Magyarhoni Földtani Társulat
Földtani Közlöny
Hungarian Geological Society

154/1, 27–46., Budapest, 2024

DOI: 10.23928/foldt.kozl.2024.154.1.27

Documentation of Middle Miocene continental vertebrate fauna from Northern Hungary and the Visegrád Mountains

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Középső miocén szárazföldi gerinces faunadokumentáció Észak-Magyarországról és a Visegrádi-hegységből

Összefoglalás

Az első szerző az utóbbi két évtized során tonnás nagyságrendű mintaanyag begyűjtésével és iszapolásával számos középső miocén (badeni és szarmata) korú kisgerinces leletegyüttest tárt fel elsősorban Észak-Magyarországon, valamint a Visegrádi-hegységben. Az iszapoláshoz a DAAMS & FREUDENTHAL (1988) által leírt berendezést alkalmazta. A faunák feldolgozása nemcsak rendszertani, ősállatföldrajzi és biokronológiai eredményeket hozott, hanem kőzetrétegtani, geokronológiai vonatkozásai is vannak. Jelen tanulmány célja ez utóbbi összefüggések ismertetése.

Kulcsszavak: Pannon-medence, miocén, szárazföldi biokronológia, kőzetrétegtan

Abstract

Nineteen Middle Miocene (Badenian and Sarmatian) microvertebrate faunas were collected by the first author in quantities of several tons of samples in the Northern Hungary region and from the Visegrád Mountains in Transdanubia over the last two decades. Sample materials were washed and sieved using the sieve system of DAAMS & FREUDENTHAL (1988). The study of these new faunas resulted in numerous taxonomic, paleobiogeographic and biochronologic conclusions (HÍR 2020, HÍR et al. 2016, 2017 and references therein), as well as lithostratigraphic and geochronologic results. The main purpose of this paper is to present and discuss the latter relationships.

Keywords: Pannonian Basin, Miocene, continental biochronology, lithostratigraphy

Introduction and methodological approach

The last summary of the biozonation and stratigraphic/biochronologic correlation of the Hungarian Early and Middle Miocene continental vertebrate findings was published by KORDOS (1985). At that time, research in Hungary on vertebrate occurences older than the Pannonian age of the Miocene was in the early stage: mainly sporadic macrovertebrate occurences had been known from that period. As a result of intense field activity by the first author, numerous microvertebrate assemblages have been unearthed during the last decades. In addition, the previously known localities of Hasznos and Szentendre, primarily investigated by KORDOS (1981, 1982, 2007), have been re-excavated. The majority of the study sites are located in Northern Hungary and one of them (Szentendre, Cseresznyés-árok/Cseresznyés Trench) is in the Visegrád Mountains (close to the right bank of the Danube) (*Fig. 1*). A special methodology was used to identify and sample the localities. Its essential elements include sampling on the tonnage scale and washing by a sieve system and pump (HÍR 2020). Here, in addition to presenting own results, we give a short interpretation of the studies on large-sized vertebrates by KRETZOI & PÁLFALVY (1969), KORDOS (1985), VÖRÖS (1989), and GASPARIK (1993, 2001).

For the biochronologic classification of the faunas, we applied the chronology of the Miocene formations of the Central Paratethys (HARZHAUSER & PILLER 2007) and the zonation of the continental vertebrate faunas developed for Western Europe (VAN DER MEULEN et al. 2011). The lithostratigraphic classification of the fossil-bearing sediments is

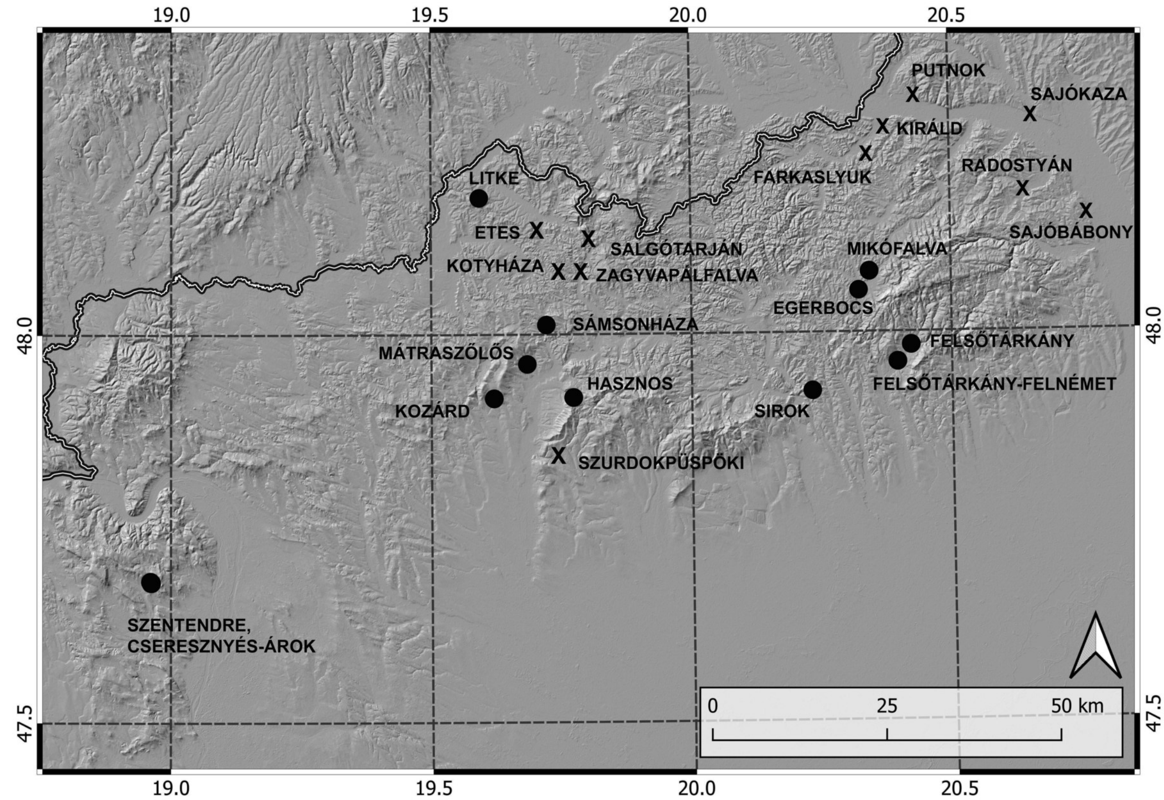

Figure 1. The geographical position of the faunas studied by the first author and the sporadic macrovertebrate finds descried by of Gasparik (1993, 2001), Kordos (1985), Kretzoi-Pálfalvy (1969), Vörös (1989).
Caption: • : microvertebrate localities, X: localities of sporadic large-sized vertebrata

1. ábra. *Az első szerző által tanulmányozott faunák, valamint a Gasparik (1993, 2001), Kordos (1985), Kretzoi-Pálfalvy (1969), Vörös (1989) által leírt nagy testű gerinces szórványleletek földrajzi helyzete.*
Magyarázat: • : kisgerinces lelőhelyek, X: nagy testű gerinces szórványlelőhelyek

after Hámor (1985), Gyalog (1996), Gyalog & Budai (2004), Lukács et al. (2022), and Babinszki et al. (2023). In the present publication, we provide lists of the studied faunas without detailed morphologic and taxonomic analysis.

The oldest microvertebrate assemblages in the study area are of Badenian age (Litke 1 and Litke 2). We only have sporadic finds from the Lower Miocene formations.

Results and discussion

Zagyvapálfalva Formation

Artiodactyla
Lagomeryx sp., Sóshartyán, Kapcás-tető (Kapcás Summit)

Proboscidea
Gomphotherium sp., Nemti
Prodeinotherium hungaricum Éhik, 1930 Salgótarján, Salgó-hegy (Salgó Hill)
Prodeinotherium hungaricum Éhik, 1930 Salgótarján, sandpit at Meszesalja
Prodeinotherium hungaricum Éhik, 1930 Zagyvapálfalva

Rodentia
Steneofiber depereti Mayet, 1908, Zagyvapálfalva, abandoned gravel pit in the western side of road no. 21., Hír (2000). *Fig. 2: S.*

The revision of the proboscidean finds was given by Gasparik (2001). The overlying bed of the Zagyvapálfalva Clay belongs to the Gyulakeszi Rhyolite Tuff Formation (Hámor et al. 1978), recently renamed to Tihamér Rhyolite Lapilli Tuff Formation (Babinszki et al. 2023). This formation is a characteristic marker horizon in the early Miocene in Northern Hungary. As for its modern radiometric dating, at first two similar $^{36}Ar/^{40}Ar$ ages 17.02 ± 0.14 Ma for Ipolytarnóc and 16.99±0.16 Ma for Nemti were published by Pálfy et al. (2007). Overall, these ages are compatible with the originally dated "Proboscidean Datum" (17.5 Ma), the earliest appearance of proboscideans in Europe (Berggren & Van Couvering 1974). Furthermore, these ages correspond to the Ottnangian age of the Paratethys and the MN4 vertebrate zone (e.g. Reichenbacher at al. 2013).

According to recent volcanological, geochronological and geochemical results, the slight age difference of Ipolytarnóc and Nemti is due to their pyroclastic succesions, which have been related to two different, subsequent eruption events. The ignimbrite occurrence at Ipolytarnóc is identical to the Eger (-Ipolytarnóc) Ignimbrite, yielding radiometric ages of 17.25±0.11 Ma (sanidine Ar-Ar age in Karátson et al. 2022) and 17.2–17.5 Ma (zircon U/Pb ages in

