

# Succession(-s) of mammalian assemblages during the Neogene – a case study from the Slovak part of the Western Carpathians

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## Abstract

The territory of the Western Carpathians as a part of the Central Paratethys represents a region strongly influenced by the orogen building processes and climatic changes. Through the Neogene, these events caused environmental changes, which mirrored in the composition of faunal assemblages as well. The aquatic environments gradually changed from marine, brackish to caspi-brackish and to freshwater lakes due to isolation, followed by development of ephemeral lakes and alluvial plains. The terrestrial record documents some faunal (mammalian) successions from the Middle Miocene to the Pliocene (HRI 3 – HRI 1), attended by the retreat of the subtropical zone vegetation at the beginning of the Late Miocene. The immigration of new „*Hipparion*“ fauna, as well as the replacement of swamp vegetation by a „coniferous forest“ of the temperate zone can be interpreted as the first appearance of the seasonality with lowered humidity at the Pannonian-Pontian boundary. The Late Pontian to Early Pliocene fauna as well as flora support the increase of humidity in temperate climate, followed by the temperature drop in next periods.

## Introduction

For some last years, an interest in the areal distribution of Cenozoic mammals and their migration as well as local evolution in Eurasia increased. All these faunal events are related by the paleogeographic, climatic, and environmental changes through the Neogene. During this period, the territory of the Western Carpathians as a part of the Central Paratethys in the Alpine – Carpathian – Pannonian junction played one of major roles for the formation and evolution of Neogene mammalian assemblages in Central Europe. The Alpine-Carpathian mountain range constituted a large natural barrier for the faunal migration between Western and Eastern Europe, or Northern and Southern Europe respectively. The paleoenvironmental changes, well preserved in sedimentary record as well as in fossil one, were controlled by both a paleogeographic configuration and climatic fluctuations. This paper yields a case study on some successions of Neogene mammalian assemblages in the Slovak territory of the Western Carpathians, focusing on HRI 3 (17.0 to 14.0 Ma), HRI 2 (11.0 to 9.0 Ma), and HRI 1 (7.0 to 4.0 Ma) intervals (Tab. 1).



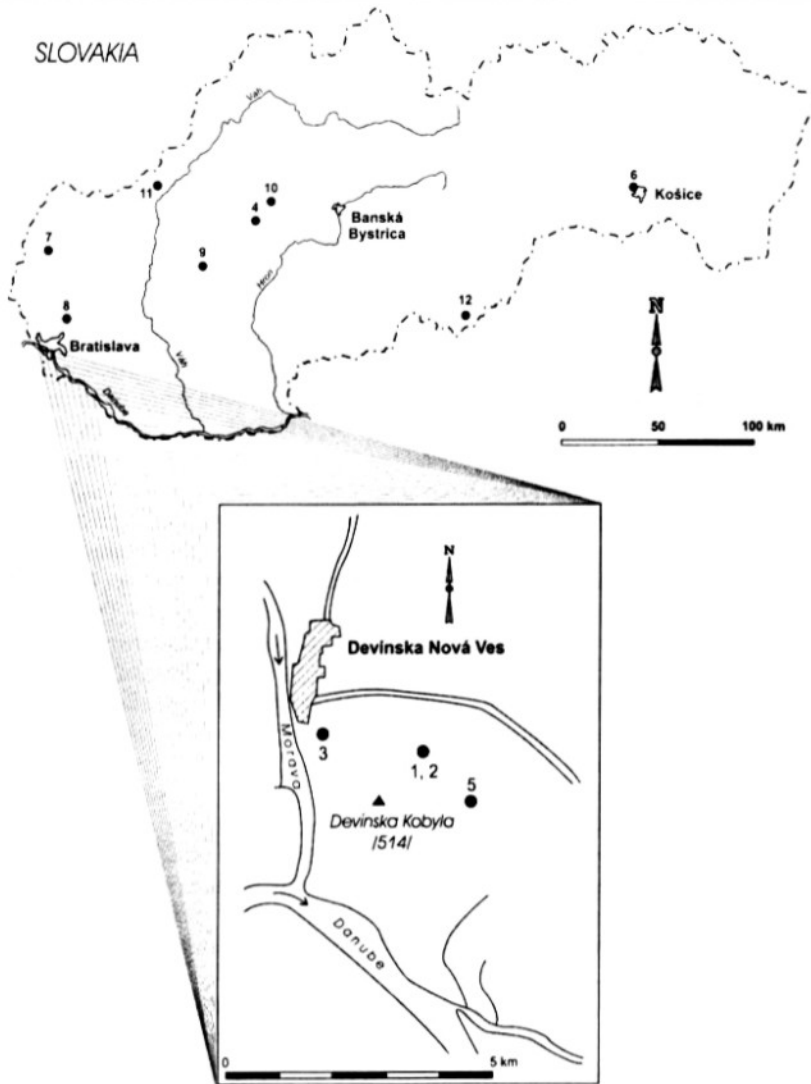


Figure 1. Location of referred Neogene mammalian sites in the Slovak part of the Western Carpathians.

