths of 0.5–2 m.

Acknowledgements

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