FRAGMENTA PALAEONTOLOGICA HUNGARICA
Volume 37 Budapest, 2021 pp. 127–144

A late Pleistocene fossiliferous paleokarst site in the Western Mecsek Mts (Bükkösd, SW Hungary)

Krisztina Sebe*[1], Zoltán Szentesi[2], Piroska Pazonyi[3,4], Gergely Surányi[5,6] & Gábor Csillag[6,7]

*[1]*Department of Geology and Meteorology, University of Pécs, H-7624 Pécs, Ifjúság ú. 6, Hungary. E-mail: sebe@gamma.ttk.pte.hu; corresponding author*
[2]*Department of Palaeontology and Geology, Hungarian Natural History Museum, H-1083 Budapest, Ludovika tér 2, Hungary. E-mail: szentesi.zoltan@nhmus.hu*
[3]*MTA–MTM–ELTE Research Group for Paleontology, H-1083 Budapest, Ludovika tér 2, Hungary. E-mail: pinety@gmail.com*
[4]*Eötvös Loránd University, Institute of Geography and Earth Sciences, H-1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
[5]*Isotope Climatology and Environmental Research Centre, Institute for Nuclear Research, H-4026 Debrecen, Bem tér 18/c, Hungary. E-mail: surda007@gmail.com*
[6]*ELKH–ELTE Geological, Geophysical and Space Science Research Group of Eötvös University, H-1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
[7]*Research Centre for Astronomy and Earth Sciences, Institute for Geological and Geochemical Research, H-1112 Budapest, Budaörsi út 45, Hungary. E-mail: gabor.csillag.53@gmail.com*

Abstract – In the framework of a project studying the karst region of the Western Mecsek Mts in 2018–19, a new paleokarst cavity containing abundant vertebrate remains was found near the village of Bükkösd, extending the sparse Quaternary vertebrate record of the region. The herpetofauna is represented by a salamandrid, a true frog, lacertid lizards and colubrid snakes, the latter dominating the vertebrate material. The poor mammal material shows that the area was inhabited by insectivores, bats, mice, hamsters and voles. The vertebrate remains show no signs of long transport. The composition of the total vertebrate fauna suggests a sunny, rocky hillside with scrub and trees in places in the immediate vicinity of the accumulation site. The age of the charcoal recovered from the cavity fill (41–42 ka) suggests that the fauna is late Pleistocene (MIS 3), this makes the assemblage the first proven MIS 3 fauna in southern Hungary. The re-evaluation of the paleokarst-related fossil material previously reported from the Mecsek revealed a further assemblage probably also of MIS 3 age, the Mélyvölgy Rock shelter. The palaeoclimate reconstructed from the palaeoecological analysis of the faunas is warmer than that from coeval sites in northern Hungary, with more closed (forested) vegetation than the northern mammoth steppes. This refers to the existence of a north-south thermal gradient in the Carpathian Basin at the time. The U-series dating of speleothems showed that the karst cavity had existed for more than 0.5 Ma. During MIS 3, the cavity stopped to be part of an active karst conduit and it was filled up by loess-derived silt. The site was lying above the karst water table then, and it may have acted as a trap either for the live animals or for the bones deposited on the surface. With 25 figures and 3 tables.

Key words – paleokarst, vertebrates, palaeoecology, MIS 3, thermal gradient

INTRODUCTION

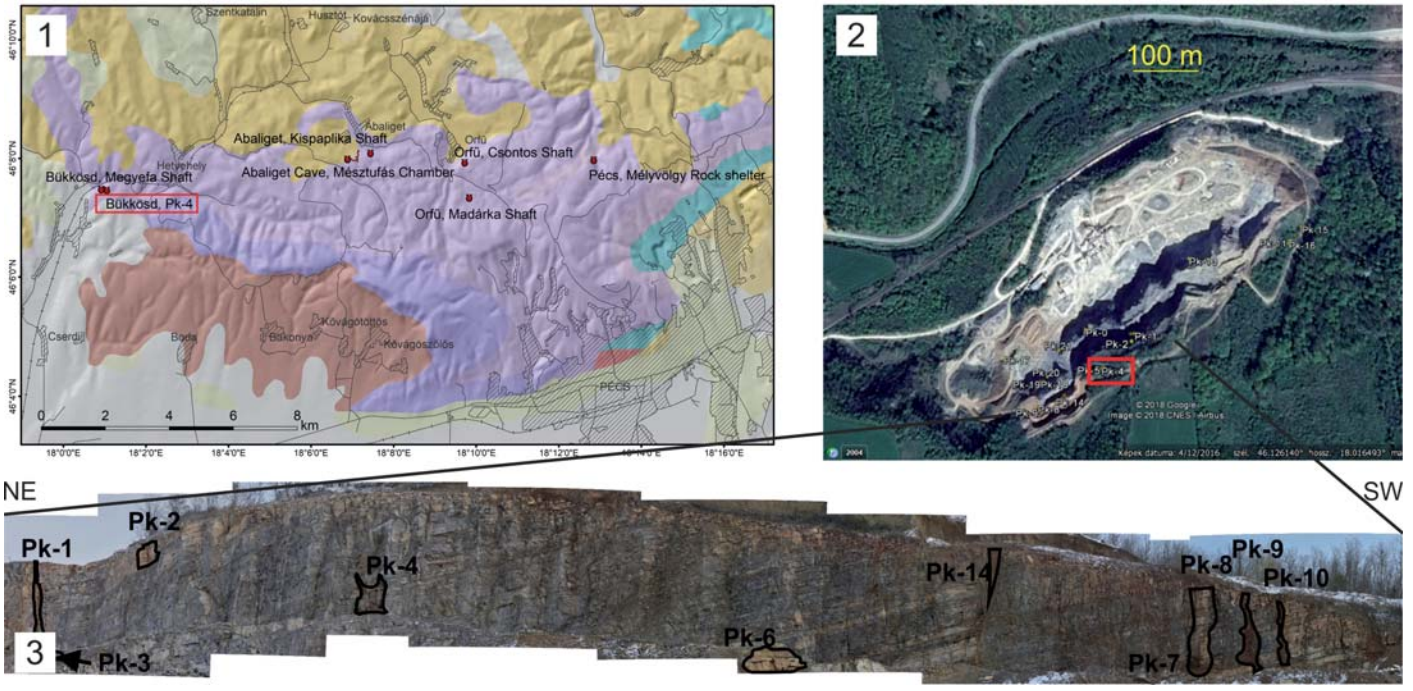
Paleokarst cavities with vertebrate remains are abundant in certain regions of the Pannonian Basin and carry valuable information on the Pliocene–Quaternary fauna and climate (e.g., Kretzoi 1956, 1962; Jánossy 1986, 1987, 1996; Pazonyi 2011; Szentesi *et al.* 2015; Pazonyi *et al.* 2018). Such data are very scarce in the Mecsek Mts, the main mountainous area of southern Hungary. So far only seven assemblages have been reported, and the location of one of them is unknown. Consequently, each further vertebrate assemblage is important and can extend our knowledge.

