Földtani Közlöny

151/4

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Első borító: Lymnocardium schedelianum, a biostratigraphic marker species from the Pannonian calcareous silts of the Pécs-Danitzpuszta sand pit (photo: Krisztina Sebe)
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c) Összefoglalás (magyarul, angolul) Kizárólag a tanulmány célját, az alkalmazott módszereket, az elért legfontosabb új eredményeket és következtetéseket tartalmazza, így önállóan is megállja a helyét. Hossza legfeljebb 300 szó. Az angol nyelvű összefoglaló lehet bővebb a magyarnál (max. 1000 szó).

d) Tárgyszavak (magyarul, angolul) Legfeljebb 8 szó / egyszerű kifejezés e) Bevezetés A munkához kapcsolódó legfontosabb korábbi szakirodalmi eredmények összefoglalása, és ebből következően a tanulmány egyértelműen megfogalmazott célja.

f) *Anyag és módszerek* A vizsgált anyag, esetleg korábbról származó adatok, a mérési, kiértékelési eszközök és módszerek ismertetése. Standard eljárások esetén csak a hivatkozott módszertől való eltérést kell megfogalmazni.

g) Eredmények Az új adatok és kutatási eredmények ismertetése, dokumentációja ábrákkal és táblázatokkal.

h) Diszkusszió A kapott eredményeknek a saját korábbi eredményekkel és a szakirodalmi ismeretekkel való összevetése, beágyazása a tágabb tudományos környezetbe.

i) Következtetések Az új következtetések tézisszerű, rövid ismertetése az eredmények és a diszkusszió ismétlése nélkül.

j) Köszönetnyilvánítás

k) Hivatkozott irodalom Csak a szövegközi, az ábrákhoz és táblázatokhoz kapcsolódóan megjelenő hivatkozásokat foglalja magába (se többet, se kevesebbet).

l) *Ábrák, táblázatok és fényképtáblák (magyar és angol felirattal)* A szemléltetni kívánt jelenség, vagy összefüggés megértéséhez szükséges mennyiségű.

m) Ábra-, táblázat- és fényképmagyarázatok (magyarul és angolul) Az illusztrációk rövid, összefogott, tartalmában érdemi magyarázata.

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Értekezés, szemle maximális összesített **terjedelme** 20 nyomdai oldal (szöveg, ábra, táblázat, fénykép, tábla együttesen). Ezt meghaladó tanulmány csak abban az esetben közölhető, ha a szerző a többletoldal költségének térítésére kötelezettséget vállal. A rövid közlemények összesített terjedelme maximálisan 4 nyomdai oldal.

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Csontos, L., Nagymarosy, A., Horváth, F. & Kovác, M. 1992: Tertiary evolution of the intra-Carpathian area: A model. — *Tectonophysics* **208,** 221–241. http://dx.doi.org/10.1016/0040-1951(92)90346-8

Jámbor Á. 1998: A Tiszai nagyszerkezeti egység karbon üledékes képződményei rétegtanának ismertetése. — In: Bérczi I. & Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* MOL Rt. — MÁFI kiadvány, Budapest, 173–185.

Varga A. 2009: A dél-dunántúli paleozoos–alsó-triász sziliciklasztos kőzetek kőzettani és geokémiai vizsgálatának eredményei. — PhD értekezés, ELTE Kőzettan–Geokémiai Tanszék, Budapest, 150 p.

Weaver, C. E. 1989: *Clays, Muds, and Shales.* — Developments in Sedimentology 44, Elsevier, Amsterdam, 819 p. http://dx.doi.org/10.1016/s0070-4571(08)×7036-0

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Middle Miocene (Badenian) macroinvertebrates from Pécs-Danitzpuszta (Mecsek Mts, SW Hungary)

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Középső miocén (badeni) makrogerinctelenek Pécs-Danitzpusztáról

Összefoglalás

Badeni normál tengeri üledékekből származó makrogerincteleneket – korallokat és puhatestűeket – vizsgáltunk a pécs-danitzpusztai homokbányából. A korallok a felső miocén, pannon-tavi homokban áthalmozva fordulnak elő, és a Lajtai Formáció középső badeni Pécsszabolcsi vagy felső badeni Rákosi Mészkő Tagozatából származhatnak. Az azonosított hét taxon szubtrópusi éghajlatra és önálló korallzátonyok hiányára utal. A puhatestűek a felső badeni Badeni Formáció Szilágyi Agyagmárga Tagozatának és a Lajtai Formáció Rákosi Mészkő Tagozatának szálban álló rétegeiből származnak. A kagylók uralta fauna az adott időszak Középső-Paratethysre jellemző fajait tartalmazza.

Kulcsszavak: Mecsek, badeni, korall, puhatestű, lajtamészkő

Abstract

This paper examines Badenian (middle Miocene) macroinvertebrates – corals and molluscs – from the Pécs-Danitzpuszta sand pit (Mecsek Mts, SW Hungary) in order to extend our knowledge on Miocene normal marine deposits of the Mecsek region. Corals occur reworked in the upper Miocene sand that was deposited in the brackish Lake Pannon, and presumably originate either from the middle Badenian Pécsszabolcs or the upper Badenian Rákos Member of the Lajta Formation. A total of seven taxa were identified. These taxa suggest subtropical conditions and a lack of coral reefs in the Badenian. Molluscs were found in situ in the upper Badenian Szilágy Clay Marl Member of the Baden Formation and the Rákos Member of the Lajta Formation. They dominantly consist of bivalves and represent benthic assemblages typical of the middle Miocene Central Paratethys.

Keywords: Mecsek Mts., Badenian, coral, mollusc, Leitha limestone

Introduction

Miocene sedimentary formations are common around the Mecsek Mts. (Hámor 1970, Chikán 1991, Sebe et al. 2015). Among these, deposits accumulated under normal marine conditions occur only in the Badenian (corresponding to the Langhian and Serravallian standard stages). At some sites the various bioclastic limestones, calcareous sands and silts contain abundant invertebrate faunas. Despite this, the number of papers describing Badenian invertebrates from the Mecsek area is rather limited. Strausz (1923, 1928) studied the mollusc fauna and the Miocene stratigraphy at Mecsekjánosi (now part of Komló), Szopók (later Mecsekfalu, now part of Komló) and Mecsekpölöske. Later, two voluminous monographs dealt with the mollusc fauna of Hidas (Csepreghy-Meznerics 1950) and the Eastern Mecsek (Bohn-Havas 1973). Recently, the Muricidae gastropods were studied in detail from Orfű-Tekeres, Mecsekpölöske, Kisbattyán, Hidas and Hosszúhetény by Kovács (2020).

As for the Miocene corals, many studies have been published about these in Hungary (Hegedűs 1970, Hegedűs & Jankovich 1972, Kopek 1954, Oosterbaan 1990, Reuss 1872, Scholz 1970); however, only very few mention sites from the Mecsek. Strausz (1923, 1928, 1942) reported coral fragments from the Leitha limestone north of Mecsekjánosi (now part of Komló), patch reefs in the same horizon near Mecsekpölöske, and coral-bearing clay near Bodolyabér, but provided neither taxonomic details nor illustrations. Földi et al. (1967) listed "Anthozoa remains" in the faunal list of the Tekeres Schlieren south of Hosszúhetény, without any further details, while Hámor (1970) mentioned solitary corals from the upper part of the same unit in the borehole Komló-XLI, drilled between Komló and Mánfa. Soósné (2013) described colonial corals from Mecsekpölöske and included photos as well. She identified the colonies as belonging to hexacorals and stated that they needed precise taxonomic classification. The summary work of Főzy & Szente (2014) writes that "fine corals can be found in the Mecsek around Pécsszabolcs". The most characteristic forms of the Hungarian localities are *Tarbellastraea*, *Porites* and *Montastraea* (Oosterbaan 1990). However, a detailed examination and description of the corals of the Mecsek region is lacking.

The Pécs-Danitzpuszta sand pit, which exposes upper Miocene Lake Pannon brackish-water calcareous marls and sands, is a famous and well-known fossil locality for upper Miocene (Pannonian) molluscs and diverse vertebrate remains (Szabó et al. 2021). The latter include redeposited middle Miocene (mostly Badenian) bones and teeth of marine fishes and mammals, but until now Badenian marine molluscs have not been reported from here. A few dozens of scleractinian corals have been found in the last few years in the sand pit by private collectors. These corals were redeposited into the upper Miocene sands. The artificial trench excavated at the sand pit in September 2018 exposed some upper Badenian sediments in situ, at the lower part of the 220 m thick section (Sebe et al. 2021). These Badenian layers yielded uncommon and not very diverse, poorly preserved mollusc fauna.

This short paper reports on Badenian molluscs and corals to extend our knowledge on Miocene normal marine deposits of the Mecsek region.

Material and methods

The studied corals were collected from the upper Miocene sands of the sand pit. The sand quarried in the pit was deposited in the brackish Lake Pannon. The examined specimens are parts of collections of the Mining and Geological Survey of Hungary (Budapest, uninventoried material), of the Local History and Natural History Museum Collection in Komló, and of the private collection of Ferenc Cserpák in Budapest (uninventoried material). In total, 37 coral specimens were examined. Analysis of the specimens was carried out using a stereo microscope (Leica Zoom 2000) and a digital caliper. Taxonomic assignment was based on macrostructural features, e.g., colony shape, calice size and shape, calicular wall, septum development, morphology of the columella and coenosteum characteristics.

Badenian molluscs were collected from in situ Badenian rocks in the exploratory trench at Pécs-Danitzpuszta. They come from the massive, crumbly, sandy limestone of layer 71 and from the thick-bedded calcareous marls of layer 72 (for the sedimentary succession see Sebe et al. 2021). The studied specimens are housed in the palaeontological collection of the Hungarian Natural History Museum, Budapest (inventory numbers INV 2021.62 – 2021.75).

Results

Corals

All examined specimens are fragments of coral colonies (*Figure 1*). The size of the fragments varies between 0.8 and 8.7 centimetres. Macroscopic features were sufficient to identify the specimens at the genus level, since the diagnostic characters had been preserved on all specimens. The 37 specimens were assigned into seven taxa. *(Table I.*). Basic morphometric data are presented in *Table II.*

Most of the specimens are colony fragments and the deeper regions of calices are filled with sand. On the surface of the largest specimen, *Tarbellastrea reussiana*, few typical borings of the mytilid *Lithophaga* sp. (*Figure 1*) were also observed.

Molluscs

Altogether 45 mollusc specimens were identified (layer 71: 25; layer 72: 20, *Table III*). With the exception of the calcite-shelled ostreids, all of the specimens are external or internal moulds (*Figure 2*). Nearly all of the molluscs belong to bivalves (44); gastropods are represented by a single *Rissoa* specimen.

All members of the fauna are typical in the middle Miocene benthic assemblages of the Central Paratethys, also including the Mecsek area (Csepreghy-Meznerics 1950, Bohn-Havas 1973). In the absence of pectinids, this mollusc fauna is not suitable for a more accurate biostratigraphic assignment, as the identified species have relatively long stratigraphic ranges.

Discussion

As appropriate circumstances for corals (e.g., normal salinity and sufficiently warm sea water) were present in the area only in the Badenian (Főzy & Szente 2014, Sebe et al. 2019), it is evident that the corals of Pécs-Danitzpuszta originate from Badenian rocks. The potential source rocks are the littoral Leitha limestones: either the middle Badenian Pécsszabolcs ("lower Leitha limestone") or the upper Badenian Rákos ("upper Leitha limestone") Member of the Lajta Formation . The lower Pécsvárad Member crops out north of the sand pit (Hámor et al. 1966), while the upper Rákos Member is identified in the exploratory trench in the sand pit, just below Sarmatian rocks (Sebe et al. 2021). Since no corals have been reported from either of the two stratigraphic units yet, the question of provenance of the corals that were found in the sand pit remains open. Still, the presence of corals is a hitherto unreported feature of Badenian deposits in the area.

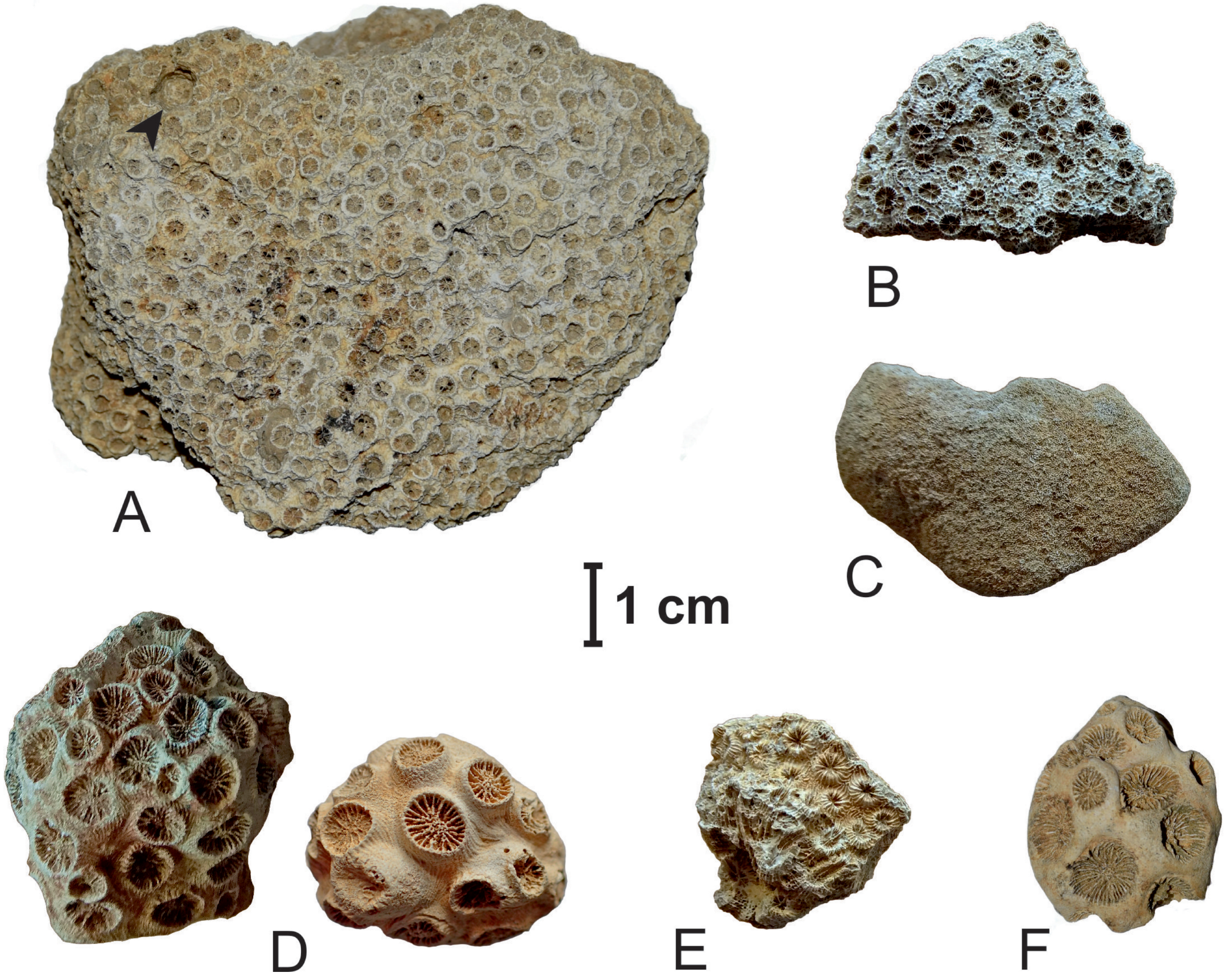

Figure 1. Scleractinian corals from Pécs-Danitzpuszta

A – *Tarbellastrea reussiana* Milne-Edwards & Haime, 1850 (Local History and Natural History Museum Collection, Komló) with *Lithophaga* boring (arrow), B – *Tarbellastrea tenera* Reuss, 1847 (Private collection of Ferenc Cserpák, Budapest), C – *Porites collegniana* Michelin, 1842 (Collection of the Mining and Geological Survey of Hungary, Budapest), D – cf. *Cladangia conferta* Reuss, 1847 (Private collection of Ferenc Cserpák, Budapest), E – cf. *Plesiastrea* sp. (Collection of the Mining and Geological Survey of Hungary, Budapest), F – cf. *Astroides subirregularis* Osasco, 1897 (Local History and Natural History Museum Collection, Komló)

***1. ábra.** Telepes kőkorallok (Scleractinia) Pécs-Danitzpusztáról*

A - Tarbellastrea reussiana *Milne-Edwards & Haime, 1850 (Komlói Helytörténeti és Természettudományi Gyűjtemény)* Lithophaga *fúrás nyomával (nyíl), B -* Tarbellastrea tenera *Reuss, 1847 (Cserpák Ferenc magángyűjteménye, Budapest), C -* Porites collegniana *Michelin, 1842 (Magyar Bányászati és Földtani Szolgálat gyűjteménye, Budapest), D - cf.* Cladangia conferta *Reuss, 1847 (Cserpák Ferenc magángyűjteménye, Budapest), E - cf.* Plesiastrea *sp. (Magyar Bányászati és Földtani Szolgálat gyűjteménye, Budapest), F - cf.* Astroides subirregularis *Osasco, 1897 (Komlói Helytörténeti és Természettudományi Gyűjtemény)*

Table I. The list of identified taxa in the three collections

I. táblázat. *A három gyűjteményben azonosított telepes kőkorallok (Scleractinia) listája*

Collection of the Mining and Geological Survey of Hungary (Budapest):	
cf. *Astroides subirregularis* Osasco, 1897	(1 specimen)
cf. *Plesiastrea* sp.	(1)
Porites collegniana Michelin, 1842	(1)
Tarbellastraea cf. *reussiana* Milne-Edwards & Haime, 1850	(20)
Tarbellastraea cf. *tenera* Reuss, 1847	(1)
cf. *Tarbellastraea* sp.	(2)
Local History and Natural History Museum Collection (Komló):	
cf. *Astroides subirregularis* Osasco, 1897	(1) (INV 2019.9.1.)
Tarbellastraea reussiana Milne-Edwards & Haime, 1850	(2) (INV 2019.10.1., 2021.1.1.)
Private collection of Ferenc Cserpák (Budapest):	
cf. *Astroides subirregularis* Osasco, 1897	(1)
cf. *Cladangia conferta* Reuss, 1847	(2)
Tarbellastraea reussiana Milne-Edwards & Haime, 1850	(1)
Tarbellastraea cf. *reussiana* Milne-Edwards & Haime, 1850	(3)
Tarbellastraea tenera Reuss, 1847	(1)

Table II. Species list and summary of the main diagnostic characters used to identify the specimens
II. táblázat. *A telepes kőkorallok (Scleractinia) fajlistája és a példányok azonosításához használt fontosabb diagnosztikus tulajdonságok*

Species	Colony	CD (mm)	No. septa	No. cycles	Coenosteum	Columella
Astroides subirregularis	M	3.0–8.5	28–32	4	Sm	S
Cladangia conferta	M, B	4.5–6.5	34–36	4	Cos	S–P
Plesiastrea sp.	M	2.0–4.5	20–24	3	Cos	–
Porites collegniana	E	0.6–1.1	12–20	3	Sp	T
Tarbellastraea reussiana	M	1.0–3.1	24–30(?)	3–(4)	Cos	T
Tarbellastraea sp.	M	1.0–2.8	22–28(?)	3–(4)	Cos	?T
Tarbellastraea tenera	M	1.6–2.2	24	3	Cos	T

Colony: B = branching, E = encrusting, M = massive. CD = calicular diameter. Coenosteum: Cos = costae present, Sm = smooth, Sp = spongy. Columella: P = papillose, S = spongy, T = trabecular
Telelepforma: B = ágas, E = kéregszerű, M = gumószerű. CD = kehelyátmérő. Köztesváz: Cos = bordázott, Sm = sima, Sp = szivacsos. Kolumella: P = szemölcsszerű, S = szivacsos, T = trabekuláris

The low (<10) number of identified species suggests less favourable circumstances for corals (Kiessling 2001, Pandolfi 2011, Scholz 1970). Due to the subtropical rather than tropical climate of the Central Paratethys, typical coral reefs did not form in the Mecsek region, similarly to other localities in the northern part of Hungary and Austria (Oosterbaan 1990, Piller & Kleemann 1991). It is likely that the Badenian corals of the Mecsek may have lived in small scattered banks or formed patch reefs and coral carpets (see Riegl & Piller 2000). Although no completely intact colony was found among the specimens, the preservation of the corals was very good. In some cases *Lithophaga* sp. borings were also observed, similarly to corals described by Piller & Kleemann (1991).

Molluscs provide information on the Lajta Formation as well. The mollusc fauna of the Leitha limestone is less diverse, but more numerous than that of the underlying Szilágy Clay Marl: only four bivalve taxa are present, with a strong dominance of *Cubitostrea digitalina* (21 out of 25 specimens). Ostreids are represented by thin-shelled and predominantly small-sized specimens. *Cubitostrea digitalina* is an epibenthic shallow-water suspension feeder, attached to hard surfaces of the sea bottoms. The small size of the specimens may refer to unfavourable environmental conditions for *Cubitostrea*. *Venus multilamella* and *Myrtea spinifera* belong to vagile infauna and they prefer soft muddy bottoms.

The less numerous mollusc fauna of the Szilágy Clay Marl is much more diverse (10 taxa; one gastropod and nine bivalve species), and the most common species, *Venus* (*Ventricoloidea*) *multilamella* is less dominant (6/20 specimens). The single gastropod, *Rissoa,* is of a small sized herbivorous taxon, living mostly on brown algae. All bivalve species belong to the inbenthos and they lived freely in muddy or fine sandy substrate, indicating a several tens of metres deep, low-energy depositional environment. Some of the bivalves (*Myrtea*, *Acanthocardia*, *Pitar,* and *Crassatina*) are suspension feeders, whereas others (*Nuculana*, *Tellina*, and *Gastrana*) are detritus feeders. Most of the bivalve external moulds show evidence of bioerosion trace fossils within the dissolved original shell materials.

Conclusions

This is the first study where Miocene coral species from the Mecsek region are identified. The relatively low number of species suggests subtropical conditions and a lack of typical coral reefs in the Badenian. Molluscs indicate similar ecological conditions and a decreasing water depth in the late Badenian.

Table III. The list of identified taxa in the studied mollusc material
III. táblázat. *A vizsgált anyagban azonosított puhatestű taxonok listája*

Layer 71 (Rákos Member of Lajta Formation; Sebe et al. 2021):	
Cubitostrea digitalina (Eichwald, 1830)	(21 specimens) (INV 2021.62.)
Pectinidae indet.	(1) (INV 2021.63.)
Myrtea spinifera (Montagu, 1803)	(1) (INV 2021.64.)
Venus (*Ventricoloidea*) *multilamella* (Lamarck, 1818)	(2) (INV 2021.65.)
Layer 72 (Szilágy Clay Marl Member of the Baden Formation; Sebe et al. 2021):	
Rissoa turricula Eichwald, 1830	(1) (INV 2021.66.)
Nuculana (*Saccella*) *fragilis* (Chemnitz, 1784)	(1) (INV 2021.67.)
Cubitostrea digitalina (Eichwald, 1830)	(2) (INV 2021.68.)
Venus (*Ventricoloidea*) *multilamella* (Lamarck, 1818)	(6) (INV 2021.69.)
Tellina? sp.	(1) (INV 2021.70.)
Myrtea spinifera (Montagu, 1803)	(1) (INV 2021.71.)
Acanthocardia? sp.	(2) (INV 2021.72.)
Pitar rudis (Poli, 1795)	(2) (INV 2021.73.)
Crassatina moravica (Hörnes, 1870)	(2) (INV 2021.74.)
Gastrana fragilis (Linnaeus, 1758)	(1) (INV 2021.75.)

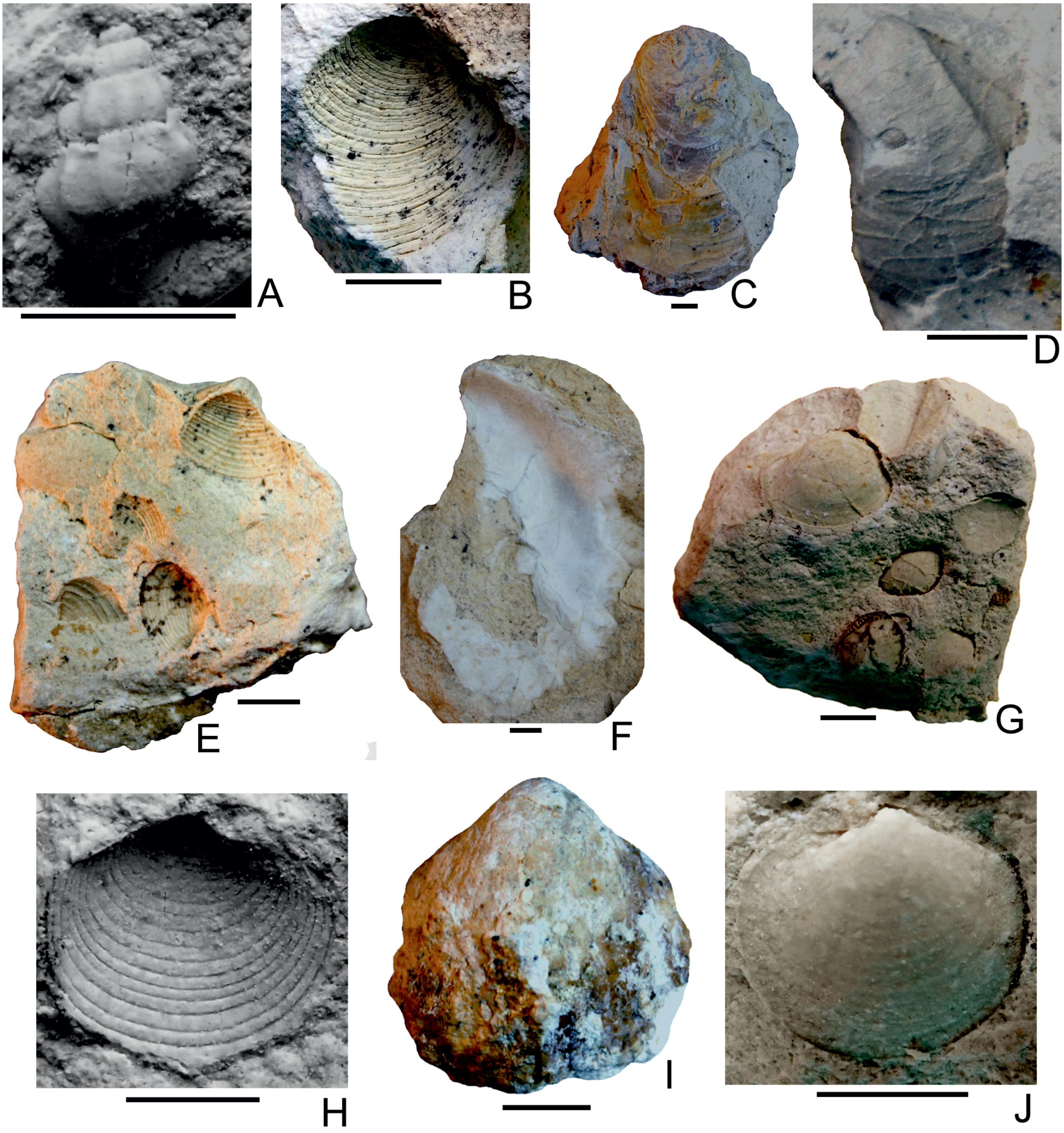

Figure 2. Molluscs from the Badenian layers of the Pécs-Danitzpuszta sand pit

A = *Rissoa turricula* Eichwald, 1830, B = *Venus* (*Ventricoloidea*) *multilamella* (Lamarck, 1818), C = *Cubitostrea digitalina* (Eichwald, 1830), D = *Crassatina moravica* (Hörnes, 1870), E = *Tellina*? sp., *Venus* (*Ventricoloidea*) *multilamella* (Lamarck, 1818), F = *Cubitostrea digitalina* (Eichwald, 1830), G = *Pitar rudis* (Poli, 1795), *Nuculana* (*Saccella*) *fragilis* (Chemnitz, 1784), H = *Myrtea spinifera* (Montagu, 1803), I = *Acanthocardia*? sp., J = *Myrtea spinifera* (Montagu, 1803). Scale = 5 mm

2. ábra. *A pécs-danitzpusztai homokfejtő badeni rétegeinek puhatestű-maradványai*

A = Rissoa turricula *Eichwald, 1830, B =* Venus *(*Ventricoloidea*)* multilamella *(Lamarck, 1818), C =* Cubitostrea digitalina *(Eichwald, 1830), D =* Crassatina moravica *(Hörnes, 1870), E =* Tellina*? sp.,* Venus *(*Ventricoloidea*)* multilamella *(Lamarck, 1818), F =* Cubitostrea digitalina *(Eichwald, 1830), G =* Pitar rudis *(Poli, 1795),* Nuculana *(*Saccella*)* fragilis *(Chemnitz, 1784), H =* Myrtea spinifera *(Montagu, 1803), I =* Acanthocardia*? sp., J =* Myrtea spinifera *(Montagu, 1803). Méretarány = 5 mm*

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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 üledékcsomagokkal 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 kövületek 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" szívkagylók 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, mindeddig ismeretlen formák.

A rétegsor következő, jelentős részét a Pannon-medence déli felében nagy elterjedést mutató „fehér márgák" teszik ki. Ezek a Pannon-tó szublitorális 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 szublitorális 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 lenyomatai 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

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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 schmidti*-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 palaeontological site. The marl is the type locality of some endemic Pannonian calcareous nannofossils (BÓNA & GÁL 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

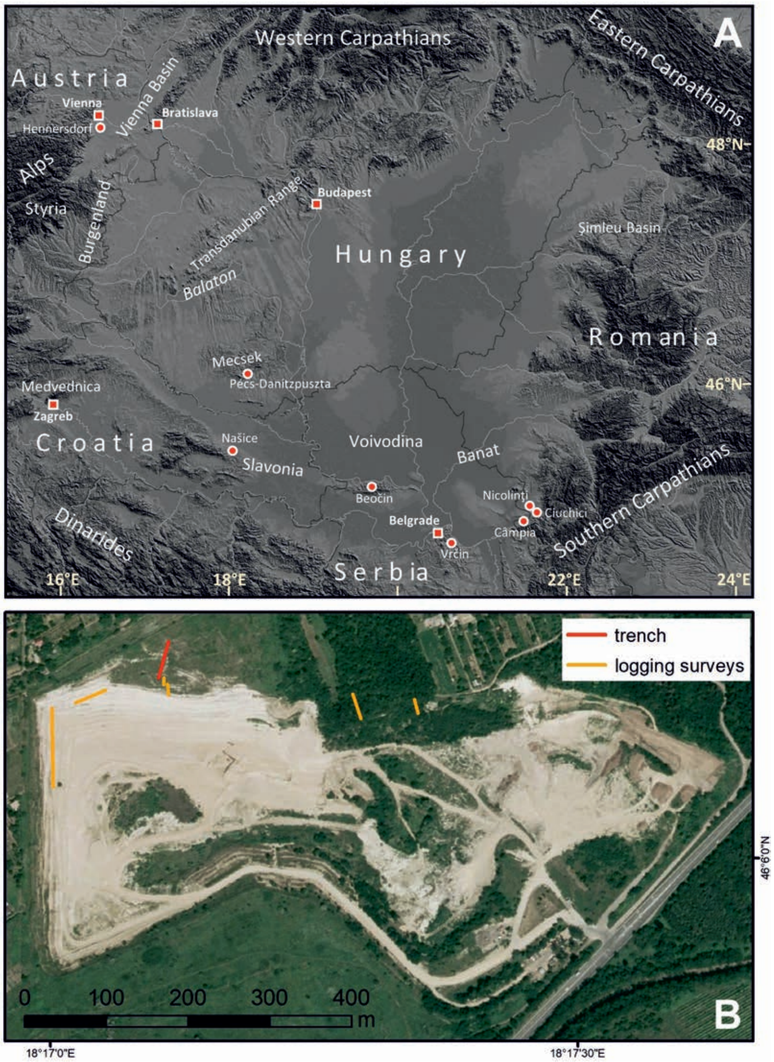

Figure 1. A: Location map of the Pannonian Basin surrounded by the Alps, Western, Eastern and Southern Carpathians and Dinarides with the geographical names referred to in the text. B: Satellite photo of the sand pit with the location of the exploratory trench and the logged surveys (SEBE et al. 2021)

***1. ábra.** A: Az Alpokkal, Kárpátokkal és Dinaridákkal körülvett Pannon-medence a szövegben hivatkozott földrajzi nevekkel. B: Műholdas felvétel a pécs-danitzpusztai bányáról a kutatóárok 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 reposited 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 microscope. 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 40×64 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 reposited 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 *Congeria*, 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 *Ervilia* 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-*

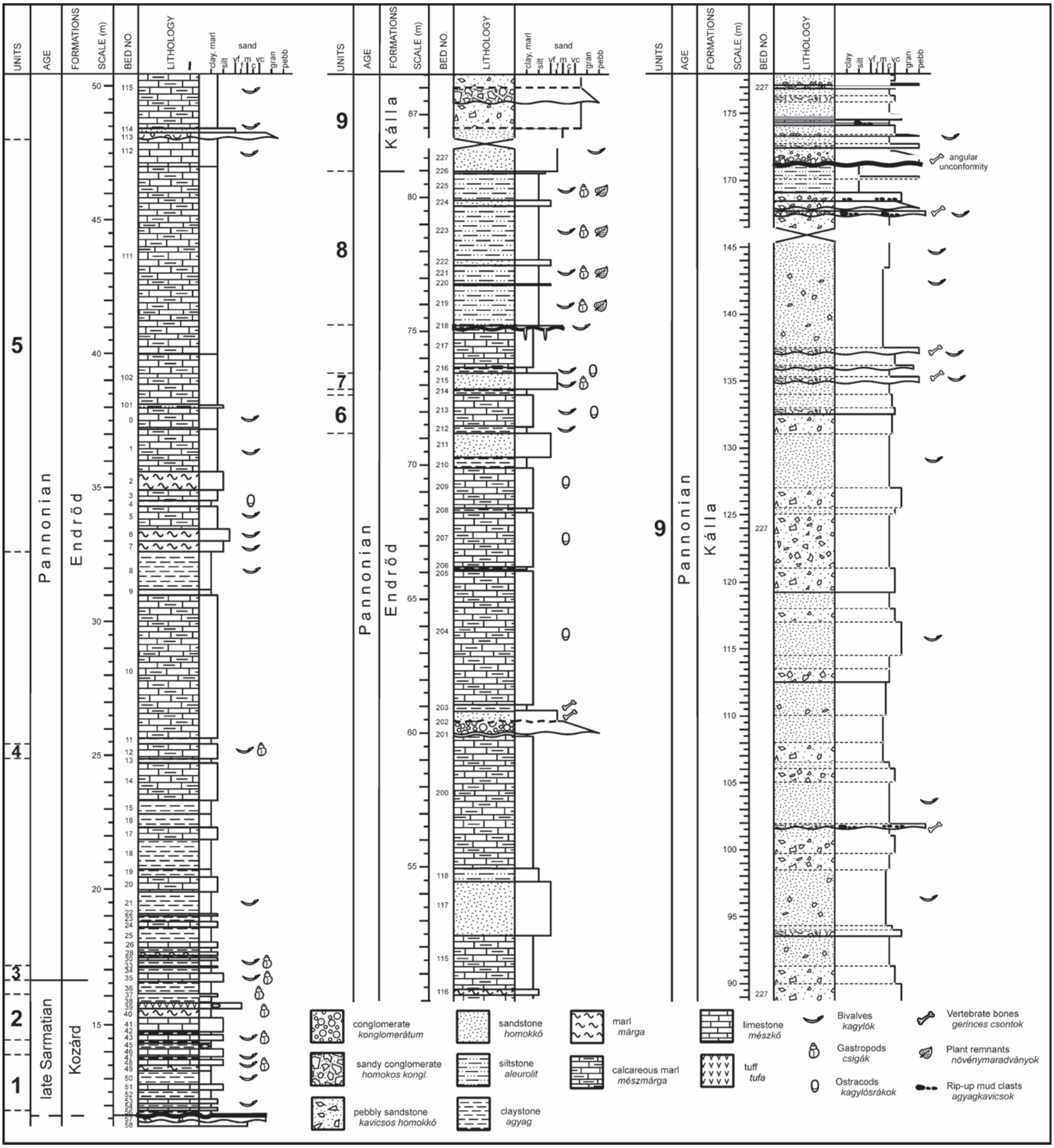

Figure 2. Lithologic log of the pécs-Danitzpuszta succession, with sample locations and layer and unit numbers. Faunal intervals are discussed in the text. (Sebe et al. 2021)

2. ábra. *A Pécs-danitzpusztai 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 Pannonian 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*" *praeponticum* (*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 cardiids, deserve a thorough study in the future.

