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TEMPORAL AND SPATIAL DISTRIBUTION OF MIOCENE MAMMALS IN THE WESTERN CARPATHIANS (SLOVAKIA)

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Abstract: Mammal fossils are found relatively rarely in the Miocene deposits of Slovakia. So far, eleven Miocene mammal localities are known. They cover a time span from the Middle Badenian to the Pannonian. Miocene mammals have been found mostly at the NE margin of the Vienna Basin (Zapfe's fissures, Sandberg, Bonanza, Wait Quarry, Glavica, Dúbravská hlavica, and Borský Svätý Jur). However, some localities are also known from the northern part of the Danube Basin (Pezinok, Topoľčany-Kalvária, and Nováky) and from the northern margin of the Transcarpathian (East Slovak) Basin (Košice-Bankov). The article provides a review of Slovak Miocene sites of fossil mammals and updates some older stratigraphical data.

Key words: Miocene, Western Carpathians, Slovakia, mammals, biostratigraphy.

Introduction

Fossil findings of mammals are found relatively rarely in the Miocene deposits of Slovakia. In total, eleven localities are known which yielded Miocene mammals. The mammal faunas date the single sites to MN 6 until MN 10–11 biozones of the Neogene European Land Mammal Zones (Table 1).

From the biostratigraphic and paleoecological point of view, localities on the slopes of Devínska Kobyla Hill near Devínska Nová Ves (the former German name of this modern suburban part of Bratislava was "Neudorf an der March" or only "Neudorf") in the SW Slovakia are the most important and the best known. The sediments of these sites contain a large quantity of Miocene marine and terrestrial mammals. Holec & Sabol (1996) gave the first detailed list of the fossil taxa known from Devínska Kobyla localities.

However, a large quantity of new data on the Neogene ecosystems and environmental changes has been published recently (e.g. "EEDEN Project"). The result of that are already well-known "high-resolution" time intervals for the Eurasian realm. The results of many paleovertebratologists have yielded new data including major changes in the composition of marine and terrestrial vertebrate communities (e.g. Rössner & Heissig 1999).

These new data have been used for the revision of the Miocene mammal faunas from Slovak territory. The older data have been restudied and some of them corrected. This article provides a detailed review of the time distribution of Miocene mammal faunas in the territory of Slovakia.

Localities

The Slovak localities with Miocene mammal fossils are situated in three basins. Most of these sites is situated at the NE margin of the Vienna Basin (Zapfe's fissures, Bonanza, Sandberg, Wait Quarry, Glavica, Dúbravská hlavica, and Borský Svätý Jur). However, fossil findings of Miocene mammals are also known from the northern part of the Danube Basin (Pezinok, Topoľčany-Kalvária, and Nováky) and from the northern margin of the Transcarpathian (East Slovak) Basin (Košice-Bankov) (Fig. 1 and Table 2).

The **Zapfe's fissures** site (also known as Neudorf-Spalte) is the biostratigraphically oldest locality with mammal fossils in Slovakia. It is situated in the northern margin of the Vienna Basin near Bratislava on the northern slope of Devínska Kobyla Hill in the Stockerau limestone pit (the exact geographical position: longitude (LG) is 17° 01′ and latitude (LA) is 48° 12′) (Fig. 1). The locality consists of some fissures in the dark recrystallized Jurassic limestone of the Tatric Devín Succession of the Malé Karpaty Mts (in sense of Plašienka et al. 1991). They are often filled by the sinter, cave sediments, "terra rossa" and "terra fusca" (Mišík 1976) with the marine sandy deposits of the Sandberg Member overlying them. The site is dated to the lower part of the MN 6 biozone (Astaracian, the uppermost part of the Middle Badenian) on the basis of fossil mammal assemblages which were found in the terrestrial sediments of two of them (Cícha et al. 1972; Fejfar 1974) (Table 2).

The **Bonanza** locality was discovered in 1984. It is situated in the territory of the same quarry as the Zapfe's fissures site (Stockerau limestone pit; the exact geographic position is same), but on its eastern margin (Fig. 1). The site is represented by a broad fissure in the protective limestone wall oriented towards the railway line from Bratislava to Prague. Marine sands, sandstone and large limestone boulders fill the fissure. The sandy sediments contain fossil remnants of marine and terrestrial vertebrates and invertebrates (Holec et al. 1987; Ivanov 1998). Hereby, frog fossils (Špinar et al. 1993) suggest the presence of a fresh-water environment in the near vicinity of the locality during the period of deposition of the fossilifer-

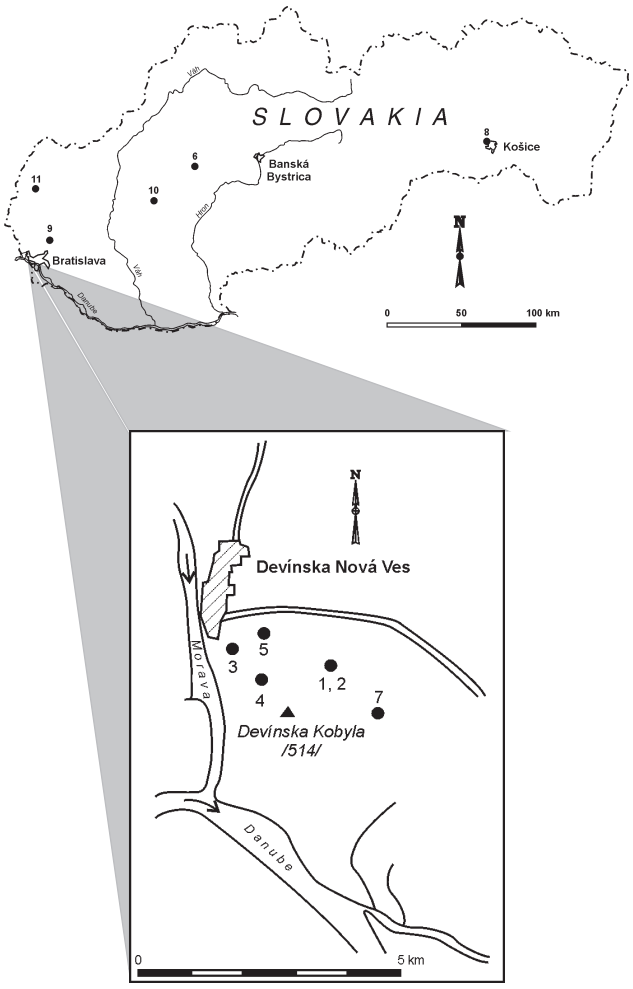


Fig. 1. Location of Slovak localities where fossil remains of Miocene mammals have been found. **1** — Zapfe's fissures, **2** — Bonanza, **3** — Sandberg, **4** — Wait Quarry, **5** — Glavica, **6** — Nováky-Mine Mier, **7** — Dúbravská hlavica, **8** — Košice- Bankov, **9** — Pezinok, **10** — Topoľčany-Kalvária, **11** — Borský Svätý Jur.

ous sediments. Their Badenian age has been determined on the basis of the presence of the bivalve *Pecten aduncus* Eichwald only (Holec et al. 1987). However, new findings of mammals (e.g. *Dinosorex zapfei* Engesser, 1975 or *Democricetodon vindobonensis* (Schaub et Zapfe, 1953)), indicate the Late Badenian age of the site (MN 6b) (Tables 2 and 3).

