

## Sarmatian and Pannonian mollusks from Pécs-Danitzpuszta, southern Hungary: a unique local faunal succession

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### *Szarmata és pannóniai puhatestű faunák különleges helyi sorrendje Pécs-Danitzpusztáról*

#### Összefoglalás

A pannóniai puhatestűek közel két évszázados kutatása során kiderült, hogy a különböző faunák földrajzi elterjedése szabályos mintázatot mutat. Mivel a Pannon-tó medre oldalirányban épülő üledéksomagokkal töltődött fel, a medencének a behordástól távoli részén kondenzált üledékképződés folyt, a peremektől a medence közepe felé pedig egyre fiatalabb sekélyvízi üledékek rakódtak le. A medencéből kiemelkedő aljzati magaslatok környékén, amennyiben ezek üledékforrásként szolgáltak, megtörik ez a szabályos trend. A késő miocén korai szakaszában a Mecsek is ilyen kiemelkedés volt. A Pécs-Danitzpusztán feltárt 200 méter vastag szarmata–pannóniai rétegsor képződését a helyi szerkezeti és üledékképződési viszonyok időben úgy alakították, hogy a különböző puhatestű faunák egyedi, másutt eddig nem tapasztalt sorrendben követik egymást.

A rétegsor alján található szarmata tengeri faunát egy édesvízi vagy oligohalin (alacsony sótartalmat elviselő) együttes követi, amely a mikrofauna alapján még szintén szarmata korú. Bár a kőületek megtartási állapota nem teszi lehetővé biztos következtetések levonását, úgy tűnik, hogy az együttes fajai – elsősorban a tüdőscsigák – a legidősebb pannóniai fauna őseit képviselik.

A következő ősmaradvány-tartalmú rétegekben egy „törpe” faunát találunk: a kis méretű, de változékony, „szarmata típusú” szivkagylók tömege sok helyről ismerős a Pannon-medencében a szarmata–pannóniai határ közeléből. Ezeknek a kagylóknak az alapos taxonómiai vizsgálata a jövő feladata; minden bizonnyal megtalálhatók köztük a jól ismert szarmata és pannóniai formákat összekötő, mindaddig ismeretlen formák.

A rétegsor következő, jelentős részét a Pannon-medence déli felében nagy elterjedést mutató „fehér márgák” teszik ki. Ezek a Pannon-tó szublitórális és profundális zónájában halmozódtak fel, faunájuk alapján pedig két egységre bonthatók ugyanúgy, mint Horvátországban vagy Szerbiában: a *Lymnocardium praeponticum* Zónára (vagy *Radix croatica* Zónára), melynek becsült kora 11,6–11,4 millió év, és a *Congeria banatica* Zónára, amely 11,4 és 9,7 millió év között képződött a Pannon-medencében.

A fehér márga lerakódása azonban Pécs-Danitzpusztán ennél hamarabb véget ért. Kőzetliszt ülepedése váltotta fel, amelynek gazdag szublitórális puhatestű faunája a *Lymnocardium schedelianum* Zónába tartozik; korát 10,5–10,2 millió évre tehetjük. Ez a fauna gyakori a Bécsi-medencében, a Dél-Bánságban és a Pannon-medence egyéb peremi területein, de sehol nem találták meg a fehér márgák fedőjében. Horvátországban és Szerbiában a mélyvízi márgák képződése ebben az időben is zajlott és tovább folytatódott.

A pécs-danitzpusztai rétegsort végül egy vastag, limonitos homoktest fedi. A homokból kagylók és csigák lenyomatjai és kőbelei kerültek elő. A fauna tipikus sekélyvízi, litorális környezetre utal, rétegtanilag a *Lymnocardium conjungens* Zóna felső részébe tartozik, kora 10,2–10,0 millió évre becsülhető. Hasonló faunák ismertek Burgenlandból, Szerbiából, a Partiumból, de ezeken a helyeken soha nem a *L. schedelianum* Zóna közvetlen fedőjéből, mint Danitzpusztán.

Pécs-Danitzpusztán tehát olyan faunák egymáshoz való rétegtani viszonyát lehet tanulmányozni, amelyek eddig nem voltak megfigyelhetők egyetlen szukcesszióban vagy akár egymáshoz nagyon közeli földrajzi pozícióban sem.

*Kulcsszavak: miocén, Pannon-tó, puhatestűek, biosztratigráfia, paleoökológia, Mecsek, szarmata–pannóniai határ*

#### Abstract

As the almost 200-year palaeontological research revealed, the geographical distribution of various fossil mollusk faunas in deposits of the late Neogene Lake Pannon displays a regular pattern. The lake basin was filled by lateral accretion of sediments, resulting in condensed sedimentary successions in the distal parts of the basin and successively

younger shallow-water deposits from the margins towards the basin center. Exposed intra-basin basement highs, however, broke this strict pattern when they acted as sediment sources during the lake's lifetime. The Mecsek Mts in southern Hungary was such an island in Lake Pannon during the early late Miocene. Deposition of the 200 m thick Sarmatian–Pannonian sedimentary succession in Pécs-Danitzpuszta at the foot of the Mecsek Mts was thus controlled by local tectonic and sedimentary processes, resulting in a unique succession of facies and mollusk faunas. A typical, restricted marine Sarmatian fauna is followed by a distinct freshwater or oligohaline interval, which, according to micropalaeontological evidence, still belongs to the Sarmatian. Although poor preservation of fossils does not allow firm conclusions, it seems that freshwater Sarmatian snails were the ancestors of the brackish-water-adapted early Pannonian pulmonate snail taxa. The successive “Sarmatian-type” dwarfed cockle fauna is similar to those widely reported from the Sarmatian–Pannonian boundary in various parts of the Pannonian Basin; however, a thorough taxonomic study of its species is still lacking. The bulk of the sedimentary succession corresponds to the sublittoral to profundal “white marls,” which are widespread in the southern Pannonian Basin. In Croatia and Serbia, they are divided into the *Lymnocardium praeponticum* or *Radix croatica* Zone (11.6–11.4 Ma) below, and the *Congeria banatica* Zone (11.4–9.7 Ma) above; this division can be applied to the Pécs-Danitzpuszta succession as well. Sedimentation of the calcareous marl, however, ceased at Pécs-Danitzpuszta at about 10.5–10.2 Ma ago (during the younger part of the *Lymnocardium schedelianum* Chron), when silt was deposited with a diverse sublittoral mollusk fauna. Similar faunas are known from the Vienna Basin, southern Banat, and other marginal parts of the Pannonian Basin System, but not from Croatia and Serbia, where deposition of the deep-water white marls continued during this time. Finally, the Pécs-Danitzpuszta succession was capped with a thick, coarse-grained sand series that contains mollusk molds and casts representing a typical littoral assemblage. This littoral fauna is well-known from easternmost Austria, northern Serbia, and northwestern Romania, but never directly from above the sublittoral *L. schedelianum* Zone. The fauna is characteristic for the upper part of the *Lymnocardium conjungens* Zone and has an inferred age of ca. 10.2–10.0 Ma. The Pécs-Danitzpuszta succession thus allows to establish the chronostratigraphic relationship between mollusk faunas that have not been observed in one succession nor in close proximity to each other in other parts of the Pannonian Basin.

**Keywords:** Miocene, Lake Pannon, mollusks, biostratigraphy, palaeoecology, Mecsek Mts, Sarmatian–Pannonian boundary

## Introduction

The upper Miocene (Pannonian) lacustrine to deltaic basin fill of the Pannonian Basin in Central Europe is exposed along the basin margins and around the intrabasinal basement highs (today hills or mountains) as a consequence of a Pliocene to Recent basin inversion (RUSZKICZAY–RÜDIGER et al. 2020 and references therein). The lacustrine layers exposed in the Pécs-Danitzpuszta sand pit in South Hungary at the foot of the Mecsek Mts (*Figure 1A*) first gained fame as a textbook example of intra-Pannonian tectonic processes that tilted the lacustrine white marls and the lower part of the overlying limonite-stained sands into a vertical position (VADÁSZ 1953; BARTHA 1966; KLEB 1968, 1973). In these reports, the dislocated layers were interpreted as “lower Pannonian”, whereas the overlying, almost horizontal sand layers were identified as “upper Pannonian”. These assignments, however, were poorly supported with biostratigraphic evidence. Only faint, poor-quality pictures of “*Congeria* sp. and *Lymnocardium* sp. in a calcareous marl layer”, “*Melanopsis*-bearing calcarenite”, and “*Congeria balatonica*” from the sand were published to support this interpretation (BARTHA 1966, KLEB 1973). Based on the lithological features, the white marl of the outcrop was correlated with the *Congeria banatica*-bearing white marls of Croatia and Serbia (“Slavonian” or “Beočin-type” beds and fauna), whereas the overlying limonitic sand was tentatively correlated with the *Congeria balatonica*- and *Lymnocardium schmidtii*-bearing, 7–8 million-year-old sand apron that covers the southern foothills of the Mecsek Mts (BARTHA 1964, 1966; KLEB 1968, 1973; KAZÁR et al. 2007).

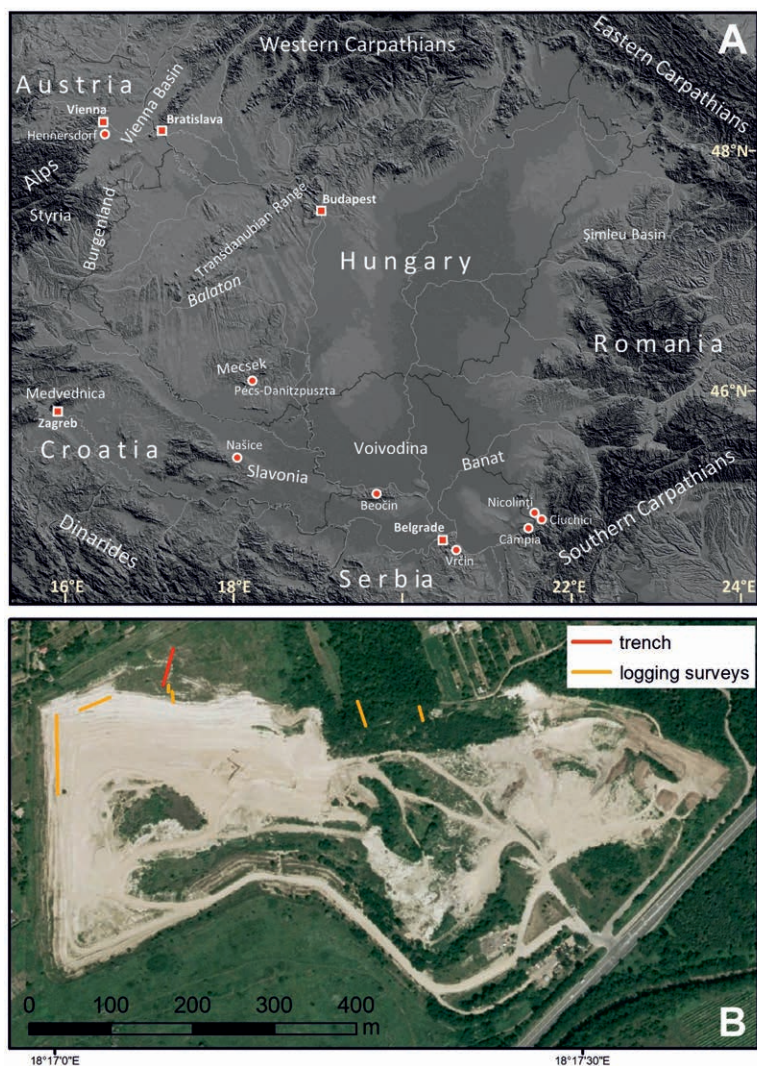
Later the outcrop also became famous as a palaeontolo-

gical site. The marl is the type locality of some endemic Pannonian calcareous nannofossils (BÓNA & GAL 1985, 1987), and the overlying sand layers were discovered to be a Mecca for vertebrate palaeontologists and amateur collectors by yielding an amazing amount and variety of reworked Miocene vertebrate fossils (SZABÓ et al. 2021, and references therein). The biostratigraphic position and age of the fossiliferous Pannonian lacustrine sediments, however, remained obscure. In the last two decades, however, large amounts of mollusk fossils were collected from the outcrop. In addition, a trench was excavated in 2018 on top of the tilted beds to expose the layers that underlie the marl (*Figure 1B*); this trench revealed a Badenian to Sarmatian to Pannonian (middle to upper Miocene) succession with several fossiliferous layers (*Figure 2*).

In this study, we present the mollusk record of the Sarmatian–Pannonian succession of the outcrop (its Badenian fossils are discussed in DULAI et al. 2021) and evaluate the mollusk fauna from biostratigraphic and palaeoecological points of view. We compare the assemblages with other well-known faunas. For a detailed geological context and description of the succession, the reader is referred to SEBE et al. (2021).

## Material and methods

The studied material includes fossils recently collected layer-by-layer from both the trench (Layers D50 to D1) and along a section on the northern wall of the pit (Layers D212 to D227; *Figures 1B, 2*), as well as specimens collected earlier by Krisztina SEBE and her students from the University



**Figure 1.** A: Location map of the Pannonian Basin surrounded by the Alps, Western, Eastern and Southern Carpathians and Dinarides with the geographical names referred to in the text. B: Satellite photo of the sand pit with the location of the exploratory trench and the logged surveys (SEBE et al. 2021)

*I. ábra.* A: Az Alpokkal, Kárpátokkal és Dinaridákkal körülvett Pannon-medence a szövegben hivatkozott földrajzi nevekkal. B: Műholdas felvétel a pécs-danitzpusztai bányáról a kutatórok és a vizsgált szelvények jelölésével (SEBE et al. 2021)

of Pécs, László KANIZSAI, a private collector, István CZICZER (University of Szeged), Imre MAGYAR, and others, from various parts of the Pannonian succession during the last two decades. The investigated fossils are repositied in the Natural History Museum, Budapest; Local History and Natural History Museum Collection, Komló; and Mining and Geological Survey of Hungary, Budapest. The fossils collected by the authors were cleaned and prepared in the laboratory of the Department of Palaeontology at the Eötvös Loránd University, Budapest, and in the Natural History Museum, Budapest. Polyvinyl acetate was used for solidifying fragile fossils. For mollusk determination, a Zeiss SteREO Discovery.V12 modular binocular stereo microscope was used in the Laboratory of MOL Plc., Budapest. Thin sections were prepared in the Laboratory of MOL Plc., and they were investigated with a Zeiss Axio Imager.A1 polarizing micro-

scope. Photos were taken by two cameras (macroscopic images: Canon EOS 40D digital camera with Canon EF 100 mm f/2.8L IS USM macro lens; microscopic images: Zeiss AxioCam MRc 5 camera mounted on the Zeiss microscopes with the help of the AxioVision 40x64 v.4.9.1.0 software). Some of the borrowed museum specimens were photographed in the Bakony Museum of the Hungarian Natural History Museum, Zirc.

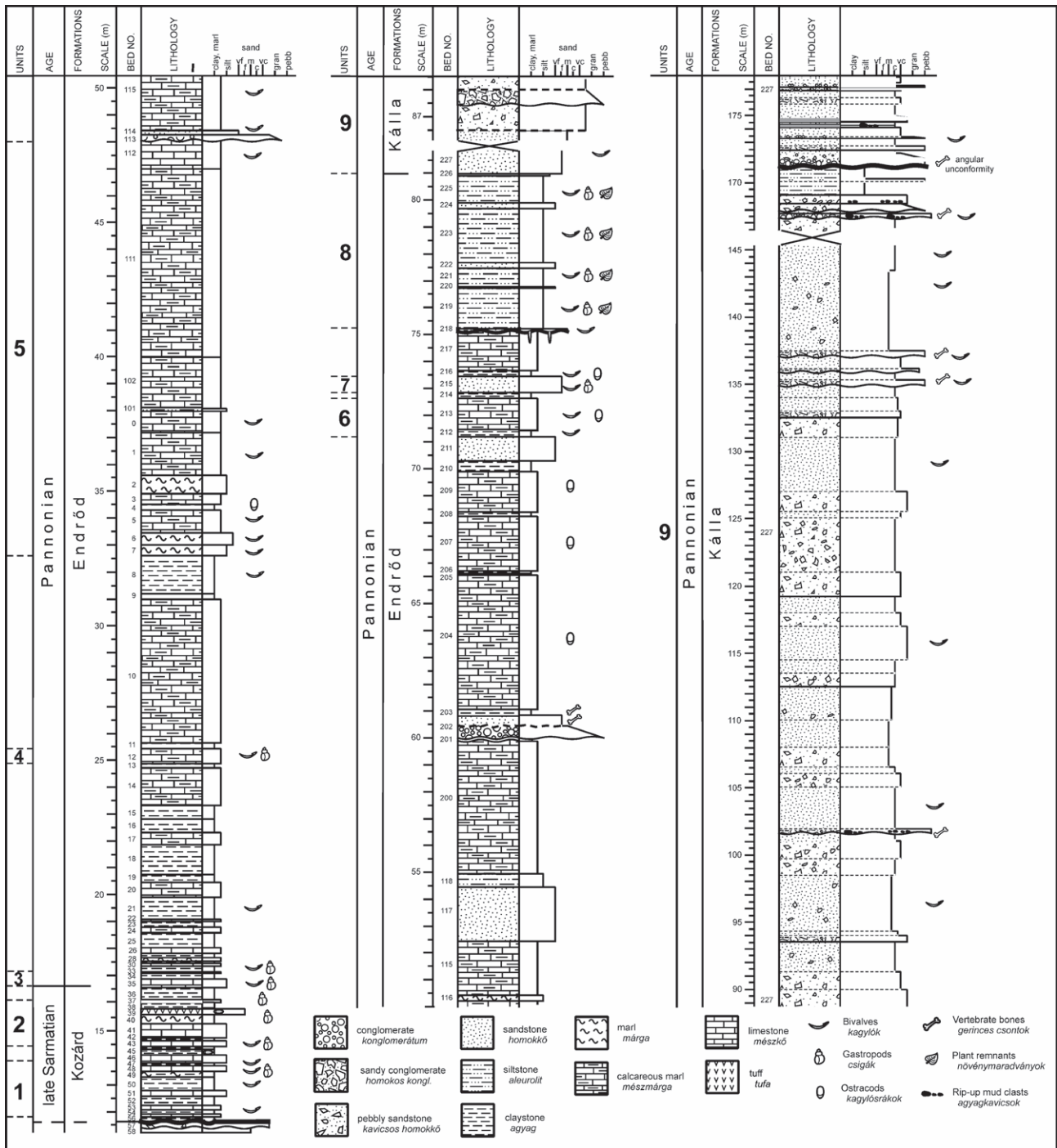
Comparison of our specimens with the type materials repositied in the Natural History Museum Vienna (NHMW), Geological Survey of Austria, Vienna (GBA), Croatian Natural History Museum, Zagreb (HPM) and Mining and Geological Survey of Hungary, Budapest (MBFSZ) led to some clarification of taxonomic identities and uncertainties that are important for correct age determination (see in Appendix). At the genus level we followed a conservative approach. All dreissenids possessing an apophysis (an appendix that served as pedal retractor catchment) are attributed here to *Congerina*, because subdivision of this large group into monophyletic flocks, supported by compelling morphological and stratigraphical arguments, has not happened so far. We use the genus *Lymnocardium* collectively for all Lake Pannon cardiids that have not been separated into clearly established genera, but put it into a quotation mark where morphological dissimilarity to the type of *Lymnocardium* argues for a different – as yet undecided – generic placement.

