

**EARLY MIOCENE SMALL MAMMAL REMAINS
(METATHERIA, CHIROPTERA, EULIPOTYPHILA)
FROM MOKRÁ-QUARRY FISSURES (SOUTH MORAVIA,
CZECH REPUBLIC) - PRELIMINARY RESULTS**

ZBYTKY SAVCŮ SPODNÍHO MIOCÉNU (METATHERIA, CHIROPTERA, EULIPOTYPHILA)
Z KRASOVÝCH PUKLIN LOMU MOKRÁ
(JIŽNÍ MORAVA, ČESKÁ REPUBLIKA) - PŘEDBĚŽNÉ VÝSLEDKY

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Abstract

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Early Miocene small mammal remains (Metatheria, Chiroptera, Eulipotyphla) from Mokrá-Quarry fissures (South Moravia, Czech Republic) - preliminary results

Mokrá-Quarry (South Moravia, Czech Republic) constitutes a unique fossil site with an extraordinary diversity of vertebrate remains. Most of the research on Mokrá-Quarry localities has focused on herpetofauna and, in most recent years, also in rodent remains. However, non-rodent small mammals have not been studied in detail. In this work, preliminary results of the small mammal assemblage belonging to the orders Chiroptera and Eulipotyphla, together with remains of *Amphiperatherium* from Mokrá-Quarry fissures are presented for the first time. The paleoecology inferred from these taxa agrees with previous studies, depicting Mokrá-Quarry as a karst landscape with open steppes, patches of woodland and close water bodies.

Key words: Herpetotheriidae, Erinaceidae, Talpidae, Rhinolophidae, Burdigalian, Moravian Karst.

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INTRODUCTION

Early Miocene fossil mammal assemblages are relatively frequent in Central Europe. In the case of the Czech Republic, several localities are known (CICHA *et al.* 1972; FEJFAR 1974, 1990; FEJFAR and ROČEK 1986; FEJFAR and KVAČEK 1993; FEJFAR *et al.* 2003; EKRT *et al.* 2016). Biostratigraphically, the oldest ones come from the early Burdigalian of Most Basin (Ohře/Eger Graben, NW Czech Republic) in Northern Bohemia. From this area, deposits of the brown coal seam of Ahníkov (MN3a) and the travertine limestones of Tuchořice (MN3b) have been identified. Regarding MN4 sites, Dolnice 1-3 in Cheb basin (Burdigalian, late Ottnangian–Karpatian) and Ořečov in South Moravia (Burdigalian, late Ottnangian) yielded abundant vertebrate remains (FEJFAR 1974, 1990). However, one of the most recent early Miocene vertebrate-bearing sites found in the territory of the Czech Republic is the open-cast limestone mine of Mokrá-Quarry, placed 12 km ENE of Brno, see IVANOV *et al.* (2006) and BONILLA-SALOMÓN *et al.* (2021a) for a detailed geological setting. Up to present, five different karst fissures have been found in Mokrá-Quarry (fig. 1): 1/2001 Turtle Joint, 2/2003 Reptile Fissure, Turtle Cave, and 4/2018 in the Western Quarry (hereinafter MWQ 1/2001, MWQ 2/2003, MWQ TC4 2001, and MWQ 4/2018, respectively); 3/2005 in the Central Quarry (MCQ 3/2005 from here on). Most of the research has focused on herpetofauna from the different fissures (IVANOV *et al.* 2006, 2018, 2020; IVANOV 2008; LUJÁN *et al.* 2017, 2021). Regarding mammals, the first preliminary ascriptions of medium-sized specimens were conducted by IVANOV and MUSIL (2004). Later, a faunal list of medium-sized and large mammals from MWQ 1/2001 and MWQ 2/2003 was published (IVANOV *et al.* 2006), but neither descriptions nor measurements of the fossil material were provided. As for small mammals, the first preliminary study of fauna from MWQ 1/2001 was conducted by SABOL *et al.* (2007). More recently BONILLA-SALOMÓN *et al.* (2021a) described for the first time in detail the small mammal remains of MWQ 1/2001, including non-rodent small mammal remains. BONILLA-SALOMÓN *et al.* (2021b) also published the sciurid material from MWQ 2/2003 and MCQ 3/2005. However, the non-rodent remains from MWQ 2/2003, MCQ 3/2005 and MWQ 4/2018 have not yet been studied in detail. In this work, preliminary results on the non-rodent small mammal fauna from all fissures in Mokrá-Quarry are presented, and the palaeoecological implications from are confronted with our current knowledge on the matter.