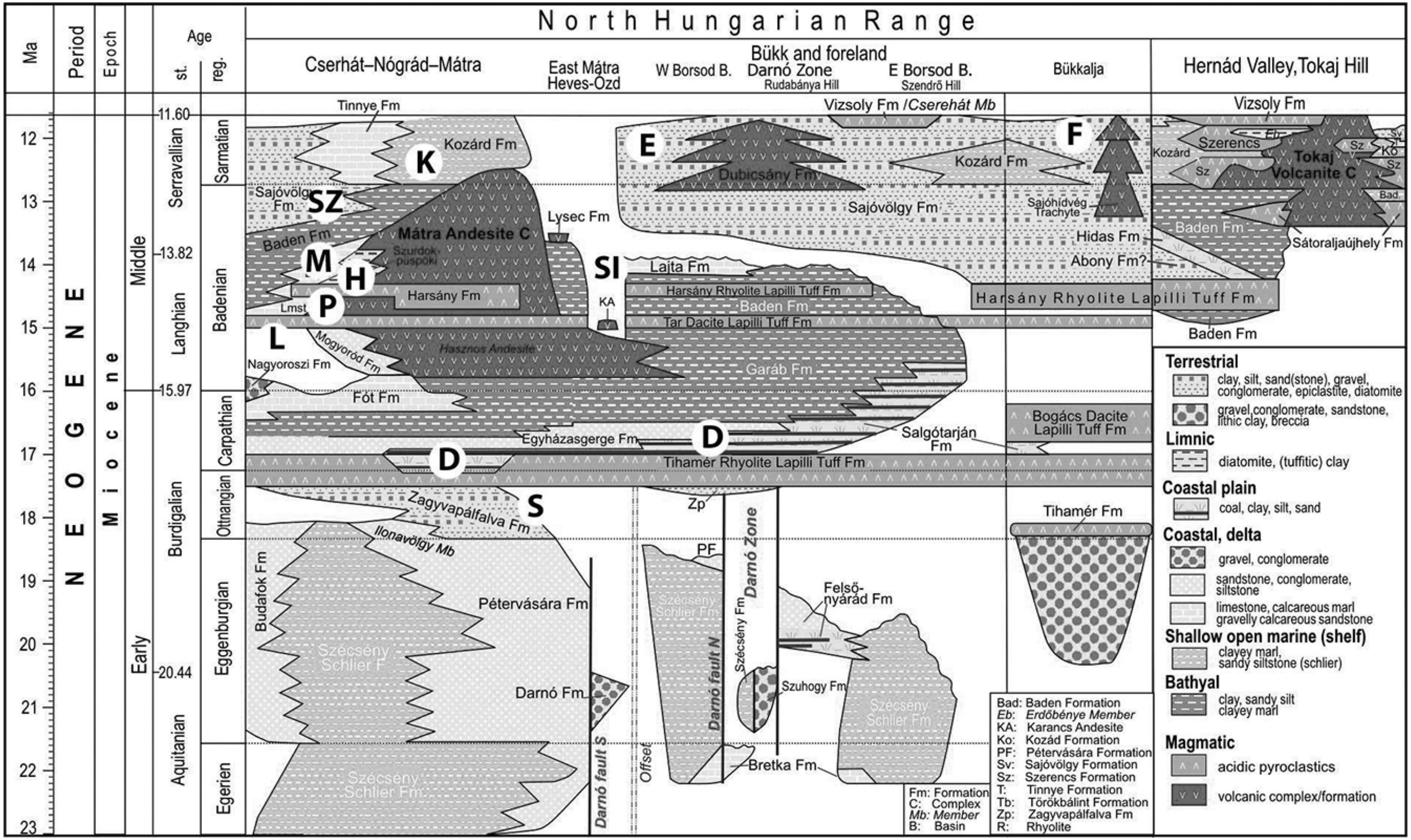

Figure 2. The lithostrtigraphic and geochronologic context of the studied faunas and important sporadic finds (N Hungary) inserted into the table of Babinszki et al. (2023)

Caption: S – sporadic finds from the Zagyvapálfalva Formation in the Salgótarján Basin; D – proboscidean sporadic finds from the Salgótarján Brown Coal Formation; L – Litke 1, 2; M – Sámsonháza 3; H – Hasznos; P – Szurdokpüspöki; SZ – Mátraszőlős; K – Kozárd; SI – Sirok 1; E – Egerbocs and Mikófalva; F – faunas of the Felsőtárkány Basin

***2. ábra.** A tárgyalt faunák és jelentősebb szórványleletek kőzetrétegtani és geokronológiai helyzete a Babinszki et al. (2023) által publikált táblázatokba illesztve*

Magyarázat: S – szórványleletek a Zagyvapálfalvai Tarkaagyagból a Salgótarjáni-medencében; D – ormányos szórványleletek a Salgótarjáni Barnakőszén Formációból; L – Litke 1, 2; M – Sámsonháza 3; H – Hasznos; P – Szurdokpüspöki; SZ – Mátraszőlős; K – Kozárd; SI – Sirok 1; E – Egerbocs és Mikófalva; F – a Felsőtárkányi-medence faunái

LUKÁCS et al. 2021); while the ignimbrite occurrence of Nemti [part of the Tihamér Rhyolite Lapilli Tuff, referred to as Mangó Ignimbrite in LUKÁCS et al. (2018), and recently renamed to Kisgyőr Ignimbrite by HENCZ et al. (2024)] has a less well-defined slightly younger age at around 17.1 Ma (LUKÁCS et al. 2018, 2021; HENCZ et al. 2021, 2024). Further occurrences of both the Eger and Kisgyőr Ignimbrites are known from the BFVA (LUKÁCS et al. 2021, KARÁTSON et al. 2022, HENCZ et al. 2024) as well as from Northern Croatia (BRLEK et al. 2023).

Salgótarján Brown Coal Formation

Based on the results of KORDOS (1985), VÖRÖS (1989) and GASPARIK (2001), the large-sized vertebrate finds were concentrated in two levels in the coal mines of the Salgótarján Basin (Etes, Kotyháza, Zagyvapálfalva), and in the Borsod Basin (Királd, Farkaslyuk, Putnok, Radostyán, Sajókaza, Sajóbábony) (*Fig. 2: D*).

Under the coal seam no. I.

Deinotherium cf. *bavaricum* (VON MEYER, 1831)
Gomphotherium angustidens (CUVIER, 1817)
Gomphotherium sp.

Under the coal seam no. III,
the "upper variegated clay"

Prodeinotherium hungaricum ÉHIK, 1930
Gomphotherium angustidens (CUVIER, 1817)
Aceratherium tetradactylum, Rhinocerotidae indet.

Sediments related to the Tar Dacite Lapilli Tuff Formation

Litke 1.: GPS: N: 48° 11,338' E: 19° 34,935'
Litke 2.: GPS: N: 48° 11,255' E: 19° 34,931'

Sections are given in *Fig. 3.*, faunal lists are given in *Table I.* Stratigraphical context is shown in *Fig. 2: L.*

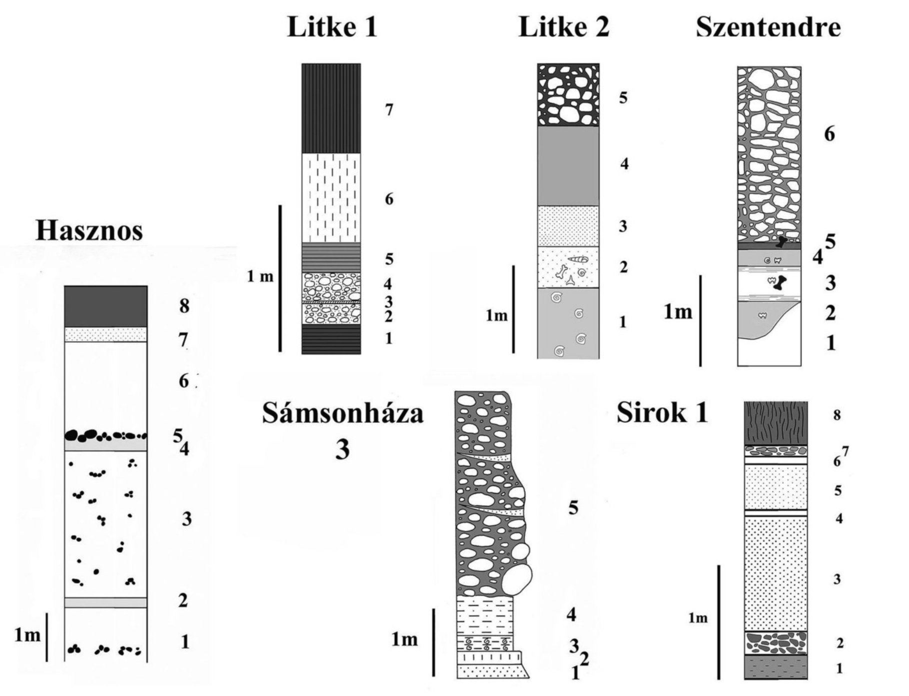

Figure 3. Sections of the studied vertebrate localities Litke 1., Litke 2., Szentendre, Hasznos, Sámsonháza 3., Sirok 1.

Litke 1.: 1 – 30 cm grayish blue diatomaceous clay contains bones; 2 – 15 cm cobble; 3 – 1 cm red limonitic line; 4 – 20 cm cobble; 5 – 20 cm gray plastic clay; 6 – 60 cm loess-like colluvium; 7 – 60 cm recent woodland soil. Litke 2.: 1 – 130 cm lightgray diatomite contains Planorbis shells; 2 – 30 cm dark gray sand contains mollusc shells and bones; 3 – 30 cm hard gray sand; 4 – 90 cm gray clay; 5 – 50 cm debris. Szentendre, Cseresznyés Trench: 1 – 50 cm white diatomite; 2 – light gray diatomite; 3 – 40 cm gray diatomite contains bones and coal strings; 4 – yellow diatomite contains bones and mollusc shells; 5 – 5 cm green clay contains bones; 6 – white hard diatomite. Sirok 1.: 1 – 20 cm green clay contains mollusc shells; 2 – 20 cm rhyolitic tuff clasts; 3 – 100 cm gray sand; 4 – 5 cm white diatomite; 5 – 40 cm gray sand contains mollusc shells and bones; 6 – 5 cm white diatomite; 7 – 10 cm gray sandstone clast; 8 – 50 cm recent soil and debris. Hasznos: 1 – 110 cm gray diatomite contains andesite pebbles; 2 – 20 cm yellowish gray diatomite contains bones; 3 – 290 cm light gray diatomite contains andesite pebbles and bones; 4 – 20 cm yellowish gray diatomite contains bones; 5 – 20 cm diatomite with large (15–20 cm diameter) andesite pebbles; 6 – 180 cm light gray diatomite; 7 – 30 cm light gray diatomite contains small andesite pebbles; 8 – 80cm recent soil. Sámsonháza 3.: 1 – calcareous sand; 2 – limestone with fossil roots; 3 – grey diatomaceous mud contains mollusc shells and bones; 4 – grey sandy mud; 5 – coarse-graines gravel with sand lenses

3. ábra. *Litke 1., Litke 2., Szentendre, Hasznos, Sámsonháza 3., Sirok 1. ősgerinces lelőhelyek szelvényei*

