

Small mammals from Vértesacsza as a contribution to chronology of the late Miocene Zagyva Formation (W Hungary)

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Abstract: The small fossils (Rodentia and Eulipotyphla) from Csönget-Völgy near Vértesacsza in Western Hungary are presented herein; and although the assemblage contains relatively poor material, we describe nine rodent taxa and two insectivore species. The rodents are *Apodemus lugdunensis*, *Kowalskia cf. polgardiensis*, *Anomalospalax cf. tardosi*, *Lophocricetus cf. cimishliensis*, *Keramidomys ermannorum*, *Eomyops sp.*, *Muscardinus sp.*, *Spermophilinus sp.*, and fragmentary beaver remains. Insectivores include *Petenya hungarica* and *Asoriculus gibberodon*. Correlation with Turolian, late Miocene is proposed based on rodent assemblage. A minor overlap of presented biostratigraphic age with authigenic ¹⁰Be/⁹Be ages obtained from the same locality is discussed. This locality adds important information to our knowledge of deposits and chronology of the late Miocene Zagyva Formation.

Keywords: Transdanubian Range, late Miocene, Turolian, stratigraphy, Mammalia, cosmogenic nuclide.

1. INTRODUCTION AND GEOLOGICAL SETTING

Dating Cenozoic terrestrial sedimentary sequences is challenging, especially when they are in an intra-continental setting, without volcanic interlayers and far too old to apply standard Quaternary radiometric dating methods. The biostratigraphy of small mammals is a strong tool to overcome insufficiency in age calibration. We apply this approach to the Zagyva Formation which formed a few thousand meters thick sedimentary column of alluvial origin accumulated in the Pannonian Basin System following Lake Pannon regression (Sztanó et al., 2013, Magyar et al., 2013). Its age in specific areas is debatable and while the time span covers the Tortonian-Messinian to the Pliocene, precise dating of this sequence is extremely important because its accumulation history has implications for timing of basin formation phases and subsequent deformation during inversion (Horváth, 1995; Fodor et al., 2005).

Our interest focuses on the southeastern flanks of the Transdanubian Range (Fig. 1B) which divides the Great Hungarian Plain from the Danube Basin to the northwest. Outcrops of the Miocene strata rim the margins of the pre-Cenozoic massive due to basin inversion and related differential vertical movements (Horváth, 1995; Ruzsiczay-Rudiger et al., 2016). The late Miocene sedimentary column consists of a shallow lacustrine Szák Formation in the Vértesacsza area, followed by regressive deltaic Beladice Fm. and capped by alluvial Zagyva Fm. reaching thickness up to 150 m (Csillag et al., 2002; Csillag et al., 2008; Uhrin et al., 2011, Sztanó et al., 2013).

The area forms part of the Vertés Hills, characterized by moderate topography covered by Quaternary loess deposits. This area, however, is subject of intense gully erosion which forms outcrops of late Miocene sequence and one of these

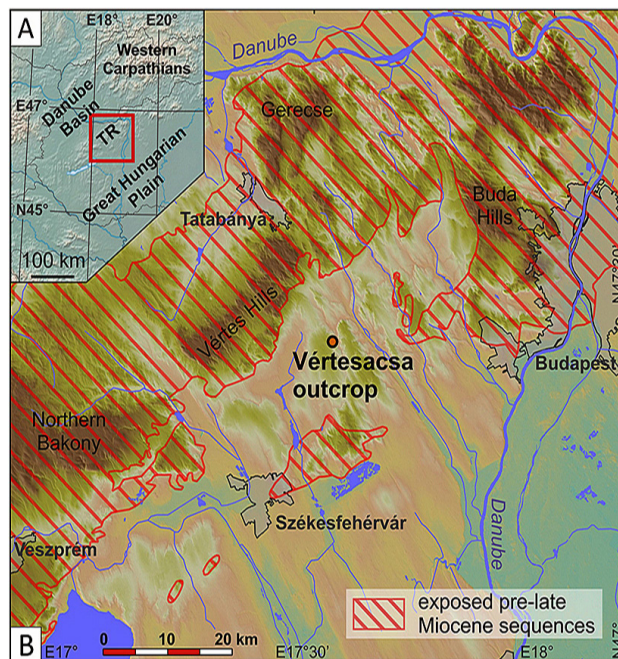


Fig. 1. Location of the study area. A. The area of interest is located on the southern flanks of the Transdanubian Range (TR); B. The Vértesacsza outcrop is located in a late Miocene depression in the Vértes Hills.

gullies with spectacular dimensions is in the Csönget-Völgy locality near Vértesacsza (Lat: 47.39074; Lon: 18.55706). The exposed succession reaches more than 7 m in height and is up to 300 m long (Fig. 2; Uhrin et al., 2011) with a channel belt of trough cross-stratified medium to fine sands and silty-fine sandy intercalations in the upper portion. The channel belt is incised in floodplain deposits observable in the lowermost