MATERIAL AND METHODS

The micromammal assemblages from MWQ 1/2001, MWQ 2/2003 and MCQ 3/2005 were discovered during the field campaigns led by M. Ivanov and R. Musil (Masaryk University, Brno, Czech Republic) during the years 2002–2005 (IVANOV and MUSIL 2004). More recently, Mokrá-Quarry has yielded another mammal-bearing fissure: MWQ4/2018. The fossil remains, mixed in sand and clays, were obtained by washing in sieves of 0.5 mm mesh (see IVANOV *et al.* 2006; LUJÁN *et al.* 2021). The material is currently housed in the collections of the Department of Geological Sciences (Faculty of Science, Masaryk University) under the inventory numbers SMM/009-09-11/372,009, Pal. 3000–4210.

The upper cheek teeth are indicated by upper case letters (DP4, P4, M1, M2, M3), whereas the lower cheek teeth by the lower case (dp4, p4, m1, m2, m3). When the distinction between first and second molars is dubious, these are indicated as M1/2 or m1/2. Micrographs were taken using a Quanta FEG 250 Scanning Electron Microscope (SEM) at Institute of Electrical Engineering of the Slovak Academy of Sciences (SAS) in Bratislava (Slovakia).

Miocene time scale and biostratigraphy are based on International Chronostratigraphic Chart (COHEN *et al.* 2020), Central and Eastern Paratethys boundaries follow GOZHYK *et al.* (2015) and KOVÁČ *et al.* (2018); modified MN-zonations follow STEININGER (1999) and HILGEN *et al.* (2012).

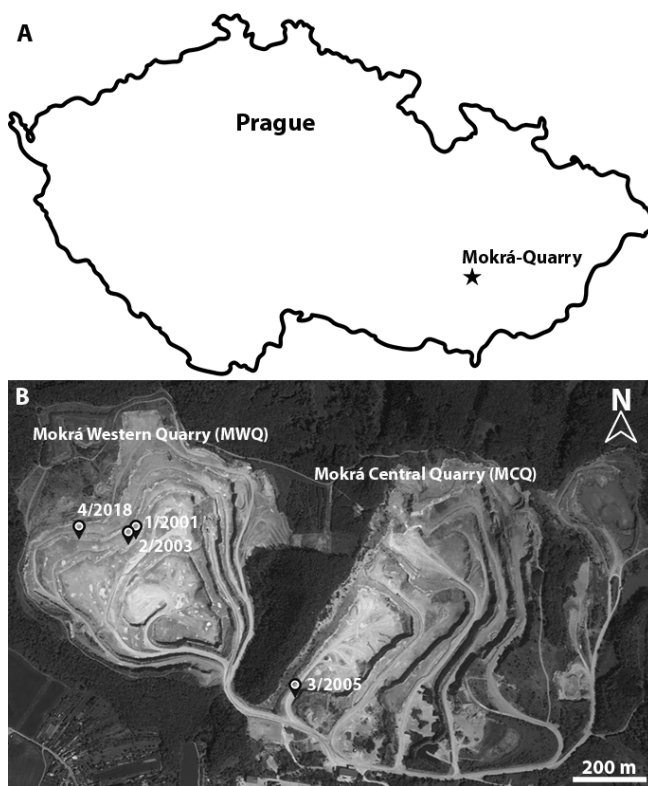


Figure 1. Location of Mokrá-Quarry. A - Geographical position of Mokrá-Quarry in the Czech Republic. B - Position of Mokrá Western and Central Quarries, as well as the location of MWQ 1/2001, MWQ 2/2003, MCQ 3/2005, MWQ 4/2018 sites; source Mapy.cz (modified).

Obr. 1. Poloha lokality Mokrá-lom. A - geografická pozice lomu Mokrá v České republice. B - pozice Západního a Středního lomu, umístění lokalit MWQ 1/2001, MWQ 2/2003, MCQ 3/2005, MWQ 4/2018; zdroj Mapy.cz (upraveno).

