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New Pleistocene vertebrate assemblages from the Villány Hills (SW Hungary): Siklós and Palkonya

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Abstract – The Villány Hills in SW Hungary have the richest archive of Pliocene–Quaternary vertebrate faunas in the Pannonian Basin, mostly in karstic cavities. Here we present three new sites that extend the list of Pleistocene vertebrate locations for the area and add information to the evolution history of the region. In the northern part of the Siklós quarry, bone breccia was found coming from fissures in Jurassic or Cretaceous limestones. Its lithofacies and fossil content are similar to those of other well-known Plio-Pleistocene karst infills of the region. As it contained mostly snake vertebrae, its age could not be constrained precisely. In the southern part of the same quarry, two vertical shafts were discovered, which are unusual in several respects. They formed in a Middle Triassic dolomite succession, a rock type generally not prone to karstification. They might have been created by gravitational deformation of the relatively steep slope, probably at different times. One of them was closed from above and contained flowstones precipitated during the late Middle Pleistocene, during the late Rissian MIS7 interglacial. The other one was filled from above with loess, rock fragments and remains of large mammals – *Equus* cf. *ferus*, *Bos primigenius* and *Coelodonta antiquitatis* –, possibly between 140–40 ka, during one of the stadials of the Weichselian or the latest Saalian. The site shows that fossil-bearing cavities could also form in lithologies not favourable for karstification, which then trapped fossils in a similar way karstic cavities do. In contrast with the previous two and with most of the other known vertebrate sites of the Villány Hills, the Palkonya outcrop is not a karst cavity fill but was deposited on the (palaeo)surface. *Bison* sp., possibly *B. schoetensacki* remains were found between the Triassic basement and Quaternary slope sediments, and within the latter succession. The *Bison* bones are probably Middle Pleistocene or late Early Pleistocene, older than ~300 ka. The overlying slope sediments originate from the reworking of various older deposits. They were covered with loess in the Weichselian (~22 ka ago), then again with slope deposits. The abundance of bones in and around the outcrop suggests that this site acted as a fossil trap as well. Bones probably enriched in the sediments during reworking of older deposits. In cold periods, loess deposition decreased (subdued) the relief through infilling the depressions. With 21 figures and 3 tables.

Key words – loess, paleokarst, Pleistocene, vertebrates

INTRODUCTION

Vertebrate assemblages retrieved from Quaternary sediments and paleokarst cavities are essential palaeoenvironmental records, while they can also provide a biochronostratigraphic framework to date the host sediments. The Villány Hills in SW Hungary have the richest archive of Pliocene–Quaternary vertebrate faunas in the Pannonian Basin (e.g., Kretzoi 1956, 1962; Jánossy 1986, 1987, 1996; Pazonyi 2009, 2011). The more than 50 localities represent a time span from 3.3 Ma to 250 ka, their fossils and sediments accumulated under various climates. Most assemblages come from paleokarst cavities.

Recently some more vertebrate remains were found near settlements where the occurrence of such assemblages has not been reported previously or has been uncertain. In 2014 large mammal fossils from the large quarry near the town of Siklós were donated to the Hungarian Natural History Museum, while in 2019 microvertebrate bone breccia was found in the same quarry. In 2012 large mammal bones were collected from loess at a construction site in the village Palkonya. Here we present the new fossils and discuss their biostratigraphic and palaeoecological interpretation.

GEOLOGICAL SETTING

The Villány Hills are a low range (maximum elevation 442 m a.s.l.) built up of Mesozoic carbonates. Tectonically they belong to the Tisza Megaunit, more precisely to the Villány-Bihor zone (Bleahu *et al.* 1994). The Middle Triassic – Upper Cretaceous succession is repeated seven times along thrust faults (Rakusz & Strausz 1953) (Fig. 1). Following a long temporal gap, the basement rocks are covered by massive red clays classified into the Tengelic Red Clay Formation. This unit often fills rock fissures and karstic cavities, where it can host rich vertebrate assemblages ranging in age from 3.3 to 1 Ma (Marsi & Koloszár 2004; Pazonyi 2009, 2011). The overlying loess-paleosol succession contains several paleosols developed under various climates during the past ~0.7–0.8 Ma (Marsi & Koloszár 2004).