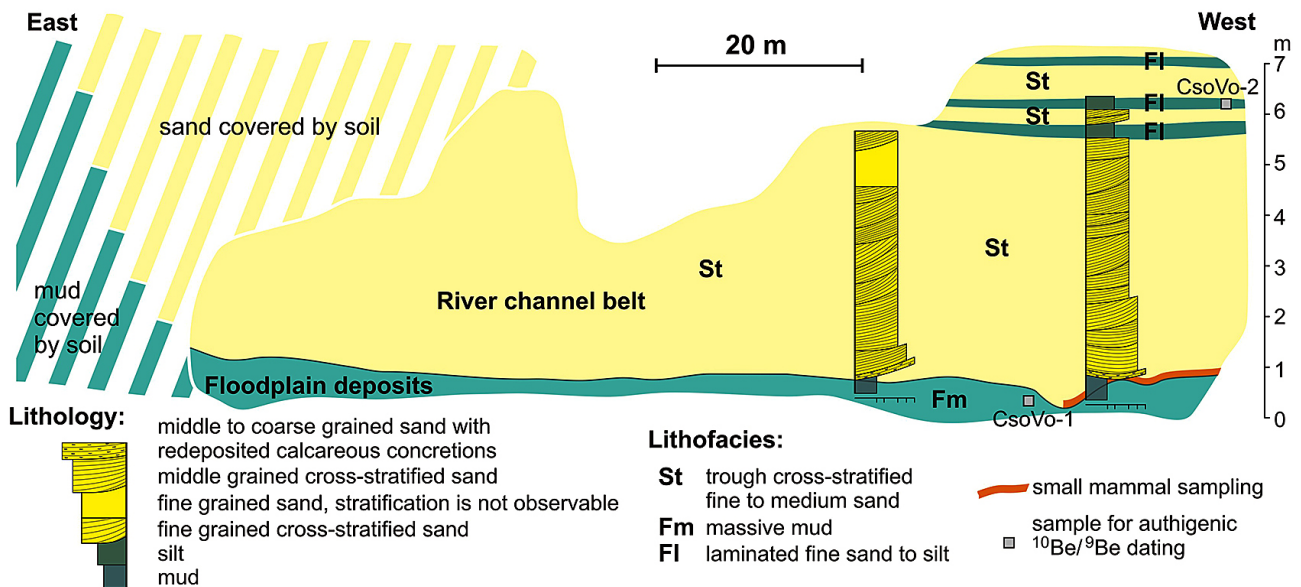


Fig. 2. Sketch of the Csönget Valley outcrop redrawn from Uhrin et al. (2011), with indication of sampling for small mammal biostratigraphy.

part of the outcrop. A 10 cm thick horizon of medium to coarse sand with redeposited concretions and clay intraclasts is preserved at the base of the fluvial cross-stratified sets, and this was subjected to sampling (Fig. 2). While previous age determinations here were based only on paleogeographic context, the authigenic $^{10}\text{Be}/^9\text{Be}$ dating method was recently applied to the studied outcrop (Šujan et al., 2016), with two analyzed samples yielding ages of 8.77 ± 0.60 Ma and 9.65 ± 0.80 Ma.

2. METHODS

Approximately 2 tons of sediment from Vértesacsza was sieved on a set of stable sieves (Daams & Freudenthal, 1988). Fossil remains were retrieved manually under the stereo-microscope. The material described here is housed in the Pásztó Municipal Museum collections.

The upper cheek teeth are indicated by upper case and the lower cheek teeth by lower case. Where distinction between first and second molars is questionable, these are indicated as m1/2 or M1/2. Teeth measurements in mm were taken by calibrated micrometer eyepiece on a Leica MZ75 stereomicroscope; providing rodent cheek teeth occlusal surface maximum length and width (L x W) unless otherwise stated. For insectivores, we also provide the trigonid width (TRW) and talonid width (TAW) on a molar and also the height (H) of incisors. Terminology used for teeth parts follows Reumer (1984) for Soricidae; van de Weerd (1976) for Murinae; Daams & Freudenthal (1988) for Cricetidae; de Bruijn (1967) for Gliridae; Engesser (1990) for Eomyidae; Cuenca Bescós (1988) for Sciuridae; and Delinschi (2014) for Lophocricetidae. Taxa were studied by direct comparison with specimens held at the Department of Geology and Paleontology, Comenius University in Bratislava, the Pásztó Municipal Museum and published data of type materials.

3. SYSTEMATIC PALEONTOLOGY

Order Eulipotyphla Waddell et al., 1999
 Family Soricidae Fischer, 1817
 Subfamily Soricinae Fischer, 1817
 Tribe Soricini Fischer, 1817
 Genus *Petenya* Kormos, 1934
Petenya hungarica Kormos, 1934
 (Fig. 3A)

Material: 1 right i1 fragment (VE43, H 1.20 mm)

Description: The lower incisor is bicuspluate, or slightly tricuspluate with the presence of a minute third posterior cusplue. The cusplues are not very prominent and the buccal cingulum is absent. The shape of the light orange pigmentation is typical, compared to specimens illustrated by Reumer (1984, pl. 16, fig. 6a).

Tribe Soriculini Kretzoi, 1965
 Genus *Asoriculus* Kretzoi, 1965
Asoriculus gibberodon (Petényi, 1864)
 (Fig. 3C-D)

Material: 1 left i1 (VE39, H 0.83 mm); 1 left m1 (VE37, L 2.93 mm).

Description: The lower incisor is most likely bicuspluate with prominent cusplues and the lingual cingulum is well developed. Although the cingulum on m1 is missing, the buccal re-entrant valley opens directly above the tooth margin. An entoconid crest is present and the entoconid and entostylid are separated by a clearly visible groove.

Eulipotyphla gen. et sp. indet.
 (Fig. 3B)

Material: 1 left m2 (VE44, L 2.03 mm, TRW 1.22 mm, TAW 1.09 mm)