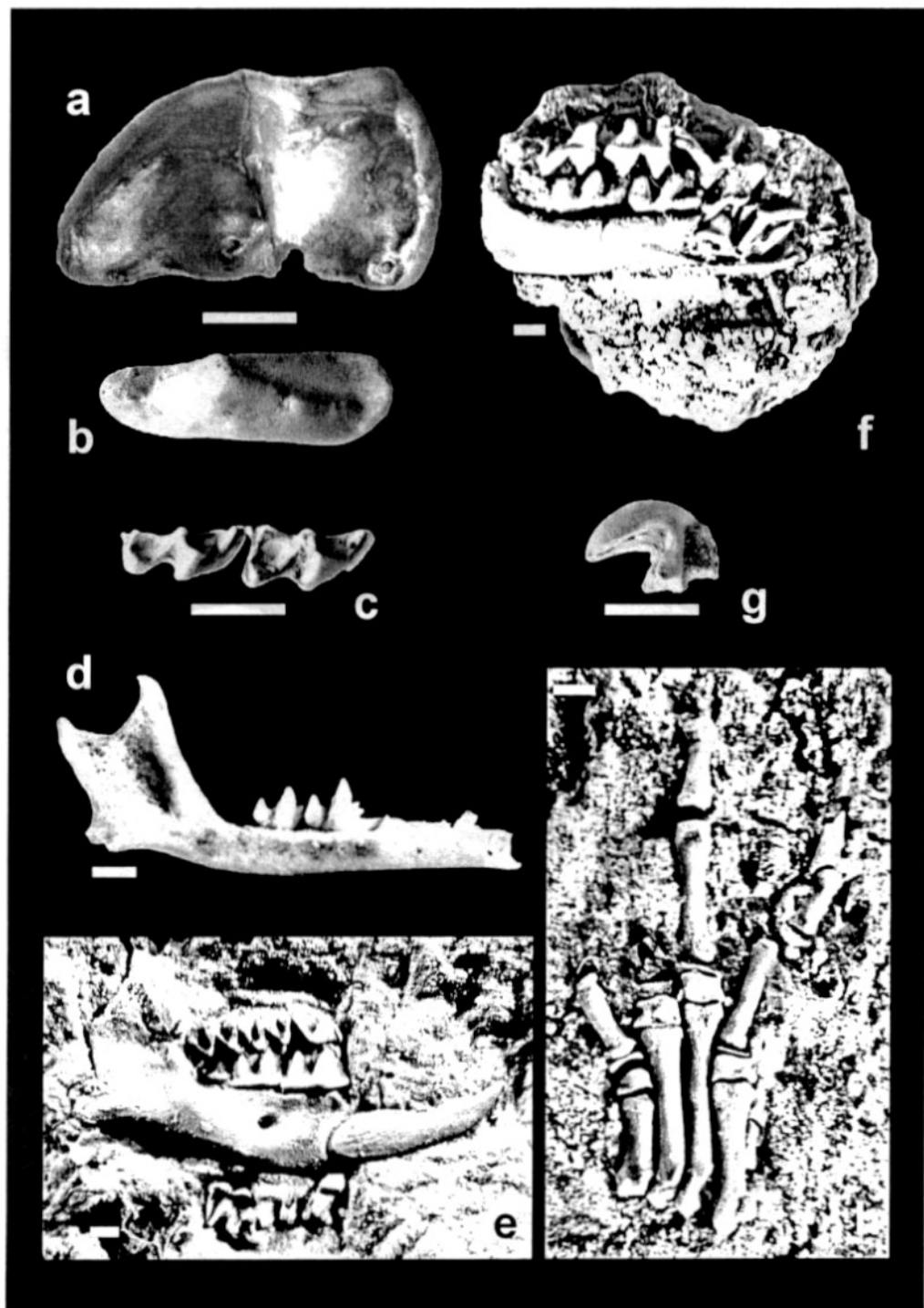
1 – Zapfe's Fissures (Neudorf-Spalte), 2 – Bonanza, 3 – Sandberg, 4 – Nováky, 5 – Dúbravská hlavica, 6 – Košice-Bankov, 7 – Borský Svätý Jur, 8 – Pezinok, 9 – Topoľčany, 10 – Veľké Bielice, 11 – Ivanovce, 12 – Hajnáčka.

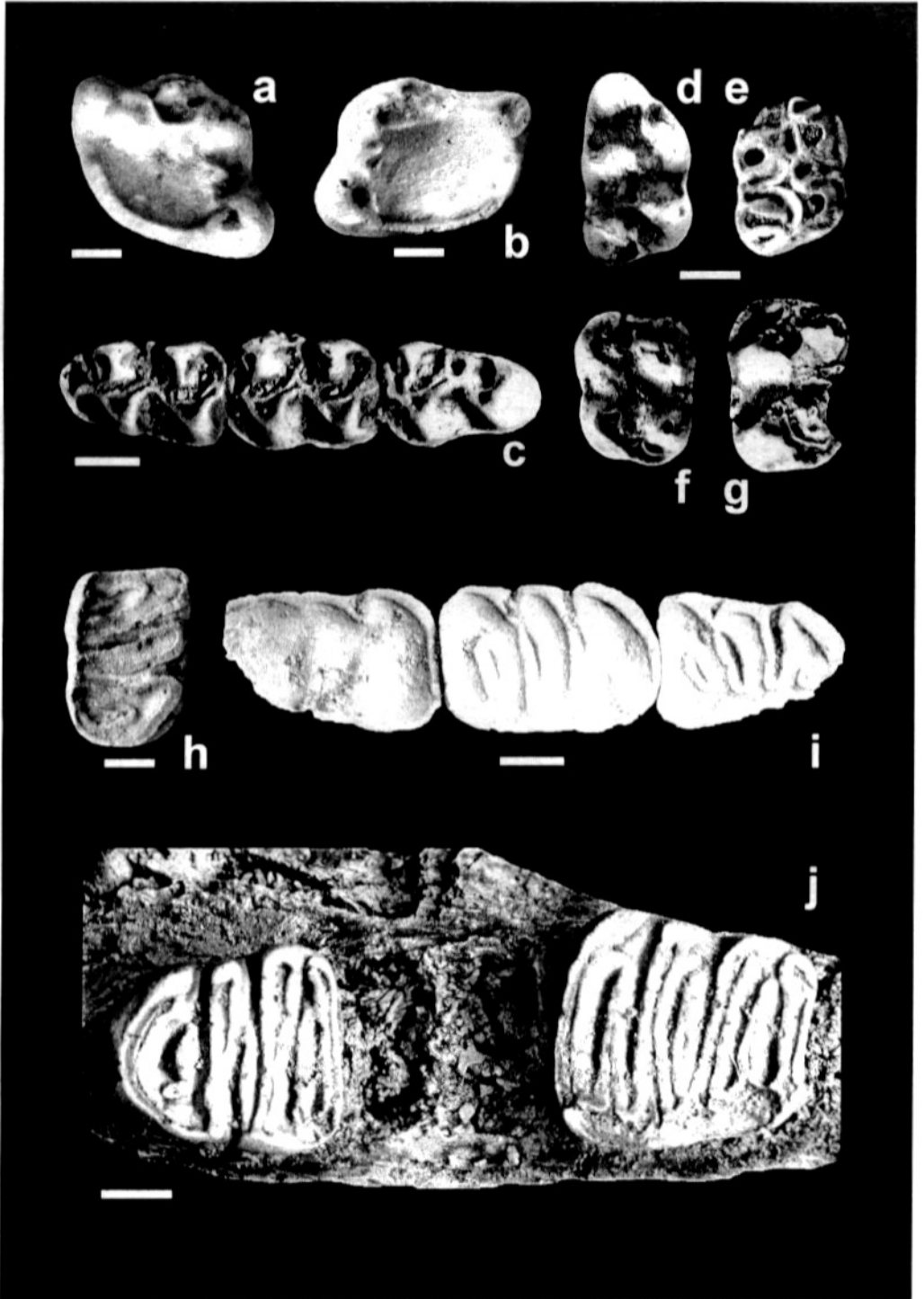
which reached the territory of Europe from Africa in the time of so-called “*Gomphotherium* Landbridge” (e. g. *Zygodon*, *Prodeinotherium*, *Aureliachoerus*, and *Dorcatherium*) or from Asia during the Early Miocene invasion (e. g. *Eotragus*, *Megacricetodon*, and *Eumyri- on*) (Agusti et al. 2001), the rodent fauna from the site (*Eumyri- on latior*, *E. weinfurteri*, *Democricetodon vindobonensis*, *Keramidomys carpathicus*, and *Megacricetodon schaubi*) corresponds to the lower part of MN 6 zone (Early Astaracian) (Fejfar 1974, 1990, 1997; Sabol, Holec 2002). The whole assemblage (Tab. 2) was accumulated in fissures filled by karstic sediments (probably a terrestrial equivalent of the marine Middle Badenian Devínska Nová Ves Member, Jakubov Fm. in Vienna Basin) still before the Late Badenian transgression in the Central Paratethys represented by marine sandy deposits in their overlying rock (Sandberg Member, Studienka Fm. in Vienna Basin).