## Mollusk assemblages and depositional environments

The Sarmatian–Pannonian succession of the Pécs–Danitzpuszta section can be divided into several intervals based on the mollusk fauna. In this chapter, a brief description of each interval is given with its typical fossil mollusk content, its characteristic lithology, and the inferred depositional environment. The full list of the identified taxa for each layer is given in the digital annex of this paper.

*Unit 1.* Layers D55 to D47 yield moulds (“steinkerns”) of poorly preserved restricted marine species, such as *Ervillea* sp. (a fragment), *Lymnocardiinae* sp. (Plate I, figures 2–3), and *Dreissenidae* sp. (Plate I, figure 1).

*Unit 2.* The overlying layers (D43–D37), consisting of marl, tuffaceous sand and limestone, contain a poorly preserved gastropod fauna with freshwater forms, such as lymnaeids [*Radix* cf. *croatica* (Plate I, figures 5–6), ?*Lymnaea* sp. (Plate I, figures 4, 7, 10)], planorbids (Plate I, figure 8), hydrobiids (Plate I, figures 11, 13), and the neritid *Theo-*



**Figure 2.** Lithologic log of the Pécs-Danitzpuszta succession, with sample locations and layer and unit numbers. Faunal intervals are discussed in the text. (SEBE et al. 2021)

**2. ábra.** A Pécs-danitzpuszti homokbánya középső-késő miocén szelvénye a vizsgált minták helyével és a fauna biosztratigráfiai és paleoökológiai értékelése alapján elkülönített intervallumokkal. (SEBE et al. 2021)

*doxus* sp. (Plate I, figure 9). A land snail also occurred, whereas bivalves are completely missing from these layers.

**Unit 3.** The limestone layers D35 and D33 are densely packed with moulds of small cardiids and a few hydrobiids (Plate II, figures 1–20). The cardiids show very high variability in terms of outline, convexity, and rib pattern. Many of them are similar to various Sarmatian and Panno-

nian taxa, such as *Inaequicostata pia* (Plate II, figures 1–2), *I. nigra* (Plate II, figures 11–12), *Obsoletiformes fischeriformis* (Plate II, figure 9), *O. kaudensis* (Plate II, figures 5, 10), *Plicatiformes plicatus*, *Planacardium* sp. (Plate II, figure 3), “*Lymnocardium*” *praeponcticum* (Plate II, figure 4) and others (Plate II, figures 6–8). Due to their extreme variability and poor preservation, we are not confident about

these identifications (see *Digital annex*). Similar cardiid faunas have been described from various parts of the Pannonian Basin, but the identification of the species remains ambiguous even when the preservation of the shells is good (e.g., JEKELIUS 1944). These assemblages, which undoubtedly include so far unknown links between the Sarmatian restricted marine and Pannonian brackish lacustrine cardiiids, deserve a thorough study in the future.

*Unit 4.* The fauna embedded into the calcareous marl of Layer D12 consists of cardiiids [*“Lymnocardium”* cf. *praeoponticum* (Plate III, figures 11–12), *“L.”* cf. *plicataeformis* (Plate III, figure 15), *Lymnocardium* sp. (Plate III, figures 13–14)], dreissenids [*Congeria* cf. *banatica* (Plate III, figures 1–4), *C.* cf. *martonfii* (Plate III, figure 5), *C.* cf. *ramphophora* (Plate III, figure 9), *C.* cf. *neumayri* (Plate III, figure 10), and *Congeria* div. sp. (Plate III, figures 6–8)], planorbids (*Gyraulus tenuistriatus* and *Orygoceras fuchsi*), lymnaeid (*Radix croatica*; Plate III, figures 17–19) and hydrobiid (*Prososthenia sundecici* and *Micromelania striata*) snails. This fauna is widespread in the southern Pannonian Basin and its embedding layers are distinguished as “Croatia formation” in Croatia. The environmental interpretation of the fauna is controversial; usually it is interpreted to represent shallow, strongly freshened water, but there are arguments for a sublittoral or even profundal habitat (for a detailed discussion see SEBE et al. 2020).

*Unit 5.* The marl, calcareous marl and limestone layers between D7 and D112 yielded small, thin-shelled cardiiids [*Paradacna* cf. *syrmensis*, *P. abichi* (Plate IV, figures 1–5), *“Lymnocardium” margaritaceum* (Plate IV, figures 10–11), and *Lymnocardiinae* sp. (Plate IV, figures 6–9)], dreissenids (*Congeria czjzeki* and *C. banatica*) and snails [Hydrobiidae sp., *Micromelania striata* (Plate IV, figure 13), *Velutinopsis* sp. (Plate IV, figure 12), *Gyraulus* sp., *Orygoceras fuchsi*, and *O. brusinae* (Plate IV, figure 14)]. This fauna is also well-known in the southern Pannonian Basin under the names “Slavonian” or “Beočin-type” or “Banatica” fauna, and it is widespread in the white marls of Voivodina (Serbia), Slavonia and Medvednica Mts. (Croatia), and southern Burgenland and eastern Styria (Austria) (e.g., GORJANOVIC-KRAMBERGER 1899, SAUERZOPF 1952, SREMAC 1981, STEVANOVIĆ & PAPP 1985, VRSALJKO 1999, VASILIEV et al. 2007, GANIĆ et al. 2010, RUNDIĆ et al. 2011, TER BORGH et al. 2013). It is characterized by small-sized and thin-shelled mollusks, commonly cardiiids, some dreissenids, and mostly pulmonate snails. These mollusks are interpreted to have lived in the sublittoral to profundal depth of Lake Pannon.

*Unit 6.* The soft clay of D212 and white marl of D213 contain scattered specimens of *Congeria partschi firmocarinata*. This species lived in the sublittoral zone of Lake Pannon (e.g., HARZHAUSER & MANDIĆ 2004).

*Unit 7.* The fossil fauna of Layer D215, a 60 cm thick quartz sandstone, is unique within the marl succession. It contains compressed molds of *Melanopsis fossilis* (Plate IV, figure 16), *M.* cf. *vindobonensis*, *Unio* cf. *atavus* (Plate IV, figure 15), *Congeria* sp., and *Lymnocardium* sp. The large *Melanopsis* species and *Unio atavus* were typical shallow-

water, littoral dwellers in Lake Pannon (e.g., HARZHAUSER et al. 2007). As both the under- and overlying, fine-grained layers contain sublittoral fauna, the littoral shells and sand of D215 were probably transported into the sublittoral zone by gravity flows.

*Unit 8.* The uppermost ca. 6 m of the fine-grained succession, consisting of yellow silty marl and clayey siltstone (D219–D226), contains the most diverse mollusk assemblage of the entire section. Preservation is variable: fresh and dissolved shells, imprints as well as moulds were found. The fauna includes *Congeria partschi firmocarinata* (Plate V, figure 1), *C. zsigmondyi* (Plate V, figures 2–3), *Dreissenomya primiformis* (Plate V, figures 4–7), *Lymnocardium schedelianum* (Plate VI, figures 1–2), *L. winkleri* (Plate V, figures 12–15), *L.* aff. *boeckhi* (Plate V, figures 8–11), *“L.” carnuntinum* (Plate VI, figures 3–4), *“L.” tegulatum* (Plate VI, figures 5–7), *“L.”* cf. *asperocostatum* (Plate VI, figure 12), *“L.”* aff. *danicici* (Plate VI, figure 8), *“Lymnocardium”* cf. *proximum* (Plate VI, figure 9), *“Pontalmyra” otiophora* (Plate VI, figure 13), *Caladacna* aff. *steindachneri* (Plate VI, figure 19), *Paradacna* sp. (Plate VI, figures 10–11), *?Parvidacna* sp., *?Pseudocatillus* sp. (Plate VI, figure 15), *?Phyllocardium* sp. (Plate VI, figure 20), *Lymnocardiinae* sp. (Plate VI, figures 14, 16–18), *Orygoceras fuchsi*, *O. brusinae*, *Gyraulus tenuistriatus* (Plate VI, figure 22), *Melanopsis fossilis*, *M. austriaca* (Plate VI, figure 21), and *?Micromelania* sp. This assemblage shares a number of species (*C. partschi firmocarinata*, *C. zsigmondyi*, *D. primiformis*, *L. schedelianum*, and *“L.” carnuntinum*) with the fauna of Hengersdorf (near Vienna; PAPP 1953, 1985; HARZHAUSER & MANDIĆ 2004) and also with the fauna of Câmpia (Langenfeld) and Nicolinți (Nikolincz) in southern Banat, at the foothills of the Southern Carpathians, Romania (*C. zsigmondyi*, *L. winkleri*, *“L.” carnuntinum* (= *L. pseudo-suessi*), and *“L.” tegulatum*) (HALAVÁTS 1882, 1886). Most of these mollusks are known to have lived in sublittoral environment (e.g., HARZHAUSER & MANDIĆ 2004, CZICZER et al. 2009). *Parvidacna*, *Pseudocatillus*, and *Phyllocardium* are littoral dwellers (e.g., MÜLLER & SZÓNOKY 1990), but they are represented by few specimens only, with incomplete preservation and/or in early ontogenetic stage, which makes their identification uncertain. The few specimens of the shallow-water *Melanopsis* could have been re-deposited from a littoral environment.

*Unit 9.* In the limonite-stained sand (D227) that overlies the marl succession, the aragonitic shells were completely dissolved, leaving behind cavities between the imprints of the inner and outer shell surfaces. In most cases, only the cemented internal mold (“steinkern”) was preserved and collected. As the mollusks are scattered in the sand, most specimens were collected from the heaps left behind by the industrial sieving of the sand. Thus, the exact stratigraphic position of the fossils within the sand body was impossible to reconstruct. In spite of this, three stratigraphic units could be distinguished: the lowermost part, the bulk of the sand, and the uppermost part separated from the bulk of the sand by a well-established unconformity surface.

From the lowermost part of the sand, *Congeria partschi* (Plate VII, figure 6) and *Lymnocardium schedelianum* were identified. The former species occurred in abundance in some samples (Plate VIII, figure 5). Species from the bulk of the sand include *Congeria unguicaprae* (Plate VII, figure 4–5), *C. hemiptycha* (Plate VII, figures 1–3), *C. partschi* (Plate VIII, figure 2–3), *C. balatonica* (Plate VIII, figure 1), *Lymnocardium schedelianum* (Plate VIII, figure 10), *L. cf. conjungens* (Plate VIII, figure 9), *L. cf. tucani* (Plate VIII, figures 6–8), *L. cf. proximum*, “*L.*” *carnuntinum*, “*L.*” *aff. danicici* (Plate VIII, figure 5), *Phyllocardium complanatum* (Plate VIII, figure 11), and *Melanopsis cf. fossilis*. The following species were collected from the top of the sand: *Congeria unguicaprae*, *Dreissenomya dactylus* (Plate VIII, figure 4), *Lymnocardium cf. conjungens*, *L. cf. hantkeni*, *Lymnocardium sp.*, and *Melanopsis vindobonensis*.

The composition of the entire fauna recovered from the sand is very similar to that of the classical Vrčín, Karagača creek site in Serbia (PAVLOVIĆ 1927, 1928) and to the littoral Pannonian faunas of Burgenland, Austria (SAUERZOPF 1952, LUEGER 1980, MAGYAR et al. 1999), Medvednica Mts., Croatia (BRUSINA 1892), and Şimleu Basin, Romania (CHIVU et al. 1966, NICORICI & KARÁCSONYI 1983, BARTHA et al. 2021). All the identified species are known from, and most of them are restricted to, littoral sandy deposits. The common occurrence of articulated valves excludes long post-mortem transport of the shells in the shoreface. Gravitational re-deposition of the shells together with the embedding sand from the littoral zone to a deeper depositional environment, however, is conceivable (e.g., BRETT & BAIRD 1986).

## Biostratigraphy and age

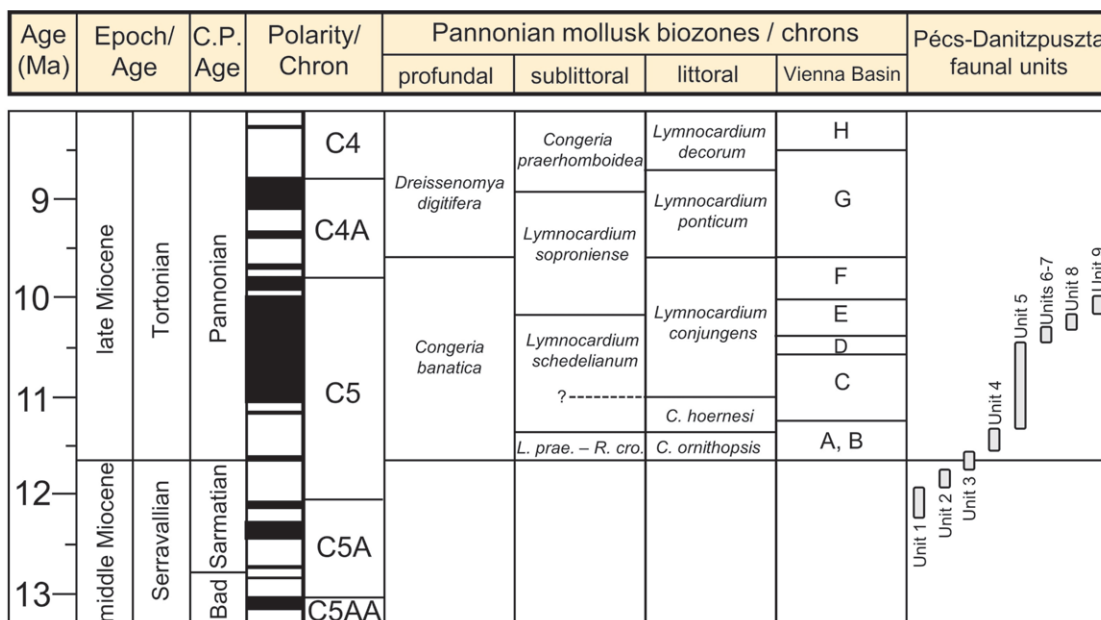
**Unit 1.** The marginal marine mollusk fauna of layers D55 to D47 indicates Sarmatian age (Figure 3).

**Unit 2.** The age of the freshwater fauna from D43–D37 is difficult to assess. *Radix croatica* is a marker fossil of the lowermost Pannonian in the white marls of Croatia and Serbia (e.g., VRSALJKO 1999, VASILIEV et al. 2007, SEBE et al. 2020), but *Radix cf. croatica* occurs here with other freshwater forms but without brackish cardiids. The preservation of the mollusks from these layers does not allow a detailed morphological comparison with their well-established Pannonian counterparts. As the microfauna indicates Sarmatian age (SZUROMI-KORECZ et al. 2021), we assume that these mollusks represent a freshwater Sarmatian fauna, with the probable ancestors of the early Pannonian forms.

**Unit 3.** The mass occurrence of small, mostly “Sarmatian-type” cardiids (D35–D33) at the Sarmatian–Pannonian boundary is a commonly reported phenomenon in the Pannonian Basin, and it is alternately assigned into the uppermost Sarmatian or lowermost Pannonian in the literature (Figure 3).

**Unit 4.** The fauna from layer D12 is attributed to the basal Pannonian “*Lymnocardium*” *praeponticum* Zone, which was interpreted to have an age of 11.6–11.4 Ma (MAGYAR & GEARY 2012; Figure 3).

**Unit 5.** Interval D7–D112 can be correlated with the *C. banatica* Zone, although *Congeria banatica* itself occurs only sporadically. Some of the identified taxa were first described from similar *C. banatica*-bearing white marls in Slavonia (GORJANOVIĆ-KRAMBERGER 1899). The age of the



**Figure 3.** Stratigraphic chart for the late middle Miocene to early late Miocene with the mollusk zones of the Pannonian (according to MAGYAR & GEARY 2012 and HARZHAUSER et al. 2004) and with the biostratigraphic interpretation of the Pécs-Danitzpuszta faunal units.

C. P.: Central Paratethys; Bad: Badenian; *L. prae. - R. cro.*: “*Lymnocardium*” *praeponticum* - *Radix croatica*; C.: *Congeria*

3. ábra. A pécs-danitzpusztai feltáráshoz azonosított puhatestű faunák biosztratógráfiai helyzetének és korának értelmezése. A rétegtani táblázat MAGYAR & GEARY (2012) és HARZHAUSER et al. (2004) alapján készült.

Rövidítések: C. P.: Középső-Paratethys; Bad: badeni; *L. prae. - R. cro.*: “*Lymnocardium*” *praeponticum* - *Radix croatica*; C.: *Congeria*

*C. banatica* Zone is estimated between 11.4–9.7 Ma (MAGYAR & GEARY 2012; Figure 3).

**Units 6 and 7.** The interval D212–D215 contains species (*Congeria partschi firmocarinata* and *Unio atavus*) that were interpreted as markers of “Zone E” by PAPP (1951, 1953), similarly to some species of the overlying Unit 8 (Figure 3).

**Unit 8.** The mollusk assemblage from D219 to D226 belongs to the *Lymnocardium schedelianum* Zone, the age of which was constrained between 11.0 and 10.2 Ma by MAGYAR & GEARY (2012). The diverse fauna of this interval resembles the fauna of Hengersdorf in the Vienna Basin (PAPP 1953) and that of Câmpia and Nicolinți in southern Banat (HALAVÁTS 1882, 1886). Based on astronomically tuned logs, the age of the carefully studied Hengersdorf outcrop was given as 10.4–10.3 or 10.5–10.4 Ma (“Zone E;” HARZHAUSER et al. 2004 and HARZHAUSER et al. 2013, respectively). As to the age of the Câmpia and Nicolinți faunas, they are placed stratigraphically above the *Valenciennius*-bearing Ciuchici (“Csukics”) outcrop (HALAVÁTS 1886, MARINESCU et al. 1977); therefore, they must be younger than the first appearance datum of *Valenciennius* (9.6–9.7 Ma or slightly older; see CZICZER et al. 2009). There are two lines of evidence, however, which suggest that the Pécs-Danitzpuszta fauna should be older than the Câmpia and Nicolinți mollusks. First, *L. aff. boeckhi* from Pécs-Danitzpuszta strongly resembles *L. boeckhi* from Câmpia, but the pentagonal rib cross-section and the straight anterior edge of the valve are less pronounced and less stable patterns in the former. Considering the mode of evolution in several cardiid lineages in Lake Pannon (MÜLLER & MAGYAR 1992, GEARY et al. 2010), it seems reasonable to suppose that the Pécs-Danitzpuszta form might represent the ancestral, less developed state of *L. boeckhi*. Second, the ostracod assemblages from Câmpia contain a lot of newly appearing, “Pontian-type” species (OLTEANU 1989, 2011), whereas the Pécs-Danitzpuszta fauna seems to belong to the older *Amplocypris abscissa* Zone (CSOMA et al. 2021), similarly to the Hengersdorf locality (DANIELOPOL et al. 2011). Considering the above arguments, the age of Unit 8 most probably falls between 10.5 and 10.2 Ma (Figure 3).