The karst area in the Western Mecsek Mts was investigated intensely during 2018–19 in the framework of a project studying the Neogene–Quaternary uplift history of the area. The project was part of a several decades long research programme aiming at the safe disposal of high-level radioactive wastes and was solicited by PURAM (Public Limited Company for Radioactive Waste Management). The work included the survey of paleokarst phenomena and the investigation of paleokarst cavity infills. Large quarries operating near the village Bükkösd are exposing numerous paleokarst cavities. One of the cavities, coded as Pk-4 during the documentation, contained abundant vertebrate remains. This paper presents the fauna and its palaeoecological and chronological evaluation and extends the sparse Quaternary vertebrate record of the region. Biochronological data are extended with U-series dating of speleothems in the cavity to improve the temporal confinement of the fauna and the infilling of the cavity.

GEOLOGICAL SETTING

The studied paleokarst cavity was exposed in the western one of the two large limestone quarries north of Bükkösd, run by Bükkösdkő Ltd. (Figs 1–2). Its coordinates are 46° 07' 13.1171" N, 18° 01' 16.0424" E in geographical and 570579.484, 86797.279 in the Hungarian (EOV) coordinate system. The quarry exposes Middle Triassic limestones belonging to two stratigraphic units, Lapis and Zuhánya Limestone Formations (Konrád & Sebe 2007). The cavity formed in the Lapis Limestone, a thin- to thick-bedded shallow marine limestone deposited in a proximal ramp environment.

Pk-4 is a paleokarst cavity with irregular shape formed by dissolution along tectonic fractures (Fig. 3). Its exposed horizontal dimensions are ~3 m×1.5 m, its height is 6 m, but its extent was possibly larger than this in every direction. The top of the cavity lies 7–8 m below the modern surface of the limestone, its bottom is 1 m above the quarry terrace. The lowermost 1 m of the cavity has a curved outline. It is lined with 2–4 cm thick flowstone, with flowstone ribs, and



Figs 1–3. Geological setting of the locality. – **Fig. 1.** Paleokarst-related vertebrate localities in the Western Mecsek Mts. – **Fig. 2.** Satellite image of the western quarry near Bükkösd (image from GoogleEarth). – **Fig. 3.** The upper level of the southeastern wall of the quarry exposing Lapis Limestone, with the locations of documented paleokarst cavities

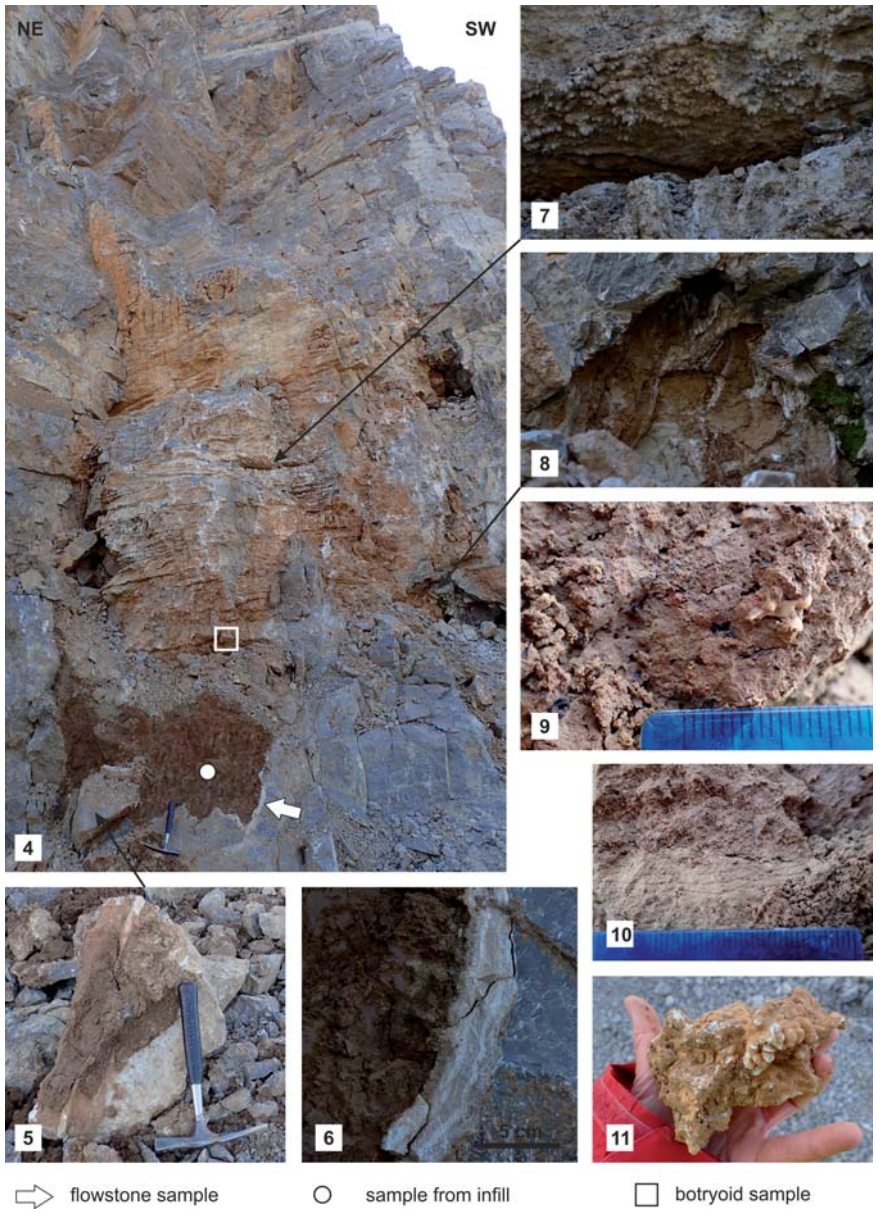
filled with brown, clayey silt. The silt is mostly structureless, in irregular patches it shows parallel or cross-lamination. It is penetrated by tubular micropores similar to those typical of loess. It contains scattered, unoriented red clay fragments of maximum a few cm-s, charcoal fragments between a few mm to 1.5 cm, and a few mm large snake vertebrae. In the upper parts of the cavity infill is lacking. The surface of the host limestone is dissolved and is covered by botryoids (Fig. 11), which often occur in rows following the weathered-out limestone beds (Figs 4, 7 and 10). The surface of botryoids is dissolved at places. In the small cavities in the western side flowstone laminae appear in red clay (Fig. 8). The relationship of the lower, filled part of the cavity and the upper part with botryoids but without a sedimentary infill remained unclear in the field.