Unit 4. The fauna embedded into the calcareous marl of Layer D12 consists of cardiids ["*Lymnocardium*" cf. *praeponticum* (*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 "Croatica 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 cardiids [*Paradacna* cf. *syrmiensis, 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. brusinai* (*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., Gorjanović-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 cardiids, 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 & Mandic 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. brusinai*, *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 Hennersdorf (near Vienna; Papp 1953, 1985; Harzhauser & Mandic 2004) and also with the fauna of Câmpia (Langenfeld) and Nicolinţi (Nikolincz) in southern Banat, at the foothills of the Southern Carpathians, Romania (*C. zsigmondyi*, *L. winkleri*, "*L.*" *carnuntinum* (=*L. pseudosuessi*), and "*L.*" *tegulatum*) (Halaváts 1882, 1886). Most of these mollusks are known to have lived in sublittoral environment (e.g., Harzhauser & Mandic 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 ungulacaprae* (*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 ungulacaprae*, *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 Vrčin, 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

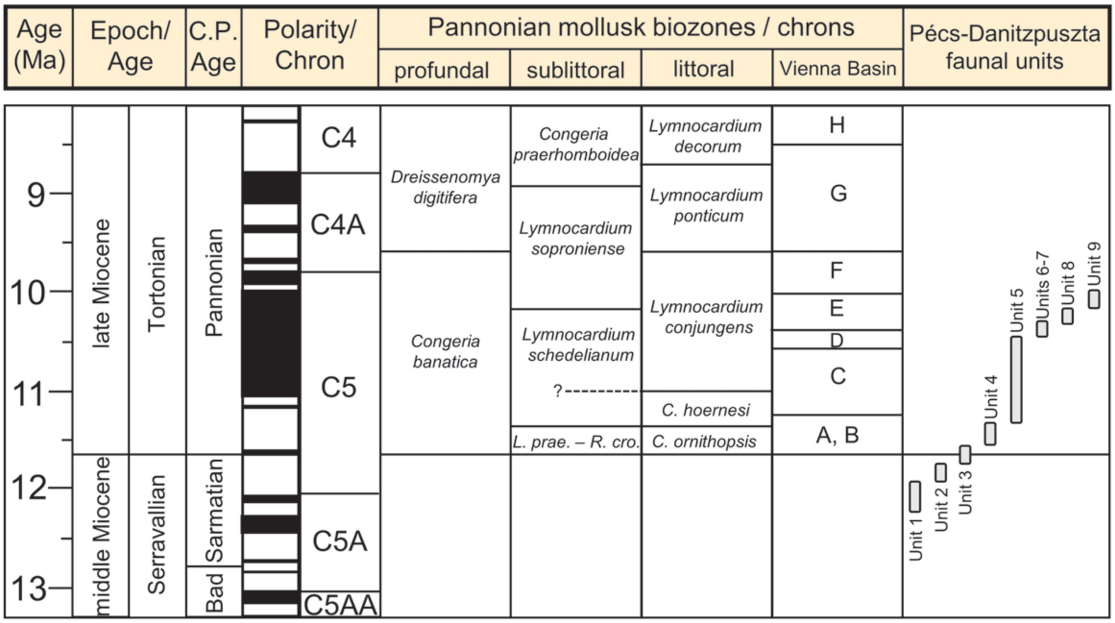

Figure 3. Stratigraphic chart for the late middle Miocene to early late Miocene with the mollusk zones of the Pannonian (according to Magyar & Geary 2012 and Harzhauser et al. 2004) and with the biochronostratigraphic interpretation of the Pécs-Danitzpuszta faunal units.
C. P.: Central Paratethys; Bad: Badenian; *L. prae.* – *R. cro.*: *"Lymnocardium" praeponticum* – *Radix croatica*; *C.*: *Congeria*

***3. ábra.** A pécs-danitzpusztai feltárásban azonosított puhatestű faunák biosztratigráfiai 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 Hennersdorf 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 Hennersdorf 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 Hennersdorf 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 Vrčin; 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 siliciclastic 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 cardiids. Cardiids 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 cardiids, again similar to the species in Unit 3. The common occurrence of originally freshwater pulmonates (lymnaeids and planorbids) and brackish-water cardiids 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 cardiids and, at the same time, allowed freshwater pulmonates to enter the brackish lake. The cardiids 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 *Lymnocardi-*

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 Şimleu 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 *Congeria 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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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: Lymnocardiinae sp., D55; 3: Lymnocardiinae 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 kutatóárokból (D55–D37, 1. és 2. szakasz). 1: Dreissenidae sp., D55; 2: Lymnocardiinae sp., D55; 3: Lymnocardiinae 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: Csiga- 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: Lymnocardiinae 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: Lymnocardiinae 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 kvarcszemcsék 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: Lymnocardiinae sp.; 10–11: *"Lymnocardium" margaritaceum*; 12: *Velutinopsis* sp.; 13: *Micromelania striata; 14: Orygoceras brusinai; 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: Lymnocardiinae sp.; 10–11:* "Lymnocardium" margaritaceum*; 12:* Velutinopsis *sp.; 13:* Micromelania striata*; 14:* Orygoceras brusinai*; 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: Lymnocardiinae 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: Lymnocardiinae 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 ungulacaprae*; 6: *Congeria partschi*

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

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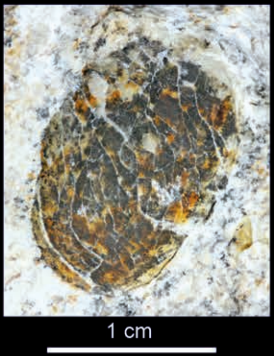

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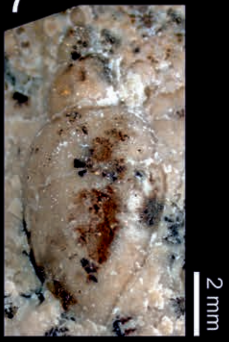

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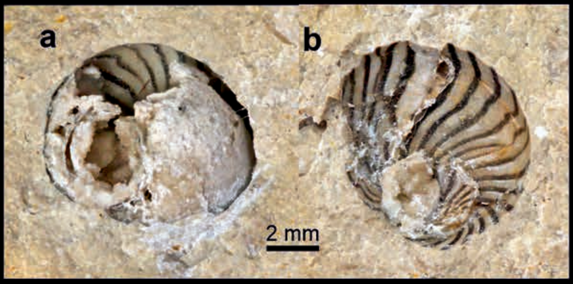

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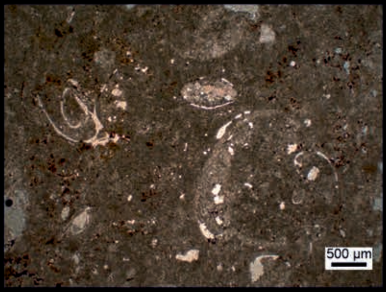

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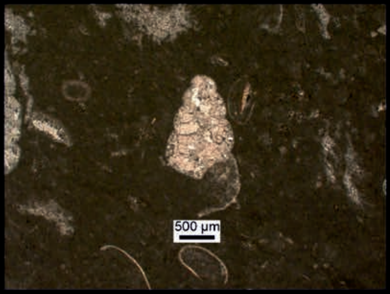

Plate II – II. tábla

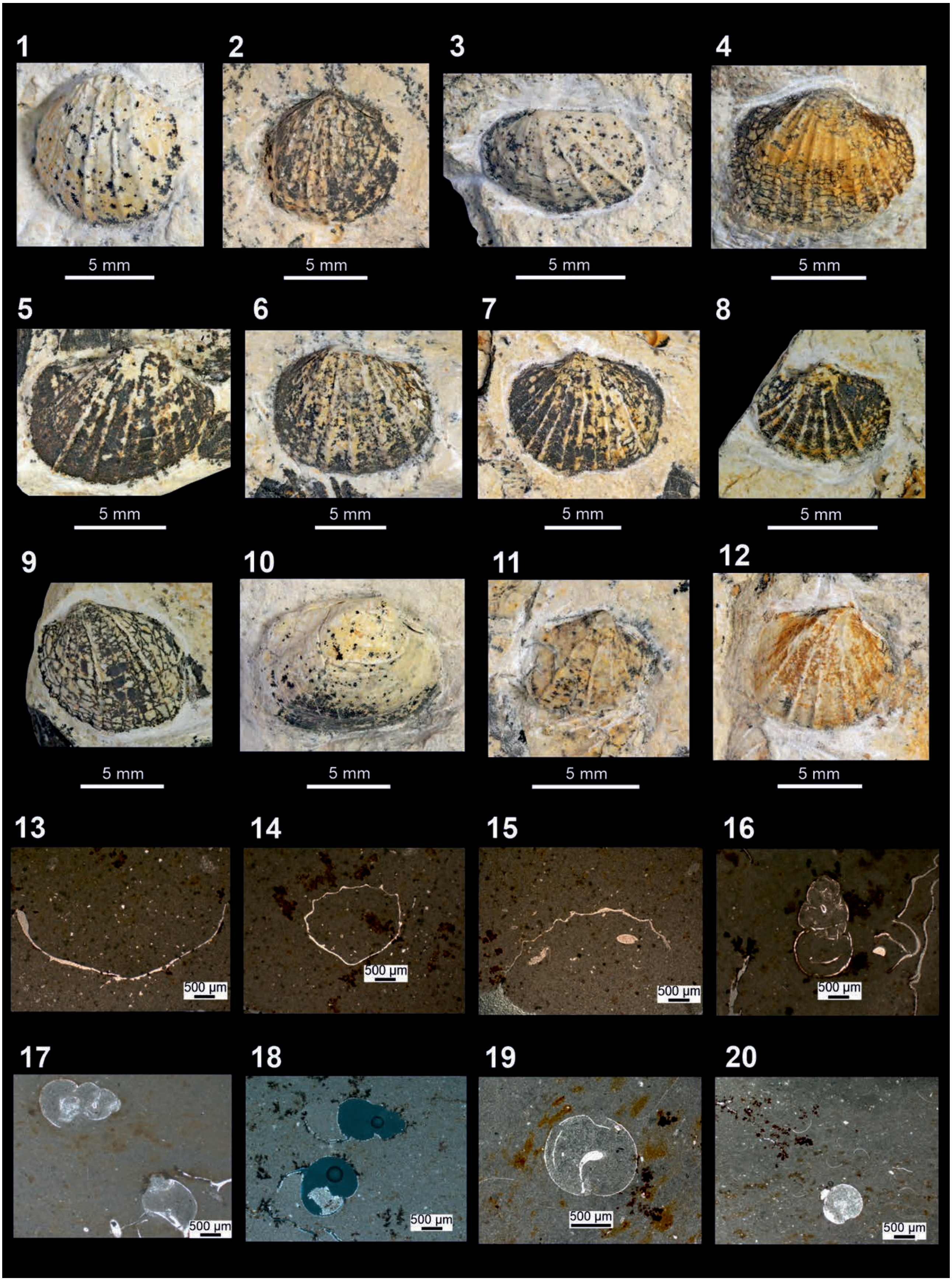

Plate III – III. tábla

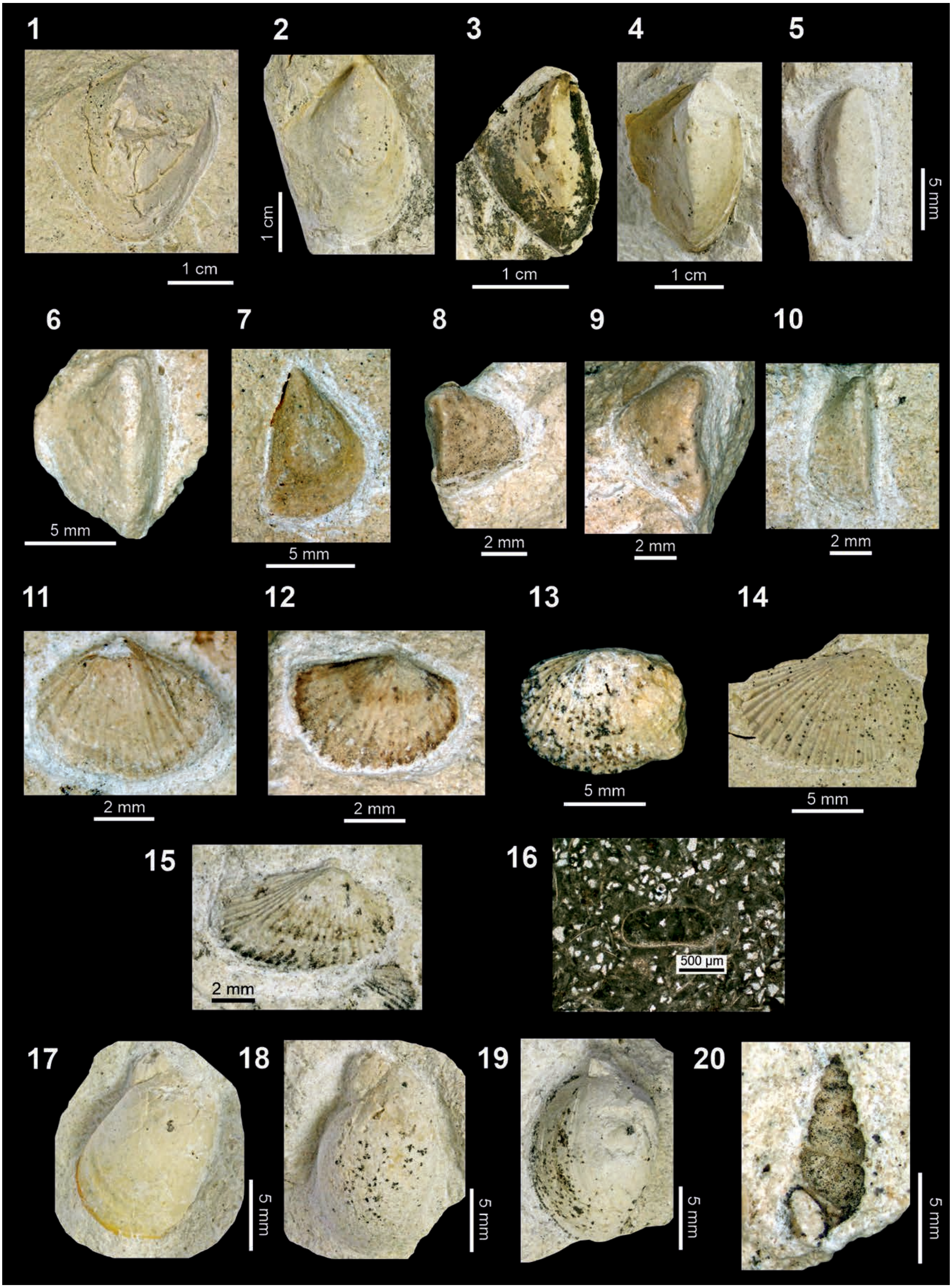

Plate IV – IV. tábla

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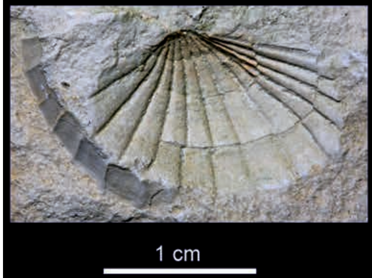

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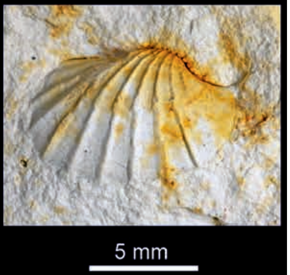

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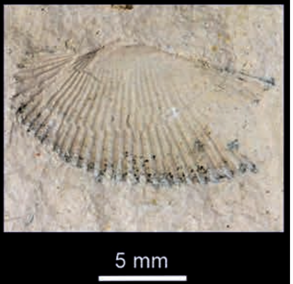

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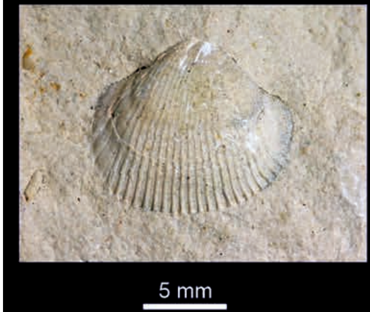

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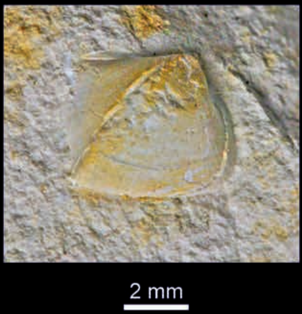

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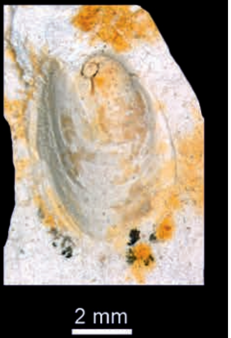

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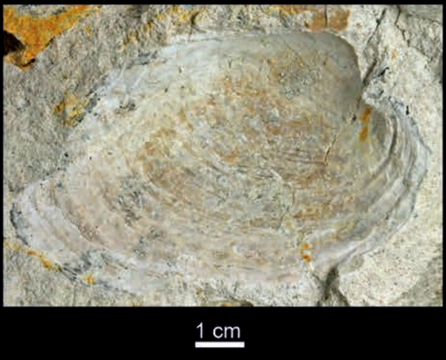

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Plate V – V. tábla

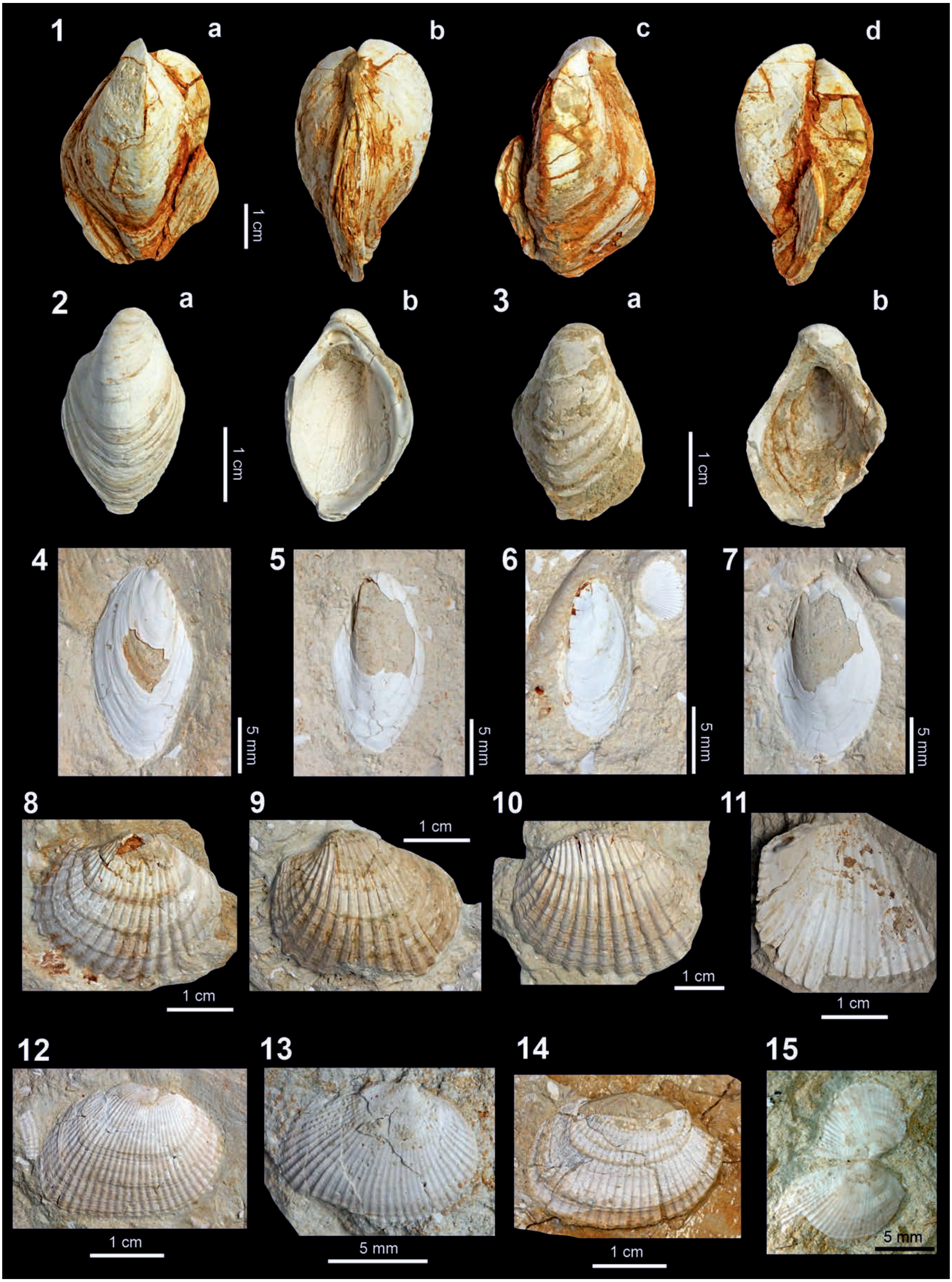

Plate VI – VI. tábla

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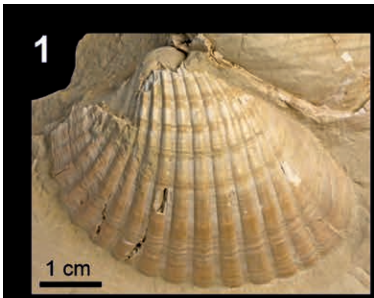

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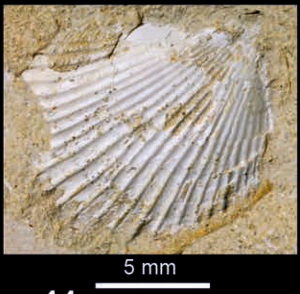

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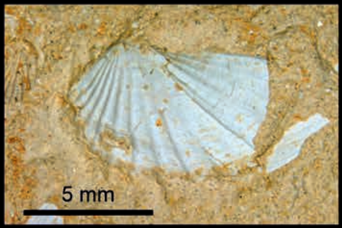

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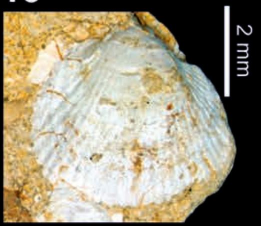

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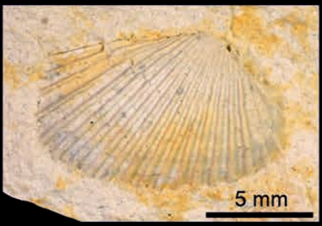

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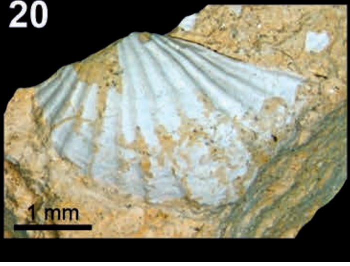

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Plate VII – VII. tábla

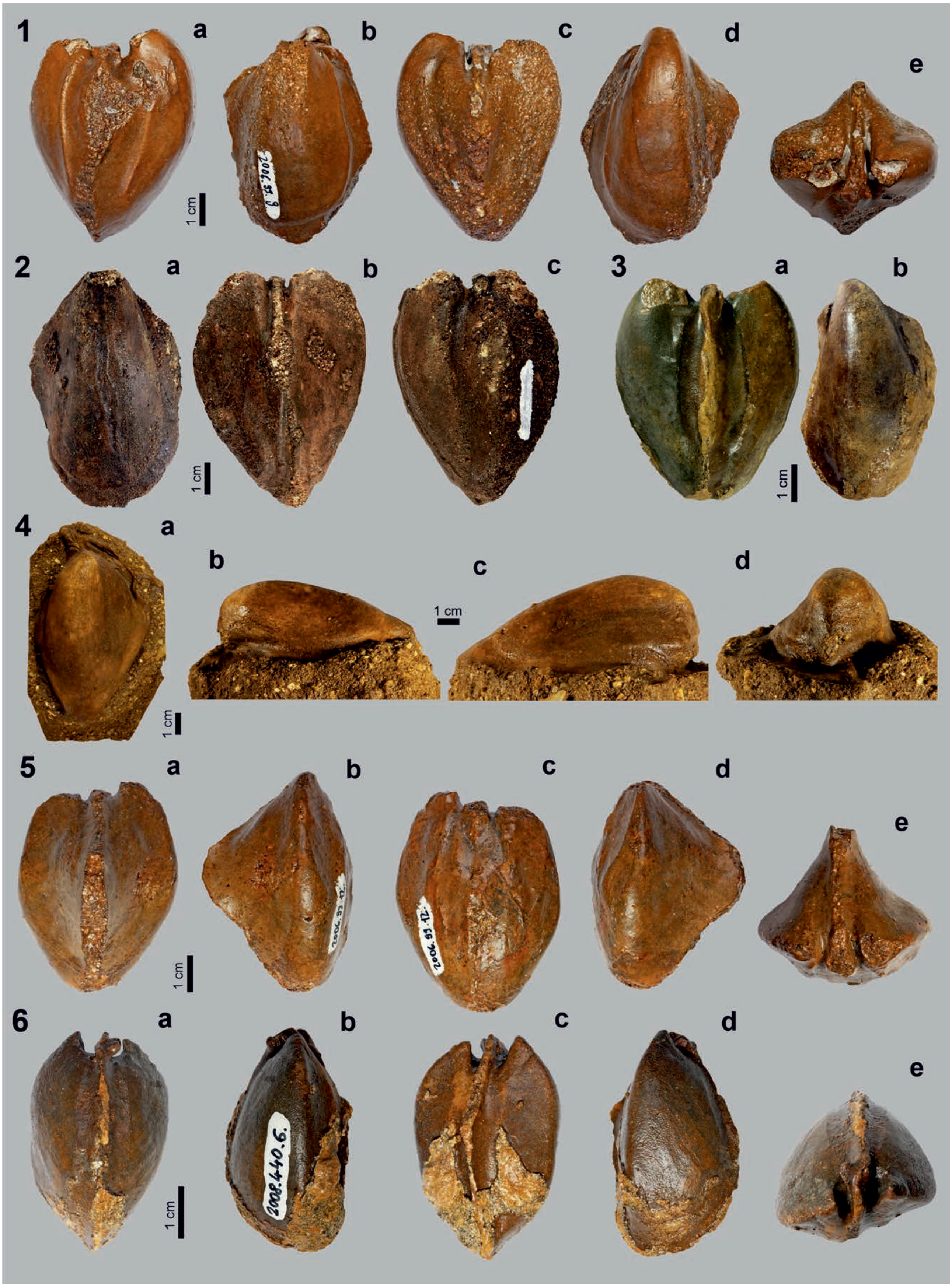
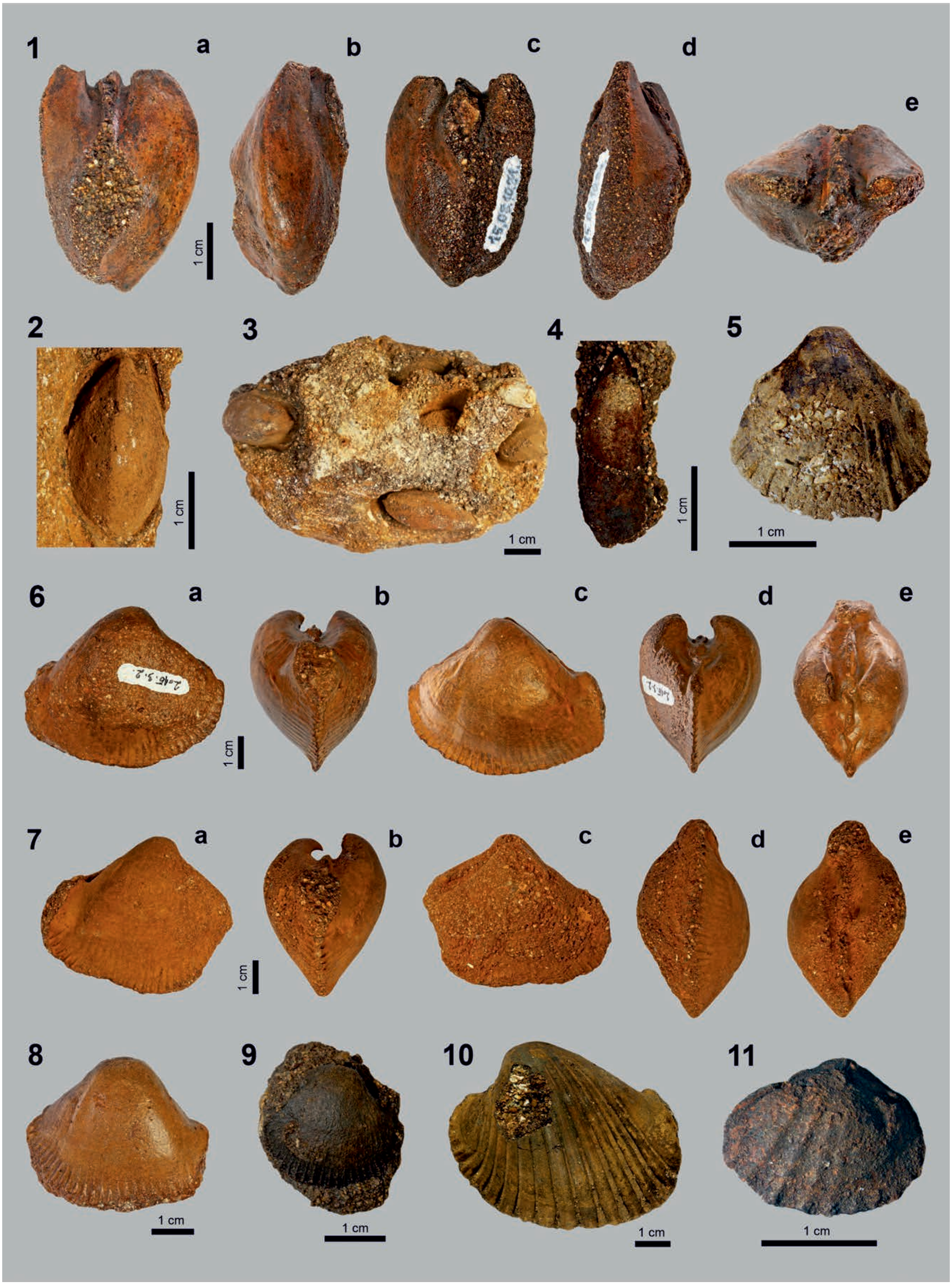


Plate VIII – VIII. tábla



Appendix

Systematic Palaeontology

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

Bivalvia Linnaeus, 1758
Cardiidae Lamarck, 1809
Lymnocardiinae 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.) – Korpás-Hódi, p. 145, pl. 1, fig. 3.
1985 *Limnocardium pseudosuessi* (Halaváts) – Korpás-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 (Korpás-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.; Korpás-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, Lőrenthey 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 *Limnocardium winkleri* Halaváts – Miletić-Spajić, pl. 8, fig. 14.
?1962 *Limnocardium winkleri* Halaváts – Széles, p. 56, pl. 3, fig. 4.
?1971 *Limnocardium 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 *Limnocardium lukae* Stev. – Stevanović, p. 341.
1980 *Limnocardium Winkleri lukae* n. subsp. Stevanović, p. 128, 139, pl. 3, figs 19–22. [new synonym]
?1980 *Limnocardium winkleri* Hal. – Stevanović, pl. 4, fig. 11.
?1983 *Limnocardium winkleri* (Halav.) – Korpás-Hódi, p. 145, pl. 1, fig. 4.
?1985 *Limnocardium winkleri lukae* Stev. – Korpás-Hódi in Jámbor et al., p. 227, pl. 19, fig. 3.
1987 *Limnocardium winkleri lukae* Stevanović – Jámbor et al., pl. 4, fig. 3.
?1992 *Limnocardium winkleri lukae* Stev. – Korpás-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 & Karácsonyi, 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–Markuševec (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 szigmondyi* [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 & Mandic, 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 *Dreyssensiomya* [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. LŐRENTHEY, 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 reposited 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 LŐRENTHEY (1893) is probably a junior synonym of *M. striata*, but the figure of LŐRENTHEY 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 – LŐRENTHEY 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).

Lymnaidae 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) – TAKTAKISHVILI, 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 reposited 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 = "Croatica 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. – Mandic 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*, *Congeria czjzeki* and *Congeria 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; Markuševec, 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 Mureş and Guşteriţa, Transylvanian Basin, Romania – Magyar 2010, Botka et al. 2019). It is a common species in the *Lymnocardium praeponticum*, *Congeria czjzeki*, and *Congeria banatica* Zones (from 11.6 to 9.5 Ma). Sporadic occurrences were reported from the much younger *Congeria 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.-Krambg. – 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; Markuševec, 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 Mureş, Transylvanian Basin, Romania – Magyar 2010). *Orygoceras brusinai* is less common than *O. fuchsi* in the *Lymnocardium praeponticum*, *Congeria czjzeki* and *Congeria banatica* Zones (from 11.6 to 9.5 Ma).

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A diverse Miocene fish assemblage (Chondrichthyes and Osteichthyes) from the Pécs-Danitzpuszta sand pit (Mecsek Mts, Hungary)

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Egy változatos miocén halfauna a Mecsekből, a pécs-danitzpusztai homokbányából

Összefoglalás

A Középső-Paratethys tengeri üledékeiben igen gyakoriak a porcos- és csontoshal-maradványok, nemcsak szórványleletek, hanem komplex, változatos halfaunák formájában is jelen vannak. Munkánk a pécs-danitzpusztai homokbánya felső miocén (pannóniai) üledékeiből gyűjtött és eddig csak hiányosan tanulmányozott halfaunát mutatja be. Összesen 22 227 halfossziliát vizsgáltunk meg, melyek 17 porcoshal- és 16 csontoshal-taxont képviselnek. A leletanyag döntő többsége sárga, limonitos, durvaszemcsés, kavicsos homokból került elő izolált leletek formájában. A homokból előkerült halfauna porcoshalai között az Odontaspididae (55,5%) és a Myliobatidae (14,4%) családok dominálnak, míg a csontos halak között a Sparidae (77,1%) család. Recens analógiák alapján a homokból előkerült 17 porcos-, valamint 12 csontoshal-taxon idősebb, középső miocén (badeni) üledékekből halmozódott át. A homok alatti mészmárgából artikulált és asszociált Latidae csontoshal-maradványok kerültek elő. Ezek egykorúak a beágyazó üledékkel és édesvízi-brakk környezetet jeleznek. Izolált csontoshal-maradványok szintén előkerültek a mészmárgából, úgy mint hallókövek, fogak, pikkelyek, csigolyák és állkapocselemek, melyeket a Gadidae, Gobiidae, Sparidae és Latidae családokhoz soroltunk. Ezek akár áthalmozottak is lehetnek, így paleoökológiai jelentőségük csekély.

Az ismertetett taxonok recens leszármazottainak ismert ökológiai igényei alapján a homokban talált összes porcoshal és a csontoshalak többsége badeni korú üledékekből halmozódott át. Egyes csontoshal-taxonok maradványai koprolitokból is előkerültek, ami azt bizonyítja, hogy ezek a halak prédaállatként a helyi táplálékhálózat részei voltak. A tengeriemlős-csontokon felfedezett, nagyragadozó cápáknak tulajdonított harapásnyomok a Középső-Paratethys badeni leletanyagaiból eddig nem voltak ismertek. A homokból előkerült Acipenseridae- és Latidae-maradványok brakk- és/vagy édesvízi üledékekhez köthetőek, emiatt szinte bármely környékbeli miocén formációból áthalmozódhattak.

Tárgyszavak: Paratethys, Pannon-tó, harapásnyomok, anadromous

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Abstract

Chondrichthyans and osteichthyans are widely reported from marine sediments of the Central Paratethys, not only by sporadic occurrences, but also by complex, diverse fish assemblages. Here we present a rich fish fauna from the upper Miocene (Pannonian, Tortonian) lacustrine sediments exposed in the Pécs-Danitzpuszta sand pit, in the SW Pannonian Basin. Altogether 22 227 specimens were investigated, and they could be classified into 17 chondrichthyan and 16 osteichthyan taxa. Among the chondrichthyans Odontaspididae (55.5%) and Myliobatidae (14.4%) are the most abundant, while the bony fishes are dominated by the Sparidae (77.1%). The limonitic, yellow, coarse-grained, gravelly sands yielded an extremely large amount of isolated fish fossils. A considerable part of the vertebrate material of the sands is likely reworked from older, middle Miocene (Badenian and Sarmatian, i.e. Langhian and Serravallian) sediments. The late Miocene calcareous marls underlying the sands also yielded a variety of fish remains. From these remains, associated and articulated latid bones are coeval with the sediment and suggest freshwater and brackish conditions in the area, in accord with other biotic data. Other, isolated fossils, namely teeth, otoliths, cycloid scales and jaw elements of Gadidae, Gobiidae, Sparidae and Latidae could have been reworked and thus have a very limited palaeoecological significance.

Based on habitat preferences of extant relatives, all chondrichthyans and most osteichthyan taxa found in the sands must be of Badenian origin. The abundant remains allow for some inferences on the environmental conditions during the Badenian. They suggest tropical-subtropical climate and a shallow, coastal environment with connection to more open water habitats. Remains of some osteichthyan taxa were found in coprolites, showing that these taxa were part of the food chain as prey items. Sirenian ribs and odontocete limb bones bearing tooth marks refer to trophic relations between marine mammals and large macropredatory sharks. The Pécs-Danitzpuszta record of shark-attributed bite marks on marine mammal bones is only the second one in the Badenian of the Central Paratethys after recent report from the Styrian Basin. Acipenserids and latids of the sands, linked to brackish and/or freshwater environments, could have originated from any Miocene stratigraphic units.

Keywords: Paratethys, Lake Pannon, bite marks, anadromous

Introduction

The Central Paratethys was a widely extended part of the epicontinental Paratethys sea, covering large areas of the Pannonian Basin System (Rögl 1998, Kováč et al. 2007, ter Borgh et al. 2013). The Paratethys was isolated from the Tethys during the late Eocene – early Oligocene (Rögl & Steininger 1983, Steininger et al. 1988, Rögl 1998; Dercourt et al. 2000), and was last connected to the Mediterranean Tethys in the Badenian (Kováčová et al. 2009). Repeated closure and reopening of oceanic gateways resulted in a distinct palaeobiogeographical province in the Central Paratethys (Báldi 1983, Rögl 1998). Badenian fish faunas (often with main focus on chondrichthyans and teleost otoliths) are widely reported from Central Paratethyan marine sediments of the Pannonian Basin (Schubert 1902, 1905, 1906, 1912; Ferenczi 1915; Noszky 1925; Brzobohatý & Schultz 1978; Kordos & Solt 1984; Solt 1987; Sebe et al. 2015; Szabó 2019; Szabó & Kocsis 2016a and references therein, 2020). These faunas are dominated by marine taxa with a characteristic presence (or sometimes dominance) of chondrichthyans. Meanwhile, the early and middle Badenian otolith associations indicate typical tropical to subtropical marine environments with normal salinity and connections both to the Atlantic and Mediterranean realms. The increasing number of gadids in the otolith assemblages relates to the gradual cooling (due to the expansion of the Antarctic ice sheet) during the late Badenian (Brzobohatý et. al. 2007, Kováčová et al. 2009). A significant transition in the fish fauna reflects immense environmental changes in the late Badenian and early Sarmatian. The abundance of previously dominant mesopelagic fishes declined or they completely disappeared and were replaced by a prosperous shallow water endemic fauna. This altered fish assemblage was more adapted to brackish marine conditions (Schwarzhans et al. 2015). The revised and detailed evaluation of these faunas started in the last few years. Documented Sarmatian fish faunas of the Pannonian Basin exclude chondrichthyans, and are mainly based on otoliths (e.g. Reichenbacher et al. 2018). These faunas indicate nearshore marine to brackish environments.

Despite the available, overwhelmingly rich fossil material, the Miocene fish assemblages of the Mecsek Mountains (southern Hungary) still remain poorly known, although these localities have been recognized for a long time (Sebe et al. 2015), and attract countless palaeontologists and amateur collectors. Besides middle Miocene sites, several localities exist in the Mecsek Mts where fish remains occur in upper Miocene (Pannonian in Central Paratethys nomenclature) lacustrine deposits. Due to reworking, these deposits include both middle and late Miocene fossils. Some of these localities have been visited and sampled so many times and for such a long time that they can be considered as classic localities for palaeontologists. The famous Pécs-Danitzpuszta sand pit is one of these localities with its extremely rich fossil vertebrate record including various aquatic, semiaquatic and terrestrial taxa (see Kretzoi 1985; Kocsis 2002; Bene 2003; Koretsky 2003; Juhász 2006, 2009; Kazár 2003, 2005, 2006, 2010; Kazár et al. 2007; Konrád et al. 2010; Főzy & Szente 2012, Sebe et al. 2015; Szentesi et al. 2019; Cserpák 2018).

The aim of the present study is to improve our knowledge about the chondrichthyan and osteichthyan diversity of the Central Paratethys basin during the middle and early late Miocene by detailing the diverse ichthyofauna unearthed from the Pécs-Danitzpuszta sand pit and its palaeoenvironmental and palaeobiogeographical aspects.

Geological setting

The Pécs-Danitzpuszta sand pit is located at the eastern edge of the city of Pécs (centre of the western wall: 46°6'1.86"N, 18°16'56.56"E), in SW Hungary, along the southern margin of the Mecsek Mts (*Figure 1*). The sand pit exposes two main lithological units, light grey, white or yellowish grey calcareous marls and silts (Endrőd Marl Formation), and the overlying yellowish brown, coarse limonitic sands (Kálla Member of the Békés Fm). Both were deposited in the brackish Lake Pannon during the late Miocene (Kleb 1973). Due to compression along the marginal fault of the Mecsek Mts, the whole exposed succession is strongly tilted, with beds reaching an overturned position in the northern part of the outcrop (Konrád & Sebe 2010, Sebe 2021).

In the top of the calcareous marl unit, a 4-5 metre thick calcareous silt contained some fish remains. These beds, numbered as layers 219–225 in the sedimentary log of the quarry (Sebe et al. 2021), are exposed in the northern wall of the sand pit in subvertical position. They represent a transition from the carbonate-dominated open lacustrine deposits towards the overlying clastics. They contain a diverse thermophilous macroflora (Hably & Sebe 2016), and a rich brackish sublittoral mollusc assemblage indicating an age of 10.5–10.2 Ma (Botka et al. 2021).

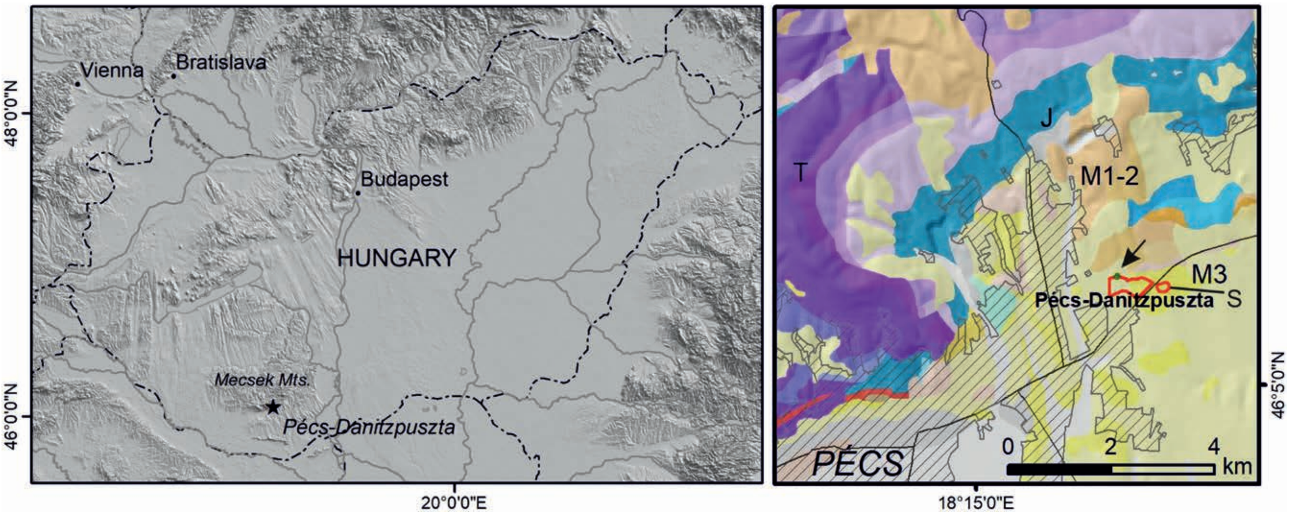

Figure 1. Geological setting of the Pécs-Danitzpuszta sand pits. Base geological map modified from Chikán & Budai (2005). The arrow indicates the location of the exploration trench. Abbreviations: T: Triassic; J: Jurassic; M1–2: lower–middle Miocene; M3: upper Miocene (Pannonian) rocks; "S" indicates the southern sand pit across the main road

1. ábra. *A pécs-danitzpusztai homokbányák elhelyezkedése. Földtani térkép Chikán & Budai (2005) után. A nyíl a kutatóárok helyét mutatja. Rövidítések: T: triász; J: jura; M1–2: alsó – középső miocén; M3: felső miocén (pannóniai) kőzetek. Az „S" betű a déli bányagödör helyét jelöli*

Beside some scattered bones and teeth, the silt layers provided associated partial skeletons and articulated skeletal parts (*Figure 2B*).

The overwhelming majority of the fish remains were collected from the overlying limonitic sands that are the main product of the sand pit. The sands are exposed in a stratigraphic thickness of at least 140 m, mostly in the western wall of the quarry (Sebe et al. 2021). They are coarse to very coarse grained, often gravelly, with poorly sorted sandy gravel interbeds (*Figure 2A*). The bedding dip gradually decreases southward and upsection, from vertical in the northern part of the sand pit to less than 10°. The sand particles had been sourced from the older Miocene and basement rocks of the mountains. The age of the sand is 10.2–9.6 Ma based on the recovered mollusk assemblage (Botka et al. 2021).

A few fish fossils were unearthed in another sand pit across the main road (*Figure 1B*). This smaller exposure is east of the large sand pit, on the southern side of the road („southern pit"), and exposes sands and sandstones with a smaller average grain size, where fine sands and even thin (<20 cm) clay intercalations occur as well. The bedding dip is less than in the northern sand pit. Although it lies in strike direction of the large sand pit, no individual layers could be correlated between the two sites, thus their stratigraphic relationship is uncertain. The southern quarry probably

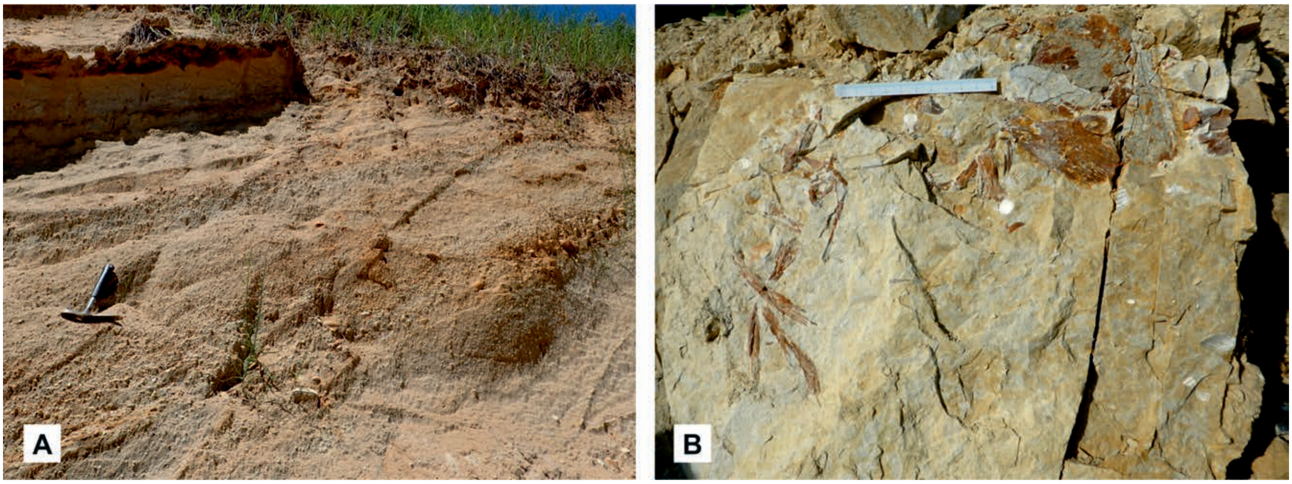

Figure 2. Typical appearance of lithologies providing fish remains. A) Poorly sorted gravelly sand providing inarticulated, mainly reworked vertebrate bones and teeth; B) calcareous silt with mollusk shells (white) and in situ fish remains (brown) (ruler for scale is 10 cm long)

2. ábra. *A halmaradványokat tartalmazó két kőzettani egység jellemző megjelenése. A) Rosszul osztályozott kavicsos homok, melyből izolált, főleg áthalmozott csontok és fogak kerültek elő. B) Mészmárga molluszkahéjakkal (fehér) és in situ halmaradványokkal (barna) (a vonalzó hossza 10 cm)* represents sediments somewhat more distal to the shore. Because of the uncertainty, fossils of this southern sand pit are treated separately from the rest of the material.