The Late Badenian transgression initiated both paleogeographic and paleoenvironmental changes affecting the biodiversity, whereas the climatic conditions were relatively more or less constant during whole this period (subtropical climate with moderate oscillations and with the possibility of a partial seasonality; Slamková, pers. comm.). One of main changes in biodiversity on the territory of Devínska Kobyla Hill was the disappearance of chalicotheres (so typical mammalian element for Zapfe’s Fissures) and the presence of semi-marine (seals) to marine (whales, dolphins, sirens) mammals. These changes are well documented in faunal assemblages from both Bonanza (Figs. 2, 3; Tab. 2) and Sandberg sites (Fig. 1). Whereas the Bonanza fauna represents a something younger mixed assemblage (land – freshwater – marine), whose terrestrial elements lived in the subtropical forested environment with fresh water lagoons or marshes in near vicinity of prograding sea (the initial phase of the transgressive event), the land assemblage of Sandberg lived probably on/near the (partially cliff-like) sea-shore (the final phase of the transgressive event), banks of which were probably covered by swamps and mesophyllous forest (Sitár, Kováčová-Slamková 1999). The age of the both assemblages corresponds to MN 6 zone or to its upper part resp., supported by the rodent fauna from Bonanza (*Democricetodon vindobonensis*, *Neocometes brunonis*, *Bransatoglis astaracensis*, *Spermophilinus bredai*) (Fig. 3), large mammals from Sandberg (*Griphopithecus suessi*, *Dicrocercus elegans*) representing new immigration elements from Africa and Asia, the Sr-dating of foraminifer shells from the near Late Badenian outer shelf deposits of Devínska Nová Ves – clay pit (13.54 Ma; Hudáková, Král 2002), and by lithological circumstances (as aforementioned yet).

Thus, all these changes and differences in the faunal composition on the Devínska Nová Ves localities are a reflection of processes relating to the gradual transition from terrestrial to marine environmental conditions through the Badenian.

Figure 2 (next page). Fauna of insectivores from Bonanza (MN 6), scale bars are 1 mm.  
 a-b: *Lantanothereium* aff. *sansaniense* (LARTET, 1851), a – m1 dext., b – p4 sin. (occlusal view); c-d: Desmaninae gen. et spec. nov., c – m2-3 dext. (occlusal view), d – right mandible with dentition (buccal view); e – *Dinosorex* cf. *zapfei* ENGESSER, 1975, right mandible with lower and upper teeth (buccal view); f – *Plesiodimylus chantrei* GAILLARD, 1897, a fragment of the left mandible with permanent dentition and milk premolars (lingual view); g – Soricidae gen. et spec. indet., I sup. dext. (lingual view); h: ?*Lipotypyla* gen. et spec. indet., a fragment of the left hand of unknown insectivore(?) (dorsal view).





### Sarmatian (upper part of inter-span HRI 3/HRI 2)

During the Sarmatian, the seaway from the Indo-Pacific to the Paratethys closed and the marine environment changed throughout the Paratethys to reduced salinity and endemic aquatic faunas (Rögl 1999). The paleogeography of the Alpine – Carpathian – Pannonian junction in this period was strongly influenced by the Alpine uplift, final stage of the Western Carpathian collision with the European platform and soft docking of the Eastern Carpathians (Kováč et al. 1998; Kováč 2000). The Danube Basin was more or less isolated from Paratethys and its environment changed to brackish with salinity not lower than 10 – 15 ‰. However, short-term reopenings of the marine connection of the Central Paratethys with the Eastern Paratethys are proved by the both foraminiferal and nannoplankton assemblages (Kováč et al. in press).

The mammalian faunas of MN 7 show no greater migrations, what could be caused by the existence of the Mediterranean-Eastern Paratethys seaway along SE Anatolia, which functioned as a barrier (Rögl 1999). Nonetheless, the fossils of rhinoceroses (*Brachypotherium* sp. from Dúbravská hlavica and Rhinocerotidae gen. et spec. indet. from Nováky coal mine), mammutids (*Zygodolophodon turicensis* from Nováky) (Sabol, Holec 2002), and a viverrid *Lophocyon carpathicus* together with undetermined remnants of mastodons from Košice-Bankov (Fejfar, Heinrich 1987) (Tab. 2) are an evidence of some intermittent faunal migrations during changing environmental conditions, caused by the both climate and paleotopography. They have been found either in brackish-marshy sediments (Dúbravská hlavica, Nováky) or in karstic ones (Košice-Bankov).

The environment of these Sarmatian faunal assemblages consists of mixed deciduous forest with the presence of more thermophilous elements, coastal hydrophilous vegetation, and sporadic swamp vegetation. This vegetation of the warm temperate to subtropical climate substituted the Badenian warm subtropical vegetation with tropical elements in the Western Carpathians during the Sarmatian (Kováč et al. in press).

### Pannonian (upper part of inter-span HRI 3/HRI 2 – HRI 2 – inter-span HRI 2/HRI 1)

During the Pannonian, a large brackish lake was situated in the territory of the Central Paratethys. Its existence was a result of paleogeographic changes, which happened in this area before and at the beginning of the Late Miocene. Paleogeography of the Alpine – Carpathian – Pannonian junction over this period was initially strongly influenced by the rifting in the basin system (Lankreijer 1998) and later by the post-rift thermal subsidence (Kováč 2000). Despite some short-term reopenings of connections with the Eastern Paratethys, the long-term isolation of the Pannonian brackish lake led to the gradual decrease of the salinity (Kováč et al. in press), associated with the reduction of the aquatic environment (Daxner-Höck 1996). As a result of that, the environment was changed by the transition from caspi-brackish to freshwater lacustrine conditions.