Approximately 2 km westwards from the Stockerau limestone pit on the north-western slope of Devínska Kobyla Hill, the **Sandberg** locality is situated on the southern border of Devínska Nová Ves (LG: 17° 00´, LA: 48° 12´) (Fig. 1). This significant paleontological site was determined as the faciostratotype for the Bulimina-Bolivina Zone of the Late Badenian (Švagrovský 1978). The locality consists of shallow littoral sediments of the Sandberg Member (basal coarse clastics, micaceous sands, clayey sands, calcareous sandstone, organogene and organodetritic limestone, breccias, and gravel layers (Baráth et al. 1994)) which are situated erosively on older sequences of the Mesozoic carbonates of the Tatric Devín Succession of the Malé Karpaty Mts (in sense of Plašienka et al. 1991). They are products of the Late Badenian transgressive event on the eastern margin of the Vienna Basin partly controlled by transtensive tectonics (Baráth et al. 1994). Abundant terrestrial and marine fauna of the vertebrates and invertebrates has been found here especially in the fine-grained gravel layers (Švagrovský 1978). On the basis of large terrestrial mammal fossils (fossils of micromammals have not been found in these marine sediments), the locality is dated to the Astaracian (MN 6b to MN 7+8?) (Table 2).

The **Wait Quarry** is the next locality in the vicinity of Devínska Nová Ves. It is an abandoned quarry on the western slope of Devínska Kobyla Hill, approximately 600–700 metres southwards from the Sandberg site (LG: 17° 00´, LA: 48° 12´) (Fig. 1). The site consist of transgressive horizontal layers of the Upper Badenian marine sands (Sandberg Member) situated in Lower Jurassic carbonates, especially in the upper parts of the quarry. Only findings of fishes, turtles and seals (Table 3) have been found here in the marine sands which fill the space of one little submarine cave (Zágoršek 1985). The age of the site probably corresponds to the age of the Sandberg site (MN 6b to MN 7+8?, Astaracian, the Late Badenian) (Table 2).

Fossils of whales (*Mesocetus* sp.) together with an undetermined mammalian rib have been found in the **Glavica** locality (Holec 2001). The locality is also situated near the Sandberg site approximately 1 km eastwards from Devínska Nová Ves (LG: 17° 00´, LA: 48° 12´) (Fig. 1). Like the Wait Quarry site, it consists of Upper Badenian marine sands in which layers of fine and coarse fractions alternate (Sandberg Member). The age of the locality was determined on the basis of the poor mollusc assemblages and it also corresponds with the Sandberg age (MN 6b to MN 7+8?, Astaracian) (Table 2).

The **Nováky-Mier Mine** locality is situated in the territory of the Danube Basin approximately 10 km south-west of Prievidza town in the central part of Slovakia (LG: 18° 35´, LA: 48° 42´) (Fig. 1). It is a coal mine where dark clays with coal and dark-green tuffaceous clays to sandy tuffites underlie the main coal bed with grey to dark-green tuffaceous clays overlying it (Takáč 1970). Andesite flows and pyroclastic rocks cover this Middle Miocene (Nováky Formation; Late Badenian–Early Sarmatian) coal complex. Besides plant fossils (especially fossils of the families *Taxodiaceae*, *Cupresaceae*, *Myriacaceae*, *Junglandaceae*, *Fagaceae*, *Hamamelidaceae*, *Lauraceae*, and others (Sitár & Takáč 1993)), one tooth of the *Zygolophodon turicensis* (Schinz, 1824) and odd fossils of rhinoceros have been found in the lignite bed too (Table 3). The more exact age of the fossils is not known. However on the basis of the flora findings, it is assumed the Late Badenian–Early Sarmatian (Sitár et al. 1987; Sitár & Takáč 1993). From the MN-zonation point of view it corresponds especially to the MN 7+8 biozone (Astaracian) (Table 2).

The **Dúbravská hlavica** locality is situated near Bratislava approximately 1-km south-eastwards from the Stockerau limestone pit and approximately 300 metres southwards from the Dúbravská hlavica trigonometric point (LG: 17° 01´, LA: 48° 11´) (Fig. 1). It consists of the Sarmatian clayey sediments (Karlová Ves Member) deposited above Late Badenian marine

Table 1: Middle to Late Miocene circum-Mediterranean marine-continental chronological correlations of the European Mammal Units and Zones (after Steininger 1999).