**Unit 9.** The littoral fauna of the overlying sand is very similar to the fauna that PAVLOVIĆ (1927, 1928) described from Serbia and to the Pannonian faunas of Burgenland, Austria, both belonging to the upper part of the *Lymnocardium conjungens* Zone (ca. 10.2–9.6 Ma; MAGYAR & GEARY 2012). Considering that the sand directly overlies the at least 10.2 Ma old marl succession, the best estimate for the age of the sand body is 10.2–10.0 Ma (Figure 3). The only species in the sand whose known stratigraphic range is not conform with this interpretation is *Dreissenomya dactylus*; it was described from the “*Congeria balatonica* Beds” (*L. decorum* Zone; Figure 3) of Lake Balaton, with a first known appearance in the *L. ponticum* Zone. The specimens from Pécs-Danitzpuszta reveal, however, that this form is identical with *D. lithodomiformis* PAVLOVIĆ (1927) from

Vrčín; thus, the known life span of *D. dactylus* has to be extended to ca. 10.2–8.1 Ma (see Appendix).

## Discussion

There are two peculiarities in the facies order and timing in the Pécs-Danitzpuszta outcrop that make this succession unique: the occurrence of a freshwater fauna close to the top of the Sarmatian, and the timing and development of siliclastic sedimentation and faunal change in the upper part of the succession.

In the upper part of the Sarmatian stage, a freshwater unit (Unit 2) overlies restricted marine (Unit 1) deposits. This 3-m-thick freshwater interval contains pulmonate snails (lymnaeids and planorbids), hydrobiids, and neritids. No marine or brackish-water forms occur in these layers. The next fossiliferous unit (Unit 3), however, is almost completely devoid of snails (apart from a few hydrobiids), and contains an abundance of various small cardiid. Cardiid have marine origin and they occur in freshwater only extremely rarely. Thus, Unit 3 can be interpreted as having deposited in brackish water. The fauna of Unit 4 contains both pulmonate snails, similar to (and partly identical with?) the species of Unit 2, and some small cardiid, again similar to the species in Unit 3. The common occurrence of originally freshwater pulmonates (lymnaeids and planorbids) and brackish-water cardiid in these lowermost Pannonian layers is a source of controversy in environmental interpretation (SEBE et al. 2020). A possible scenario is that the salinity of the Sarmatian seawater decreased to such an extent that it exerted stress on marine cardiid and, at the same time, allowed freshwater pulmonates to enter the brackish lake. The cardiid responded by adopting r-strategy (e.g., MONTES et al. 2020), whereas the pulmonates took advantage of their ability to survive in waters of up to 10–11 psu salinity (*Stagnicola palustris*, *Radix ovata*, and *Lymnaea stagnalis* are recent examples from the bays of the Åland Islands in the Baltic Sea; CARLSSON 2006). All these faunal changes from Unit 1 to 4 took place under relatively stable conditions in the depositional environment, where clay and limestone layers formed alternately.

The bulk of the Pécs-Danitzpuszta section consists of white or light grey calcareous marls with mollusks that are widespread in the southern part of the Pannonian Basin and can be studied in surface outcrops in the Croatian and Serbian parts of the basin. These marls were deposited in the profundal zone of Lake Pannon, away from the entry points of intense clastic input, under slow sedimentation rates. Deposition of these marls lasted as long as favorable conditions prevailed. The top of the marl was subsequently eroded in the outcrops of Beočin, Serbia (TER BORGH et al. 2013) and Našice, Croatia (VASILIEV et al. 2007); the age of the uppermost layers preserved below the unconformity is 9.9 Ma in Beočin based on magnetostratigraphy (TER BORGH et al. 2013) and less than 8 Ma in Našice based on dinoflagellate stratigraphy (BARANYI, pers. comm.). In contrast, in Pécs-Danitzpuszta, the marl is capped with the 10.5–10.2 Ma old sublittoral *Lymnocardium*

um *schedelianum* Zone (Unit 8); the deposition of the distal marls thus ended here much earlier than in the Croatian and Serbian localities. Finally, the overlying littoral fauna that represents the upper part of the *Lymnocardium conjungens* Zone has been known elsewhere from above the sublittoral *Lymnocardium soproniense* Zone (10.2–8.9 Ma; in Burgenland, MAGYAR et al. (1999) and in the Šimleu Basin, BARTHA et al. 2021), or directly from above pre-Neogene basement (PAVLOVIĆ 1927, 1928), but never from above the *L. schedelianum* Zone. The Pécs-Danitzpuszta faunal succession thus testifies a temporal overlap between the *Congerina banatica* Zone deposited in the profundal depth of Lake Pannon, the *Lymnocardium schedelianum* Zone representing sublittoral sedimentation, and the upper part of the *Lymnocardium conjungens* Zone that formed in shallow, littoral waters of the lake.

### Conclusions

Deposition of the Sarmatian–Pannonian succession at the foot of an intrabasinal basement high, the Mecsek Mts, was controlled by local tectonic and sedimentary processes that overprinted the regional trends. As a consequence, this succession offers a unique opportunity to correlate various mollusk assemblages that do not usually occur in a single vertical succession or in close proximity to each other in other parts of the Pannonian Basin.

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### References – Irodalom

- ANDRUSOV, N. I. 1903: Studien über die Brackwassercardiden. Lieferung 1. – *Mémoires de l'Académie Impériale des Sciences de St.-Petersbourg*, VIIIe Série, Classe physico-mathématique **13**, 1–82.
- BARTHA F. 1959: Finomrétegtani vizsgálatok a Balaton környéki felső-pannon képződményeken. (Feinstratigraphische Untersuchungen am Oberpannon der Balatongegend.) – *Annals of the Hungarian Geological Institute* **48**, 1–191.
- BARTHA F. 1964: A Mecsekhegység és tágabb környéke pannon üledékeinek biosztratigráfiai vizsgálata. (Biostratigraphische Untersuchung der pannonischem Ablagerungen des Mecsek-Gebirges und seiner weiteren Umgebung.) – *Annual Report of the Hungarian Geological Institute of 1961*, 175–183. (in Hungarian with German and Russian abstracts)
- BARTHA, F. 1966: Examen biostratigraphique des couches pannoniennes de la montagne Mecsek. – *Acta Geologica* **10**, 159–194.
- BARTHA, I. R., BOTKA, D., CSOMA, V., KATONA, L. T., TÓTH, E., MAGYAR, I., SILYE, L. & SZTANÓ, O. 2021: From marginal outcrops to basin interior: a new perspective on the sedimentary evolution of the eastern Pannonian basin. – *International Journal of Earth Sciences*, in press.
- BASCH, O. 1990: Die Molluskenfauna der pontischen Stufe in Kroatien. – In: STEVANOVIĆ, P. M., NEVESSKAJA, L. A., MARINESCU, F., SOKAČ, A. & JÁMBOR, Á. (eds): *Chronostratigraphie und Neostratotypen. Neogen der Westlichen ("Zentrale") Paratethys VIII, P11, Pontien*. JAZU and SANU, Zagreb–Beograd, 538–557.
- BASCH, O. & ŽAGAR-SAKAČ, A. 1992: Dreissenidae (Mollusca, Lamellibranchiata) pontskoga kata u Hrvatskoj. Dreissenidae (Mollusca, Lamellibranchiata) der Pontischen Stufe in Kroatien. – *Hrvatska Akademija Znanosti i Umjetnosti, Acta Geologica* **22**, 1–96.
- BÓNA, J. & GÁL, M. 1985: Kalkiges Nannoplankton im Pannonien Ungarns. – In: PAPP, A., JÁMBOR, Á. & STEININGER, F. F. (eds): *Chronostratigraphie und Neostratotypen, M6 Pannonien (Slavonien und Serbien)*. Akadémiai Kiadó, Budapest, 482–515.
- BÓNA J. & GÁL M. 1987: A kunsági (pannóniai s. str.) emeletbe tartozó képződmények nannoplanktonja Magyarországon. – In: Jámbor Á. (szerk.): A magyarországi kunsági emeletbeli képződmények földtani jellemzése. *Annals of the Hungarian Geological Institute* **69**, 229–258.
- BOTKA, D., MAGYAR, I., CSOMA, V., TÓTH, E., ŠUJAN, M., RUSZKICZAY-RÜDIGER, Zs., CHYBA, A., BRAUCHER, R., SANT, K., ČORIĆ, S., BARANYI, V., BAKRAČ, K., KRIZMANIĆ, K., BARTHA, I. R., SZABÓ, M. & SILYE, L. 2019: Integrated stratigraphy of the Gușterița clay pit: a key section for the early Pannonian (late Miocene) of the Transylvanian Basin (Romania). – *Austrian Journal of Earth Sciences* **112**, 221–247. <https://doi.org/10.17738/ajes.2019.0013>



- BRETT, C. E. & BAIRD, G. C. 1986: Comparative taphonomy: a key to paleoenvironmental interpretation based on fossil preservation. – *Palaios* **1**, 207–227.
- BRUSINA, S. 1892: Fauna fossile terziaria Markuševac in Croazia. – *Glasnik hrvatskoga naravoslovnoga društva* **7**, 113–210.
- BRUSINA, S. 1894: Note préliminaire sur le groupe des *Aphanotylus*, nouveau genre de Gastropode de l'horizon à *Lyrcaea*, et sur quelques autres espèces nouvelles de Hongrie. – *Glasnik Hrvatskoga naravoslovnoga društva* **6**, 241–248.
- BRUSINA, S. 1902: Iconographia molluscorum fossilium in tellure Tertiaria (Hungariae, Croatiae, Slavoniae, Dalmatiae, Bosniae, Herzegovinae, Serbiae et Bulgariae inventorum.), Atlas II, *Plates* 1–30, Zagreb.
- CARLSSON, R. 2006: Freshwater snail assemblages of semi-isolated brackish water bays on the Åland Islands, SW Finland. – *Boreal Environment Research*, **11**, 371–382.
- CHIVU, M., VALENTINA, V., ENACHE, G., ISAC, D. & MĂRGĂRIT, E. 1966: Contribuții la stratigrafia Neogenului din bazinul Silvaniei. Geological research in the Sylvania Basin. – *Dări de seamă ale ședințelor, Comitetul Geologic* **52**, 239–254. (in Romanian with English abstract and French summary)
- CZICZER, I., MAGYAR, I., PIPÍK, R., BÖHME, M., ČORIĆ, S., BAKRAČ, K., SÜTŐ-SZENTAI, M., LANTOS, M., BABINSZKI, E. & MÜLLER, P. 2009: Life in the sublittoral zone of long-lived Lake Pannon: paleontological analysis of the Upper Miocene Szák Formation, Hungary. – *International Journal of Earth Sciences* **98**, 1741–1766. <https://doi.org/10.1007/s00531-008-0322-3>
- CSOMA, V., MAGYAR, I., SZUROMI-KOPECZ, A., SEBE, K., SZTANÓ, O., BUCZKÓ, K. & TÓTH, E. 2021: Pannonian (late Miocene) ostracod fauna from Pécs-Danitzpuszta in Southern Hungary. – *Földtani Közlöny* **151/3**, 305–326.
- DANIELOPOL, D. L., GROSS, M., HARZHAUSER, M., MINATI, K. & PILLER, W. E. 2011: How and why to achieve greater objectivity in taxonomy, exemplified by a fossil ostracod (*Amplocypris abscissa*) from the Miocene Lake Pannon. – *Joannea Geologie & Paläontologie* **11**, 273–326.
- DULAI, A., HENN, T. & SEBE, K. 2021: Middle Miocene (Badenian) macroinvertebrates from Pécs-Danitzpuszta (Mecsek Mts., SW Hungary). – *Földtani Közlöny* **151/4**, 329–334.
- EBERZIN, A. G. 1947: *Rod Limnocardium Stoliczka v plioštene ponto-kaspiskogo basseina*. – Akademiia Nauk SSSR, Trudy Paleontologicheskogo Instituta **13**, 1–156. (in Russian)
- FUCHS, TH. 1870: Beiträge zur Kenntnis fossiler Binnenfaunen 4 und 5: Die Fauna der Congerenschichten von Tihany am Plattensee und Kúp bei Pápa in Ungarn. – *Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt* **20**, 531–548.
- GANIĆ, M., RUNDIĆ, L. J., KNEZEVIĆ, S. & CVETKOV, V. 2010: The Upper Miocene Lake Pannon marl from the Filijala Open Pit (Beočin, northern Serbia): new geological and paleomagnetic data. – *Annales Géologiques de la Péninsule Balkanique* **71**, 95–108.
- GEARY, D. H., HUNT, G., MAGYAR, I. & SCHREIBER, H. 2010: The paradox of gradualism: phyletic evolution in two lineages of limnocardiid bivalves (Lake Pannon, central Europe). – *Paleobiology* **36**, 592–614. <https://doi.org/10.1666/08065.1>
- GORJANOVIĆ-KRAMBERGER, K. 1890: Die praepontischen Bildungen des Agramer Gebirges. – *Glasnik hrvatskoga naravoslovnoga društva* **5**, 151–163.
- GORJANOVIĆ-KRAMBERGER, K. 1899: Die Fauna der unterpontischen Bildungen um Londjica in Slavonien. – *Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt* **49**, 125–134.
- HALAVÁTS GY. 1882: Őslénytani adatok Délmagyarország neogén korú üledékei faunájának ismeretéhez. I. A langensfeldi pontusi korú fauna. – *A Magyar Királyi Földtani Intézet Évkönyve* **4**, 147–156.
- HALAVÁTS GY. 1886: Őslénytani adatok Délmagyarország neogén korú üledékei faunájának ismeretéhez. II–V. – *A Magyar Királyi Földtani Intézet Évkönyve* **8**, 119–135.
- HALAVÁTS GY. 1902: A balatonmelléki pontusi korú rétegek faunája. – In: *A Balaton tudományos tanulmányozásának eredményei* 1/1, Őslénytani függelék 4/2, Budapest, 74 p.
- HARZHAUSER, M. & MANDIC, O. 2004: The muddy bottom of Lake Pannon – a challenge for dreissenid settlement (Late Miocene; Bivalvia). – *Palaeogeography, Palaeoclimatology, Palaeoecology* **204**, 331–352. [https://doi.org/10.1016/S0031-0182\(03\)00735-1](https://doi.org/10.1016/S0031-0182(03)00735-1)
- HARZHAUSER, M., DAXNER-HÖCK, G., PILLER, W. E. 2004: An integrated stratigraphy of the Pannonian (Late Miocene) in the Vienna Basin. – *Austrian Journal of Earth Sciences* **95–96**, 6–19.
- HARZHAUSER, M., LATAL, C. & PILLER, W. E. 2007: The stable isotope archive of Lake Pannon as a mirror of Late Miocene climate change. – *Palaeogeography, Palaeoclimatology, Palaeoecology* **249**, 335–350. <https://doi.org/10.1016/j.palaeo.2007.02.006>
- HARZHAUSER, M., MANDIC, O., KERN, A. K., PILLER, W. E., NEUBAUER, T. A., ALBRECHT, C. & WILKE, T. 2013: Explosive demographic expansion by dreissenid bivalves as a possible result of astronomical forcing. – *Biogeosciences Discussions* **10**, 12009–12027. <https://doi.org/10.5194/bgd-10-12009-2013>
- HÖRNES, M. 1862: *Die fossilen Mollusken des tertiär-Beckens von Wien. Conchifera (Acephala)* **2**, 479 p.
- JÁMBOR, Á., KÖRPÁS-HÓDI, M., SZÉLES, M. & SÜTŐ-SZENTAI, M. 1985: Zentrales Mittleres Donaubecken: Bohrung Lajoskomárom Lk-1, S-Balaton. – In: PAPP, A., JÁMBOR, Á. & STEININGER, F. F. (eds): *Chronostratigraphie und Neostatotypen. Miozän der Zentralen Paratethys VII, M6, Pannonien*. Akadémiai Kiadó, Budapest, 204–241.
- JÁMBOR, Á., KÖRPÁS-HÓDI, M., SZÉLES, M. & SÜTŐ-SZENTAI, M. 1987: A kunsági (pannóniai s. str.) emelet magyarországi faciessztrató-típusának jellemzése. – In: JÁMBOR, Á. (szerk.): *A magyarországi kunsági emeletbeli képződmények földtani jellemzése. Annals of the Hungarian Geological Institute* **69**, 37–93.
- JEKELIUS, E. 1944: Sarmat und Pont von Soceni (Banat). – *Memoriile Institutului Geologic al Romaniei* **5**, 1–167.
- KATONA L., MAGYAR I., BERTA T., VARGA A. & SZTANÓ O. 2015: Pannóniai puhatestű fauna a Fűzfői-öböl környékének két feltárásából. Pannonian mollusc fauna from two outcrops near Balatonfűzfő. – *Földtani Közlöny* **145**, 127–150. (in Hungarian with English abstract)
- KAZÁR, E., KORDOS L. & SZÓNOKY M. 2007: Danitz-puszta, homokbánya, pannóniai emelet. – In: PÁLFY J. & PAZONYI P. (szerk.): *Őslénytani kirándulások Magyarországon és Erdélyben*. Hantken Kiadó, Budapest, 131–132.