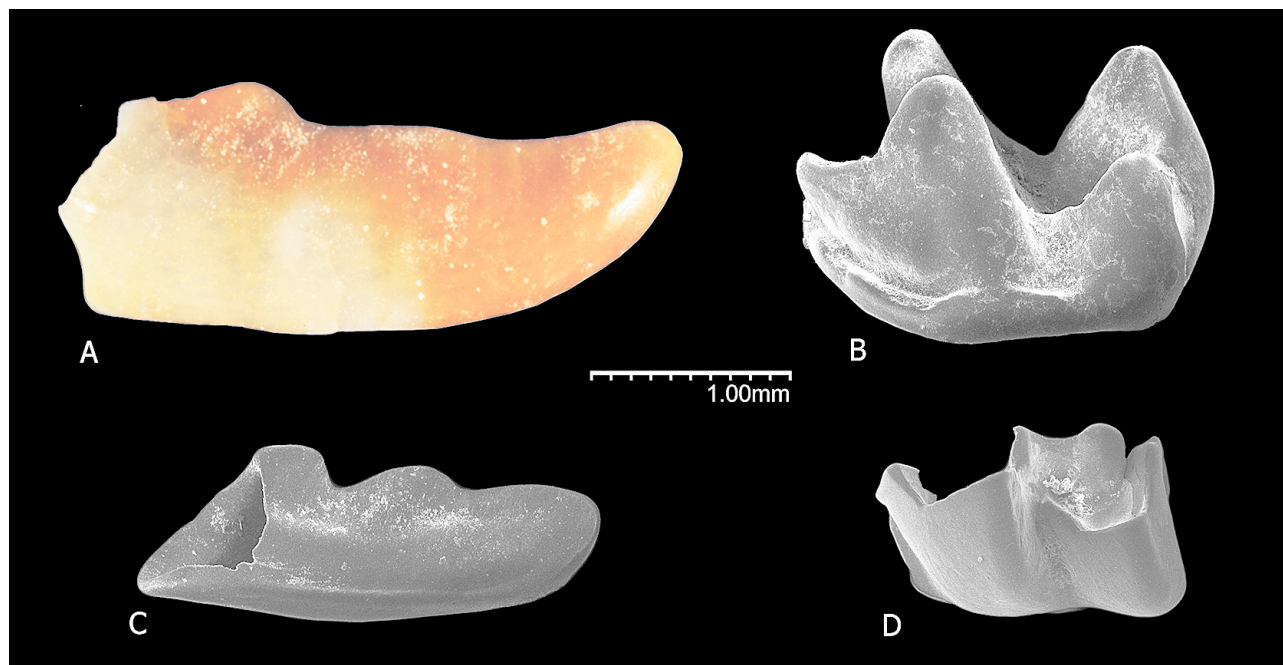


Fig. 3. A. *Petenyia hungarica*, i1 (VE43); B. *Eulipotyphla* gen. et sp. indet., m2 (VE44); C-D. *Asoriculus gibberodon*, C. i1 (VE39), D. m1 (VE37).

Description: The tooth is short and broad, and the entoconid is high without an entoconid crest. The buccal cingulum is well-developed and reaches anteriorly almost to the front of the teeth. The buccal re-entrant valley opens directly above the cingulum. The large size of this tooth is very characteristic, but its precise determination is impossible due to poor preservation.

Order Rodentia Bowdich, 1821
 Family Muridae Illiger, 1811
 Subfamily Murinae Illiger, 1811
 Genus *Apodemus* Kaup, 1829
Apodemus lugdunensis (Schaub, 1938)
 (Fig. 6A–F)

Material: 4 M2 (VE03 1.27 x 1.17; VE04 1.2 x 1.23; VE08 1.24 x 1.26; VE19 1.08 x 1.1), 2 m1 (VE01 1.67 x 1.22; VE06 - x -), 2 m2 (VE02 1.24 x 1.04; VE07 - x -), 2 m3 (VE05 1.08 x 0.94; VE22 - x -).

Description: Most specimens are preserved as enamel only, and none have preserved roots.

M2- the tooth outline is oval with a small indentation between t1 and t4. t1 is larger than t3 and both cusps are connected to the anterior wall of t5. The connection between t6 and t9 is present in all specimens. While t7 is missing in specimen VE19, it is developed as a low crest in another two (VE08, VE04) and as a very small cusp in specimen VE03. t9 is placed anteriorly to t8 and t12 is developed as a small crest.

m1 - the anteroconid cusp is small and low, connected to the lingual anteroconid. The lingual and labial anteroconid cusps are equally developed, and the anteroconid-protoconid connection is central and weak. The longitudinal crest is absent and the terminal heel is oval and connected to the entoconid. The posterior accessory cusp (c1) is pronounced with low connection to the

hypoconid, while the accessory cusp next to the protoconid is smaller and separated. The labial border has only cingulum, and no other accessory cusps.

m2 - this material is fragmentary; one tooth with a damaged central part and one fragment with preserved lingual and posterior tooth portions. The antero-labial cusp is low and connects to the anterior wall of the protoconid. There are two labial accessory cusps developed on the low labial cingulum. The posterior heel is oval and connects to the hypoconid and entoconid.

m3 - one specimen has only tooth enamel preserved and the second has a damaged anterior wall. The antero-labial cusp is developed as a small and low ridge connected to the base of the protoconid and the protoconid and metaconid are connected. The hypoconid is fused with the entoconid forming a large sub-triangular cusp in one specimen while the cusp in the second specimen is curved and tear-shaped.

Remarks: Martín-Suárez & Mein (1998) provided a revision of the taxonomy of the genera *Apodemus* and *Parapodemus*, transferring most *Parapodemus* species to *Apodemus* and providing an emended diagnosis. Features enabling us to identify this small-sized murid as belonging to the genus *Apodemus* are; connecting crest between t4 and t8; united t6 and t9; presence of t12; missing t1bis on upper molars; missing longitudinal connections between cusps in lower molars and development of an anteroconid cusp in m1. Based on the small size and morphology which corresponds well to *A. lugdunensis*, the Vértesacsa material can be attributed to this species. All other late Miocene and Pliocene *Apodemus* species are significantly larger with more advanced morphology (Daxner - Höck & Höck, 2015). The small size of the molars, especially in specimen VE19, is also comparable with some *Occitanomys* species. However, this assignment is less likely because of different morphology and there is also no known record of *Occitanomys* in Central Europe.

Family Cricetidae, Rochebrune, 1883

Subfamily Cricetidae, Murray, 1866

Genus *Kowalskia*, Fahlbusch, 1969

Kowalskia cf. *polgardiensis* (Freudenthal & Kordos, 1989)

(Fig. 6G–L)

Material: 4 M2 (VE10 1.82 x 1.46; VE11 1.73 x 1.45; VE12 1.76 x 1.52; VE82 1.9 x 1.52), 5 M3 (VE13 1.46 x 1.44; VE14 - x -; VE15 1.4 x 1.35; VE80 1.42 x 1.22; VE81 1.64 x 1.42), 2 m2 (VE16 - x -; VE17 1.74 x -).