MATERIAL AND METHODS

Samples were collected for several investigations (Figs 4–12). 20–30 kg of the fossil-bearing silt was collected for palaeontological studies. In the laboratory, the sample was first dried, then sieved through a 0.5 mm sieve and finally dried again. The material was then sieved on two sieves with two different hole diameters (2 mm and 1 mm). Fossils were selected under a Nikon SMZ stereo microscope from the three fractions obtained.

The flowstone crust and the botryoids were sampled for U-series dating, while vertebrate remains (snake vertebrae, Fig. 13) and charcoal for radiocarbon (^{14}C) measurements. U/Th measurements were carried out on two samples. Sample preparation was performed at Eötvös University, Budapest, multi-collector inductively-coupled plasma mass spectrometric analyses were performed at the Institute for Nuclear Research, Debrecen. After dissolution and spiking the samples by triple spike (^{236}U–^{233}U–^{229}Th) the separation of U and Th was taken on UTEVA resin. The final aliquots were 1ml for both U and Th fractions. The uncertainties of the ages were calculated by Monte Carlo method using the half-lives described in Cheng *et al.* (2013). Radiocarbon measurements were carried out in the Hertelendi Laboratory of Environmental Studies (HEKAL) in Debrecen, Hungary, following the protocols described in Major *et al.* (2019*a*, *b*). Conventional ages were calibrated with Calib Rev 8.1.0 (Reimer *et al.* 2020).

To obtain a regional view during the evaluation of the studied site, we collected information on all known vertebrate-bearing karst cavities in the area, many of which were only available in unpublished research reports. We re-evaluated the faunal lists of the sites to assess the age and environment of the fossil assemblages.



Figs 4–11. The paleokarst cavity Pk-4. – **Fig. 4.** Overview of the cavity with sample locations. – **Fig. 5.** A fragment of the wall of the lower part of the cavity, with flowstone ribs. – **Fig. 6.** Flowstone lining the lower part of the cavity. – **Fig. 7.** Botryoids in the upper part of the cavity. – **Fig. 8.** Small side cavity with botryoids, flowstone laminae and red clay infill. – **Fig. 9.** Silt filling the lower part, with charcoal and red clay fragments and snake vertebra. – **Fig. 10.** Laminated patch in the silt. – **Fig. 11.** Botryoid sample from the upper part

Fig. 12. Sampling at the locality for paleontological investigations

RESULTS

Vertebrate fauna

The recovered vertebrate material, separately for herpetofauna and mammal fauna, is summarised in Tables 1 and 2. A total of 1055 herpetofaunal elements (Figs 14–23) and 38 mammalian remains belonging to 26 individuals were recovered from the site.

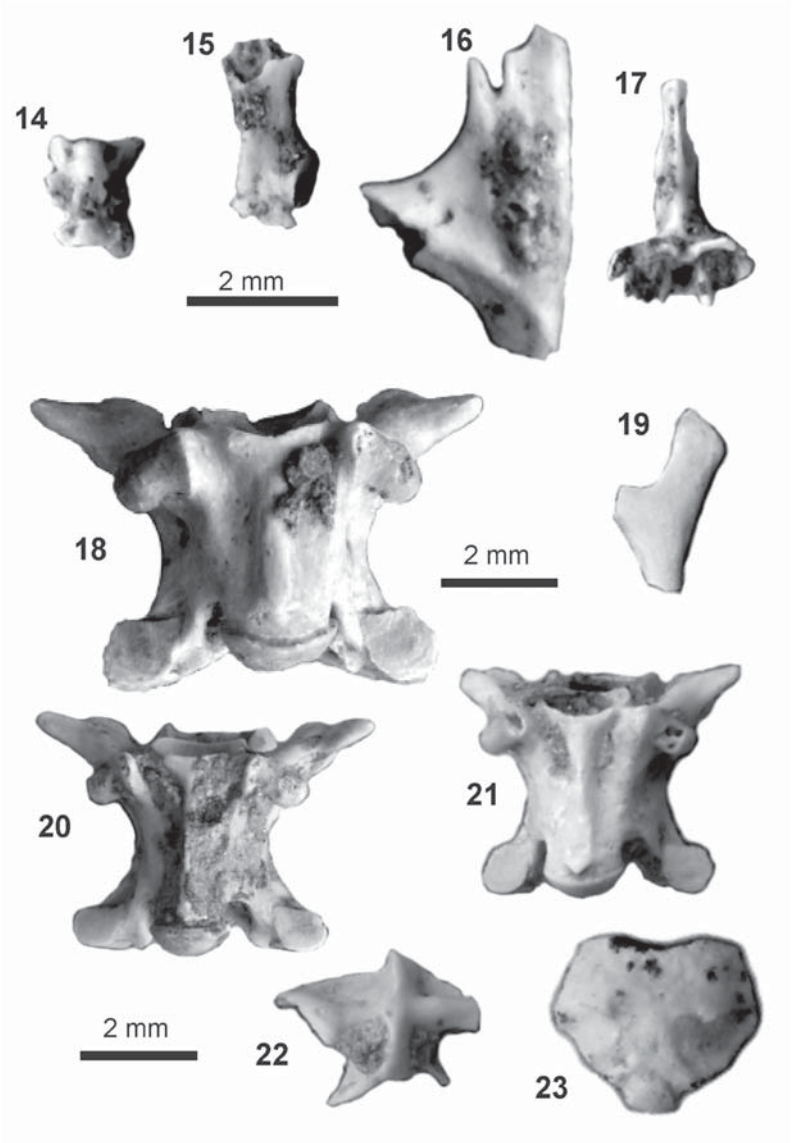
Table 1. Herpetofauna of site Pk-4 with the minimum number of individuals (MNI) and the percentage of the MNI of each taxon in the herpetofauna