Litke 1.: 1 – 30 cm szürkéskék, diatomás agyag; 2 – 15 cm durva kavics; 3 – 1 cm vörös limonitsáv; 4 – 20 cm durva kavics; 5 – 20 cm szürke, plasztikus agyag; 6 – 60 cm löszszerű lejtőüledék; 7 – 60 cm jelenkori erdőtalaj. Litke 2.: 1 – 130 cm világosszürke kovaföld Planorbis-héjakkal; 2 – 30 cm sötétszürke homok puhatestűhéjakkal és csontmaradványokkal; 3 – 30 cm kötött, szürke homok; 4 – 90 cm szürke agyag; 5 – 50 cm lejtőüledék. Szentendre, Cseresznyés-árok: 1 – 50 cm fehér kovaföld; 2 – világosszürke kovaföld; 3 – 40 cm csontmaradványokat tartalmazó, szürke diatomit szénzsinórokkal; 4 – 30 cm csontmaradványokat és puhatestűhéjakat tartalmazó, sárga diatomit; 5 – 5 cm csontmaradványokat tartalmazó, zöld agyag; 6 – fehér színű, kemény, rögös kovaföld. Sirok 1.: 1 – 20 cm zöld agyag puhatestűhéjakkal; 2 – 20 cm riolittufa klasztok; 3 – 100 cm szürke homok; 4 – 5 cm fehér kovaföld; 5 – 40 cm szürke homok puhatestűhéjakkal és csontmaradványokkal; 6 – 5 cm fehér kovaföld; 7 – 10 cm szürke homokkőklasztok; 8 – 50 cm talaj és lejtőüledék. Hasznos: 1 – 110 cm szürke kovaföld diónyi andezitkavicsokkal; 2 – 20 cm sárgásszürke, csontmaradványokat tartalmazó kovaföld; 3 – 290 cm világosszürke, andezitkavicsokat és csontmaradványokat tartalmazó kovaföld; 4 – 20 cm sárgásszürke, csontmaradványokat tartalmazó kovaföld; 5 – 20 cm kovaföld 15-20 cm átmérőjű andezitkavicsokkal; 6 – 180 cm világosszürke kovaföld; 7 – 30 cm világosszürke kovaföld apró andezitkavicsokkal; 8 – 80 cm recens talaj. Sámsonháza 3.: 1 – mészhomok; 2 – mészkő gyökérnyomokkal; 3 – szürke diatomás iszap puhatestűhéjakkal és csontmaradványokkal; 4 – finomszemcsés homok és iszap; 5 – durva kavics homokbetelepülésekkel

Table I. Faunal list of the localities Litke 1 (L 1) and Litke 2 (L 2) after HÍR (2013), and HÍR et al. (2016)

I. táblázat. *A Litke 1 (L 1) és Litke 2 (L 2) lelőhelyek faunalistái HÍR (2013), valamint HÍR et al. (2016) nyomán*

	L 1	L 2
Eulipotyphla		
Parasorex sp.	+	+
Erinaceinae indet.	+	
Soricidae gen. et sp. indet.	+	
cf. *Paenelimnoecus* sp.	+	
? *Desmanodon crocheti* PRIETO, 2010	+	
Lagomorpha & Rodentia		
Alloptox katinkae ANGELONE & HÍR 2012		+
Prolagus oeningensis (KÖNIG, 1825)	+	+
Palaeosciurus sutteri ZIEGLER & FAHLBUSCH, 1986		+
Spermophilinus besana CUENCA-BESCOS, 1988	+	+
Miopetaurista dehmi DE BRUIJN et al., 1980	+	
Paraglis astaracensis BAUDELOT, 1970	+	
Miodyromys sp.	+	+
Keramidomys cf. *thaleri* HUGENEY & MEIN, 1968	+	
Megacricetodon minor (LARTET, 1851)	+	+
Democricetodon mutilus FAHLBUSCH, 1964	+	+
Cricetodon meini FREUDENTHAL, 1963	+	+

The author two assemblages at Litke were collected by the first authorwho washed 14 tons of sediment between 2001 and 2013. The most characteristic element of the two faunas from Litke is *C. meini*. This species was an immigrant from the Aegean Region shortly before 15 Ma, and is well known in a series of vertebrate faunas from France, the Northern Alpine Foreland Basin and the Balkan Peninsula. Most of them were classified in zone MN5 (FORTELIUS 2011). *C. meini* is absent in the reference fauna of the MN5 zone (Pontlevoy-Thenay-Faluns), but it is typical in Southern Germany under the "Brock horizon," in the OSM-E-EBE local zone.

The "Brock horizon" is result of an asteroid impact (Ries impact) and it forms a characteristic stratigraphical marker horizon in the Northern Alpine Foreland Basin (DAXNER-HÖCK 2003, PRIETO & RUMMEL 2016). Over the past 50 years, 70 different age determinations have been carried out by the K–Ar, ^{40}Ar/^{39}Ar, and fission-track dating techniques (SCHWARZ et al. 2020 and citations therein). However, the exact age is still a matter of debate (ROCHOLL et al. 2018, SCHMIEDER et al. (2018).

Based on the latest results of ROCHOLL et al. (2017), the age of the Ries impact is between 14.93 and 15.00 Ma (Pb–U and Zircon ages obtained from tuff beds overlying and underlying the impact-generated "Brock horizon"). From the underlying faunas *C.* aff. *meini* has beeen recovered, the oldest (earliest) occurence of which was reported from Ebershausen, Southern Germany. The age of the fauna was dated at 15.2 Ma by the ^{40}Ar/^{39}Ar method (ABDUL-AZIZ et al. 2010, PRIETO et al. 2008, DAXNER-HÖCK 2003, LÓPEZ-GUERRERO et al. 2013). By analogy, the age of the Litke faunas can be estimated at 15.2–15.0 Ma.

The age of the fossiliferous freshwater clay at Litke has been the subject of a long debate. The intercyclic position of this sediment was first described by BALOGH et al. (1966) who classified it as of Badenian age. It is intercalated between the Tar Dacite Lapilli Tuff Formation and the Sámsonháza Member of the Lajta Limestone Formation. The latter unit is classified as the Pécsszabolcs Limestone Member within the Lajta Limestone Formation in the latest lithostratigraphic system of Hungary (BABINSZKI et al. 2023). Previously, HÁMOR (1985) and BARTKÓ (1985) defined the Litke freshwater sediment as the terminal element of the Karpatian marine cycle.

Reinforcing the concept of BALOGH et al. (1966), our results on the microvertebrate fauna suggest a Badenian age. However, the stratigraphic interpretation is complicated by two layers of the Tar Dacite Lapilli Tuff Formation having been mapped by BARTKÓ (in BALOGH et al. 1966, fig. 17.) in the vicinity of Litke and Nógrádszakál. Zircon U-Pb ages of the Tar Dacite Tuff Formation were published by LUKÁCS et al. (2018): 15.0-14.8 Ma (LA-ICP-MS), 14.88 ± 0.014 Ma (ID-TIMS).

Szentendre, Cseresznyés-árok ("Cseresznyés Trench")

GPS: N: 47° 41,683' E: 19° 0,600'

The section is given in *Fig. 2.*, and the faunal list in *Table II.* Stratigraphical context is shown in *Fig. 4: SE.*

The locality was first sampled by KORDOS (1982) accompained by Péter Solt. In 2017, the section was reexcavated by Lukács Mészáros and János Hír. During the years of

Table II. The faunal list of the locality Szentendre, Cseresznyés-árok after KORDOS (1982), and HÍR & VENCZEL (2018) updated

II. táblázat. *A Szentendre, Cseresznyés-árok lelőhely javított faunalistája KORDOS (1982), és HÍR & VENCZEL (2018) nyomán*

Rodentia
Albanensia sansaniensis (LARTET, 1851)
Palaeosciurus sp.
Spermophilinus bredai DE BRUIJN & MEIN 1968
Eomyops sp.
Muscardinus sansaniensis (LARTET, 1851)
Myoglis meini (DE BRUIJN, 1966)
Microdyromys koenigswaldi DE BRUIJN, 1966
Miodyromys sp. I.
Miodyromys sp. II.
Glirulus lissiensis (HUGUENEY & MEIN, 1965)
Cricetodon aureus MEIN & FREUDENTHAL, 1971
Democricetodon hasznosensis KORDOS, 1986
Megacricetodon minor (LARTET, 1851)
Eumyarion sp.
Anomalomys gaudryi GAILLARD, 1900
Artiodactyla
Suidae indet. (? *Listriodon*)
Lagomeryx seu *Palaeomeryx* sp.
Eocerus sp.
Perissodactyla
Chalicotherium grande (BLAINVILLE, 1849)
Aceratherium incisivum KAUP, 1832
Anchitherium aurelianense CUVIER, 1812

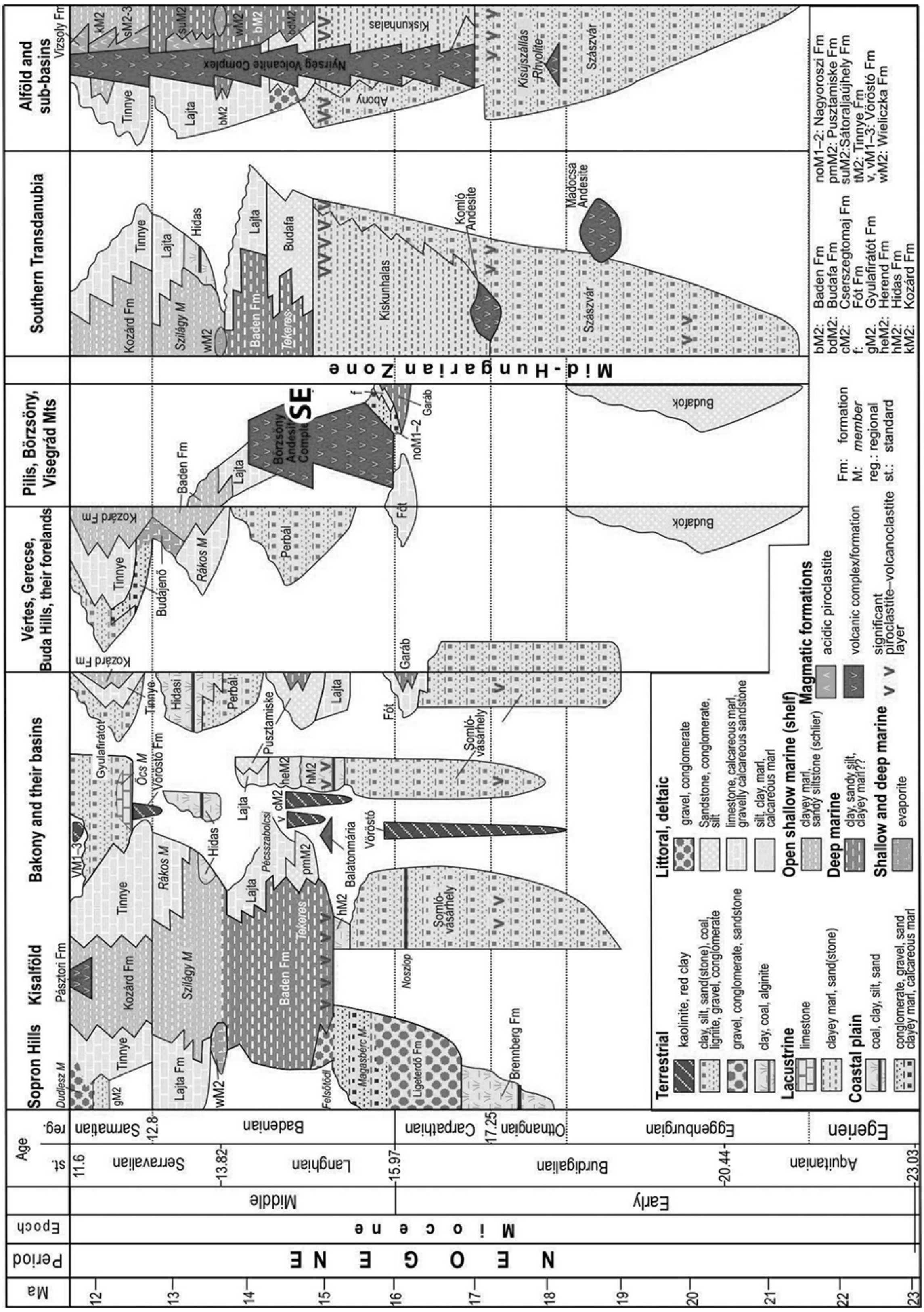

Figure 4. The possible lithostratigraphic and geochronologic context of the fauna Szentendre, Cseresznyés-árok inserted into the table of Babinszki et al. (2023)
Caption: SE – Szentendre, Cseresznyés-árok