Description: M2 - the labial and lingual branch of the anteroloph are equally developed. The mesoloph is long in two specimens and has medium length in another. Both protoloph and metaloph are double in all specimens. The anterior metaloph connects to the mesoloph and the posterior metaloph connects with the posteroloph which is well developed and encloses the posterosinus.

M3 - the lingual anteroloph is weaker than the labial. The protoloph is double and the metaloph is always complete; with a short, anteriorly directed pendicle in some specimens. The mesoloph is variable, either absent, short or long and reaching the labial margin of the tooth. The hypocone and metacone are connected within the posterior wall and a weak interruption is present in two specimens.

m2 - only one molar with damage in the metaconid area and one posterior portion of a molar were found. The mesolophid is long, almost reaching the tooth lingual border. The hypolophulid is single and directed anteriorly. There is a small protuberance at the point where the hypoconid meets the posterolophid. The posterolophid descends smoothly after this protuberance towards the posterolingual wall of the entoconid. The roots are not preserved.

Remarks: The synonymy of *Kowalskia* and *Neocricetodon* suggested by Freudenthal et al. 1998 is still subject to dispute and detailed discussion is beyond the scope of this paper. Daxner Höck & Höck (2015), Sinitsa & Delinschi (2016) and references therein contain the most recent references, and we follow the Daxner-Höck & Höck (2015) use of *Kowalskia* in the European record until *Kowalskia* and *Neocricetodon* synonymy is proven. Measurements of the quite scarce material from Vértesacsza correspond well with the *Kowalskia polgardiensis* described by Freudenthal & Kordos (1989) from Polgárdi (MN13). However, it also corresponds to the upper range of *Kowalskia fahlbuschi* described by Bachmayer & Wilson (1970) from Kohfidisch (MN11) and partly to the lower range of *Kowalskia magna* described by Fahlbusch (1969) from Podlesice (MN14). Our limited material differs from *K. fahlbuschi* in always having double M2 metaloph, and from *K. magna* by less reduced M3. While the morphology and dimensions of the molars from Vértesacsza fit with *K. polgardiensis*, several typical dental features important for species determination, especially in the lower m1 and upper M1, are not present in our collection. Therefore, determination of these isolated cheek teeth at the species level cannot be made with certainty.

Subfamily Anomalomyiinae Schaub, 1925

Genus *Anomalospalax* Kordos, 1985

Anomalospalax cf. *tardosi* Kordos, 1985

(Fig. 6M–N)

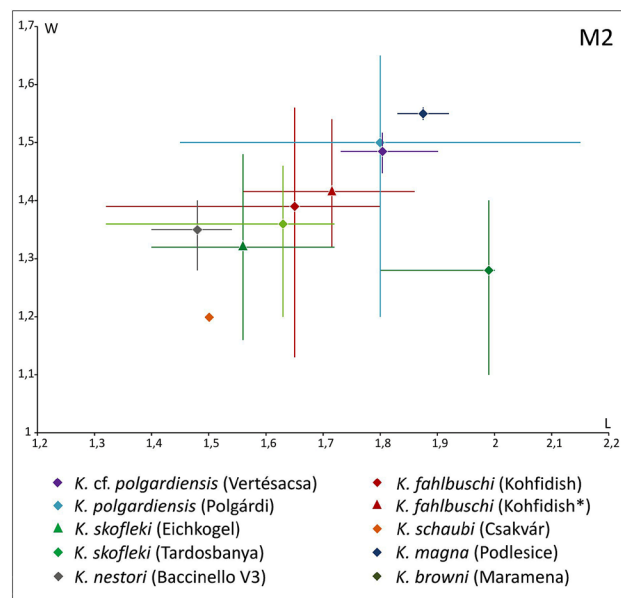


Fig. 4. Scatter diagram of length against width in the second upper molars of *Kowalskia*. Data after Fahlbusch (1969), Daxner Hock (1972), Bachmayer & Wilson (1980), Kordos (1987), Engesser (1989), Freudenthal & Kordos (1989), Daxner-Höck (1995), and Freudenthal et al. (1998). * Measurements provided by Freudenthal et al. (1998).

Material: Right M1 (VE027 - x 1.74), right M2 (VE028 1.86 x 1.66).

Description: M1 - the tooth is slightly worn with small damage on the anterior wall. The anterior lobe is connected to the intermediate lobe by a thin enamel bridge, and therefore the sinus and anterosinus are not united. The intermediate lobe (paracone-hypocone) is connected to the posterior lobe (posteroloph-metacone) in the hypocone area by a metaloph (?) - forming a small, deep enamel island. The mesosinus is approximately the same length as the anterosinus and a small indentation is developed from the mesosinus towards the metacone. The roots are not preserved.

M2 - only outer enamel of the tooth is preserved. The anterior lobe is isolated and the paracone is completely isolated from the rest of the intermediate lobe by a shallow valley. The anterior enamel of the intermediate lobe continues to the posterior lobe and completely surrounds both posterior and posterolabial margins of the tooth; thus the intermediate and posterior lobes are connected lingually. The posterocentral part of the tooth is missing and roots are not preserved.