Figure 3 (previous page). Fauna of rodents from Bonanza (MN 6), scale bars are 0.5 mm. a-b: *Spermophilinus bredai* (H. von MEYER, 1848), a – m1 dext., b – m2 sin.; c-g: *Democricetodon vindobonensis* (SCHAUB & ZAPFE, 1953), c – m1-3 dext., d – M1 dext., e – M1 dext., f – M2 sin., g – m2 sin.; h-i: *Neocometes brunonis* SCHAUB & ZAPFE, 1953, h – m2 dext., i – m1-3 dext.; j: *Bransatoglis astaracensis* (BAUDELLOT, 1970), left mandible with m1 and m3; all records are in occlusal view.



One of consequences of these changes was the immigration of new faunal elements from Asia and the extinction of the Middle Miocene ones. This new immigration wave of Asian mammals is represented by the occurrence of "hipparions" in Europe at the beginning of the Vallesian (~ 11.2 Ma) and their overall expansion in the Northern Hemisphere (Rögl 1999). The oldest record of "hipparions" ("*Hipparion*" s. s.) from the Slovak part of the Western Carpathians are known from Borský Svätý Jur in the Vienna Basin. The age of fossiliferous sediments on the site was determined as the Early Vallesian (middle to upper part of MN 9) on the basis of rodent findings (*Megacricetodon minutus*, *Democricetodon* sp., *Eumiarion leemani*, *Microtocricetus molassicus*, *Muscardinus hispanicus*, *Glirulus lissiensis*, *Keramidomys thaleri*, *Eomyops catalaunicus*, *Spermophilinus* sp., *Trogotherium minutum*, and *Steneofiber* sp.) (Fig. 4), supported by the record of the Pannonian E zone molluscs and ostracods (Jiříček 1985; Pipík, Holec, 1998) (in Austrian part of the Vienna Basin, findings of "hipparions" (*Hippotherium primigenium*) are already known from the base of Pannonian C zone; Rögl, Daxner-Höck 1996). Fossils of carnivores (*Eomellivora wimani*, *Ictitherium viverrinum*), insectivores and artiodactyls complement the whole mammal assemblage of Borský Svätý Jur (Tab. 2).

Next "hipparion" fauna has been found in Pezinok (MN 10) and Topoľčany (MN 9-10?) in the Danube Basin (Fig. 5, Tab. 2). The presence of "hipparions" in the both basins is related to the enlargement of open grassy areas with presence of sparse (coniferous?) forest during the Pannonian, what is in good agreement with a broad regression at the end of the Sarmatian (Kováč et al. in press). Findings of semi-aquatic rodents (*Trogotherium minutum* and *Steneofiber* sp.) prove also the presence of swamps and wetlands along the banks of rivers and lakes covered by softwood trees.

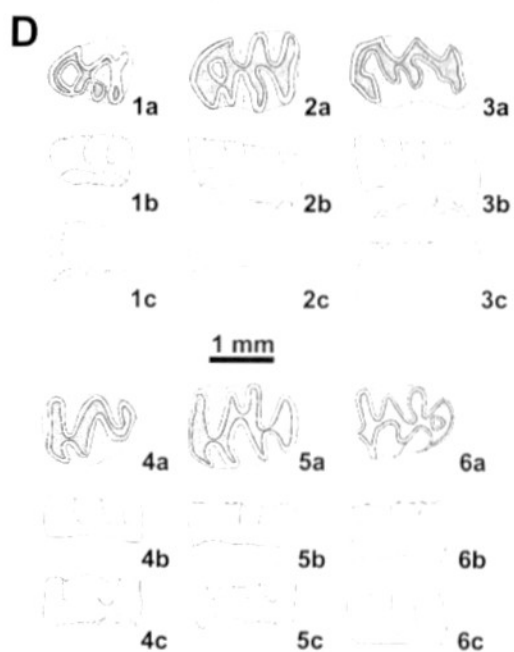
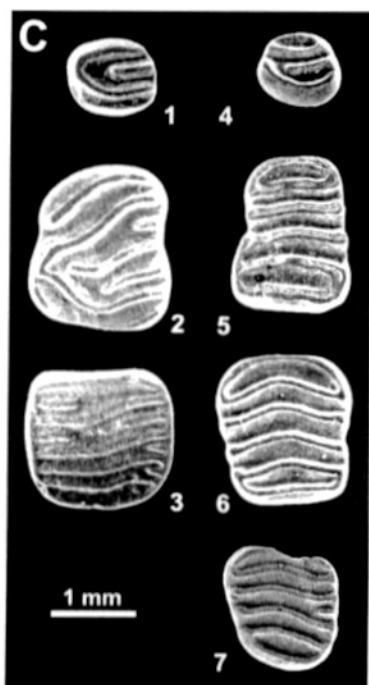
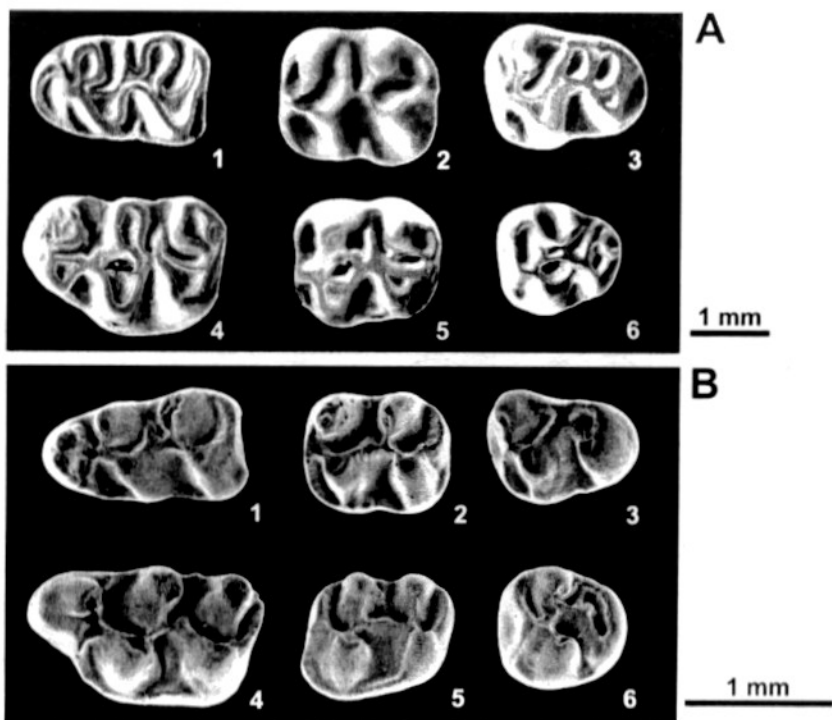
Records of invertebrates (especially molluscs and ostracods) and flora supplement the whole picture of the Pannonian environment in the Western Carpathians part of the Central Paratethys. Invertebrate fossils document the transition from a brackish and caspiabrackish estuarine environment during the Early Pannonian (Pipík, Holec 1998) over the Middle to Late Pannonian freshwater one of ephemeral lakes in alluvial plains, swamps and marshes (Kováč et al. in press) to dynamic shallow water environments of the latest Pannonian (Töröková, Fordinál 1999).