4. ábra. *A Szentendre, Cseresznyés-árokban feltárt fauna legvalószínűbb kőzetrétegtani és geokronológiai helyzete a Babinszki et al. (2023) által publikált táblázatba illesztve*
Magyarázat: SE – Szentendre, Cseresznyés-árok

2018 and 2019, three metric tons of samples were unearthed. The above listed rich fauna was collected from that material. From a biochronologic point of view, the most relevant element of the assemblage is *C. aureus*. The stratigraphic importance of this species can be understood in the Northern Alpine Foreland (NAF) Basin. ABDUL AZIZ et al. (2008) found that the vertebrate localities belonging to OSM F local zone are located between the "Brock horizon and the main bentonite layer, both in the Landshut (e.g. Salmannsberg) and the Augsburg area (e.g. Laimering 3) (HEISSIG 2006). *C. aureus* is a characteristic element of these faunas. A 14.925±0.012 Ma $^{206}Pb/^{238}U$ age is published by ROCHOLL et al. (2017) from the Laimering bentonite. Based on the above-mentioned data we conclude that the age of the "*C. aureus* faunas" can be placed between 14.9–15.0 Ma. Based on LUKÁCS et al. (2018: table 2) the Laimering bentonite in the NAF Basin and the Demjén Ignimbrit Unit in the Pannonian Basin migt be correlated. The fifteen occurrences of *C. aureus* are listed by FORTELIUS (2011). All of them are located in Frace, Germany and Switzerland. The species is absent in Spain, in the Balkan and in Anatolia.

The lithostratigraphic relationship of the fossiliferous diatomite with the volcanic rocks of the surrounding area of the Visegrád Mts. is not clear in the "Cseresznyés Trench." The size of the exposure is insuffîcent due to extensive coverage of the Miocene succession by Quaternary colluvium. According to WEIN (1939), MAJZON (1953) and KORDOS (1982), the diatomite is interbedded in the overlying andesitic volcaniclastics. However, HALMAI (1982) published a different concept: after studying the Fót 1, Mogyoród 1 and Budapest 4 boreholes he claimed that the diatomaceous sediment is a member of the Fót Formation (HALMAI 1982) and the overlying tuffite can be correlated with the Tar Dacite Lapilli Tuff Formation. Volcanic stratigraphy of the Visegrád Mts., correlating K-Ar dating and palaeomagnetism, confirmed the ca. 15 Ma age of the andesitic volcaniclastics (KARÁTSON et al. 2007, KARÁTSON 2009). Our results on the vertebrate fauna support this suggestion. In addition, the lithological characteristics of the Szentendre fossiliferous diatomaceous earth are similar to the sediments of the Szurdokpüspöki Formation, while the vertebrate fossil assemblage is older than the fossils from the Hasznos site at the Western Mátra Mountains.

Sirok 1

GPS: N: 47° 55,830', E: 20° 14,094'

The section is given in *Fig. 3.*, faunal list is given in *Table III.* Stratigraphical context is shown in *Fig. 2: SI.*

The locality is found to the east from Sirok village in a section to the side of a forest road. In 2021, one ton of sample was collected by the first author from the tuffaceous sand. The finds were published in a manuscript report (HÍR 2021). The recovered material is not rich, but it is suitable for an approximate biochronologic determination. The taxa *C. sansaniensis* and *D.* cf. *vindobonensis* are known in Neudorf Spalte (=Devinska Nová Ves= Dévényújfalu) close to Bratislava/Pozsony (Slovakia), a paleovertebrate locality of a fissure filling. It is covered by the marine sediments of the Studienka Formation dated at 13.6 Ma by the $^{86}Sr/^{87}Sr$ technique by KOVÁČ & HUDAČKOVÁ (1997). This date can be the potential minimal age of the fossil-bearing karstic sediments.

Table III. Faunal list of the locality Sirok 1
III. táblázat. *A Sirok 1. lelőhely faunalistája*

Keramidomys cf. *thaleri* HUGUENEY & MEIN 1968
Eomyops cf. *oppligeri* ENGESSER, 1990
Paraglis astaracensis BAUDELOT, 1970
Democricetodon cf. *vindobonensis* (SCHAUB & ZAPFE, 1953)
Cricetodon sansaniensis LARTET, 1851
Megacricetodon minor (LARTET, 1851)
Anomalomys gaudryi GAILLARD, 1900

The age relationships of the locality need further studies. The fossiliferous level of the Sirok 1 section is bedded in the reworked volcaniclastics of the Harsány Rhyolite Lapilli Tuff Formation (GÁL et al. 2020, GÁL 2023 personal communication) with an age of 14.361± 0.016 Ma (zircon ID TIMS U-Pb: LUKÁCS et al. 2018).

Such a date can be the potential maximal age of the Sirok fauna hosted in a reworked fossiliferous tuffaceous sand. The occurrences *C. sansaniensis* in Switzerland were published by RUMMEL & KÄLIN (2003): Zeglingen, Niderwis, Oeschgraben, Tschöplihof 720, Mühlrüti, Metlen 4, and referring to KÄLIN & KEMPF (2009), these faunas are classified to the Late MN6 Zone and the local *M. gersii - M. similis local intervallum zone.* From a lithostratigraphic point of view, the localities are found under the Leimbach bentonite. The age of this bentonite layer was determined as 14.2 ± U-Pb Ma by GUBLER et al. (1992), confirming a possible correlation with the Harsány Rhyolite Lapilli Tuff Formation.

We note that close to the Sirok 1 locality there is another exposure (GPS: N: 47° 55,591', E: 20° 14,206'), where 2.5 m greenishgray clay is embedded under the vulcaniclastics (Harsány Rhyolite Lapilli Tuff Formation?). However, in spite of the intense test sampling, this clay yielded no fossil material, only fragments of freshwater molluscs.

Szurdokpüspöki Formation

Hasznos

GPS: N: 47° 55,572', E: 19° 45,528'

The section of the locality is given in *Fig. 3.*, the faunal list is given in *Table IV.* The stratigraphical context is shown in *Fig. 2: H.*

The fossiliferous sediment is unconsolidated duster diatomaceous earth. Its underlying bed is the Nagyharsány Andesite Formation, which (namely, the lower layer of the nearby Sámsonháza section) was dated at 14.99 ± 0.61 Ma by the K–Ar method (PÓKA et al. 2004). The overlying bed of the diatomaceous earth is the alluvial strata of Gombástető (Gombás Hill), which is regarded as belonging to the Sajóvölgy Formation (HÁMOR 1985). The occurrences of the diatomaceous sediments of the Western Mátra Region

Table IV. Faunal list of the locality Hasznos after Hír & Pászti (2012), Kordos 1981, 1986, Kretzoi (1976), Prieto et al. (2015), and Rosina et al. (2015)

IV. táblázat. *A hasznosi lelőhely faunalistája Hír & Pászti (2012), továbbá Kordos 1981, 1986, Kretzoi (1976), Prieto et al. (2015), valamint Rosina et al. (2015) nyomán*

Eulipotyphla & Chiroptera
Parasorex sp.
Lantanotherium sansaniense (Lartet, 1851) vel *Lantanotherium longirostre* Thenius, 1949
Desmanodon aff. *crocheti* Prieto, 2010
cf. *Postpalerinaceus intermedius* (Gaillard, 1899) vel *Mioechinus* sp.
cf. *Paenelimnoecus* sp.
Soricidae gen. et sp. indet.
Crocidosoricidae gen. et sp. indet.
Myotis bavaricus Ziegler, 2014
Miostrellus cf. *petersbuchensis* Rosina & Rummel, 2012
Rodentia
Palaeosciurus ultimus Mein & Ginsburg, 2002
Spermophilinus sp.
Blackia miocaenica Mein, 1970
Microdyromys sp.
Cricetodon hungaricus (Kordos 1986)*
Democricetodon hasznosensis (Kordos 1986)*
Megacricetodon minor (Lartet, 1851)
Eumyarion cf. *bifidus* Fahlbusch, 1964
Anomalomys gaudryi Gaillard, 1900
Perissodactyla
Palaeomeryx eminens Meyer, 1847
Palaeomeryx sp. I-II.
Dorcatherium sp.
Heteroprox elegans Lartet, 1837

were included in the Szurdokpüspöki Formation by Gyalog & Budai (2004). Systematic sampling and the study of the vertebrate material was initiated by Kordos (1985). Intense sampling at Hasznos site was performed by the first author between 2011 and 2013.

The biochronologic classification of the Hasznos fauna changed several times as follows:
"*referred to as the MN6–7 zones*" Kordos (1981)
"*MN8 zone (Sarmatian)*" Kordos (1985)
"*end of Badenian, but rather Sarmatian*" Kordos (1986)
"*MN 6 Zone*" De Bruijn et al. (1993)

The classification of Kordos (1981) was based on the presence of a small-sized ruminant *Heteroprox elegans*. The MN6 classification by De Bruijn et al. (1993) was due to the revision of the finds of *Depertomys hagni hungaricus* n. ssp. (Kordos 1986) from Hasznos, reclassifying them as *Cricetodon hungaricus*. Another important evidence is the m1 of *Anomalomys gaudryi* in Hasznos with a morphotype, which is very close to the same species described from Neudorf (= Devinská Nová Ves/Dévényújfalu: Kordos 1989). This latter fauna is regarded as a typical MN6 assemblage in the Pannonian Basin. This improved classification was accepted by Prieto et al. (2015) after the study of Eulipotyphla. As a consequence, we can correlate the Hasznos fauna with the Middle Badenian and the MN6 zone (Hír et al. 2016, 2017).

Szurdokpüspöki

GPS: N: 47° 50,555', E: 19° 43,828'

Section is figured in Hajós (1968), the faunal list is given in *Table V.*, the stratigraphical context is shown in *Fig. 2: P*.

Between the towns of Szurdokpüspöki and Gyöngyöspata, a diatomaceous earth complex overlies the surface of the Nagyhársas Andesite Member of the Mátra Andesite Complex. The type section of the diatomite is the Szurdokpüspöki open-pit mine. The lowermost part of the section is a dark gray clayey diatomaceous earth with 5 m thickness deposited in a freshwater lake. Two levels were described in this sediment with frequent bone ocurrences (Kretzoi & Pálfalvy 1969). The diatomaceous earth is overlain by a several-m-thick rhyolite tuff (Hajós 1968) whose stratigraphic position, however, is poorly constrained.