The large quarry of Siklós, also called Vízügy quarry or Szabolcs Valley quarry, lies in the western part of the range, NW of the town Siklós, on the southern slope of the hill Tenkes. It exposes Upper Jurassic and Lower Cretaceous lime-

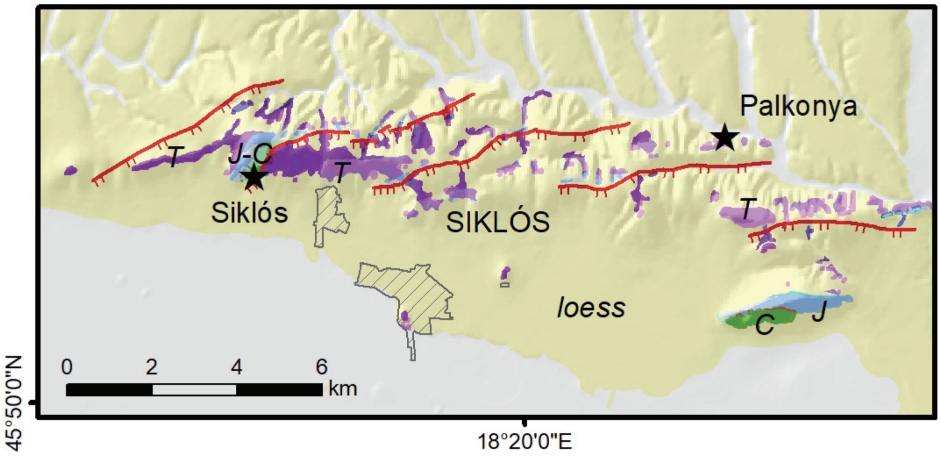
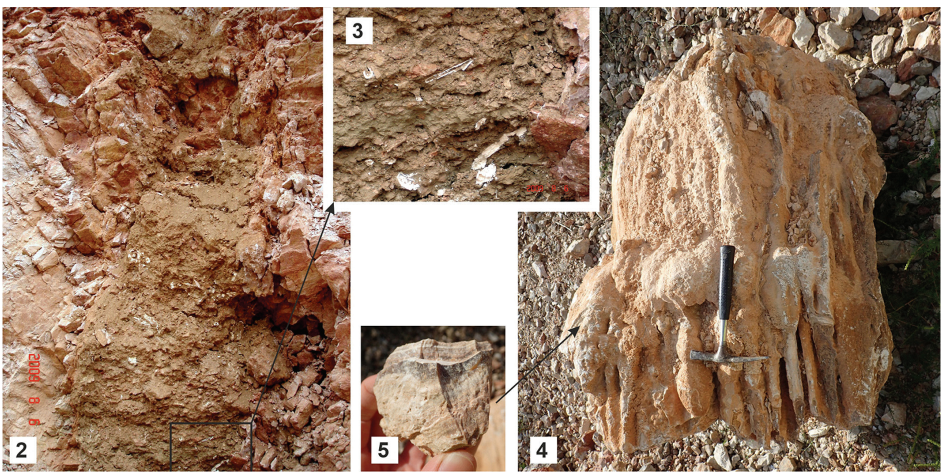


Fig. 1. Location of the vertebrate localities within the Villány Hills. Legend: T – Triassic; J – Jurassic; C – Cretaceous rocks. Red lines border thrust sheets

stones, and Middle Triassic dolomites thrust over them in the southeastern part (Benkovics 1997; Császár 2002; Petrik 2009, 2010) (Fig. 1). In the southern part of the quarry, between 2009 and 2011 mining activity exposed a few metres deep and maximum 1 m wide vertical shaft in the Triassic dolomites (Fig. 2). The lead mining engineer noticed that the shaft contained bones and teeth of large mammals, and saved the best-preserved ones before excavation proceeded and