- KITTL, E. 1886: Ueber die miocenen Pteropoden von Oesterreich-Ungarn. – *Annalen des k.k. Naturhistorischen Hofmuseums* **1**, 4–74.
- KLEB B. 1968: A Mecsek-hegység déli előtere pannóniai képződményeinek üledékföldtani vizsgálata. (Sedimentologische Untersuchungen der pannonischen Ablagerungen im südlichen Vorlande des Mecsekgebirges.) – *Földtani Közlöny* **98**, 335–359. (in Hungarian with German abstract)
- KLEB B. 1973: A mecseki pannon földtana. (Geologie des Pannons im Mecsek.) – *Annals of the Hungarian Geological Institute* **53**, 747–943.
- KORPÁS-HÓDI M. 1983: A Dunántúli-középhegység északi előtere pannóniai mollusca faunájának paleoökológiai és biosztratigráfiai vizsgálata. (Palaeoecology and biostratigraphy of the Pannonian mollusca fauna in the Northern Foreland of the Transdanubian Central Range.) – *Annals of the Hungarian Geological Institute* **66**, 1–163.
- LŐRENTHEY I. 1893: Szilágymegye és az erdélyi részek alsó pontusi lerakódásainak ismeretéhez. – *Értesítő az Erdélyi Múzeum-Egylet Orvos-Természettudományi Szakosztályából II Természettudományi Szak* **18**, 195–230.
- LŐRENTHEY, E. 1902: Die Pannonische Fauna von Budapest. – *Palaeontographica* **48**, 137–294.
- LŐRENTHEY I. 1903: Néhány megjegyzés az *Orygoceras Fuchsi* Kittl sp.-ről. – *Földtani Közlöny* **33**, 470–472.
- LŐRENTHEY I. 1905: Adatok a Balaton melléki pannóniai korú rétegek faunájához és stratigrafiai helyzetéhez. – In: *A Balaton tudományos tanulmányozásának eredményei 1/1*, Óslénytani függelék 4/3, Budapest, 193 p.
- LUBENESCU, V. 1981: Studiul biostratigrafic al neogenului superior din sud-vestul Transilvaniei. Biostratigraphic study of the Upper Neogene in the South-West of Transylvania. – *Anuarul Institutului de Geologie și Geofizică* **63**, 123–202. (in Romanian with English abstract and French summary)
- LUBENESCU, V. & LUBENESCU, D. 1977: Observații biostratigrafice asupra pannonianului de la Lopadea Veche (Depresiunea Transilvaniei). [Biostratigraphic observations on the Lopadea Veche Pannonian (Transylvania Depression)]. – *Dări de Seamă ale Ședințelor* **63**, 57–64. (in Romanian with English and French abstracts)
- LUBENESCU, V. & POPESCU, A. 1984: Une nouvelle espèce de *Congerina* au Pannonien sens restreint (=Malvensien) de la Dépression de Transylvanie. – *Dări de seamă ale ședințelor*, **69**, 25–28.
- LUEGER, J. P. 1980: Die Molluskenfauna aus dem Pannon (Obermiozän) des Fölligberges (Eisenstädter Bucht) im Burgenland (Österreich). – *Mitteilungen der Österreichischen Geologischen Gesellschaft* **73**, 95–134.
- MAGYAR I. 2010: *A Pannon-medence ősföldrajza és környezeti viszonyai a késő miocénben. (Paleogeography and environment in the Pannonian Basin during the late Miocene)*. – Geolitera, SZTE TTIK Földrajzi és Földtani Tanszéksoport, Szeged, 140 p. (in Hungarian)
- MAGYAR, I. & GEARY, D. H. 2012: Biostratigraphy in a late Neogene Caspian-type lacustrine basin: Lake Pannon, Hungary. – In: BAGANZ, O. W., BARTOV, Y., BOHACS, K. & NUMMEDAL, D. (eds): Lacustrine sandstone reservoirs and hydrocarbon systems. – *American Association of Petroleum Geologists Memoir* **95**, 255–264. <https://doi.org/10.1306/13291392M953142>
- MAGYAR, I., MÜLLER, P., GEARY, D. H., SANDERS, H. C. & TARI, G. C. 1999: Diachronous deposits of Lake Pannon in the Kisalföld basin reflect basin and mollusc evolution. – *Abhandlungen der Geologischen Bundesanstalt* **56**, 669–678.
- MAGYAR, I., CZICZER, I., SZTANÓ, O., DÁVID, Á. & JOHNSON, M. 2016: Palaeobiology, palaeoecology and stratigraphic significance of the Late Miocene cockle *Lymnocardium soproniense* from Lake Pannon. – *Geologica Carpathica* **67**, 561–571. <https://doi.org/10.1515/geoca-2016-0035>
- MARINESCU, F. L., OLTEANU, R., ROGGE-ȚĂRANU, E. & POPESCU, A. 1977: Le Pannonien du Banat. – *Dări de seamă ale ședințelor*, 4. Stratigrafie **63**, 65–133.
- MILAN, A., SAKAČ, K. & ŽAGAR-SAKAČ, A. 1974: *Katalog originala tipova vrsta pohranjenih u geolosko-paleontoloskom muzeju u Zagrebu. Katalog der im Geologisch-paläontologischen Museum in Zagreb aufbewahrten Originale von Artentypen*. – Geološko-Paleontološki Muzej u Zagrebu, Zagreb, 186 p.
- MONTES, A., OLABARRIA, C. & VÁZQUEZ, E. 2020: Reproductive plasticity in the invasive *Xenostrobus securis* (Bivalvia: Mytiloidea) in northwestern Spain. – *Journal of Sea Research* **159**, 101893. <https://doi.org/10.1016/j.seares.2020.101893>
- MOOS, A. 1944: Neue Funde von Lymnaeiden, insbesondere von Valenciennesiiden im Pannon Kroatiens. – *Geološki vjesnik* **2**, 343–390.
- MÜLLER, P. & MAGYAR, I. 1992: Continuous record of the evolution of lacustrine cardiid bivalves in the late Miocene Pannonian Lake. – *Acta Palaeontologica Polonica* **36**, 353–372.
- MÜLLER, P. & SZÓNOKY, M. 1990: Faciostratotype the Tihany-Fehérszék (Hungary) (“Balatonica Beds”, by Lőrenthey, 1905). – In: STEVANOVIĆ, P., NEVESSKAJA, L. A., MARINESCU, F. L., SOKAČ, A. & JÁMBOR, Á. (eds): *Chronostratigraphie und Neostratotypen, Neogen der Westlichen (“Zentrale”) Paratethys, VIII, P11 Pontien*. JAZU and SANU, Zagreb–Beograd, 427–435.
- NICORICI, E. & KARÁCSONYI, C. 1983: La faune pannonicienne de Nădișul Hododului (Bassin Șimleu) et sa signification stratigraphique. – *Memoriile Secțiilor Științifice* **4**, 227–233. (in Romanian with French abstract)
- OLTEANU, R. 1989: The “Cimpia Moment” (late Miocene, Romania) and the Pannonian–Pontian boundary, defined by ostracods. – *Journal of Micropalaeontology* **8**, 239–247.
- OLTEANU, R. 2011: Atlas of the Pannonian and Pontian ostracods from the eastern area of the Pannonian basin. – *Geo-Eco-Marina* **17**, 135–177.
- PAPP, A. 1951: Das Pannon des Wiener Beckens. – *Mitteilungen der Geologischen Gesellschaft in Wien* **39–41**, 99–193.
- PAPP, A. 1953: Die Molluskenfauna des Pannon im Wiener Becken. – *Mitteilungen der Geologischen Gesellschaft in Wien* **44**, 85–222.
- PAPP, A. 1956: Paläontologische Beobachtungen im Pannon von Podsused bei Zagreb. – *Geološki vjesnik* **8–9**, 67–79.
- PAPP, A. 1985: Gastropoda (Neritidae, Viviparidae, Valvatidae, Hydrobiidae, Stenothyridae, Truncatellidae, Bulimidae, Micromelaniidae, Thiariidae) und Bivalvia (Dreissenidae, Lymnocardiiidae, Unionidae) des Pannonien. – In: PAPP, A., JÁMBOR, Á. & STEININGER, F. (eds): *Chronostratigraphie und Neostratotypen, M6 Pannonien (Slavonien und Serbien)*. Akadémiai Kiadó, Budapest, 276–339.
- PAVLOVIĆ, P. S. 1927: *Donjopontiski mekushtsi iz okoline Beograda*. – Serbian Royal Academy, Belgrade, 121 p.

- PAVLOVIĆ, P. S. 1928: Les mollusques du pontien inférieur des environs de Beograd. – *Annales géologiques de la Péninsule Balkanique* **9**, 1–74. (French translation of PAVLOVIĆ 1927)
- RUNDIĆ, L. J., GANIĆ, M., KNEŽEVIĆ, S. L. & SOLIMAN, A. 2011: Upper Miocene Pannonian sediments from Belgrade (Serbia): new evidence and paleoenvironmental considerations. – *Geologica Carpathica* **62**, 267–278. <https://doi.org/10.2478/v10096-011-0021-z>
- RUSZKICZAY-RÜDIGER, ZS., BALÁZS, A., CSILLAG, G., DRIJKONINGEN, G. & FODOR, L. 2020: Uplift of the Transdanubian Range, Pannonian Basin: How fast and why? – *Global and Planetary Change* **192**, 103263. <https://doi.org/10.1016/j.gloplacha.2020.103263>
- SAUERZOPF, F. 1952: Beitrag zur Entwicklungsgeschichte des südburgenländischen Pannons. – *Burgenländische Heimatblätter* **14**, 1–16.
- SCHULTZ, O. 2003: *Catalogus Fossilium Austriae, Band 1/Teil 2: Bivalvia neogenica (Lucinoidea-Mactroidea)*. – Austrian Academy of Sciences Press, X + 310 p., 39 Plates, ISBN 3-7001-3180-X
- SCHULTZ, O. 2005: *Catalogus Fossilium Austriae, Band 1/Teil 3: Bivalvia neogenica (Solenioidea-Clavagelloidea)*. – Austrian Academy of Sciences Press, V + 522 p., 57 Plates, 51 text-figures, ISBN 3-7001-3499-1
- SEBE, K., KOVAČIĆ, M., MAGYAR, I., KRIZMANIĆ, K., ŠPELIĆ, M., BIGUNAC, D., SÜTŐ-SZENTAI, M., KOVÁCS, Á., SZUROMI-KORECZ, A., BAKRAČ, K., HAJEK-TADESSE, V., TROSKOT-ČORBIĆ, T. & SZTANÓ, O. 2020: Correlation of upper Miocene–Pliocene Lake Pannon deposits across the Drava Basin, Croatia and Hungary. – *Geologia Croatica* **73**, 177–195. <https://doi.org/10.4154/gc.2020.12>
- SEBE, K., KONRÁD, GY. & SZTANÓ, O. 2021: An exceptional surface occurrence: the middle to upper Miocene succession of Pécs-Danitzpuszta (SW Hungary). – *Földtani Közlöny* **151/3**, 235–252.
- SREMAC, J. 1981: Some new and less known species of molluscs of the Croatica-Beds and the Banatica-Beds in northern Croatia. – *Geološki vjesnik* **33**, 107–121.
- STEVANOVIĆ, P. 1980: Neue Beiträge zur Stratigraphie und Paläontologie der maecotischen und pannonischen Stufe in Serbien und Bosnien. – *Annales géologiques de la Péninsule Balkanique* **43–44**, 97–140.
- STEVANOVIĆ, P. & PAPP, A. 1985: Beočin, Syrmien (Jugoslawien). – In: PAPP, A., JÁMBOR, Á. & STEININGER, F. F. (eds): *Chronostratigraphie und Neostatotypen. Miozän der Zentralen Paratethys VII, M6, Pannonien*. Akadémiai Kiadó, Budapest, 250–255.
- SZABÓ, M., KOCSIS, L., BOSNAKOFF, M. & SEBE, K. 2021: A diverse Miocene fish assemblage (Chondrichthyes and Osteichthyes) from the Pécs-Danitzpuszta sand pit (Mecsek Mts., Hungary). – *Földtani Közlöny* **151/4**, 363–410.
- SZTANÓ O., MAGYAR I., SZÓNOKY M., LANTOS M., MÜLLER P., LENKEY L., KATONA L. & CSILLAG G. 2013: A Tihanyi Formáció a Balaton környékén: típusszelvény, képződési körülmények, rétegtani jellemzés. (Tihany Formation in the surroundings of Lake Balaton: type locality, depositional setting and stratigraphy.) – *Földtani Közlöny* **143**, 73–98. (in Hungarian with English abstract)
- SZUROMI-KORECZ, A., MAGYAR, I., SZTANÓ, O., CSOMA, V., BOTKA, D., SEBE, K. & TÓTH, E. 2021: Various marginal marine environments in the Central Paratethys: Late Badenian and Sarmatian (middle Miocene) marine and non-marine microfossils from Pécs-Danitzpuszta, southern Hungary. – *Földtani Közlöny* **151/3**, 275–304.
- TER BORGH, M., VASILIEV, I., STOICA, M., KNEŽEVIĆ, S., MAJENCO, L., KRIJGSMAN, W., RUNDIĆ, L. J. & CLOETINGH, S. 2013: The isolation of the Pannonian basin (Central Paratethys): new constraints from magnetostratigraphy and biostratigraphy. – *Global and Planetary Change* **103**, 99–118. <https://doi.org/10.1016/j.gloplacha.2012.10.001>
- VADÁSZ E. 1953: *Magyarország földtana*. – Akadémiai Kiadó, Budapest, 395 p.
- VASILIEV, I., BAKRAČ, K., KOVAČIĆ, M., ABDUL AZIZ, H. & KRIJGSMAN, W. 2007: Palaeomagnetic results from the Sarmatian/Pannonian boundary in North-Eastern Croatia (Vranović section, Nasice quarry). – *Geologia Croatica* **60**, 151–163.
- VITÁLIS I. 1908: A Tihanyi Fehérpart pliocénkorú rétegsora és faunája. (Die pliozäne Schichtenreihe des Fehérpart bei Tihany und deren Fauna.) – *Földtani Közlöny* **38**, 665–678; 701–716.
- VITÁLIS I. 1915: A „*Congeria dactylus* Brus.” rendszertani helyzete. – *Mathematikai és Természettudományi Értesítő* **33**, 331–338.
- VRŠALJKO, D. 1999: The Pannonian palaeoecology and biostratigraphy of molluscs from Kostanjek – Medvednica Mt., Croatia. – *Geologia Croatica* **52**, 9–27.
- WANEK F. 2016: IV. nap: Tanulmányi kirándulás az Erdélyi-medence harmadidőszaki üledéksorának megismeréséhez. [Day 4: Field trip for an insight into the Tertiary succession of the Transylvanian Basin]. – In: LENGYEL H. (ed.): VI. Kárpát-medencei Összegytemi Terepgyakorlat, Erdélyi-szigethegység, 2016. augusztus 15–21., Torockó. [6th Annual Field Trip of the Youth Committee of the Hungarian Geological Society, Apuseni Mountains, 15–21 August 2016, Rimetea]. – Guidebook, August 2016, Cluj-Napoca, 22–35. (in Hungarian)

### Plate I – I. tábla

Sarmatian mollusks from the Pécs-Danitzpuszta exploratory trench (D55 to D37 interval, Units 1 and 2). 1: Dreissenidae sp., D55; 2: Lymnocardinae sp., D55; 3: Lymnocardinae sp., D47; 4: ?*Lymnaea* sp., D43; 5: *Radix* cf. *croatica*, D43; 6: *Radix* cf. *croatica*, D40; 7: ?*Lymnaea* sp., D39; 8: Planorbidae sp., D37; 9: *Theodoxus* sp., D37; 10: ?*Lymnaea* sp., thin section, 1N, D39; 11: Limestone densely packed with gastropods, mostly hydrobiids, D43; 12: Gastropod and ostracod segments, thin section, 1N, D40; 13: Hydrobiid snail and ostracod segments, thin section, 1N, D39

*Szarmata puhatestűek a pécs-danitzpusztai kutatóárokából (D55-D37, 1. és 2. szakasz). 1: Dreissenidae sp., D55; 2: Lymnocardinae sp., D55; 3: Lymnocardinae sp., D47; 4: ?Lymnaea sp., D43; 5: Radix cf. croatica, D43; 6: Radix cf. croatica, D40; 7: ?Lymnaea sp., D39; 8: Planorbidae sp., D37; 9: Theodoxus sp., D37; 10: ?Lymnaea sp., vékonycsiszolat, 1N, D39; 11: Csigás mészkő, főként Hydrobia-félékkel, D43; 12: Csigá- és kagylósrák-metszetek, vékonycsiszolat, 1N, D40; 13: Hydrobia-féle csiga- és kagylósrák-metszetek, vékonycsiszolat, 1N, D39*

### Plate II – II. tábla

Sarmatian-type mollusks of layer D35 (Unit 3), Pécs-Danitzpuszta, exploratory trench. 1–2: *Inaequicostata* cf. *pia*; 3: ?*Planacardium* sp.; 4: “*Lymnocardium*” cf. *praeponticum*; 5 and 10: *Obsoletiformes* cf. *kaudensis*; 6–8: Lymnocardinae sp.; 9: *Obsoletiformes* cf. *fischeriformis*; 11–12: *Inaequicostata* cf. *nigra*; 13–15: Cardiid bivalves in thin sections, 1N; 16–20: Hydrobiid snails in thin sections, 1N

*Szarmata típusú puhatestűek a D35-ös rétegből (3. szakasz), Pécs-Danitzpuszta, kutatóárok. 1–2: Inaequicostata cf. pia; 3: ?Planacardium sp.; 4: “Lymnocardium” cf. praeponticum; 5 és 10: Obsoletiformes cf. kaudensis; 6–8: Lymnocardinae sp.; 9: Obsoletiformes cf. fischeriformis; 11–12: Inaequicostata cf. nigra; 13–15: Cardium-féle kagylók vékonycsiszolatokban, 1N; 16–20: Hydrobia-féle csigák vékonycsiszolatokban, 1N*

### Plate III – III. tábla

Pannonian mollusks of layer D12 (Unit 4), Pécs-Danitzpuszta, exploratory trench. 1–4: *Congeria* cf. *banatica*; 5: *Congeria* cf. *martonfii*; 6–8: *Congeria* div. sp.; 9: *Congeria* cf. *ramphophora*; 10: *Congeria* cf. *neumayri*; 11–12: “*Lymnocardium*” cf. *praeponticum*; 13–14: *Lymnocardium* sp.; 15: “*Lymnocardium*” cf. *plicataeformis*; 16: Ostracod valve and quartz grains in thin section, 1N; 17–19: *Radix* *croatica*; 20: Hydrobiidae? sp.