Table V. Faunal list of the locality Szurdokpüspöki after Kretzoi & Pálfalvy (1969)

V. táblázat. *A szurdokpüspöki lelőhely faunalistája Kretzoi & Pálfalvy (1969) nyomán*

Proboscidea
Prodeinotherium aff. *bavaricum* (von Meyer, 1831)
Gomphotherium angustidens (Cuvier, 1817)
Perissodactyla
Macrotherium grande (Blainville, 1849)
Brachypotherium brachypus (Lartet, 1837)
"Aceratherium" tetradactylum (Lartet, 1837)
Rhinocerotidarum gen. et sp. indet.

All of them were large sized animals, who visited the lake for a drink or a wallow. Kretzoi & Pálfalvy (1969) postulated that the surroundings of the lake could have been a special ecological islet, because the close neighborhood of the lake was forested, but in the more distant area there might have been a dry scrub. Kretzoi & Pálfalvy (1969) proposed a "Helvetian–Tortonian" age for the diatomaceous earth series. Kordos (1985) published a Badenian age with "MN 6-7 Zones" for the Szurdokpüspöki finds. According to Gasparik (2001: table 1), the fauna can be referred to the Badenian-Sarmatian boundary with the age matching the MN7 Zone. With no microvertebrate finds, a more accurate biochronological classification is not possible.

Lajta Limestone Formation

Sámsonháza 3

GPS: N: 48° 00,162', E: 19° 43,876'

The section is given in *Fig. 3.*, and the faunal list is in *Table VI.* The stratigraphical context is shown in *Fig. 2: M*.

The study of the Miocene rocks and the well-documented fossil localities in the surroundings of the village has a long history (Schafarzik 1892, Strausz 1924, Sümeghy 1924, Noszky 1940, Bogsch 1943, Hámor 1985, Izing 2002, Selmeczi & Szuromi-Korecz 2016, Selmeczi et al.

Table VI. Faunal list of the locality Sámsonháza 3 after HÍR & MÉSZÁROS (2002), and PRIETO et al. (2012)

VI. táblázat. *A Sámsonháza 3. lelőhely faunalistája HÍR & MÉSZÁROS (2002), valamint PRIETO et al. (2012) nyomán*

Eulipotyphla
Parasorex sp.
Lantanotherium sansaniense (LARTET, 1851) vel *Lantanotherium longirostre* THENIUS, 1949
Plesiodimylus sp.
cf. *Paenelimnoecus* sp.
Soricidae gen. et sp. indet.
Desmanodon sp.
Rodentia
Spermophilinus bredai VON MEYER 1848
Muscardinus sansaniensis (LARTET, 1851)
Microdyromys complicatus DE BRUIJN, 1966
Miodyromys aegercii (BAUDELOT, 1972)
Miodyromys aff. *aegercii* (BAUDELOT, 1972)
Megacricetodon minor (LARTET, 1851)
Cricetodon cf. *hungaricus* (KORDOS, 1986)
Eumyarion medius (LARTET, 1851)

2016). From a vertebrae paleontological point of view, the most important localities are the the Szálláska Valley with pebbles and Oszkoruzsa Valley with a lagoonal series (The latter one is mentioned in the historical literature as a "valley leading to the top of the Halastó Hill"). Sporadic finds were reported from these localities: Rodentia indet. (Sciuridae?), Artiodactyla indet. (KORDOS 1985).

The sites of the Oszkoruzsa Valley were sampled by the first author between1995 and 1998. The most diverse fauna was collected from Sámsonháza 3. The studied sites are located close to the type section of the Sámsonháza Formation (HÁMOR 1985). This lithostratigraphic unit was recently reclassified as the Pécsszabolcs Member of the Lajta Limestone Formation (BABINSZKI et al. 2023). The classification of the biochronologic position of the Sámsonháza 3 fauna is based on the following:

- The metrical and morphological characters of *C.* cf. *hungaricus* is close to the type material of *C. hungaricus* from Hasznos. It differs from the material of the type locality in some morphological details such as the lack of the funnel structure and shorter mesolophs in M1, M2. In m1 the lingual anterolophid is absent. It was regarded as an advanced variant of *C. hungaricus* by HÍR & MÉSZÁROS (2002).
- The coexistence of *Muscardinus sansaniensis, Megacricetodon minor, Eumyarion medius*.
- The presence of two sympatric *Miodyromys* species.
- The presence of *Parasorex socialis* in the Euliopytyphlan fauna.

Based on the above, the microvertebrate fauna can be correlated with the MN6 zone.

A rich mollusc fauna was collected from the Sámsonháza 3 locality. It was studied by József Kókay. In the fossil assemblage, marine, restricted marine, and freshwater elements were equally found indicating a lagoon environment. However, the ontogeny of the marine mollusc species was limited because in the restricted marine environment they stayed in larval or in juvenile stage (HÍR et al. 1998).

Synthethising the stratigraphic constraints, the age of Hasznos and Sámsonháza 3 can be estimated between 14.9–14.0 Ma. However, such a Middle Badenian classification is in conflict with the concept of geologists who studied the surroundings of Sámsonháza, i.e., NOSZKY (1940), HÁMOR (1985), and IZING (2002). They classified the vertebrate bearing lagoonal and freshwater series as Sarmatian, following the studies of SÜMEGHY (1924) on the mollusc fauna of the Sámsonháza Vár-hegy ("Castle Hill"). Unfortunately, the identification of this latter historical locality is not possible today.

Sajóvölgy Formation

The localties of Mátraszőlős, Rákóczi-kápolna (Rákóczi Chapel)

Mátraszőlős 1: GPS: N: 47° 57,989, E: 19° 41,078'
Mátraszőlős 2: GPS: N: 47° 57,957', E: 19° 41,101'
Mátraszőlős 3: GPS: N: 47° 57,904', E: 19° 41,116'

The sections are given in *Fig. 5.*, and the faunal list is in *Table VII.* The stratigraphical context is shown in *Fig. 2*: *SZ.*

Green clays with shells of freshwater molluscs, yelow and grey diatomaceous earth and a lignite seam were exposed in the northern surroundings of Mátraszőlős village in a road cut between Gomba Street and the Rákóczi Chapel. This succession was first described by HORUSITZKY (1942). The Late Badenian age determination of the three faunas is based on the rich mollusc material (HÍR & KÓKAY 2004,

Table VII. Faunal list of the localities at Mátraszőlős 1., 2., 3. (SZ 1, SZ 2, SZ 3) after HÍR & KÓKAY (2004, 2011), and HÍR et al. (2016)

VII. táblázat. *A Mátraszőlős 1., 2., 3. (SZ 1, SZ 2, SZ 3) lelőhelyek faunalistái HÍR & KÓKAY (2004, 2011), valamint HÍR et al. (2016) nyomán*

	SZ 1	SZ 2	SZ 3
Eulipotyphla & Chiroptera			
Schizogalerix cf. *voesendorfensis* RABEDER, 1973	+	+	+
Erinaceidae indet.	+		
Paenesorex sp.		+	+
Soricidae gen. et sp. indet.	+		
Plesiodimylus sp. ?	+		
Metacordylodon cf. *schlosseri* (ANDREAE, 1904)	+		
Talpa sp.		+	
Talpidae indet.	+	+	+
Chiroptera div. sp.		+	+
Lagomorpha & Rodentia			
Eurolagus fontannesi (DEPERET, 1887)	+	+	
Spermophilinus bredai (VON MEYER, 1848)		+	
Albanensia sp.			+
Blackia miocaenica MEIN, 1970			+
Muscardinus aff. *sansaniensis* (LARTET, 1851)		+	
Paraglis sp.		+	
Eomyops oppligeri ENGESSER, 1990		+	
Keramidomys mohleri ENGESSER, 1972		+	
Democricetodon cf. *brevis* (SCHAUB, 1925)		+	+
Democricetodon freisingensis FAHLBUSCH, 1964		+	
Megacricetodon minor (LARTET, 1851)	+	+	
Megacricetodon cf. *minutus* DAXNER, 1967			+
Cricetodon sp. I	+	+	
Cricetodon sp. II			+
Eumyarion medius (LARTET, 1851)	+	+	
Eumyarion sp.			+
Anomalomys gaudryi GAILLARD, 1900		+	+