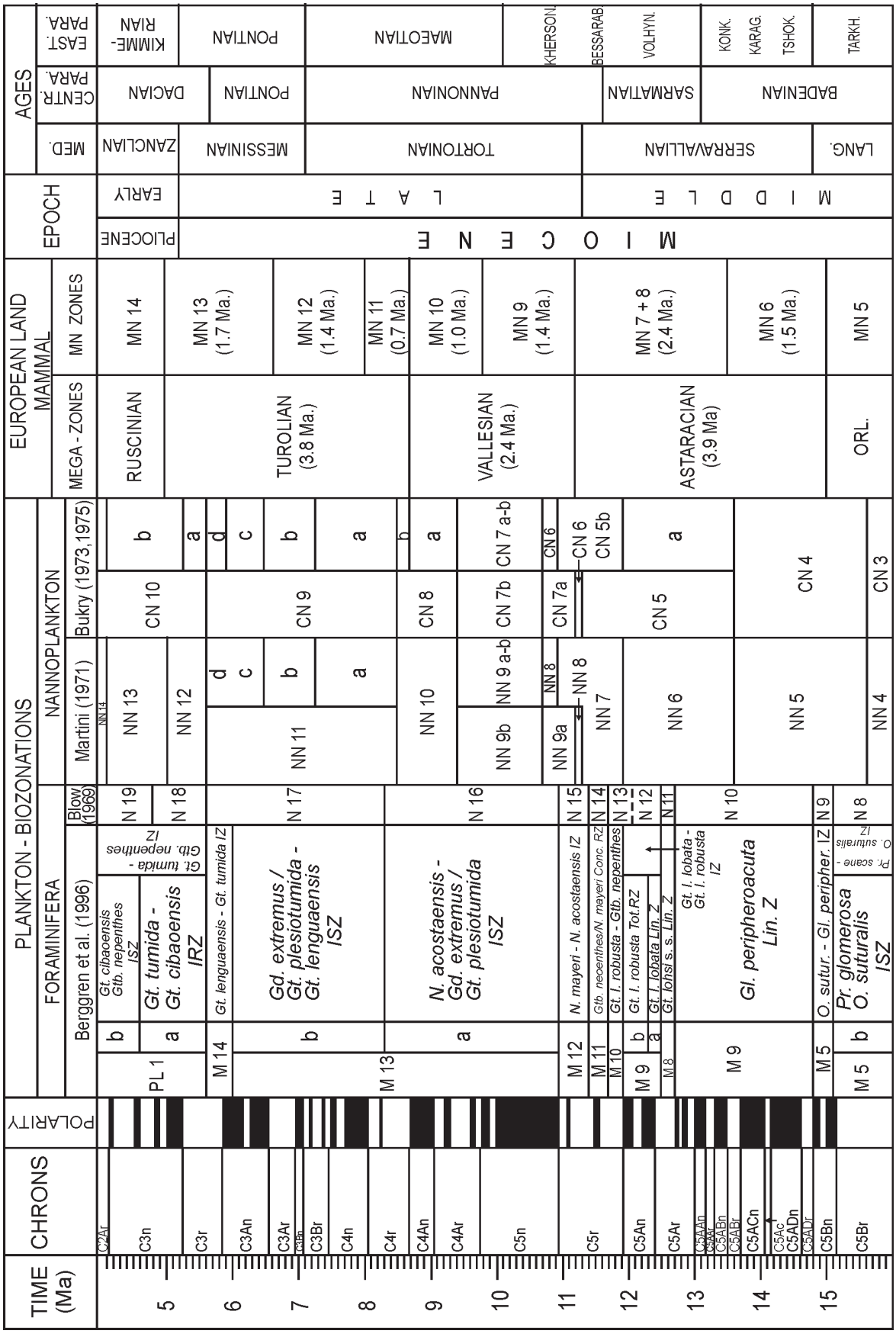


Table 2: Age of individual Slovak localities where the fossil remains of the Miocene mammals have been found.

Locality	Basin	Age	European Land Mammal		References
		Cent. Paratethys	Mega-zone	MN unit	
Zapfe's fissures	Vienna Basin	Middle Badenian	Astaracian	6a	Zapfe 1949, 1950a,b, 1951, 1952, 1953, 1954, 1960, 1976, 1979, 1983 Thenius 1952 Wettstein-Westtersheimb 1955 Estes 1969 Cícha et al. 1972 Fejfar 1972, 1974, 1990 Špinar 1975 Holec 1986 Holec & Sabol 1996
Bonanza	Vienna Basin	Late Badenian	Astaracian	6b	Holec et al. 1987 Špinar et al. 1993 Holec & Sabol 1996 Ivanov 1998
Sandberg	Vienna Basin	Late Badenian	Astaracian	6b – 7+8?	Hoernes 1848 Pia & Sickenberg 1934 Thenius 1952 Holec 1986 Holec & Sabol 1996
Wait Quarry	Vienna Basin	Late Badenian	Astaracian	6b – 7+8?	Zágoršek 1985 Holec & Sabol 1996
Glavica	Vienna Basin	Late Badenian	Astaracian	6b – 7+8?	Holec & Sabol 1996 Holec 2001
Nováky-Mier Mine	Danube Basin	Late Badenian–Early Sarmatian	Astaracian	7+8	Takáč 1970 Sitár et al. 1987 Sitár & Takáč 1993
Dúbravska hlavica	Vienna Basin	Sarmatian	Astaracian	7+8	Holec & Sabol 1996
Košice-Bankov	East-Slovak Basin	Sarmatian	Astaracian	7+8	Fejfar et al. 1987
Pezinok	Danube Basin	Pannonian	Vallesian	9	Fordinál 1997 Pipík 2000
Topoľčany-Kalvária	Danube Basin	Pannonian	Vallesian	9 – 10	Silnický 1930
Borský Svätý Jur	Vienna Basin	Pannonian	Vallesian–Turolian	10 – 11?	Lupták 1995a,b Pipík & Holec 1998

sands with fossils of the gastropod genera *Turitella* and *Conus* (Sandberg Member). Fossils of one rhinoceros individual have been found in the Sarmatian clayey deposits only (Holec & Sabol 1996) (Table 2).

The fossils of the Miocene mammals have been described from one locality in the territory of Eastern Slovakia only. It is the magnesite mine of **Bankov** (Fig. 1) at the north-western border of Košice town (LG: 21° 13´, LA: 48° 44´) where the Neogene rhyodacitic tuffs and tuffites fill paleokarst fissures in the metasomatic Carboniferous carbonates of the Ochtiná Formation. The fossils of the rare viverrid *Lophocyon carpathicus* Fejfar, Schmidt-Kittler et Zacharov, 1987 and proboscidean tusk fragments have been found in one of the fissures only (Table 3). Fejfar et al. (1987) suppose a Sarmatian age for the findings (MN 7+8, Astaracian) (Table 2).

Lower Pannonian fossiliferous strata are exposed by the **Pezinok** brickyard situated in the WNW part of the Danube Basin approximately 10 km northwards from Bratislava (LG: 17° 16´, LA: 48° 16´) (Fig. 1). The fossiliferous sediments (Ivánka Formation) consist of fine pelitic clays, green-grey sandy clays, fine sands and isolated little lignite beds in clays. Light and dark clays with isolated carbonate concretions are situated above this sequence. Besides findings of invertebrates, fossils of the *Hippotherium primigenium* H. v. Meyer, 1829 and *Trogontherium* have been found especially in the overlying clays. On the basis of the mollusc assemblage (with *Congeria subglobosa subglobosa* Partsch, *C. subglobosa longitesta* Papp, *Dreissenomya primiformis* Papp, and *Monodacna viennesis* Papp) (Fordinál 1997), the whole sedimentary complex has been dated to the upper part of the E zone (in sense of Papp 1951) (Early Pannonian, MN 9, Vallesian; Table 2).

The next locality in the territory of the Danube Basin is situated on the south-western border of Topoľčany town in the part known as **Kalvária** (LG: 18° 09´, LA: 48° 33´) (Fig. 1). The Upper Miocene coarse grey sands underlie the Quaternary sediments. Mandible fragments of *Hippotherium primigenium* have been found in the psammites in 1967 (Holec 1981) together with the proboscidean molars of a so-called "grandincisivoid" taxon (described by Silnický (1930) as *Stegotetrabelodon grandincisivus*). On the basis of these mammal fossils, the sediments of the site have been dated to the MN 9–10 biozone (Vallesian) which indicate the Pannonian age (Table 2).

The biostratigraphically youngest locality with findings of Miocene mammals in the territory of Slovakia (Table 2) is situated in the northern margin of the Slovak part of the Vienna Basin approximately 75 km north of Bratislava. It is loam pit of the brickyard in **Borský Svätý Jur** (LG: 17° 02´, LA: 48° 36´) (Fig. 1). The locality consist of clayey silts with some sandy beds, silty sands and fine sands which contain fossils of the ostracods, molluscs and vertebrates, especially mammals (e.g. *Eomellivora wimani* Zdansky, 1924; *Ictitherium viverrinum* Roth et Wagner, 1854; and "*Hipparion*" s.s.) (Pipík & Holec 1998). On the basis of mammal fossils, the locality is

preliminarily dated to the MN 11 biozone (Turolian, Middle Pannonian), but it is not excluded that they are older (Table 2).