Flora points out a continuous climatic cooling during the Pannonian. The vegetation of the moderately temperate geographical zone replaced the subtropical one of the Sarmatian. Swamps and deciduous woods became a dominant habitat indicating a start of the seasonality (Kováč et al. in press).

Figure 4 (next page). Fauna of rodents from Borský Svätý Jur (MN 9).

A: *Democricetodon* sp., 1 – m1 sin., 2 – m2 sin., 3 – m3 sin., 4 – M1 sin., 5 – M2 sin., 6 – M3 sin. (all in occlusal view); B: *Megacricetodon minutus* (DAXNER-HÖCK, 1967), 1 – m1 sin., 2 – m2 sin., 3 – m3 sin., 4 – M1 sin., 5 – M2 sin., 6 – M3 sin. (all in occlusal view); C: *Muscardinus hispanicus* DE BRUIJN, 1966, 1 – P4 in., 2 – M1 sin., 3 – M2 sin., 4 – p4 sin., 5 – m1 sin., 6 – m2 sin., 7 – m3 sin. (all in occlusal view); D: *Microtocricetus molassicus* FAHLBUSCH & MAYR, 1975, 1 – M3 sin., 2 – M2 sin., 3 – M1 sin., 4 – m3 sin., 5 – m2 sin., 6 – fragment of m1 dext. (a – occlusal view, b – buccal view, c – lingual view).





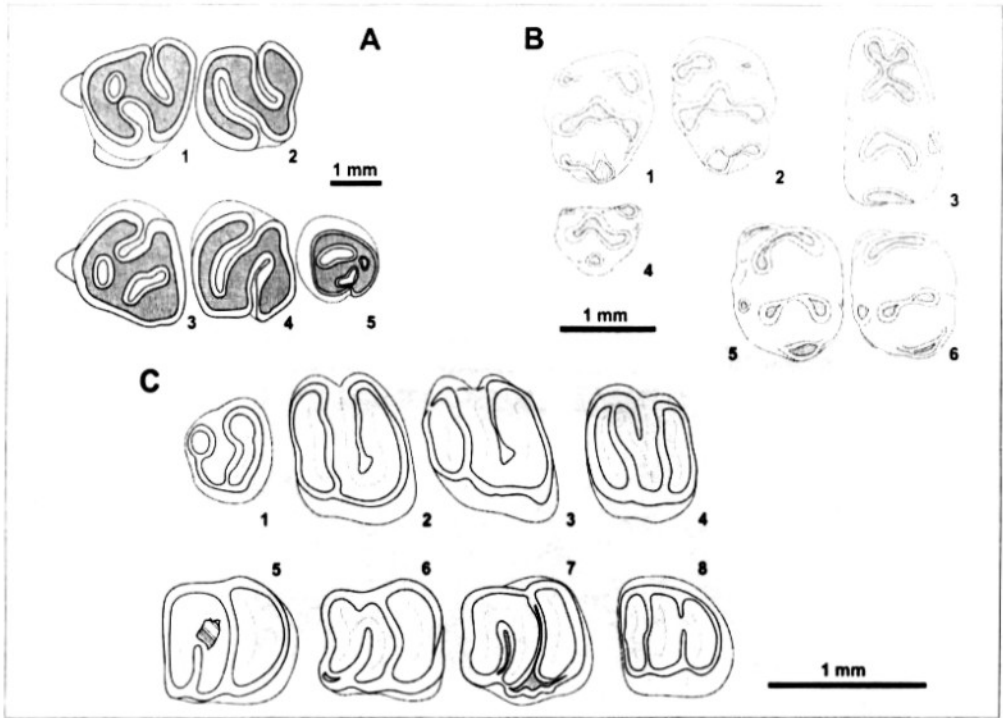


Figure 5. Fauna of rodents from: Pezinok (MN 10).

A: *Anomalomys gaillardii* VIRET & SCHAUB, 1946, left (1-2) and right (3-5) upper molars, occlusal view; B: *Progonomys* sp., m1 dext. (3), m2 sin. (5-6), M2 dext. (1), M2 sin. (2), M3 dext. (4), occlusal view; C: *Graphiurops austriacus* BACHMAYER & WILSON, 1980, 1- P4 sin. (inv.), 2 - M1 sin. (inv.), 3 - M1 sin. (inv.), 4 - M2 sin., 5 - m1 sin. (inv.), 6 - m2 sin., 7 - m2 sin. (inv.), 8 - m3 sin., all in occlusal view.

Figure 6 (next page). New elements in mammalian assemblage of Hajnáčka (MN 16a). a: *Sciurus* sp., m1-2 sin., occlusal view; b: *Ungaromys* sp., m1 sin., occlusal view; c: Ursidae gen. et spec. indet., P1 dext./p3 sin., lateral view; d: *Talpa* cf. *minor* FREUDENBERG, 1914, left mandible with p4 and m1, buccal view; e: *Talpa fossilis* PETÉNYI, 1864, m2 dext., buccal view; f: *Deinsdorfia hibbardii* (SULIMSKI, 1962), left mandible with m1-3, buccal view.



a



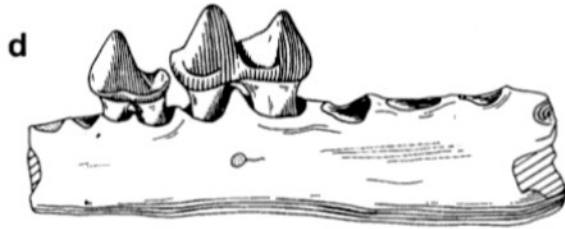
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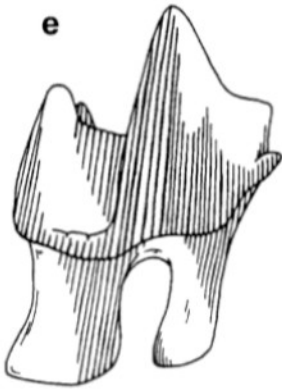
c