taxon	MNI	%
Salamandridae indet.	1	7.6
Ranidae indet.	1	7.6
Lacerta cf. *viridis*	2	15.6
Podarcis cf. *muralis*	2	15.6
Hierophis cf. *viridiflavus*	1	7.6
H. gemonensis	1	7.6
Coronella cf. *austriaca*	1	7.6
Zamenis cf. *longissimus*	2	15.6
Natrix natrix	1	7.6
N. tesselata	1	7.6
Total	**13**	**100**

Table 2. Mammal fauna of the Pk-4 site. Lower teeth are marked with lowercase letters (i = incisor, c = canine, p = premolar, m = molar), upper teeth are marked with uppercase ones (I = Incisor, A = Antemolar, P = Premolar, M = Molar), MNI stands for minimum number of individuals

taxon	**description**	**MNI**
Talpa sp.	1 claw	1
Sorex araneus	1 right A1	1
	1 right P4	
	1 left i1	
	1 left m1	
	1 right m3	
Crocidura leucodon	1 left maxilla with I1 and A2	2
	1 left maxilla with M1-M2	
	1 left mandible with m2-m3	
	1 left mandible with i-m1	
	1 left i1	
	1 left m2	
	1 right A1	
	2 left A1	
	1 left P4	
	1 left M1	
	1 left M3	
Crocidura sp.	1 left mandible with m1-m2 fragment	1
Myotis sp.	1 left maxilla fragment with P4 and M2	1
	1 left M1	
	1 left M3	
Chiroptera gen. et sp. indet.	1 right m2	1
Apodemus sylvaticus	1 right mandible	1
	1 left m1	
	1 left m3	
	1 right m3	
	1 left M1	
Micromys minutus	1 right P3	1
Cricetus cricetus	1 right m1	1
	1 molar fragment	
Arvicola amphibius	1 left m2	1
Clethrionomys glareolus	1 right M1	1
	1 right M3	
Microtus (*Microtus*) *arvalis*	1 right mandible with m1	1
	1 right m2	
Microtus (*Terricola*) *subterraneus*	1 right m1	1
Arvicolidae indet.	5 molars	1
Total	42 remnants	15

Fig. 13. Snake vertebrae in the sieved material (grid cell is 5 mm)



Figs 14–23. Herpetofaunal remains from the locality. – **Fig. 14.** Precaudal vertebra of Salamandridae indet. in ventral view. – **Fig. 15.** Fragmentary left scapula of Ranidae indet. – **Fig. 16.** Right pterygoid fragment of *Lacerta viridis* in ventral view. – **Fig. 17.** Intermaxilla of *Podarcis muralis* in posterior view. – **Fig. 18.** Presacral vertebra of *Hierophis viridiflavus* in ventral view. – **Fig. 19.** Fragmentary right ectopterygoid of *Hierophis gemonensis* in dorsal view. – **Fig. 20.** Presacral vertebra of *Coronella austriaca* in ventral view. – **Fig. 21.** Presacral vertebra of *Zamenis longissimus* in ventral view. – **Fig. 22.** Left exoccipital of *Natrix natrix* in lateral view. – **Fig. 23.** Basioccipital of *Natrix tesselata* in ventral view

The herpetofauna is poor in amphibians: only a fragmentary salamandrid (Salamandridae indet.) vertebra and a true frog (Ranidae indet.) related scapula and humerus fragments were unearthed from this cavity. The lizard and snake fauna are richer. Cranial and postcranial bones of lacertids – *Lacerta viridis* and *Podarcis muralis* – have been detected in the screen-washed material. The remains of the colubrid snakes are the most frequent vertebrate fossils in this studied material. Among several snake vertebrae, some well-preserved cranial bones were found as well. Based on these the presence of the following six species from the family Colubridae has been verified: *Hierophis viridiflavus*, *H. gemonensis*, *Coronella austriaca*, *Zamenis longissimus*, *Natrix natrix* and *N. tesselata*.

In addition to the herpetofauna, a poor mammal material was recovered from the cavity, with altogether 38 jaw fragments and teeth. The identifiable remains show that the area was inhabited by insectivores, bats, mice, hamsters and voles. The mammal species recovered from the site are listed in Table 2.

Radiometric dating

U-series dating of speleothems – The botryoid sample (Pk-4) was free from detrital contamination, the correction for the initial ^{230}Th was negligible. The correction for the flowstone sample (Pk-4/2) was calculated using an estimated atomic ^{230}Th/^{232}Th ratio of $4(\pm 2) \times 10^{-6}$. Those are the values for a material at secular equilibrium, with the crustal ^{232}Th/^{238}U value of 3.8. The errors are arbitrarily assumed to be 50%. The upper limit of the 95% confidence interval of the age of the sample Pk-4 reaches the secular equilibrium (Table 3).