Faunal History

The oldest fauna of Tertiary mammals in the territory of Slovakia is known from the period of the Middle Badenian (MN 6a). The fossils of single vertebrate taxa of this Astaracian fauna have been found in terrestrial sediments of the Zapfe's fissures locality on Devínska Kobyla Hill. During this period, the hill was probably a part of peninsula or it was part of a territory of insular character. The presence of this Middle Badenian fauna (Table 3) is result of migration waves into the territory of Europe during this period, especially from Africa. The most important elements of this African immigration are pliopithecids (*Pliopithecus (Epipliopithecus) vindobonensis* Zapfe et Hürzeller, 1957). According to Rögl (1999), they could still migrate into Europe before the short Langhian re-opening of the Tethyan Seaway to the Mediterranean. However, the older mammal elements which are present in the European fauna since the Early Badenian, are represented in the taxocenoses too. Many of these elements reached the territory of Europe from Africa (*Zygolophodon, Prodeinotherium, Aureliachoerus, Dorcatherium* and others) in the time of the so-called "*Gomphotherium* Landbridge", whereas the presence of other mammal taxa is a result of the Early Miocene invasion from Asia (*Eotragus, Megacricetodon, Eumyarion* and others) (Agustí et al. 2001; Rögl 1999).

Before the short transgressive event in the Late Badenian, which reached the Vienna Basin, the terrestrial fauna of mammals probably still persisted in the territory of Devínska Kobyla Hill. This fauna has been described from the marine sands of the Sandberg locality, and its composition is very similar to that from the Zapfe's fissures site (Table 3). However, the Sandberg taxocenoses shows also the presence of some different, especially younger elements (e.g. *Griphopithecus suessi* Abel, 1902, *Hemicyon goeriachensis* (Toula, 1884), *Tapirus telleri* Hofmann, 1893), whereas other ones (e.g. insectivores, rodents or chalicotheres) are missing here. It is not out of question that fauna of this composition also lived in the territory of Devínska Kobyla Hill near of the sea-shore during the transgression or in the time after this short Late Badenian marine cycle reached its maximum level. In this period, seals (*Devinophoca claytoni* (tentative name) and *Pristiphoca vetusta,* Zapfe) occupied the marine coast (Bonanza, Sandberg and Wait Quarry) and sirens (*Halitherium cordieri* Christol, *Thalatosiren petersi* (Abel), and *Metaxitherium* sp.) together with whales (*Mesocetus hungaricus* Kadic) and dolphins (*Schizodelphis* cf. *sulcatus* (Gervais, 1861)) lived in waters of this Late Badenian sea as well (Sandberg, Glavica) (Table 3).

The closure of the seaway between the Indo-Pacific and the Paratethys in the Early Sarmatian caused the change of salinity in the Paratethys (Rögl 1999) which was accompanied by a gradual regression, especially in its central part. Fossils of rhinoceros (*Brachypotherium* sp. from the Dúbravská hlavica site, and Rhinocerotidae gen. et spec. indet. from the Nováky-Mier Mine site), mammutids (*Zygolophodon turicensis* from the Mier Mine too) and the viverrid *Lophocyon carpathicus* together with undetermined remnants of "mastodons" from the Košice-Bankov site in the territory of Eastern Slovakia are known from this period only (MN 7+8) (Table 3). However, these finds are evidence of some intermittent faunal migrations in the time of changing environmental conditions, caused by the both marine regression and increased volcanic activity in the area of the Central Paratethys.

The beginning of the MN 9 biozone (Vallesian) is well defined by the first occurrence of "hipparions" in Europe and their overall expansion in the Northern Hemisphere (Rögl 1999). In this time, the Pannonian Lake had been situated in the territory of Central Paratethys. Its existence was a result of paleogeographical changes, which happened in this area before and at the beginning of the Late Miocene. A diferent consequence of these changes was the immigration of new faunal elements from Asia (including "hipparions" too) and the extinction of the Middle Miocene elements. The first appearance of "hipparions" in European territory is observed from the Late Bessarabian layers of the Nessebar site on the Bulgarian coast of the Black Sea (Bakalov & Nikolov 1962). However, the oldest findings of "hipparions" (*Hippotherium primigenium*) in the Slovak territory are known only from younger layers of the Pannonian (Pezinok, Topoľčany). Apart from the equid findings, the fossils of rodents (*Trogontherium* sp.) and a so-called "grandincisivoid" taxon (gen. indet. *grandicisivus*) have been found in the Lower Pannonian sediments in Slovak territory (Table 3).

The reduction of the Paratethys aquatic environment also continued after the Early Pannonian (Daxner-Höck 1996). The mammal assemblage in the sediments of the Borský Svätý Jur site is the only one of this period found in Slovakia. Fossil insectivores, carnivores, rodents, artiodactyls and perissodactyls have been found here. Finds of *Eomellivora wimani* (Lupták 1995a), *Ictitherium viverrinum* (Lupták 1995b), and "*Hipparion*" s.s. (described as *Hipparion* sp.; Pipík & Holec 1998) are among the most important of them (Table 3). The finding of *Eomellivora wimani* from the Borský Svätý Jur site is the northernmost occurrence of this giant mustelid species (Lupták 1995a).

So far, no fossils of terrestrial mammals from the younger deposits of the Late Miocene are known in the territory of Slovakia. However, it is not excluded that mammalian fauna of these periods (Late Pannonian–Pontian–Early Dacian) was also present here. Its presence in Europe is connected with the isolation of the Paratethys with nearly fresh-water conditions and with the migration pathways between Eurasia and Africa which remained open in the Near East area (Rögl 1999).

Discussion

The biostratigraphy of the Cainozoic continental sediments is established on the fossil assemblages of the terrestrial mammals, especially on the basis of rodent findings. In spite of good characterization of single mammalian biozones for the Neogene by the key-fossils, some differences exist in the opinions of scientists on the determination of the chronological calibration of single biozones, mainly for the Miocene Period (Table 4). These differences can also be observed in the dating

Table 3: The Miocene mammal taxa from Slovak localities. "Sandberg" — presence of the taxon in the site, "**Sandberg**" — type locality for present taxon, "*Sandberg*" — site of the taxon with the problematic taxonomical name.