1 mm

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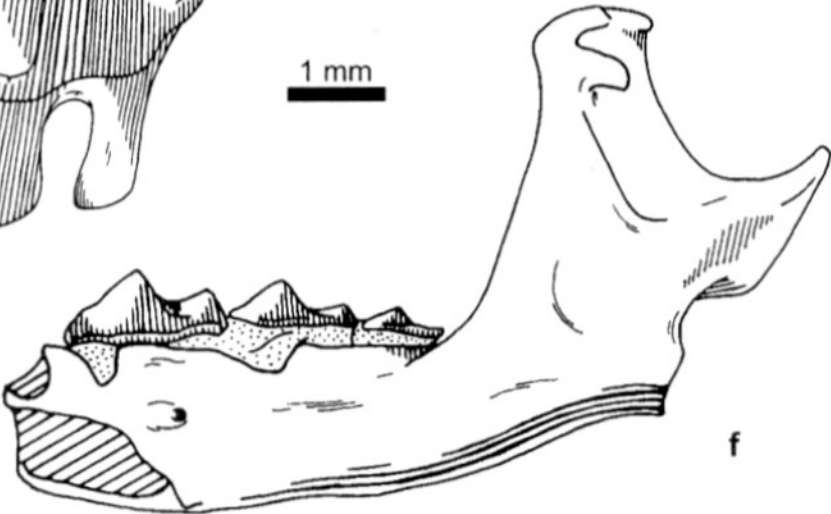


d



e

1 mm



f

### **Pontian (early HRI 1)**

The Pontian history of the Paratethys includes its isolation with nearly freshwater conditions (Rögl 1999). Whereas the uplift of the Western Carpathians mountain range continued in the north (Kováč 2000), the Pannonian Lake moved towards the southeast to the Drava, Sava and the Great Hungarian Plain sedimentary areas (Magyar et al. 1999).

During the Pontian, the mammal migration corridor between Eurasia and Africa remained open in the Near East and the desiccation of the Mediterranean (the Messinian salinity crisis) enabled the opening of new landbridge between northern Africa and southern Europe (Rögl 1999).

Only fossil remains of *Anancus arvernensis* and *Mammuth borsoni* from Velké Bielice are probably known from this period (MN 13), though their younger age (Early Pliocene) is not excluded (Tab. 2). Despite that, the both mentioned proboscidean taxa together with floristic data and sedimentary record yield important information about paleoecology and climate – the environment of this time consisted of a deciduous broad-leaved mesophytic forest with the presence of open areas as well as meandering rivers, shallow lakes, swamps and marshes.

All these data (especially floristic ones) point out the continuous climatic cooling related with an increase of the humidity (Kováč et al. in press).

### **Dacian & Romanian (late HRI 1 – pre-HRI 1)**

Through Pliocene, nearly present-day conditions were attained in the Central Paratethys (Rögl 1999). The Early Pliocene paleogeography of the Alpine – Carpathian – Pannonian junction was still controlled by moderate tectonics associated with the continuing uplift of the Western Carpathians (Kováč 2000), followed by the Late Pliocene tectonic inversion (Horváth 1993).

The Early Pliocene mammalian fauna in the Slovak territory of the Western Carpathians is known from karstic fissures near Ivanovce (Tab. 3). Based on the rodent key-fossils (e. g. *Mimomys gracilis*, *M. davakosi*, *Bjornkurtenia cantarranensis*, and *Trilophomys depereti*), the age of the site was assigned to the Late Ruscinian (MN 15b) (Fejfar 2001). The Ivanovce fossil assemblage is very similar to that of Hajnáčka (Fig. 6, Tab. 3). However, the assemblage of fossil rodents at Hajnáčka (e. g. *Mimomys stehlini* and *M. hassiacus*) indicates a slightly younger age in comparison with the karst fillings of Ivanovce and it has been correlated with the lower part of the Villanyian (MN 16a) (Fejfar et al. 1998). Thus, the both sites represent stratigraphically two chronologically distinct faunal phases in time succession (late Early Pliocene to early Late Pliocene) (Fejfar, Sabol 2004).

The situation cannot be explained simply by paleoecology, because the paleoenvironmental conditions were probably comparable as shown by corresponding occurrence of frogs, desmans, mastodons and tapirs. These both sites represent a humid forest belt along a volcanic lake (in a maar crater) in Hajnáčka or along a broad river valley with a karstified limestone massif in Ivanovce. Furthermore, the both sites were probably surrounded by an open drier habitat in higher elevations (Fejfar, Sabol 2004).

In context with floristic data showing the dominance a swamp vegetation and arctotertiary elements with decreasing tendency of mountain vegetation elements, the Pliocene climate in the territory under study can be characterized as moderate temperate one of wet lowlands (Kováč et al. in press). Towards the Pleistocene, the climate became more continental with a severe winter season and lower precipitation during the summer warm temperate conditions (Sitár et al. 1989).

Mammalian taxa	ZF	BO	SA	NO	DH	KB	BSJ	PE	TO	VB
<b>RODENTIA</b>										
<i>Albanensia</i> sp.								+		
<i>Spermophilinus bredai</i> (H. v. Meyer, 1848)	+	+						cf.		
<i>Spermophilinus</i> sp.							+			
<i>Blackia miocenica</i> Mein, 1970	+									
Sciuridae gen. et spec. indet.		+								
<i>Steneofiber</i> sp.							+			
<i>Trogontherium (Euroxenomys) minutum</i> (H. v. Meyer, 1838)							+	+		
<i>Microtocricetus molassicus</i> Fahlbusch & Mayr, 1975							+	+		
<i>Eumyarion latior</i> (Schaub & Zapfe, 1953)	+									
<i>Eumyarion weinfurteri</i> (Schaub & Zapfe, 1953)	+									
<i>Eumyarion leemani</i> (Hartenberger, 1965)							+			
<i>Eumyarion</i> sp.		+								
<i>Megacricetodon gregarius</i> (Schaub, 1925)	+									
<i>Megacricetodon schaubi</i> Fahlbusch, 1964	+									
<i>Migacricetodon minutus</i> (Daxner-Höck, 1967)							+			
<i>Megacricetodon</i> sp.		+								
<i>Democricetodon vindobonensis</i> (Schaub & Zapfe, 1953)	+	+								
<i>Democricetodon</i> sp.		+					+			
<i>Lartetomys zapfei</i> Mein & Freudenthal, 1971	cf.									
<i>Cricetodon sansaniensis</i> Lartet, 1851	+									
Cricetidae gen. et spec. indet.								+		
<i>Neocometes brunonis</i> Schaub & Zapfe, 1953	+	+								
<i>Anomalomys gaudryi</i> Gaillard, 1900	+									
<i>Anomalomys gaillardi</i> Viret & Schaub, 1946								+		
<i>Bransatoglis astaracensis</i> (Baudelot, 1970)	+	+								
<i>Microdyromys miocaenicus</i> (Baudelot)	?									
<i>Miodyromys hamadryas</i> F. Major, 1899	+									
<i>Myoglis larteti</i> Baudelot, 1965	?									
<i>Muscardinus sansaniense</i> (Lartet, 1851)	+									
<i>Muscardinus hispanicus</i> de Bruijn, 1966							+			
<i>Glirulus lissiensis</i>							+			
<i>Graphiurops austriacus</i> Bachmayer & Wilson, 1980								+		
<i>Paraglrulus</i> sp.								+		
Gliridae gen. et spec. indet.		+					+			
<i>Eomyops catalaunicus</i> (Hartenberger, 1966)							+	+		
<i>Eomyops</i> sp.	+	+								
<i>Keramidomys carpathicus</i> (Schaub & Zapfe, 1953)	+									
<i>Keramidomys thaleri</i> Huguenev & Mein, 1968							+			
<i>Progonomys</i> sp.								+		
<i>Apodemus</i> sp.								+		