Material and methods

The vertebrate remains were collected by hand-quarrying, screen-washing, and dry sieving with 2-4 mm sieves. Vertebrate fossils found in the sands are exclusively inarticulated remains, often fragmentary, eroded to a varying degree, and reddish-brown to yellowish in colour due to limonite. Needles and brushes were used for cleaning, and broken specimens were repaired with cyanoacrylate adhesive (superglue).

Both museum and private collection specimens were investigated. Institutional abbreviations: MGSH – Mining and Geological Survey of Hungary, NHMUS – Hungarian Natural History Museum, PTE – University of Pécs, NHCEU – Natural History Collection of the Eötvös University, JACLMC – József Attila City Library and Museum Collection (Komló).

Systematics and tooth terminology of sharks and rays follow that of CAPPETTA (2012), in accordance with BOR et al. (2012), REINECKE et al. (2011, 2014) and HOVESTADT & HOVESTADT-EULER (2013). Osteichthyan systematics are based on NELSON et al. (2016). Osteological terminology of bony fishes mainly follows CARNEVALE & GODFREY (2018) and PURDY et al. (2001), although latid anatomical terminology follows exclusively that of OTERO (2004). Terminology of otoliths follows that of NOLF (1985).

In case of well-marked heterodonty in some of the described chondrichthyans (e.g., Odontaspididae indet., *Notorynchus primigenius*, *Hemipristis serra*) the teeth were figured according to their in-life jaw position. Artificial tooth sets were also illustrated (see *H. serra* and *Galeocerdo aduncus*). For the Systematic Palaeontology (describing *Plate I–XVII*) see Appendix. Digital Annex 1 includes data on the studied museum and private collection materials.

Discussion

Palaeoenvironmental inferences and age of fish remains of the calcareous marls

Fish remains from the older white marls are much less abundant and less diverse than from the younger sands, therefore they allow fewer inferences on the palaeoenvironment. However, only the marls contain fish fossils which are certainly in situ and thus able to provide information on the coeval environmental conditions.

The associable latid cranial and postcranial remains and the articulated actinopterygian hyoid region could not have been redeposited, therefore they must be coeval with the host sediments. Biostratigraphic dating of this interval of the marls gave an age range between 10.5 and 10.2 Ma (BOTKA et al. 2021), thus these fishes inhabited the brackish Lake Pannon at this time. Latid fishes have already been reported from the middle Miocene sediments of the Central Paratethys (see SCHWARZHANS et al. 2017). Latids generally are of freshwater preference, but some taxa survive in brackish and estuarine waters as well (SORBINI 1975; FROESE & PAULY 2019 and references therein), thus they suggest the presence of freshwater environments (rivers) in the area, connected to the brackish lake. This agrees with the palaeobotanical results, which reconstructed extensive swamps for the lakeshore lowlands and indicated freshwater habitats farther away from the shores as well (HABLY & SEBE 2016). The freshwater interpretation also agrees with the presence of giant salamander remains of possibly Pannonian origin, which require riverine habitats for their reproduction (SZENTESI et al. 2019).

Unfortunately, a precise habitat preference is not possible to infer based on the single gadid otolith found in the marls, as it is not possible to identify the fish more precisely than family rank. Extant sparid fishes are generally marine, but brackish and freshwater taxa are also known among them (NELSON et al. 2016). As the sparid material of the marls is incomplete and not identifiable precisely, it has no palaeoenvironmental significance either. The case is similar to the unidentified actinopterygians: unless they are identified at a lower taxonomic level, their palaeoenvironmental implication is highly limited. Thus, the possible age of the isolated, possibly reworked fossils from the listed taxonomic groups remains unknown as well.

Palaeoenvironmental inferences and age of fish remains of the sands

Preliminary reports on the fish fauna of the sand pit appeared in only few documents. Regarding the chondrichthyan taxa, KOCSIS (2002) reported a fauna list of *Carcharias cuspidata*, *C. acutissima*, *Isurus desori*, *I. hastalis*, *Lamna* sp., *Carcharocles megalodon*, *Hemipristis serra*, *Galeocerdo aduncus*, *Carcharhinus priscus*, *Sphyrna* sp., *Myliobatis* sp., *Aetobatis arcuatus*, *Dasyatis* sp. Most of these taxa were recorded in our study, though with updated views on the taxonomy and taxonomical ranks of the material. Later JUHÁSZ (2006) described a somewhat different fauna composition based on poorly preserved material. However, we consider the JUHÁSZ (2006) report invalid, due to clear misidentifications and/or the lack of informative illustrations in case of the following taxa: *Striatolamia* aff. *macrota*, *Synodontaspis hopei*, *Carcharias* cf. *cuspidata*, *Lamna* sp., *Scyliorhinus distans* and *Negaprion eurybathrodon*. Concerning the bony fish fauna, BENE (2003) reported the genera *Archosargus*, *Chrysophrys*, *Dentex*, *Diplodus*, *Pagellus*, *Pagrus*, *Sparnodus* and *Sparus* from the same fossiliferous formation of the pit. This material is poorly preserved as well, and except for *Diplodus*, *Pagrus* and *Sparus* (note, that the latter two genera are represented by clearly identifiable bone elements in the sands; see above), we consider these taxa invalid.

Moreover the isolated molariform and conical teeth of these genera are not clearly distinguishable.

The numerous fish taxa of the sands make up a dominantly marine fish fauna, with a wide range of ecological requirements, including forms indicating tropical through subtropical to temperate, and littoral through neritic to pelagic habitats (Digital Annex 2). However, it is known that a considerable percent of the vertebrate remains in the sands is reworked from older, middle Miocene (Badenian and Sarmatian) sediments (KAZÁR et al. 2007, SEBE et al. 2015), and this is obviously the case for the fish fossils as well. Regarding their environmental preferences and the general range of taxa, the fishes found in the sands can be divided into 2 groups.

1. The chondrichthyan faunal elements and most of the osteichthyan forms are typical marine animals and require euhaline conditions. As marine conditions with normal salinity are restricted to the Badenian in the area (PALCU et al. 2015; SEBE et al. 2015, 2019), these fossils must be of Badenian age. Strontium isotope analyses ($^{87}Sr/^{86}Sr$) of a shark tooth from Danitzpuszta also corroborate the Badenian origin, however other teeth from here and the nearby Himeshaza reworked site yielded much younger ages, which most possibly reflect diagenetic overprint (KOCSIS et al. 2009, KOCSIS 2016). The chondrichthyan fauna is very similar to other Badenian assemblages in the Central Parathethys (SZABÓ & KOCSIS 2016a) in terms of composition and abundance. The teeth of the Odontaspididae (55.5%) and Myliobatidae (14.4%) families are the most abundant. These forms, accompanied by the also common dasyatids, could indicate widespread shallow, coastal environments in the Badenian, under a subtropical-tropical climate. The presence of relatively large and pelagic forms (e.g., *Isurus, Cosmopolitodus, Alopias*) together with littoral/neritic habitat taxa (e.g., *Squatina*, *Dasyatis*) could reflect connections toward more open seas. Deeper water can be related to the asymmetric, quickly deepening, rift-related basins, which are known in the area in the Badenian (BÁLDI et al. 2002). The marine osteichthyan fauna is dominated by Sparidae (*Diplodus* sp., *Pagrus cinctus* and *Sparus umbonatus*, not counting the indeterminate sparid remains; altogether 77.1% of the fish material found in the limonitic sands). Sparid fishes are widespread in shallow, temperate-tropical waters. Common inhabitants of pelagic waters (e.g., Sphyraenidae, Scombridae) reflect connection with open water habitats. Labridae and Scaridae are typically reef-associated forms, their presence could refer to a nearby coral reef, which is also testified by re-worked coral fragments found in the sand (DULAI et al. 2021).

2. Two noteworthy taxa, acipenserids (sturgeons) and latids (latid perches) might have different palaeoenvironmental significance. Modern acipenserids typically inhabit high-energy environments, including freshwater lacustrine and riverine, estuarine, and less typically nearshore marine habitats (BEMIS & KYNARD 1997). Extant sturgeons are considered to be anadromous (NELSON et al. 2016), meaning that adults migrate upstream to spawn but they spend most of their lives feeding in river deltas and estuaries. The other interesting taxon is *Lates* sp., represented by the largest variety of skeletal elements. Extant African *Lates* species have a freshwater preference, but *Lates niloticus* (Nile perch), the latid geographically and anatomically closest to the studied fossil material, has been reported to survive in brackish and estuarine waters as well (e.g., Lake Maryut in Egypt) (SORBINI 1975; FROESE & PAULY 2019 and references therein). The lifestyle of these two fishes, especially that of acipenserids, which require fluvial environments for spawning, is related to freshwater, which indicates the presence of a nearby, probably fluvial environment. Given the wide salinity tolerance of latids, and that riverine environments are reconstructed both for the late Miocene and – based on various vertebrate remains – for the middle Miocene (e.g., KAZÁR et al. 2007), the original age of these fish fossils remains unknown.

Trophic interactions of the marine vertebrate fauna found in the sands

Extremely large amounts of vertebrate coprolites were found in the limonitic sands. They are irregular to elongate, usually with rounded edges, most of them are straight, but a few specimens have weakly curved axes. It is unknown if the producers of these coprolites were aquatic, semiaquatic or terrestrial animals. However, some coprolite specimens contain vertebrate inclusions, such as jaws of various osteichthyan taxa like sparids and scarids (*Figure 3*). These occur in several coprolite morphotypes, suggesting that fish served as prey for various animals.

As several large predators occur among the fish taxa described here, it is also worth examining what could have provided their food source. Based on the feeding habits of their extant relatives and fossil evidence of feeding habits, the presence of five selachians from the sands (*Notorynchus primigenius*, *Cosmopolitodus hastalis*, *Isurus oxyrinchus*, *Otodus* (*Megaselachus*) *megalodon* and *Galeocerdo aduncus*) can be related to the presence of marine mammals. The modern hexanchid *Notorynchus cepedianus* consumes a wide variety of prey, including elasmobranchs, teleosts and even marine mammals (EBERT 2002 and references therein). Modern *Isurus* species (ecologically close ancestors of *C. hastalis*) prey on a wide variety of cartilaginous and bony fishes, cephalopods and various further invertebrates, but very large individuals could occasionally catch small pelagic cetaceans (dolphins) (COMPAGNO 2002). The trophic spectrum of *Otodus* (*Megaselachus*) *megalodon* could have covered a wide range of prey items, e.g. invertebrates, chondrichthyans, osteichthyans, marine reptiles, seabirds, sirenians, various cetaceans and seals (COLLARETA et al. 2017). The modern tiger shark *Galeocerdo cuvier* also preys on a large variety of invertebrates, chondrichthyans, osteichthyans, sea turtles and marine mammals (COMPAGNO 1984).

Over the years of collecting, a large range of marine mammals has been collected in the Pécs-Danitzpuszta sand

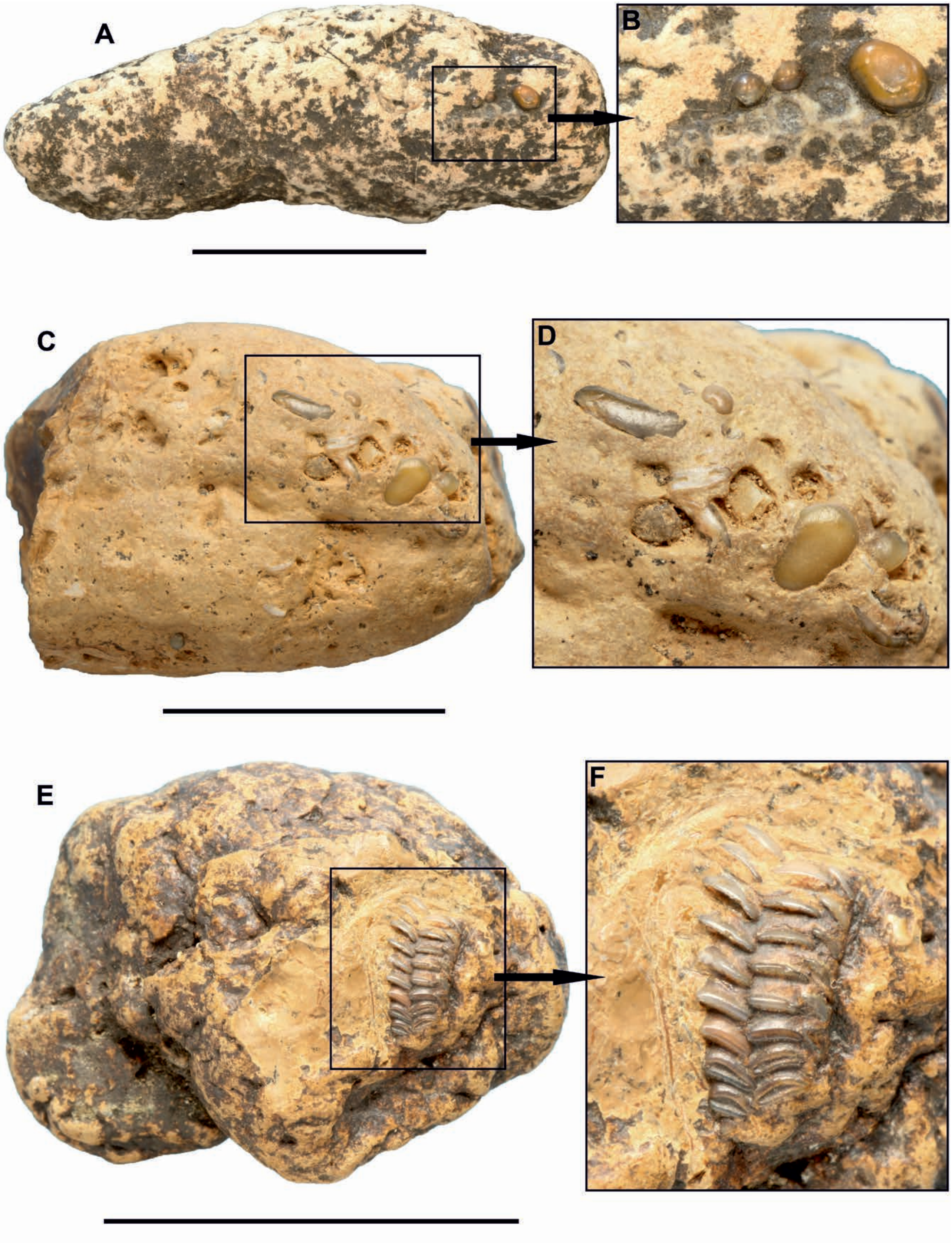

Figure 3. Coprolites from the limonitic sands

A) Sparidae indet. jaw element in coprolite (Kanizsai L. coll.). B) Close-up of image A. C) Sparidae indet. teeth in coprolite (Cserpák F. coll., inv. nr: Dp9164). D) Close-up of image C. E) *Calotomus* sp. upper pharyngeal tooth plate in coprolite (Cserpák F. coll., inv. nr.: Dp3923). F) Close-up of image E. Scale bars: 20 mm

3. ábra. *Koprolitok a limonitos homokból*

A) Sparidae indet. állkapocselem koprolitban (Kanizsai L. gyűjteménye), B) Közeli kép az A ábráról. C) Sparidae indet. fogak koprolitban (Cserpák F. gyűjteménye, leltári szám: Dp9164), D) Közeli kép a C ábráról. E) Calotomus *sp. garatfoglemez koprolitban (Cserpák F. gyűjteménye, leltári száma: Dp3923), F) Közeli kép az E ábráról. Méretarányok: 20 mm* pit. These marine mammals could have served as preys for large sharks. Kazár (2003, 2005, 2006, 2010) reported the following odontocetes from Pécs-Danitzpuszta: *Acrodelphis letochae*, *Pachyacanthus suessi*, Delphinoidea indet., Kentriodontidae indet., *Kentriodon fuchsii*, ?*Kentriodon* sp., *Sophianacetus commenticius*. Cserpák (2018) reported humeri of mysticetes cf. *Cetotherium priscum*, „*Cetotherium*" aff. *maiopicum* and cf. Cetotheriidae indet. in detail. One phocid species, *Praepusa magyaricus* has been described from the locality (Koretsky 2003, Gasparik M. in Sebe et al. 2015). Sirenians are also known from the pit, they are most commonly represented by rib fragments, occassionally by isolated teeth, but incomplete limb bones and vertebrae are also known in private collections. The hundreds of unidentified sirenian remains most probably belong to the genus *Metaxytherium* (Gasparik in Sebe et al. 2015). Odontocetes from the limonitic sands are attributed to the Sarmatian, however, family Kentriodontidae occurs in the Badenian of the Central Paratethys as well (Kazár 2006), therefore it can not be excluded that some Pécs-Danitzpuszta kentriodontids may originate from the Badenian. It cannot be excluded that two of the cetotheriid baleen whale taxa („*Cetotherium*" aff. *maiopicum* and cf. Cetotheriidae indet.) are of Badenian origin (Cserpák 2018). The seal remains probably belong to the Sarmatian Stage (Koretsky 2003), while the sirenians most likely represent the Badenian (Kazár 2003, after Kordos L. pers. comm.). Thus, the middle Miocene marine mammals known from the area (some kentriodontid odontocetes, mysticetes and sirenians) could have served as preys for the large sharks during the Badenian.

Cetotheriidae (a cetacean family known from the sands, Cserpák 2018) is an extinct baleen whale family, characterized by generally small body sizes (2.5–7 metres of length) (Bouetel & de Muizon 2006, Boessenecker 2013, Gol'din 2018), which made these mysticetes suitable for predation by adult *Otodus* (*Megaselachus*) *megalodon*. As an example, Collareta et al. (2017) identified *Piscobalaena nana*, member of family Cetotheriidae as prey or scavenging item for *Otodus* (*Megaselachus*) *megalodon* in the upper Miocene deposits of southern Peru. During the early to middle Badenian, sirenians were also abundant in the Central Paratethys (Kretzoi 1951; Kordos 1985, 1992). These generally slow-moving, herbivorous mammals could have also been common prey items for the Pécs-Danitzpuszta *Otodus* (*Megaselachus*) *megalodon* individuals, since their body provided a large amount of fat required to fulfil the caloric demands of these large-sized sharks (after Lambert et al. 2010).

In order to confirm direct trophic connections between predator and prey, we checked the available marine mammal material for tooth marks. Up to now, a radius of a kentriodontid, a radius of an indeterminate odontocete, and a sirenian rib (all are housed in private collections) have been found to bear tooth marks possibly corresponding to sharks (*Figure 4*). It is worth mentioning that the low number of shark vs. marine mammal predational evidence may be linked to the re-deposition of these remains, which might have damaged the bones or eroded away fine surface structures (e.g. tooth marks). Based on the suggested age of the local marine mammals (see above), it is highly plausible that kentriodontids, cetotheriids, and sirenians provided a stable food source (either as living preys or carcasses) for macro-predatory sharks in the Mecsek area during the Badenian. Up to the present paper, only a single occurrence of similar remains has been published from the middle Miocene of the Central Paratethys by Feichtinger et al. (2021), who reported a shark-bitten partial skeleton of an immature sirenian (*Metaxytherium* cf. *medium*) from the Styrian Basin (Austria).

A major marine extinction event occurred in the Central Paratethys at the Badenian–Sarmatian boundary (Rögl et al. 1978, Palcu et al. 2015). At this time, the conditions changed from open marine to brackish, caused by sea level drop of the Mediterranean and the resulting closure of the Slovenian Strait. During the early Sarmatian the Central Paratethys has regained connection to the Mediterranean through the Eastern Paratethys (Rögl 1998) and new pinnipedian and cetacean taxa – particularly small odontocetes – arrived, replacing the Badenian taxa (= Sarmatian Marine Mammal Event; Grigorescu & Kazár 2006). However, no post-Badenian occurrence of these large sized macropredatory sharks have been reported from the Central Paratethys, indicating that these taxa did not return to the region after the Badenian.

Fish fossils and the reworking of older sediments

Fish remains not only provide palaeoecological data, they can also be used to constrain the sedimentary units that got reworked to build up the sand body of Danitzpuszta. Based on the mineralogical composition, Kleb (1973) proposed that the provenance of the sands had been older Miocene rocks. Fish fossils provided data to identify the source units.

Chondrichthyans restricted to normal marine conditions must come from Badenian sediments. Potential lithostratigraphic units supplying these remains are the lower–middle Badenian nearshore Budafa Formation and its offshore counterpart, the Tekeres Schlieren Member of the Baden Fm, the middle and upper Badenian littoral Lajta Limestone Fm, and the upper Badenian Szilágy Claymarl Member of the Baden Fm. Other taxa that tolerated brackish or freshwater may have originated from any Badenian or younger Miocene rock units of the area.

No vertebrate fossils have been reported from the middle Miocene rocks in the direct surroundings of the sand pit. However, the lithostratigraphic units in question are known to contain fish remains elsewhere in the Mecsek region. Among Badenian marine deposits, shark and sparid teeth occur in the Budafa Fm. and in the Lajta Limestone Fm in the western Mecsek Mts. (Kordos & Solt 1984, Szabó in Sebe et al. 2015), and various otoliths dominated by gobiids and gadids in the Szilágy Claymarl (Bosnakoff 2013). In the Badenian brackish-water Hidas Lignite Fm. a gobiid-dominated otolith assemblage was reported from the eastern

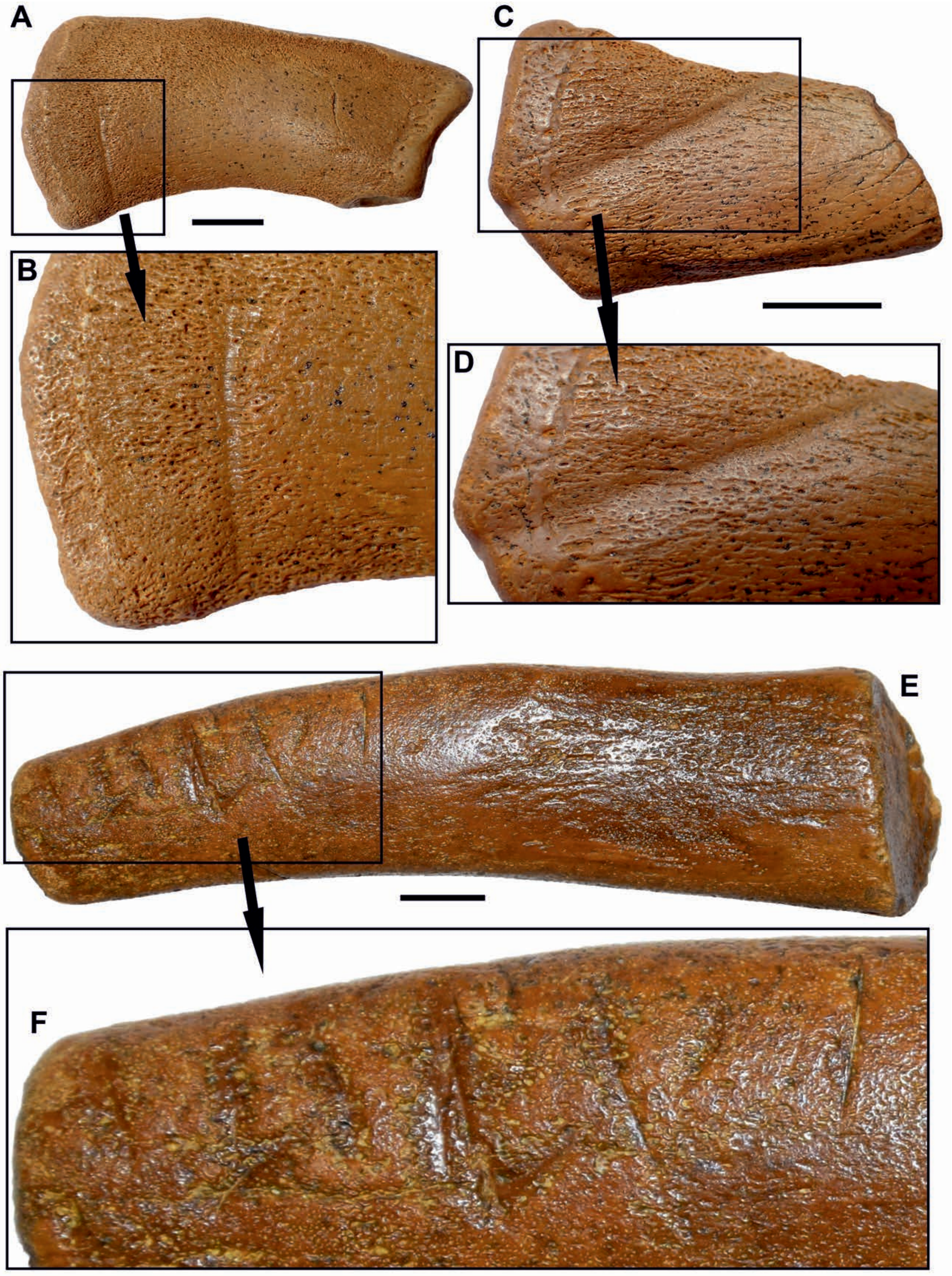

Figure 4. Bite marks on marine mammal bones from the limonitic sands

A) Kentriodontidae indet. radius (KANIZSAI L. coll.), B) Close-up of the tooth mark in figure A. C) Odontoceti indet. distal fragment of ulna (KANIZSAI L. coll.), D) Close-up of the tooth mark in figure C. E) Sirenian rib (KANIZSAI L. coll.), F) Close-up of the tooth marks in figure E. Scale bars: 10 mm

***4. ábra.** Harapásnyomok a limonitos homokból származó tengeriemlős-csontokon.*

A) Kentriodontidae indet. radius (KANIZSAI L. gyűjteménye), B) Közeli kép az A ábrán látható harapásnyomról. C) Odontoceti indet. ulna disztális töredéke (KANIZSAI L. gyűjteménye), D) Közeli kép a C ábrán látható harapásnyomról. E) Tengeritehén-borda (KANIZSAI L. gyűjteménye), F) Közeli kép az E ábrán látható harapásnyomokról. Méretarányok: 10 mm

Mecsek Mts (Baranyai 2010). Sarmatian laminites in the western part of the mountains contain yet unidentified fish skeletons (Kordos & Solt 1984, Konrád & Dulai 2013).

Direct evidence for reworking possibilities was provided by an exploration trench excavated in the NW part of the sand pit in order to reveal the underlying rock units (*Figure 1*; Sebe et al. 221). The trench exposed upper Badenian and Sarmatian deposits below the upper Miocene ones. In the Upper Badenian sandy limestone layer D-71 of the trench, a shark tooth with close relation to the Odontaspididae genus *Araloselachus* was found (*Figure 5A, B*). Similar teeth occur in the Lake Pannon sands of the pit (see above). The difference between the teeth in the Pannonian and Badenian sediments is that the fresh, in situ tooth in the middle Miocene limestone is reddish white and all the fine surface characteristics are preserved on its main cusp, while teeth in the Pannonian sands are heavily worn and rusty brown due to limonite impregnation. Sarmatian deposits also revealed unidentifiable fish bone fragments.

Although no vertebrate fossils have been reported from the lower and middle Miocene rocks of the area, in the Danitzpuszta sand pit dozens of vertebrate, dominantly fish remains – mostly teeth and bone fragments – can be collected during a single visit without major effort, by hand-

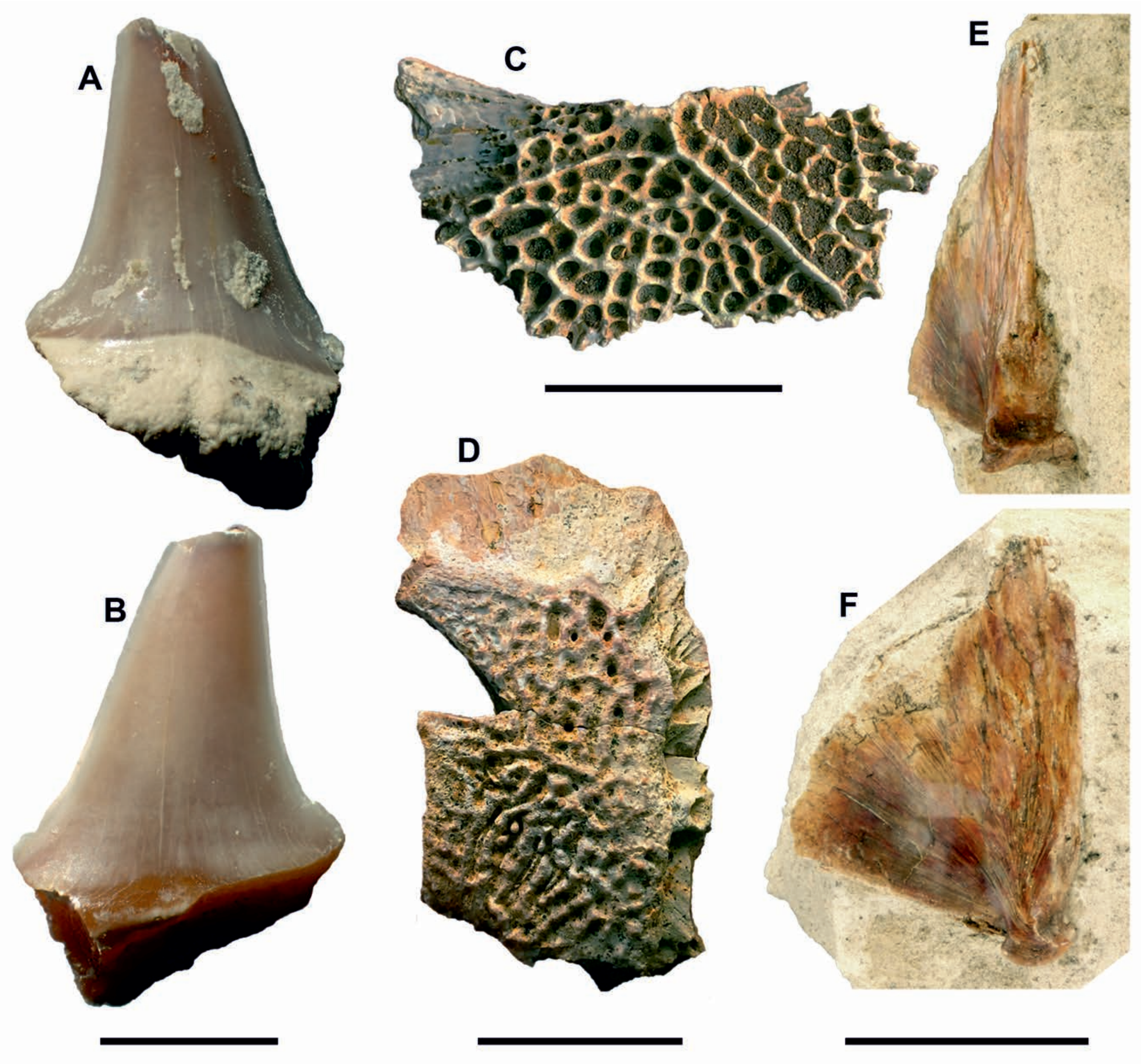

Figure 5. Fish remains from the exploration trench (A, B) and the southern pit (C–F)

A, B) Odontaspididae indet. tooth (PTE_5161). C, D) Acipenseridae indet. dermal scutes (Krizsán S. coll.). E, F) *Lates* sp. quadrate (PTE_5162). A) in lingual view; B) in labial view; C, D) in dorsal view; E) in posterior view; F) in lateral view. Scale bars: A, B) 5 mm; C, D) 20 mm; E, F) 30 mm

***5. ábra.** Halmaradványok a kutatóárokból (A, B) és a déli bányából (C–F).*

A, B) Odontaspididae indet. fog (PTE_5161). C, D) Acipenseridae indet. bőrcsontok (Krizsán S. gyűjteménye). E, F) Lates *sp. quadratum (PTE_5162). A) linguális nézet; B) labiális nézet; C, D) dorzális nézet; E) poszterior nézet; F) laterális nézet. Méretarányok: A, B) 5 mm; C, D) 20 mm; E, F) 30 mm* picking. The strong enrichment of vertebrate fossils in the Lake Pannon sands indicates intense denudation of the terrestrial hinterland at the time of sedimentation. When older Miocene rocks were exposed at, or transported to the lake, wave action could continue their comminution, while winnowing effect could have removed the fine silisiclastic fractions, leaving the coarse material (i.e., coarse sand, gravel, and gravel-sized fossils) to accumulate. The high carbonate content of some limestone- or marl-dominated units could become dissolved. The syn-sedimentary uplift of the mountains (Sebe 2021) could further increase the denudation rate.

The smaller southern sand pit contains much fewer fossils than the northern one, and fish remains found here exclusively belong to fresh- or brackish-water, eurihaline forms, namely acipenserids and latids (*Figure 5C–F*). This may be linked to the fact that it represents partly an upward and partly a lakeward continuation of the succession exposed in the northern sand pit. Vertebrate remains redeposited from older sediments are enriched in the basal layers of the sand unit – in the northern pit – and did not seem to travel far from the shore either. These, together with the taxonomic composition of the fossils suggest that acipenserid remains found here may not be redeposited, but these fishes may have lived in Lake Pannon.

Conclusions

The upper Miocene brackish lacustrine sediments of the Pécs-Danitzpuszta sand pit yielded a wealth of fish remains. 22 227 specimens were investigated, and they were classified into a total of 33 taxa. Following analogies of modern relatives, all the 17 chondrichthyans (namely *Notorynchus primigenius*, *Squatina* sp., Odontaspididae indet., *Cosmopolitodus hastalis*, *Isurus oxyrinchus*, *Otodus* (*Megaselachus*) *megalodon*, *Alopias exigua*, *Antodus retroflexus*, *Hemipristis serra*, *Carcharhinus priscus*, *Galeocerdo aduncus*, *Sphyrna laevissima*, Dasyatidae indet., *Aetobatus arcuatus*, *Aetomylaeus* sp., *Myliobatis* sp., *Rhinoptera* cf. *schultzi*) and 12 identified osteichthyan taxa (namely Carangidae indet., *Sphyraena* sp., cf. *Thunnus* sp., Scombridae indet., *Labrodon* sp., *Trigonodon jugleri*, *Calotomus* sp., Sciaenidae indet., *Diplodus* sp., *Pagrus cinctus*, *Sparus umbonatus*, Tetraodontiformes indet.) found in the sands are regarded to belong to the Badenian Stage and must therefore have been redeposited into the upper Miocene sediments from Badenian rocks. Vast majority of the fossils came from the limonitic sands, among these specimens chondrichthyans are dominated by Odontaspididae (55.5%) and Myliobatidae (14.4%), while among the bony fishes the Sparidae (77.1%) are the most abundant. Acipenserids and latids do not fit into the typical marine conditions of the Badenian. Extant adult sturgeons inhabit freshwater and brackish habitats (river deltas and estuaries), and modern latids prefer brackish and freshwater environments. Brackish or freshwater could be present in the area throughout the Miocene, thus remains of these taxa may have been re-deposited from any Miocene stratigraphic units. Bone elements bearing tooth marks and coprolites prove that sparids, scarids and some marine mammals – sirenians and some of the local kentriodontids – were part of the food chain as preys, hunted among others by macropredatory sharks. As the Pécs-Danitzpuszta sirenians are attributed to the Badenian, the proof of their trophic interaction further supports their suggested age. The Pécs-Danitzpuszta record of shark-attributed bite marks on bones of marine mammals is the second one in the Badenian of the Central Paratethys.

The calcareous marls underlying the sands yielded associated latid cranial and postcranial fossils and an articulated hyoid region of an indeterminate actinopterygian, which must be coeval with the host sediment, i.e., upper Miocene (Pannonian). The detailed evaluation of the latter remain could be part of a future study, as articulated Miocene fishes are very rare in the Mecsek Mts. Latids suggest freshwater and brackish conditions in the area, in accordance with other biotic data. The age of isolated fish remains (representing Gadidae, Gobiidae, Sparidae and further, yet indeterminate actinopterygian taxa) coming from the same layers is unsure, as they do not provide environmental implications.