Table 3. Results of the U-series measurements of the speleothems. Analytical errors are 2σ of the mean

Sample	Age [ky]	δ^{234}U (measured)	^{230}Th/^{238}U (activity)	^{230}Th/^{232}Th (activity)	Sample weight [g]	U content [ppm]
Pk-4 (botryoid)	562 (-186/+∞)	177.4±0.4	1.24±0.02	636.0±3.2	0.200	1.32
Pk-4/2 (flowstone)	314 (-46/+73)	141.3±0.3	1.12±0.02	62.8±1.5	0.287	0.20

Radiocarbon dating – The small mammal bones from the cavity-filling silt turned out to have a collagen content of <1%, thus they were not appropriate for radiocarbon measurement. The charcoal fragments gave a conventional ^{14}C age of 37.460 ± 470 (Molnár & Veres 2020), corresponding to 41.402–42.414 cal BP (±2σ).

DISCUSSION

Palaeoecology

The vertebrate remains show no signs of long transport, and the fractures observed may be due to trampling or sediment movement. The analysis of the rich herpetofauna shows that the majority of the species recovered from the site are heliophilic (50%) or hygrophilous (26%), with a subordinate amount of forest elements and opportunistic species (8–8%) (Fig. 24).

The mammalian fauna is also mainly composed of species that prefer warm environments (European pine vole, Eurasian harvest mouse, white-toothed shrew) and those that prefer more humid, closed, bushy, woody environments (wood mouse, European water vole, bank vole, common shrew). The composition of the total vertebrate fauna suggests a sunny, rocky hillside with scrub and trees in places in the immediate vicinity of the accumulation site.

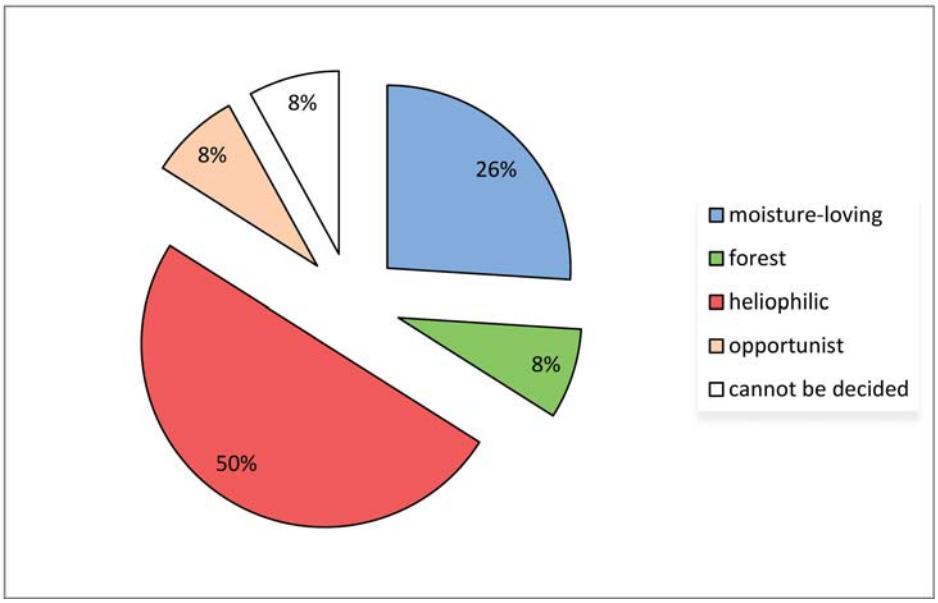


Fig. 24. Ecological preferences of the identified taxa. Moisture-loving taxa: Salamandridae indet., *Natrix natrix* and *N. tesselata*; forest taxon: *Zamenis longissimus*; heliophilic taxa: *Lacerta* cf. *viridis*, *Podarcis* cf. *muralis*, *Hierophis* cf. *viridiflavus*, *H. gemonensis*; opportunist taxon: *Coronella* cf. *austriaca*; taxon with unidentified ecological niche: Ranidae indet.

Karst-related vertebrate localities in the Mecsek Mts

Karst cavities with vertebrate fossils have only been reported from the western part of the mountains (Fig. 1), which are important to consider in order to place the studied Bükkösd site in a regional setting. Some of them were only mentioned in unpublished reports, the location of some others is uncertain, and they have never been summarised in a scientific paper. Because of these reasons we briefly present them here.

The locality "Megyefai-zsomboly" (Megyefa Shaft; the former settlement Megyefa now belongs to the village Bükkösd) was mentioned by Jánossy (1986, p. 141) as a "lower Würmian" site. Kretzoi (1942) described the locality as a nearly vertical cavity in dolomite in the village quarry, with abundant remains of large mammals. The remains were collected by Ottokár Kadić, then Kretzoi (1942) published the taxon list, emphasizing the lack of cave bear and interpreting the cavity as a trap for animals. The fauna was dominated by cave wolf (*Canis spelaeus*), and mammoth was also abundant. Szabó (1961) gave a more detailed description of the site: "The Megyefa Shaft belongs to a fossil karst cavity (out of the map to the west, north of Bükkösd, south of the railway line turning sharply to the east". It was exposed in 1927 during quarrying. It was completely filled with Pleistocene clay; in the clay bones of large animals (mammoth, cave lion, giant deer, deer, horse, aurochs, wolf etc.) typical of the middle and upper Pleistocene were preserved. These died from falling into the cleft. In order to locate the site exactly, we searched for excavation reports or any other paper by Kadić, but failed to find any further information. Thus, based on available data, we conclude that the Megyefa site can have been located within the presently active western quarry of Bükkösd, owned by Bükkösdkő Ltd., and had long been removed by quarrying. Jánossy & Vörös (1979) mentioned a rock shelter from Megyefa; this is probably an erroneous naming and they must have meant the locality mentioned above.

The fossil site Mélyvölgy Rock shelter ("Mélyvölgyi-kőfülke") on the southern side of the valley Nagy-mély-völgy was thoroughly described by Vértes (1952). It lies in gently dipping Middle Triassic Lapis Limestone and used to be a spring cave according to Vértes (1952). Excavations in 1946 found numerous small mammal remains, cave bear, and traces of ancient men as well. Vértes (1952) reported silicified "mountain pine" and alder branch fragments directly above the limestone and deciduous tree (*Acer*, *Fraxinus*, *Sorbus*) and subordinately *Picea* (possibly *Larix*) charcoal pieces in the overlying layers. In his interpretation the spring ceased to be active at the end of Würmian I. (now corresponding to Subalyuk phase, MIS 4) shown by the silicified wood fragments, while the sedimentary infill was deposited during the Würmian I–II interstadial (Tokod phase, MIS 3) based on the rich small mammal fauna of the overlying lay-

ers. During the Aurignacian the cave, at that time possibly larger than now, was inhabited by people (Szabó 1961). The fossils are stored in the Collection of the Mining and Geological Survey of Hungary.