Table 2 (this and next two pages). The Miocene mammal taxa from referred Slovak sites. ZF – Zapfe's Fissures (Neudorf-Spalte), BO – Bonanza, SA – Sandberg, NO – Nováky, DH – Dúbravská hlavica, KB – Košice-Bankov, BSJ – Borský Svätý Jur, PE – Pezinok, TO – Topoľčany, VB – Veľké Bielice.



Mammalian taxa	ZF	BO	SA	NO	DH	KB	BSJ	PE	TO	VB
<b>PRIMATES</b>										
<i>Pliopithecus antiquus</i> Blainville, 1839			+							
<i>Pliopithecus vindobonensis</i> Zapfe & Hürzeller, 1957	+									
<i>Griphopithecus suessi</i> Abel, 1902			+							
<b>CETACEA</b>										
<i>Mesocetus hungaricus</i> Kadic, 1907			+							
<i>Schizodelphis sulcatus</i> (Gervais, 1861)			cf.							
<b>ARTIODACTYLA</b>										
<i>Aureliachoerus aurelianensis</i> (Stehlin, 1899)	+									
<i>Conohyus simorrensis</i> (Lartet, 1851)			+							
<i>Hyotherium soemeringi</i> H. v. Meyer, 1829 sive 1934	+		+							
Listriodontinae gen. et spec. indet.			+							
<i>Albanohyus pygmaeum</i> (Depéret, 1892)			+							
<i>Taucanamo sansaniense</i> (Lartet, 1851)			+							
<i>Dorcatherium naui</i> Kaup, 1834			+							
<i>Dorcatherium vindobonense</i> H. v. Meyer, 1846	+		+							
<i>Palaeomeryx kaupi</i> H. v. Meyer, 1834			+							
<i>Palaeomeryx magnus</i> Lartet, 1851	+		+							
<i>Lagomeryx parvulus</i> (Roger, 1898)		+	+							
<i>Dicrocerus elegans</i> Lartet, 1837	+		+							
<i>Heteroprox larteti</i> (Filhol, 1891)	+		+							
<i>Eotragus haplodon</i> (H. v. Meyer, 1846)	?		?							
<i>Ecocerus</i> sp.			?							
Bovidae (Boselaphini) gen. et spec. indet.			+							
Artiodactyla gen. et spec. indet.							+			
<b>PERISSODACTYLA</b>										
<i>Anchitherium aurelianense</i> Cuvier, 1812			+							
<i>Hippotherium primigenium</i> H. v. Meyer, 1829								+	+	
"Hipparion" s. s.							+			
<i>Chalicotherium grande</i> (Blainville, 1849)	+									
<i>Aceratherium</i> sp.			+							
<i>Haploaceratherium tetractylum</i> (Lartet, 1851)	cf.									
<i>Brachypotherium</i> sp.					+					
<i>Dicerorhinus stenheimensis</i> (Jager, 1839)	+		+							
Rhinocerotidae gen. et spec. indet.	+			+						
<i>Tapirus telleri</i> Hofmann, 1893			+							
<b>SIRENIA</b>										
<i>Thalattosiren petersi</i> (Abel, 1949)			+							
<b>PROBOSCIDEA</b>										
<i>Prodeinotherium bavaricum</i> (H. v. Meyer, 1831)	+		+							
<i>Zygodon turicensis</i> (Schinz, 1824)	+	+	+	+						
<i>Mammut borsoni</i> (Hays, 1834)										+
<i>Anancus arvernensis</i> (Crozet & Jobert, 1828)										+
gen. indet. <i>grandicisivus</i> (Schlesinger, 1917)									+	
Proboscidea gen. et spec. indet.						+				



Mammalian taxa	Ivanovce	Hajnáčka
	(MN 15b)	(MN 16a)
<b>LAGOMORPHA</b>		
<i>Ochotonoides csarnotanus</i> Kretzoi, 1959	+	
<i>Hypolagus brachygnathus</i> Kormos, 1934	+	+
<i>Pliopentalagus dietrichi</i> (Fejfar, 1961)	+	
Lagomorpha gen. et spec. indet.		+
<b>RODENTIA</b>		
<i>Sciurus</i> sp.	+	+
<i>Pliopetaurista dehneli</i> (Sulimski, 1964)	+	
<i>Pliopetaurista pliocaenica</i> (Depéret, 1897)	+	+
<i>Eutamias</i> sp.	+	
<i>Castor fiber</i> ssp.	+	+
<i>Trogotherium minus</i> Newton, 1890		+
<i>Palaeomys</i> sp.	+	
<i>Dipoides problematicus</i> Schlosser, 1902	cf.	
<i>Estramomys</i> sp.	+	
<i>Eomyops</i> sp.	+	
<i>Selevinia</i> sp.	+	
Seleviniidae gen. et spec. indet.		+
<i>Muscardinus pliocaenicus</i> Kowalski, 1956	+	
<i>Glis minor</i> Kowalski, 1956	+	
<i>Trilophomys depereti</i> Fejfar, 1961	+	
<i>Bjornkurtenia cantarranensis</i> Kowalski, 1992	+	
<i>Baranomys loczyi</i> Kormos, 1933	+	+
<i>Cricetus</i> sp.	+	
<i>Kowalskia intermedia</i> Fejfar, 1970	+	
<i>Allocricetus bursae</i> Schaub, 1930	cf.	
<i>Germanomys parvidens</i> Fejfar, 1961	+	
<i>Germanomys weileri</i> Heller, 1936	+	
<i>Germanomys</i> sp.		+
<i>Ungaromys</i> sp.		+
<i>Mimomys davakosi</i>	+	
<i>Mimomys</i> ( <i>Cseria</i> ) <i>gracilis</i> (Kretzoi, 1959)	+	
<i>Mimomys</i> ( <i>Mimomys</i> ) <i>hassiacus</i> Heller, 1936		+
<i>Mimomys</i> ( <i>Cseria</i> ) <i>stehlini</i> Kormos, 1931		+
<i>Mimomys</i> sp.		+
<i>Dolomys occitanus</i> (Thaler, 1955)	+	
Arvicolinae gen. et spec. indet.		+
<i>Apodemus</i> sp.	+	+
<i>Rhagapodemus frequens</i> Kretzoi, 1959	+	
<i>Prospalax priscus</i> (Nehring, 1897)	+	+
<i>Hystrix primigenia</i> (Wagner, 1848)	cf.	