SYSTEMATIC PALEONTOLOGY

Infraclass: METATHERIA Huxley, 1880

Family: HERPETOTHERIIDAE Trouessart, 1879

Genus: *Amphiperatherium* Filhol, 1879

Amphiperatherium frequens (von Meyer, 1846)

Included material: Four isolated teeth belonging to *Amphiperatherium frequens* have been identified in MWQ 2/2003, including an M2 and a M4 (fig. 2A, B). Furthermore, a fragment of mandible with m3 and m4 from MWQ 4/2018 has also been attributed to the species.

Remarks: The teeth, even though they are scarce, show clear and distinct morphology of Metatheria, such as the presence of a fourth molar. This allows straightforward attribution of the species. *Amphiperatherium frequens* represents the last occurrence of an herpetotheriid species in Europe and even the last herpetotheriid ever. Herpetotheriidae is an extinct metatherian family, a sister group of all living marsupials (SÁNCHEZ-VILLAGRA *et al.* 2007; HOROVITZ *et al.* 2009), but with no extant relatives. This metatherian group reached its diversity peak during the early Eocene, from which started to decrease in both relative abundance and number of species within mammal associations. The species *A. frequens* has

been recorded in other MN4 localities in Central Europe, such as Forsthart and Rembach (ZIEGLER and FAHLBUSCH 1986), Petersbuch 28 (KLIETMAN *et al.* 2014) or Oberdorf 3 and 4 (DÄXNER-HÖCK 1998). As for Czech sites, it has also been recorded in Ahnikov I and Tuchořice (FEJFAR *et al.* 2003) and in Dolnice 1-3 (FEJFAR and KVAČEK 1993). The genus is no longer recorded in Czech sites during the middle Miocene; however, one of the latest records of the genus come from the German locality of Sandelzhausen (MN5; FAHLBUSCH, 2003).

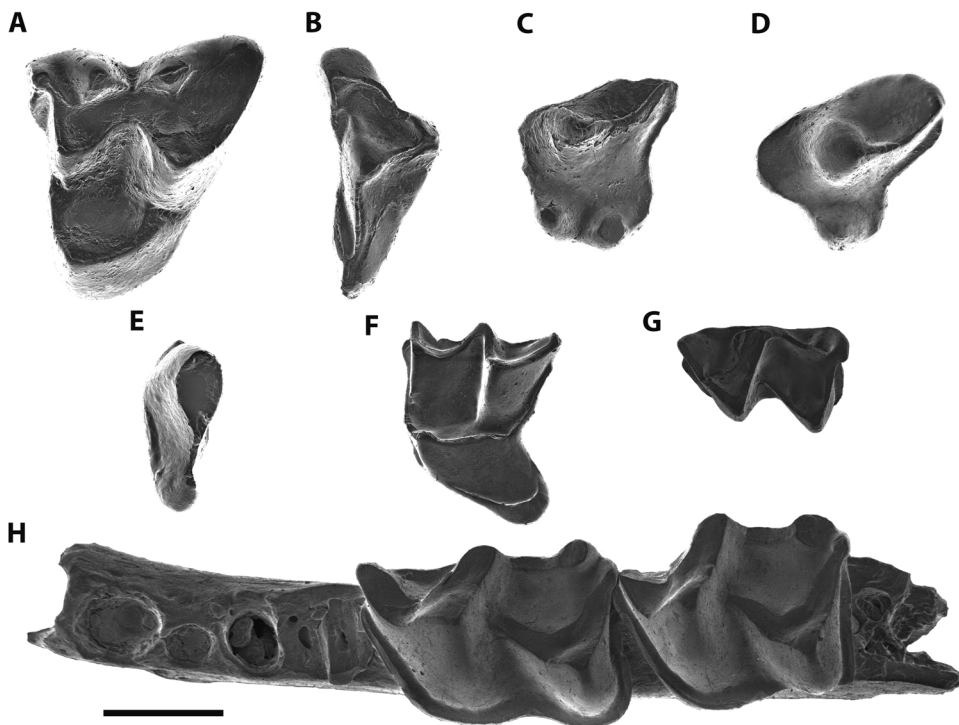


Figure 2. Scanning electron micrographs of small mammal remains from Mokrá-Quarry in occlusal view. **A** - Left M2 of *Amphiperatherium frequens* (Pal. 3546); **B** - Right M4 of *Amphiperatherium frequens* (Pal. 3547); **C** - Right P3 of *Galerix* sp. I (Pal. 3525); **D** - Right P3 of *Galerix* sp. II (Pal. 3543). **E** - Upper premolar of *Talpa* sp. (Pal. 3522); **F** - left M1 of *Rhinolophus* sp. II (Pal. 3676); **G** - fragment of left m1/2 of *Rhinolophus* sp. II (Pal. 3670); **H** - Fragment of left mandible with m1-m2 of *Rhinolophus* sp. I (Pal. 3628). Scale bar represents 1 mm. All teeth are figured as left elements.