A locality called "Mecsek, Sárkánykút" (Mecsek, Dragon well) is mentioned by Vértes (1952) in connection with cave bear fossil sites. In the 1850s S. Petényi collected cave bear (*Ursus spelaeus*), horse (*Equus*) and cave hyena (*Crocuta crocuta spelaea*) remains here, which were donated to the Hungarian Natural History Museum by Scroll in 1866 and under the locality name Drachenbrunn (Dragon well in German). Unfortunately the location of the site was unknown already to Vértes, who proposed several possible places: the Tettye tufa cave in Pécs, the spring of the "Sárkányvölgy" (Dragon Valley) in Orfű, the intermittent spring Sárkány-kút at Orfű, or the spring "Sárkányforrás" (Dragon Spring) near Mecsekszabolcs (Pécs). Three of these four sites are springs, which are hard to imagine to contain fossils. The word "kút" (well) might also refer to some deep geomorphic feature, e.g. sinkhole or shaft, but we do not have information on any sinkhole containing the described fossils either. Among the springs, the third one would be the best candidate, since it used to be called Drachenbrunn by the German-speaking coal miners who lived in that part of Pécs in the 19th century (Rónaki 2012). The spring used to be located in the quarter of Pécs called Pécsbánya or Colonia – both referring to the coal mining and the mining colony –, at the 588923; 84391 EOV (Hungarian) co-ordinates. It dried up in 1873 when the Sarmatian limestone aquifer was drained by the newly established Cassián Shaft of the coal mine nearby. As a spring seems improbable to contain fossils, the bones might have been collected somewhere near the spring. If it was possible to locate the fossil site, this rich assemblage could provide valuable data to the evolution history of the Mecsek.

In the Kispaplika Shaft (Kispaplika-zsomboly) near Abaliget numerous mammal bones were collected from the clayey infill in 2016, at a depth of 26–27 m (Angyal 2017). Taxonomic investigations by Mihály Gasparik identified five species typical of glacial faunas, among others woolly rhinoceros, moose and steppe bison. The remains are stored in the Palaeontological Collection of the Hungarian Natural History Museum. In the Abaliget Cave a woolly mammoth tooth was found cemented onto the cave roof above the travertine steps leading to the Mésztufás Chamber (Dezső 2011).

Numerous mammoth bones were found in the Csontos Shaft (Csontos-zsomboly) south of Orfű, at depths of 5, 10 and 17 metres (Rónaki 1977). In the nearby Madárka Shaft (Madárka-zsomboly) several fossils were found in the same year, two of which were identified by M. Kretzoi as *Mammuthus primigenius* tooth plate and *Bos primigenius* or *Bison priscus* upper left 3rd molar (Rónaki 1977). We do not have information on the present location of these finds.

Age of the fauna and evolution history of the site

The age of the charcoal recovered from the site [41.402–42.414 cal BP ($\pm 2\sigma$)] suggests that the fauna is late Pleistocene (MIS 3; Fig. 25). However, the palaeoecological analysis of faunas of similar age in the Carpathian Basin (Szeleta Cave, Istállóskő Cave, Tokod I site) suggests that this period had a cooler climate than what can be reconstructed from the vertebrate fauna of site Pk-4, although recent unpublished studies also suggest a warmer period for the Tokod I site (oral communication by Mihály Gasparik, 2021). It should be noted that the listed sites are all located in northern Hungary (Bükk and Gerecse mountains) and it has long been known that – as it is the case today – the climate and vegetation of northern and southern Hungary differ significantly from the Pliocene onwards (Jánossy 1986). In addition to vertebrate data, the existence of a temperature gradient is also suggested by climate and environment reconstructions based on snail faunas for the Carpathian Basin during the late Pleistocene (Krolopp & Sümegi 1995; Sümegi & Krolopp 2002). As no proven MIS 3 vertebrate faunas have been known from southern Hungary so far, it was not possible to compare the climate and vegetation conditions of the two areas during this time interval. The re-evaluation of the fossil material previously recovered from the Mecsek (presented in the previous section) revealed one faunal assemblage probably also of MIS 3 age. The Mélyvölgy Rock shelter material published by Vértes (1952) indicates a warm climate and closed vegetation with the dominance of species like wood mouse (*Apodemus sylvaticus*), edible dormouse (*Glis glis*), bank vole (*Clethrionomys glareolus*) and common shrew (*Sorex araneus*) and, most importantly, the European pine vole [*Microtus* (*Terricola*) *subterraneus*], a warm-indicating mammal, present in Pk-4 as well. It can be concluded that the Mecsek had a rather warm climate and closed (forested) vegetation during MIS 3, in contrast to the northern Hungarian areas (Bükk, Gerecse), which had a cooler climate and more open, mammoth steppe vegetation.