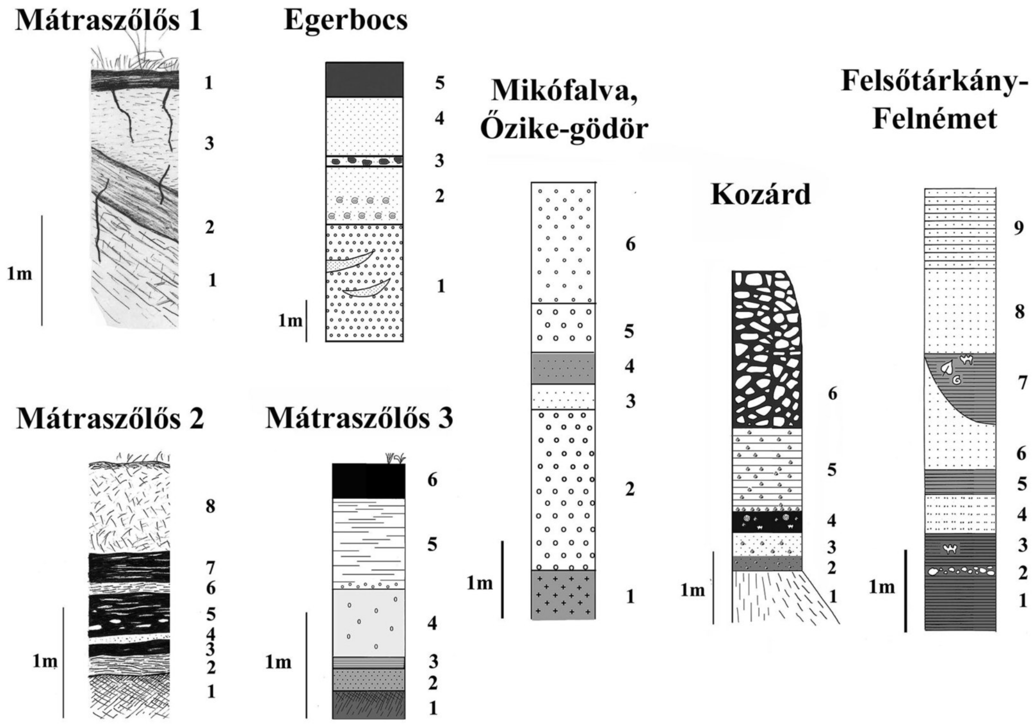

Figure 5. Sections of the studied vertebrate localities Mátraszőlős 1., Mátraszőlős 2., Mátraszőlős 3., Mikófalva, Őzike Trench, Kozárd, Felsőtárkány -Felnémet
Mátraszőlős 1.: 1 – 100 cm green clay containing mollusc shells and bones; 2 – 30 cm yellow diatomaceous mud containing shells and bones; 3 – 40–120 cm colluvium; 4: 20 cm recent soil. Mátraszőlős 2.: 1 – green clay containing mollusc shells and bones; 2 – gray diatomaceous earth containing mollusc shells and bones; 3 – 8 cm lignite; 4 – 5 cm yellow sand; 5 – 20 cm lignite containing gypsum ballstones; 6 – 5 cm greenish gray clay; 7 – 15 cm lignite; 8 – 100 cm greenis gray clay. Mátraszőlős 3.: 1 – dark gray clay; 2 – 20 cm gray silt with mollusc shells and bones; 3 – 10 cm gren clay with mollusc shells and bones; 4 – 60 cm green clay with calcareous concretions having the size of a walnut; 5 – 80 cm debris with small pebles in its lowermost 10 cm; 6 – 30 cm recent soil. Egerbocs: 1 – 300 cm pebble with sandy intercalations; 2 – 130 cm sand with small pebbles containings mollusc shells and bones; 3 – 30 cm sand containing root holes filled by clay; 4 – 150 cm sand; 5 – 70 cm recent soil. Őzike Trench at Mikófalva: 1 – 150 cm rhyolitic tuff; 2 – 200 cm coarse gravel; 3 – 30 cm gray sand containing vertebrate finds; 4 – 40 cm reddish sand; 5 – 60 cm coarse gravel; 6 – 150 cm small pebble. Kozárd: 1 – debris; 2 – reddish calcareous sand containing mollusc shells; 3 – gray calcareous sand containing mollusc shells; 4 – dark gray diatomaceous mud containing molusc shells, Celtis stones and bones; 5 – greenish gray calcareous marl containing mollusc shells; 6 – debris and recent soil. Felsőtárkány-Felnémet: 1 – 70 cm dark gray clay; 2 – 5–10 cm limonitic concretions in dark gray clay; 3 – 40 cm gray clay containing vertebrate finds (FF 2/3); 4 – 50 cm laminated gray sand; 5 – 30 cm laminated gray clay; 6 – 60 cm gray sand; 7 – chanell-filling gray silt and and clay containing plant imprints, mollusc shells and bones (FF 2/7); 8 – 90 cm gray sand; 9 – 100 cm gray sand with calcareous lamina

5. ábra. *A Mátraszőlős 1., Mátraszőlős 2., Mátraszőlős 3., Mikófalva, Őzike-gödör, Kozárd, Felsőtárkány -Felnémet ősgerinces lelőhelyek szelvényei*
Mátraszőlős 1.: 1 – 100 cm puhatestűhéjakat és csontokat tartalmazó, zöld agyag; 2 – 30 cm puhatestűhéjakat és csontokat tartalmazó, sárga, kovaföldes iszap; 3 – 40–120 cm lejtőüledék; 4 – 20 cm recens talaj. Mátraszőlős 2.: 1 – puhatestűhéjakat és csontokat tartalmazó, zöld agyag; 2 – puhatestűhéjakat és csontokat tartalmazó, szürke kovaföld; 3 – 8 cm lignit; 4 – 5 cm sárga homok; 5 – 20 cm lignit gipszkonkréciókkal; 6 – 5 cm zöldesszürke agyag; 7 – 15 cm lignit; 8 – 100 cm zöldeszürke agyag. Mátraszőlős 3.: 1 – sötétszürke agyag; 2 – 20 cm szürke silt puhatestűhéjakkal és csontmaradványokkal; 3 – 10 cm szürke agyag puhatestűhéjakkal és csontmaradványokkal; 4 – 20 cm szürke silt puhatestűhéjakkal és csontmaradványokkal; 5 – 80 cm lejtőüledék, alsó10 cm szintjében apró kavicsokkal; 6 – 30 cm recens talaj. Egerbocs: 1 – 300 cm kavics homokbetelepülésekkel; 2 – 130 cm aprókavicsos homok puhatestűhéjakkal és csontmaradványokkal; 3 – 30 cm homok agyaggal kitöltött gyökérjáratokkal; 4 – 150 cm homok; 5 – 70 cm rcens talaj. Mikófalva, Őzike-gödör: 1 – 150 cm riolittufa; 2 – 200 cm durva kavics; 3 – 30 cm szürke homok gerinces maradványokkal; 4 – 40 cm vörös homok; 5 – 60 cm durva kavics; 6 – 160 cm apró kavics. Kozárd: 1 – lejtőtörmelék; 2 – puhatestűhéjakat tartalmazó, vöröses mészhomok; 3 – puhatestűhéjakat tartalmazó, szürke mészhomok; 4 – puhatestűhéjakat, Celtis-magvakat és csontmaradványokat tartalmazó, sötétszürke, diatomás iszap; 5 – puhatestűhéjakat tartalmazó, zöldesszürke mészmárga; 6 – lejtőüledék és recens talaj. Felsőtárkány-Felnémet: 1 – 70 cm sötétszürke agyag; 2 – 5–10 cm szint limonitkonkréciókkal; 3 – 40 cm gerinces maradványokat tartalmazó, szürke agyag (FF 2/3); 4 – 50 cm laminált, szürke homok; 5 – 30 cm laminált, szürke agyag; 6 – 60 cm szürke homok; 7 – mederkitöltést formázó silt és agyag levéllenyomatokkal, puhatestűhéjakkal és gerinces maradványokkal (FF 2/7); 8 – 90 cm szürke homok; 9 – 100 cm szürke homok laminaszerű mészkiválásokkal

2011). The position in the continental biochronology is based on the occurence of *Democricetodon freisingensis, Democricetodon* cf. *brevis* and a small sized *Megacricetodon* cf. *minor*. This association is characteristic of the MN7+8 zone in the Upper Freshwater Molasse of Southern Germany and Switzerland (Bolliger 1994, Kälin & Kempf 2009).

The lithostratigraphic position of the fossil bearing freshwater sediments at Mátraszőlős can be evaluated based on the results from boreholes Mátraszőlős 1 and 2. The boreholes demonstrate that the studied nonmarine sediments are intercalated between the Lajta Limestone Formation and the Sarmatian Kozárd Formation.The latter one contains "*Mohrensternia* fauna", a characteristic assemblage of the Early Sarmatian (Hír & Kókay 2004). We estimate the age of the Mátraszőlős vertebrate faunas between 13.4–13.0 Ma.

Egerbocs

GPS: N: 48° 00.895', E: 20° 17,285'

The section is given in *Fig. 5*. The faunal list is given in *Table VIII.* The stratigraphical context is shown in *Fig. 2: E.*

The locality is an abandoned open-pit pebble mine situated at the fork of road no. 25 leading to the village of Egerbocs. Referring to the manuscript diary of the self-educated palaeontologist Ferenc Legányi (his handwritten diary is deposited in the Mátra Museum at Gyöngyös), *Chalicotherium* teeth were recovered in the mine during the 1960's. Shells of freshwater molluscs were also mentioned from the mine by Szentes (1959). Five hundred kg sand sample was collected by the first author in 2000 and some rodent teeth were identified.

Table VIII. Faunal list of the locality Egerbocs after HÍR (2001)

VIII. táblázat. *Az egerbocsi lelőhely faunalistája HÍR (2001) nyomán*

Rodentia
Palaeosciurus sp.
Forsythia gaudryi (GAILLARD, 1899)
Megacricetodon sp.
Democricetodon sp.

The flying squirrel *Forsythia* has biochronologic significance because this genus is characteristic of the faunas of M 7+8 Zone (DAXNER-HÖCK & HÖCK 2015).

Mikófalva, Őzike-gödör (Őzike Trench)

GPS: N: 48° 02,095', E: 20° 18,235'

The section is given in *Fig. 5*. and the stratigraphical context is shown in *Fig. 2: E.*

The locality is found in the northwestern foreland of the Bükk Mountains. Alternating bedded strata of Sarmatian freshwater sediments and rhyolitic tuff layers were described from the Őzike Trench based on the geological mapping by DÉR (1957). Otherwise, the surroundings of Mikófalva village are memorable in the Hungarian palaeontological literature for the occurences of well-preserved silicified trunks (ANDREÁNSZKY 1956). The pyroclastic series was defined as the Felnémet Rhyolite Tuff by PELIKÁN (2005), but after the revision of LUKÁCS et al. (2022), the rhyolite tuffs/lapilli tuffs were included in the Harsány Rhyolite Lapilli Tuff Formation. Two *Albanensia albanensis* teeth were collected by HÍR (2019) from the fluvial sand of the Őzike Trench. Based on this sporadic find, we suggest a Sarmatian age and MN 7+8 Zone.

Tinnye Limestone Formation

Kozárd

GPS: N: 47° 55,137' E: 19° 37,142')

The section is given in *Fig. 5*, and the faunal list is given in *Table IX.* The stratigraphical context is shown in *Fig. 2: K.*

The locality is situated in an erosional gully, which is found at the eastern side of the road between the villages of Kozárd and Nagymező Puszta. Limestone, argillaceous limestone, and calcareous sand are exposed in the 300-m-long gully. Well-preserved and extremely rich marine mollusc material is found in these rocks, the fauna of which was first described by BOKOR (1941) who gave only faunal lists. The detailed description was given by BODA (1959, 1972, 1974). The section was classified as the type section of the Kozárd Formation by HÁMOR (1985). Recently, BABINSZKI et al. (2023) reclassified the exposure of Kozárd as part of the Tinnye Limestone Formation.

Table IX. Faunal list of the locality Kozárd after HÍR (2015), and HÍR et al. (2016, 2019)

IX. táblázat. *A kozárdi lelőhely faunalistája HÍR (2015), valamint HÍR et al. (2016, 2019) nyomán*

Rodentia
Albanensia albanensis (MAJOR, 1893)
Spermophilinus bredai (MEYER, 1848)
Muscardinus cf. *sansaniensis* (LARTET, 1851)
Myoglis meini BAUDELOT, 1965
"Cricetodon" cf. *klariankae* HÍR, 2007
Megacricetodon minor – Megacricetodon minutus gr.
Democricetodon sp.
Anomalomys gaudryi GAILLARD, 1900

Microvertebrate finds were first recovered from a 15–20 cm thick dark gray diatomaceous mud layer from the Kozárd section by the first author in 2014. The above listed fauna is the result of the washing of three tons of samples. From a biochronological classification aspect, the most important taxa are the following:

- "*Cricetodon*" cf. *klariankae*, the dominant element of the fauna. Regarding the dimensions and the value of the hypsodonty, it is more evolved than the same characters of "*Cricetodon*" *venczeli* from Vârciorog/Vércsorog, Partium (Transylvania, Romania: HÍR et al. 2019). Notably "*C.*" cf. *klariankae* is close to the "*C." klariankae* described by HÍR (2007) from the Felsőtárkány Basin.
- *Democricetodon* sp. n. (sensu KÄLIN & ENGESSER 2001) also occurs in Kozárd, but it is rare.