Remarks: The teeth from Vértesacsza are slightly smaller than *Anomalomys gaillardi* and larger than *Anomalomys gaudryi*. While sizes in our material correspond well to the *Anomalospalax tardosi* from Tardosbánya (MN12) described by Kordos (1985), this author provided detailed description only for the lower dentition and his illustrated specimens are only of adult and worn specimens. Therefore, morphological variability in relatively unworn upper specimens remains unclear. Hordijk & de Bruijn (2009) consider the genus *Anomalospalax* Kordos 1985 a junior synonym for genus *Prospalax* Mehély 1908. We consider the suggested synonymy as possible, but poorly illustrated

Anomalospalax material precludes proof. Therefore, we maintain the generic name *Anomalospalax*, at least until morphological variability of all dental elements of *Anomalospalax* are confirmed. Nevertheless, while the general tooth pattern and size of our material appears to correspond to *A. tardosi*, the possibility that it represents some advanced *Anomalomys* species cannot be excluded. We therefore prefer to leave this species in open nomenclature until further material is available.

Family Dipodidae Fischer, 1817
Genus *Lophocricetus* Schlosser, 1924
Lophocricetus cf. *cimishliensis* Delinschi, 2014
(Fig. 6O)

Material: 1 right m1 (VE021 1.62 x 1.08).

Description: The tooth crown is relatively high with deep main sinusids. The anteroconid is a small but distinctive cusp with low connection to the metaconid. The protoconid is tear-shaped and connects to the anterior arm of the metaconid. The mesoconid is a strong triangular cusp. The ectomesolophid is well developed, reaching the low ectostylid. A distinctive ridge (mesolophid?) running lingually from ectolophid is developed on the posterior metaconid wall. The mesostylid is absent. The entoconid is connected to mesoconid and hypoconid. The posterostylid is low, posteriorly elongated and connected to the labial wall of the hypoconid. The hypoconulid is strong; forming a posterolophid and connecting to the posterior arm of the hypoconid. The ectosinusid is oriented anteriorly while sinus between mesoconid and hypoconid and endosinusid are oriented posteriorly and the posterior endosinusid is transverse. The roots are not preserved.

Remarks: The rather large size, connection of the hypoconid to entoconid and protoconid connected to the metaconid distinguish our specimen from *Heterosminthus* and *Paralophocricetus* and enable us to identify it as *Lophocricetus*. The lower molar of *Lophocricetus* from Vértésacsa corresponds in size with those of *L. cimishliensis* but also fits the lower range of *Lophocricetus vinogradovi* and *Lophocricetus grabaui*. Delinschi (2014) described a new species *L. cimishliensis* from Turolian deposits in the Republic of Moldova which shows great variability in dental morphology. Some specimens figured by Delinschi (2014, fig. 3.12-13) have developed "a rudimentary ridge between the protoconid and mesoconid" and a similar ridge (mesolophid?) is developed on the metaconid posterior wall of our specimen. Qiu (1985, p. 49) also reports a similar ridge in the large population of *L. grabaui* from Mongolia, but only on three teeth (Ertemte 2 and Harr Obo 2). Most distinctive characters for *Lophocricetus* species, however, are associated with the upper molars and it is therefore difficult to make advanced comparison with other taxa based on the single m1 available from Vértésacsa. For this reason we prefer to leave this form in open nomenclature. Nevertheless, the presence of *Lophocricetus* in Vértésacsa is the westernmost occurrence of the genus so far.

Family Eomyidae Depéret & Douxami, 1902
Genus *Keramidomys* Hartenberger, 1966
Keramidomys ermannorum Daxner-Höck & Höck, 2009
(Fig. 6P)

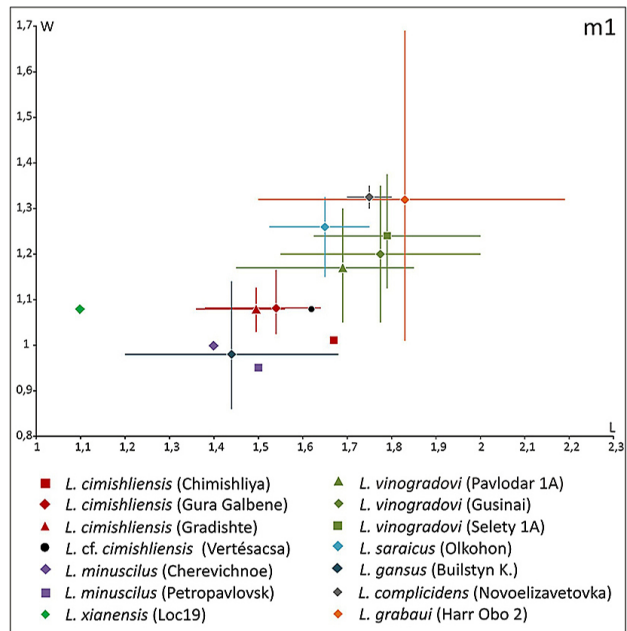


Fig. 5. Scatter diagram of length against width in the lower first molars of *Lophocricetus*. Data after Topachevski et al. (1984), Qiu (1985), Daxner-Höck (2001), Zazhigin et al. (2002), Qiu et al. (2008), and Delinschi (2014).

Material: 1 left M1 (VE025 0.79 x 0.92).

Description: The occlusal surface is flat and rectangular. The longitudinal crest is weak but complete. The protocone is dominant. The protoloph is thin, oblique and curved anteriorly and the mesoloph is long and connected to the paracone. 1st, 2nd and 4th synclines are labially closed while 3rd syncline is labially open. The sinus is strongly curved anteriorly. The metaloph is slightly curved posteriorly and connected to the metacone. The posteroloph is long, forming the posterior margin of the occlusal surface and connecting to the metacone. The roots are not preserved.

Remarks: The only available *Keramidomys* tooth has a flat occlusal surface, deep sinus and strong tendency to the lophodonty and labial connections of lophs that are all typical features for *K. ermannorum*. Although size variation in the Vértésacsa population is unknown, the available specimen is slightly larger than type material and corresponds well with the size of *K. ermannorum* from a younger population. Daxner-Höck & Höck (2009) reported the following basic evolutionary trends within Austrian populations of *K. ermannorum* from the Vallesian through the early Turolian: increase of size and lophodonty, larger and deeper sinus and flattening of the occlusal surface. The specimen from Vértésacsa has a large and deep sinus and very lophodont pattern with flat occlusal surface thus probably represents more advanced form of *K. ermannorum*.