Taxon	Locality	Age of Locality		MN range	References	Comments
Insectivora						
"Allosorex" gracilidens (Viret et Zapfe, 1951)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	4 - 6	Viret & Zapfe, 1951	
Amphechinus intermedius (Gaillard, 1899)	Zapfe´s Fissures	Middle Badenian	MN 6a	7+8	Zapfe, 1951	
Dinosorex zapfei Engesser, 1975	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6	Zapfe, 1951	
	Bonanza	Late Badenian	MN 6b			
Lanthanotherium sansaniense (Lartet, 1851)	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 7+8	Zapfe, 1951	
Lartetium dehmi (Viret et Zapfe, 1951)	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 7+8	Viret & Zapfe, 1951	
Plesiodimylus chantrei Gaillard, 1897	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 11	Zapfe, 1951	
	Bonanza	Late Badenian	MN 6b			
"Scaptonyx" edwardsi Gaillard, 1899	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 9	Zapfe, 1951	
Talpa minuta Blainville, 1840	Zapfe´s Fissures	Middle Badenian	MN 6a	3 - 9	Zapfe, 1951	
?Urotrichus dolichochir (Gaillard, 1899)	Zapfe´s Fissures	Middle Badenian	MN 6a	7+8	Zapfe, 1951	
Erinaceidae gen. et spec. Indet.	Bonanza	Late Badenian	MN 6b			
Soricidae gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
Talpidae gen. et spec. indet.	Zapfe´s Fissures	Middle Badenian	MN 6a		Zapfe, 1951	
	Bonanza	Late Badenian	MN 6b		Holec et al., 1987	
Insectivora gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
	Borský Svätý Jur	Pannonian	MN 10 - 11?		Pipík & Holec, 1998	
Chiroptera						
Megaptera lugdunensis (Depéret, 1892)	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 6	Zapfe, 1950b	
Miniopterus fossilis Zapfe, 1950	**Zapfe´s Fissures**	Middle Badenian	MN 6a	4 - 13	Zapfe, 1950b	
Paleptesicus priscus (Zapfe, 1950)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6 - 7+8	Zapfe, 1950b	
Rhinolophus delphinensis Gaillard, 1899	Zapfe´s Fissures	Middle Badenian	MN 6a	3 - 13	Zapfe, 1950b	
Rhinolophus grivensis (Depéret, 1892)	Zapfe´s Fissures	Middle Badenian	MN 6a	3 - 10	Zapfe, 1950b	
Chiroptera gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
Primates						
Griphopithecus suessi Abel, 1902	**Sandberg**	Late Badenian	MN 6b - 7+8?	6	Thenius, 1952	
Pliopithecus antiquus Blainville, 1839	Sandberg	Late Badenian	MN 6b - 7+8?	5 - 8	Thenius, 1952	
Pliopithecus vindobonensis Zapfe et Hürzeller, 1957	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6	Zapfe, 1952	
Carnivora						
Alopecocyon leptorhynchus (Filhol)	*Zapfe´s Fissures*	Middle Badenian	MN 6a	?	Zapfe, 1950a	
Amphicyon major Blainville, 1841	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 7+8	Zapfe, 1950a	
Amphicyon cf. *steinheimensis* Fraas, 1885	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 7	Zapfe, 1950a	
Amphicyon sp.	Sandberg	Late Badenian	MN 6b - 7+8?	1 - 11	Thenius, 1952	
Devinophoca claytoni Koretsky (tentative name)	Bonanza	Late Badenian	MN 6b	6		
Eomellivora wimani Zdansky, 1924	Borský Svätý Jur	Pannonian	MN 10 - 11?	11 - 12	Lupták, 1995a	
Hemicyon goeriachensis (Toula, 1884)	Sandberg	Late Badenian	MN 6b - 7+8?	6 - 9	Thenius, 1952	
Hemicyon sansaniensis Lartet, 1851	Zapfe´s Fissures	Middle Badenian	MN 6a	5b - 6	Zapfe, 1950a	
Hemicyon cf. *sansaniensis* Lartet, 1851	Zapfe´s Fissures	Middle Badenian	MN 6a	5b - 6	Zapfe, 1950a	
Ictitherium viverrinum Roth et Wagner, 1854	Borský Svätý Jur	Pannonian	MN 10 - 11?	9 - 12	Lupták, 1995b	
Lartetictis dubia (Blainville, 1842)	Sandberg	Late Badenian	MN 6b - 7+8?	6	Thenius, 1952	
Lophocyon carpathicus Fejfar et al., 1987	Košice-Bankov	Sarmatian	MN 7+8	7+8	Fejfar et al., 1987	
Potamotherium miocenicum (Petters, 1868)	Sandberg	Late Badenian	MN 6b - 7+8?	4a - 6	Thenius, 1952	
*Pristiphoca vetusta (*Zapfe)	Bonanza	Late Badenian	MN 6b	6 - 7+8?	Holec et al., 1987	
	Sandberg	Late Badenian	MN 6b - 7+8?		Holec & Sabol, 1996	
	Wait Quarry	Late Badenian	MN 6b - 7+8?		Zágoršek, 1985	
Pseudaelurus lorteti Gaillard, 1899	Sandberg	Late Badenian	MN 6b - 7+8?	4a - 7+8	Thenius, 1952	
Pseudaelurus turnauensis (Hoernes, 1882)	Sandberg	Late Badenian	MN 6b - 7+8?	3 - 9	Thenius, 1952	
Pseudaelurus sp.	Zapfe´s Fissures	Middle Badenian	MN 6a	3 - 9	Zapfe, 1950a	
Pseudarctos aff. *bavaricus* Schlosser, 1899	Sandberg	Late Badenian	MN 6b - 7+8?	4 - 9	Thenius, 1952	
Sansanosmilus jourdani (Filhol, 1883)	Zapfe´s Fissures	Middle Badenian	MN 6a	6b - 9	Zapfe, 1950a	
Trocharion albanense F. Major, 1903	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 9	Zapfe, 1950a	
	Bonanza	Late Badenian	MN 6b		Holec et al., 1987	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Ursavus brevirhinus (Hofmann, 1887)	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 6	Zapfe, 1950a	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Phocidae gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
Mustelidae gen. et spec. indet.	Zapfe´s Fissures	Middle Badenian	MN 6a			
	Sandberg	Late Badenian	MN 6b - 7+8?		Holec & Sabol, 1996	revised
Viverrinae gen. et spec. indet.	Bonanza	Late Badenian	MN 6b		Lupták, 1999	
Rodentia						
Anomalomys gaudryi Gaillard, 1900	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 9	Schaub & Zapfe, 1953	
Blackia miocenica Mein, 1970	Zapfe´s Fissures	Middle Badenian	MN 6a	2 - 11	Fejfar, 1974	
Bransatoglis astaracensis (Baudelot, 1970)	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 9	Fejfar, 1974	
	Bonanza	Late Badenian	MN 6b			
Cricetodon sansaniensis Lartet, 1851	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 7+8	Zapfe, 1949	
Democricetodon vindobonensis (Schaub et Zapfe, 1953)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6	Schaub & Zapfe, 1953	
	Bonanza	Late Badenian	MN 6b			
Democricetodon sp.	Bonanza	Late Badenian	MN 6b	4 - 9		
Eomyops sp.	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 14	Fejfar, 1974	
	Bonanza	Late Badenian	MN 6b			
Eumyarion latior (Schaub et Zapfe, 1953)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6	Schaub & Zapfe, 1953	
Eumyarion weinfurteri (Schaub et Zapfe, 1953)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	(4) - 6	Schaub & Zapfe, 1953	
Eumyarion sp.	Bonanza	Late Badenian	MN 6b	4 - 9	Holec et al., 1987	
Keramidomys carpathicus (Schaub et Zapfe, 1953)	**Zapfe´s Fissures**	Middle Badenian	MN 6a	(5) - 6	Schaub & Zapfe, 1953	
Lartetomys cf. *zapfei* Mein et Freudenthal, 1971	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 6	Fejfar, 1974	
*Megacricetodon gregarius (*Schaub, 1925)	Zapfe´s Fissures	Middle Badenian	MN 6a	7+8	Zapfe, 1949	
Megacricetodon schaubi Fahlbusch, 1964	Zapfe´s Fissures	Middle Badenian	MN 6a	6	Fejfar, 1974	
Megacricetodon sp.	Bonanza	Late Badenian	MN 6b	4 - 9		
Microdyromys miocaenicus (Baudelot)	*Zapfe´s Fissures*	Middle Badenian	MN 6a	?	Fejfar, 1974	
Miodyromys hamadryas F. Major, 1899	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 7+8	Zapfe, 1949	
Muscardinus (Eomuscardinus) sansaniense (Lartet, 1851)	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 7+8	Fejfar, 1974	
Myoglis larteti Baudelot, 1965	*Zapfe´s Fissures*	Middle Badenian	MN 6a	?	Fejfar, 1974	
Neocometes brunonis Schaub et Zapfe, 1953	**Zapfe´s Fissures**	Middle Badenian	MN 6a	6 - 8	Schaub & Zapfe, 1953	
	Bonanza	Late Badenian	MN 6b			
Spermophilinus bredai (H. von Meyer, 1848)	Zapfe´s Fissures	Middle Badenian	MN 6a	6 - 7+8	Fejfar, 1974	
	Bonanza	Late Badenian	MN 6b			
Trogontherium (Euroxenomys) minutum (H. v. Meyer, 1838)	Borský Svätý Jur	Pannonian	MN 10 - 11?	(3)4 - 13	Pipík & Holec, 1998	revised
Trogontherium sp.	Pezinok	Pannonian	MN 9	(3)4 - 13		
	Borský Svätý Jur	Pannonian	MN 10 - 11?		Pipík & Holec, 1998	