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Plate I – I. tábla
Fish remains from the calcareous marls – Halmaradványok a mészmárgából

A, B, Gadidae indet. otolith (PTE_5151), A, internal view, B, external view. C–E, Gobiidae indet. teeth (PTE_5152, PTE_5153), C and D, profile view, E, labial view. F, Gobiidae indet. otolith (PTE_5154) in internal view. G–P, *Lates* sp.; G, associated parasphenoid and ethmoid bones (PTE_5155); H–L, associable postabdominal vertebrae (PTE_5148); H, set of vertebrae in a piece of the embedding calcareous marl; I, J, prepared vertebra; K, L, prepared vertebra; M, N, second abdominal vertebra (PTE_5149); O, P, *Lates* sp. caudal vertebra (PTE_5150). A, F in internal view; B in external view; C, E in profile view; D in labial view; I, K, M, O in lateral view; J, L, N in articular view; P in anterior view. Scale bars: A, B, 5 mm; C, F, 0.5 mm; D, E, 0.25 mm; G–P, 10 mm

A, B, Gadidae indet. otolith (PTE_5151), A, belső nézet, B, külső nézet. C–E, Gobiidae indet. fogak (PTE_5152, PTE_5153), C és D, profilnézet, E, labiális nézet. F, Gobiidae indet. otolith (PTE_5154) belső nézetben. G–P, Lates *sp.; G, asszociált parasphenoid és ethmoideumok (PTE_5155); H–L, asszociált posztabdominális csigolyák (PTE_5148); H, mészmárgában ülő csigolyák; I, J, kipreparált csigolya; K, L, kipreparált csigolya; M, N, második abdominális csigolya (PTE_5149); O, P,* Lates *sp. farki csigolya (PTE_5150). A, F, belső nézet; B, külső nézet; C, E, profilnézet; D, labiális nézet; I, K, M, O, laterális nézet; J, L, N, ízesülési felület felőli nézet; P, anterior nézet. Méretarányok: A, B, 5 mm; C, F, 0.5 mm; D, E, 0.25 mm; G–P, 10 mm*

Plate II – II. tábla
Fish remains from the calcareous marls – Halmaradványok a mészmárgából

A, Sparidae indet. premaxilla (PTE_5156) in medial view. B, Actinopterygii indet. tooth (PTE_5157). C, Actinopterygii indet. tooth (PTE_5158). D, Actinopterygii indet. cycloid scale (PTE_5159). E, Actinopterygii indet. articulated hyoid elements (PTE_5160). Scale bars: A, 10 mm; B, C, 1 mm; D, 5 mm; E, 50 mm

Halmaradványok a mészmárgából. A, Sparidae indet. premaxilla (PTE_5156) mediális nézetben. B, Actinopterygii indet. fog (PTE_5157). C, Actinopterygii indet. fog (PTE_5158). D, Actinopterygii indet. cycloid pikkely (PTE_5159). E, Actinopterygii indet. artikulált hyoid csontelemek (PTE_5160). Méretarányok: A, 10 mm; B, C, 1 mm; D, 5 mm; E, 50 mm

Plate III – III. tábla
Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–R, *Notorynchus primigenius*; A–C, upper anterior tooth (PTE_5005); D–F, upper anterior tooth (SÖVÉR L. coll.); G, H, upper anterolateral tooth (KANIZSAI L. coll.); I, J, upper anterolateral tooth (PTE_5002); K, L, upper anterolateral/ lateral tooth (PTE_5000); M, N, lower anterolateral/ lateral tooth (PTE_5003); O, P, lower anterolateral/ lateral tooth (BÉCSI L. coll.); Q, R, lower lateral tooth (PTE_5004). S–X, *Squatina* sp.; S–U, anterior tooth (NHMUS VER 2020.178.); V–X, lateral tooth (KANIZSAI L. coll.). A, D, G, I, K, M, O, Q, S, V in lingual view; B, E, T, W in profile view; C, F, H, J, L, N, P, R, U, X in labial view. Scale bars: A–R, 10 mm; S–X, 5 mm

A–R, Notorynchus primigenius*; A–C, felső anterior fog (PTE_5005); D–F, felső anterior fog (SÖVÉR L. gyűjteménye); G, H, felső anterolaterális fog (KANIZSAI L. gyűjteménye); I, J, felső anterolaterális fog (PTE_5002); K, L, felső anterolaterális/ laterális fog (PTE_5000); M, N, alsó anterolaterális/ laterális fog (PTE_5003); O, P, alsó anterolaterális/ laterális fog (BÉCSI L. gyűjteménye); Q, R, alsó laterális fog (PTE_5004). S–X,* Squatina *sp.; S–U, anterior fog (NHMUS VER 2020.178.); V–X, laterális fog (KANIZSAI L. gyűjteménye). A, D, G, I, K, M, O, Q, S, V, linguális nézet; B, E, T, W, profilnézet; C, F, H, J, L, N, P, R, U, X, labiális nézet. Méretarányok: A–R, 10 mm; S–X, 5 mm*

Plate IV – IV. tábla
Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–H, Odontaspididae indet.; A, B, anterior tooth (PTE_5020); D–F, anterior tooth (PTE_5021); G, H, upper lateral tooth (PTE_5038). I–R, *Cosmopolitodus hastalis*; I, upper tooth (PTE_5056); J, lower tooth (PTE_5054); K, upper tooth (SÖVÉR L. coll.); L, upper tooth (SÖVÉR L. coll.); M, upper tooth (SÖVÉR L. coll.); N, upper tooth (KANIZSAI L. coll.); O, upper tooth (KANIZSAI L. coll.); P, upper tooth (KANIZSAI L. coll.); Q, upper tooth (KANIZSAI L. coll.); R, upper tooth (KANIZSAI L. coll.). S–V, *Isurus oxyrinchus*; S, T, upper tooth (KANIZSAI L. coll.); U, V, upper tooth (KANIZSAI L. coll.). A, D, G, I–R, S, U in lingual view; B, E in profile view; C, F, H, T, V in labial view. Scale bars: 10 mm

A–H, Odontaspididae indet.; A, B, anterior fog (PTE_5020); D–F, anterior fog (PTE_5021); G, H, felső laterális fog (PTE_5038). I–R, Cosmopolitodus hastalis*; I, felső fog (PTE_5056); J, alsó fog (PTE_5054); K, felső fog (SÖVÉR L. gyűjteménye); L, felső fog (SÖVÉR L. gyűjteménye); M, felső fog (SÖVÉR L. gyűjteménye); N, felső fog (KANIZSAI L. gyűjteménye); O, felső fog (KANIZSAI L. gyűjteménye); P, felső fog (KANIZSAI L. gyűjteménye); Q, felső fog (KANIZSAI L. gyűjteménye); R, felső fog (KANIZSAI L. gyűjteménye). S–V,* Isurus oxyrinchus*; S,* *T, felső fog (Kanizsai L. gyűjteménye); U, V, felső fog (Kanizsai L. gyűjteménye). A, D, G, I–R, S, U, linguális nézet; B, E, profilnézet; C, F, H, T, V, labiális nézet. Méretarányok: 10 mm*

Plate V – V. tábla

Chondrichthyan remains from the limonitic sands. *Otodus* (*Megaselachus*) *megalodon* teeth – Porcoshal-maradványok a limonitos homokból: *Otodus* (*Megaselachus*) *megalodon* fogak

A, B, upper anterior tooth (Kanizsai L. coll.); C, D, upper anterior tooth (PTE_5014); E–H, ?anterolateral tooth with pathological deformity (Bécsi L. coll.; G, H, close-ups of the pathological section of the distal cutting edge); I, J, lower anterior tooth (Kocsis L. coll.); K, L, distal tooth (Bécsi L. coll.); M, N, posterior tooth (Cserpák F. coll., inv. nr.: Dp2095); O, P, juvenile anterior tooth (Bécsi L. coll.). A, C, E, I, K, M, O in lingual view; B, D, F, J, L, N, P in labial view. Scale bars: A–F, I, J, 50 mm; K, L, 20 mm; M–P, 10 mm

A, B, felső anterior fog (Kanizsai L. gyűjteménye); C, D, felső anterior fog (PTE_5014); E–H, patológiás ?anterolaterális fog (Bécsi L. gyűjteménye; G, H, Közeli képek a disztális vágóél patológiás részéről); I, J, alsó anterior fog (Kocsis L. gyűjteménye); K, L, disztális fog (Bécsi L. gyűjteménye); M, N, poszterior fog (Cserpák F. gyűjteménye, leltári szám: Dp2095); O, P, fiatal egyed anterior foga (Bécsi L. gyűjteménye). A, C, E, I, K, M, O, linguális nézet; B, D, F, J, L, N, P, labiális nézet. Méretarányok: A–F, I, J, 50 mm; K, L, 20 mm; M–P, 10 mm

Plate VI – VI. tábla

Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–D, *Alopias exigua*; A, B, lateral-anterolateral tooth (Bécsi L. coll.); C, D, lateral-anterolateral tooth (A. Anderson coll.). E–P, *Anotodus retroflexus*; E, F, lateral tooth (Kanizsai L. coll.); G, H, ?anterolateral tooth (Cserpák F. coll.); I, J, lateral tooth (Kanizsai L. coll.); K, L, lateral tooth (Kanizsai L. coll.); M, N, anterolateral tooth (Kanizsai L. coll.); O, P, ?anterolateral tooth (Kanizsai L. coll.). A, C, E, G, I, K, M, O in lingual view; B, D, F, H, J, L, N, P in labial view. Scale bars: A–D, 5 mm; E–P, 10 mm

A–D, Alopias exigua*; A, B, laterális-anterolaterális (Bécsi L. gyűjteménye); C, D, laterális-anterolaterális fog (A. Anderson gyűjteménye). E–P,* Anotodus retroflexus*; E, F, laterális fog (Kanizsai L. gyűjteménye); G, H, ?anterolaterális fog (Cserpák F. gyűjteménye); I, J, laterális fog (Kanizsai L. gyűjteménye); K, L, laterális fog (Kanizsai L. gyűjteménye); M, N, anterolaterális fog (Kanizsai L. gyűjteménye); O, P, ?anterolaterális fog (Kanizsai L. gyűjteménye). A, C, E, G, I, K, M, O, linguális nézet; B, D, F, H, J, L, N, P, labiális nézet. Méretarányok: A–D, 5 mm; E–P, 10 mm*

Plate VII – VII. tábla

Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–K, *Hemipristis serra* artificial tooth set; A, B, upper lateral tooth (Sövér L. coll.); C, D, upper anterior tooth (PTE_5047); E, upper anterior tooth (PTE_5043); F–H, lower lateral tooth (PTE_5042); I–K, lower anterior tooth (PTE_5041). L–U, *Galeocerdo aduncus* artificial tooth set; L, M, distal tooth (PTE_5012); N, O, lateral tooth (PTE_5011); P, Q, lateral tooth (PTE_5009); R, S, anterolateral tooth (PTE_5008); T, U, anterior tooth (PTE_5006). V–A', *Carcharhinus priscus*; V, W, anterior tooth (PTE_5030); X, Y, lateral tooth (PTE_5032); Z, A', lateral tooth (PTE_5029). B'–E', *Sphyrna laevissima*; B', C', lateral tooth (PTE_5017); D', E', lateral tooth (Bécsi L. coll.). A, C, E, F, I, L, N, P, R, T, V, X, Z, B', D' in lingual view; G, J in profile view; B, D, H, K, U, S, Q, O, M, W, Y, A', C', E' in labial view. Scale bars: A–M, 10 mm; V–E', 5 mm

A–K, Hemipristis serra *sematikus kompozit fogazat; A, B, felső laterális fog (Sövér L. gyűjteménye); C, D, felső anterior fog (PTE_5047); E, felső anterior fog (PTE_5043); F–H, alsó laterális fog (PTE_5042); I–K, alsó anterior fog (PTE_5041). L–U,* Galeocerdo aduncus *sematikus kompozit fogazat; L, M, disztális fog (PTE_5012); N, O, laterális fog (PTE_5011); P, Q, laterális fog (PTE_5009); R, S, anterolaterális fog (PTE_5008); T, U, anterior fog (PTE_5006). V–A',* Carcharhinus priscus*; V, W, anterior fog (PTE_5030); X, Y, laterális fog (PTE_5032); Z, A', laterális fog (PTE_5029). B'–E',* Sphyrna laevissima*; B', C', laterális fog (PTE_5017); D', E', laterális fog (Bécsi L. coll.). A, C, E, F, I, L, N, P, R, T, V, X, Z, B', D', linguális nézet; G, J, profilnézet; B, D, H, K, U, S, Q, O, M, W, Y, A', C', E', labiális nézet. Méretarányok: A–M, 10 mm; V–E', 5 mm*

Plate VIII – VIII. tábla

Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–C, Dasyatidae indet. female-type tooth (NHMUS VER 2020.209.). D–F, ?Dasyatidae indet. female-type tooth (NHMUS VER 2020.210.). G–Q, *Aetobatus arcuatus*; G, lower tooth plate (NHMUS VER 2020.146.) specimen embedded in a piece of limonitized sand in occlusal view, H, Close-up of image G; I, J, lower tooth plate (PTE_5065); K, L, lower tooth plate (PTE_5064); M–Q, upper tooth plate (NHCEU coll.). R–A', *Aetomylaeus* sp.; R–V, tooth plate (NHCEU coll.); W–A', tooth plate (PTE_5070). A, D, G, H, I, K, M, R, W, in occlusal view; C, F, J, L, P, U, Z in basal view; B, E, Q, V, A' in profile view; N, S, X in lingual view; O, T, Y in labial view. A–C, 2 mm; D–F, 1 mm; G, I–Q, W–A', 10 mm; R–V, 20 mm

A–C, Dasyatidae indet. nőstény fog (NHMUS VER 2020.209.). D–F, ?Dasyatidae indet. nőstény fog (NHMUS VER 2020.210.). G–Q, Aetobatus arcuatus*; G, alsó fog (NHMUS VER 2020.146.) egy darab limonitos homokba ágyazva, H, Közeli kép a G ábráról; I, J, alsó fog (PTE_5065); K, L, alsó fog (PTE_5064); M–Q, felső fog (NHCEU gyűjtemény). R–A',* Aetomylaeus *sp.; R–V, fog (NHCEU gyűjtemény); W–A', töredékes fog (PTE_5070). A, D, G, H, I, K, M, R, W, okkluzális nézet; C, F, J, L, P, U, Z, bazális nézet; B, E, Q, V, A', profilnézet; N, S, X, linguális nézet; O, T, Y, labiális nézet. Méretarányok: A–C, 2 mm; D–F, 1 mm; G, I–Q, W–A', 10 mm; R–V, 20 mm*

Plate IX – IX. tábla
Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–T, *Myliobatis* sp.; A–D, partial lower tooth plate (PTE_5068); E–H, partial upper tooth plate (Cserpák F. coll.); I–L, partial lower tooth plate (NHCEU coll.); M–Q, incomplete medial tooth (Kanizsai L. coll.); R–T, lateral tooth (PTE_5069). U–I', *Rhinoptera* cf. *schultzi*; U–Y, lateral tooth (NHCEU coll.); Z–D', lateral tooth (PTE_5071); E'–I', lateral tooth (NHCEU coll.). J'–M', K', Myliobatiformes indet.; J', K', partial caudal spine (PTE_5079); L', M', partial caudal spine (PTE_5078). A, E, I, M, R, U, Z, E' in occlusal view; B, F, J, N, S, X, C', H' in basal view; C, G, K, Q, T, Y, D', F', I' in lateral view; O, V, B', G' in labial view; D, H, L, P, W, A' in lingual view; J', L' in dorsal view; K', M' in ventral view. Scale bars: A–L, U–M', 10 mm; M–T, 5 mm

A–T, Myliobatis *sp.; A–D, részleges alsó rágólemez (PTE_5068); E–H, részleges felső rágólemez (Cserpák F. gyűjteménye); I–L, részleges alsó rágólemez (NHCEU gyűjtemény); M–Q, töredékes mediális fog (Kanizsai L. gyűjtemény); R–T, laterális fog (PTE_5069). U–I',* Rhinoptera *cf.* schultzi*; U–Y, laterális fog (NHCEU gyűjtemény); Z–D', laterális fog (PTE_5071); E'–I', laterális fog (NHCEU coll.). J'–M', K', Myliobatiformes indet.; J', K', részleges faroktövis (PTE_5079); L', M', részleges faroktövis (PTE_5078). A, E, I, M, R, U, Z, E', okkluzális nézet; B, F, J, N, S, X, C', H', bazális nézet; C, G, K, Q, T, Y, D', F', I', laterális nézet; O, V, B', G', labiális nézet; D, H, L, P, W, A', linguális nézet; J', L', dorzális nézet; K', M', ventrális nézet. Méretarányok: A–L, U–M', 10 mm; M–T, 5 mm*

Plate X – X. tábla
Chondrichthyan remains from the limonitic sands – Porcoshal-maradványok a limonitos homokból

A–H, Chondrichthyes indet. vertebrae; A, B, vertebra morphotype 1 (Kanizsai L. coll.); C–E, vertebra morphotype 1 (Cserpák F. coll., inv. nr.: Dp6291); F–H, vertebra morphotype 2 (Cserpák F. coll., inv. nr.: Dp1826). I, J, Chondrichthyes indet. cartilage (Cserpák F. coll., inv. nr.: Dp7690). A, C in articular view; B, D in profile view; E, H in medial view; F, in dorsal or ventral view; G, in oblique view; I, in outer view; J, in inner view. Scale bars: 10 mm

A–H, Chondrichthyes indet. csigolyák; A, B, csigolya morfotípus 1 (Kanizsai L. gyűjteménye); C–E, csigolya morfotípus 1 (Cserpák F. gyűjteménye, leltári szám: Dp6291); F–H, csigolya morfotípus 2 (Cserpák F. gyűjteménye, leltári szám: Dp1826). I, J, Chondrichthyes indet. porcmaradvány (Cserpák F. gyűjteménye, leltári szám: Dp7690). A, C, artikulációs felület felőli nézet; B, D, profilnézet; E, H, mediális nézet; F, dorzális vagy ventrális nézet; G, döntött nézet; I, külső nézet; J, belső nézet. Méretarány: 10 mm

Plate XI – XI. tábla
Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–J, Acipenseridae indet.; A, B, skull element (Kanizsai L. coll.); C, D: dermal scute (PTE_5163); E, F, dermal scute (NHMUS VER 2020.212.); G, H, pectoral spine (PTE_5135). I–N, Carangidae indet.; I–K, dentary (Kanizsai L. coll.); L–N, dentary (NHMUS VER 2020.158.). O, P, *Sphyraena* sp. tooth (PTE_5083) in two different views. A, C, E, J, M in dorsal view; B in ventral view; D, F in anterior or posterior view; G, I, L in lateral view; H in posterior view; K, N in medial view. Scale bars: 10 mm

A–J, Acipenseridae indet.; A, B, koponyaelem (Kanizsai L. gyűjteménye); C, D: bőrcsont (PTE_5163); E, F, bőrcsont (NHMUS VER 2020.212.); G, H, mellúszó-tövis (PTE_5135). I–N, Carangidae indet.; I–K, dentale (Kanizsai L. gyűjteménye); L–N, dentale (NHMUS VER 2020.158.). O, P, Sphyraena *sp. fog (PTE_5083) két nézetben. A, C, E, J, M, dorzális nézet; B, ventrális nézet; D, F, anterior vagy poszterior nézet; G, I, L, laterális nézet; H, poszterior nézet; K, N, mediális nézet. Méretarányok: 10 mm*

Plate XII – XII. tábla
Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–O, cf. *Thunnus* sp.; A–C, premaxilla (Kanizsai L. coll.); D–F, dentary (NHMUS VER 2020.161.); G–I, dentary (MGSH coll.); J–L, abdominal vertebra (MGSH coll.); M–O, caudal vertebra (NHMUS VER 2020.174). P–A', Scombridae indet.; P, Q, premaxilla (PTE_5094); S–U, dentary (PTE_5097); V–X, dentary (PTE_5095); Y–A', dentary (PTE_5096). A, D, G, K, N, P, S, V, Y in lateral view;

B, Q in ventral view; M in ?ventral view; C, F, I, R, U, X, A' in medial view; E, H, J, T, W, Z in dorsal view; L, O in ?anterior view. Scale bars: 10 mm

A–O, cf. Thunnus *sp.; A–C, premaxilla (Kanizsai L. gyűjtemény); D–F, dentale (NHMUS VER 2020.161.); G–I, dentale (MGSH gyűjtemény); J–L, abdominális csigolya (MGSH gyűjtemény); M–O, farki csigolya (NHMUS VER 2020.174). P–A', Scombridae indet.; P, Q, premaxilla (PTE_5094); S–U, dentale (PTE_5097); V–X, dentale (PTE_5095); Y–A', dentale (PTE_5096). A, D, G, K, N, P, S, V, Y, laterális nézet; B, Q, ventrális nézet; M, ?ventrális nézet; C, F, I, R, U, X, A', mediális nézet; E, H, J, T, W, Z, dorzális nézet; L, O, ?anterior nézet. Méretarányok: 10 mm*

Plate XIII – XIII. tábla

Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–D, *Labrodon* sp.; A, B, pharyngeal tooth plate (PTE_5082); C, D, pharyngeal tooth plate (Kanizsai L. coll.). E–H, *Trigonodon jugleri* tooth (Cserpák F. coll., inv. nr.: Dp2792). I, J, *Calotomus* sp. pharyngeal tooth plate (Cserpák F. coll., inv. nr.: Dp 3923) in two different views. A, C, G in occlusal view; B, D in basal view; E in labial view; F in lingual view; H in profile view. Scale bars: 5 mm

A–D, Labrodon *sp.; A, B, garatfoglemez (PTE_5082); C, D, garatfoglemez (Kanizsai L. gyűjteménye). E–H,* Trigonodon jugleri *fog (Cserpák F. gyűjteménye, leltári szám: Dp2792). I, J,* Calotomus *sp. garatfoglemez (Cserpák F. gyűjteménye, leltári szám: Dp 3923) két nézet. A, C, G, okkluzális nézet; B, D, bazális nézet; E, labiális nézet; F, linguális nézet; H, profilnézet. Méretarányok: 5 mm*

Plate XIV – XIV. tábla

Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–N, *Lates* sp.; A, B, vomer (JACLMC 2006.156.74); C–E, parasphenoid (NHMUS VER 2020.248.); F, basioccipital (NHMUS VER 2020.154.); G, H, quadrate (JACLMC 2006.145.113); I, J, quadrate (PTE_5109); K, L, premaxilla (Kanizsai L. coll.); M, N, premaxilla (NHMUS VER 2020.165.). A, C, F in ventral view; B, E in dorsal view; D, H, I, K, M in lateral view; G, J in posterior view; L, N in medial view. Scale bars: 10 mm

A–N, Lates *sp.; A, B, vomer (JACLMC 2006.156.74); C–E, parasphenoideum (NHMUS VER 2020.248.); F, basioccipitale (NHMUS VER 2020.154.); G, H, quadratum (JACLMC 2006.145.113); I, J, quadratum (PTE_5109); K, L, premaxilla (Kanizsai L. gyűjteménye); M, N, premaxilla (NHMUS VER 2020.165.). A, C, F, ventrális nézet; B, E, dorzális nézet; D, H, I, K, M, laterális nézet; G, J, poszterior nézet; L, N, mediális nézet. Méretarányok: 10 mm*

Plate XV – XV. tábla

Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–L, *Lates* sp.; A, B, maxilla (JACLMC 2006.145.114); C, D, dentary (Kanizsai L. coll.); E, dentary (Kanizsai L. coll.); F, angulo-articular (JACLMC 2015.9.84); G, angulo-articular (JACLMC 2015.9.120); H, anterior abdominal vertebra (PTE_5130); I, anterior abdominal vertebra (NHMUS VER 2020.148.); J, postabdominal vertebra (MGSH coll.); K, L, median fin spine (PTE_5113). M–R, Sciaenidae indet.; M–O, premaxilla (PTE_5106); P–R, premaxilla (PTE_5105). A, C, E, F, G, H, I, J, M, P in lateral view; B, K in anterior view; D, O, R in medial view; L in posterior view, N, Q in ventral view. Scale bars: 10 mm

A–L, Lates *sp.; A, B, maxilla (JACLMC 2006.145.114); C, D, dentale (Kanizsai L. gyűjteménye); E, dentale (Kanizsai L. gyűjteménye); F, angulo-articulare (JACLMC 2015.9.84); G, angulo-articulare (JACLMC 2015.9.120); H, anterior abdominális csigolya (PTE_5130); I, anterior abdominális csigolya (NHMUS VER 2020.148.); J, postabdominális csigolya (MGSH coll.); K, L, medián úszótüske (PTE_5113). M–R, Sciaenidae indet.; M–O, premaxilla (PTE_5106); P–R, premaxilla (PTE_5105). A, C, E, F, G, H, I, J, M, P, laterális nézet; B, K, anterior nézet; D, O, R, mediális nézet; L, poszterior nézet, N, Q, ventrális nézet. Méretarányok: 10 mm*

Plate XVI – XVI. tábla

Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A, B, *Diplodus* sp.; tooth (NHMUS VER 2020.211.). C–K; *Pagrus cinctus*; C, D, premaxilla (Sövér L. coll.); E, F, premaxilla (Kanizsai L. coll.); G, H, premaxilla (Kanizsai L. coll.); I–K, dentary (PTE_5090). L–U, *Sparus umbonatus*; L, M, premaxilla (PTE_5088); N, O, premaxilla (PTE_5089); P–R, dentary (NHMUS VER 2020.172.); S–U, enlarged crushing tooth (PTE_5085). V–Z, Tetraodontiformes indet.; V–X, tooth plate (A. Anderson coll.; W, close-up of the occlusal surface); Y, Z, tooth plate (Sövér L. coll.). A in labial view; B in lingual view; C, E, G, M, O in lateral view; I, P in ?lateral view; D, F, H, L, N in medial view; K, R in ?medial view; J, Q in dorsal view; S, V, Y in occlusal view; T in profile view; U, X, Z in basal view. Scale bars: A, B, 1 mm; C–V, X–Z, 10 mm

A, B, Diplodus *sp. fog (NHMUS VER 2020.211.). C–K;* Pagrus cinctus*; C, D, premaxilla (SÖVÉR L. gyűjteménye); E, F, premaxilla (KANIZSAI L. gyűjteménye); G, H, premaxilla (KANIZSAI L. gyűjteménye); I–K, dentale (PTE_5090). L–U,* Sparus umbonatus*; L, M, premaxilla (PTE_5088); N, O, premaxilla (PTE_5089); P–R, dentale (NHMUS VER 2020.172.); S–U, megnagyobbodott, őrlésre módosult fog (PTE_5085). V–Z, Tetraodontiformes indet.; V–X, foglemezek (A. ANDERSON gyűjteménye; W, Közeli kép az okklúzális felszínről); Y, Z, foglemezek (SÖVÉR L. gyűjteménye). A, labiális nézet; B, linguális nézet; C, E, G, M, O, laterális nézet; I, P ?laterális nézet; D, F, H, L, N, mediális nézet; K, R, ?mediális nézet; J, Q, dorzális nézet; S, V, Y, okkluzális nézet; T, profilnézet; U, X, Z, bazális nézet. Méretarányok: A, B, 1 mm; C–V, X–Z, 10 mm*

Plate XVII – XVII. tábla

Osteichthyan remains from the limonitic sands – Csontoshal-maradványok a limonitos homokból

A–L, Actinopterygii indet. hyperostotic bone elements; A, B, ?rib (MGSH coll.); C, D, ?rib (KANIZSAI L. coll.); E, F, ?rib (MGSH coll.); G, H, ?rib (NHMUS VER 2020.170.); I, J, vertebra (MGSH coll.); K, L, vertebra (MGSH coll.). A, C, E, G, J, L in lateral view; B, D, F, H, I, K in medial view. Scale bars: 10 mm

A–L, Actinopterygii indet. hiperosztotikus csontelemek; A, B, ?borda (MGSH gyűjtemény); C, D, ?borda (KANIZSAI L. gyűjteménye); E, F, ?borda (MGSH gyűjtemény); G, H, ?borda (NHMUS VER 2020.170.); I, J, csigolya (MGSH gyűjtemény); K, L, csigolya (MGSH gyűjtemény). A, C, E, G, J, L, laterális nézet; B, D, F, H, I, K, mediális nézet. Méretarányok: 10 mm