Genus *Eomyops* Engesser, 1979
Eomyops sp.
(Fig. 6Q)

Material: Damaged d4 (VE23 - x 0,66).

Description and remarks: A very small tooth slightly damaged anteriorly. The partly damaged protoconid is anterior to the

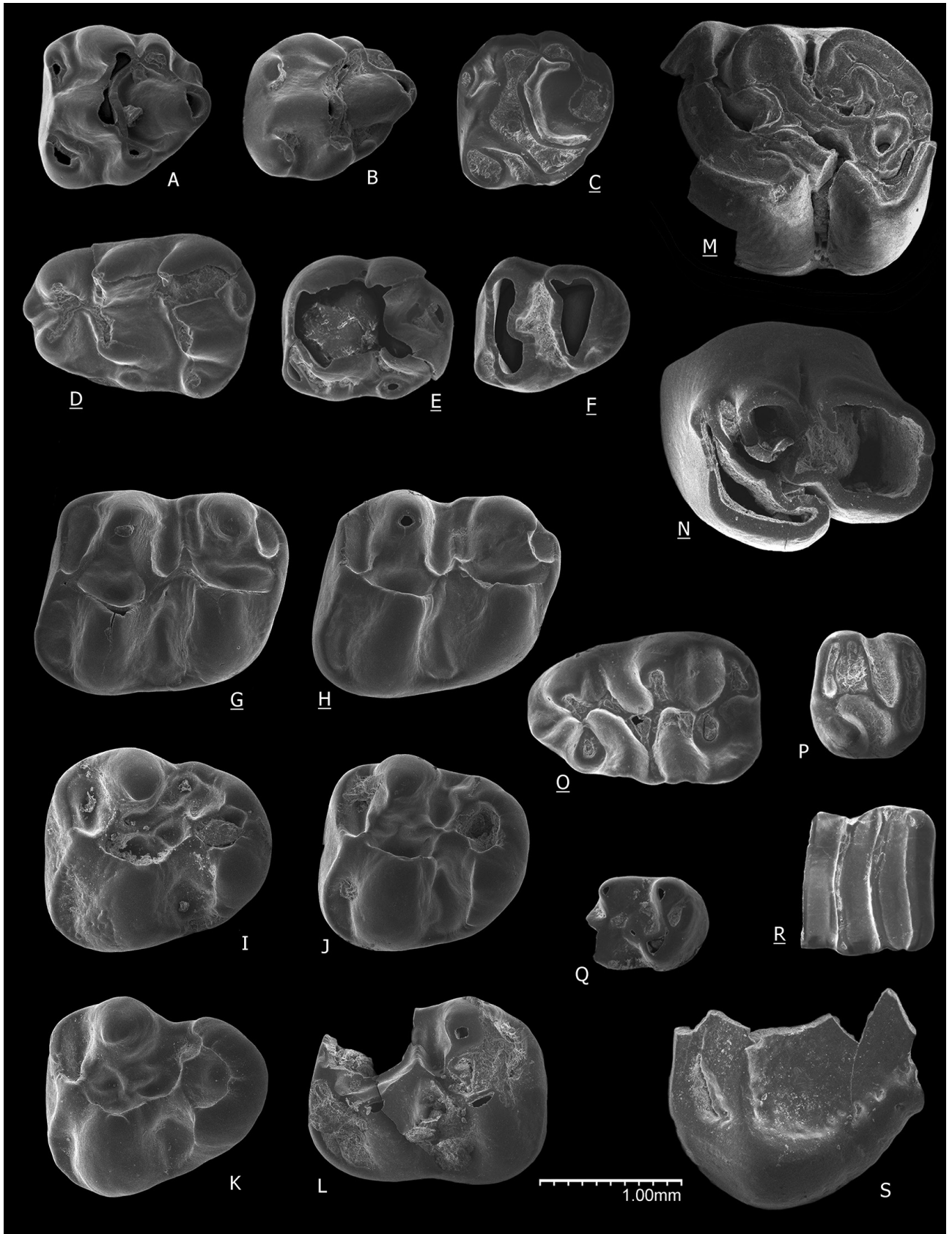


Fig. 6. A–F. *Apodemus lugdunensis*, A. M2(VE04), B. M2(VE03), C. M2(VE19), D. m1(VE01), E. m2 (VE02), F. m3 (VE05); G–L. *Kowalskia cf. polgardiensis*, G. M2 (VE10), H. M2 (VE11), I. M3 (VE81), J. M3 (VE13), K. M3 (VE80), L. m2 (VE17); M–N. *Anomalospalax cf. tardosi*, M. M1 (VE27), N. M2 (VE28); O. *Lophocricetus cf. cimishliensis*, m1 (VE21); P. *Keramidomys ermannorum*, M1 (VE25); Q. *Eomyops* sp., d4 (VE23); R. *Muscardinus* sp., m1/2 (VE24); S. *Spermophilinus* sp., M1/2 (VE30). Underlined letters indicate reversed specimens.

metaconid. The metaconid and entoconid are approximately equally developed and higher than the hypoconid. The metalophid is short, directed anteriorly and connects to the protoconid. The hypolophid is directed posteriorly and connects to the posterior arm of the hypoconid. The mesolophid is short, with a small, low cusp at the point where it connects to the longitudinal crest. The posterolophid is low and separated from the entoconid. The labial sinus is widely open. Although further identification is impossible, we assign this small tooth with its peculiar morphology as a deciduous tooth of *Eomyops* because its size and basic morphology are similar to known deciduous teeth of *Eomyops*.

Family Gliridae Muirhead, 1819

Genus *Muscardinus* Kaup, 1829

Muscardinus sp.

(Fig. 6R)

Material: 1 broken right? m1/2 (VE024 - x 1.04).