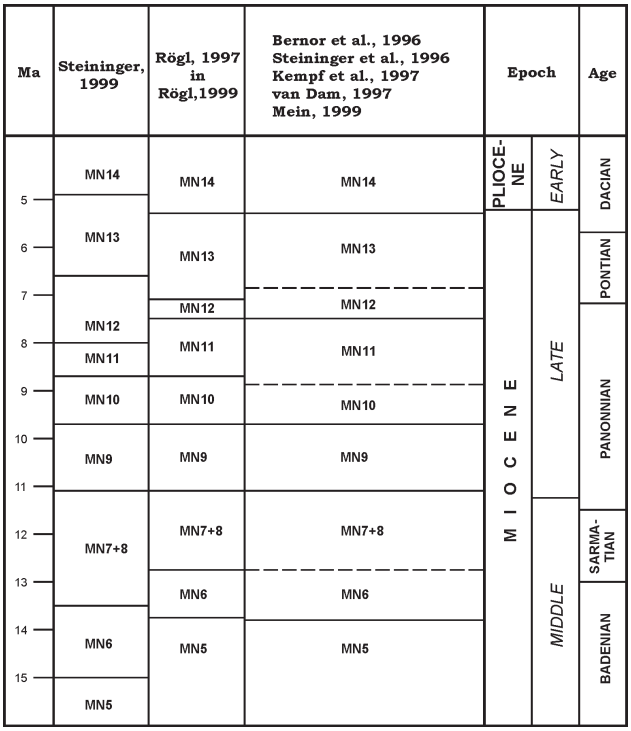
Table 3: *Continued.*

Gliridae gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
Sciuridae gen. et spec. indet.	Bonanza	Late Badenian	MN 6b			
Rodentia gen. et spec. indet.	Borský Svätý Jur	Pannonian	MN 10 - 11?		Pipík & Holec, 1998	revised
Perissodactyla						
Aceratherium sp.	Sandberg	Late Badenian	MN 6b - 7+8?	9 - 10	Thenius, 1952	
Anchitherium aurelianense Cuvier, 1812	Sandberg	Late Badenian	MN 6b - 7+8?	3 - 10	Thenius, 1952	
Brachypotherium sp.	Dúbravská hlavica	Sarmatian	MN 7+8	6 - 9	Holec & Sabol, 1996	revised
Chalicotherium grande (Blainville, 1849)	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 7	Zapfe, 1976	
Dicerorhinus stenheimensis (Jager, 1839)	Zapfe´s Fissures	Middle Badenian	MN 6a	7 - 9	Zapfe, 1949	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Haploaceratherium cf. *tetradactylum* (Lartet, 1851)	Zapfe´s Fissures	Middle Badenian	MN 6a	6	Zapfe, 1949	
"Hipparion" s. s.	Borský Svätý Jur	Pannonian	MN 10 - 11?	11 - 13	Pipík & Holec, 1998	revised
Hippotherium primigenium H. v. Meyer, 1829	Pezinok	Pannonian	MN 9	9 - 10	Holec, 1981	revised
	Topoľčany-Kalvária	Pannonian	MN 9 - 10		Holec, 1981	revised
Tapirus telleri Hofmann, 1893	Sandberg	Late Badenian	MN 6b - 7+8?	6	Thenius, 1952	
Rhinocerotidae gen. et spec. indet.	Zapfe´s Fissures	Middle Badenian	MN 6a		Zapfe, 1949	
	Nováky - Mier Mine	Late Badenian - Early Sarmatian	MN 7+8			revised
Proboscidea						
Deinotherium laevius (Jourdan)	*Sandberg*	Late Badenian	MN 6b - 7+8?	?	Thenius, 1952	
Prodeinotherium bavaricum (H. v. Meyer, 1831)	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 9	Zapfe, 1954	
Zygolophodon turicensis (Schinz, 1824)	Zapfe´s Fissures	Middle Badenian	MN 6a	3b - 10	Zapfe, 1954	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
	Bonanza	Late Badenian	MN 6b		Holec et al., 1987	
	Nováky - Mier Mine	Late Badenian - Early Sarmatian	MN 7+8			
gen. indet. *grandincisivus* (Schlesinger, 1917)	Topoľčany-Kalvária	Pannonian	MN 9 - 10	7+8 - 10	Silnický, 1930	revised
Proboscidea gen. et spec. indet.	Košice-Bankov	Sarmatian	MN 7+8		Fejfar et al., 1987	
Sirenia						
Halitherium cordieri Christol	Sandberg	Late Badenian	MN 6b - 7+8?	7+8?	Thenius, 1952	
Metaxitherium sp.	Sandberg	Late Badenian	MN 6b - 7+8?	7+8?	Thenius, 1952	
Thalatosiren petersi (Abel)	Sandberg	Late Badenian	MN 6b - 7+8?	7+8?	Thenius, 1952	
Artiodactyla						
Albanohyus pygmaeum (Depéret, 1892)	Sandberg	Late Badenian	MN 6b - 7+8?	4 - 9	Thenius, 1952	
Aureliachoerus aurelianensis (Stehlin, 1899)	Zapfe´s Fissures	Middle Badenian	MN 6a	3+4	Zapfe, 1983	
Conohyus simorrensis (Lartet, 1851)	Sandberg	Late Badenian	MN 6b - 7+8?	5 - 9	Thenius, 1952	
Dicrocerus elegans Lartet, 1837	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 6	Zapfe, 1949	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Dorcatherium naui Kaup, 1834	Sandberg	Late Badenian	MN 6b - 7+8?	4 - 10	Thenius, 1952	
Dorcatherium vindobonense H. v. Meyer, 1846	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 6(9)	Zapfe, 1949	
	Sandberg	Late Badenian	MN 6b - 7+8?		Meyer, 1846	
Eocetrus sp.	*Sandberg*	Late Badenian	MN 6b - 7+8?	?	Thenius, 1952	
Eotragus haplodon (H. v. Meyer)	*Zapfe´s Fissures*	Middle Badenian	MN 6a	?	Zapfe, 1949	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Heteroprox larteti (Filhol, 1891)	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 7+8	Zapfe, 1949	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Hyotherium soemeringi H. v. Meyer, 1829 sive 1934	Zapfe´s Fissures	Middle Badenian	MN 6a	4 - 6(9)	Zapfe, 1983	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Lagomeryx parvulus (Roger, 1898)	Sandberg	Late Badenian	MN 6b - 7+8?	4 - 6	Thenius, 1952	
	Bonanza	Late Badenian	MN 6b		Holec et al., 1987	
Palaeomeryx kaupi H. v. Meyer, 1834	Sandberg	Late Badenian	MN 6b - 7+8?	4 - 6	Thenius, 1952	
Palaeomeryx magnus Lartet, 1851	Zapfe´s Fissures	Middle Badenian	MN 6a	5 - 6	Zapfe, 1993	
	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	
Taucanamo sansaniense (Lartet, 1851)	Sandberg	Late Badenian	MN 6b - 7+8?	5 - 6	Thenius, 1952	
Listriodontinae gen. et spec. indet.	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	revised
Bovidae (Boselaphini) gen. et spec. indet.	Sandberg	Late Badenian	MN 6b - 7+8?		Thenius, 1952	revised
Artiodactyla gen. et spec. indet.	Borský Svätý Jur	Pannonian	MN 10 - 11?		Pipík & Holec, 1998	revised
Cetacea						
Mesocetus hungaricus Kadic	Sandberg	Late Badenian	MN 6b - 7+8?	7+8?	Holec & Sabol, 1996	
Mesocetus sp.	Glavica	Late Badenian	MN 6b - 7+8?		Holec, 2001	
Schizodelphis cf. *sulcatus* (Gervais, 1861)	Sandberg	Late Badenian	MN 6b - 7+8?	7+8?	Holec & Sabol, 1996	
Mammalia						
Mammalia gen. et spec. indet.	Glavica	Late Badenian	MN 6b - 7+8?		Holec & Sabol, 1996	