*Pannóniai puhatestűek a D12-es rétegből (4. szakasz), Pécs-Danitzpuszta, kutatóárok. 1–4: Congeria cf. banatica; 5: Congeria cf. martonfii; 6–8: Congeria div. sp.; 9: Congeria cf. ramphophora; 10: Congeria cf. neumayri; 11–12: “Lymnocardium” cf. praeponticum; 13–14: Lymnocardium sp.; 15: “Lymnocardium” cf. plicataeformis; 16: Kagylósrák teknő és kvarczszemcsék vékonycsiszolatban, 1N; 17–19: Radix croatica; 20: Hydrobiidae? sp.*

### Plate IV – IV. tábla

Pannonian mollusks of the white marls (D7 to D215 interval, Units 5–7), Pécs-Danitzpuszta sand pit. 1–5: *Paradacna* *abichi*; 6–9: Lymnocardinae sp.; 10–11: “*Lymnocardium*” *margaritaceum*; 12: *Velutinopsis* sp.; 13: *Micromelania* *striata*; 14: *Orygoceras* *brusinae*; 15: *Unio* cf. *atavus*; 16: *Melanopsis* *fossilis*

*Pannóniai puhatestűek a fehér márgából (D7-D215, 5–7. szakasz), pécs-danitzpusztai homokbánya. 1–5: Paradacna abichi; 6–9: Lymnocardinae sp.; 10–11: “Lymnocardium” margaritaceum; 12: Velutinopsis sp.; 13: Micromelania striata; 14: Orygoceras brusinae; 15: Unio cf. atavus; 16: Melanopsis fossilis*

### Plate V – V. tábla

Pannonian mollusks of the silts (D219 to D226 interval, Unit 8), Pécs-Danitzpuszta sand pit. 1: *Congeria* *partschi* *firmocarinata*; 2–3: *Congeria* *zsigmondyi*; 4–7: *Dreissenomya* *primiformis*; 8–11: *Lymnocardium* aff. *boeckhi*; 12–15: *Lymnocardium* *winkleri*

*Pannóniai puhatestűek az aleurolitból (D219-D226, 8. szakasz), pécs-danitzpusztai homokbánya. 1: Congeria partschi firmocarinata; 2–3: Congeria zsigmondyi; 4–7: Dreissenomya primiformis; 8–11: Lymnocardium aff. boeckhi; 12–15: Lymnocardium winkleri*

### Plate VI – VI. tábla

Pannonian mollusks of the silts (D219 to D226 interval, Unit 8), Pécs-Danitzpuszta sand pit. 1–2: *Lymnocardium* *schedelianum*; 3–4: “*Lymnocardium*” *carnuntinum*; 5–7: “*Lymnocardium*” *tegulatum*; 8: “*Lymnocardium*” aff. *danicici*; 9: “*Lymnocardium*” cf. *proximum*; 10–11: *Paradacna* sp.; 12: “*Lymnocardium*” cf. *asperocostatum*; 13: “*Pontalmyra*” *otiophora*; 14 and 16–18: Lymnocardinae sp.; 15: ?*Pseudocatillus* sp.; 19: *Caladacna* aff. *steindachneri*; 20: ?*Phyllocardium* sp.; 21: *Melanopsis* *austriaca*; 22: *Gyraulus* *tenuistriatus*

*Pannóniai puhatestűek az aleurolitból (D219-D226, 8. szakasz), pécs-danitzpusztai homokbánya. 1–2: Lymnocardium schedelianum; 3–4: “Lymnocardium” carnuntinum; 5–7: “Lymnocardium” tegulatum; 8: “Lymnocardium” aff. danicici; 9: “Lymnocardium” cf. proximum; 10–11: Paradacna sp.; 12: “Lymnocardium” cf. asperocostatum; 13: “Pontalmyra” otiophora; 14 and 16–18: Lymnocardinae sp.; 15: ?Pseudocatillus sp.; 19: Caladacna aff. steindachneri; 20: ?Phyllocardium sp.; 21: Melanopsis austriaca; 22: Gyraulus tenuistriatus*

### Plate VII – VII. tábla

Pannonian mollusks of the limonitic sand (Layer D227, Unit 9), Pécs-Danitzpuszta sand pit. 1–3: *Congeria* *hemiptycha*; 4–5: *Congeria* *ungulacprae*; 6: *Congeria* *partschi*

*Pannóniai puhatestűek a limonitos homokból (D227-es réteg, 9. szakasz), pécs-danitzpusztai homokbánya. 1–3: Congeria hemiptycha; 4–5: Congeria unguilacprae; 6: Congeria partschi*

**Plate VIII – VIII. tábla**

Pannonian mollusks of the limonitic sand (Layer D227, Unit 9), Pécs-Danitzpuszta sand pit. 1: *Congeria balatonica*; 2-3: *Congeria partschi*; 4: *Dreissenomya dactylus*; 5: "*Lymnocardium*" aff. *danicici*; 6-8: *Lymnocardium* cf. *tucani*; 9: *Lymnocardium* cf. *conjungens*; 10: *Lymnocardium schedelianum*; 11: *Phyllocardium complanatum*

Pannóniai puhatestűek a limonitos homokból (D227-es réteg, 9. szakasz), pécs-danitzpusztai homokbánya. 1: *Congeria balatonica*; 2-3: *Congeria partschi*; 4: *Dreissenomya dactylus*; 5: "*Lymnocardium*" aff. *danicici*; 6-8: *Lymnocardium* cf. *tucani*; 9: *Lymnocardium* cf. *conjungens*; 10: *Lymnocardium schedelianum*; 11: *Phyllocardium complanatum*

Plate I – I. tábla

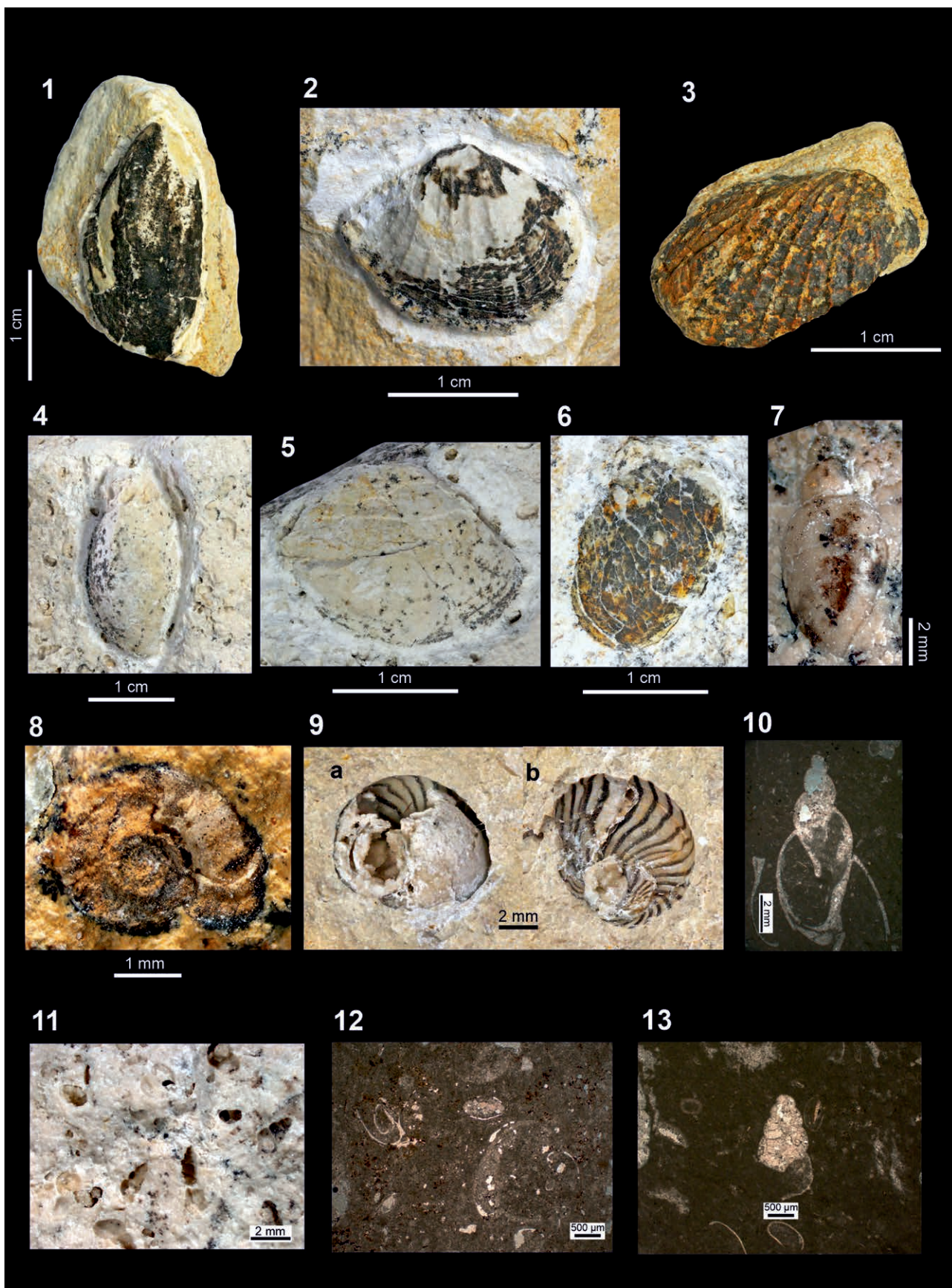
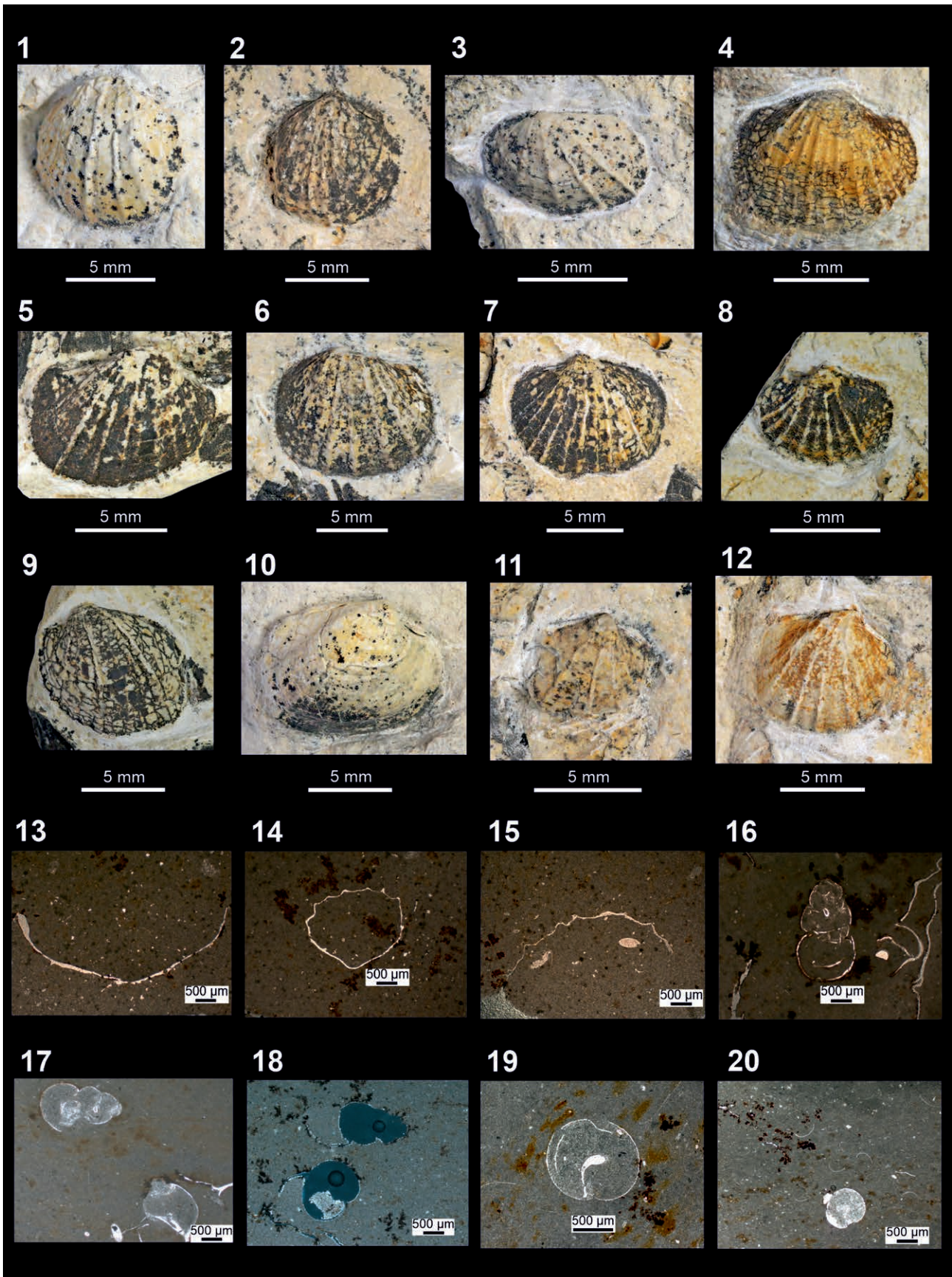