Description: The first two ridges and the anterior wall of the third ridge in the anterior part of this tooth are missing. The posterior wall of third ridge is straight while the fourth, fifth and sixth are slightly curved anteriorly. The third ridge is labially and lingually free. The fifth and sixth ridges are separated and have small cones developed on their labial margins. The lingual ends converge and were most likely connected but the tooth has a small break in this area. A small notch is developed in the middle of the posterior wall of the sixth ridge. No roots are preserved.

Remarks: The width of the preserved specimen is comparable with *Muscardinus hispanicus* and also with the lower range of *Muscardinus pliocaenicus austriacus*. However, this incomplete *Muscardinus* lower molar lacks the distinctive characters essential for determination at the species level.

Family Sciuridae Fischer, 1817

Genus *Spermophilinus* de Bruijn & Mein, 1968

Spermophilinus sp.

(Fig. 6S)

Material: Fragment of M1/2 (VE30 - x -), fragment of M3 (VE26 - x -).

Description: The preserved part of M1/2 has the paracone area with a well-developed mesostyl attached to the base of the paracone. The M3 fragment retains the tooth protocone area with partly preserved anteroloph and protoloph. The central depression is smooth; without ridges. The notch between the protocone and the hypocone is indistinct. Both fragments lack roots.

Remarks: De Bruijn and Bosma (2012) discussed the validity of generic names *Spermophilinus* and *Csakvaromys*, both valid names for the same genus of common Miocene European ground squirrel. They concluded that both are valid names because their definition meets the requirements of the International Code of Zoological Nomenclature. Although *Csakvaromys* has priority, they argued that maintaining *Spermophilinus* is in the interest of nomenclature stability. We agree with their interpretation and therefore we use the genus *Spermophilinus*.

By direct comparison with various *Spermophilinus bredai* and *Spermophilinus turolensis* populations available from Slovak late

Miocene localities, the fragments from Vértesacsa can be identified as *Spermophilinus*. De Bruijn (1995) demonstrated clear size-increase trend from the oldest representative *Spermophilinus besana* (MN4), through *Spermophilinus bredai* (MN6–12) and *Spermophilinus turolensis* (MN9–13) to the largest *Spermophilinus giganteus* (MN14). Although our fragmentary material cannot be measured, it approximates *S. turolensis* in size when directly compared with *S. bredai* and *S. turolensis* material from various localities.

Family Castoridae Hemprich, 1820

Castoridae indet.

Material: One fragment of indeterminate lower (?) molar (VE84).

Remarks: This small fragment of castorid molar does not provide sufficient morphological characters for precise classification. It has only a posterior(?) enamel fold with a connection towards the next fold. A small facet is preserved on the outer enamel. The fragment size with height 11.1 mm and width 4.6 mm corresponds to small-sized late Miocene castorids like *Euroxenomys*.

4. DISCUSSION

4.1. Composition and age of the assemblage

Despite the enormous quantity of processed sediment, the rodent assemblage from Vértesacsa is quite scanty. Only 30 identifiable rodent specimens and 4 insectivore remains were recovered. Moreover, most of these are preserved only as tooth enamel without dentine and therefore very fragile and easily damaged. Nevertheless, the insectivore record includes *Asoriculus gibberodon* and *Petenyia hungarica*. The first occurrence of *Asoriculus gibberodon* in Hungary was reported by Mészáros (1998) from the late Miocene MN 12 Zone and persisted to the end of the early Pleistocene (Rzebik-Kowalska, 2000). *Petenyia hungarica* has a long stratigraphic range from the Miocene/Pliocene boundary to the end of the early Pleistocene (Rzebik-Kowalska, 2000). Its certain first occurrence was in Maramena (MN 13/14 Zone) but is also mentioned from the Turkish locality of Düzyayla (Saraç, 2003), and this supports the hypothesis for the extension of this species' stratigraphic range.

The rodent assemblage is more diverse than the insectivores. The most abundant are *Kowalskia* (11 teeth) and *Apodemus* (10 teeth). The remaining taxa are represented by two preserved teeth (*Anomalospalax* and *Spermophilinus*), or by a single tooth or only molar fragments (*Keramidomys*, *Eomyops*, *Lophocricetodon*, *Muscardinus* and beaver). Such scarcity does not provide sufficient dental morphological variation and metric ranges essential for species identification. Therefore many taxa found in Vértesacsa remain in open nomenclature, thus, the biostratigraphic interpretation of the assemblage is rather tricky. For age identification (Fig. 7) the co-occurrence of *Apodemus lugdunensis* (MN10–MN11) together with the middle Turolian species as *Anomalospalax* cf. *tardosi* and *Lophocricetus* cf. *cimishliensis* is significant. Occurrence of advanced form of *Kowalskia* is peculiar because it has only been