Plate I – I. tábla

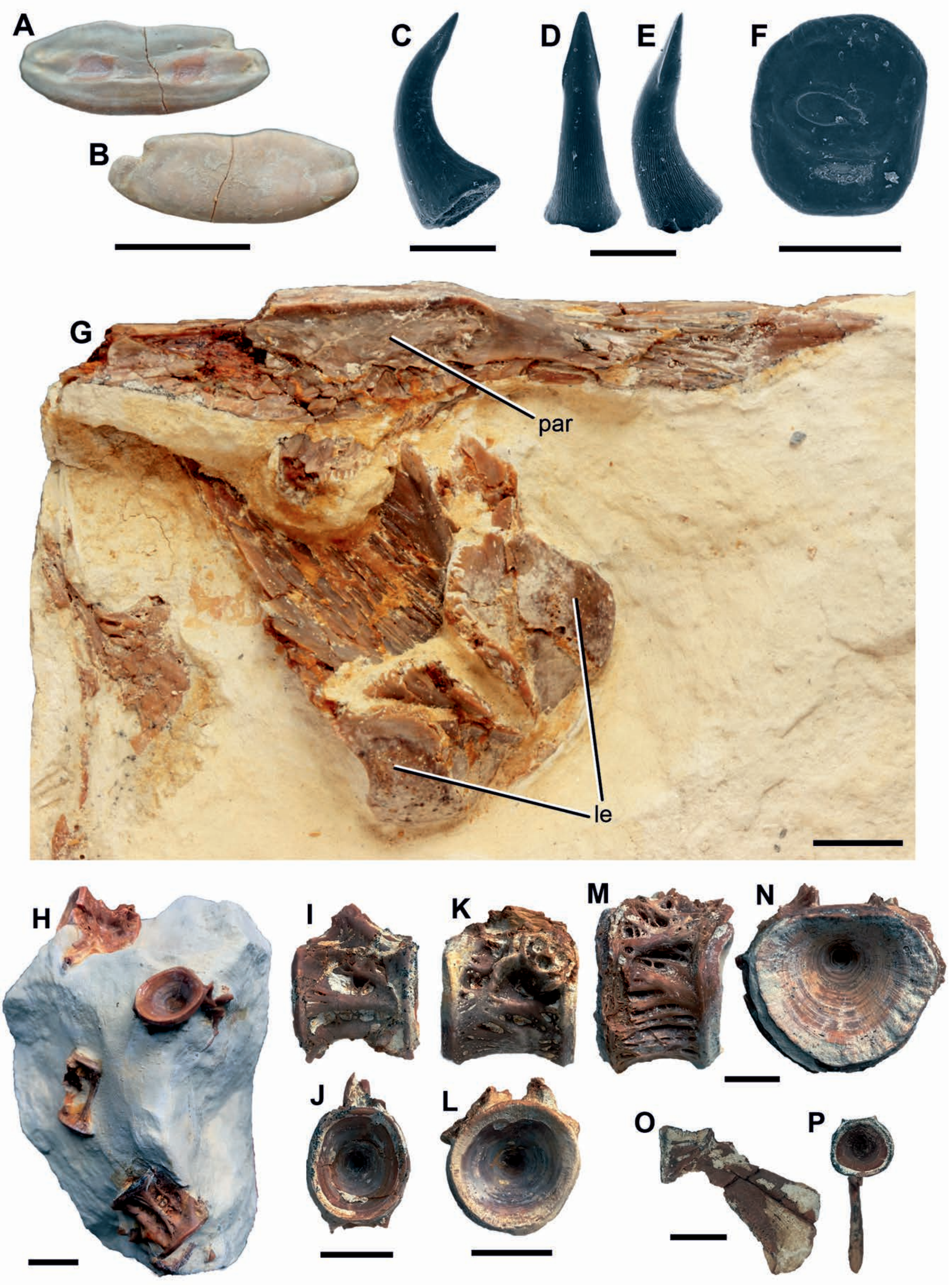


Plate II – II. tábla

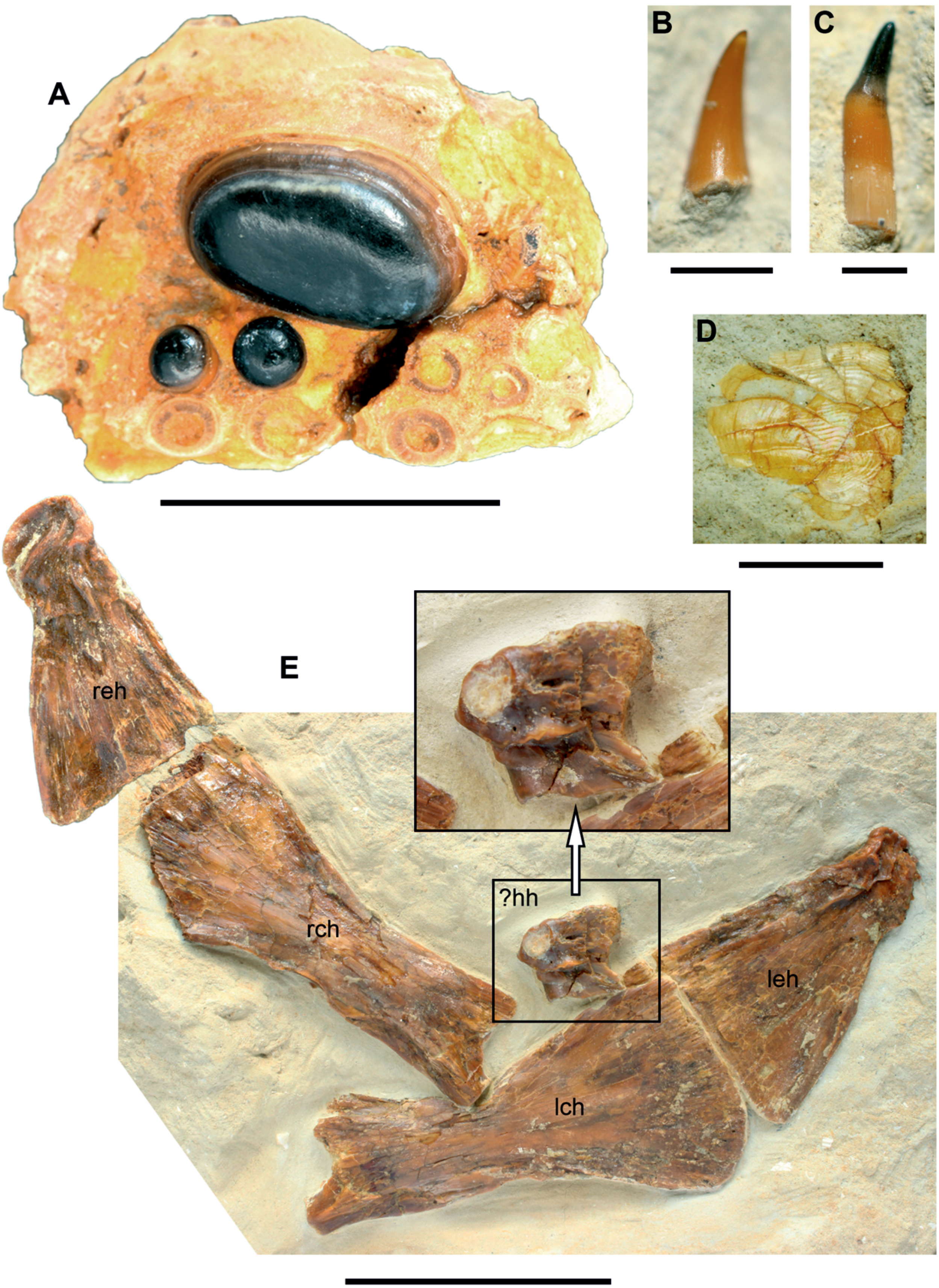


Plate III – III. tábla

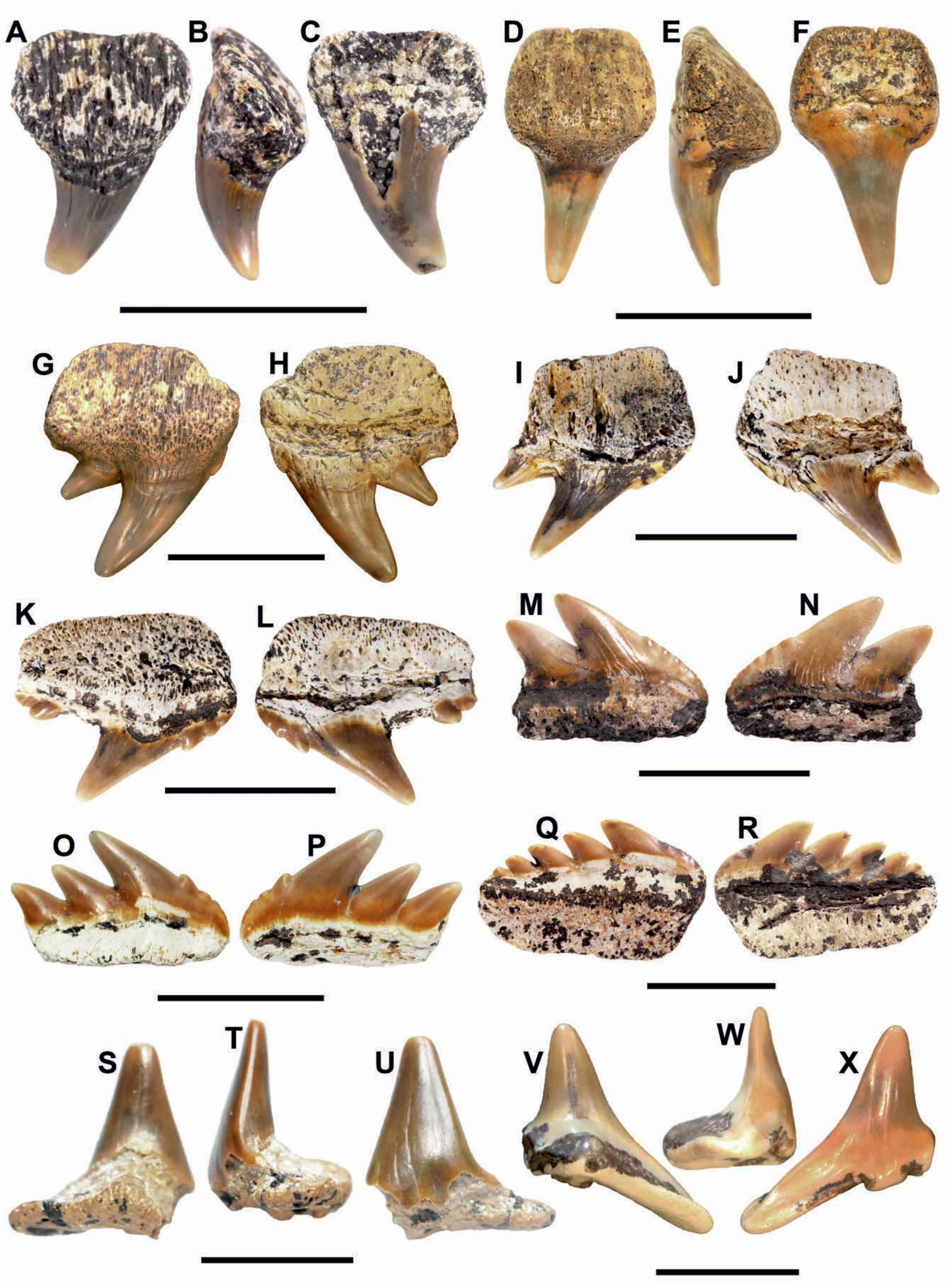


Plate IV – IV. tábla

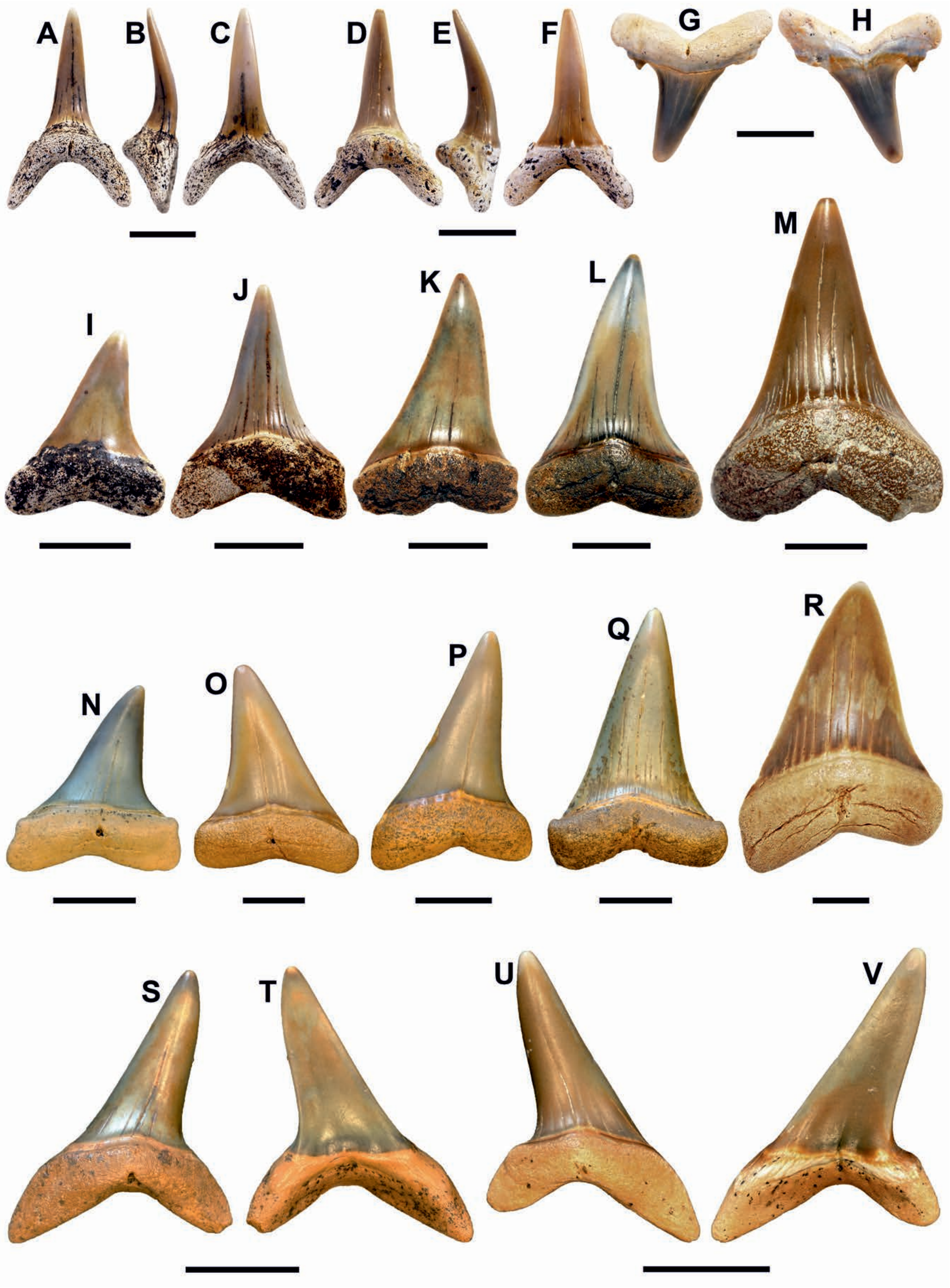


Plate V – V. tábla

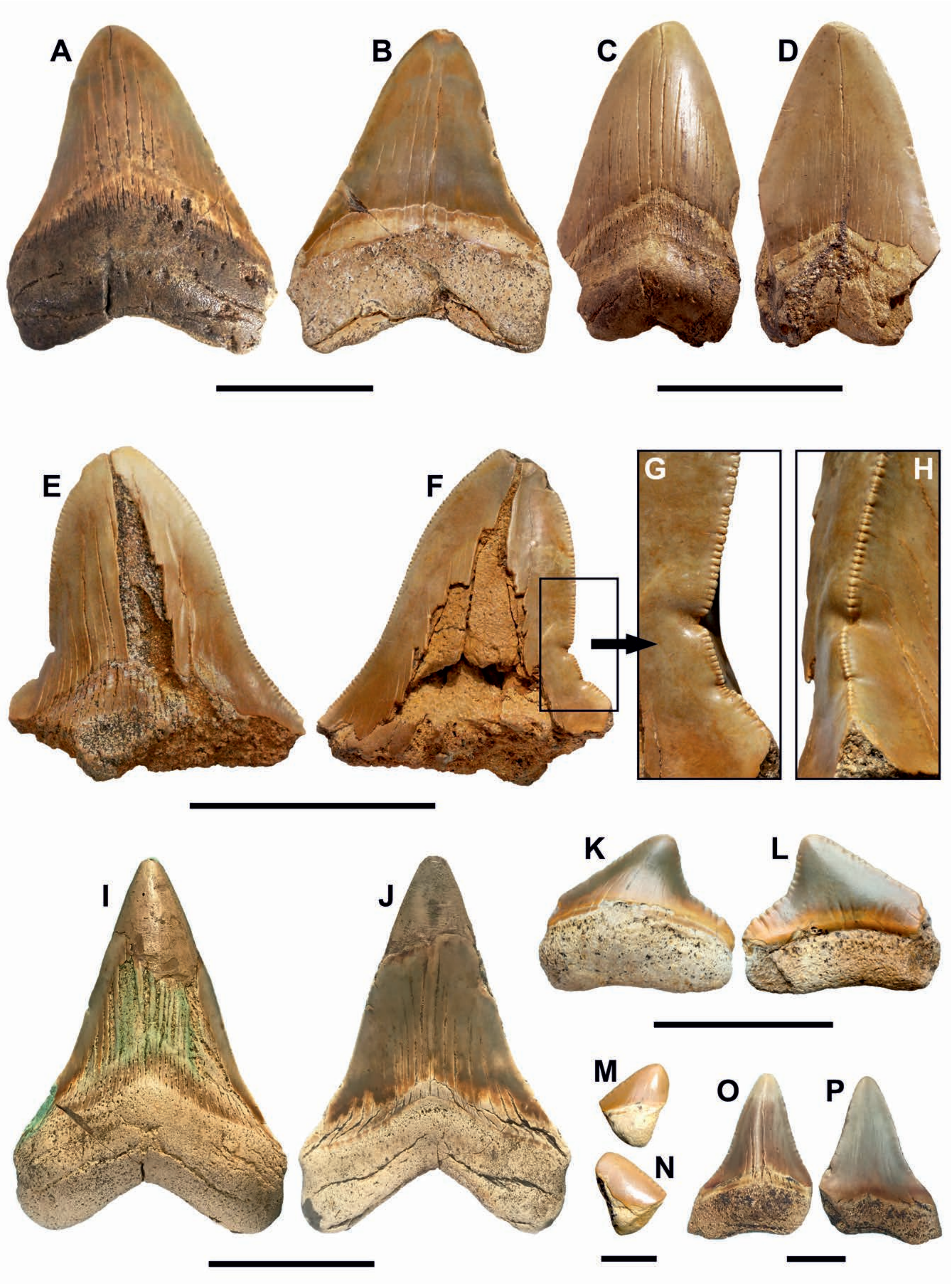


Plate VI – VI. tábla

Plate VII – VII. tábla

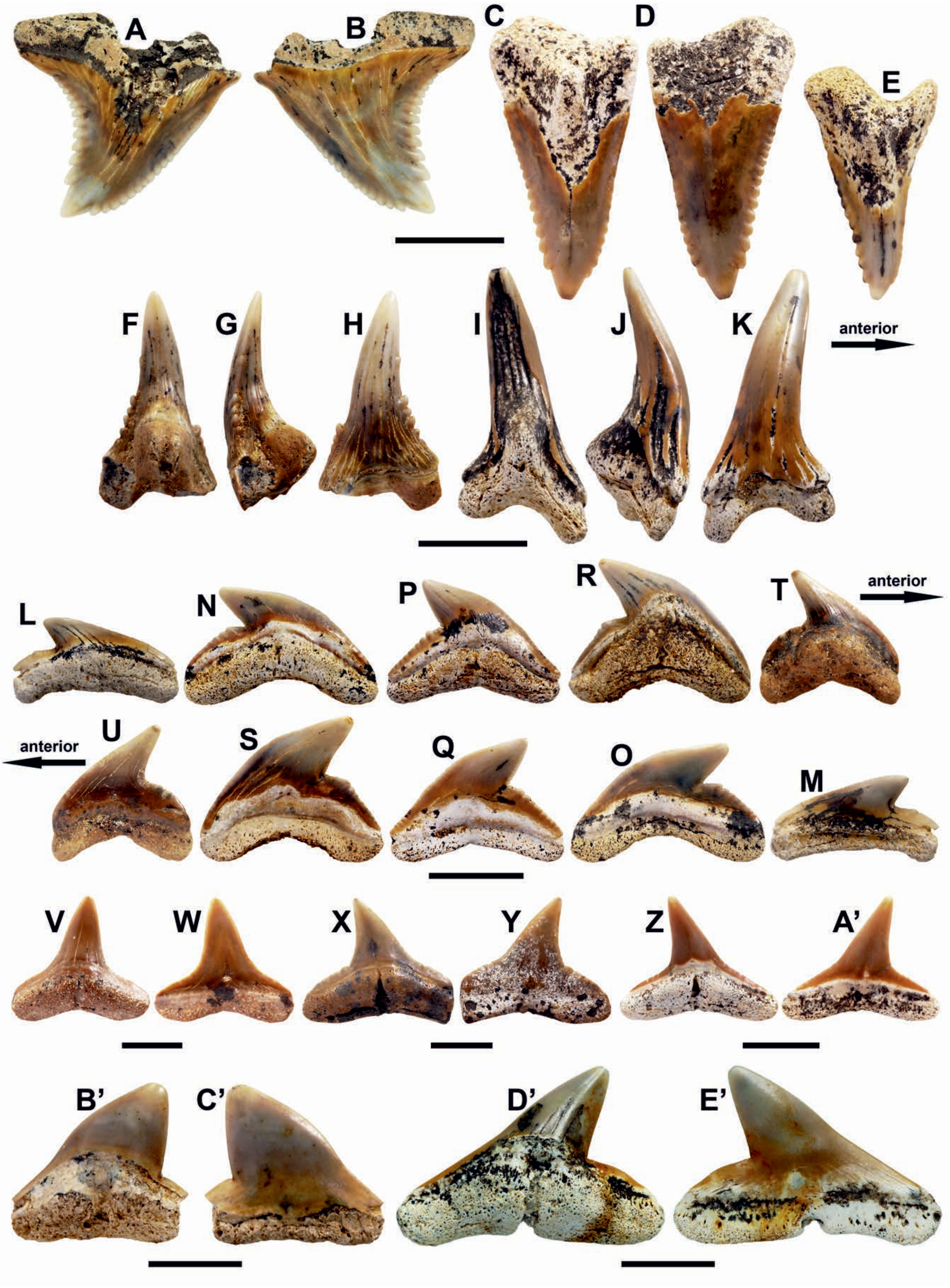


Plate VIII – VIII. tábla

Plate IX – IX. tábla

Plate X – X. tábla

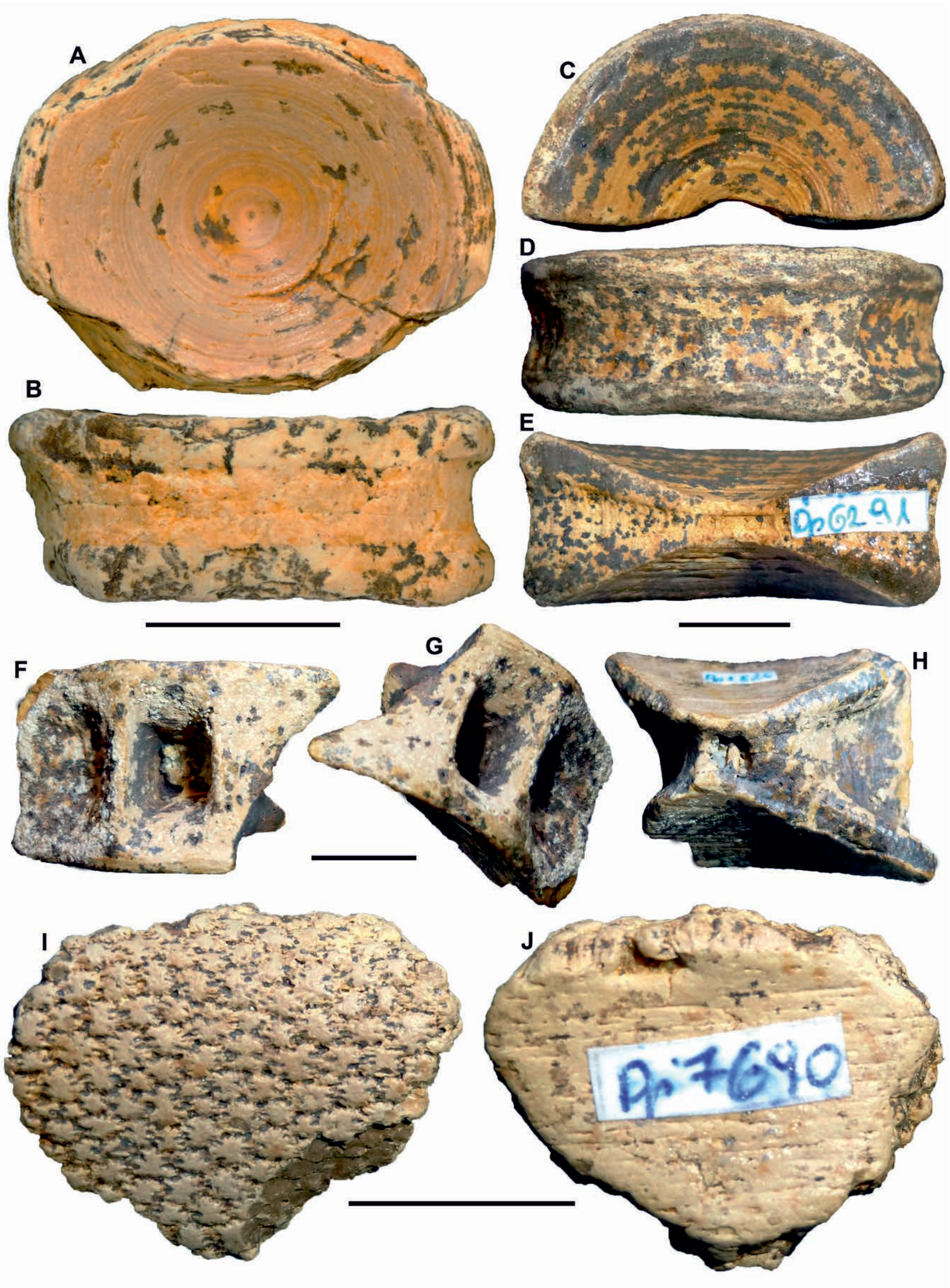


Plate XI – XI. tábla

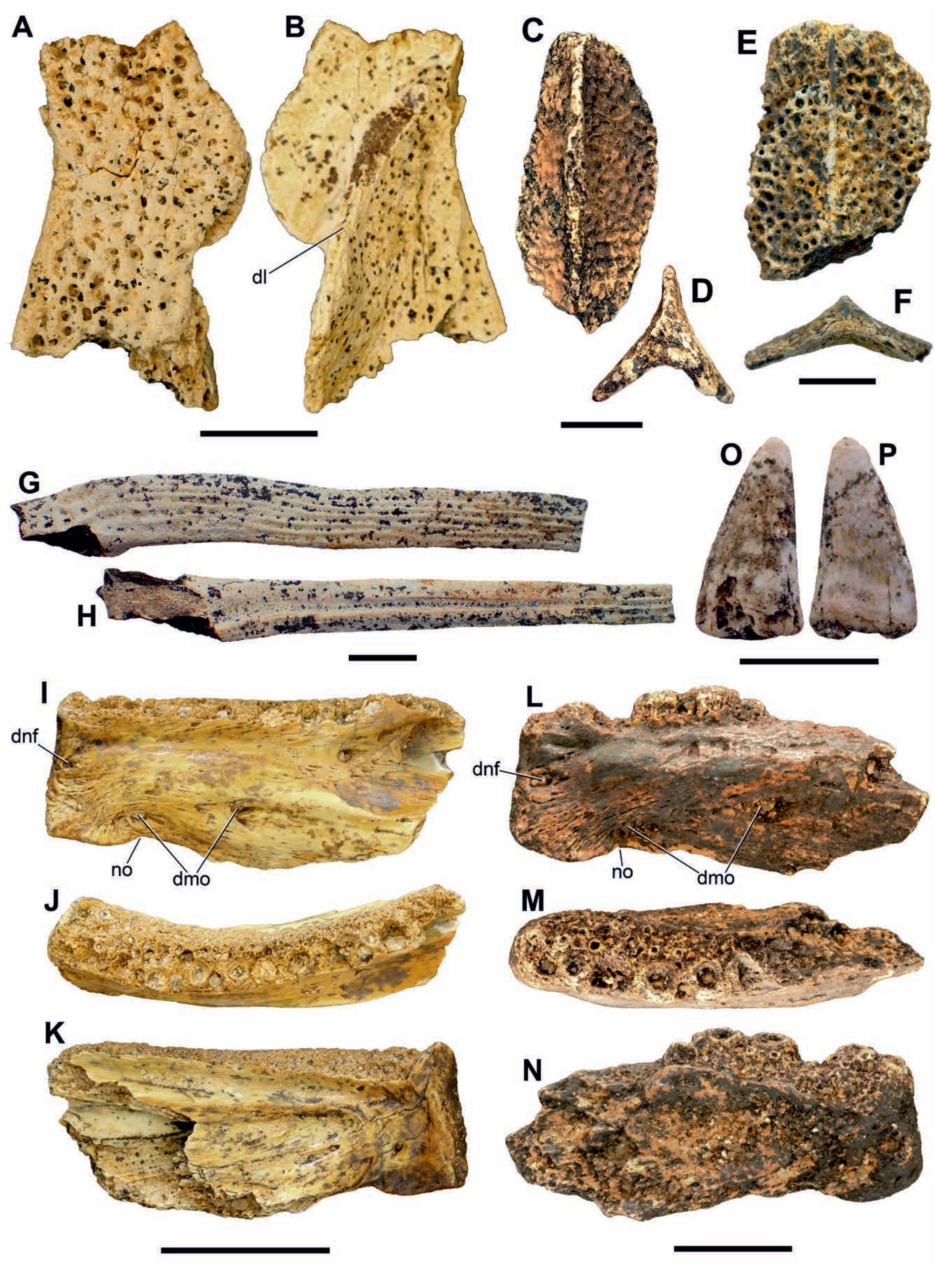


Plate XII – XII. tábla

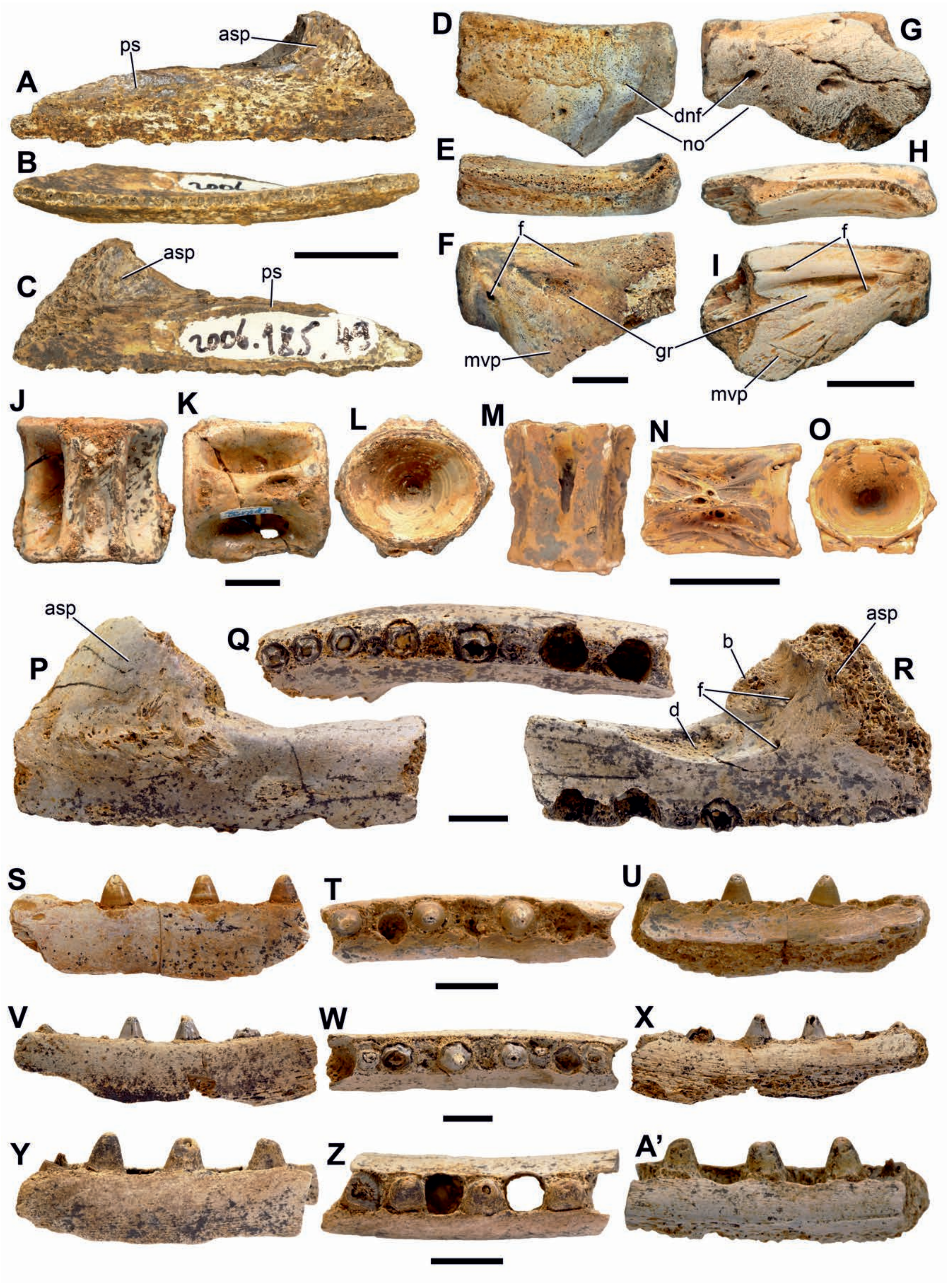


Plate XIII – XIII. tábla

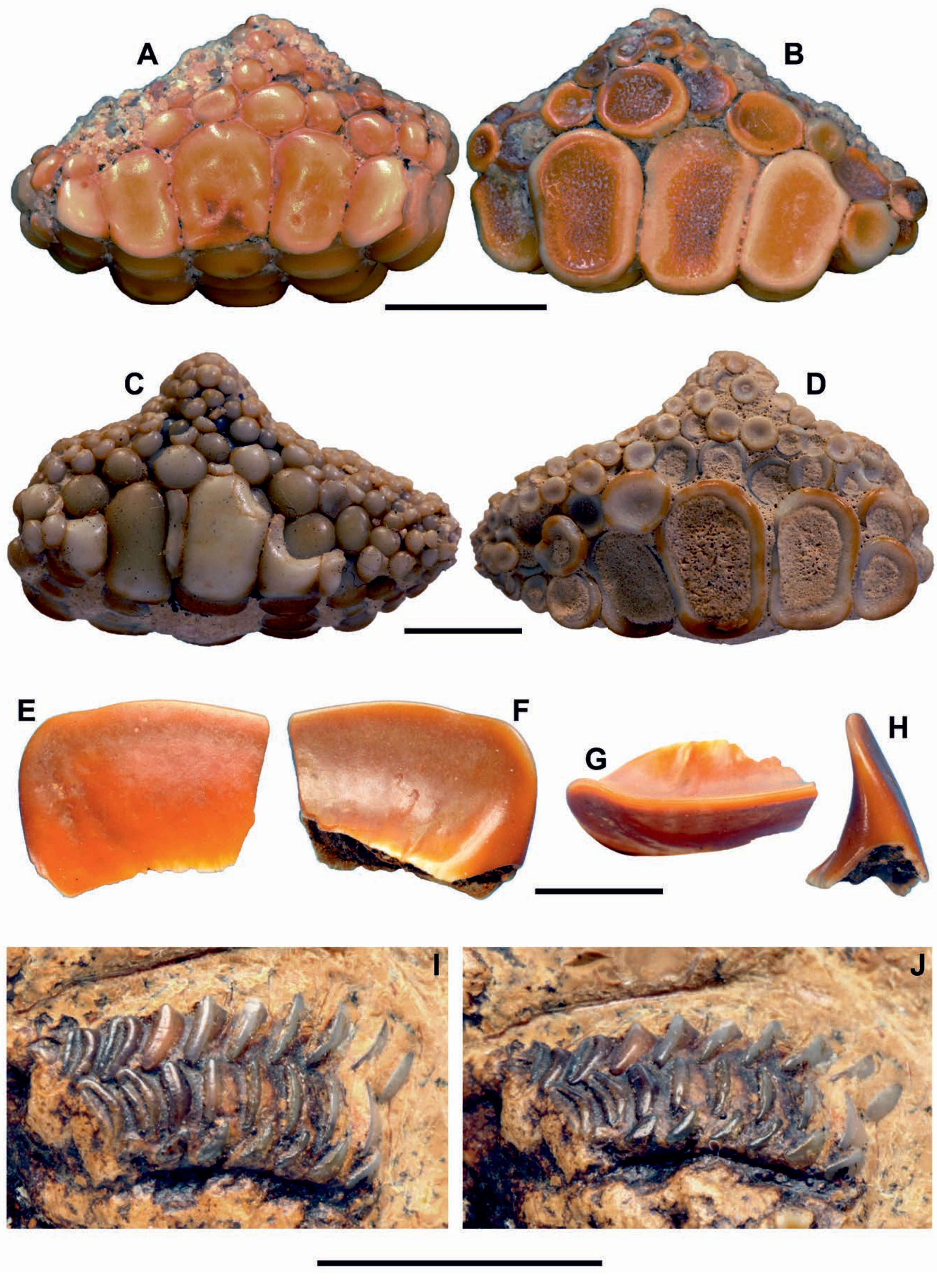


Plate XIV – XIV. tábla

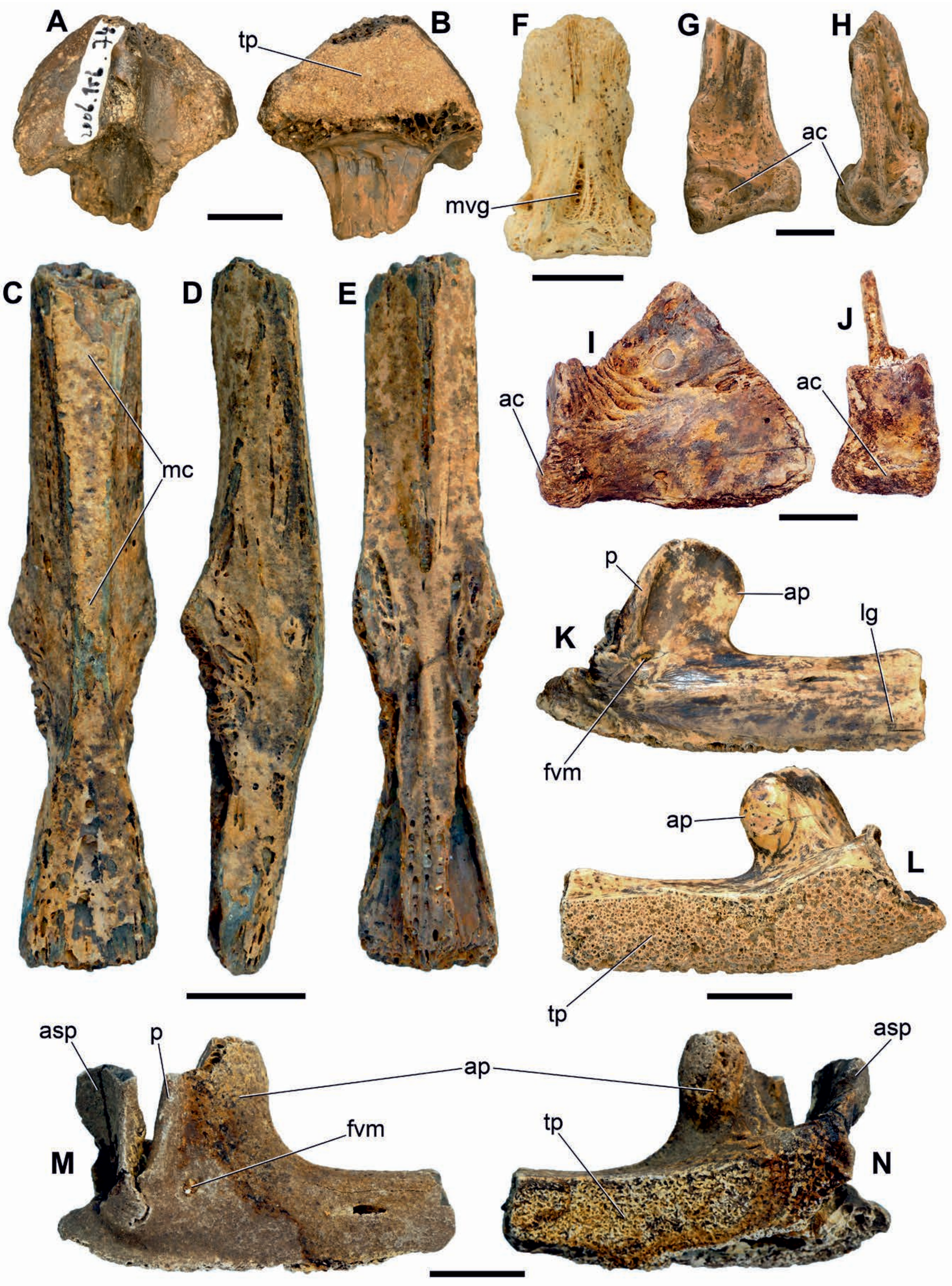


Plate XV – XV. tábla

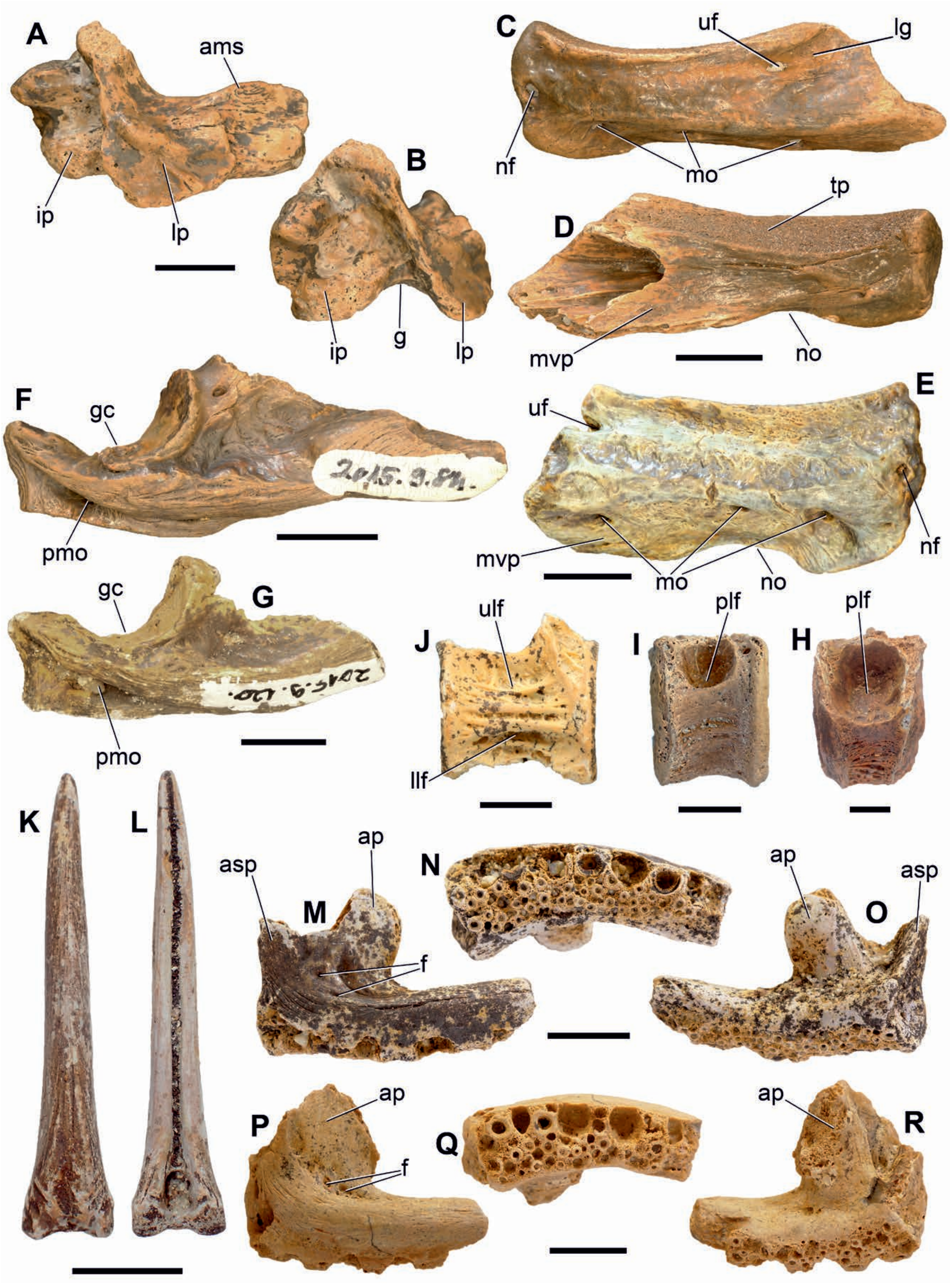


Plate XVI – XVI. tábla

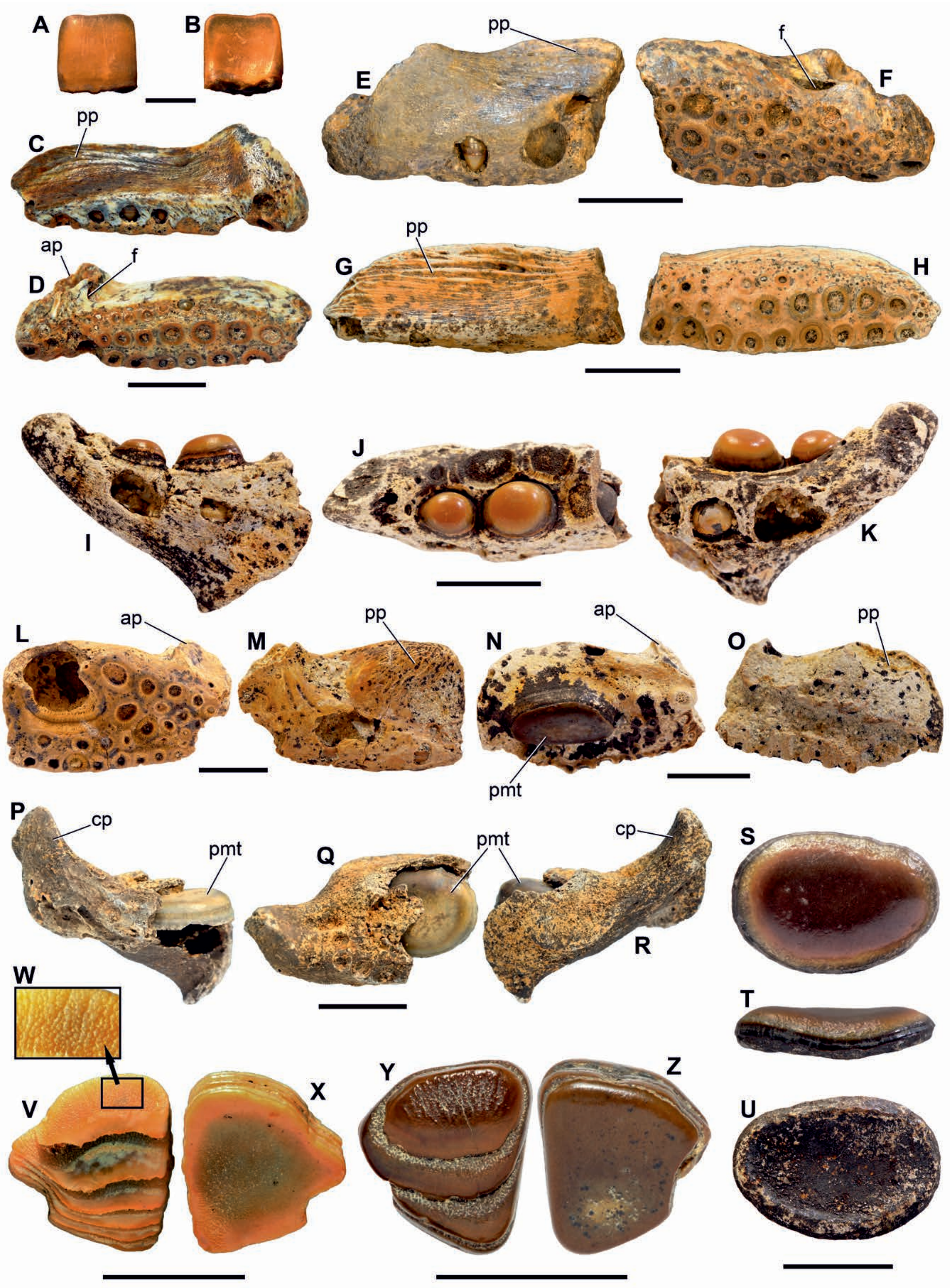
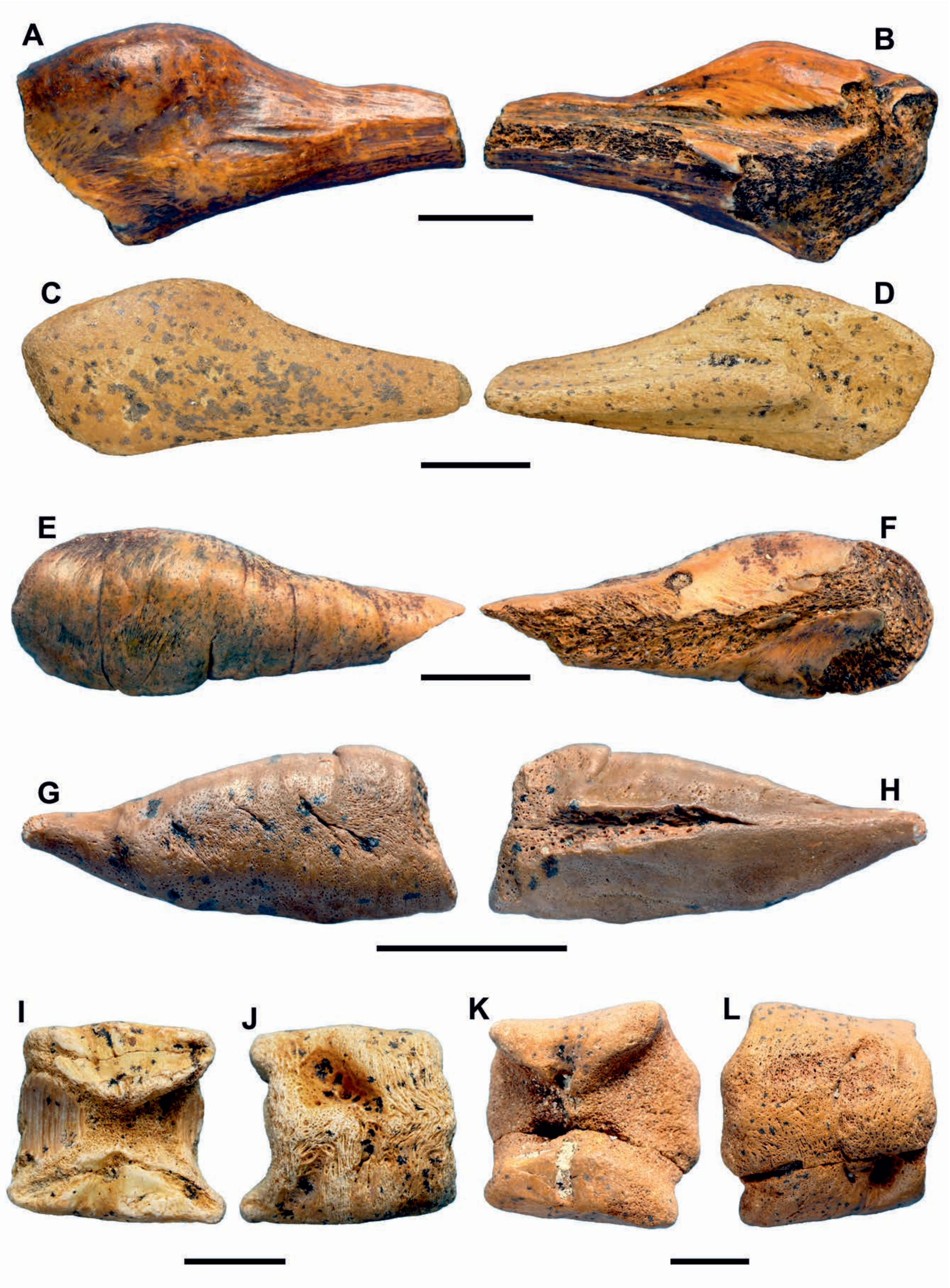


Plate XVII – XVII. tábla



Appendix

Systematic Palaeontology

Calcareous marls (Endrőd Marl Fm)

Class Osteichthyes Huxley, 1880
Subclass Actinopterygii Klein, 1885
Order Gadiformes Goodrich, 1909
Family Gadidae Rafinesque, 1810

Gadidae indet.
Plate I, A–E

Referred material: 1 otolith, 2 teeth.

Description: A relatively large otolith was referred to an indeterminate gadid taxon (*Plate I, A, B*). The otolith is elongated with smooth rims. The outer surface is smooth without ornamentation except a well-defined furrow at the rostral end. The inner face is moderately convex lengthwise. The ventral rim is gently curved towards both the anterior and the posterior tips, slightly rounded anteriorly. The dorsal rim has a weakly developed predorsal angle, the medio-dorsal part is slightly depressed, the postdorsal angle is marked. The dorsal rim bears a deep pinch between the postdorsal angle and the posterior tip. The anterior tip is bluntly pointed above the tiny rostrum. The rather shallow sulcus is straight with median position, ending in a narrow channel towards the anterior rim. The ostium is slightly shorter than the cauda, the collum is rather wide. The colliculi are shallow and do not extend to the margins. The ostial colliculum is smaller and has a trapezoidal shape. The caudal colliculum is fading away towards the posterior rim. The pseudocolliculum is well-developed. The ventral furrow is distinct and close to the ventral rim.

Two teeth were referred to indeterminate gadid fishes (*Plate I, C–E*). Their base is curved, and circular in cross-section. The tooth base bears fine or moderately coarse apicobasal striations. The slightly reclining cap is lanceolate.

Remarks: The morphology of the teeth does not provide specific characteristics; therefore identification on a level closer than Gadidae indet. is not posibble Morphologically similar or identical teeth were published in Brzobohatý & Pană (1985, pl. 58, fig. 28) and Botka et al. (2019, fig. 9A–D) as gadid teeth. The otolith specimen is similar to otoliths of *Gadiculus* (Nolf 2013) or *Palimphemus* (Bratishko et al. 2015), but its closer identification requires further specimens.

Family Gobiidae Cuvier, 1816

Gobiidae indet.
Plate I, F

Referred material: 1 otolith.

Description: Well-preserved, very small otolith. It is rounded, and the sulcus is hardly visible. The sulcus is wide with high ostial lobe and small cauda. The ventral furrow is broad, running far from the ventral rim of the otolith. The outer surface is convex and smooth without ornamentation.

Remarks: This specimen represents a juvenile individual, therefore is mentioned only at family level.

Order Perciformes Bleeker, 1859
Family Latidae Jordan, 1888
Genus *Lates* Cuvier & Valenciennes, 1828

Lates sp.
Plate I, G–P

Referred material: 1 partial skeleton, 1 block of associable vertebrae, 2 isolated vertebrae.

Description: An incomplete parasphenoid with associable ethmoid bones embedded in a piece of marl (*Plate I, G*). The parasphenoid (*Plate I, G, par*) is elongated and in lateral view, it has a slightly curved ventral border. The lateral ethmoids (*Plate I, G, le*) are slightly deformed, but they possess the palatine facets.

A block of marl includes associable vertebrae (of which two were prepared for closer examination) representing the postabdominal section of the spine (*Plate I, H–L*).

A large, isolated vertebra possibly belongs to the second abdominal position (*Plate I, M, N*). Based on its long haemal spine another isolated vertebra represents the caudal skeleton (*Plate I, O, P*).

Remarks: The morphology of the described remains clearly refers them to the latid genus *Lates* (see Murray et al. 2018, Otero 2004). This taxon is extremely abundant in the sands (see the section of the limonitic sands), from where comparable skeletal elements were unearthed.

Order Spariformes Bleeker, 1860
Family Sparidae Bonaparte, 1832

Sparidae indet.
Plate II, A

Referred material: 1 premaxilla.

Description: A fragmentary premaxillary bone was referred to a sparid fish. This premaxillary bears an enlarged molariform tooth, oval in occlusal view, and further, smaller, hemisphaerical molariform teeth and empty tooth positions. The broken tooth bases show radial ridges arranged around a large circular pulp cavity.

Remarks: The specimen is similar to the remains of *Sparus umbonatus* (see in the fauna of the limonitic sands), but it is much smaller, and somewhat less robust, which indicate closer resemblance to other sparids, e.g., *Sparus auratus*.

Actinopterygii indet.
Plate II, B-E

Referred material: 2 teeth, 2 cycloid scales, 1 articulated hyoid region.

Description: A few isolated teeth (*Plate II, B, C*) and cycloid scales (*Plate II, D*) were referred to indeterminate actinopterygians. The articulated hyoid region is of large size (*Plate II, E*), it comprises a left and a right ceratohyal (*Plate II, E, lch* and *rch*) with matching epihyals (*Plate II, E, leh* and *reh*) and a possible hypohyal (*Plate II, E, ?hh*).

Remarks: The teeth and cycloid scales referred here are of too general morphology and low number for a closer identification. The investigation of the hyoid elements is yet to be carried out, but it clearly differs from hyoid region of gadiforms (Hussain 1986, Endo 2002), latids (Otero 2004) and sparids (Day 2002). Until more fish remains are fund in the Endrőd Formation, here we refer these specimens as unidentified actinopterygian remains.

Limonitic sands (Kálla Member of the Békés Formation)

Class Chondrichthyes Huxley, 1880
Superorder Selachimorpha Nelson, 1984
Order Hexanchiformes de Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Notorynchus* Ayres, 1855

Notorynchus primigenius (Agassiz, 1835)
Plate III, A–R

Referred material: 17 teeth.

Description: Both upper and lower teeth are known. Upper anterior teeth (*Plate III, A–F*) have a single cusp, weakly curved lingually. Upper anterolateral and lateral teeth (*Plate III, G–L*) have a distally inclined main cusp, flanked by cusplets both mesially and distally. The root of upper teeth is flattened and rectangular, it gradually becomes wider than it is high in distal direction along the upper jaw. Lower files (*Plate III, M–R*), the most characteristic elements of the species have a distally inclined main cusp, followed by up to 5 distal cusplets. Further cusplets, smaller than the distal ones, are situated mesially to the main cusp. This part of the crown is usually eroded in the studied upper anterolateral-lateral and lower hexanchid teeth. The root is wider than it is high, and – similarly to that of upper teeth – it has a rectangular outline in labial and lingual view.

Remarks: The hexanchid species *N. primigenius* is widely reported from the Miocene marine sediments of the Central Paratethys (e.g.,Holec et al. 1995; Kocsis 2007; Szabó & Kocsis 2016a, table 2). Its global fossil record consists of isolated teeth only, found in Oligocene–Miocene marine sediments of North America, Europe and Australia (Cappetta 2012).

Order Squatiniformes de Buen, 1926
Family Squatinidae Bonaparte, 1838
Genus *Squatina* Duméril, 1806

Squatina sp.
Plate III, S–X

Referred material: 2 teeth.

Description: Both teeth are incomplete and miss nearly the half of the root. The anterior tooth has an upright main cusp perpendicular to the root (*Plate III, S–U*), while the cusp of the lateral tooth is distally inclined (*Plate III, V–X*). The crown of both specimens has convex labial and lingual faces. In profile view, the crown is weakly curved lingually. Both cutting edges are straight, no serrations are present or preserved. The crown basally continues on the root lobes both mesially and distally. Faint remains of the rounded, labial apron (characteristic for the genus) are visible. The preserved root portions refer to a triangular outline in basal view (not illustrated).

Remarks: The dentition of *Squatina* is very stable over geological times, therefore distinguishing species sloley based on isolated teeth is not well-established (Cappetta 2012). Numerous Oligocene–Miocene reports show the presence of the genus in the Central Paratethys (e.g., Holec et al. 1995; Kocsis 2007; Szabó & Kocsis 2016a, table 2; Szabó et al. 2017).

Order Lamniformes Berg, 1958
Family Odontaspididae Müller & Henle, 1839

Odontaspididae indet.
Plate IV, A–H

Referred material: 1500 teeth.

Description: Anterior teeth are Y-shaped, and symmetrical in labial and lingual views (*Plate IV, A–F*). The crown is slender and upright, with sigmoid profile. The cutting edges are smooth all along, they run basally from the tip, not reaching the crown base. The lingual face is strongly, while the labial is only weakly convex to flat. Due to reworking it is uncertain if the lingual crown face had any surface ornamentation. The root is bilobate, with well-separated lobes with rounded extremities. The lobes meet in a large lingual protuberance, usually bearing a well-developed nutritive groove. Faint remains of lateral cusplets are present on both lobes of the best preserved specimens. Upper lateral files are distinguishable by their distally inclined main cusp, and non-sigmoid profile outline (*Plate IV, G, H*).

Remarks: Miocene odontaspids of the Central Paratethys are represented by the genera *Araloselachus*, *Carcharias* and *Carcharoides* (see Szabó 2019; Szabó & Kocsis 2016a, table 2; Szabó & Kocsis 2020). These taxa are easily distinguishable by the fine characteristics of the main cusp (robustness, surface ornamentation, etc.) and the root (number and morphology of cusplets, outline of the root lobes, etc.) (Cappetta 2012). All specimens are markedly worn due to reworking, resulting in the disappearance of delicate surface features (e.g., lingual crown ornamentation, such as apicobasal folds), which could help closer identification. We leave the teeth referred here with open nomenclature. Nevertheless, the investigated odontaspid material is most similar to two species, *Carchaias acutissima* and *Araloselachus cuspidatus*, that are commonly reported from the Central Paratethys (Szabó & Kocsis 2016a and references therein).