Plate II – II. tábla



## Plate III – III. tábla

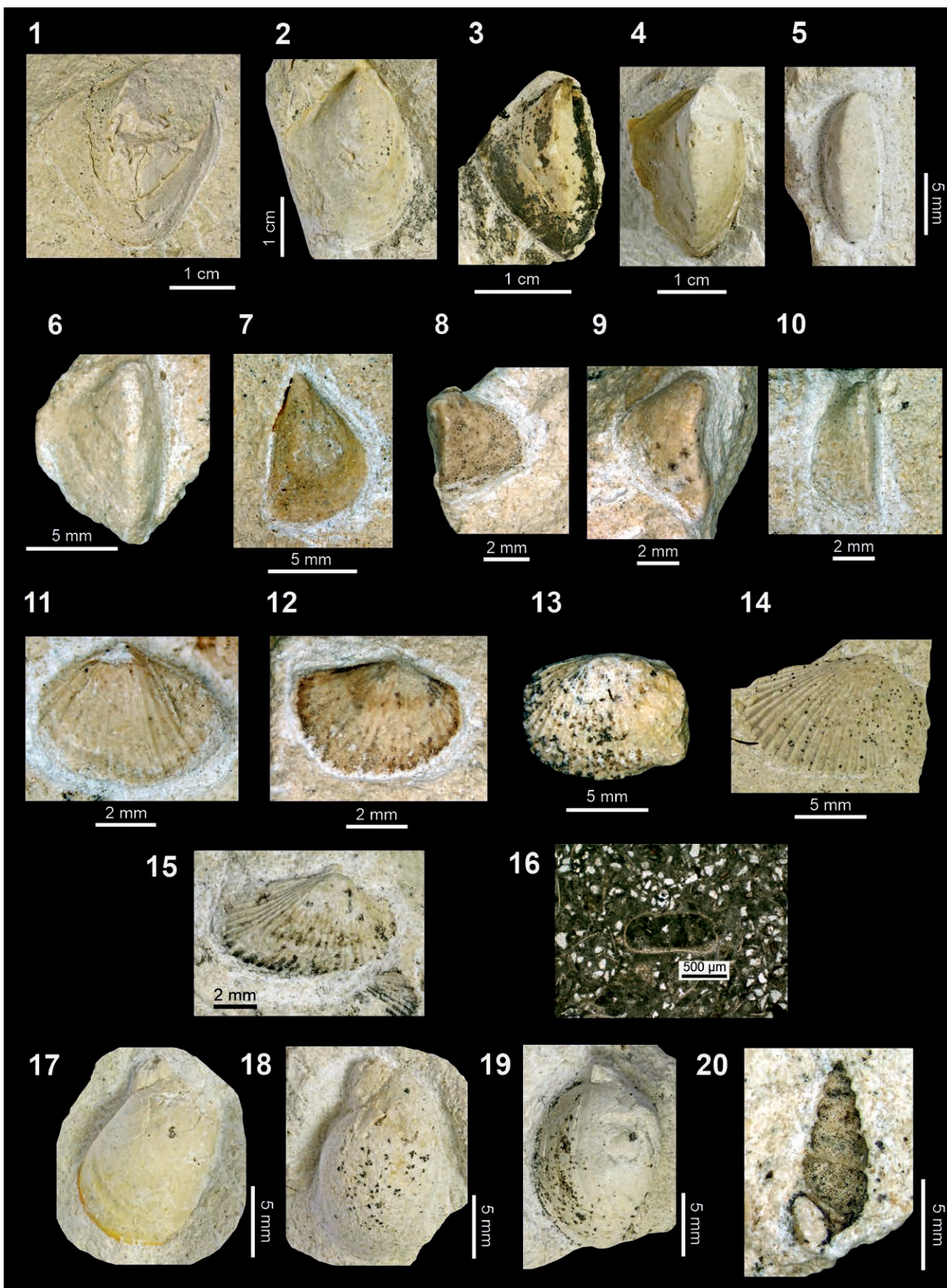




Plate IV – IV. tábla

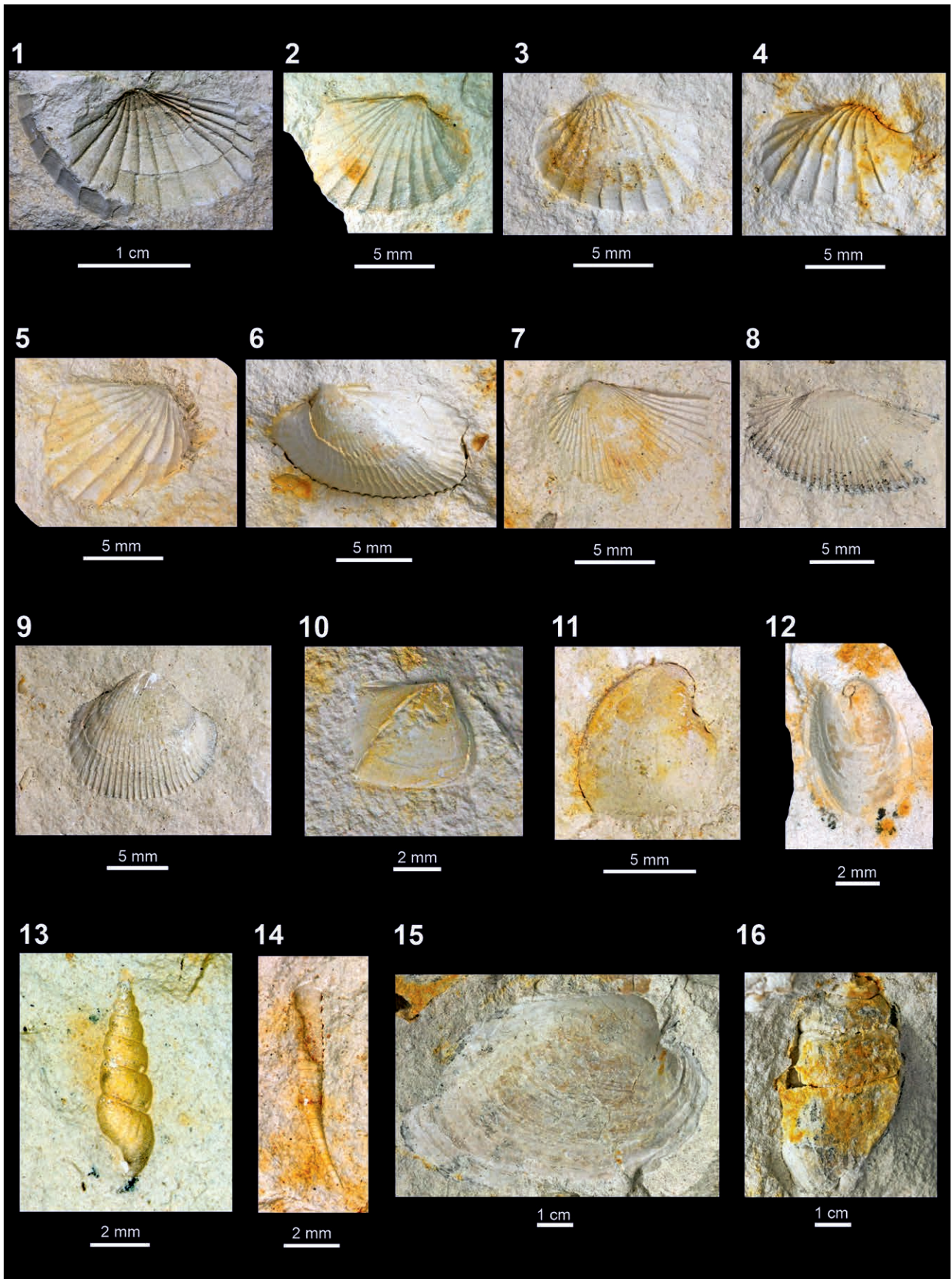


Plate V – V. tábla

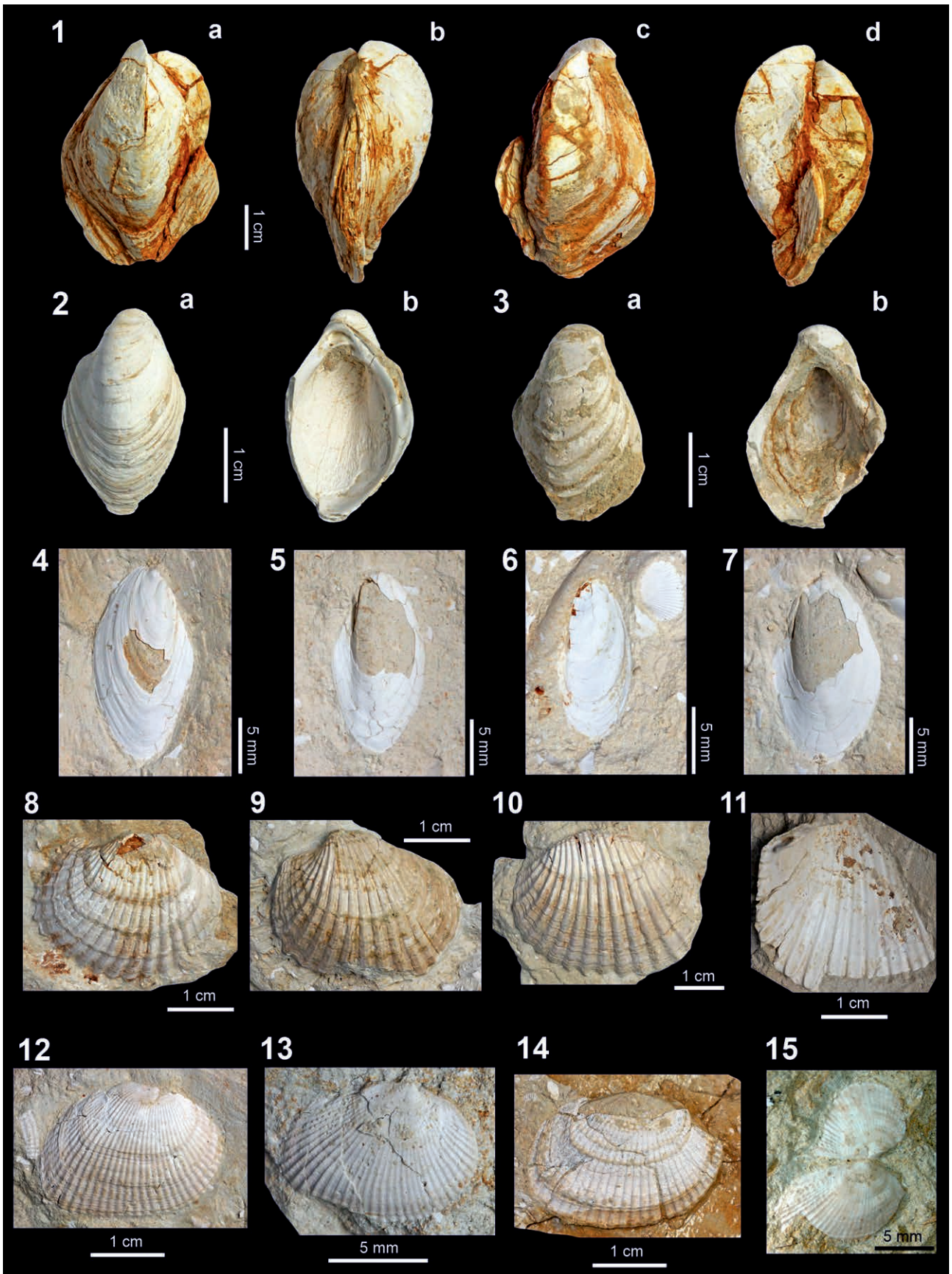
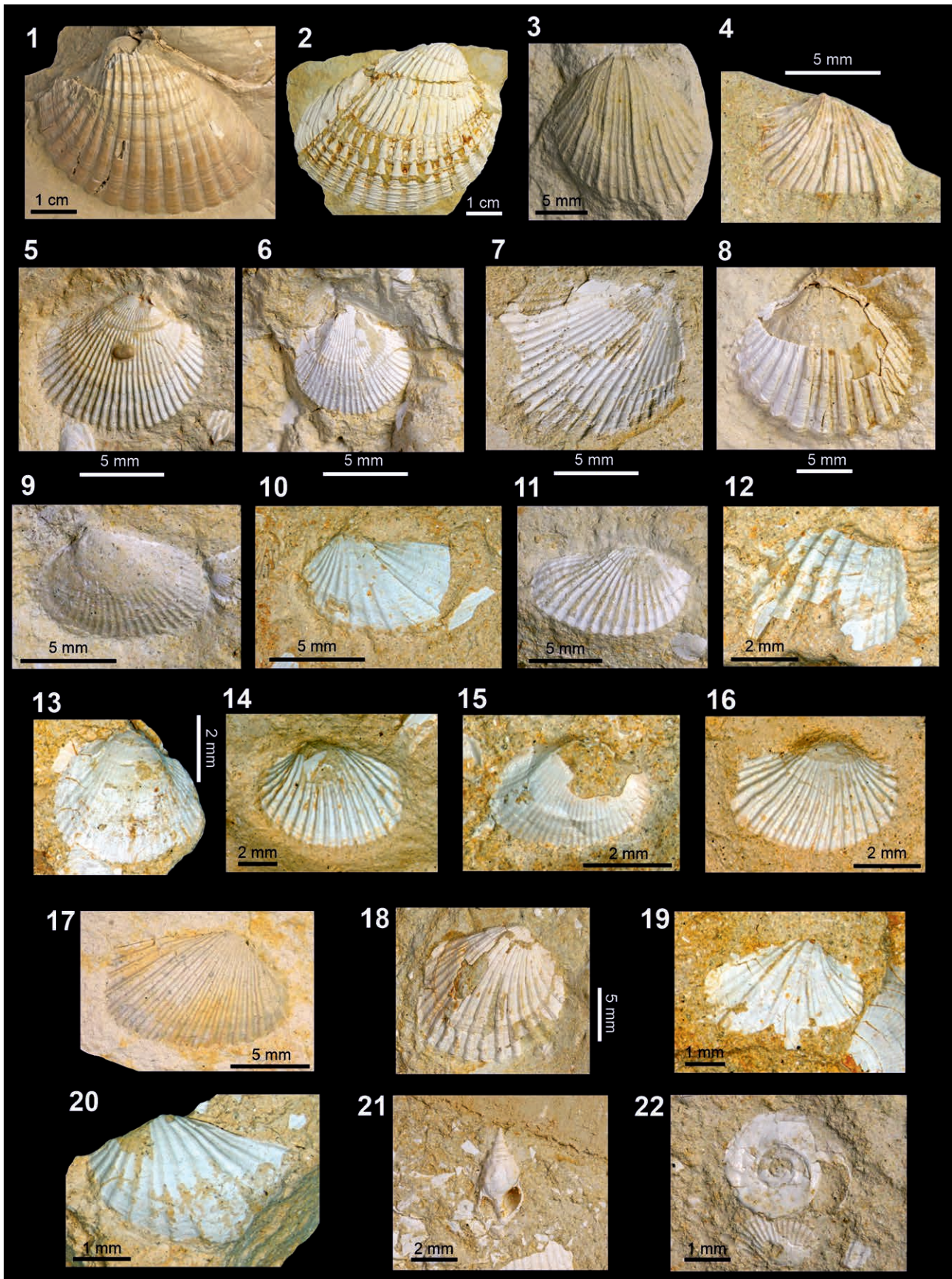


Plate VI – VI. tábla



## Plate VII – VII. tábla

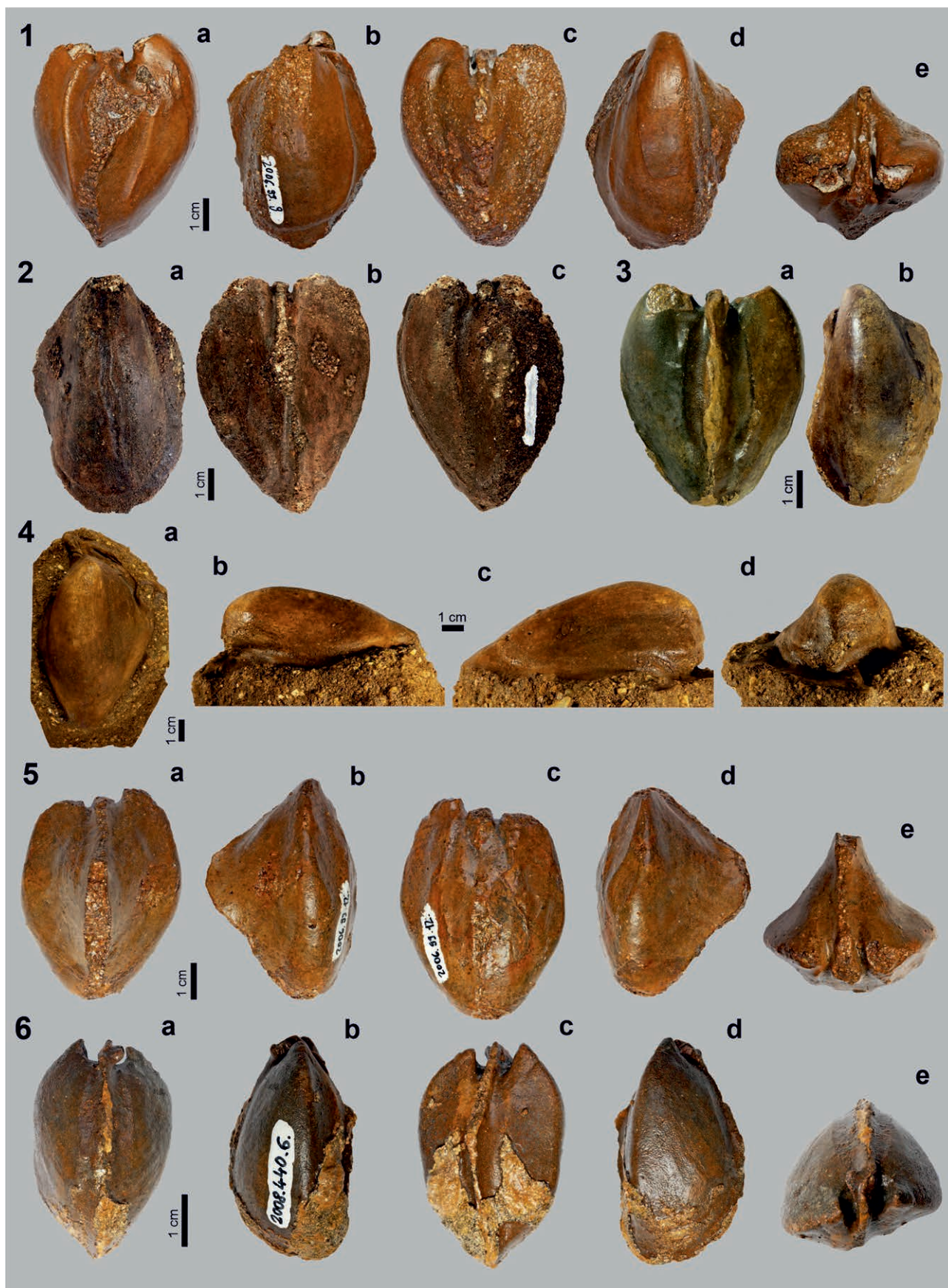
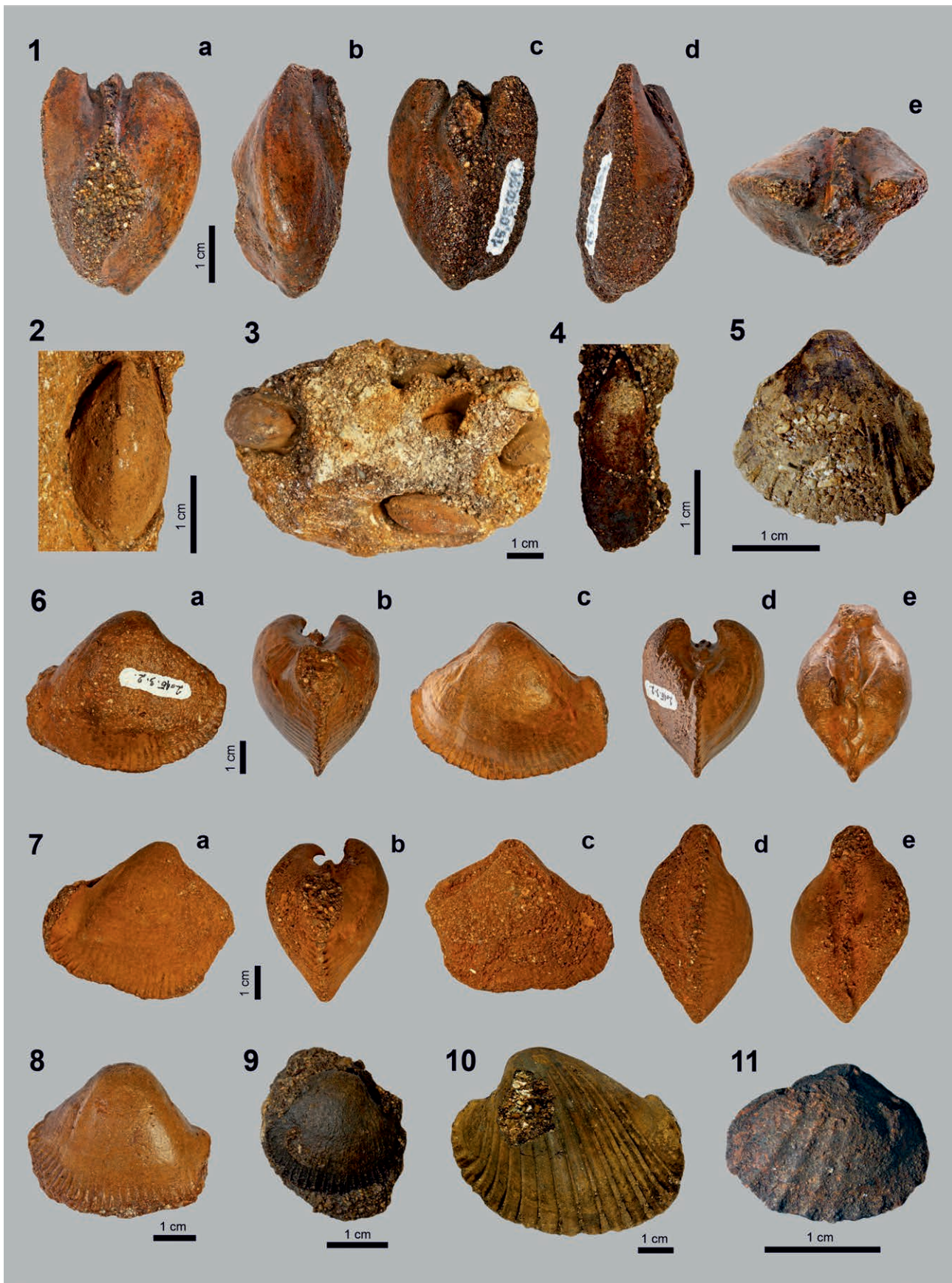


Plate VIII – VIII. tábla



## Appendix

### Systematic Palaeontology

Our approach to taxonomic identifications is outlined in chapter *Material and methods*.

Bivalvia LINNAEUS, 1758

Cardiidae LAMARCK, 1809

Lymnocypridae STOLICZKA, 1870

Genus *Lymnocardium* STOLICZKA, 1870

Type species: *Cardium haueri* M. HÖRNES, 1862; original designation

“*Lymnocardium*” *carnuntinum* (M. HÖRNES, 1862)  
(Plate VI, figs 3–4)

\*1862 *Cardium Carnuntinum* M. HÖRNES, p. 204, pl. 30, fig. 2.

1882 *Cardium (Adacna) Suessi* BARB. – HALAVÁTS, p. 150, pl. 14, figs 6–8.

1886a *Cardium (Adacna) pseudo-Suessi* HALAVÁTS, p. 127, pl. 6, figs 1–5. [new synonym]

1886b *Cardium (Adacna) pseudo-Suessi* HAL. – HALAVÁTS, p. 128, pl. 25, figs 3–4.

non 1899 *Limnocardium pseudo-Suessi* HÁL. – GORJANOVIĆ-KRAMBERGER, p. 236.

1953 *Limnocardium carnuntinum* (PARTSCH, HOERNES) – PAPP, p. 199, pl. 23, figs 17–19; pl. 24, Fig. 5.

1959 *Limnocardium pseudosuessi* HALAVÁTS – MILETIĆ-SPAJIĆ, pl. 8, figs 9–10.

1966 *Limnocardium carnuntinum* PARTSCH – CHIVU et al., p. 246, pl. 2, fig. 5.

?1968 *Limnocardium pseudosuessi* HALAVÁTS – SAGATOVICI, pl. 14, fig. 4.

1983 *Limnocardium pseudosuessi* (HALAV.) – KÖRÖSI-HÓDI, p. 145, pl. 1, fig. 3.

1985 *Limnocardium pseudosuessi* (HALAVÁTS) – KÖRÖSI-HÓDI in JÁMBOR et al., p. 227, pl. 19, fig. 2.

1985 *Limnocardium carnuntinum* (PARTSCH) – PAPP, p. 307, pl. 42, figs 8–10.

2003 *Lymnocardium (Lymnocardium) carnuntinum* (HÖRNES) – SCHULTZ, p. 616, pl. 87, figs 9–10; pl. 88, fig. 7.