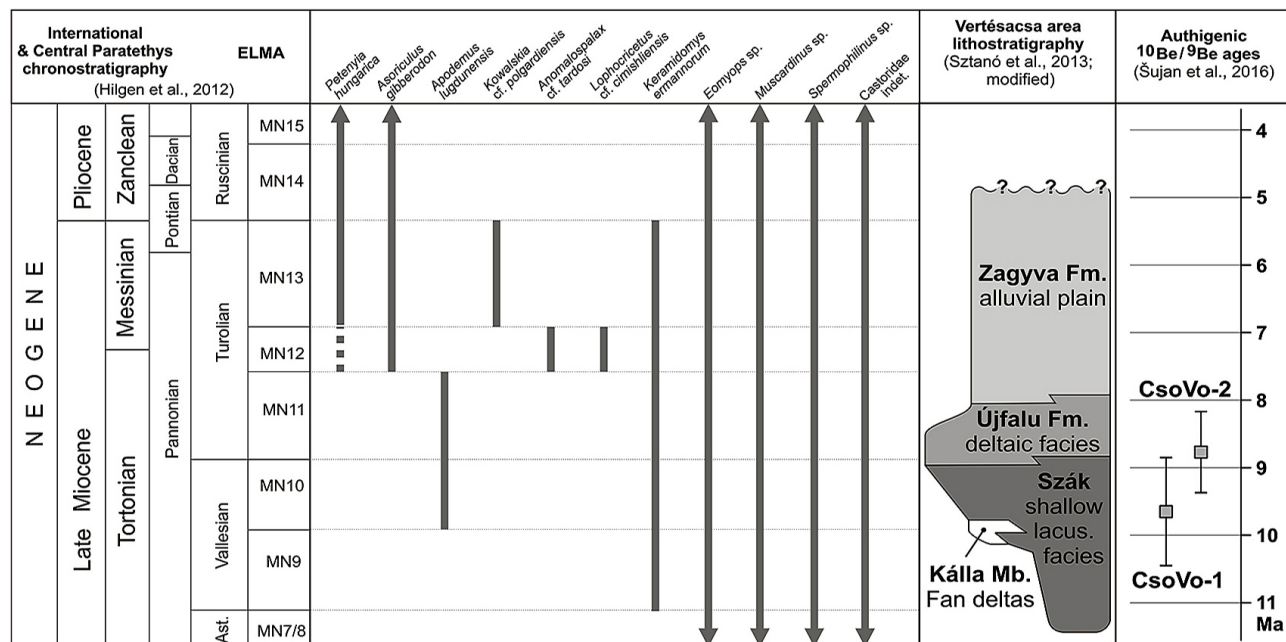


Fig. 7: Stratigraphical ranges of mammal taxa, lithostratigraphy of the Vértesacsza area and authigenic $^{10}\text{Be}/^{9}\text{Be}$ ages.

reported from the Hungarian locality Polgárdi (MN13) so far. During early and middle Turolian *Kowalskia fahlbuschi* and *K. skofleki* are more common in Central Europe. Other taxa are of minor importance because their stratigraphical range is too wide (*Keramidomys ermannorum*, MN9–MN13/14) or are identified only on the genus level (*Spermophilinus* sp., *Muscardinus* sp.). The rodent assemblage described above confidently indicates the Turolian age. More precise correlation of the assemblage from Vértesacsza to MN12 Zone is quite likely but clear evidence for such correlation is not yet available.

4.2. Authigenic $^{10}\text{Be}/^{9}\text{Be}$ ages and chronology of the Zagyva Formation

While the Turolian mammal megazone coincides with 8.9 to 5.3 Ma time interval, the MN12 Zone ranges from 7.6 to 6.8 Ma (Hilgen et al. 2012). Our presented small mammal dating shows only minor overlap with the authigenic $^{10}\text{Be}/^{9}\text{Be}$ ages of 9.65 ± 0.80 Ma and it fits into 8.77 ± 0.60 Ma age (both measured from this outcrop; Fig. 3). The obtained $^{10}\text{Be}/^{9}\text{Be}$ ages also appear too old within uncertainty considering the paleogeographic evolution of the area which was discussed in Šujan et al. (2016). According to Sztanó et al. (2013) and Magyar et al. (2013) we would expect the deltaic environment to be present in this area up to 8.0 Ma, and the alluvial plains formed only later. Therefore, we suspect that the initial $^{10}\text{Be}/^{9}\text{Be}$ ratio in the Vértesacsza area was affected by different ^9Be input compared to that in the Danube Basin during the Tortonian (Šujan et al. 2016).

4.3. Implications for sedimentary environment of the Zagyva Formation

The result obtained for small mammal biostratigraphy appears reasonable because it falls within the range defined by

paleogeographic proxies. The alluvial Zagyva Formation in the Vértes Hills is in continuous succession from the underlying deltaic sequence, and based on this we can consider the start of alluvial deposition at approximately 8.0 Ma and the upper limit of its presence up to 5.3 Ma; the upper limit of the Turolian. The duration of alluvial sedimentation divided by its thickness of up to 150 m provides depositional rate in the order of 50–100 mm/ka, and this value is normal when compared with standard river floodplain aggradation rates (e.g., Bruno et al., 2017; Ishii et al., 2016). Moreover, it almost fits the interval of approximately 100–2,000 mm/ka expected for an anastomosing river (e.g., Smith, 1983; Makaske, 2001; Gradziński et al., 2003; Roza et al., 2012). Uhrin et al. (2011) interpreted the narrow shape of the river channel belts in the Vértesacsza area as a result of aggradation related to river anastomosis. This deposition appears reasonable in light of expected accumulation rates, and in relationship to the aggrading deltaic to shelf slope systems feeding neighboring Lake Pannon.

5. CONCLUSION

Small mammal fossils (Rodentia and Eulipotyphla) from the Csönget-Völgy locality near Vértesacsza in Western Hungary are described for the first time. The following rodent species were recovered: *Apodemus lugdunensis*, *Kowalskia* cf. *polgardiensis*, *Anomalospalax* cf. *tardosi*, *Lophocricetus* cf. *cimishliensis*, *Keramidomys ermannorum*, *Eomyops* sp., *Muscardinus* sp., *Spermophilinus* sp., together with fragmentary beaver remains. Insectivores are represented at least by *Petenyia hungarica* and *Asoriculus gibberodon*. The age of the assemblage is interpreted as Turolian, late Miocene. Moreover, *Lophocricetus* cf. *cimishliensis* is described for the first time from the Central European region and is the westernmost reported occurrence of this genus.

The authigenic $^{10}\text{Be}/^9\text{Be}$ ages gained from the Csönget-Völgy locality infer slightly older ages than biostratigraphical results indicate. This difference could be related to different ^9Be input to the alluvial environment compared to the Danube Basin against which the method was calibrated. Further, ^9Be input depends on the composition of rock massifs eroded in the drainage basin of a river, and we therefore suspect that the stream depositing the Vértesacsa succession drained slightly petrographically different areas to the Tortonian Danube Basin floodplains.

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