Table. 3 (this and next two pages). The Pliocene mammal taxa from referred Slovak sites (modified and supplemented according to Fejfar, Heinrich 1985 and Fejfar et al. 1990).

Mammalian taxa	Ivanovce	Hajnáčka
	(MN 15b)	(MN 16a)
<b>CARNIVORA</b>		
<i>Lutra bravardi</i> Pomel, 1843		cf.
<i>Lutra</i> sp. I & II	+	
Lutrini gen. et spec. indet.	+	
<i>Mustela</i> sp.		+
Mustelidae gen. et spec. indet.	+	
<i>Parailurus anglicus</i> (Dawkins, 1888)	cf.	
<i>Parailurus hungaricus</i> Kormos, 1934		+
Ursidae gen. et spec. indet.		+
<i>Hesperoviverra carpathorum</i> (Kretzoi & Fejfar, 1982)	+	
Viverridae gen. et spec. indet.	+	
<i>Megantereon</i> sp.		+
<i>Hyaena perrieri</i> Croizet & Jobert, 1828		+
<b>LIPOTYPHILA</b>		
<i>Sorex minutus</i> Linnaeus, 1766	+	
<i>Drepanosorex praeearaneus</i> (Kormos, 1934)	+	
<i>Deinsdorfia hibbardi</i> (Sulimski, 1962)		+
<i>Deinsdorfia</i> sp.	+	
" <i>Zelceina soriculoides</i> (Sulimski, 1959)"	+	
<i>Petenya hungarica</i> Kormos, 1934	+	+
<i>Paenelimnoecus pannonicus</i> (Kormos, 1934)	+	
<i>Blarinoides mariae</i> Sulimski, 1959	+	+, cf.
<i>Beremendia fissidens</i> (Petényi, 1864)	+	+
<i>Episoriculus gibberodon</i> (Petényi, 1864)	+	
<i>Allosorex stenodus</i> Fejfar, 1966	+	
Soricidae gen. et spec. indet.		+
<i>Talpa minor</i> Freudenberg, 1914		cf.
<i>Talpa fossilis</i> Petényi, 1864		+
<i>Talpa</i> sp. 1 and 2	+	+
<i>Desmana nehringi</i> Kormos, 1913	+	+
<i>Dibolia</i> sp.	+	
<b>CHIROPTERA</b>		
<i>Rhinolophus variabilis</i> Topál, 1970	cf.	
<i>Rhinolophus lissiensis</i> Mein, 1964	+	
<i>Rhinolophus kowalskii</i> Topál, 1979	aff.	
<i>Myotis kormosi</i> Heller, 1936	+	
<i>Myotis podlesicensis</i> Kowalski, 1956	cf.	
<i>Myotis exilis</i> Heller, 1936	cf.	
<i>Myotis mystacinus</i> (Kuhl, 1818)	cf.	
<i>Myotis delicatus</i> Heller, 1936	cf.	
<b>PRIMATES</b>		
Colobinae gen. et spec. indet.	+	+

Mammalian taxa	Ivanovce	Hajnáčka
	(MN 15b)	(MN 16a)
<b>ARTIODACTYLA</b>		
<i>Sus minor</i> Depéret, 1890	+	+
<i>Cervus perrieri</i> - <i>Ardenoceros ardei</i> close relative form		+
<i>Cervus pardinensis</i> Croizet & Jobert, 1828		+
<i>Croizetoceros ramosus</i> (Croizet & Jobert, 1828)		+
<i>Capreolus</i> sp.	+	+
<i>Muntiacus</i> sp.		+
Cervidae gen. et spec. indet. 1 and 2		+
<i>Parabos boodon</i> Depéret, 1890	+	
<b>PERISSODACTYLA</b>		
<i>Dicerorhinus jeanvireti</i> Guerin, 1972		+
<i>Dicerorhinus</i> sp.		+
Rhinocerotidae gen. et spec. indet.	+	+
<i>Tapirus arvensis</i> Devéze & Bouillet, 1827	+	+
<b>PROBOSCIDEA</b>		
<i>Mammut borsoni</i> (Hays, 1834)	+	+
<i>Anancus arvensis</i> Croizet & Jobert, 1828	+	+

## Conclusion

In the territory of the Slovak part of the Western Carpathians, fossil findings of Neogene mammals are known from MN 6 – MN 10 (Middle Badenian-Early Astaracian to Early Pannonian-Vallesian), MN 13? (Pontian-Late Turolian), MN 15 (Early Romanian-Late Ruscini-an), and MN 16 (Early Romanian-Early Villanyian) zones of the European Land Mammal Biostratigraphical Scale.

During this whole time span, three main faunal (mammalian) successions can be observed: 1) from the Middle Badenian (Zapfe's Fissures, lower part of MN 6) to the Late Badenian (Bonanza and Sandberg, upper part of MN 6), 2) through the Pannonian from MN 9 (Borský Svätý Jur) to MN 10 (Pezinok), and 3) from MN 15b (Ivanovce) to MN 16a (Hajnáčka) during the Early Romanian. All these successions are demonstrated by faunal turnovers caused by both paleogeographic and climatic changes.

The Badenian succession is characteristic by the disappearance of chalicotheres (so typical for Zapfe's Fissures) and the occurrence of semi-marine (seals) to marine (whales, dolphins, sirens) mammals in younger chronological phase (Bonanza and Sandberg), what is a reflection of processes relating to the gradual transition from terrestrial to marine environmental conditions through this period.

The extinction of the Middle Miocene faunal elements and the occurrence of the "hipparion" fauna in the Slovak part of the both Vienna and Danube Basins represent the Pannonian succession accompanied by the expansion of open grassy areas with sparse forests and wetlands in terrestrial ecosystems and by the change of aquatic environments in Pannonian Lake from brackish to freshwater caused by the isolation of the Central Paratethys.

The Pliocene succession is mainly reflected in the replacement of ancient rodent (cricetid) taxa by more modern ones, whereas assemblage of large mammals (e. g. tapirs, rhinos, masto-

dons) was more or less stable during whole this period. The situation cannot be explained simply by paleoecology, because the Pliocene paleoenvironmental conditions were probably identical on the both referred sites (Ivanovce and Hajnáčka).

In context with floristic data, the faunal turnovers are also a reflection on climatic changes, which are represented by the continuous transition from tropical and/or subtropical conditions over conditions of the warm temperate zone to the nearly present-day ones with a seasonality.

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