Obr. 2. Mikrosnímky ze skenovacího elektronového mikroskopu zachycující zbytky drobných savců z okluzální strany na lokalitě Mokrá-lom. **A** - levý M2 druhu *Amphiperatherium frequens* (Pal. 3546); **B** - pravý M4 druhu *Amphiperatherium frequens* (Pal. 3547); **C** - pravý P3 druhu *Galerix* sp. I (Pal. 3525); **D** - pravý P3 druhu *Galerix* sp. II (Pal. 3543). **E** - horní premolár *Talpa* sp. (Pal. 3522); **F** - levý M1 druhu *Rhinolophus* sp. II (Pal. 3676); **G** - fragment levého m1/2 druhu *Rhinolophus* sp. II (Pal. 3670); **H** - fragment levé mandibuly s m1-m2 druhu *Rhinolophus* sp. I (Pal. 3628). Měřítko odpovídá 1 mm. Všechny zuby jsou zobrazeny jako levé elementy.

Infraclass: EUTHERIA Huxley 1880
Order: ERINACEOMORPHA Gregory, 1910
Family: ERINACEIDAE Fischer von Waldheim, 1817
Subfamily: Erinaceinae Fischer von Waldheim, 1817
Genus *Amphechinus* Aymard, 1850
Amphechinus sp.

Included material: 12 isolated teeth of the genus *Amphechinus* have been identified from MWQ 2/2003, the only fissure that has yielded remains of this genus.

Remarks: *Amphechinus* is characterized by its more rectangular shape in upper molars and the relative size of M2. Despite the scarce assemblage, it constitutes one of the richest collections of *Amphechinus* from the lower Miocene in Central Europe, because *Amphechinus* is a very rare finding in early Miocene assemblages in this area. It has also been recorded in other few MN4 sites in Central Europe, but in smaller amount: from Petersbuch 2 and Erkerthshofen, both sites in Germany, only 6 teeth and an M2 fragment have been found, respectively (ZIEGLER 1990). In the Iberian Peninsula there are more records of *Amphechinus*, although no detailed description has been provided (HOEK OSTENDE and FURÍÓ 2005). In all, this genus is still poorly known in European assemblages during the early Miocene. The detailed description of the material from Mokrá-Quarry will help understand its characteristics and ecological requirements.

Subfamily: Galericinae Pomel, 1848
Genus *Galerix* Pomel, 1848
Galerix sp. I and II

Included material: The genus *Galerix* is found in three fissures in Mokrá-Quarry: MWQ 2/2003, MCQ 3/2005 and MWQ 4/2018. The remains of the genus are more abundant in MWQ 2/2003, whereas in MCQ 3/2005 the assemblage consists only of 5 isolated teeth and in MWQ 4/2018 even scarcer, with only 2 recovered so far.

Remarks: The overall assemblage recovered from Mokrá-Quarry could represent the presence of two species of this genus. This is well supported by the presence of two different P3 morphologies in fissure MWQ 2/2003. One of them (Pal. 3525, fig. 2C) shows the diagnostic features of *Galerix symeonidisi*, such as the presence of a second cusp, the hypocone, on the lingual side (DOUKAS 1986). There is, however, another P3 (Pal. 3543, fig. 2D) that lacks hypocone, which could indicate that belongs to a different species of the same genus. A few localities in the lower Miocene are known to have yielded two different species of *Galerix*, such as Erkerthshofen 1 and 2 and Petersbuch 2 in Germany (ZIEGLER 2006), where the forms *G. aurelianensis* and *G. symeonidisi* coexist. At any rate, the complete study of the available remains of *Galerix* from Mokrá-Quarry will help elucidate the taxonomic content of the genus and the implications of its presence in the paleoenvironmental reconstruction.