Family Lamnidae Bonaparte, 1835
Genus *Cosmopolitodus* Glikman, 1964

Cosmopolitodus hastalis (Agassiz, 1838)
Plate IV, I–R

Referred material: 170 teeth.

Description: Due to dignathic heterodonty upper and lower teeth are easy to distinguish. Lower teeth, especially lower anterior files, have a narrower crown, which is more convex on its lingual face than the upper teeth. Upper teeth have a high, triangular crown, with a weakly convex lingual and a practically flat labial face. The cutting edges are running from the tip to the crown base and are entirely smooth. No lateral cusplets are present. The root of uppers is moderately, while that of lowers is strongly bifurcate with a weak lingual protuberance, usually having a foramen (unclear in the Pécs-Danitzpuszta teeth).

Remarks: The species is of worldwide distribution from Miocene to Pliocene marine sediments (Cappetta 2012). It is also widespread in the Miocene of the Central Paratethys (e.g. Holec et al. 1995; Kocsis 2007; Szabó & Kocsis 2016a, table 2). Several aspects of the classification and taxonomy of *C. hastalis* have been published in the last few decades, therefore different names have been used for the species. *C. hastalis* was originally grouped in genus *Oxyrhina*, and later in *Isurus*. According to the hypothesis of Glikman (1964), *C. hastalis* and *Carcharodon carcharias* (Great white shark) represent chronospecies as *C. hastalis* is replaced by a morphologically intermediate form, named *Carcharodon hubbelli* and finally *C. carcharias* (Ehret et al. 2012). To clarify this question is beyond the aims of the present paper, and the classification here follows that of Cappetta (2012).

Genus *Isurus* Rafinesque, 1810

Isurus oxyrinchus Rafinesque, 1810
Plate IV, S–V

Referred material: 13 teeth.

Description: The crown is narrow, triangular, distally inclined with a very weak curvature in profile view. The lingual crown face is convex, while the labial face is flat. Both faces and the cutting edges are entirely smooth. The cutting edges do not reach the base of the crown. No lateral cusplets are present. The root is bilobate and asymmetrical, caused by the distal lobe being shorter than the mesial one. Characteristically, both root lobes have angled extremities. The lingual protuberance is moderately developed, with a nutritive foramen.

Remarks: Fossil teeth of this species are known from Oligocene to Pliocene deposits, and they have been reported from Miocene sediments of the Central Paratethys as well (see Reinecke et al. 2011 and references therein).

Lamnidae indet.

Referred material: 7 teeth.

Description: These teeth are rather poorly reserved crowns, which could belong to both of the Pécs-Danitzpuszta lamnids. The crowns show a triangular outline in labial and lingual view, the crown faces are smooth, and the cutting edges are not serrated.

Remarks: Because of their poor quality, these teeth are not described closer than family rank.

Family Otodontidae Glikman, 1964
Genus *Otodus* Agassiz, 1838
Subgenus *Otodus* (*Megaselachus*) Glikman, 1964

Otodus (*Megaselachus*) *megalodon*
(Agassiz, 1843)
Plate V

Referred material: 72 teeth.

Description: These massive “megalodon” teeth are the most spectacular among all fish remains of the sands. The crown is broad, triangular, erect, massive, it reaches its maximum thickness at its base. The lingual crown face is strongly convex, while the labial face is usually flat or only slightly convex. The cutting edges are originally strongly serrated, however from some of the Pécs-Danitzpuszta specimens this feature was completly abraded off. The root-crown boundary bears a chevron-shaped band of thinner enameloid on the lingual crown face (= “lingual neck” in Boessenecker et al. 2019; also called as “bourlette”). Going backwards distally along the dentition, the height of the teeth decreases, they gradually become wider, with an increasing distal inclination. The root is thick and bifurcate with a massive lingual protuberance. The lobes are usually similar in size, and both have rounded extremities.

Remarks: A strongly pathological tooth is known in a private collection (*Plate V, E–H*). Based on their size, some teeth are referable to juvenile individuals (*Plate V, M–P*) (Gottfried et al. 1996, Pimiento et al. 2010, Shimada 2019).

Family Alopiidae Bonaparte, 1838
Genus *Alopias* Rafinesque, 1810

Alopias exigua (Probst, 1879)
Plate VI, A–D

Referred material: 2 teeth.

Description: Two lateral teeth were referred here; both are higher than they are wide. The cusp is distally inclined, the cutting edges are smooth, no lateral cusplets are present. The lingual crown face is strongly convex, while the labial is nearly flat, except for its base, where it continues in calloused enamel shoulders both mesially and distally, overhanging the root. A well-developed lingual protuberance with nutritive grooves is present on both specimens. The root lobes form an arched contour and posses rounded extremities.

Remarks: Fossil teeth of *Alopias* are never common in the Miocene sediments of the Central Paratethys. *A. exigua* ranges from the Early Oligocene to the Middle Miocene (REINECKE & RADWAŃSKI 2015; SZABÓ & KOCSIS 2016b, 2020). This species has previously been reported from only one Badenian locality in Hungary (SZABÓ & KOCSIS 2020).

Genus *Anotodus* LE HON, 1871

Anotodus retroflexus (AGASSIZ, 1843)
Plate VI, E–P

Referred material: 27 teeth.

Description: Medium to large alopiid teeth are typical, relatively common in the studied material. The crown of anteriors (unknown from the Pécs-Danitzpuszta material) is symmetrical and erect, while that of laterals is distally inclined, therefore weakly asymmetrical. In profile view, the crown of all files slightly bends lingually. The cutting edges are smooth, and the crown faces bear no ornamentation. The root is bilobate, and the root lobes are thick and well-separated. The labial crown enamel basally continues on both root lobes as enamel heels. These heels slightly overhang the lobes. The lobes have angled extremities, they meet in a lingual protuberance, bearing a faint nutritive groove, less typical with a large foramen.

Remarks: Genus *Anotodus* was erected by LE HON (1871) and re-classified in Alopiidae by HERMAN (1979). Until recently, the described teeth were widely regarded as *Isurus retroflexus*, as a member of the family Lamnidae, but the species were synonymized and replaced within the Alopiidae (CAPPETTA 2012). KENT (2018) found smaller teeth and anterior teeth of *A. retroflexus* more similar to those of lamnids, and he included the species within Lamnidae as *Isurus retroflexus*.

Order Carcharhiniformes COMPAGNO, 1973
Family Hemigaleidae HASSE, 1879
Genus *Hemipristis* AGASSIZ, 1835

Hemipristis serra AGASSIZ, 1835
Plate VII, A–K

Referred material: 101 teeth.

Description: The species is characterized by clear dignathic heterodonty. Upper teeth – except for the first upper anteriors – have large, labiolingually flattened, triangular, distally inclined crown with strongly serrated cutting edges (*Plate VII, A–E*). The root of upper files is asymmetrical, high and bilobate, bearing a lingual protuberance. Lower anterior teeth have slender, upright crown with slightly sigmoid profile view. The cross-section is circular. Lower anterior teeth (*Plate VII, I–K*) less typically bear a pair of lateral cusplets, which are missing from all Pécs-Danitzpuszta lower anteriors as a result of re-deposition. The cutting edge is smooth, it runs from the apex only to the upper third of the apicobasal height. In lower lateral files the teeth become asymmetrical (the mesial cutting edge becomes longer), the number of lateral cusplets increases (see figs *Plate VII, F–H*). The roots of all lower files are bilobate, with a well-marked lingual protuberance.

Remarks: Teeth of *H. serra* are characteristic and easy to identify. The species has been widely reported from the Miocene of the Central Paratethys (see SZABÓ & KOCSIS 2016a, table 2).

Family Carcharhinidae JORDAN & EVERMANN, 1896
Genus *Galeocerdo* MÜLLER & HENLE, 1838

Galeocerdo aduncus AGASSIZ, 1835
Plate VII, L–U

Referred material: 163 teeth.

Description: The teeth have a triangular crown bent toward the rear, except for the very anterior teeth, which have a somewhat more erect cusp. The lingual tooth face is convex, while the labial is flat. Both crown faces are smooth. The convex mesial cutting edge bears fine, irregular serrations; however, this feature is worn away in most Pécs-Danitzpuszta teeth. The distal cutting edge is short, straight to slightly convex, finely serrated (all teeth studied here lack this character due to re-working). It continues in a distal enamel shoulder, which has a serration built up by rather large serrations, large enough to be preserved in almost all Pécs-Danitzpuszta teeth. The root is mesiodistally wide, the lingual protuberance is low with a nutritive groove.

Remarks: This species is also widely reported from the Miocene of the Central Paratethys (see SZABÓ & KOCSIS 2016a, table 2). The Pécs-Danitzpuszta material covers all important tooth positions. Teeth of the modern species *G. cuvier* was also reporterd from late Miocene deposits (e.g. PURDY et al. 2001) but their teeth are rather robust with cutting edges bearing secondary serrations, which is missing from the mesial cutting edge of *G. aduncus* (CIGALA-FULGOSI & MORI 1979). The serration of the Pécs-Danitzpuszta teeth is typically worn, however their size, shape and proportions somewhat differ from teeth of *G. cuvier*.

Genus *Carcharhinus* BLAINVILLE, 1816

Carcharhinus priscus (AGASSIZ, 1843)
Plate VII, V–A'

Referred material: 130 teeth.

Description: Both upper and lower teeth are present in the studied material. Upper jaw dentition includes teeth with triangular crowns. The crown is straight in profile view, upright in anterior files, while distally inclined in lateral and distal teeth. Lower teeth (not illustrated due to their poor preservation) also have an upright crown, more convex faces, and are slightly bent lingually. The root is mesiodistally wide, bilobate, and they meet in a low lingual protuberance with a nutritive groove.

Remarks: This species has widely been reported from the Miocene deposits of Europe, including those of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2). ANDRIANAVALONA et al. (2015) considered that *C. priscus* may represent a species group rather than a discrete species.

Family Sphyrnidae GILL, 1872
Genus *Sphyrna* RAFINEQUE, 1810

Sphyrna laevissima (COPE, 1867)
Plate VII, B'–E'

Referred material: 6 teeth.

Description: Only lateral teeth are known from Pécs-Danitzpuszta. The distally inclined crown has a convex lingual and a flat labial face. Both faces are smooth. The mesial cutting edge is smooth all along; it is straight on its basal half, while slightly convex on the apical half. The distal cutting edge is smooth and short; it continues in a convex and smooth, distal enamel shoulder. The root is mesiodistally wide and bilobate. The lobes have rounded extremities, and they meet in a very low lingual protuberance bearing a large nutritive groove.

Remarks: Hammerhead sharks are relatively uncommon in the middle Miocene sediments of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2).

Superorder Batomorphii CAPPETTA, 1980
Order Myliobatiformes COMPAGNO, 1973
Family Dasyatidae JORDAN, 1988

Dasyatidae indet.
Plate VIII, A–C

Referred material: 1 tooth.

Description: The only tooth referred here is small and nearly complete; however, it is strongly worn due to re-deposition. The crown is rectangular in occlusal view, and it bears a well-developed but low transversal crest. The crest separates the labial and the lingual visors. This morphology refers the tooth to a female individual. Neither occlusal ornamentation, nor facets on the basal crown surface are visible. The root is bilobate, and a large foramen is situated between the lobes.

Remarks: Various dasyatid species have been reported under the genus *Dasyatis* from the middle Miocene of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2), but the Pécs-Danitzpuszta material is too worn for a closer identification, therefore we leave it with open nomenclature until further material is unearthed. It must be pointed out that the classification of Dasyatidae has been revised (LAST et al. 2016), and previously described fossil "*Dasyatis*" species might belong to other genera such as *Himantura* or *Maculabatis*.

?Dasyatidae indet.
Plate VIII, D–F

Referred material: 1 tooth.

Description: The crown is low, bearing a lingually arched transversal crest, which separates the labial and lingual faces (or visors). In occlusal view, the crown shows a rounded anterior margin, while the posterior outline is angular. No apron is present. The crown is wider than the root, and the root shows two widely separated lobes. The root lobes are slightly shifted posteriorly. Based on the preserved characteristics, the tooth belongs to a female individual.

Remarks: The only tooth referred here was collected and illustrated by JUHÁSZ (2006, pl. 2, figs 3, 4), who identified it as *Raja* sp. Poorly preserved rajid and dasyatid teeth show similar morphology, therefore the taxonomical assignment of this tooth remains confusing. Nevertheless, it shows more affinity to dasyatids. The specimen was re-housed in the NHMUS collection.

Family Aetobatidae AGASSIZ, 1858
Genus *Aetobatus* BLAINVILLE, 1816

Aetobatus arcuatus (AGASSIZ, 1843)
Plate VIII, G–Q

Referred material: 50 teeth.

Description: Both lower (*Plate VIII, G–L*) and upper teeth (*Plate VIII, M–Q*) were recognized in the Pécs-Danitzpuszta material. Lower teeth are distally arched, they reach their maximal lenght at their mediolateral midline. The crown is low, it is separated from the root lobes by a lingual bulge. The lingually shifted root is built up by numerous parallel lobes. Upper teeth are fairly rectilinear, except for the lingually bent lateral edges. The root of the upper teeth is less shifted lingually and has about the same height as the crown.

Remarks: A. arcuatus is a common eagle ray species in the Miocene marine sediments of Europe (RADWAŃSKI 1965; SZABÓ & KOCSIS 2016a, table 2). Its tooth remains are easily distinguishable from those of other Miocene myliobatiform taxa of Europe.

Family Myliobatidae BONAPARTE, 1838
Genus *Aetomylaeus* GARMAN, 1908

Aetomylaeus sp.
Plate VIII, R–A'

Referred material: 17 teeth.

Description: The dentition of *Aetomylaeus* is similar to that of *Myliobatis* (also present in the limonitic sands), but significant morphological differences can be recognized in the lower dentition. *Aetomylaeus* typically has seven anteroposteriorly running tooth rows: one medial (or central) and three-three lateral ones on both sides (CAPPETTA 2012). Unlike in *Myliobatis*, the medial files of *Aetomylaeus* are arched. The root and the crown of the medial files are thicker medially than laterally, the tooth is oblique in lateral view. The labial side bears a rich ornamentation built up by a dense network of ridges. The slightly lingually directed root is high, at some medial sections it can be higher than the crown.

Remarks: Aetomylaeus and *Pteromylaeus* have been traditionally regarded as separate genera (e.g. CAPPETTA 2012). However, systematic analysis by WHITE (2014) suggests that *Pteromylaeus* is a junior synonym of *Aetomylaeus*, and this hypothesis is accepted here. The genus *Aetomylaeus* is known from the middle Miocene, but its appearance in the fossil record could have been much earlier, since their teeth have often been confused with those of *Myliobatis* spp. (CAPPETTA 2012). The genus is very scarce in the middle Miocene of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2).

Genus *Myliobatis* CUVIER, 1826

Myliobatis sp.
Plate IX, A–T

Referred material: 292 teeth and 3 partial tooth plates.

Description: In the Pécs-Danitzpuszta material *Myliobatis* is represented by tooth plates as well. Currently three, partially preserved tooth plates are known, all have been illustrated (*Plate IX, A–L*).

The isolated medial (*Plate IX, M–Q*) and lateral teeth have straight and mediolaterally widened crown, with angled lateral edges. Medial files are mediolaterally wider than laterals (*Plate IX, R–T*), which are therefore more hexagonal in occlusal view. The root of all files consists of numerous, mediolaterally flattened, parallel lobes.

Remarks: These remains were distinguished from those of *Rhinoptera* (also present in the limonitic sands) by having a relatively lower crown, different root lobe proportions and tooth connection structure. As dental characteristics of *Myliobatis* are conservative over geological time, distinguishing the species only by their isolated teeth is uncertain. For this reason, here we identify these remains only at the genus rank. *Myliobatis* is abundant all over the Miocene marine deposits of Europe, including those of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2).

Myliobatidae indet.

Referred material: 77 teeth.

Description: Poorly preserved, worn or fragmentary teeth of myliobatid morphology are referred here.

Remarks: Based on the connecting structures of the teeth, they certainly do not represent the family Rhinopteridae. Due to their poor preservation, we do not refer them closer than family rank as multiple myliobatid genera inhabited the area.

Family Rhinopteridae JORDAN & EVERMANN, 1896
Genus *Rhinoptera* CUVIER, 1829

Rhinoptera cf. *schultzi* HIDEN, 1995
Plate IX, U–I'

Referred material: 6 teeth.

Description: The *Rhinoptera* teeth are hexagonal in occlusal view, the occlusal surface is weakly concave. The crown is massive and thick. The root consists of numerous parallel lobes and is lower apicobasally than the crown. It is also less displaced lingually than those of *Aetomylaeus* and *Myliobatis* (see above).

Remarks: Compared to teeth of *Aetomylaeus* and *Myliobatis*, the root of *Rhinoptera* teeth is not or only slightly shifted lingually (SZABÓ & KOCSIS 2016a). Also, the connection between the teeth is more complex in *Rhinoptera* than in *Aetomylaeus* and *Myliobatis* (so-called „tenon and mortise" connections; BOURDON 2002). Based on these characteristics, the Pécs-Danitzpuszta teeth clearly represent the genus *Rhinoptera*.

Two species, *R. schultzi* and *R. studeri* have been reported from the middle Miocene of the Central Paratethys (SZABÓ & KOCSIS 2016a, table 2). *R. schultzi* differs from *R. studeri* in having smaller teeth, with much thinner crown with smaller width/length ratio, and also in the absence of ornamentation of the labial and lingual faces (HIDEN 1995). The differences between the proportions of the teeth of the two species can be easily observed in lateral view (see HIDEN 1995, text-fig. 11 and SZABÓ et al. 2017, figs 9p, u). Based on the observable characters, the Pécs-Danitzpuszta teeth are more similar to *R. schultzi*. However, because of the quality and low number of the specimens referred here, further teeth are required for a more certain identification.

Myliobatiformes indet.
Plate IX, J'–M'

Referred material: 22 caudal spines.

Description: Myliobatiform caudal spines are also known from the Pécs-Danitzpuszta site. All are incomplete, and they have serrated lateral edges.

Remarks: Since all myliobatiform caudal spines have very similar characters (HOVESTADT & HOVESTADT-EULER 2013), and the Pécs-Danitzpuszta specimens are very fragmentary, a closer identification is impossible.

Chondrichthyes indet.
Plate X

Referred material: 22 vertebral centra, 1 piece of fossilized cartilage.

Description: Although the chondrichthyan centra referred here are incomplete, the preserved portions refer to a circular outline in articular view. Centra of morphotype 1 (*Plate X, A–E*) are aseptate and short in profile view, giving an overall discoid shape to the centra. No large ventral or dorsal foramina are present. Morphotype 2 (*Plate X, F–H*) bears large dorsal and/or ventral foramina, however, all specimens referred here are fragmentary.

The only cartilage specimen referred here (*Plate X, I, J*) is built up by stellate units of cartilage tissue. Chondrichthyans are characterized by the presence of tesserate mineralization of the cartilaginous endoskeleton (MAISEY 2012).

Remarks: Vertebral centra morphologically similar to centrum moprhotype 1 were published in LOPES et al. (2016, figs 9.1–2) as ray vertebrae. Centra morphotype 2 are generally similar to those of Carcharhiniformes (see PURDY et al. 2001, fig 52; SZABÓ et al. 2017, figs 8k–n; SZABÓ &

Kocsis 2020, fig. pl. 10, figs 1–12), but they are too incomplete for a close identification; therefore, they are left with open nomenclature.

Fossilized cartilage is exceptionally rare, and it has only been reported in case of a few specimens from the Oligocene–Miocene of the Central Paratethys (Szabó 2019). Cartilage that makes up the chondrichthyan skeleton is easily crushed and dissociated during fossilization (Maisey 2012).

Class Osteichthyes Huxley, 1880
Subclass Actinopterygii Klein, 1885
Order Acipenseriformes Berg, 1940
Family Acipenseridae Bonaparte, 1831

Acipenseridae indet.
Plate XI, A–H

Referred material: 1 indeterminate skull element, 4 dermal scutes, 2 pectoral spines.

Description: The skull element (*Plate XI, A, B*) has an ornamented outer surface, while a distinct descending lamina (*Plate XI, B, dl*) is present on its ventral side. The scutes (*Plate XI, C–F*) exhibits a strong, honeycomb like ornamentation on its outer surface and a nearly smooth inner surface. The lateral surfaces of the fin spine (*Plate XI, G, H*) bear marked longitudinal ridges, and the posterior surface have a deep concavity.

Remarks: Following parsimony, here we assign all Pécs-Danitzpuszta acipenserid remains to a single taxon, until further specimens lead us to a different conclusion. Although the dermal scutes are exceptionally similar to that of *Acipenser sturio* (Desse-Berset 2011, fig. 7.4C), the studied material is too incomplete for an identification closer than Acipenseridae indet.

Order Carangiformes Jordan, 1923
Family Carangidae Rafinesque, 1815

Carangidae indet.
Plate XI, I–N

Referred material: 2 dentaries.

Description: The dentaries are incomplete; and the preserved portions refer to a subtriangular outline in lateral view. A large neural foramen opens at the middle of the symphysial edge on the outer surface of the dentary (*Plate XI, I, L, dnf*). The symphysial edge is high and angular both dorsally and ventrally. A wide longitudinal groove runs along the lateral side of the bone, starting just behind the symphysial edge. The mandibular sensory canal opens anteriorly on the lateral surface of the bone, posteriorly to the large neural foramen, and on the lateroventral side of the dentary (*Plate XI, I, L, dmo*). The ventral margin of the dentary bears a notch (*Plate XI, I, L, no*). Labially a row of enlarged teeth runs along the dentary. Lingually, much smaller teeth are arranged in multiple rows.

Remarks: Based on the tooth row morphology, the high and angular symphyseal, and the arrangement of the lateral foramina, the dentaries resemble the most those of extant carangid genera (see Terceire et al. 2019). However, due to the low number and poor quality of the remains here we identify them only as Carangidae indet.

Order Istiphoriformes Betancur-R et al., 2013
Family Sphyraenidae Rafinesque, 1815
Genus *Sphyraena* Klein, 1778

Sphyraena sp.
Plate XI, O, P

Referred material: 1 tooth.

Description: A single tooth is labiolingually flattened, and has a triangular outline in profile view. The tooth bears faint remains of fine striations, and the tip is missing.

Remarks: As the only tooth referred here is heavily worn and incomplete, a species level identification is impossible. Family Sphyraenidae (barracudas) includes genus *Sphyraena* only (Gottfried et al. 2017). Genus *Sphyraena* has previously been reported from the Miocene of the Central Paratethys (Schultz 2013, Schultz et al. 2010, Szabó & Kocsis 2020). There are 28 extant barracuda species around the world, and all are common predators of tropical and subtropical seas (Froese & Pauly 2019).

Order Scombriformes Rafinesque, 1810
Family Scombridae Rafinesque, 1815
Genus *Thunnus* South, 1845

cf. *Thunnus* sp.
Plate XII, A–O

Referred material: 1 premaxilla, 18 dentaries, 3 vertebrae.

Description: The premaxilla (*Plate XII, A–C*) is slender, slightly curved with a single row of small, closely positioned, circular alveoli. Only the very base of the ascending process (*Plate XII, A, C, asp*) is preserved. The posterior shank of the premaxilla (*Plate XII, A, C, ps*) is long. The bone surface is quite eroded; therefore, no characteristic foramina are observable. The dentaries (*Plate XII, D–I*) bear a thick medioventral plate (*Plate XII, F, I, mvp*). A large neural foramen opens behind the symphysial edge, above a shallow ventral notch (*Plate XII, D, G, dnf* and *no*). The medial bone surface bears a posteriorly widening groove with numerous foramina (*Plate XII, F, I, gr* and *f*). The abdominal centrum (*Plate XII, J–L*) is characterized by deep fossae separated by a strong median ridge along the lateral sides. The caudal vertebral centrum (*Plate XII, M–O*) has rectangular dorsal, ventral, and lateral outline, caused by its dorsoventral compression. In anterior and posterior views, the caudal vertebra shows a hexagonal outline.

Remarks: At the moment it is unclear whether this morphotype represents a single taxon, but based on the general appearance of the bones we tentatively refer the remains to the same morphogroup until more specimens disprove this. The specimens resemble the most those of *Thunnus* (Carnevale & Godfrey 2018, Plate I.16A–E, G, H; Purdy et al. 2001, fig. 76; Terceire et al. 2019); however, further specimens are required for a more precise identification.

Scombridae indet.
Plate XII, P–A'

Referred material: 1 premaxillary, 158 dentaries.

Description: This scombrid morphogroup represents a rather large taxon. The premaxilla (*Plate XII, P–R*) is massive, and it has a wide ascending process (*Plate XII, P, R, asp*), which is only partially preserved. A major part of the posterior shank is missing. The medial side of the premaxilla bears a large, rounded depression with large foramina in it (*Plate XII, R, d* and *f*). Posteriorly to the base of the articular process a large bulge is visible (*Plate XII, R, b*). The dentaries are of poor quality, only their tooth-bearing portions are preserved. Both the premaxillae and the dentaries bear a series of large, closely spaced alveoli. A few specimens still have some fragmentary, subtriangular teeth preserved in situ.

Remarks: Similarly, to the specimen PTE_5094, premaxillae of extant *Euthynnus*, *Scomber* and *Thunnus* bear a bulge-like structure posteriorly to the base of the ascending process (TERCEIRE et al. 2019). However, the fossils here also resemble those of large sized fossil scombrid taxa *Acanthocybium solandri* (CARNEVALE & GODFREY 2018, Plate I.15A–D; PURDY et al. 2001, fig. 77) and *Pelamycybium partschi* (see SCHULTZ 2013, pl. 71, figs 1, 2). These Pécs-Danitzpuszta scombrid elements are too fragmentary for a more precise identification.

Order Labriformes KAUFMAN & LIEM, 1982
Family Labridae CUVIER, 1817
Genus *Labrodon* GERVAIS, 1857

Labrodon sp.
Plate XIII, A–D

Referred material: 2 pharyngeal tooth plates, 1 isolated tooth.

Description: The two pharyngeal tooth plates have triangular outline in occlusal view. Both specimens comprise multiple layers of phyllodont teeth. The posterior rows include larger, oval teeth, while the more anterior rows inlcude teeth with circular outline. An isolated tooth (not illustrated) has been found with screening. Its basal surface is characteristically ornamented by crenulations.

Remarks: Labrid fishes are widely reported from the middle Miocene of the Central Paratethys (see BELLWOOD et al. 2019, SCHULTZ et al. 2010, SZABÓ 2019, SZABÓ & KOCSIS 2020). Based on the shape and proportions of the teeth and the shape of the tooth plates, the Pécs-Danitzpuszta remains resembles most the *L. pavimentation* (see ÁVILA et al. 2020, BETANCORT et al 2016).

Genus *Trigonodon* SISMONDA, 1847

Trigonodon jugleri (MÜNSTER, 1846)
Plate XIII, E–H

Referred material: 1 tooth.

Description: A single incomplete tooth is referred here. The specimen is of incisiform morphology; therefore, it belongs to the anterior section of the jaw apparatus.

Remarks: Diplodus jomnitanus, a fossil sparid widespread in the Miocene of Europe also has large incisiform teeth, but these are rectangular and more symmetrical in labial view, unlike those of *T. jugleri*, which are mesiodistally much wider, asymmetrical and have a trapezoid to almost triangular outline. *T. jugleri* is widely reported from the middle Miocene of the Central Paratethys, and its oldest fossils are from the early Miocene of Italy and Austria (SCHULTZ & BELLWOOD 2004, SZABÓ & KOCSIS 2020).

Family Scaridae RAFINESQUE, 1810
Genus *Calotomus* GILBERT, 1890

Calotomus sp.
Plate XIII, I, J

Referred material: 1 pharyngeal tooth plate.

Description: The tooth plate is composed of three parallel, anteroposteriorly running rows of small, ovoid to sub-rectangular teeth. The specimen is sitting in a piece of coprolite.

Remarks: Upper pharyngeal bones with 1-3 rows of teeth are a unique character found only in the family Scaridae (BELLWOOD & SCHULTZ 1991). *Calotomus priesli*, a species described from the middle Miocene of Austria (BELLWOOD & SCHULTZ 1991) is the only representative of the genus from the middle Miocene of Europe. As this species has been described from an articulated head region of an individual, it is uncertain if the Pécs-Danitzpuszta fossil represents the same species. Therefore, we describe it as *Calotomus* sp. until further specimens provide more taxonomical details.

Order Perciformes BLEEKER, 1859
Family Latidae JORDAN, 1888
Genus *Lates* CUVIER & VALENCIENNES, 1828

Lates sp.
Plate XIV, A–N and Plate XV A–L

Referred material: 11 vomers, 57 parasphenoids, 51 quadrates, 247 premaxillae, 7 maxillae, 446 dentaries, 80 fragmentary upper or lower jaw elements, 34 anguloarticulars, 776 vertebrae, 114 fin spines.

Description: Vomers (*Plate XIV, A, B*) are stocky, and they have a rounded anterior margin in ventral view. The vomer bears a perfectly fused tooth patch (*Plate XIV, B, tp*) in all latid species. The vomer distally connects to the mesethmoid and the parasphenoid. The parasphenoid (*Plate XIII, C–E*) is an elongated bone element, ranging along the ventral side of the neurocranium. Parasphenoids referred here have a ventral border slightly curved in lateral view. In transverse section, their ventral face is slightly concave. A well-developed median crest (*Plate XIV, C, mc*) is present along the ventral surface, between the orbits. The basioccipital (*Plate XIV, F*) bears a median ventral groove

(*Plate XIV, F, mvg*), which does not reach the parasphenoid (characteristic for all known extant and extinct species of *Lates*). The most complete quadrates (*Plate XIV, G–J*) are nearly as long as they are high. The articular condyle (*Plate XIV, G–J, ac*) and the base of the posterior border are wide compared to the rest of the bone. Latid premaxillae (*Plate XIV, K–N*) are characterized by a long ascending process (*Plate XIV, M, N, asp*), which are incomplete or missing in all Pécs-Danitzpuszta specimens. The articular process is large and globular (*Plate XIV, K–N, ap*). The anterior margin of the articular process bears a massive, dorsoventrally running pad (*Plate XIV, K, M, p*). A large foramen for venous vessels and the maxillary nerve branch opens at the base of the articular process (*Plate XIV, K, M, fvm*). Unfortunately, all Pécs-Danitzpuszta latid premaxillae lack the posterior process. A very low longitudinal groove develops along the alveolar process (*Plate XIV, K, lg*); it starts anteriorly just below the articular process. The tooth plate develops along the ventromedial surface of the alveolar process (*Plate XIV, L, N, tp*). The maxilla of latids has a large posterior dorsal plate, but this part of the bone is missing in all Pécs-Danitzpuszta specimens (*Plate XV, A, B*). The shape of the articular head is intraspecifically variable in extant forms. The premaxillary internal process is medioventrally directed (*Plate XV, A, B, ip*). The adductor mandibulae I surface (*Plate XV, A, ams*) is situated posteriorly of the extended lateral plate (*Plate XV, A, B, lp*). The internal process and the lateral plate are separated by a deep groove (*Plate XV, B, g*). The dentary (*Plate XV, C–E*) bears a medioventral plate and a large lateral groove (*Plate XV, C–E, mvp* and *lg*). The upper foramen of the dentary is situated anteriorly to the lateral groove (*Plate XV, C, E, uf*). A large neural foramen opens near the middle of the symphysial edge on the outer surface of the dentary (*Plate XV, C, E, nf*). The mandibular sensory canal runs in a bony tube ventrally bordered by the medioventral plate, it opens anteriorly on the lateral surface of the bone, posteriorly to the large neural foramen, and on the lateroventral side of the dentary (*Plate XV, C, E, mo*). The ventral margin of the dentary bears a notch posterior to the symphysis (*Plate XV, D, E, no*). Angulo-articulars (*Plate XV, F, G*) have a wide and deep glenoid cavity (*Plate XV, F, G, gc*). The mandibular sensory canal runs in a bony tube with a posterior opening (*Plate XV, F, G, pmo*) in a groove below the glenoid cavity on the lateral side of the bone. Vertebrae (*Plate XV, J–H*) have striated bone surface with enlarged lateral fossae. The anteriormost vertebral centra are higher than they are long. These proportion turns to the opposite caudally. The anterior abdominal vertebrae have a large and deep primary lateral fossa (*Plate XV, I, H, plf*). Postabdominal vertebrae have a lower and an upper (or dorsal) lateral fossa (*Plate XV, J, llf* and *ulf*), which are separated by a bundle of striated bone. All Pécs-Danitzpuszta specimen lack the neural spine, and only their bases are preserved in some caudal vertebrae. Median fin spines (*Plate XV, K, L*), similar to those of generalized perciforms are here assigned to the genus *Lates*.

Remarks: Remains of *Lates* sp. are frequent osteichthyan elements of the Pécs-Danitzpuszta sand pit. Altogether, this is the anatomically best known Pécs-Danitzpuszta osteichthyan.

Fossils of *Lates* are relatively common in the Cenozoic of the old world. They are known from Italy, Portugal, Austria, Moldavia, Croatia, Israel, Oman, Saudi-Arabia and various localities in Africa (CARNEVALE & LANDINI 2001). The oldest representative is from the Oligocene. The genus started its diversification during the Miocene. Most finds are isolated, and their identification is often problematic at specific level (GAGNAISON & COSSARD 2013, MURRAY et al. 2018, OTERO & GAYET 2001). Here we leave the Pécs-Danitzpuszta material undetermined.

Order Acanthuriformes JORDAN, 1923
Family Sciaenidae CUVIER, 1829

Sciaenidae indet.
Plate XV, M–R

Referred material: 61 premaxillae.

Description: The premaxillae are labiolingually curved, they bear a flattened, elongated ascending process (*Plate XV, M, O, asp*) and an oblong, well-developed articular process (*Plate XV, M, O, P, R, ap*). The two processes are incomplete in all investigated Pécs-Danitzpuszta premaxillae. Large foramina open at the base of the articular process (*Plate XV, M, P, f*). The labialmost tooth row consists of enlarged teeth. Lingually to this row, smaller teeth are arranged in multiple rows.

Remarks: The closely spaced labial teeth are similar to those of *Sciaenops* (PURDY et al. 2001). Among all extant genera, based on the labiolingual curvature of the premaxillae and the arrangement and proportions of tooth rows, the Pécs-Danitzpuszta sciaenid material resembles most the *Sciaena* (TERCEIRE et al. 2019). Due to the low number of the specimens referred here we identify them only as Sciaenidae indet., until more specimens provide further information.

Order Spariformes BLEEKER, 1860
Family Sparidae BONAPARTE, 1832
Genus *Diplodus* RAFINESQUE, 1810

Diplodus sp.
Plate XVI, A, B

Referred material: 27 teeth.

Description: The teeth referred here are labiolingually flattened and show a rectangular labial (and lingual) outline. The labial face is convex, while the lingual is concave. Both faces are entirely smooth, and they lack any surface ornamentation.

Remarks: Teeth of the genus are very common in the fossil record of the Central Paratethys (SCHULTZ 2013, SZABÓ & KOCSIS 2020). BENE (2003) assigned 43 molariform crushing teeth to this genus. However, if multiple sparid taxa are present at the same fossil site, it is uncertain if this tooth morphotype of sparids can be referred to a genera. The original report of BENE (2003) does not include scale bars and the location of the material is currently unknown. Until further material is discovered, here we refer only 24 of the reported incisiform teeth to *Diplodus*.

Genus *Pagrus* Cuvier, 1816

Pagrus cinctus (Agassiz, 1839)
Plate XVI, C–K

Referred material: 6 premaxillae, 1 dentary.

Description: The ascending process is missing in all examined Pécs-Danitzpuszta premaxillae (*Plate XVI, C–H*). In a private collection specimen, only the base of the articular process is preserved (*Plate XVI, D, ap*). On the medial side of the bone, a large foramen opens at the base of the articular process (*Plate XVI, D, F, f*). The posterior process (*Plate XVI, C, E, G, pp*) is low and wide, and it bears well-developed longitudinal striation. Multiple rows of circular tooth positions are running anteroposteriorly. All premaxillae have non-functional teeth preserved inside the bony base. The dentary (*Plate XVI, I–K*) is incomplete, and it bears massive hemisphaerical teeth of molariform morphology.

Remarks: This species is among the most widely reported osteichthyans of the Miocene sediments of Europe (Schultz 2013, Szabó & Kocsis 2020). Well-preserved premaxillae and dentaries of *P. cinctus* have been illustrated by Schultz (2013, pl. 67, figs 9, 10).

Genus *Sparus* Linnaeus, 1758

Sparus umbonatus (Münster, 1846)
Plate XVI, L–U

Referred material: 30 premaxillae, 1 dentary, 15 incomplete upper or lower jaw elements, 16455 isolated teeth.

Description: The premaxillae (*Plate XVI, L–O*) are shorter and stockier than those of *P. cinctus* (see above). The posterior process (*Plate XVI, M, P, pp*) is much higher, and bears stritation. Only the base of the articular process (*Plate XVI, L, N, ap*) is preserved in some specimens. Most of the premaxillae have only empty tooth positions, but some have *in situ* the enlarged, posterior molariform tooth preserved (*Plate XVI, N, pmt*). The dentary (*Plate XVI, P–R*) is incomplete, massive and stocky. The coronoid process (*Plate XVI, P, cp*) is high. An enlarged, massive molariform posterior tooth (*Plate XVI, Q, R, mtd*) is visible, matching that observable in the premaxillae.

Remarks: This fish species was collected in the highest number in the Pécs-Danitzpuszta sand pit. Its isolated, enlarged molariform teeth were found in extremely high numbers. A large percent of them bears signs of functional wear (see Bene 2003), which together with the high number of these teeth, indicates that these teeth regularly dropped out and re-grew. Schultz (2013, pl. 68, fig. 1) illustrated a well-preserved premaxilla of *S. umbonatus*.

Sparidae indet.

Referred material: 569 teeth, 1 upper or lower jaw element in coprolite.

Description: Isolated teeth of sparid morphology – conical anterior and hemisphaerical posterior teeth – are referred here.

Remarks: As isolated teeth of fossil sparids are very similar, in the presence of more than one sparid genera their generic identification is uncertain (except for the enlarged oval crushing teeth of *S. umbonatus*, see above).

Order Tetraodontiformes Berg, 1955

Tetraodontiformes indet.
Plate XVI, V–Z

Referred material: 4 tooth plates.

Description: The tooth plates referred here have subtriangular outline in occlusal view. They are built up of overlapping sheets of teeth that are fused together. The enamel surface is richly crenulated (*Plate XVI, W*). The size of the tooth-sheets decreases upwards.

Remarks: The order Tetraodontiformes includes numerous extant and fossil families. Several tetraodontiform taxa have been reported from the Miocene of Europe (Schultz 2006, 2013), however, their synonymy remains problematic (see synonym lists in Schultz 2013). More complete dental remains are needed for a definite identification.

Actinopterygii indet.
Plate XVII, A–L

Referred material: 31 hyperostotic ribs, 34 hyperostotic vertebrae, 30 indeterminate fragmentary bone elements, 1 dentary, 1 ?angulo-articular, 11 vertebrae, 1 skull element, 1 gill-arch element, 227 fin spines.

Description: Elongated droplet-shaped bones (*Plate XVII, A–H*) and massive, stocky vertebrae (*Plate XVII, I–L*), showing the signs of hyperostosis, are referred here. A very high number of poorly preserved fragmentary fish bones are also included here.

Remarks: Hyperostotic bones (or swollen bones) are the result of hyperostosis, indicating an abnormally high amount of primary bone deposition (Francillon-Vieillot et al. 1990, Chanet 2018). Such structures have been observed in 38 different teleost genera, but they are more frequent in trichiurid, carangid and sciaenid taxa (Smith-Vaniz et al. 1995). As bone characteristics of the specimens referred here are unclear, and both Carangidae and Sciaenidae are recognized in the Pécs-Danitzpuszta fish material, here we refer these remains only as hyperostotic bones of indeterminate actinopterygians. Fossil hyperostotic bones of *Caranx carangopsis*, which are morphologically very similar to the Pécs-Danitzpuszta specimens have been illustrated by Schultz (2013, pl. 67, figs 13–15).

The large numbers of fragmentary actinopterygian bones with no taxonomical characteristics are not identifiable at lower taxonomical ranks.

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Structural features in the Miocene sediments of the Pécs-Danitzpuszta sand pit (SW Hungary)

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A pécs-danitzpusztai homokbánya miocén üledékeinek szerkezeti elemei

Összefoglalás

A pécs-danitzpusztai homokbánya a Mecsek hegységperemi vetőzónája mentén fekszik, középső és felső miocén (badeni–pannóniai) üledékeket tár fel. Az erősen tektonizált rétegsor kora pannóniai és annál fiatalabb deformációk nyomait őrzi, amelyeket más feltárásban nem tanulmányozhatunk. Jelen cikkben több mint húsz év megfigyeléseit foglaljuk össze, a deformációs események korát puhatestű-rétegtan segítségével határoljuk be, és ezek alapján következtetünk a terület szerkezetalakulására. A 10,2–10,0 millió évvel ezelőtti időszak elején ÉÉNy–DDK-i irányú extenzió (transztenzió) hatására normálvetők, árokszerkezetek, negatív virágszerkezetek képződtek. Arra mutatnak, hogy a litoszféra-megnyúláshoz kapcsolódó vetőműködés még a késő miocénben is zajlott, bár kérdéses, hogy ez a deformációs esemény a Pannon-medence geodinamikai fejlődéstörténetében a szin- vagy a poszt-rift fázishoz tartozik-e. Nem sokkal később, még mindig a 10,2–10,0 millió évvel ezelőtti időszak első felében a terület É–D-i vagy ÉÉNy–DDK-i összenyomás alá került. E feszültségmező hatására feltolódások alakultak ki a pannóniai mészmárgában és homokban, és a teljes középső – felső miocén üledéksor meggyűrődött, a réteglapok mentén csúszás és a ridegebb kőzetek blokkos elforgása történt. Az éppen leülepedő homok rétegei dél felé vastagodtak, dőlésük folyamatosan változott. A homokon belül szögdiszkordancia alakult ki, képződésében a Pannon-tó vízszintjének változása is közrejátszhatott. A kompressziós eseményt Afrika és Európa közeledésével magyarázhatjuk, de regionálisan nem tudjuk korrelálni, idősebb a medenceinverzióhoz köthető eddig publikált szerkezeti eseményeknél.