The U-series dating of botryoids showed that the karst cavity has existed for more than 0.5 Ma. The lower, flowstone-lined part of the cavity itself is also at least 314 ka old. Flowstone precipitation happened during MIS 9, in an interglacial interval, therefore under a mild and relatively humid climate similar to today. The large difference between these dates and the age of the sedimentary infill indicates that this karst conduit had either been actively transferring water for several hundreds of thousands of years, or even if it got clogged with sediment, it opened up and cleared again later, still before MIS 3. Based on the relatively homogeneous, porous structure of the infilling silt and the cross-bedded or cross-laminated patches in it, loess, together with bones and charcoal fragments, was transported into the cavity by flowing water, but

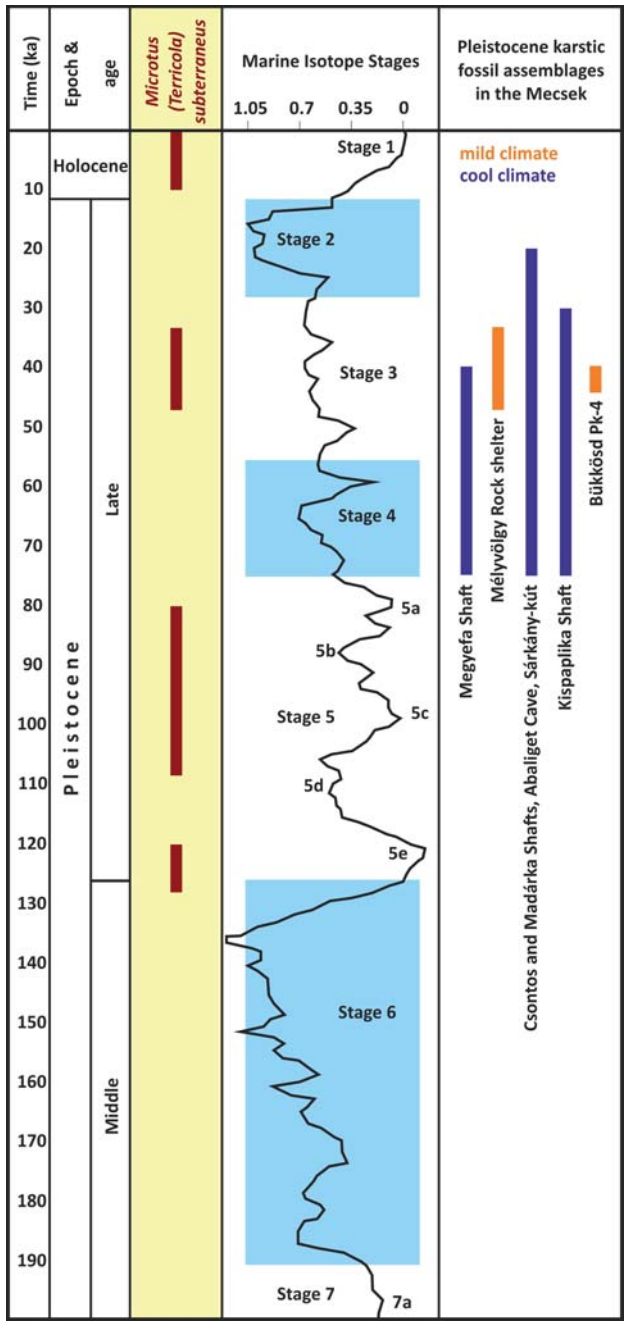


Fig. 25. Climatic and chronological data of paleokarst vertebrate localities in the Western Mecsek Mts

it accumulated in the vadose zone, above the karst water table. The relatively large density of bones suggests that the cavity may have acted as a trap either for the live animals, or for the bones deposited on the surface, in the immediate surroundings of the hole, similarly to what was observed in the Villány Hills (Pazonyi *et al.* 2018).

CONCLUSIONS

The herpetofauna is represented by a salamandrid, a true frog, lacertid lizards and colubrid snakes, the latter dominating the vertebrate material. The poor mammal material shows that the area was inhabited by insectivores, bats, mice, hamsters and voles. The condition of vertebrate remains shows no signs of long transport. The composition of the total vertebrate fauna suggests a sunny, rocky hillside with scrub and trees in places in the immediate vicinity of the accumulation site. The age of the charcoal recovered from the cavity fill (41–42 ka) suggests that the fauna is late Pleistocene (MIS 3), this makes the assemblage the first proven MIS 3 fauna in southern Hungary. The re-evaluation of the paleokarst-related fossil material previously reported from the Mecsek revealed a further assemblage probably also of MIS 3 age, the Mélyvölgy Rock shelter. The palaeoclimate reconstructed from the palaeoecological analysis of the faunas is warmer than that from coeval sites in northern Hungary, with vegetation more closed (forested) than the northern mammoth steppes. This refers to the existence of a north-south thermal gradient in the Carpathian Basin at the time.

The U-series dating of speleothems showed that the karst cavity already existed more than 0.5 Ma ago. During MIS 3, the cavity stopped to be part of an active karst conduit and it was filled up by loess-derived silt. The site was lying above the karst water table then, and it may have acted as a trap either for the live animals or for the bones deposited on the surface.

*

Acknowledgements – Work was solicited by PURAM (Public Limited Company for Radioactive Waste Management). We are grateful to István Csendes (Bükkösdkő Ltd.) for always supporting our work in the quarry. Márton Bauer and András Jankovics helped with sample and data collection. We thank Lukács Mészáros for reviewing the manuscript, and him and Mária Trembeczki for helping in the identification of some fossils. This is MTA–MTM–ELTE Paleo contribution No. 348.

REFERENCES

Angyal D. 2017: Holocén és pleisztocén emlősmaradványok a Kispaplika-zsombolyból. [Holocene and Pleistocene mammal remains from the Kispaplika Shaft.] – *Pro Natura Karszt- és Barlangkutató Egyesület jelentése a 2016. évi kutatási tevékenységéről* [Research report of the Pro Natura Karst and Cave Research Association on 2016], Pécs, pp. 4–8.

Cheng H., Edwards R. L., Shen C.-C., Polyak V. J., Asmeromd Y., Woodhead J., Hellstrome J., Wang Y., Kong Y., Spötl C., Wang Y. & Alexander Jr., E. C. 2013: Improvements in ^{230}Th dating, ^{230}Th and ^{234}U half-lives, and U-Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. – *Earth and Planetary Science Letters* **371–372**: 82–91. https://doi.org/10.1016/j.epsl.2013.04.006

Dezső J. 2011: A dél-dunántúli karsztos területek morfológiai, üledékföldtani vizsgálata és összehasonlító értékelésük analóg képződményekkel. [*Morphological and sedimentological examination of the karst areas in the Southern Transdanubean Region (Hungary) and their comparative assessment with analogous formations.*] – PhD dissertation, University of Pécs, 183 pp. (in Hungarian)

Jánossy D. 1986: *Pleistocene vertebrate faunas of Hungary*. – Akadémiai Kiadó, Elsevier, 208 pp.