In sum, the fauna can be classified as MN 7+8 zone.

The vertebrate-bearing horizon at Kozárd was sampled by TÓTH & CSOMA (2015). They studied Ostracods and Foraminifers and found that the material belonged to the *Elphidium reginum* Zone of the Early Sarmatian. The age of this zone was dated at 12.6–12.3 Ma by GROSS et al. (2014).

The faunas of the Felsőtárkány Basin

The study of Miocene fossils in the vicinity of Felsőtárkány village has a history of more than a century. The sediments, exposed in the northern margin of the settlement (in the "Güdör-kert", *Fig. 6.*) was first mentioned by SCHRÉTER (1913). The fossil molluscs were described by SÜMEGHY (1923, 1924). The vertebrate fossils, collected by Ferenc Legányi, were published by ÉHIK (1926) and KRETZOI (1982). A rich macroflora was collected by Gábor Andreánszky and his students from the section of the "Güdör-kert" (ANDREÁNSZKY & KOVÁCS 1955, ANDREÁNSZKY 1958).

The revision of this fossil flora is given by ERDEI (1999), ERDEI & HÍR (2002), and HABLY (2013).

Microvertebrate faunas were collected by the first author between 2000 and 2007. Continental Sarmatian sediments were described by an earlier geological mapping by (BALOGH & RÓNAI 1965) in the surroundings of the fossil localities. These sediments were classified into the Kozárd Formation recently (PELIKÁN 2005), which is is the overlying bed of the Felnémet Rhyolite Tuff Formation. Based on the revision by LUKÁCS et al. (2022) this formation might be referred to as the Harsány Rhyolite Lapilli Tuff Formation.

The section Felsőtárkány–Felnémet

GPS: N: 57,274', E: 20° 23,490'

The section is given in *Fig. 5*. The faunal list is given in *Table X.* The stratigraphical context is shown in *Fig. 2: F*.

A bicycle-road was constructed between Eger and Felsőtárkány in 2003. Two hillsides were cut during this work, and two fauna-bearing levels were detected in the fresh section of the hillside that is situated closer to Felsőtárkány. The locality Felsőtárkány-Felnémet 2/3 is a dark gray clay, which forms a continuous layer along the section. The locality Felsőtárkány-Felnémet 2/7 is not a continuous layer, exposed only in the northern part of the section. The deposit of this latter locality is a gray silt with reddish patches. *Helix* and *Planorbis* shells and poorly preserved plant fossil were recovered from the silt.

From the biochronological point of view the most important taxa are the following:

• *Anomalomys gaudryi*. The frequency of the *Anomalomys* finds is significantly increased in the faunas of the Felsőtárkány Basin. This genus is rare in the Badenian and Early Sarmatian assemblages. Based on the morphological characteristics, we infer that the Felsőtárkány population is more evolved than the type population of *A. gaudryi* at La Grive (France) and Anwil (Switzerland) (Engesser 1972). However, after the morphology of the mesolophid in m1, the presence of *A. rudabanyensis* can be excluded.

• *Collimys dobosi*. It is the dominant cricetid of the Felsőtárkány faunas. In the Northern Alpine Foreland Basin, the species occurs in Hillenloh. The age of this locality was determined at 11.3 Ma by Kirscher et al. (2016).

• "*Cricetodon" klariankae*. It is a moderately hypsodont cricetodontid, and the last representative of the tribus in the Pannonian Basin. *Cricetodon, Hispanomys* and *Byzantinia* species are absent in the faunas of the "Güdör-kert" section of Felsőtárkány, like in the assemblages of Pannonian age (= Vallesian and Turolian) all over the Carpathian Basin.

Table X. Faunal lists of the localities Felsőtárkány–Felnémet 2/3 (FF 2/3) and Felsőtárkány-Felnémet 2/7 (FF2/7) after Hír (2006), and Hír et al. (2016, 2017)

X. táblázat. *A Felsőtárkány -Felnémet 2/3 (FF 2/3) és a Felsőtárkány -Felnémet 2/7 (FF2/7) lelőhelyek faunalistái Hír (2006), valamint Hír et al. (2016, 2017) nyomán*

Taxon	FF 2/3	FF 2/7
Eulipotyphla		
Schizogalerix voesendorfensis Rabeder, 1973	+	+
Dinosorex sp.	+	+
Paenelimnoecus sp.		+
Crusafontina cf. *exulta* (Franzen et al., 2003)		+
Soricidae gen. et sp. indet.	+	
Proscapanus sp.		+
Desmanella sp.	+	+
Talpa sp.		+
Talpidae indet.	+	
Desmanella sp.		+
Plesiodimylus sp.	+	
Lagomorpha & Rodentia		
Prolagus oeningensis (König, 1825)	+	+
Trogontherium minutum (Von Meyer, 1838)	+	+
Spermophilinus bredai (Von Meyer, 1848)	+	+
Albanensia sp.	+	
Blackia miocaenica Mein, 1970	+	+
Muscardinus sp.	+	+
Myoglis meini Baudelot, 1966	+	+
Microdyromys complicatus De Bruijn, 1966		+
Miodyromys hamadryas (Forsyth-Major, 1899)	+	
Keramidomys sp.	+	+
Eomyops oppligeri Engesser, 1990	+	
Cricetodon klariankae Hír, 2007	+	+
Megacricetodon minor (Lartet, 1851)	+	+
Democricetodon brevis (Schaub, 1925)	+	+
Collimys dobosi Hír, 2005	+	+
Eumyarion medius (Lartet, 1851)	+	+
Anomalomys gaudryi Gaillard, 1900	+	+
Perissodactyla		
Micromeryx sp.	+	
Bovidae indet.	+	
Cervidae indet.	+	
Ruminantia indet.	+	
Bovidae vel Cervidae indet.		+

Felsőtárkány 1 and 2

GPS: N: 47° 58,523' E: 20° 24,704' (1)
GPS: N: 47° 58,522' E: 20°24,708' (2)

The sections ares given in *Fig. 6*., and the faunal lists are given in *Table XI.* The stratigraphical context is shown in *Fig. 2: F*.

Table XI. Faunal lists of the localities Felsőtárkány 1 (FT 1) and Felsőtárkány 2 (FT 2) after Hír & Kókay (2009), and Hír et al. (2016, 2017)

XI. táblázat. *A Felsőtárkány 1. (FT 1) és a Felsőtárkány 2. (FT 2) lelőhelyek faunalistái Hír & Kókay (2009), valamint Hír et al. (2016, 2017) nyomán*

	FT1	FT2
Eulipotyphla		
Schizogalerix voesendorfensis Rabeder, 1973		+
Soricidae gen. et sp. indet.		+
Talpidae indet.		+
Spermophilinus bredai (Von Meyer, 1848)	+	
Lagomorpha & Rodentia		
Eurolagus fontannesi (Deperet, 1887)		+
Pteromyinae indet.		+
Microdyromys complicatus De Bruijn, 1966	+	
Myoglis meini Baudelot, 1965	+	
Glirulus lissiensis (Hugueney & Mein, 1965)		+
Paraglirulus werenfelsi Engesser, 1972	+	
Keramidomys cf. *mohleri* Engesser, 1972	+	
Eomyops oppligeri Engesser, 1990	+	
Megacricetodon minutus Daxner, 1967	+	+
Democricetodon sp.	+	+
Collimys dobosi Hír, 2005	+	+
Anomalomys gaudryi Gaillard, 1900	+	
Perissodactyla		
Micromeryx sp.	+	
Cervidae indet.	+	

The Felsőtárkány 1 and 2 localities are found in the tributary valley of "Güdör-kert." The fossiliferous sediment is green clay in both occurrences. From a biochronological point of view the most relevant components are the following:

• The diverse mollusc fauna. Based on (Hír & Kókay 2009) it is Sarmatian in age.

• *Megacricetodon minutus*. The dimensions of the *Megacricetodon* finds are closer to *M. minutus*. The *Collimys dobosi, Megacricetodon minutus, Democricetodon* sp. hamster association is frequent in the MN 7+8 faunas in the Pannonian Basin.

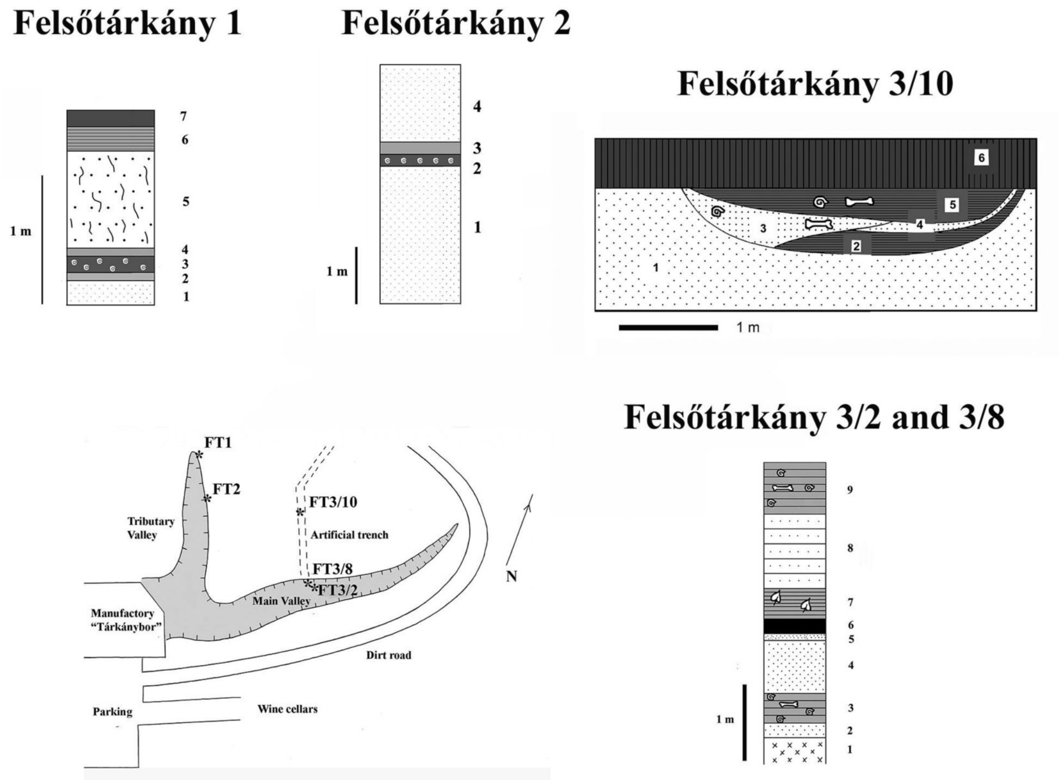

Figure 6. Sketch of the topography at Felsőtárkány "Güdör-kert" and the sections of the vertebrate localities

Felsőtárkány 1.: 1 – gray sand; 2 – 10 cm greenish gray mud; 3 – 20 cm green vlay containing mollusc shells and vertebrate finds; 4 – 10 cm greenish gray mud; 5 – 60 cm gray sand containing fossil roots; 6 – 301 cm debris; 7 – 15 cm recent soil. Felsőtárkány 2.: 1 – 250 cm gray sand; 2 – 20 cm green clay containing mollusc shells and vertebrate fossils; 3 – 20 cm green mud; 4 – 140 cm gray sand. Felsőtárkány 3/2 and 3/8: 1 – rhyolitic tuff; 2 – 20 cm tuffitic sand; 3 – 40 cm gray mud containing mollusc shells and vertebrate fossils (locality 3/2); 4 – 70 cm tuffitic sand; 5 – 10 cm brown sand; 6 – 20 cm lignite; 7 – 40 cm laminated clay containing leaf imprints (Felsőtárkány makroflora); 8 – 100 cm tuffitic sand; 9 – 70 cm green clay containing mollusc shells and vertebrate fossils (locality 3/8). Felsőtárkány 3/10: 1 – gray sand; 2 – brown clay; 3 – yellow sand containing mollusc shells and vertebrate fossils; 4 – red sand; 5 – brown clay containing mollusc shells and vertebrate fossils.