Kulcsszavak: Pannon-medence, Mecsek, tektonika, poszt-rift, medenceinverzió

Abstract

The Pécs-Danitzpuszta sand pit in southern Hungary exposes middle and upper Miocene (Badenian to Pannonian/ Langhian to Tortonian) sediments along the mountain front fault zone of the Mecsek Mts and preserves an essential record of tectonic events during and after the early late Miocene, which are not exposed elsewhere in the region. In this paper we present structural observations recorded over 20 years of work, date the deformation events with mollusk biostratigraphy and make inferences on the structural evolution of the area. At the beginning of the time interval between 10.2–10.0 Ma, NNW–SSE (to NW–SE) extension created normal faults and negative flower structures. These show that extension-related fault activity lasted here up to the late Miocene. Shortly thereafter, still in the early part of the time interval between 10.2–10.0 Ma, N–S to NNW–SSE compression ensued and dominated the area ever since. Deformations under this stress field included reverse faulting in the Pannonian marls and sands, folding of the whole succession, with bedding-plane slip and shearing-related block rotation in the already deposited middle and upper Miocene marl layers and continuously changing bedding dips and southward thickening layers in the Pannonian sands. Lake level changes of Lake Pannon must have played a role in the formation of an angular unconformity within the sands besides compression. The compressional event can be explained by the Africa (Adria) – Europe convergence, but cannot be correlated regionally; it pre-dates basin inversion-related events reported from the region so far.

Keywords: Pannonian Basin, Mecsek Mts, tectonics, post-rift, basin inversion

Introduction

The Pécs-Danitzpuszta sand pit in southern Hungary exposes sediments from the early history of the late Miocene – Pliocene brackish-water Lake Pannon, a descendant of the Central Paratethys. It is located along the SE margin of the Mecsek Mountains and is the most important and best-known outcrop of the lower part of Pannonian (upper Miocene) deposits in the region, both calcareous marls and limonitic sands. It has long been known for the deformations visible in the sands (Vadász 1960), and is a type locality of Lake Pannon sediments in the Mecsek area (Kleb 1973). Because of its large extent, its location along the mountain-front fault zone, and because the exposed rock units represent an age interval hardly accessible elsewhere, it preserves an essential record of tectonic events during and after the early late Miocene.

Although multiple papers mentioned structural features from the sand pit in the past decades (Benkovics 1997, Csontos et al. 2002, Konrád & Sebe 2010), they contain a limited amount of observations, and the dating of events carries uncertainties as well. Since then, we have collected numerous structural measurements and observations across the large sand pit. In order to expose structural features in the Pannonian calcareous marls, a 50 m long trench was excavated in 2018 in the northern part of the sand pit. This created a marvelous exposure, revealing the downward continuation of the sedimentary succession and deformations in the mountain-front fault zone, which cannot be observed with other methods. Moreover, with the advance of mollusk biostratigraphy, it became possible to link numerical ages to Lake Pannon deposits (Magyar 2021), and this can be used for a relatively accurate dating of tectonic events as well. This dating is much needed in the fine-tuning of our knowledge about the structural evolution of the Pannonian Basin (Fodor 2019), especially in the eventful Neogene (Csontos et al. 1991; Fodor et al. 1999, 2005; Bada et al. 2007). Here we present structural observations collected in the sand pit in the past >20 years and the structural evolution of the area that can be deduced from the observations, with the highest temporal resolution achieved so far.

Geological setting

The Pécs-Danitzpuszta sand pit lies on the southern boundary fault zone of the Mecsek Mts, the Mecsekalja Fault Zone (*Figure 1*). It exposes two main lithological units of late Miocene (Pannonian/Tortonian) age: light grey, white or yellowish grey calcareous marls and silts (Endrőd Formation) in the northern wall, and the overlying yellowish brown, coarse limonitic sands (Kálla Member of the Békés Fm.) in the rest of the area (*Figure 2*). The trench starting from the northern wall of the sand pit exposed Sarmatian and Badenian (Langhian and Serravallian) mixed carbonate and clastic deposits stratigraphically below the Pannonian sediments. The whole succession is strongly tilted, thus younging is dominantly towards the south and not upwards. In the western wall, the limonitic sands are divided by an angular unconformity, observed previously in more eastern outcrops, e.g., by Vadász (1960) or Kleb (1973). For a detailed description of the sand pit, see Sebe et al. (2021).

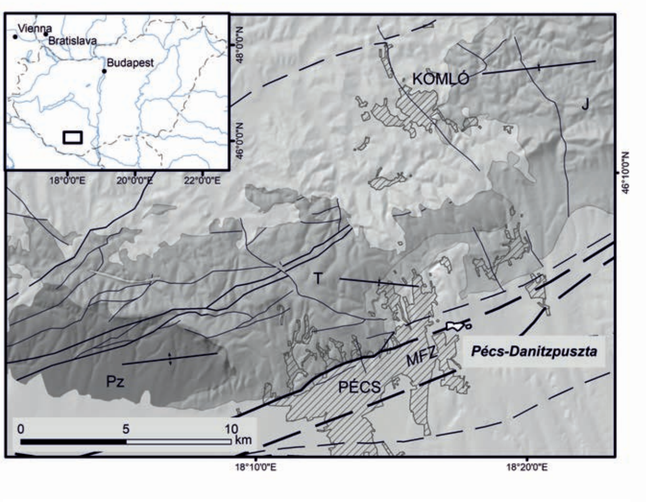

Figure 1. Tectonic setting of the Pécs-Danitzpuszta sand pit. Base map: Konrád et al. (2010)
Legend: Pz: Paleozoic; T: Triassic; J: Jurassic rocks; MFZ: Mecsekalja Fault Zone

1. ábra. *A pécs-danitzpusztai homokbánya szerkezeti helyzete. Alaptérkép: Konrád et al. (2010)*
Jelmagyarázat: Pz: paleozoos, T: triász, J: jura kőzetek. MFZ: Mecsekalja-öv

Two deformation events were identified in the sand pit: syn-sedimentary transtension during the deposition of the lowermost part of the sands and syn- to post-sedimentary N–S compression (Konrád & Sebe 2010, Csontos et al. 2002). The tilting of the succession and the different dips were explained with compression-related folding above a blind, south-vergent thrust fault during the late Pannonian (Benkovics 1997, Csontos et al. 2002).

Methods

Structural measurements were carried out in various parts of the sand pit. Kinematic indicators like slickenlines were measured in the marls. They were absent in the limonitic sands; thus, in these cases the stress orientations are inferred with some uncertainty from Mohr pairs (Anderson 1951, Fodor 2010). Because of the low dip angle and the diffuse bedding planes, bedding dip measurements have uncertainties especially in case of the sand layers above the unconformity and in the uppermost, gently dipping beds below it. Stereoplots are lower hemisphere Schmidt projections.

Deformation events were dated by biostratigraphy, mostly by mollusks, based on the endemic species of Lake Pannon (Magyar & Geary 2012; Sebe & Magyar submitted). This provides a resolution on the order of magnitude of ~1 Ma. For this, systematic collection of mollusks was carried out in the Pannonian calcareous marls. In the limonitic sands, most mollusks came from the industrial sieving of the sands, they were found in the coarse fraction remaining after sieving. Thus their exact stratigraphic position was usually

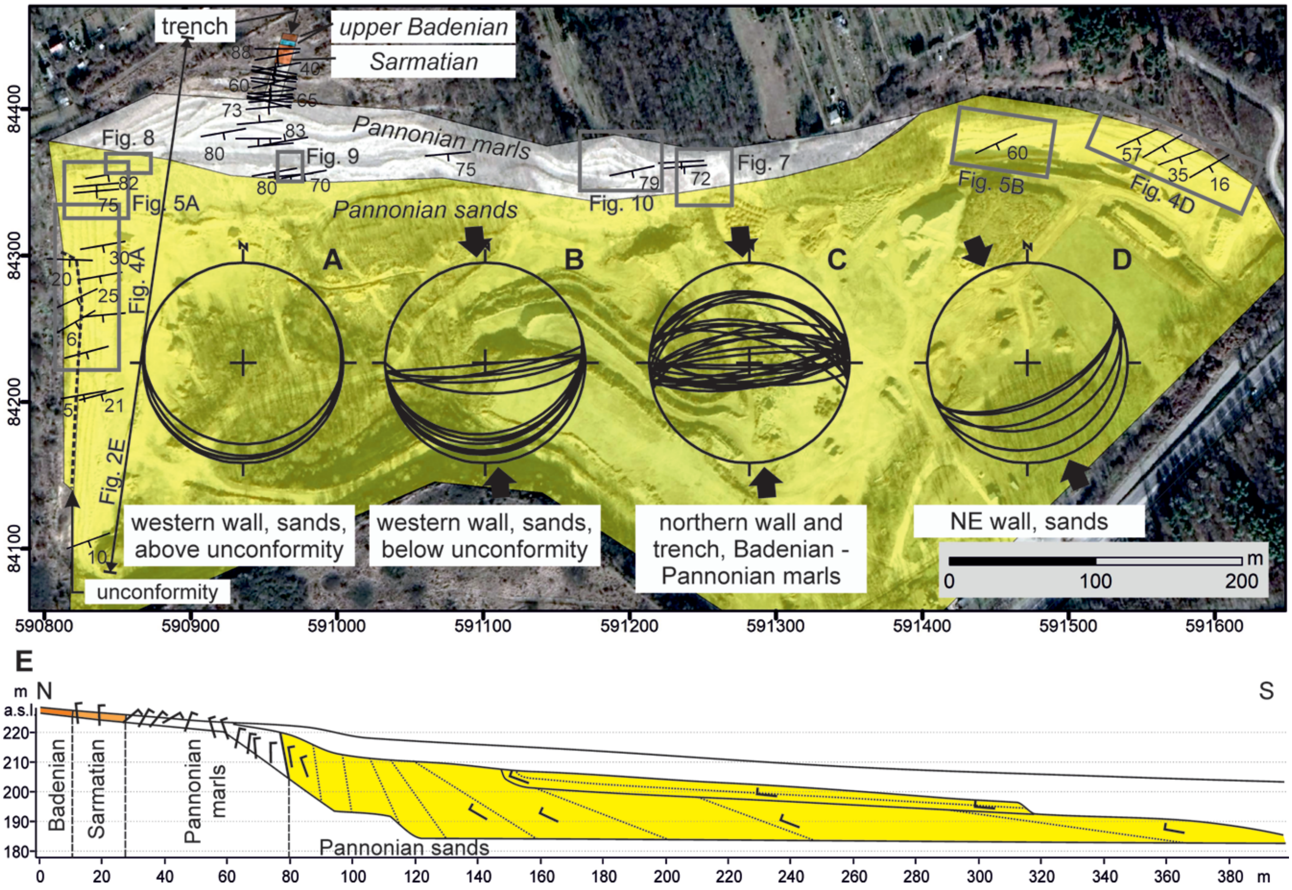

Figure 2. Stratigraphic units and bedding dips in the sand pit. All northerly dips belong to overturned beds. Marks in the cross-section indicate true dip angles

2. ábra. *A bányában észlelt rétegtani egységek és rétegdőlések. Az északias dőlések átbuktatott rétegek dőlései. A szelvény jelei a valódi dőlésszögeket mutatják*

unknown, it could only be confined to a relatively large portion of the wall being extracted at the given time. We therefore executed collecting campaigns targeted for tectonically interesting parts of the sand pit, e.g., above the unconformity or at the very base of the sands.

Results

Bedding dips

The older, northern part of the succession – the Sarmatian deposits and most of the upper Miocene calcareous marls – is dominantly overturned, with varying dip angles (*Figure 2E*). Bedding dip then decreases within the upper part of the Pannonian marls, i.e., it approaches the vertical in the southern end of the trench (*Figure 3*). The marl/sand boundary within the Pannonian succession is vertical or subvertical, though both its dip angle and dip direction vary along strike. Bedding dip returns to normal in the Pannonian sands and decreases continuously towards the south, i.e., upsection, to ~15°, observable both in the western and northeastern wall of the sand pit. This succession with the continuously changing dip angles is truncated by a sharp angular unconformity, visible in the western wall, and is overlain by nearly horizontal sand layers of the same lithology (*Figure 3*, *Figure 4A*). Dip directions scatter around SSE for layers with normal dip and N–NNW for overturned beds (*Figure 2*).

Figure 3. Northward-dipping, overturned Pannonian calcareous marls in the trench (foreground), and south-dipping sands in the western wall of the sand pit (background). Photo taken along the trench, looking southwest. Western wall pictured in the top of the photo (cf., map of *Figure 2*)

3. ábra. *Észak felé dőlő, átbuktatott pannóniai mészmárgaösszlet a kutatóárokban (előtérben) és délre dőlő homokrétegek a bánya nyugati falában (háttérben). A kép az árok mentén készült, DNy felé nézve. A bánya nyugati fala a kép felső részén látható (a feltárások elhelyezkedését l. a* 2. ábrán*)*

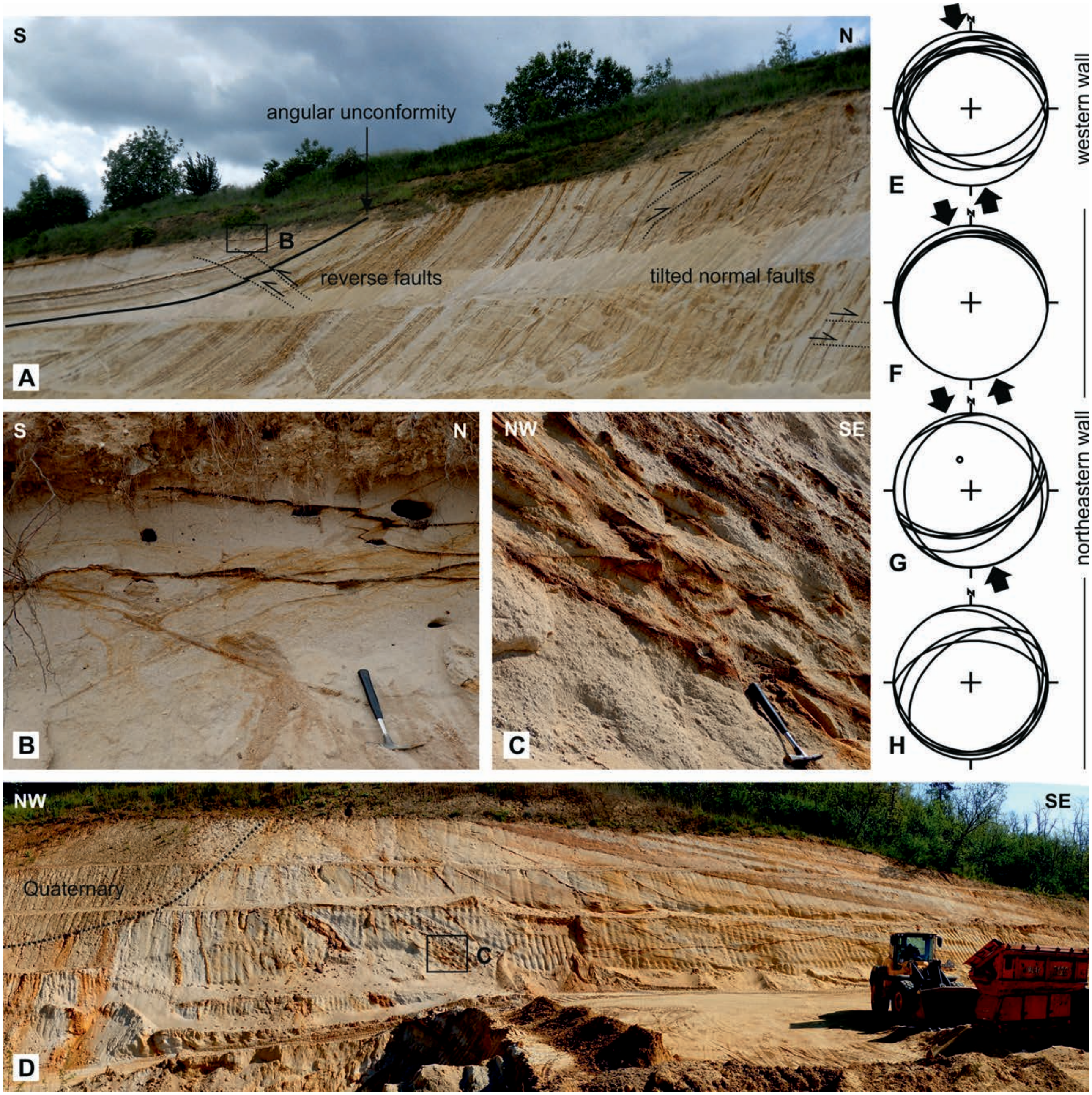

Figure 4. Structural features in the sands. A) Changing dip angle and angular unconformity in the western wall in 2016; B) reverse faults in the western wall displacing dark limonitic bands (2021); C) tilted reverse faults in the NE wall highlighted by the displaced limonite banding (2020); D) changing dip angle in the NE wall (2020); E–H) stereoplots of reverse faults: western wall (E), post-tilt faults of NE wall (F), syn-tilt faults of the NE wall in Fig. C, with pole of local bedding dip (G), the latter backtilted with bedding (H)

***4. ábra.** Szerkezeti elemek a pannóniai homokösszletben. A) Változó rétegdőlés és szögdiszkordancia a nyugati falban 2016-ban; B) vastag limonitsávokat elvető feltolódások a nyugati falban (2021); C) limonitosodás miatt kipreparálódott kibillent feltolódások az ÉK-i falban (2020); D) változó dőlésszögű rétegek az ÉK-i falban (2020); E-H) a feltolódások sztereogramjai: nyugati fal (E), az ÉK-i fal billenés utáni vetői (F), a C kép billenés alatti vetői az ÉK-i falban, a helyi rétegdőlés pólusponttal jelölve (G), valamint ez utóbbiak a rétegdőléssel visszabillentve (H)*

The trench has revealed that the uppermost 1–2 m of the steeply dipping layers are dragged downslope by surface processes. In some cases this includes a change in dip direction: e.g., in the Sarmatian and Badenian beds, the dip of the same bed is southerly near the bottom of the trench, while northerly (overturned) in the dragged upper part of the layers (see *Figure 5.* in Sebe et al., 2021). This resolves the problem that Konrád & Sebe (2010) called attention to, namely that significantly different bedding dips were observed within a distance of just a few metres (20–30° northerly and 70° southerly dip within 10 m). The trench revealed that there is no fault between the differently dipping layers; it is surface drag (slope creep) that caused the difference in the dips. This also means that dip angles recorded in small surface outcrops should be handled with caution, even in seemingly in situ, well-layered sediments. Because of the near-surface deformation, bedding dips in the trench were measured at the deepest possible location along a given bed.

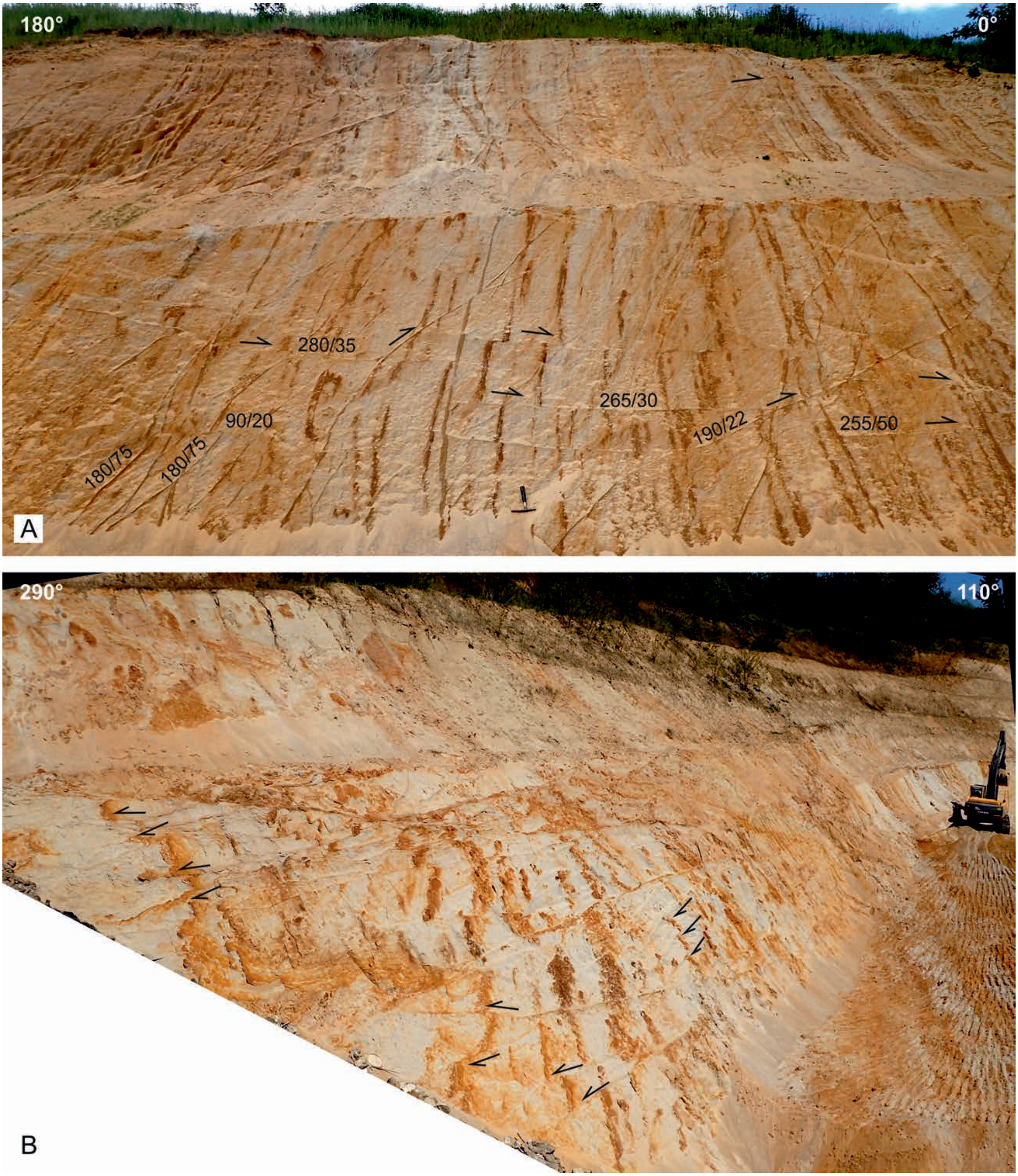

Figure 5. Syn-sedimentary normal fault arrays in sands. A) Northern end of the western wall, 2016. Bedding dips are all 80–70° to the south (*Figure 2B*), the beds in the right side of the image appear overturned only because of the wide viewing angle. Stereoplots in *Figure 6A. B*) Eastern end of the northern wall, 2020. Note that the photo was taken oblique to the wall, approximately in strike direction of the layers. Stereoplots in *Figure 6E*

***5. ábra.** Üledékképződéssel egyidejű normálvető-rajok a homokban. A) A Ny-i fal északi vége 2016-ban. A rétegdőlés végig délies, 70–80° körüli, a kép jobb oldalán a rétegek csak a széles látószög miatt tűnnek átbuktatottnak. A vetők sztereogramja a* 6A *ábrán* *látható. B) Az északi fal K-i vége 2020-ban. A fénykép nem a falra merőlegesen, hanem ferde szögben, a rétegek csapásirányában készült. Sztereogram a* 6E *ábrán*

Normal faults

Arrays of originally normal faults, both antithetic and synthetic, were recorded in the uppermost few metres of the calcareous marls (in the transitional interval towards the sands, composed of marls and calcareous silts) and in the lowermost 15-20 m of the sands. An example just above the marl/sand boundary was shown by KONRÁD & SEBE (2010) (*Figure 6C*). The deeper parts of the succession have not been exposed in large surfaces, so faults, even if existent,

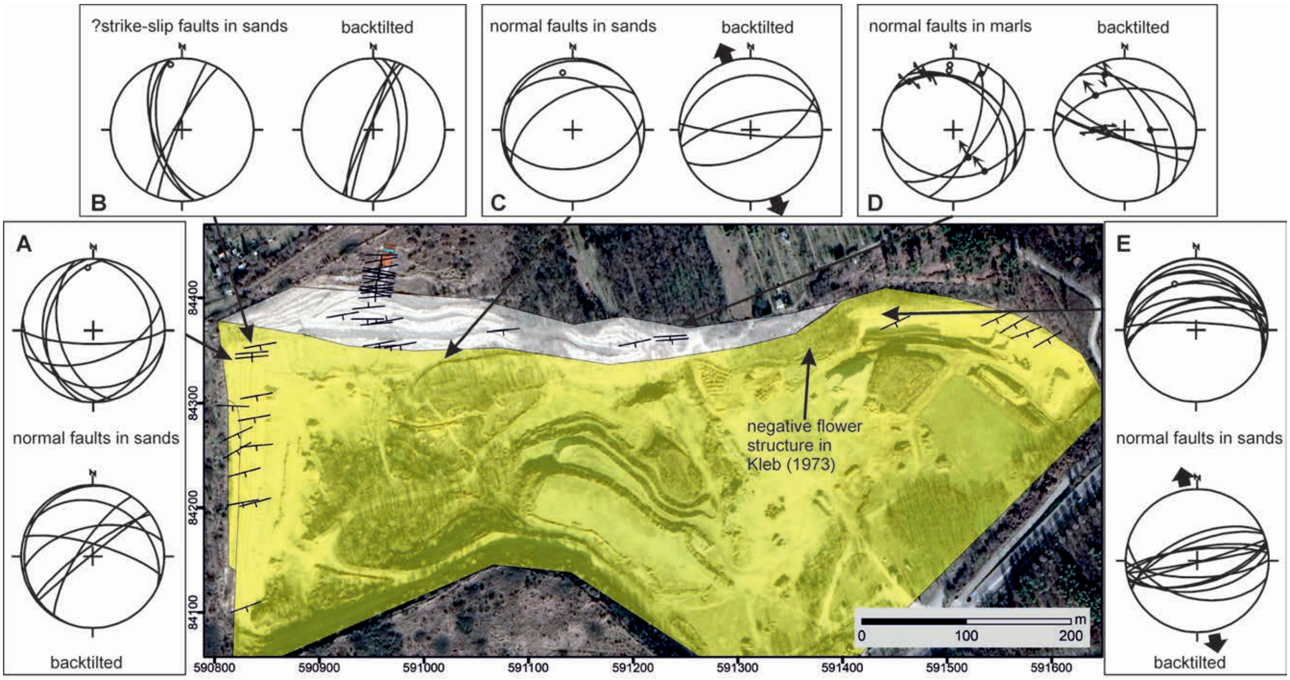

Figure 6. Spatial orientation of normal and strike-slip faults
6. ábra. *A normálvetők és eltolódások térbeli helyzete*

could go unnoticed. The fault arrays occur in subvertical layers and thus appear mostly as reverse faults today, but their geometries and their orientation relative to bedding suggest that they formed as faults with normal component before the tilting of the succession. Therefore, their present dip data were backtilted with the local bedding dips to investigate their original orientation.

Faults in the sands are distributed at a few tens of cm from each other and have displacements of a few tens of cm (*Figure 5*). Strictly speaking, all types of faults in the sands are deformation bands; however, for the sake of simplicity, we refer to them as faults. As bed boundaries in the sand are uneven and rather diffuse, it is hard to say if beds systematically thicken along one side of a certain fault. Nevertheless, the faults, which have relatively low dip angles today, die out and are sealed upwards, suggesting syn-sedimentary movement. The sense of movement was mostly normal in these cases, but also some reverse slips occur.

If backtilted with the local bedding dip, the faults have ENE–WSW or NE–SW strikes and their dips reach relatively steep angles, close to vertical (*Figure 6A, C, E*). In the NE wall, the faults now appear as north-dipping reverse faults, but their dip angles show too large scatter (*Figure 5B, Figure 6E*). If backtilted with the local bedding, their orientations give a symmetrical pattern typical of fault arrays with normal component (*Figure 6E*). The backtilted pattern is similar for the centre of the northern wall (*Figure 6C*). Slickenlines are not preserved in the coarse sands, but the relatively steep dip angles and occasionally opposite (inverse instead of normal) movement directions of some faults refer to oblique – normal plus strike-slip – movement of the fault arrays. So do flower structures like the one shown by Kleb (1973, figure 19). In the western wall, gently west- and east-dipping faults show dominantly strike-slip displacement today (*Figure 5A*); if backtilted, most of them become normal faults as well, with strikes similar to the previous two locations (*Figure 6A*). Differently oriented further faults in this wall may point to multiple deformation events. Less steep south-dipping faults might have formed as reverse faults as well during the tilting (folding) of the succession.

In the uppermost part of the marls, faults with originally normal component appear at varying distances from each other (*Figure 7*). At present, single faults could also be interpreted as reverse faults, but their convergence and merging downsection (towards older layers) (*Figure 7B*) indicates that they belong to normal fault sets. They often crosscut only a few layers (*Figure 7A*), sometimes they form antithetic pairs. Although in cross-section they appear as normal faults, slickenlines indicate oblique, dominantly strike-slip displacement (*Figure 6D*).

Faults with normal component are restricted to a relatively small interval of the sedimentary succession, and this evokes the conclusion that they formed during the same deformation event, in the same stress field. The features pointing to normal displacement indicate that they were created before the tilting of the succession. Besides being syn-sedimentary, relatively short normal faults – crosscutting only a limited number of layers – can also form along fold hinges due to local stretching (fold-accommodation faults), in a buried position. It cannot be excluded that normal faults around the marl/sand boundary were created this way during the folding of the succession. The asymmetry of some fault groups in backtilted position (e.g., in the marls, *Figure 6D* and *Figure 7B*) may refer to compression-related (syn-tilt)

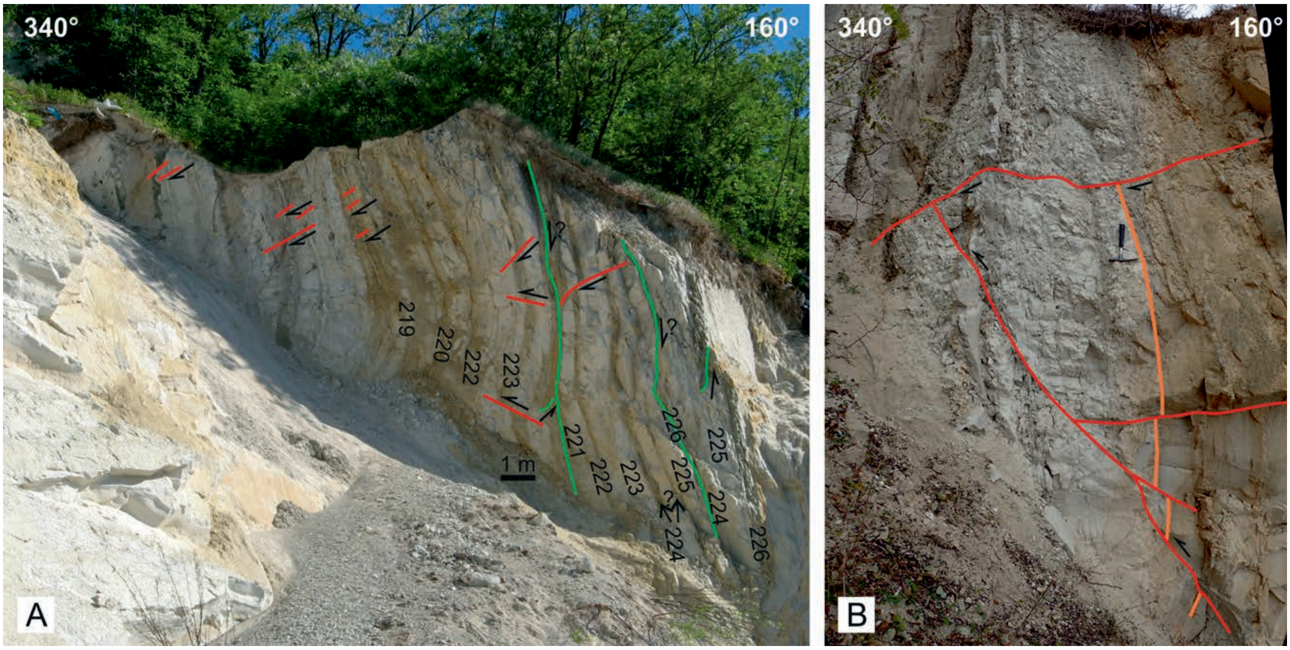

Figure 7. Tilted normal faults (light red) and post-sedimentary thrusts between repeated layer packages (green, partly along bedding planes) in marls and silts. A) Central part of northern wall, 2015. B) Detail of a parallel outcrop ~40 m to the west, 2020; hammer for scale. The sense of thrusts (whether originally north- or south-vergent) could not be identified

7. ábra. Kibillent normálvetők (pirossal jelölve) és ismétlődő rétegcsoportok közti későbbi feltolódások (zöld, részben réteglapok mentén) a pannóniai mészmárgasorozat felső részében. A) Feltárás az északi fal középső részén 2015-ben. B) Az előzőtől nyugatra kb. 40 m-re húzódó párhuzamos feltárás részlete, 2020. Nem volt megállapítható, hogy a feltolódások eredetileg észak vagy dél felé mozogtak

formation. No obvious bed thickening could be observed in the succession along faults, which could be decisive in this case. However, the appearance of normal faults in a concave curvature, like the one above the 1 m sign in *Figure 7A*, point to syn-sedimentary movement.

Despite the narrow stratigraphic range of the normal faults, their original, backtilted orientations show quite large scatter even in this relatively small area (*Figure 6*). This does not necessarily mean that they were created during separate deformation events. An explanation for this may be the different competence of the marls and the sands. Another factor that complicates the picture is that the sand pit lies on the front of a basement block projecting south from the main body of the mountains, between the Pécsbánya embayment in the west and the mountain foreland in the east (*Figure 1*). This geometry caused different folding (tilting) directions in the Neogene sediments around the basement block, the strike orientations of tilted beds show an arcuate pattern (*Figure 2*). Although the backtilting of earlier faults with the local bedding dips should eliminate the effect of different folding directions, the irregular mountain front geometry still could have caused locally varying orientations of earlier fault groups as well. This setting warns us not to differentiate too many deformation events based on small differences in fault orientations.

Strike-slip? faults

In the western corner of the northern wall, steep, subparallel faults with westerly dips were observed (*Figure 8*, *Figure 6B*). Their apparent displacements attain a maximum of a few tens of cm. Some of them have normal, some others reverse sense; this may refer to strike-slip movement for the whole fault array. It is uncertain which fault group and deformation event they belong to. They are located very close to the tilted normal faults of the western wall, but they have different orientations (*Figure 6*). In case these two fault groups are coeval, the strike-slip faults could have acted as tear faults between normal ones. They could have formed posterior to tilting as well, but their orientation does not fit into a common stress field with the reverse faults.

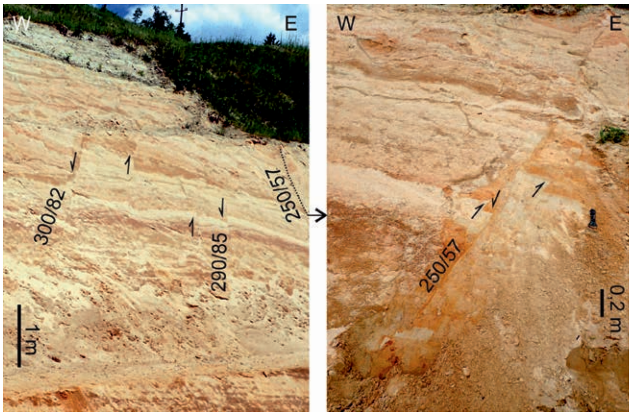

Figure 8. Possible strike-slip faults near the western end of the northern wall. Stereoplots in *Figure 6A*. Note the varying apparent reverse and normal separation along the set

8. ábra. *Valószínű eltolódások az északi fal nyugati végében, változó irányú látszólagos elvetéssel. Sztereogram a* 6. A ábrán

Reverse faults

Reverse faults were observed in the Pannonian deposits, both in marls and sands. Their size is variable, the smallest ones crosscut only a few layers, while the largest ones displace sediment packages with tens of metres of thickness.

Small faults can be observed in the Pannonian calcareous marls, which crosscut layers and often terminate at bedding planes (*Figure 9*). They appear as normal faults in their present position, in the subvertical marl layers. However, the rounded shape of the striations ("soft striae") refers to an early formation of the faults, before the complete lithification of the deposit. If backtilted with the local bedding dip (170/80), they point to SSE-vergent thrusting. A minor sinistral component is indicated by the slickenlines. No tensional features have been observed that post-date the large-scale folding and tilting of the succession, and the backtilted orientation of the studied faults fits the compression direction for the area, so they are most probably reverse faults that formed at the onset of shortening, before the folding of the succession.

Reverse faults crosscut the sands both in the western and in the northeastern wall of the sand pit (*Figure 4*). They occur at irregular intervals. Due to the lack of slickenlines, it is not possible to measure the exact slip direction along them; their visible displacement is usually only a few tens of cm. Most of the reverse faults must have formed when the layers had already reached their present-day (tilted) position. There was a group of reverse faults in the NE wall that enclose acute angles (20–30°) with the bedding (*Figure 4C, G*). If completely backtilted with the bedding, their orientation is still asymmetric (*Figure 4H*). They become symmetrical at an intermediate stage of tilting between the original and the present bedding dip; thus, these can be syn-tilt features.

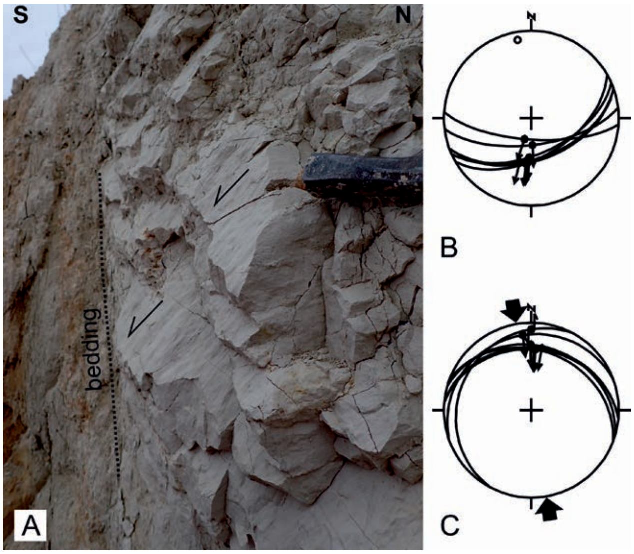

Figure 9. Small faults in the calcareous marls. A) Field photo of the originally reverse, now tilted faults; B) their orientation in stereoplot; C) orientation backtilted to supposed original position

9. ábra. *Kis vetők mészmárgában. A) Az eredetileg rátolódásos, kibillent vetők terepi képe; B) sztereogramjuk; C) visszabillentett, eredeti helyzetük sztereogramja*

The upper part of the Pannonian marls seems to be most affected by reverse faulting. In most cases outcrop conditions did not allow us to follow the exact trace of faults, but it was possible to notice displacement or repetition of layers. Slip planes often include bedding planes along parts of their lengths (*Figure 7*, *Figure 10B*). A few m thick intervals were observed to be repeated in the uppermost marl and silt layers, where slip happened mostly along bedding planes (*Figure 7*). The vergency of thrusting – whether originally north- or south-vergent – could not be identified. Differences in the thickness and the number of beds in the sedimentary succession at various locations in the sand pit also refer to partly bedding-parallel thrusting. The interval between a tuff layer (205 according to bed numbering in Sebe et al. 2021) and the transitional, yellowish marl and calcareous silt interval capping the "white marls" (from layer 218) is 9 m thick in the centre of the sand pit, and includes two green clay – sand – green clay packages (*Figure 10A*). It is only 5.5 m thick in the NW part, with one clay-sand-clay package and another clay layer missing there. In the seemingly conformable succession brecciated intervals occur from place to place, and apparently continuous and undisturbed layers may change their thickness or disappear along strike (*Figure 10A*). A major thrust fault was exposed by excavations in the central part of the sand pit in 2012, along which a wedge-like body of the succession is repeated (*Figure 10A* (background) and *C*, marked with arrows). The fault plane has a dip of approximately 60° towards the SE in its present orientation, while backtilting with local bedding dip gives an original dip towards the NE at the time of its formation. Drag of layers along the plane indicates presently top-to-SE normal, originally SW-vergent reverse movement.

Folds

Folds are not widespread in the sand pit, but some features point to large-scale folding. Bedding dips in the entire sand pit give the general view of a large south-vergent asymmetrical anticline, with its southern, subvertical limb making up the northern wall of the sand pit, and a connected syncline within the sand pit, with its lower, subhorizontal limb lying below and to the south of the sand pit (*Figure 2E*, *Figure 11C*). This picture is in accord with the model proposed by Csontos et al. (2002). The fold axis is somewhat curved, as shown by the laterally changing strike of the layers (*Figure 2*). The fold amplitude must exceed 100 m; thus, the curvature of the layers is rarely visible in outcrops of limited size. One such location is in the northern wall, where landslides exposed vertically more extensive outcrops than elsewhere, making the arcuate shape of the calcareous marl layers visible (*Figure 7*). Here only a small section of the fold is exposed, thus the fold can be either an overturned or a recumbent one; it is not possible to exactly assess the position of the axial plane. The dip of the steep sand layers in the western wall also somewhat increases upwards.