Jánossy D. 1987: Ältestpleistozäne Vertebratenfauna von Beremend 15 (Süd-Ungarn). – *Fragmenta Mineralogica et Palaeontologica* **13**: 89–96.

Jánossy D. 1996: Lower Pleistocene vertebrate faunas from the localities 16 and 17 of Beremend (Southern Hungary). – *Fragmenta Mineralogica et Palaeontologica* **18**: 91–102.

Jánossy D. & Vörös I. 1979: Grossäuger – Streufunde aus dem Pleistozän Ungarns. – *Fragmenta Mineralogica et Palaeontologica* **9**: 21–60.

Konrád Gy. & Sebe K. 2007: Bükkösd. Középső-triász, Lapisi és Zuhányai Mészkő formációk. [Bükkösd. Middle Triassic, Lapis and Zuhánya Limestone Formations.] – In: Pálfy J. & Pazonyi P. (eds.): *Őslénytani kirándulások Magyarországon és Erdélyben* [Paleontological excursions in Hungary and Transylvania.], Hantken Press, Budapest, pp. 140–147. (in Hungarian)

Kretzoi M. 1942: Spelaeus-Fauna aus dem Mecsek-Gebirge ohne Höhlenbären. – *Földtani Közlöny* **72**: 364.

Kretzoi M. 1956: A Villányi hegység alsó-pleisztocén gerinces-faunái. (Die altpleistozänen wirbeltier faunen des Villányer Gebirges.) – *Geologica Hungarica Series Palaeontologica* **27**: 1–264.

Kretzoi M. 1962: A csarnótai fauna és faunaszint. – *A Magyar Állami Földtani Intézet Évi Jelentése az 1959. évről*, pp. 297–395.

Krolopp E. & Sümegi P. 1995: Palaeoecological reconstruction of the late Pleistocene, based on loess malacofauna in Hungary. – *GeoJournal* **36**: 213–222.

Major I., Dani J., Kiss V., Melis E., Patay R., Szabó G., Hubay K., Túri M., Futó I., Huszánk R., Jull A. J. T. & Molnár M. 2019*a*: Adoption and evaluation of a sample pretreatment protocol for radiocarbon dating of cremated bones at HEKAL. – *Radiocarbon* **61**(1): 159–171. https://doi.org/10.1017/RDC.2018.41

Major I., Futó I., Dani J., Cserpák-Laczi O., Gasparik M., Jull A. J. & Molnár M. 2019*b*: Assessment and development of bone preparation for radiocarbon dating at HEKAL. – *Radiocarbon* **61**(5): 1551–1561. https://doi.org/10.1017/RDC.2019.60

Molnár M. & Veres M. 2020: *AMS 14C vizsgálati jegyzőkönyv (projektazonosító: I/2191 sorozat, 3-as mintával)* [AMS 14C laboratory report.] – Manuscript, Mecsekérc Ltd. Archives, Pécs, 3 pp.

Pazonyi P. 2011: Palaeoecology of Late Pliocene and Quaternary mammalian communities in the Carpathian Basin. – *Acta zoologica cracoviensia* **54A**(1–2): 1–29. https://doi.org/10.3409/azc.54a_1-2.01-29

Pazonyi P., Virág A., Gere K., Botfalvai G., Sebe K., Szentesi Z., Mészáros L., Botka D., Gasparik M. & Korecz L. 2018: Sedimentological, taphonomical and palaeoecological aspects of the late early Pleistocene vertebrate fauna from the Somssich Hill 2 site (South Hungary). – *Comptes Rendus Palevol* **17**(4): 296–309. https://doi.org/10.1016/j.crpv.2017.06.007

Reimer P., Austin W. E. N., Bard E., Bayliss A., Blackwell P. G., Bronk Ramsey C., Butzin M., Cheng H., Edwards R. L., Friedrich M., Grootes P. M., Guilderson T. P., Hajdas I., Heaton T. J., Hogg A. G., Hughen K. A., Kromer B., Manning S. W., Muscheler R., Palmer J. G., Pearson C., van der Plicht J., Reimer R. W., Richards D. A., Scott E. M., Southon J. R., Turney C. S. M., Wacker L., Adolphi F., Büntgen U., Capano M., Fahrni S., Fogtmann-Schulz A., Friedrich R., Köhler P., Kudsk S., Miyake F., Olsen J., Reinig F., Sakamoto M., Sookdeo A. & Talamo S. 2020: The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). – *Radiocarbon* **62**(4): 725–757. https://doi.org/10.1017/RDC.2020.41.

Rónaki L. 1977: *A Mecseki Karsztkutató Csoport jelentése 1977-évről.* [Report of the Mecsek Cave research Group on 1977.] – Pécs, 58 pp.

Rónaki L. 2012: *Sárkány és ördög elnevezések a Mecsek-villányi karszton.* [Place names with dragon and devil in the Mecsek-Villány karst area.] – Pécs-Baranyai Origó-Ház Egyesület, 141 pp.

Sümegi P. & Krolopp E. 2002: Quartermalacological analyses for modeling of the Upper Weichselian palaeoenvironmental changes in the Carpathian Basin. – *Quaternary International* **91**: 53–63.

Szabó P. Z. 1961: A Mecsek és a Villányi-hegység barlangjai. [Caves of the Mecsek Mts and Villány Hills.] – *Karszt és Barlangkutatás*, I. félév: 3–20.

Szentesi Z., Pazonyi P. & Mészáros L. 2015: Albanerpetontidae from the late Pliocene (MN 16A) Csarnóta 3 locality (Villány Hills, South Hungary) in the collection of the Hungarian Natural History Museum. – *Fragmenta Palaeontologica Hungarica* **32**: 49–66. https://doi.org/10.17111/FragmPalHung.2015.32.49

Vértes L. 1952: A Mélyvölgyi-kőfülke és néhány más mecseki barlang kutatásáról. [On the exploration of Mélyvölgy rock shelter and some other caves in the Mecsek mountains.] – *Földtani Közlöny* **82**(7–9): 270–278.