6. ábra. *A Felsőtárkány „Güdörkert" helyszínvázlata és az ősgerinces lelőhelyek szelvénye*

Felsőtárkány1.: 1 – szürke homok; 2 – 10 cm zöldesszürke iszap; 3 – 20 cm zöld agyag puhatestűhéjakkal és gerinces maradványokkal; 4 – 10 cm zöldesszürke iszap; 5 – 60 cm szürke homok gyökérnyomokkal; 6 – 30 cm lejtőtörmelék; 7 – 15 cm recens talaj. Felsőtárkány 2.: 1 – 250 cm sárga homok; 2 – 20 cm zöld agyag puhatestűhéjakkal és gerinces maradványokkal; 3 – 20 cm zöld iszap; 4 – 140 cm szürke homok. Felsőtárkány 3/2 és 3/8: 1 – riolittufa; 2 – tufithomok; 3 – 40 cm szürke iszap puhatestűhéjakkal és gerinces maradványokkal (3/2 gerinces lelőhely); 4 – 70 cm tufithomok; 5 – 10 cm barna homok; 6 – 20 cm lignit; 7 – 40 cm szürke, lemezes agyag levéllenyomatokkal (felsőtárkányi makroflóra lelőhelye); 8 – 100 cm tufithomok; 9 – 70 cm zöld agyag puhatestűhéjakkal és gerinces maradványokkal (3/8 gerinces lelőhely). Felsőtárkány 3/10: 1 – szürke homok; 2 – barna agyag; 3 – puhatestűhéjakat és csontmaradványokat tartalmazó, sárga homok; 4 – vörös homok; 5 – puhatestűhéjakat és csontmaradványokat tartalmazó, barna agyag; 6 – recens talaj

Felsőtárkány 3/2

GPS: N: 47° 58,526' E: 20° 24,715'

The section is given in *Fig. 6*, and the faunal list is given in *Table XII.* The stratigraphical position is shown in *Fig. 2: F*.

It crops out in the main valley of "Güdör-kert." This locality revealed the most abundant and most diverse fossil material, and it most probably corresponds to the "historic" locality, which was studied by scholars at the beginning of the 20th century. The locality was sampled by the first author between 2000 and 2005, and six tons of sediment was obtained. The most important elements (with biochronological relevance) are the following.

- A diverse nonmarine mollusc fauna. Referring to Kókay (in Hír et al. 2001) it can be classified into the Sarmatian.
- *Muscardinus* sp. The population has a special morphology and differs from *M. hispanicus*. This latter species is charactersitic in Late Astarcian–Early Vallesian faunas.
- *Albanensia grimmi*. This large-sized flying squirrel population is different from the Early Sarmatian *Albanensia albanensis* finds and also different from the *Albanensia* population of Rudabánya (MN9) (Hír 2019).
- Presence of *Megacricetodon minutus, Anomalomys gaudryi* and *Collimys dobosi* (type population of the species).

Felsőtárkány 3/8 and 3/10

GPS: N: 47° 58,526' E: 20° 24,715' (3/8)
GPS: N: 47° 58,539' E: 20° 24,700' (3/10)

The sections are given in *Fig. 6*. The faunal lists are given in *Table XIII.* The stratigraphical position is shown in *Fig. 2: F*.

From lithostratigraphic and biochronologic aspects, the faunas FT 3/8 and FT 3/10 are the uppermost and youngest fossil assemblages within the Felsőtárkány Basin. They contain species that are found in Early Pannonian (MN9) faunas: *Microtocricetus molassicus, Eomyops oppligeri, Glis vallesiensis*. However, the dominant element of these faunas is *C. dobosi*. It is important to note that in the Early Vallesian faunas of the Vienna Basin (Vösendorf, Inzersdorf, Hennersdorf, Götzendorf, Richardhof-Golfplatz, Richardhof-

Table XII. Faunal list of the locality Felsőtárkány 3/2. Updated list is after BEGUN et al. (2006), HÍR & KÓKAY (2010), and HÍR el al. (2016, 2017)

XII. táblázat. *Felsőtárkány 3/2 lelőhely javított faunalistája BEGUN et al. (2006), HÍR & KÓKAY (2010) és HÍR el al. (2016, 2017) nyomán*

Eulipotyphla
Schizogalerix voesendorfensis (RABEDER, 1973)
Dinosorex sp.
Crusafontina cf. *exulta* (FRANZEN et al., 2003)
Soricidae gen. et sp. indet.
Proscapanus sp.
Talpa sp.
Desmanella sp.
Talpidae indet.
Primates
Pliopithecoidea gen. et sp. indet.
Lagomorpha et Rodentia
Eurolagus fontannesi (DEPERÉT, 1887)
Trogontherium minutum (VON MEYER, 1838)
Spermophilinus bredai (VON MEYER, 1848)
Miopetaurista sp.
Albanensia grimmi (BLACK, 1966)
Neopetes sp.
Blackia miocaenica MEIN, 1970
Muscardinus sp.
Paraglirulus werenfelsi ENGESSER, 1972
Myoglis meini BAUDELOT, 1965
Keramidomys mohleri ENGESSER, 1972
Megacricetodon minutus DAXNER, 1967
Eumyarion medius (LARTET, 1851)
Collimys dobosi HÍR, 2005*
Anomalomys gaudryi GAILLARD, 1900
Perissodactyla
Micromeryx sp.
Cervidae indet.
Bovidae indet. vel Cervidae indet.

Table XIII. Faunal list of the localities Felsőtárkány 3/8 (F 3/8) and Felsőtárkány 3/10 (F 3/10) after HÍR et al. (2016), and HÍR & KÓKAY (2010)

XIII. táblázat. *Felsőtárkány 3/8 (F 3/8) és Felsőtárkány 3/10 (F 3/10) lelőhelyek faunalistái HÍR et al. (2016) és HÍR & KÓKAY (2010) nyomán*

	F 3/8	F 3/10
Eulipotyphla		
Schizogalerix voesendorfensis RABEDER, 1973	+	+
Crusafontina cf. *exulta* (FRANZEN et al., 2003)		+
Soricidae gen. et sp. indet.		+
Proscapanus sp.	+	+
Talpa sp.	+	+
Talpidae indet.	+	
Desmanella sp.		+
Lagomorpha & Rodentia		
Eurolagus fontannesi (DEPÉRET, 1887)	+	+
Trogontherium minutum (VON MEYER, 1838)		+
Neopetes sp.		+
Muscardinus sp.		+
Myoglis meini BAUDELOT, 1965		+
Glirulus cf. *lissiensis* (HUGUENEY & MEIN, 1965)	+	
Paraglirulus werenfelsi ENGESSER, 1972	+	+
Glis vallesiensis AGUSTI, 1981		+
Eomyops oppligeri ENGESSER, 1972	+	+
Keramidomys mohleri ENGESSER, 1972		+
Megacricetodon minutus DAXNER, 1967		+
Collimys dobosi HÍR, 2005		+
Eumyarion medius (LARTET, 1851)	+	+
Microtocricetus molassicus FAHLBUSCH & MAYR, 1975	+	+
Anomalomys gaudryi GAILLARD, 1900	+	+

Wald), *Collimys* is absent (DAXNER-HÖCK & HÖCK 2015). The mollusc material is regarded as representing Sarmatian (HÍR & KÓKAY 2010). We postulate that FT 3/8 and FT 3/10 faunas are older than the *Hippotherium* date and their most probable age is between 11.8–11.1 Ma. This is in good agreement with the age of the fauna of Hammerschmiede in Southern Germany where *Microtocricetus molassicus* and *Collimys* were described, and the age is dated at 11.62 Ma based on magnetostratigrphic correlation (KIRSCHER et al. 2016).

Conclusions

After two decades of field activity, we have demonstrated that microvertebrate faunas can be successfully collected from the Badenian and Sarmatian nonmarine sediments of Northern Hungary, including the Visegrád Mountains. For a long time, these rocks were not considered to have any perspective from a vertebrate paleontological point of view. The study of Badenian and Sarmatian microvertebrate faunas allows lithostratigraphic and chronologic conclusions and it has important systematic and palaeoecologic implications.

1. Regarding the Middle Badenian freshwater sediments at Litke, we (HÍR 2013) disproved its former classification as Karpatian by HÁMOR (1985) and BARTKÓ (1985).

2. The Middle Badenian age of the lagoonal series of Sámsonháza has been verified (HÍR & MÉSZÁROS 2002), while its former historical classification by SÜMEGHY (1924), NOSZKY (1940), HÁMOR (1985), IZING (2002) in the Sarmatian was refuted.

3. In the case of the freshwater sediments of the Felsőtárkány Basin, we gave a more accurate chronological classification than the Early Pannonian concept of KRETZOI (1982).

4. The presented biochronological data on Szentendre, Cseresznyés Trench, and Sirok 1, and the radiometric ages obtained on the volcanic rocks of the Visegrád Mountains and the rhyolite tuffs close to Sirok 1 sites, confirm each other.

Acknowledgements

The field work and the study was supported by the completed projects no. T029148, T046719 and T115472 and the ongoing K131894 project of the Hungarian Scientific Research Fund (OTKA) and the SYNTHESYS Projects (NL-TAF-619 (2010), ES-TAF-624 (2010), AT-TAF-2187 (2012), ES-TAF-2742 (2013) http://www.synthesys.info/ which were financed by the European Community Research Infrastructure Action under the FP6 and FP7 B Capacities Programs. Support from the "Genius Program" of the Hungarian Cultural Fund (NKA) project no. 650132/00031 is acknowledged.

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Manuscript received: 18/10/2023