In the trench the lower part of the Pannonian marls and the upper Sarmatian deposits have diverse lithologies. These

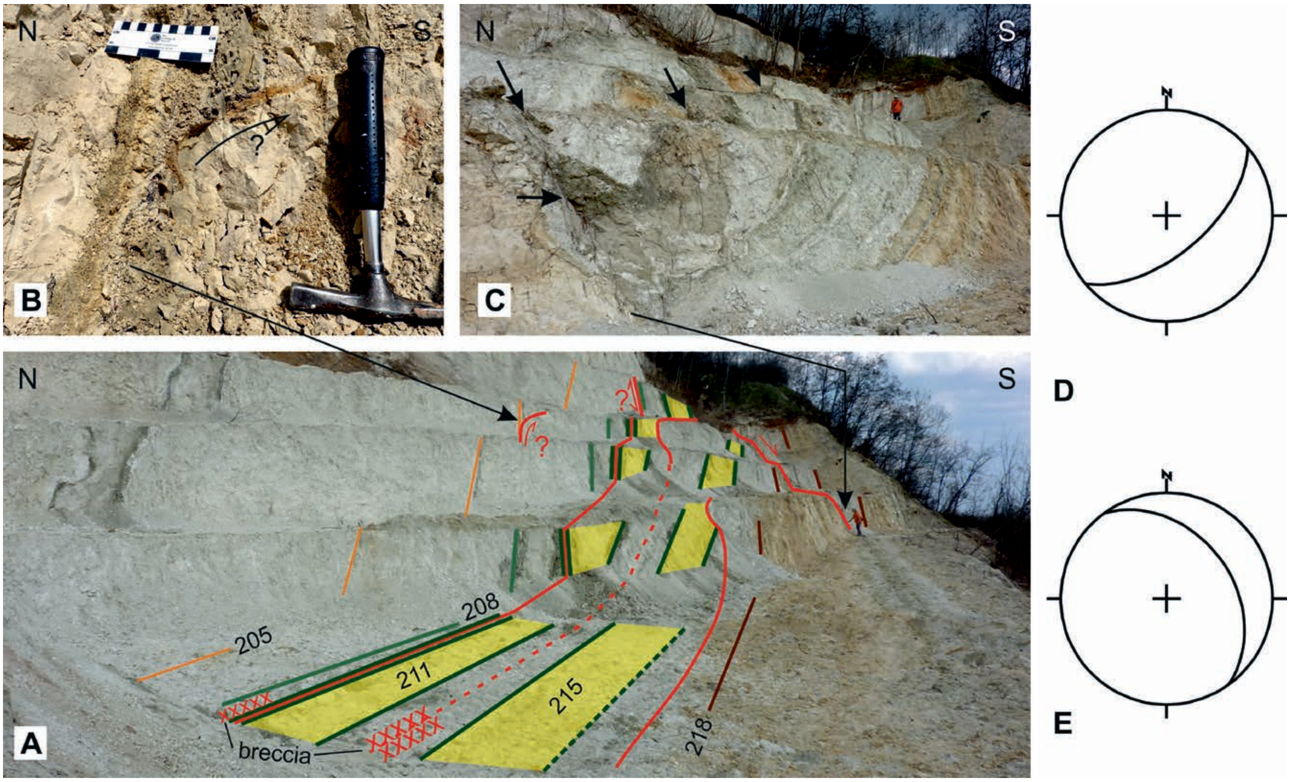

Figure 10. Reverse faults in Pannonian calcareous marls and silts in the central part of the northern wall (A, C: 2012; B: 2016). In fig. C, arrows indicate the location of thrust plane. D) Stereoplot of the major fault plane marked with arrows in A and C. E) The same, backtilted with local bedding dip

10. ábra. *Rátolódások a pannóniai mészmárgaösszlet tetejében az északi fal középső részén (A, C: 2012; B: 2016). A C ábrán a nyilak a rátolódási sík helyét mutatják. D) Az A és C ábra nagy, nyíllal jelölt vetősíkjának sztereogramja. E) Ugyanez a helyi rétegdőléssel visszabillentve*

preserved signs of bedding-plane shearing, which can be related to folding (*Figure 11A*). Where a competent rock type (hard calcareous marl or limestone) was enclosed by incompetent, soft layers (clays, clay marls), it became dissected by fractures. The produced dominoes got rotated, and the rotation direction is opposite to what would be produced by simple southward thrusting (*Figure 11B*). Instead, it speaks for flexural slip along bedding planes in a fold limb (*Figure 11C*).

Folding is visible in the sands as well (*Figure 3*, *Figure 4*). In the western wall, the same sand layers become somewhat steeper upwards, i.e., they seem to be gently folded. The northern end of the unconformity surface within the sands is also bent upward, indicating that the uplift and southward thrusting of the hanging wall and the induced folding continued after the formation of the unconformity.

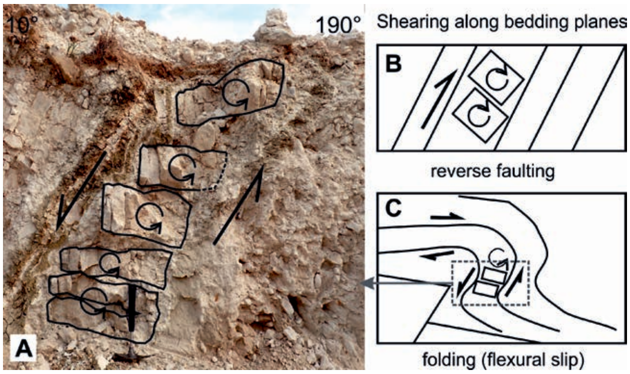

Figure 11. A) Rotated limestone dominoes between clay and marl layers in the eastern wall of the trench; B–C) possible models to explain their formation

11. ábra. *Mészkőréteg nyírás hatására elfordult darabjai agyag- és márgarétegek közt a kutatóárok keleti falában; B–C) keletkezésük lehetséges magyarázatának modellje*

Some previous fold observations need to be reevaluated based on the new observations. The “fold with subvertical axis and several tens of metres of radius” reported by Konrád & Sebe (2010) is now interpreted to have been produced by mining-related landsliding, and the “heavily folded calcareous marl layer in green clay” within the same structure is now explained by pedogenic precipitation instead of deformation.

Discussion

Deformation events

The observed structural features can be arranged in chronological order, and they define several deformation events.

1. Pre-tilt features

The earliest event happened before the tilting and folding of the sediments and is represented by the observed normal fault sets in the marls and sands (*Figures 5, 6, 7*) and the negative flower structure of Kleb (1973, fig. 19) in the sands. These features indicate syn-sedimentary transtension, which ceased shortly after the onset of sand accumulation. Based on fault orientations, the main extension direction is estimated to be NNW–SSE to NW–SE. Tentatively, strike-slip faults in the sands (*Figure 8*) can also be assigned to this event.

A part of the shortening-related structures also pre-dates tilting, namely reverse faults in the marls (*Figure 9*). These can be linked to the start of compression (already during sand deposition), with NNW–SSE shortening.

2. Syn-tilt features

The majority of structures in the sand pit is connected to the large-scale syn-sedimentary compressional deformation of the deposits and fit the model of folding above a blind, south-vergent thrust fault proposed based on scarce data by Benkovics (1997) and Csontos et al. (2002). Bedding dip directions and reverse fault orientations refer to N–S or NNW–SSE compression during deformation. Folding of the succession caused bedding-plane slip and shearing-related block rotation in the already deposited marl layers (*Figures 7, 11*), while the sand layers accumulating during that time acquired gradually changing bedding dips and tapering shapes, thickening towards the south (*Figures 2, 3*). In the sands some reverse faults formed during the folding process and were then further tilted together with the sediments (*Figure 4C, G, H*). Erosional truncation of the folded succession produced a sharp unconformity surface in the sands. This angular unconformity can be correlated with the one photographed by Vadász (1960, p. 255), Bartha (1971, p. 144) and Juhász (1987, unpaginated table after p. 336). Considering the areal extent of the sand pit at that time, the photos were likely taken in the eastern third of the present-day sand pit. The unconformity thus can be followed for approximately 500 m in the E–W direction. As this surface is overlain by the same lacustrine sands that make up the succession below the surface, i.e., subaqueous sedimentation returned, temporary erosion and renewed submergence can be explained at least partly by lake level change and not just by vertical tectonic movements (i.e., lake level fall and rise, or tectonic uplift, then lake level rise). The facts that there are no pedogenic features along the unconformity surface and that the lithofacies of the sands below and above it is identical suggest that emersion and erosional truncation of the lower unit must have been fast.

3. Post-tilt features

Folding continued after the renewal of sand deposition, shown by the upward bending of the unconformity surface. Gently north- and south-dipping reverse faults in the sands indicate that N–S oriented shortening continued after the layers have reached their present-day dips.

Age of deformations

Benkovics (1997) and Csontos et al. (2002) placed the shortening between the “lower” and “upper” Pannonian, while Kleb (1973) wrote that the unconformity lies within the “upper Pannonian” sands. Based on new palaeontological results (Botka et al. 2021), now the age of deformations can be confined using time-calibrated mollusk biostratigraphy. The mollusk association in the sand refers to the younger part of the *Lymnocardium conjungens* littoral mollusk biochron (9.6–11.0 Ma; Botka et al. 2021). The underlying marls are dated into the youngest part of the *Lymnocardium schedelianum* sublittoral mollusk biochron (11.45–10.2 Ma). Therefore, the age of the sands is estimated to 10.2–10.0 Ma (Botka et al. 2021). Extension could have happened at the beginning of this interval, while compression dominated most of the time afterwards. Folding and related features were syn-sedimentary, i.e., still before 10.0 Ma, somewhat earlier than the dating suggested by Csontos et al. (2002) (“late Pannonian”). Post-tilt shortening may have happened any time afterwards.

Geodynamic interpretation

The interpretation of the described deformation events in a geodynamic framework is rather complex. The observed pre-tilt NW–SE transtension along the Mecsekalja Fault Zone before or around 10 Ma is in accord with the coeval event along the same fault zone deduced by Csontos et al. (2002, fig. 15) from a nearby geological cross-section at Pécsszabolcs, just west of the Danitzpuszta sand pit. Further observations (Sebe & Magyar, submitted) show that sedimentation during the earliest Pannonian occurred in fault-controlled subbasins near the mountain fronts in the Mecsek Mts, similarly to the Transdanubian Range (Fodor 2008, Fodor et al. 2021). These could mean that fault-controlled syn-rift extension did not cease in the middle Miocene in the region, as suggested by Balázs et al. (2016), but continued into the early late Miocene. Alternatively, the mentioned events may belong already to the post-rift phase, implying that fault activity continued in the region even in this phase generally characterised by thermal subsidence and modest deformation (e.g., Horváth et al. 2006).

The ~N–S compression driving the progressive tilting, folding, truncation and reverse faulting of the sediments started between 10.2–10.0 Ma, and is again difficult to evaluate. The “post-Sarmatian inversion event” proposed by Horváth (1995, 2007) might fit in time with the Danitzpuszta compression features. This short inversion phase was described to be manifested in a basinwide unconformity, folding and uplift of pre-Pannonian rocks, the erosion of Sarmatian deposits and non-deposition of early Pannonian rocks, and placed in time between the latest Sarmatian and the early Pannonian, ~12–9 Ma (Horváth 1995, 2007; Fodor et al. 1999; Horváth et al. 2006). It was attributed to the docking/soft collision of the eastward moving basement of the Pannonian Basin onto the European margin when subduction stopped under the Eastern Carpathians and consequently rifting also ceased in the basin (Horváth 1995, 2007; Balázs et al. 2016). In NW Croatia, Tomljenović & Csontos (2001) reported late Sarmatian, pre-Pannonian (~12–11 Ma) shortening, while Csontos et al. (2002) described folding and erosion at the Sarmatian-

Pannonian boundary in the northern foreland of the Mecsek Mts. However, observations in the Serbian part of the Pannonian Basin, where compressional structures are lacking near this horizon, speak against a basinwide, contemporaneous inversion event (MATENCO & RADIVOJEVIĆ 2012). The 10 Ma event at Danitzpuszta is very close in time to the end of the rifting in the Pannonian Basin as proposed by BALÁZS et al. (2016); i.e., the syn-/post-rift boundary. However, the NNW–SSE compression direction in the Mecsek makes it difficult to regard this the "post-Sarmatian inversion event", which was characterised by E–W shortening (FODOR et al., 1999). Local north-southerly compression (or transpression) could be caused by a right-lateral (constraining) activity of the entire Mecsek transpressive wedge, as proposed for the neotectonic inversion phase due to the Adria push by CSONTOS et al. (2002).

The other candidate, neotectonic basin inversion started ~8.5–8 Ma years ago in the SW Pannonian Basin based on new data and on published ones re-calibrated using mollusk biostratigraphy (SEBE & MAGYAR submitted, based on data from TOMLJENOVIĆ & CSONTOS 2001, FODOR et al. 2005, UHRIN et al. 2009, MATENCO & RADIVOJEVIĆ 2012, SEBE et al. 2020), much later than the deformation documented in the sand pit. Thus, shortening at the Pécs-Danitzpuszta site can be related to the Africa (Adria) – Europe convergence based on the compression direction, but within this process it is difficult to correlate it with other deformation events in the SW part of the Pannonian Basin; it pre-dates the events in the region, which were interpreted to be linked to the onset of neotectonic basin inversion.

Conclusions

The Pécs-Danitzpuszta sand pit exposed numerous structural features – tilted beds, faults and folds – from an interval of the Neogene sedimentary succession of SW Hungary, which is strongly underrepresented in surface outcrops. The measurement of the features and the examination of their relationships allowed us to discern two closely succeeding deformation events, while the dating of the deformed sediments with mollusk biostratigraphy enabled us to constrain their timing. At the beginning of the time interval between 10.2–10.0 Ma, NNW–SSE extension (transtension) created normal fault sets and negative flower structures and possibly strike-slip faults in the Pannonian marls and the lowermost part of the Pannonian sands. Right thereafter, still in the early part of the mentioned time interval, NNW–SSE compression ensued and has continued to dominate the area ever since. Deformations under this stress field started with small-scale reverse faulting in the Pannonian marls. They continued with the folding of the succession, driven by south-vergent thrusting of the mountains towards their southern foreland. Folding created bedding-plane slip and shearing-related block rotation in the already deposited middle and upper Miocene marl layers and continuously varying bedding dips, southward thickening layer shapes and reverse faults in the Pannonian sands. In the formation of an angular unconformity within the sands, lake level changes of Lake Pannon must also have played a role besides compression. Continuing shortening is shown by the bending of the unconformity and additional post-tilt reverse faults.

The observations show that extension- or transtension-related fault activity lasted here up to the late Miocene, though its assignment to the syn- or post-rift phase of the geodynamic evolution of the Pannonian Basin is uncertain. The linkage of the following compressional deformation to the post-rift phase or to the late-stage inversion of the basin cannot be confirmed, either. The compressional event cannot be correlated regionally; it pre-dates basin inversion-related events reported from the region so far.

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Kézirat beérkezett: 11/05/2021

Magyarhoni Földtani Társulat
Földtani Közlöny
Hungarian Geological Society

151/4, 423–426., Budapest, 2021

Hírek, ismertetések

Összeállította: Cserny Tibor

Események, rendezvények

Beszámoló a X. Kárpát-medencei Összegyetemi Terepgyakorlatról

Papuk, Horvátország, 2021. augusztus 23–29.

A 2011-ben létrejött program célja kiemelkedő hazai és külföldi földtani szaktekintélyek együttműködése révén a hazai földtudományi képzésben részt vevő egyetemi hallgatók részére, évente változó helyszínekkel egy közös, nyári, földtani terepgyakorlat szervezése. Az összegyetemi terepgyakorlatok a hallgatókat komplex gondolkodásra és gyakorlati feladatok megoldására ösztönzik, amellyel mind a terepi látásmódjuk, mind a problémamegoldó készségük fejlődik. Továbbá a program célja a hallgatók kapcsolati rendszerének bővítése is, valamint egy olyan szakmai műhely létrehozása, amely szervesen kötődik a Magyarhoni Földtani Társulathoz, a földtannal foglalkozó szakemberek szakmai közösségéhez.

Idén tizedik alkalommal vettek részt közös terepgyakorlaton a hazai egyetemek földtudomány szakos hallgatói és az évente megrendezésre kerülő programhoz rendszeresen visszatérő, már pályakezdő fiatalok. Augusztus 23. és 29. között egy felejthetetlen hetet töltött el a közel 20 résztvevő, idén először a horvátországi Papuk-hegységben. Külön öröm, hogy a programon egyre többen vesznek részt vidéki egyetemekről érkezett vagy ott végzett hallgatók (közel 2/3). A részt vevők nagy izgalommal – sokan már régi barátként – érkeztek meg hétfőn, a nulladik napon a Zirci Ciszterci Apátság pécsi szálláshelyére, ahol egy ismerkedési est várta őket.

A X. Kárpát-medencei Összegyetemi Terepgyakorlat hatnapos programja augusztus 24-én reggel indult. Az első nap körülbelül háromórás buszút várt ránk, míg megérkeztünk jankovaci szállásunkhoz, ahol az első két nap terepi vezetői, a Horvát Geológiai Szolgálat, valamint a Zágrábi Egyetem képviseletében Marija Horvat, Adriano Banak és Uroš Barudžija fogadott minket. A jankovaci parkerdőben felállított papuki elvi rétegoszlop körül állva elsajátíthattuk a hegységről rendelkezésre álló alapvető földtani, rétegtani és szerkezetfejlődési ismereteket. Ezután a Papuk UNESCO Geopark tanösvényeinek feltárásait látogattuk meg. Az első napon triász dolomit, permotriász sziliciklasztos kőzetek és prealpi metamorf képződmények kerültek terítékre. A nap végén pedig Kutjevo városában vettünk részt borkóstolón, Horvátország legnagyobb múltú (a 13. században alapított) és legnagyobb területen (>800 ha) működő borászatában, ahol megkóstolhattuk a Kárpát–Pannon-térség legjobb olaszrizlingjeinek (horvátul grasevina) egyikét. A második napon a Papuk kréta vulkáni és telérkőzeteivel, variszkuszi granitoidokkal, valamint a hegység triász karbonátkomplexumával ismerkedtünk meg. A harmadik napon Marijan Kovačić vezetésével tanulmányoztuk a Papuk, a Krndija és a Dilj hegységek miocén (alsó miocén, badeni, szarmata, pannóniai) rétegsorát. A negyedik napon csatlakozott hozzánk a Papuk UNESCO Geopark munkatársa Goran Pavić, aki egy 28 km-es gyalogtúrára invitálta a csapatot. A túra célja a Papuk természeti értékeinek (geológiai és geomorfológiai érdekességek) megismerése volt. A társaság megmászta a 913 méter magas Ivačka Glava csúcsot, Velikába érve pedig megtekintette a „House of the Pannonian Sea” fosszília-gyűjteményét. Az 5. napon a Pozsegai-medencébe látogattunk, ahol meghívták a résztvevőket a „Polytechnic in Požega” gyakorló pincészetébe. Az oktatási intézményben egyenesen az ott dolgozó szakoktatóktól és helyi diákoktól ismerhettünk meg a szlavóniai szőlészet és borászat részleteit a homoktalajos dűlőktől a finom borokig. Ezután megtekintettük Pozsega városát. A 6. napon a korábban tervezett villányi terep helyett még Horvátországban maradtunk, ugyanis az előző napi programon felhívták a figyelmünket egy feltételezhetően szarmata, gerinces faunát tartalmazó, felhagyott homokbányára. Így kaptunk az alkalmon, és meglátogattuk a lelőhelyet, ahol kedvünkre gyűjtögethettünk fog- és csontmaradványokat, valamint koprolitokat. Miután kiástuk magunkat a homokból, megindultunk hazafelé. Végül Pécsett váltak el útjaink egymástól, azonban csupán abban a reményben, hogy egy év múlva a Tokaji-hegységben újból találkozunk.

A terepgyakorlat nem jöhetett volna létre, ha nincsenek lelkes támogatóink, ezért szeretnénk nekik köszönetet mondani: Magyarhoni Földtani Társulat, Horvát Földtani Szolgálat, Zágrábi Egyetem, Papuk UNESCO Geopark, Papuk Természeti Park, GeoLog Környezetvédelmi és Geofizikai Kft., Hantken Miksa Alapítvány, GeoLitera, Geomega Kft., KRILL Zrt., Papp Simon Alapítvány a Hazai Szénhidrogénföldtani Oktatásért, Biocentrum Környezetvédelmi és Vízgazdálkodási Kft.

Szeretnék köszönetet mondani továbbá a terepgyakorlat összes vezetőjének és a két főszervezőnek, Botka Dánielnek és Szemerédi Máténak, valamint Simon István korábbi Ifjúsági Bizottsági elnöknek is.

A terepgyakorlat kirándulásvezetőjét letölthetik az alábbi linken: http://foldtan.hu/hu/kirandulasvezetok. A terepgyakorlaton készült képek az alábbi helyen érhetők el: http://mftib.blogspot.com/p/iii-osszegyetemi-terepgyakorlat.html

Miklós Dóra Georgina
MFT IB elnök

11. Kőzettani és Geokémiai Vándorgyűlés, Sopron,

2021. szeptember 2–4.

A tavalyi év helyett idén került csak sor a 11. KGVGY-re Átalakulások címmel, ahol a vulkanológia, köpenylitoszféra, xenolitok, granulit, leukofillit, karbonatit mellett szó volt cseppkövekről, izotóparányokról, hidrogéntárolásról, reaktívtranszport-modellezésről, nanoőrleményekről, permokarbon képződményekről, mikromineralógiáról, titanitról, névlegesen vízmentes ásványokról. Ezenkívül még szerkezetföldtani ismeretekkel és modellekkel is gazdagodhattunk. Csak felsorolásszerűen, a teljesség igénye nélkül, a Bükki-paraautochtonon, Szamár-hegyen, Zemplénen és Börzsönyön kívül készültek tanulmányok a Pajzsi Komplexumról, a Firiza bazaltról, Šumovit Grebenről, Orotváról és Oldoinyo Lengairól…

Az idei rendezvényt a metamorf kőzettannak szenteltük. A két előadói nap között egy, a Soproni-hegység metamorfitjait bemutató szakmai kiránduláson vettünk részt, amit a terület legjobb ismerője, Török Kálmán vezetett. Gneiszek, csillámpalák, leukofillitek kontaktusait, egymáshoz való viszonyait, metamorf fejlődéstörténetüket, valamint kapcsolataik és átalakulásaik bizonytalanságát ismertük meg.

Jó hangulatú, családias rendezvény volt 78 regisztrált résztvevővel, plusz segítőkkel, amely eseménynek az Eötvös Loránd Kutatási Hálózat Földfizikai és Űrtudományi Kutatóintézet adott otthont. A feszített menetrend ellenére sokat tanultunk, megismertük egymás futó munkáit, jókat vitáztunk, találkoztunk, beszélgettünk, ettünk és kirándultunk.

Mint minden évben, a 30 év alatti hallgatók/kutatók előadásai és poszterei is megmérettettek. Első előadói kategóriában Halász Noémi és Pánczél Emese lett megosztott 1. helyezett, míg Ali Shebl Ali Elshazly Rady 3. helyezést ért el. Tapasztalt előadóként 1. helyezett Gál Péter, 2. helyezett Fehér Kristóf, 3. helyezett Cseresznyés Dóra lett.

Találkozunk jövőre Aggteleken, a 12. Kőzettani és Geokémiai Vándorgyűlésen, amelyet a Csillagászati és Földtudományi Kutatóközpont Földtani és Geokémiai Intézet fog szervezni.

Király Edit

24. Magyar Őslénytani Vándorgyűlés

2021. szeptember 9–11.

Immár 24. alkalommal rendezte meg a Magyarhoni Földtani Társulat Őslénytani és Rétegtani Szakosztálya a Magyar Őslénytani Vándorgyűlést. A rendezvényt évről évre máshol tartjuk, így a helyi őslénytani és rétegtani sajátosságokat a helyszínen tudjuk megvitatni, megismerve a Kárpát-medence fontos geológiai objektumait. Ezúttal a Zempléni-hegységben, Nagyhután voltak az előadási napok. A rendezvény színhelye a község melletti Kőkapu Vadászkastély és Hotel volt. A konferenciához kapcsolódó egynapos buszos terepbejárás ezúttal a Pálháza–Erdőbénye–Vizsoly–Tállya útvonalon történt. A terület sajátosságai miatt a terepi programban kainozoos lelőhelyek megtekintése szerepelt, külön kiemelve a legújabb rétegtani eredményeket, melyekről Szepesi János írt kirándulásvezetőt és Haranginé Lukács Réka számolt be. A terepi megállóhelyek rövid bemutatása az 52 oldalas konferenciakiadvány kötetében található.

A jelentkezők száma 54 fő volt, akik 21 hazai és 2 külföldi intézmény képviseletében vettek részt a rendezvényen, illetve mutatták be az elmúlt év legérdekesebb őslénytani eredményeit. A rendezvényt a Magyarhoni Földtani Társulat Őslénytani-Rétegtani Szakosztályának vezetősége szervezte Főzy István elnök és Szives Ottilia titkár vezetésével. A rendezvényhez ebben az évben is kapcsolódott egy ún. „0. napi” ismeretterjesztő program, melynek keretében a sárospataki MNM Rákóczi Múzeumának Lovagtermében tartott előadást Főzy István. Az előadás előtt a helyi televízió is interjút készített az előadóval, a programon 38 fő vett részt.

A konferencián a hagyományoknak megfelelően az első és harmadik napon hangzottak el szakmai előadások: a kollégák összesen 5 szekcióban 25 előadást tartottak és 9 posztert mutattak be. A változatos program során a recens tornádóüledékektől a csillaghegyi vámpíron át a triász karni pluviális eseményig ismerhettük meg az aktuális eredményeket.

Idén került sor a szakosztály háromévenkénti rendes tisztújítására is. A jelölőbizottságot Pazonyi Piroska vezette. A választáson a bizalmat a korábbi elnök, Főzy István kapta ismét újabb három évre (2021–2024). Mellettük a Vezetőség tagja maradt Szives Ottilia titkár, Pálfy József, Ősi Attila, Bosnakoff Mariann, új tagok Botfalvai Gábor és Virág Attila, a Vezetőség póttagjai Mohr Emőke és Karádi Viktor lettek.

A konferenciát a Nemzeti Kulturális Alap támogatásával rendeztük. A támogatást részben a terepi program buszköltségére, részben az absztraktkötet megjelentetésére fordítottuk. Az NKA pályázati keretből lehetőségünk volt még 6 hallgató teljes részvételi költségének fedezésére is. A hallgatói támogatásra a diákok a beadott előadás- vagy poszterkivonattal pályázhattak, az absztraktokat a Magyarhoni Földtani Társulat Őslénytani-Rétegtani Szakosztályának vezetősége bírálta el. A díjakat a korábbi évekhez hasonlóan az idén is a Hantken Miksa Alapítvány ajánlotta fel. A díjazottak két kategóriában vehették át jutalmaikat. A hallgatói kategóriában az I., II., és a III. helyezést Kicsi Anna Réka, Szabó Kata Alexa és Kolláti Réka (ELTE) nyerte el. A PhD-kategóriában Gere Kinga, Magyar János és Szabó Bence (ELTE) voltak a nyertesek.

A Magyar Őslénytani Vándorgyűlés szervezői 24 éve rendületlenül elkötelezettek a haladó hagyományok ápolása mellett; így a fiatal generáció tagjai és a pályakezdők segítséget, ötleteket és szakmai támogatást kapnak a tapasztaltabb kollégáktól. Ezúton is köszönjük az NKA, az MFT és a Hantken Alapítvány támogatását.

Szives Ottilia
titkár

Kapolcs–Balatonhenye Geotóp napi túra

2021. október 10.

A Balaton-felvidéki Nemzeti Park Kapolcsról induló Geotóp napi geotúráján 10 elszánt résztvevő indult útnak az ország legkülönbözőbb pontjairól (Monostorapáti, Balatonfüred, Veszprém, Székesfehérvár, Sárvár, Szombathely), vállalva akár a várható egész napos esőt és a csaknem 14 km hosszú távot.

A túra előtt bemutatásra került a Magyarhoni Földtani Társulat és a Földtani Intézet térségre vonatkozó 4 ismeretterjesztő földtani–földrajzi kiadványa.

Szinte hihetetlen módon az eső elkerülte a csapatot, és tiszta kilátásnak örülhettünk a Király-kő bazaltoszlopainak tetejéről elénk táruló Dörögdi-medencére és a Déli-Bakony vulkáni hegyeire.

Menet közben átléptünk számos határt:

– A Déli-Bakonyban fekvő Kapolcsról átgyalogoltunk a Balaton-felvidékhez tartozó Balatonhenyére,

– a bazalt hazájából eljutottunk a karbonátos kőzetek szigetére (mely egykor valóban sziget volt a Pannon-tó birodalmában),

– jártunk a Balaton-felvidéken mintegy 60 km hosszan végig húzódó és 1,5 km mélységig lenyúló Litéri-törés feltolódási síkjának mindkét oldalán,

– néhány száz méteren 3 kőzettani határt, és közel 50 millió évet hagytunk a hátunk mögött,

– és végül, de nem utolsósorban saját határainkat is feszegettük: egyik túratársunk cipőjének mindkét talpa levált menet közben…

Az, hogy ő végig tudta járni ezt a túrát, azért volt lehetséges, mert

– kitartó volt, és nem fordult vissza,

– a többiek nejlonzacskókkal, kötelekkel (ebbe bugyolálta a cipőjét) és buzdítással segítették,

– és akadt egy veszprémi a csapatban, aki hazavitte Székesfehérvárra…

Azt hiszem, igazi csapattá kovácsolódtunk ez alatt a hét óra alatt, és mindenki szép élményekkel és hasznos ismeretekkel gazdagodva mehetett haza.

A geotúrán készült fotók albuma az alábbi linken tekinthető meg: https://photos.google.com/share/AF1QipOQixX3Rr8yH3d82KrKeWP_Y468qzL71rw9nObv1712663AyV8-bj2jUdbhF7_sxQ?key=eDhCc2w3b09CNUtpVmhZSFhheERSXzNZZndvVEp3

Sárdy Julianna

Beszámoló a rudabányai terepgyakorlatról

2021. október 16.

Jó szerencsét! köszönéssel kezdődött a szombat reggeli találkozás Rudabányán, a Bányászattörténeti Múzeum előtt, ahol a parkolóban a geológusok egymást várták.

Rendkívül élveztük az első, nem iskola által szervezett terepgyakorlatot, amelyen részt vettünk. Mint amilyen az amerikai filmekben, családias hangulat, jókedv, figyelem és tudatosság jellemezte a kirándulást. Rudabányára már korábban is szívesen elmentünk volna, de földrajzi helyzete számunkra nem kedvező. BSc-s hallgatóként sok új ismerettel gazdagodtunk, amely a felkészült oktatóknak és túravezetőknek köszönhető (Földessy János és Németh Norbert). Biztosan hasznunkra válik a megszerzett tudás a jövőbeli tanulmányainkhoz.

Először a Bányászattörténeti Múzeumba látogattunk el, ahol a térség bányászati múltját mutatták be, emellett életnagyságú bányajárat-rekonstrukciókat is láthattunk. Meg kell jegyzni, a sztereotípiáknak ellentmondva, viszonylag nagy szélességűek voltak. Innen egy rövidebb kocsikázás után elérkeztünk a bányatóhoz, mely szemkápráztató látványt nyújtott, ám hozzá kell tenni, hogy az időjárás is a mi oldalunkon állt. Itt a környék földtanára fordítottunk nagy figyelmet, ami igencsak részletesen volt elmesélve, ám le kell szögezni, hogy amilyen bonyolultnak tűnt, nem is meglepő. Nem tudtuk, hogy az itteni érctelep voltaképp nem is „egy nagy”, hanem több kisebb lépés során keletkezett érctelepek összessége. Szimpatikus volt, hogy nem szárazon tálalták az információkat, hanem gyakran példákkal színesítették a mondanivalót, ami segített a megértésben. Tetszett, hogy a helyszín kutatásának problémás pontjairól is szó esett, így betekintést nyerhettünk, hogy milyen bonyodalmakkal kell számolni egy esetleges fúrás vagy mintavétel közben.

Dúskálhattunk a gyűjthető ásványokban is, ilyenek többek között a barit, termésréz, pirit, szfalerit, galenit, illetve muszkovit is. Ezeket az egyes megállóhelyeken kalapáccsal a „rutin meg az évek” alapján könnyűszerrel meg lehetett találni, ki lehetett szedni. Bizonyos praktikákkal is segítettek minket, hogy miként lehet elkülöníteni néhány Zn-tartalmú anyagot, amelyről még nem hallottunk.

Végül, de nem utolsósorban terepünk záróakkordjaként meglátogattuk a világhírű, Rudabányáról elnevezett *Rudapithecus hungaricus* Látogatóközpontot. Itt megfigyelhettük a területen talált leleteket, a *Rudapithecus* jelentőségéről szóló kisfilmet, melyet Kordos László professzor riportja mutatott be. A helyszínen a Hernyák Gábor emlékszobra állít emléket az egykori rudabányai vasércbánya főgeológusának, az előember-maradványok első megtalálójának, akiről a leletet Gabinak nevezték el.

Összegezve, csak ismételni tudjuk magunkat, úgy éreztük, hogy ennél keresve sem találhattunk volna jobb elfoglaltságot egy átlagos szombati napra, gyarapítottuk tudásunkat, új embereket ismertünk meg, szimplán jól éreztük magunkat. Ezúton is meg szeretnénk köszönni a lehetőséget.

Leszkó Márton Milán,
Ádámcsik Árpád

Személyi hírek

Kimagasló elismerés az ELTE-nek és a magyar hidrogeológus szakterületnek, hogy a Hidrogeológusok Nemzetközi Szövetsége (International Association of Hydrogeologists, IAH) a 2021. évi elnöki díját, a “Presidents' Award”-ot Mádlné Szőnyi Juditnak (MTA doktor, egyetemi docens, ELTE, TTK, FFI, Általános és Alkalmazott Földtani Tanszék, Tóth József és Erzsébet Hidrogeológia Professzúra vezető, ENeRAG H2020 projekt tudományos koordinátor) ítélte oda. Ez a siker azért is egyedülálló, mert hazánkban munkálkodó hidrogeológus először részesült ebben az elismerésben.

A kitüntetés átadására a Brüsszelben rendezett 48. IAH Kongresszuson (2021. szeptember 6–10.), került sor. Mádlné Szőnyi Judit kitüntetése a felszín alatti vízáramlási rendszerek megértésében és megismertetésében végzett magas szintű nemzetközi munkájának elismerésén alapult. *https://iah.org/about/awards/presidents-award-2021*

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Csath Béla okleveles bányamérnöknek, Társulatunk tagjának a Miskolci Egyetem rektora Rubin oklevelet adott át 2021. augusztus 21-én, közmegbecsülésre méltó munkássága elismeréséül. Csath Béla a Miskolci Nehézipari Műszaki Egyetem Bányamérnöki Karán hetven éve szerzett oklevelet.

A Magyarhoni Földtani Társulat vezetősége jó egészséget, erőt és további békés éveket kíván!

Gyászhír

Fájdalommal tudatjuk, hogy
Matus Lászlóné tagtársunk 2021. július 22-én elhunyt.
Antal Sándor tagtársunk 2021. augusztusában elhunyt.
Kovácsné Dr. Bodrogi Ilona 2021. október 26-án elhunyt.

Emlékük szívünkben és munkáikban tovább él!

Könyvismertetés

Barna Tamás, Tóth László: A mélységektől a magasságokig. Ásványok a Bibliában

(Kiadta: Barna Tamás, Kecskemét, 2020, 99 p.)

Szép kiállítású, nagyon jó minőségű ásványfotókat tartalmazó album jelent meg Kecskeméten, amelynek a szövegét Barna Tamás, a fényképeket Tóth László készítette. Az ásványképeket összefogó gondolati vezérfonal a Biblia. Ez a téma az utóbbi húsz évben már szinte külön műfajt képvisel, amelyben az úttörő Nagy Mihály debreceni tanár 2003-ban kiadott könyve volt. 2006-ban Kecskeméten is megjelent már egy füzet Ásványok a Bibliában címmel, amely Fuxreiter Andrásnak az ottani Ráday Múzeumban bemutatott ásványgyűjteményéhez szolgált kiállításvezetőül. Ennek szerzője Fogarasi Zsuzsa volt. Majd 2009-ben Ócsai Árpád Nyírbogdányban is megjelentetett egy könyvet (Ásványok a Bibliában), mely az internetről szabadon letölthető. Ennek beosztása hasonló a jelen kiadványhoz, de nem tartalmaz képeket.

Míg Nagy Mihály műve egyértelműen a Református Egyházhoz és a Károli-Bibliához kötődött, és erősen missziónáló szellemű volt, Barna Tamás inkább semleges vallási tekintetben, és egy-

438ánt használta a Károli-Biblia régebbi, 1868-as és 1821-es kiadásait, valamint az 1973-as katolikus Bibliát. Ugyanakkor jelentős újítása a szerzőnek, hogy bevonta a zsidó vallás ilyen témájú iratait is, ezeket LÖW Immánuel (1854–1944) szegedi főrabbi munkái képviselik. A könyv elején az egész művet is az ő emlékének ajánlják. LÖW Immánuel olyan jelenség lehetett, mint a római katolikus egyházban PROHÁSZKA Ottokár vagy TÓTH Mike, akik a teológiai tudásuk mellett komoly földtudományi és ásványtani ismeretekkel is rendelkeztek.

A Bibliában előforduló ásványokat a szerzők három nagy csoportra osztják: 1) fémek, 2) drágakövek, 3) egyéb ásványok. Az egyes ásványok tárgyalása az alábbi módon történik:

Először az ásványtani alapokat idézik a szakirodalomból szóról szóra, nagyon helyesen nem a saját megfogalmazásuk szerint, mert itt fontos az adatok pontossága. Erre elsősorban FEHÉR Béla Ásványkalauzát (2009) és a KOCH–SZTRÓKAY-féle Ásványtant (1986) használják. Ezt egészítik ki minden ásványnál a szebbnél szebb fotók. A képek színe is valószerűnek tűnik, és különösen jól érvényesülnek az éles kontúrú kristályformák. (Egy kép, a 16. ábra kissé megtévesztő, mert a kalcedon kocka kristályformát mutat, ami nem saját alakja, hanem valószínűleg fluorit utáni pszeudomorfóza.)

Ezután következnek a bibliai idézetek, felváltva a háromféle Bibliából. Nem lehet pontosan tudni, hogy mikor melyik kiadást részesítik előnyben, és inkább zavaró, hogy egy helyen ugyanannak bibliai szakasznak egyes sorait különböző helyről idézik (pl. Jób 28. fejezete az arany címszónál). A bibliai idézeteket rövid, tárgyilagos tartalmi összefoglalások és magyarázatok követik.

Talán a legértékesebb rész az egyes ásványok leírásánál a kultúrtörténeti magyarázat, mely az ókori Keletnek az ásványokról való felfogását idézi. Ez a drágakövek esetében főleg két régebbi publikáción alapul, Schmidt Sándor 1890-ben és DUDICHNÉ VENDL Mária és KOCH Sándor 1935-ben kiadott munkáin. Itt jelennek meg LÖW Immánuel írásai is, aki a zsidó hagyomány szakértője és az ótestamentumi részek hivatott értelmezője volt. A rabbinista írásmagyarázat szép példáját adja például a Mózes által készített érckígyóról, amely vörösrézből készült. A réz vörös színét bajelhárító hatásúnak tartották, de LÖW szerint nem ez hatott, hanem azok közül, akik rátekintettek, csupán azok gyógyultak meg, akiknek a szívében Isten szeretete volt jelen. Azt viszont nem tartom valószínűnek, hogy a gyógyszerészek jelképe nem Aszklépiosz kígyójától, hanem a bibliai érckígyótól származna.

Az ásványok csoportjai közül mind a három másféle tárgyalásmódot kívánt.

A fémek közé tartoznak a nemesfémek, az arany és az ezüst, valamint a termésréz, amelyek valódi ásványok. A többi fém, részben a réz, de különösen a vas, az ón és az ólom előfordul ugyan a természetben nagyon ritkán terméselem formájában, de valódi alkalmazásuk más ércásványok feldolgozása által válik lehetővé. A bibliai említések is ilyen, már kinyert fémekre, és nem az illető elem termésváltozatára vonatkoznak. Ezért a főbb ércásványokat is meg lehetett volna említeni, amelyekből a bibliai korban ezeket kinyerték. Különösen Salamon király Sinai-félszigeten található rézércbányáira vonatkozólag lett volna érdekes megtudnunk, hogy a mai tudomány fogalmaival milyen teleptani típusba tartoznak, és milyen ércásványokat tartalmaztak.

A drágakövekkel kapcsolatban a szerző rámutat, hogy az ásvány- és drágakőnevek azonosítása a mai tudományos elnevezésekkel nagyon bizonytalan, mert az ókorban még nem voltak pontos meghatározási módszerek, és az eredeti héber szavak jelentése a többszörös fordítás következtében is módosulhatott. Ez magyarázza a mai bibliakiadások közötti eltéréseket is. A drágakövek a Bibliában főleg két egymással valószínűleg összefüggő téma keretében fordulnak elő, ez a főpap hósenje, azaz melltáskája, a másik az új Jeruzsálem alapkövei a Jelenések könyvében. A 12-es szám mind a két helyen Isten népe teljességét jelképezheti. De olyan magyarázatot is említ a könyv, amely a drágaköveket a 12 apostollal azonosítja. Ez azzal lehet összhangban, hogy az egyház „az apostoloknak és prófétáknak alapkövén” épül fel (Efézus 2,20).

A harmadik csoport egyéb ásványokat tartalmaz. Ezeket főleg praktikus felhasználásuk miatt említi a Biblia. Ilyen a kősó, amelynek azonban komoly szimbolikus jelentése is van, és az aszfalt, amely szigorúan véve nem is ásvány, de a bibliai tájakon gyakran előforduló természetes anyag, valamint a kén. Ide tartoznak még a leginkább kozmetikai célra vagy dísztárgyak készítésére használt ásványok, az antimonit, a cinnabarit és az alabástrom.

Bár tudom, hogy egy ilyen mű sem törekedhet teljességre, én két további bibliai témát mégis bevettem volna a felsorolásba. Az egyik az ezüstnél az a szép mondás, hogy „ha ő kőfal, építsünk azon ezüstből palotát” (Énekek Éneke 8,9), a másik Lót felesége, aki sóbálvánnyá változott. Bár nem ásvány, de nagy gyakorlati jelentősége és a teremtésben játszott szerepe miatt meg lehetett volna még említeni az agyagot, azaz „a föld porát”, amelyből Isten az embert formálta. Van még egy rejtett utalás a bentonitra Ézsaiás 7,3-ban: így szólt az Úr Ézsaiáshoz: „Menj ki Seárjásúb fiaddal együtt Áházhoz a Felső-tó vízvezetékének a végéhez, a Ruhafestők mezejéhez vezető útra”. BENEKE német agyagásványkutató, kolloidikus szerint itt bentonit található, azért voltak ott a ruhafestők.

A Biblia az élet teljességét felöleli, és ez a benne említett ásványok sokféleségében is megnyilvánul. Ezt fejezi ki a könyv címe: A mélységektől a magasságokig. A mélységekben talált ásványok a mennyei magasság kiábrázolói lesznek.

A könyv megrendelhető a szerzőnél, dr. BARNA Tamás, Kecskemét, e-mail cím: barnaesfiai@gmail.com.

VICZIÁN István

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Tartalom — Contents

Nemzeti Kulturális Alap
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