2008 *Lymnocardium pseudosuessi* (HALAVÁTS) – CZICZER et al., pl. 30 figs 5a–b.

*Type locality*: Vienna, 10th district (Inzersdorf, Wienerberg)

*Type material*: Syntypes: NHMW, 1851/II/158

*Remarks*: Neither the description nor the illustrations by HÖRNES (1862) refer to the distinct primary and secondary radial ribs of this species. HALAVÁTS (1886) recognized *L. pseudosuessi* as a new species based on this characteristic rib pattern. A comparison of the syntypes of *L. pseudosuessi*

with those of *L. carnuntinum*, however, unanimously shows that they represent the same species.

*L. carnuntinum* is widely known from the marginal parts of the Pannonian Basin System, such as the Vienna Basin in Austria, the Avala Mts. and Morava Valley in Serbia, the southern Banat, Oaş, and Şimleu Basins in western Romania, and in the margins of the Transdanubian Range in Hungary.

*Stratigraphic range and age*: The oldest known dated occurrence of the species was reported from borehole Lajoskomárom (Lk)–1, 585.3–572 m (KÖRÖSI-HÓDI in JÁMBOR et al. 1985), from the *Spiniferites oblongus* Zone (SÜTŐ-SZENTAI in JÁMBOR et al. 1985), which is thought to be ca. 11.2–10.8 Ma (MAGYAR & GEARY 2012). The latest occurrences are known from the northwestern foreland of the Transdanubian Range, dated as 9.4–8.9 Ma (Szák Fm.; KÖRÖSI-HÓDI 1983; CZICZER et al. 2009).

*Lymnocardium schedelianum* (FUCHS, 1870)  
(Plate VI, figs 1–2; Plate VIII, fig. 10)

1862 *Cardium apertum* MÜNSTER – M. HÖRNES, p. 201, pl. 29, figs 5–6.  
\*1870 *Cardium Schedelianum* FUCHS, p. 354.

non 1884 *Adacna Schedeliana* PARTSCH – BRUSINA, p. 151, pl. 28, fig. 43.

1903 *Limnocardium Schedelianum* PARTSCH – ANDRUSOV, p. 39, pl. 3, figs 18–21.

non 1943 *Limnocardium schedelianum* PARTSCH – GILLET, p. 58, pl. 5, fig. 11.

?1943 *Limnocardium schedelianum* PARTSCH var. *sarbiense* Gillet, p. 59, pl. 5, fig. 12.

1953 *Limnocardium schedelianum* (PARTSCH) – PAPP, p. 198, pl. 24, fig. 3.

?1966 *Limnocardium schedelianum* PARTSCH – CHIVU et al., p. 246, pl. 2, fig. 7.

1967 *Limnocardium schedelianum* (PARTSCH) – SPAJIĆ, p. 115, pl. 2, figs 1–5.

1980 *Limnocardium schedelianum* PARTSCH – STEVANOVIĆ, pl. 4, fig. 13.

1980 *Limnocardium schedelianum* (PARTSCH) – LUEGER, pl. 3, fig. 1.  
1983 *Limnocardium schedelianum* (PARTSCH) – NICORICI & KARÁCSONYI, pl. 3, fig. 2.

1985 *Limnocardium schedelianum* (PARTSCH) – PAPP, p. 307, pl. 42, fig. 11.

1988 *Lymnocardium* cf. *soproniense* VITÁLIS – MAGYAR, p. 212, pl. 1, fig. 4.

1995 *Lymnocardium schedelianum* (BRUSINA) – FORDINÁL, p. 32, pl. 5, fig. 2.

- 1999 *Lymnocardium schedelianum* (PARTSCH) – MAGYAR et al., p. 672, pl. 1, fig. E.  
 2003 *Lymnocardium (Lymnocardium) schedelianum* (FUCHS) – SCHULTZ, p. 626, pl. 89, figs 10, 12.

*Type locality:* Brunn am Gebirge (FUCHS 1870)

*Type material:* Syntypes: NHMW, 1846/37/668

*Remarks:* In the 19th century, this species was confused with *Lymnocardium apertum* (MÜNSTER) (see HÖRNES 1862; FUCHS 1870). A possible source of this confusion was that a typical *L. schedelianum* specimen was labelled in the old collection of the Natural History Museum Vienna as coming from Tihany, where *L. apertum* is a common species. As the recent revision of *L. schedelianum* (see SCHULTZ 2003) maintained the notion of HÖRNES (1862), FUCHS (1870), and ANDRUSOV (1903) that this species occurs in Tihany, we find it important to emphasize that repeated exhaustive collections in Tihany (HALAVÁTS 1902, LÖRENTHEY 1905, VITÁLIS 1908, BARTHA 1959, MÜLLER & SZÓNOKY 1990, SZTANÓ et al. 2013) failed to yield *L. schedelianum* specimens from any outcrop of the region. To our best understanding, this species evolved into other forms and thus went extinct by the time when the Tihany beds were deposited (MAGYAR et al. 2016). Therefore, we argue that the Tihany specimen of *L. schedelianum* in the Vienna museum collection was mislabeled.

In fact, *L. schedelianum* can be easily distinguished from *L. apertum* by its more elongated outline, higher number of ribs, and significantly larger size. It shows, however, very close resemblance to *L. soproniense* VITÁLIS and *L. variocostatum* VITÁLIS, which can be considered as its descendants (MAGYAR et al. 2016).

*Lymnocardium schedelianum* is a widely distributed species in the Pannonian Basin: it occurs in the Vienna Basin in Austria and the Czech Republic, in the Danube Basin in Austria, Slovakia, and Hungary, in the northern and eastern margins of the Great Hungarian Plain in Hungary and Romania, south of the Danube and the Sava in Serbia and Bosnia, along the Sava in Slovenia, and in Burgenland in Austria. *Lymnocardium schedelianum* is recovered from both sublittoral clay layers and littoral sand deposits.

*Stratigraphic range:* *Lymnocardium schedelianum* and *L. conjungens* Zones (?11.0–9.6 Ma). According to PAPP (1953), the oldest occurrences of the species belong to “Zone D” in the Vienna Basin (10.6–10.4 Ma according to HARZHAUSER et al. 2004). The youngest specimens in the sublittoral deposits are ca. 10.2 Ma and ca. 9.6 Ma old in the littoral deposits (MAGYAR et al. 2016).

*Lymnocardium winkleri* (HALAVÁTS, 1882)  
 (Plate V, figs 12–15)

- \*1882 *Cardium (Adacna) Winkleri* nov. form. HALAVÁTS, p. 153, pl. 15, figs 3–4.  
 1883 *Cardium (Adacna) Winkleri* nov. form. HALAVÁTS, p. 169, pl. 15, figs 3–4.  
 1959 *Lymnocardium winkleri* HALAVÁTS – MILETIĆ-SPAJIĆ, pl. 8, fig. 14.  
 ?1962 *Lymnocardium winkleri* HALAVÁTS – SZÉLES, p. 56, pl. 3, fig. 4.  
 ?1971 *Lymnocardium winkleri* HALAVÁTS – SZÉLES, p. 327, pl. 1, fig. 8.

- (?)1977 *Pseudocatillus* sp. – V. LUBENESCU & D. LUBENESCU, pl. 3, figs 17–18.  
 (?)1977 (?) *Pseudocatillus* sp. – V. LUBENESCU & D. LUBENESCU, pl. 4, fig. 8.  
 1978 *Lymnocardium lukae* STEV. – STEVANOVIĆ, p. 341.  
 1980 *Lymnocardium Winkleri lukae* n. subsp. STEVANOVIĆ, p. 128, 139, pl. 3, figs 19–22. [new synonym]  
 ?1980 *Lymnocardium winkleri* HAL. – STEVANOVIĆ, pl. 4, fig. 11.  
 ?1983 *Lymnocardium winkleri* (HALAV.) – KÖRPÁS-HÓDI, p. 145, pl. 1, fig. 4.  
 ?1985 *Lymnocardium winkleri lukae* STEV. – KÖRPÁS-HÓDI in JÁMBOR et al., p. 227, pl. 19, fig. 3.  
 1987 *Lymnocardium winkleri lukae* STEVANOVIĆ – JÁMBOR et al., pl. 4, fig. 3.  
 ?1992 *Lymnocardium winkleri lukae* STEV. – KÖRPÁS-HÓDI, pl. 1, fig. 4.  
 ?1995 *Lymnocardium* aff. *winkleri* (HALAVÁTS) – MAGYAR, fig. 4F.

*Type locality:* Câmpia (Langenfeld, Néramező) (HALAVÁTS 1882)

*Type material:* Syntypes: MBFSZ, Pl. 6379

*Remarks:* *Lymnocardium winkleri* represents the early stage of the probably anagenetic evolutionary lineage that leads to *L. majeri* (HÖRNES) then to *L. peregrinum* (in the Eastern Paratethys). For this lineage EBERZIN (1947) erected the subgenus *Arpadicardium*. Distinction of the subspecies *L. winkleri lukae* (STEVANOVIĆ, 1980) is probably not justified, because neither the description nor the illustration of this subspecies contained any obvious diagnostic feature by which it could be distinguished from *L. winkleri*. Therefore, here we treat *L. winkleri lukae* as a junior synonym of *L. winkleri*.

*Stratigraphic range:* The stratigraphic range of the species is weakly constrained. The oldest dated occurrence is known from the Lajoskomárom (Lk)–1 borehole, 577.6 m, belonging to the *Spiniferites oblongus* Zone (ca. 10.8–11.2 Ma) (JÁMBOR et al. 1985). Stratigraphically upward, the transition to *L. majeri* is gradual, and no criterion has been suggested so far for the distinction between the two chronospecies.

Dreissenidae GRAY, 1840

Genus *Congeria* PARTSCH, 1835

Type species: *Congeria subglobosa* PARTSCH, 1835; subsequent designation, STOLICZKA, 1870

*Congeria hemiptycha* BRUSINA, 1902  
 (Plate VII, figs 1–3)

- 1892 *Congeria subglobosa* PARTSCH – BRUSINA, p. 180.  
 v \*1902 *Congeria subglobosa hemiptycha* BRUS. – BRUSINA, pl. 20, figs 1–3.  
 1927 *Congeria Pančići* nov. spec. PAVLOVIĆ, p. 16, pl. 2, figs 5–7; pl. 3, figs 1–3. [new synonym]  
 1928 *Congeria Pančići* nov. spec. PAVLOVIĆ, p. 11, pl. 2, figs 5–7; pl. 3, figs 1–3.  
 1939 *Congeria subglobosa hemiptycha* BRUS. – KOLLMANN, p. 55.  
 1944 *Congeria hemiptycha* BRUSINA – JEKELIUS, p. 146, pl. 62, fig. 4.  
 1952 *Congeria pancici pancici* PAVLOVIĆ – SAUERZOPF, p. 4.  
 1952 *Congeria pancici hemiptycha* BRUSINA – SAUERZOPF, p. 4.  
 1952 *Congeria pancici longiconcha* n. ssp. SAUERZOPF, p. 11, pl. 1, figs 3–4. [new synonym]

- 1953 *Congeria pancici pancici* PAVLOVIĆ – PAPP, p. 176, pl. 17, figs 1–2.
- 1959 *Congeria subglobosa mlavica* n. ssp. MILETIĆ-SPAJIĆ, p. 108, 121, pl. 5, fig. 1. [new synonym]
- 1959 *Congeria* cf. *pancici* PAVLOVIĆ – MILETIĆ-SPAJIĆ, pl. 5, fig. 2.
- 1968 *Congeria subglobosa longitesta* PAPP – SAGATOVICI, pl. 12, fig. 27; pl. 13, figs 1–2.
- 1974 *Congeria hemiptycha* BRUSINA – MILAN et al., p. 32.
- 1980 *Congeria pancici* – LUEGER, pl. 2, fig. 1.
- 1980 *Congeria* sp. – LUEGER, p. 111, pl. 2, fig. 4.
- 1981 *Congeria pancici pancici* PAVLOVIĆ – V. LUBENESCU, p. 167, pl. 10, fig. 1.
- 1981 *Congeria subglobosa hemiptycha* BRUSINA – V. LUBENESCU, p. 170–171, pl. 10, fig. 3.
- 1983 *Congeria pancici pancici* PAVLOVIĆ – NICORICI & KARÁCSO-NYI, p. 231, pl. 1, figs 1–2.
- 1985 *Congeria pancici* PAVLOVIĆ – PAPP, p. 301, pl. 39, figs 1–2.
- v 1988 *Congeria* sp. – MAGYAR, p. 212, pl. 1, fig. 1.
- 2003 *Congeria pancici pancici* PAVLOVIĆ – SCHULTZ, p. 811, pl. 110, figs 1–3.
- 2003 *Congeria pancici longiconcha* SAUERZOPF – SCHULTZ, p. 812, fig. 20.

*Type locality*: Zagreb–Markuševac (BRUSINA 1902)

*Type material*: Syntypes: HPM, 2787-433, 392.1-4, 393.I-II

*Remarks*: The “holotype” designation by MILAN et al. (1974) cannot be accepted as valid lectotype designation according to ICZN Article 74.5. The “stratum typicum” is also erroneously given by MILAN et al. (1974) as “marls;” the species occurred in sand (see BRUSINA 1892).

The only difference between the type specimens of *C. hemiptycha* BRUSINA and *C. pancici* PAVLOVIĆ is that the former has a corrugated posterior field. The presence and degree of corrugation, however, is highly variable among the specimens, and can hardly be considered a diagnostic feature.

*Congeria hemiptycha* occurs in littoral sands in the Vienna Basin (Austria), Kál Basin (Hungary), Oaş and Şimleu Basins, Banat region and Transylvanian Basin (Romania), Avala Mts. (Serbia), Medvednica Mts. (Croatia), and several locations in Burgenland (Austria).

*Stratigraphic range and age*: According to PAPP (1985), this species occurs in “Zone D” (very rarely) and “Zone E” (common and typical). SCHULTZ (2003), however, listed a lot of localities belonging to “Zone D” and some even to “Zone C”. Following the age model of HARZHAUSER et al. (2004), *C. hemiptycha* was already present at ca. 10.6 Ma (beginning of “Chron D”), but its first appearance and ancestry remains vague. The youngest occurrences belong to the upper part of the *Lymnocardium conjungens* Zone and thus can be as young as ca. 9.6 Ma. After that, *C. hemiptycha* disappeared from the fossil record so the lineage probably went extinct.

*Congeria partschi firmocarinata* PAPP, 1953  
(Plate V, fig. 1)

- \*1953 *Congeria partschi firmocarinata* n. ssp. PAPP, p. 174, pl. 16, fig. 7.

- 1977 *Congeria partschi firmocarinata* PAPP – V. LUBENESCU & D. LUBENESCU, pl. 2, figs 6–7.
- ? 1980 *Congeria partschi firmocarinata* PAPP – LUEGER, p. 118, 121, pl. 2, figs 2–3.
- 1985 *Congeria partschi firmocarinata* – PAPP, p. 296, pl. 38, fig. 3.
- 2005 *Congeria partschi firmocarinata* PAPP – SCHULTZ, p. 815, pl. 110, figs 4–5; pl. 111, fig. 4.

*Type locality*: Hennersdorf (PAPP 1953)

*Type material*: Holotype: NHMW, 787/1969, Coll. PAPP 632

*Remarks*: Although our specimens were heavily deformed by lithostatic pressure, it can be established that the Pécs-Danitzpuszta and Hennersdorf specimens are morphologically indistinguishable.

*Stratigraphic range and age*: According to PAPP (1953, 1985), this species is restricted to “Zone E”, dated as 10.4–10.1 Ma by HARZHAUSER et al. (2004).

*Congeria zsigmondyi* HALAVÁTS, 1882  
(Plate V, figs 2–3)

- \*1882 *Congeria Zsigmondyi* n. form. HALAVÁTS, p. 154, pl. 15, figs 7–10.

- 1883 *Congeria Zsigmondyi* n. form. HALAVÁTS, p. 171, pl. 15, figs 7–10.

- 1897 *Congeria zsigmondyi* – ANDRUSOV, p. 214, pl. 11, figs 21–26.

- 1944 *Congeria zsigmondyi* HALAVÁTS – JEKELIUS, p. 144, pl. 60, figs 4–7, excl. f. 8.

- 1953 *Congeria zsigmondyi* HALAVÁTS – PAPP, p. 175, pl. 16, figs 5–6.

- 1966 *Congeria zsigmondyi* HAL. – BARTHA, pl. 3, figs 1–3.

- ?1971 *Congeria zsigmondyi* [sic!] HALAVÁTS – GRÄF et al., text-fig. 3: 3, pl. 1, figs 2–6, 10–11.

- 1971 *Congeria zsigmondyi* HALAVÁTS – BARTHA in GÓCZÁN & BENKŐ, pl. 25, figs 1–3.

- ?1981 *Congeria zsigmondyi* HALAVÁTS – V. LUBENESCU, pp. 164–165, pl. 9, fig. 5.

- 1985 *Congeria zsigmondyi* HALAVÁTS – PAPP, p. 297, pl. 38, figs 7–10.

- 1999 *Congeria zsigmondyi* – MAGYAR, p. 11, fig. 2.

- 2001 *Congeria zsigmondyi* HALAVÁTS – GULYÁS, fig. 7.

- 2004 *Congeria zsigmondyi* – HARZHAUSER & MANDIĆ, p. 342, fig. 9/2.

- 2005 *Congeria zsigmondyi* HALAVÁTS 1882 – SCHULTZ, p. 828, pl. 113, figs 2–3.

*Type locality*: Câmpia (Langenfeld, Néramező) (HALAVÁTS 1882)

*Type material*: Syntypes: MBFSZ, Pl. 1

*Remarks*: This species is commonly reported from various parts of the Pannonian region: Vienna Basin in Austria, NW Romania, Transylvanian Basin, southern Banat, and Mecsek Mts in Hungary.

*Stratigraphic range and age*: According to PAPP (1985), this species is restricted to clays of “Zone E.” SCHULTZ (2005), however, lists a few localities conditionally assigned to “Zone D.” The Soceni locality is also considered older than Zone “E,” but the occurrence of *C. zsigmondyi* in Soceni is questionable, because three of the four depicted specimens in JEKELIUS (1944) are from Câmpia, and the only specimen depicted from Soceni probably represents another species. On the other hand, the type locality of the species is most probably somewhat



younger than “Zone E” in the Vienna Basin. Thus, the age interval of *C. zsigmondyi* can be estimated as 10.6–9.6 Ma.

Genus *Dreissenomya* FUCHS, 1870

Type species: *Congeria schroeckingeri* FUCHS, 1870; original designation

*Dreissenomya (Sinucongeria) dactylus* (BRUSINA, 1894)  
(Plate VIII, fig. 4)

1894 *Congeria dactylus* n. sp. BRUSINA, p. 243.