of some Slovak sites where the fossils of the Miocene mammals have been found.

The oldest fossil findings of mammals in Slovakia were described from the Zapfe's fissures locality. However, the more exact determination of their age is more or less problematical, because the biostratigraphical range of the most taxa of this terrestrial mammal assemblage is mainly from MN 5 to MN 8 biozones. On the other hand, the typical taxa of the MN 6 biozone (e.g. *Dinosorex zapfei* Engesser, 1975 (Ziegler 1999), *Eumyarion latior* (Schaub et Zapfe, 1953), *E. weinfurteri* (Schaub et Zapfe, 1953), *Democricetodon vindobonensis* (Schaub et Zapfe, 1953) (Kälin 1999), *Keramidomys carpathicus* (Schaub et Zapfe, 1953) (Engesser 1999), *Megacricetodon schaubi* Fahlbusch, 1964 (Kälin 1999) and others) are dominating. In spite of that, some scientists (e.g. Rögl 1999) contemplate the dating of this locality to the end of the MN 5 biozone. Their conclusions are especially based on the findings of the primate species *Pliopithecus (Epipliopithecus) vindobonensis* a representative of pliopithecids which migrated to Europe from Africa during the period of the MN 5 biozone. However, others (Köhler et al. 1999) date the fossil remnants of the pliopithecids from these fissures to the MN 6 biozone! Hereby, the rodent fauna of this site is distinctly younger than that from the MN 5 sites (e.g. Langenmoosen, Franzensbad, Teiritzberg, Ober Gänserndorf and others). It corresponds well with the opinion of Fejfar (1974, 1990, 1997). He dates the locality on the basis of the fossil rodent findings to the upper part of the Middle Badenian and excludes its dating to the MN 5 biozone (pers. commun.). An unanswered question is the exact species determination of some mammal fossils which do not fall into the assumed age of the locality by their biostratigraphic range. These findings have been determined as *Am-*

Table 4: Comparison of opinions on the dating of single Middle to Late Miocene MN-zones (modified after Bernor et al. 1996; van Dam 1997; Kempf et al. 1997; Mein 1999; Rögl 1999; Steininger 1999; Steininger et al. 1996).



phechinus intermedius (Gaillard, 1899) (MN 7+8), *Urotrichus dolichochir* (Gaillard, 1899) (MN 7+8), *Megacricetodon gregarius* (Schaub, 1925) (MN 7+8), *Dicerorhinus steinheimensis* (Jager, 1839) (MN 7–9), *Aureliachoerus aurelianensis* (Stehlin, 1899) (MN 3–4), and others (Table 3). It is not out of question that the fossils are either incorrectly determined or their original biostratigraphic range is larger. In spite of these discrepancies, we can conclude from the lithological circumstances that the Zapfe's fissures locality is older than the Sandberg site which is dated to the Late Badenian. On this basis, the locality is dated to the lower part of the MN 6 biozone (as MN 6a), whereas the dating to the MN 5 biozone can be excluded by the different character of the index small mammalian taxa.