Family: TALPIDAE Fischer von Waldheim, 1817
Subfamily: Talpinae Fischer von Waldheim, 1817
Genus *Talpa* Linnaeus, 1758
Talpa sp.

Included material: one upper premolar from MQW 2/2003 and isolated postcranial elements of MWQ 2/2003 and MCQ 3/2005.

Remarks: A single tooth has been recovered from MWQ 2/2003 (fig. 2E), which makes it difficult to provide a definitive attribution at the species level. However, the slenderness of the premolar together with the unequivocal morphology of the identified humerus point towards the genus *Talpa*. Besides the presence of this genus in Mokrá-Quarry, remains of the species *Talpa minuta* have also been found in other Czech localities of roughly the same age as Mokrá-Quarry (i.e., Dolnice 1–3 and Ořechov). As for other MN4 locali-

ties in Central Europe, Petersbuch 2 and Oberdorf 3 (Germany and Austria, respectively) have also yielded remains of the species (ZIEGLER 2006).

Talpa is a very rare find within early Miocene small mammal assemblages; its presence is indicative of a very rich diversity among Eulipotyphla and is very relevant for paleoecological reconstructions (see the section below). *Talpa minuta* is the only species of the genus known in Central Europe during the early Miocene. The type population of the species comes from Sansan (ENGERSSER 2009; middle Miocene, MN6), so its use for stratigraphical purposes is irrelevant.

Order: CHIROPTERA Blumenbach, 1779

Family: RHINOLOPHIDAE Gray, 1825

Genus: *Rhinolophus* Lacépède, 1799

Rhinolophus sp. I and II

Included material: 100 dentognathic elements from MWQ 2/2003; a single fragment of mandible with m1-m2 from MCQ3/2005.

Remarks: Chiroptera remains are very abundant in MWQ 2/2003, with 100 elements including fragments of mandible and maxilla. However, the most abundant remains are isolated teeth. They constitute around 25% of all small mammal remains recovered from this fissure. In MCQ 3/2005, however, their relative abundance is much less relevant, since only a fragment of mandible with m1-m2 has been recovered. In MWQ 4/2018 no tooth remains of bats have been recovered. This fissure has yielded a very poor assemblage of small mammals so far (only 7 teeth have been found). However, the absence of Chiroptera in this karst fissure, where they constitute one of the most present groups (ZIEGLER, 2003), is still relevant. In the previously studied MWQ 1/2001 two different species of the genus *Rhinolophus* were found: one large form attributed to *R. cf. cluzeli*, and a smaller one identified as *R. cf. grivensis* (see BONILLA-SALOMÓN *et al.* 2021a, for a detailed discussion). In MWQ 2/2003 two different groups of rhinolophid bats have also been identified: one small (fig. 2F, G) and another one of larger dimensions (fig. 2H). The assemblage from MWQ 2/2003 is much richer than the already studied MWQ 1/2001, so a complete study of these elements would provide a much deeper insight into the Chiroptera populations from Mokrá-Quarry, thereby expanding our knowledge of early Miocene rhinolophid bats from Central Europe. For the time being and waiting for a detailed study, the Chiroptera elements from MWQ 2/2003 are identified as *Rhinolophus* sp. I and II.

PALAEOECOLOGY AND BIOCHRONOLOGY

For biochronologic purposes, the record of rodents is very important. The recent study conducted by BONILLA-SALOMÓN *et al.* (2021a) on the rodent assemblage from MWQ 1/2001 determined an early Miocene age for Mokrá-Quarry (Burdigalian, MN4). These conclusions agreed with the preliminary results on the small mammal fauna presented by SABOL *et al.* (2007). Furthermore, MWQ 1/2001 assemblage yielded a similar small mammal fauna than other early Miocene Czech localities, such as Dolnice 1–3 and Ořeřchov. For that reason, Mokrá-Quarry is considered to be roughly the same age. The small mammal assemblages from the rest of the fissures are currently under study by the authors, but the first results points towards a similar age for all fissures from Mokrá-Quarry.

Regarding the palaeoenvironment, the small mammal fauna presented here agree with the previous research on ecological conditions in Mokrá-Quarry. *Amphiperatherium* is a genus that during the early Miocene was mostly present in Central European localities. The limited presence of this taxon is probably a result of the limited tolerance towards climatic and environmental changes. During the early Miocene, environmental conditions were more humid in Central Europe than in other regions (UTESCHER *et al.* 2011), which could explain the higher presence of *Amphiperatherium* in this region.