1900 *Congeria dactylus* BRUSINA – ANDRUSOV, p. 80, 125.

1902 *Congeria dactylus* BRUS. – BRUSINA, pl. 20, figs 9–13 (14–17?).

1915 *Dreissensiomya* [sic!] *dactylus* BRUS – VITÁLIS, p. 334, pl. 2, figs 2–3.

1927 *Dreissensiomya lithodomiformis* nov. spec. PAVLOVIĆ, p. 24, pl. 4, figs 1–2. [new synonym]

1928 *Dreissensiomya lithodomiformis* nov. spec. PAVLOVIĆ, p. 17, pl. 4, figs 1–2.

1974 *Congeria dactylus* BRUSINA – MILAN et al., p. 26.

1990 *Congeria dactylus* BRUSINA – BASCH, p. 555, pl. 3, fig. 3.

1992 *Dreissenomya (Sinucongeria) dactyla* (BRUSINA) – BASCH & ŽAGAR-SAKAČ, p. 27, pl. 17, figs 3–6.

2005 *Mytilopsis* cf. *scrobiculata scrobiculata* (ANDRUSOV) – SCHULTZ, p. 798, pl. 105, figs 9–10.

2015 *Dreissenomya dactylus* (BRUSINA) – KATONA et al., p. 149, pl. 11, fig. 8.

*Type locality*: “between Balatonkenese and Siófok” (BRUSINA 1894), i.e., south of Balatonkenese

*Type material*: Lectotype: HPM, 2789-435 (subsequently designated by MILAN et al. 1974)

*Remarks*: BRUSINA (1894) characterized his new species as “presenting the appearance of a *Lithodomus*,” but he did not give further description. In our view, his remark can be considered a valid diagnosis because *D. dactylus* is the only dreissenid that resembles the marine mytilid boring bivalve “*Lithodomus*” (*Lithophaga*), also known as date mussel. PAVLOVIĆ (1927, 1928) also noted this similarity, hence the name *lithodomiformis*. The species was illustrated from Balatonkenese (BRUSINA 1902), Tihany (VITÁLIS 1915), Vrčin-Karagača creek (PAVLOVIĆ 1927, 1928), Jagnjedovec (BASCH 1990, BASCH & ŽAGAR-SAKAČ 1992), Vösendorf (SCHULTZ 2005), and Balatonalmádi (KATONA et al. 2015).

*Stratigraphic range and age*: The oldest known occurrence, Vösendorf, is assigned to “Zone E” of PAPP (1951, 1953), dated as 10.4–10.1 Ma (HARZHAUSER et al. 2004). The occurrences in Tihany, Balatonalmádi and Balatonkenese belong to the *Lymnocardium decorum* Zone, 8.7–8.0 Ma (MAGYAR & GEARY 2012), whereas the biostratigraphic position and age of the Jagnjedovec material (BASCH 1990) is unknown to us.

Gastropoda CUVIER, 1795

Hydrobiidae STIMPSON, 1865

Genus *Micromelania* BRUSINA, 1874

*Type species*: *Micromelania cerithiopsis* BRUSINA, 1874; subsequent designation, DOLLFUS, 1912

*Micromelania striata* GORJANOVIĆ-KRAMBERGER, 1890  
(Plate IV, fig. 13)

v \*1890 *Micromelania striata* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 157, pl. 6, figs 9–9a.

(?)1893 *Micromelania lapadensis* nov. form. LÖRENTHEY, p. 311, pl. 4, fig. 14b. [new synonym?]

1985 *Micromelania striata* GORJ.-KRAMB. – JÁMBOR et al., pl. 23, figs 5–6.

1987 *Micromelania striata* GORJ.-KRAMB. – JÁMBOR et al., pl. 8, figs 5–6.

2013 *Micromelania* sp. – TER BORGH et al., fig. 9:20.

*Type locality*: Zagreb–Vrapče (GORJANOVIĆ-KRAMBERGER 1890)

*Type material*: Syntypes: HPM, 5165-330/1-2 (MILAN et al. 1974); GBA

*Remarks*: In addition to the syntypes deposited in HPM, a specimen collected by the author of the species is also available in the type collection of GBA.

The shell has 9–11 whorls with fine parallel growth lines and longitudinal striae, resulting in a square grid ornamentation. This can only be observed on well-preserved shells or sometimes on imprints. *Micromelania lapadensis* described by LÖRENTHEY (1893) is probably a junior synonym of *M. striata*, but the figure of LÖRENTHEY does not allow precise comparison.

*Stratigraphic range and age*: This species was described and mentioned from old Pannonian offshore (sublittoral and profundal) marls all over the Pannonian Basin proper (Vrapče, Medvednica Mts., Croatia – GORJANOVIĆ-KRAMBERGER 1890; Lopadea Veche, Transylvanian Basin, Romania – LÖRENTHEY 1893; Lajoskomárom-1 borehole, Hungary – JÁMBOR et al. 1985, 1987; Beočin, Fruška Gora Mts., Serbia – TER BORGH et al. 2013). It is a common species in the *Lymnocardium praeponticum*, *Congeria czjzeki* and *Congeria banatica* Zones (from 11.6 to 9.5 Ma).

Lymnidae RAFINESQUE, 1815

Genus *Radix* MONTFORT, 1810

Type species: *Radix auriculatus* MONTFORT, 1810; original designation

*Radix croatica* (GORJANOVIĆ-KRAMBERGER, 1890)  
(Plate III, figs 17–19)

v \*1890 *Limnaea croatica* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 154, pl. 6, figs 1–3.

?v 1890 *Limnaea extensa* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 155, pl. 6, fig. 4. [new synonym?]

1944 *Radix (Limnaea) croatica* KR.-G. – MOOS, p. 344.

1956 *Radix kobelti* BRUSINA – PAPP, p. 71.

1967 *Radix croatica* (GORJANOVIĆ-KRAMBERGER) – TAKTAKISH-VILLI, text-fig. 7a.

1985 *Radix croatica* (GORJ.-KRAMB.) – JÁMBOR et al., pl. 23, fig. 4.

1985 *Radix kobelti* REUSS – STEVANOVIĆ & PAPP, pl. 27, fig. 11.

1987 *Radix croatica* (GORJ.-KRAMB.) – JÁMBOR et al., pl. 8, fig. 4.

2013 *Radix kobelti* REUSS – TER BORGH et al., fig. 9:19.

*Type locality*: Zagreb–Vrapče (GORJANOVIĆ-KRAMBERGER 1890)

*Type material:* Syntypes: HPM 5178-343–5180-345 (MILAN et al. 1974), GBA

*Remarks:* In addition to the syntypes deposited in HPM, a specimen collected by the author of the species is also available in the type collection of GBA, subsequently labelled as “syntype.”

Fine growth lines, four whorls (in most cases, just three whorls can be seen, the last whorl covers the third one), and a strongly widening last whorl with an oval and rimmed aperture characterize this species. Protoconch can be observed only in well-preserved specimens. *Limnaea extensa* species of GORJANOVIĆ-KRAMBERGER is probably a steinkern of a *R. croatica* specimen and shows the internal structure and ornamentation and all the four whorls of *R. croatica*. *Radix kobelti* is not a synonym of *R. croatica*, but it is frequently confused with *R. croatica*. *Radix kobelti* is a shallow-water species of young Pannonian (“Pontian”) sands, whereas *R. croatica* is a typical member of old Pannonian marls and limestones.

*Stratigraphic range and age:* This species was described and mentioned from old Pannonian offshore (sublittoral and profundal) marls all over the Pannonian Basin (Vrapče, Medvednica Mts., Croatia – GORJANOVIĆ-KRAMBERGER 1890; Kostanjek/Podsused, Medvednica Mts., Croatia – PAPP 1956, VRSALJKO 1999; Gojlo-4 and Bujavica-9 boreholes, Sava Basin, Croatia – MOOS 1944; Lajoskomárom-1 borehole, Hungary – JÁMBOR et al. 1985, 1987; Beočin, Fruška Gora Mts., Serbia – STEVANOVIĆ & PAPP 1985, TER BORGH et al. 2013). *Lymnocardium praeponticum* mollusk biozone = “Croatia Beds” in Croatia (from 11.6 to 11.45 Ma). It is a common member of the *L. praeponticum* – *R. croatica* dwarf fauna.

Planorbidae RAFINESQUE, 1815

Genus *Gyraulus* CHARPENTIER, 1837

Type species: *Planorbis albus* O. F. MÜLLER, 1774; subsequent designation, DALL, 1870

*Gyraulus tenuistriatus* (GORJANOVIĆ-KRAMBERGER, 1899)  
(Plate VI, fig. 22)

- v \*1899 *Planorbis tenuistriatus* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 129, pl. V fig. 7.
- 1956 *Planorbis* (*Gyraulus*) cf. *tenuistriatus* GORJ.-KRAMBG. – PAPP, p. 70.
- 1977 *Planorbis tenuistriatum* [sic!] GORJ.-KRAMB. – V. LUBENESCU & D. LUBENESCU, pl. 2 fig. 5.
- 1984 *Gyraulus* sp. – V. LUBENESCU & POPESCU, pl. 1 fig. 8.
- 1985 *Gyraulus tenuistriatus* (GORJ.-KRAMB.) – JÁMBOR et al., pl. 23 fig. 3.
- 1987 *Gyraulus tenuistriatus* (GORJ.-KRAMB.) – JÁMBOR et al., pl. 8 fig. 3.
- 2009 „*Gyraulus*” *tenuistriatus* (GORJANOVIĆ-KRAMBERGER) – CZICZER et al., fig. 6o.
- 2010 „*Gyraulus*” *tenuistriatus* (GORJANOVIĆ-KRAMBERGER) – MAGYAR, fig. 11.
- 2013 *Gyraulus praeponticus* (GORJ.-KRAMB.) – TER BORGH et al., fig. 9: 17–18.
- 2016 *Gyraulus* sp. – MANDIĆ et al., fig. 17.
- 2016 *Planorbi* [sic!] sp. – WANEK, p. 29, fig. 5.
- 2019 *Gyraulus tenuistriatus* (GORJANOVIĆ-KRAMBERGER) – BOTKA et al., fig. 3: f.

*Type locality:* Babindol, south of Londžica (GORJANOVIĆ-KRAMBERGER 1899)

*Type material:* Syntype: HPM 5457-607

*Remarks:* According to ICZN Article 74.5, the “holotype” designation by MILAN et al. (1974) cannot be accepted as valid lectotype designation.

This species has a planispiral shell with four whorls and fine growth lines, which can be thickened forming a slightly bulging ornamentation. Width of the aperture is ca. 1/3 of the shell width. It clearly differs from *G. praeponticus* GORJANOVIĆ-KRAMBERGER, which has only three whorls and wider aperture.

*Stratigraphic range and age:* This species was described and mentioned from old Pannonian offshore (sublittoral and profundal) marls all over the Pannonian Basin (Londžica, Krndija Mts., Croatia – GORJANOVIĆ-KRAMBERGER 1899; Kostanjek/Podsused, Medvednica Mts., Croatia – PAPP 1956; Lajoskomárom-1 borehole, Hungary – JÁMBOR et al. 1985, 1987; localities of the northern foreground of the Transdanubian Range, Hungary – CZICZER et al. 2009; Beočin, Fruška Gora Mts., Serbia – TER BORGH et al. 2013; various localities from the Transylvanian Basin, Romania – V. LUBENESCU & D. LUBENESCU 1977, LUBENESCU 1981, LUBENESCU & POPESCU 1984, MAGYAR 2010, WANEK 2016, BOTKA et al. 2019). It is a common species in the *Lymnocardium praeponticum*, *Congerina czjzeki* and *Congerina banatica* Zones (from 11.6 to 9.5 Ma).

Genus *Orygoceras* BRUSINA, 1882

Type species: *Orygoceras cornucopiae* BRUSINA, 1882; subsequent designation, COSSMANN, 1921

*Orygoceras fuchsi* (KITTL, 1886)

\*1886 *Creseis Fuchsi* n. f. KITTL, p. 50, pl. 2, figs 1–3.

- v 1890 *Orygoceras levis* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 158, pl. 6, fig. 11. [new synonym]
- v 1892 *Orygoceras corniculum* BRUSINA n. sp. – BRUSINA, pp. 169–171.
- 1893 *Orygoceras levis* KRAMB.-GORJ. ? – LŐRENTHEY, pp. 310–311.
- 1902 *Orygoceras corniculum* BRUSINA – BRUSINA, pl. 2, figs 34–37.
- 1902 *Orygoceras corniculum* BRUS. – LŐRENTHEY, pp. 194–196, pl. 11, figs 20–22; pl. 12, fig. 11.
- 1944 *Orygoceras fuchsi* KITTL – JEKELIUS, p. 118, pl. 43, figs 22–23.
- 1956 *Orygoceras fuchsi fuchsi* (KITTL) – PAPP, p. 70.
- 1985 *Orygoceras laevis* [sic!] GORJ.-KRAMB. – JÁMBOR et al., pl. 23, figs 7–8.
- 1985 *Orygoceras fuchsi fuchsi* (KITTL) – PAPP, p. 288, text-figs 38–39: 1–2c.
- 1987 *Orygoceras laevis* [sic!] GORJ.-KRAMB. – JÁMBOR et al., pl. 8, figs 7–8.
- 1999 *Orygoceras fuchsi* KITTL – LENNERT et al., pl. 5, figs 10–11.
- 2010 *Orygoceras levis* GORJANOVIĆ-KRAMBERGER – MAGYAR, fig. 29b: E.
- 2019 *Orygoceras levis* GORJANOVIĆ-KRAMBERGER – BOTKA et al., fig. 3: g.

*Type locality:* Forchtenstein (KITTL 1886). According to LŐRENTHEY (1903), the type locality is not correct, the specimens described and figured by KITTL (1886) must have originated from the Sopron area, where old Pannonian layers are exposed.

*Type material:* unknown

*Remarks:* The species has a thin, smooth, dentaliform shell. Growth lines can sometimes be seen. Protoconch is a half smooth whorl. According to LŐRENTHEY (1903), *O. corniculum* is a junior synonym of *O. fuchsi*. We share this opinion and add that the same applies to *O. levis*.

*Stratigraphic range and age:* This species was described and mentioned from old Pannonian offshore (sublittoral and profundal) marls all over the Pannonian Basin (?Forchtenstein, Eisenstadt–Sopron Basin, Austria – KITTL 1886; Vrapče, Medvednica Mts., Croatia – GORJANOVIĆ-KRAMBERGER 1890; Lopadea Veche, Transylvanian Basin, Romania – LŐRENTHEY 1893; Markuševac, Medvednica Mts., Croatia – BRUSINA 1892, 1902; Ripanj, Šumadija Hills, Serbia – BRUSINA 1902; Budapest-Kőbánya, Pannonian Basin and Tinnye, Zsámbék Basin, Hungary – LŐRENTHEY 1902; Soceni, Pannonian Basin, Romania – JEKELIUS 1944; Lajoskomárom–1 borehole, Hungary – JÁMBOR et al. 1985, 1987; Kostanjek/Podsused, Medvednica Mts., Croatia – PAPP 1956; Leobersdorf, Vienna Basin, Austria – PAPP 1985; Oarba de Mureș and Gușterița, Transylvanian Basin, Romania – MAGYAR 2010, BOTKA et al. 2019). It is a common species in the *Lymnocardium praeponticum*, *Congerina czjzeki*, and *Congerina banatica* Zones (from 11.6 to 9.5 Ma). Sporadic occurrences were reported from the much younger *Congerina rhomboidea* Zone (from 8 to ?5 Ma) as well.

*Orygoceras brusinai* GORJANOVIĆ-KRAMBERGER, 1890  
(Plate IV, fig. 14)

- v \*1890 *Orygoceras Brusinai* KRAMB.-GORJ. – GORJANOVIĆ-KRAMBERGER, p. 158, pl. 6, figs 10–10a.
- v 1892 *Orygoceras filocinctum* BRUSINA n. sp. – BRUSINA, p. 171. [new synonym]
- v 1892 *Orygoceras cultratum* BRUSINA n. sp. – BRUSINA, p. 171. [new synonym]
- 1902 *Orygoceras filocinctum* BRUSINA – BRUSINA, pl. 2, figs 23–28.
- 1902 *Orygoceras cultratum* BRUSINA – BRUSINA, pl. 2, figs 29–33.

- 1902 *Orygoceras cultratum* BRUS. – LŐRENTHEY, p. 196, pl. 12, fig. 13; pl. 13, figs 2–5.
- 1902 *Orygoceras filocinctum* BRUS. – LŐRENTHEY, p. 197, pl. 11, fig. 23; pl. 12, fig. 12; pl. 13, fig. 1.
- 1944 *Orygoceras fuchsi filocinctum* BRUSINA – JEKELIUS, p. 118, pl. 43, figs 24–25.
- 1944 *Orygoceras fuchsi cultratum* BRUSINA – JEKELIUS, p. 118, pl. 43, figs 26–28.
- 1956 *Orygoceras fuchsi brusinai* GORJ.-KRAMB. – PAPP, p. 70.
- 1985 *Orygoceras fuchsi filocinctum* BRUSINA – PAPP, p. 288, text-fig. 40:3a–b.
- 2010 *Orygoceras brusinai* GORJANOVIĆ-KRAMBERGER – MAGYAR, fig. 29b:D.

*Type locality:* Zagreb–Vrapče (GORJANOVIĆ-KRAMBERGER 1890)

*Type material:* Syntype: HPM 5162-327

*Remarks:* This species has thin dentaliform shell, ornamented with rings on the upper part. Growth lines can sometimes be seen on well-preserved specimens. Protoconch is a half smooth whorl. *Orygoceras brusinai*, *O. filocinctum*, and *O. cultratum* are probably junior synonyms. *Orygoceras cultratum* bears less rings, which are far from each other, while *O. filocinctum* has more, closer spaced rings. However, this observation might be a matter of the preservation state or intraspecific variability.

*Stratigraphic range and age:* This species was described and mentioned from old Pannonian offshore (sublittoral and profundal) marls all over the Pannonian Basin (Vrapče, Medvednica Mts., Croatia – GORJANOVIĆ-KRAMBERGER 1890; Markuševac, Medvednica Mts., Croatia – BRUSINA 1892, 1902; Budapest-Kőbánya, Pannonian Basin and Tinnye, Zsámbék Basin, Hungary – LŐRENTHEY 1902; Soceni, Pannonian Basin, Romania – JEKELIUS 1944; Kostanjek/Podsused, Medvednica Mts., Croatia – PAPP 1956; Leobersdorf, Vienna Basin, Austria – PAPP 1985; Oarba de Mureș, Transylvanian Basin, Romania – MAGYAR 2010). *Orygoceras brusinai* is less common than *O. fuchsi* in the *Lymnocardium praeponticum*, *Congerina czjzeki* and *Congerina banatica* Zones (from 11.6 to 9.5 Ma).