The Sandberg site is another more or less problematic locality. According to the latest researches (Baráth et al. 1994), the marine sediments of the Sandberg Member have been deposited during the transgressive cycle. In spite of this, some opinions about the regression origin of these marine deposits are still always occurring in some papers (e.g. Rögl 1999). The transgression started in the Late Badenian period (14–13 Ma in sense of Rögl 1998), which is in good agreement with the age obtained on the basis of the Sr-dating of some Sandberg mollusc shells (13.6–13.5 Ma; Kováč et al. 1994). From the mammal-zones point of view, this time level corresponds to the end of the MN 6 biozone (Table 1). On the other hand, the findings of nannoplankton suggest the NN 6 biozone (Grigorovič et al., in press). After Steininger (1999), this nannoplankton biozone corresponds to the final phase of the MN 6 biozone, but mainly to the relevant part of the MN 7+8 biozone. Thus, a discrepancy exists between the age of this site determined on the basis of nannoplankton fossils and the age determined on the basis of the terrestrial mammals. From the mammal-zones point of view, the dating of the locality to the MN 6 biozone (Fejfar 1990) is especially supported by the findings of primate species *Griphopithecus suessi* Abel, 1902 (*G. darwini* (Abel, 1902) after Andrews et al. 1997) (African immigrant) and cervid species *Dicrocerus elegans* Lartet, 1837 (Asian immigrant). The fossils of the Sandberg suid, formerly determined to the species *Listriodon lockharti*, probably belong either to the species *Bunolistriodon lockharti* (Pomel, 1848), which is typical for the MN 4–5 biozones (Hünermann 1999), or to the other species of the genus *Listriodon* (e.g. *L. splendens* Meyer, 1846, MN 6–9). As in the case of the Zapfe's fissures locality, some other problematic findings of terrestrial mammals have been found here too (Table 3). They belong mainly to the taxa *Aceratherium* sp. (typical genus for the MN 9–10 biozones) and *Dicerorhinus steinheimensis* (MN 7–9). Besides the terrestrial mammals, fossil seals, sirens, whales and dolphins are also known from this site. However, these animals are probably younger (MN 7+8?) than the terrestrial ones. It is not out of question that the whole problem of locality age is caused by the redeposition of older osteological remnants of terrestrial mammals (MN 6) into younger marine sediments (NN 6, MN 7+8) during the transgressive period. In this time, the up-grading sea probably attacked the karst forms (fissures) which could serve as natural traps in the time of the MN 6 biozone (Table 2).

The marine sandy sediments of the Sandberg Member are widespread over the larger territory of Devínska Kobyla Hill. Besides the Wait Quarry and Glavica localities, they also fill the fissure in the Bonanza locality where terrestrial mammals and seals together with other vertebrates have been found. The terrestrial vertebrate assemblage of this site is very similar to that of Zapfe's fissures (especially mammals; Table 3). However, on the basis of the lithological circumstances we can conclude that the Bonanza fissure is younger than the Zapfe's fissures. It is also possible that the site is older than the Sandberg locality (Holec et al. 1987). Possibly, the Sandberg and Bonanza represent two stages of the transgressive event. Whereas the Sandberg deposits represent probably the top to final phase of the transgression, the sediments of the Bonanza can represent the initial phase of this Late Badenian marine event. From this point of view, the Bonanza site is dated to the upper part of the MN 6 biozone only.

The osteological remnants of the rhinoceros from the Dúbravská hlavica site belong to the genus *Brachypotherium* (Holec & Sabol 1996). Two species of this genus are known in the Miocene of Europe — older *B. brachypus* (Lartet, 1837) (MN 6 to MN 8) and younger *B. goldfussi* (Kaup, 1834) from the MN 9 biozone (Heissig 1999). Because the rhinoceros fossils have been not determined to the species, the age of the locality can be considered on the basis of the finding circumstances only. The overlying clayey sediments, in which mammal fossils have been found, are younger than the underlying sandy deposits of the Late Badenian and their age is probably the Sarmatian. On account of that, the rhinoceros

finding is preliminarily dated to the MN 7+8 biozone (Astaracian, Sarmatian), but it is not out of question that it is younger (MN 9?) (Table 2).

The beginning of the Vallesian is defined by the first occurrence of "hipparions" in Europe. The lower boundary of this Early Pannonian mammalian mega-zone has been determined as 11.1 Ma on the basis of the dating in the Vallés-Penedés Basin in Spain (Agustí 1996). This is in good agreement with the estimated age of the *Hippotherium primigenium* first occurrence at the base of the Pannonian C zone in the Vienna Basin with the age of 11.2 Ma (Rögl & Daxner-Höck 1996). However, the oldest specimens of this equid species in Slovak territory have been found at the Pezinok site in the Danube Basin where the clayey and sandy sediments have been dated to the upper part of the E zone (in sense of Papp 1951) (Fordinál 1997; Kováč et al. 1998; Baráth et al. 1999; Pipík 2000). The age of the Pannonian E zone in the Vienna Basin is determined at 8.9 to 9.7 Ma (Rögl et al. 1993). It is correlated with the MN 10 biozone (Rögl 1996), whereas the age of the E zone in the Danube Basin is more than 9.88 Ma (upper part of the Early Pannonian) (Fordinál et al. 2001) which corresponds to the upper part of the MN 9 biozone (Table 1). On the basis of that, the mammal findings from Pezinok are dated to the upper part of the MN 9 biozone (Table 2).

On the basis of both invertebrate and vertebrate fossils, the Borský Svätý Jur locality was dated to the period from the Pannonian to the Early Pontian (Pipík & Holec 1998). Whereas the most of the ostracod findings belong to the Early Pannonian E zone (in sense of Jiříček 1985), the mammal fossils indicate the younger period. Because the total biostratigraphic range of the mammal taxa from the site is relatively wide (from MN 9 to MN 13) (Table 3), the finding of the *Eomellivora wimani* (Lupták 1995a) is significant for the determination of their age. This large mustelid species lived in the territory of Europe during the Early Turolian only (MN 11 to MN 12 biozones; Ginsburg 1999). On this basis, the fossil mammals from the Borský Svätý Jur locality are preliminarily dated to the MN 11 biozone (Turolian, Middle Pannonian), but it is not excluded that they are older (e.g. according to Joniak (pers. commun.) new unpublished fossils of rodents from this site indicate the MN 10 biozone).

The absence of the mammal elements in the younger periods of the Late Miocene in Slovak territory could also be caused by the gradual aridization of the environmental conditions, which probably caused the Messinian crisis.

Conclusion

So far, findings of Miocene mammals are known from the sediments of eleven localities in the territory of Slovakia. They cover a time span from the Middle Badenian to the Pannonian. The Miocene mammals have been found at sites on the NE margin of the Vienna Basin, the northern part of the Danube Basin, and from the northern margin of the Transcarpathian (East Slovak) Basin. On the basis of new data and correction of older information, single localities can be dated to the MN-zones as it follows: MN 6a (Zapfe's fissures), MN 6b (Bonanza), MN 6b–7+8? (Sandberg, Wait Quarry, and Glavica), MN 7+8 (Dúbravská hlavica, Nováky-Mier Mine, and Košice-Bankov), MN 9–10 (Pezinok and Topoľčany-Kalvária), and MN 10–11? (Borský Svätý Jur).

Altogether more than 100 mammalian taxa have been described from the Slovak Miocene sites. Besides the terrestrial mammals, the marine ones have been found in four sites too (Bonanza, Sandberg, Wait Quarry, and Glavica). The presence of all these mammal assemblages in the sites is a result of paleogeographical and paleoenvironmental changes in the territory of the Central Paratethys in the time from the Middle to Late Miocene. The fossil mammals are evidence of repeated migration waves between Eurasia and Africa.

The open problem is the more exact determination of the age of some localities. This is mainly caused by the absence of some key fossils and the presence of taxa with a wide biostratigraphical range. The exact age of these problematic sites probably be found only by the magnetostratigraphy of their fossiliferous sediments.

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