Ampechinus, and the subfamily Erinaceinae, are in general not abundant in Europe during the Miocene. Moreover, there are very few localities in which they are more abundant than Galericinae. Mokrá-Quarry is one of those few sites. The genus *Galerix*, on the other hand, is characterized by its presence in forested environments and close to water bodies, where they would feed on plant matter and invertebrates (ZIEGLER 1999). However, GARCÍA-ALIX *et al.* (2008) consider that *Galerix* and other Miocene Galericipini were adapted to a high diversity of habitats. At any rate, the presence of open steppes, with woodland and close water bodies, would constitute a good habitat for *Galerix*. The representatives of the genus *Talpa* are adapted to the subterranean lifestyle, where they dig burrows and feed mostly on invertebrates (e.g., earthworms). Therefore, they have a clear preference for relatively humid environments. Rhinolophid bats, according to STORCH (1999), are strict cave-dwellers that feed on invertebrates they find on foliage. Furthermore, the presence of this group of bats is indicative of a large cave in time of deposition.

In all, the small mammal fauna presented here agrees with previous studies on the palaeoecology of Mokrá-Quarry (IVANOV *et al.* 2006, 2018, 2020; SABOL *et al.* 2007; IVANOV 2008; LUJÁN *et al.* 2017, 2021; BONILLA-SALOMÓN *et al.* 2021a), which has been characterized as a karst landscape, with patches of forest and steppes and close to water bodies. BONILLA-SALOMÓN *et al.* (2021b) described the sciurid remains from fissures MWQ 2/2003, MCQ 3/2005 and MWQ 4/2018, and noticed a higher number of flying squirrel teeth in MCQ 3/2005. The authors interpreted the high accumulation of these remains as the presence of nocturnal predators feeding on them. These nocturnal predators would find a place to rest in the karst rocks. Since bats are solely represented by one tooth in this fissure it would indicate that the predators had a preference for other groups of small mammals, such as rodents, which are much more abundant.

CONCLUSIONS

The small mammal fauna presented here include non-rodent remains recovered from MWQ 2/2003, MCQ 3/2005 and MWQ 4/2018. In the preliminary study several taxa have been identified: *Amphiperatherium frequens*, *Ampechinus* sp., *Galerix* sp. I and II, *Talpa* sp., and two species of *Rhinolophus*. This faunal assemblage represents a wide diversity of non-rodent small mammal taxa. The preliminary results agree with the previous paleoenvironmental conditions estimated for the locality, depicting Mokrá-Quarry as a karst landscape, with open steppe and patches of a forest close to water bodies. The complete study of these remains, together with the detailed description of the rodent assemblage will broaden our knowledge on small mammal faunas during the early Miocene in Central Europe.

SOUHRN

Při těžbě vápence v prostoru velkolomu Mokrá (Jižní Morava, Česká republika) se v průběhu posledních asi 20 let podařilo objevit několik krasových puklin vyplněných fosiliferními sedimenty spodního miocénu. Jedná se o unikátní naleziště fosilií s mimořádnou rozmanitostí pozůstatků obratlovců. Většina výzkumů obratlovců z těchto puklin však byla zaměřena na výzkum herpetofauny a v posledních letech i na pozůstatky hlodavců. Ostatní drobní savci nebyli dosud podrobně studováni. V této práci jsou z puklin MWQ 2/2003, MCQ 3/2005 a MWQ 4/2018 poprvé prezentovány předběžné výsledky studia zástupců řádů Chiroptera a Eulipotyphla spolu s pozůstatky Metatheria, přičemž identifikovány byly následující taxony: *Amphiperatherium frequens*, *Ampechinus* sp., *Galerix* sp. I a II, *Talpa* sp. a dva druhy rodu *Rhinolophus*. Paleoekologie odvozená z těchto taxonů souhlasí s předchozími studii zobrazujícími lokalitu Mokrá jako součást krasové krajiny s mozaikou otevřených stepních biotopů a lesů v blízkosti vodních rezervoárů. Kompletní studium těchto

to pozůstatků spolu s podrobným popisem hlodavců rozšíří naše znalosti o spodnomiocenní fauně drobných savců v oblasti střední Evropy.

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