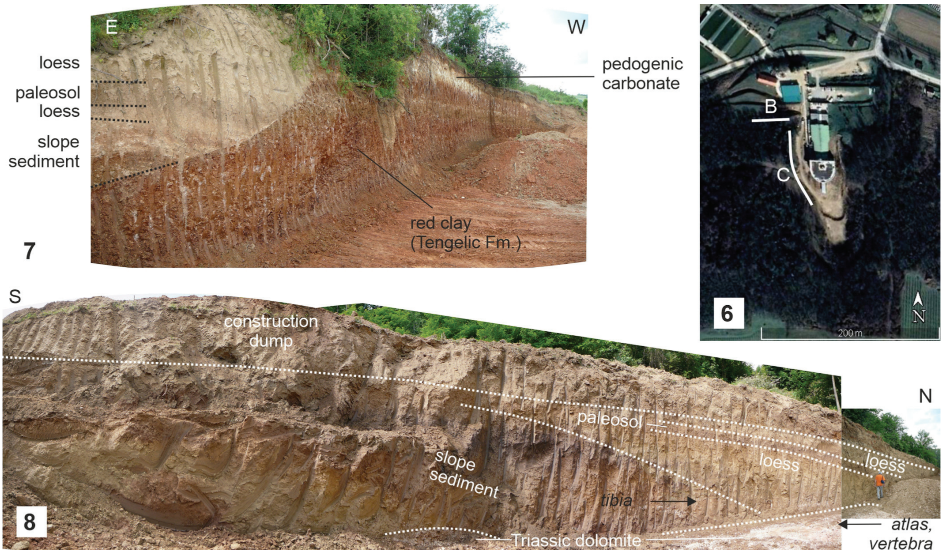


Figs 2–5. Cavity fills in Middle Triassic dolomites in the Szabolcs Valley quarry NW of Siklós. – **Figs 2–3.** Fissure infill composed of dolomite debris, large mammal bones and reworked loess (photos courtesy of Dezső Solti). Outcrop section in image 2 is ~1.5 m high. – **Figs 4–5.** Flowstone, with sample for U-series dating

destroyed the shaft. The shaft was filled with angular dolomite clasts and weathered large mammal bones in a matrix of redeposited loess (Fig. 3). The infill was loose, porous, uncompacted, though this may also have been a secondary effect of mining-related rock removal. Small parts of the wall were encrusted with thin flowstone. The location of the shaft must have been somewhere near the point 45° 52' 52.04" N, 18° 14' 59.55" E, at an elevation of approximately 210 m a.s.l. In another cavity, within 10–20 m from the fossiliferous shaft, massive flowstone and dripstone precipitations were found in the dolomites. Some large (>1 m high and >0.5 m thick) speleothems were laid aside by the quarry workers and were visible until years later (Fig. 4).

At the foot of the highest, northern wall of the same quarry, a piece of bone breccia in a red clay matrix was found in 2019. The block was hard, cemented by calcite. As the wall was several tens of metres high, nearly vertical and inaccessible, it was not possible to identify the original location of the bone breccia. Examination of the wall with a drone showed a fissure filled with carbonate clasts and red clay at the top of the wall (~290 m a.s.l.), and a fainter, uncertain patch of reddish rock at about the middle of the wall (250–260 m a.s.l.). If the source of the bone breccia fragment had been on the wall visible at that time, and not in a slice of rock excavated and removed previously, then the upper location is more probable.

The exposure at Palkonya was excavated during the construction of a new winery (Mokos Winery, 45° 53' 24.17" N, 18° 23' 32.11" E, 130 m a.s.l.). The works produced two long N–S walls and a shorter E–W one (Figs 6–8). The lowermost stratigraphic unit, ~5 m of red clay with carbonate concretions (Tengelic Fm.) cropped out in the northern wall (Fig. 7). Above an erosional unconformity, irregularly stratified slope sediments followed with a steep northerly dip. In the southern outcrop, slope sediments overlay directly the basement, red clay was missing (Fig. 8). Right at their base, in a small depression on the dolomite surface two large vertebrae were found. The upper part of one of them was cut by a bagger when the overlying deposits were removed, it is therefore not possible to know whether there had been more bones at the spot. The main constituent of the slope sediments was reworked loess, and they also contained redeposited dolomite clasts from the basement, carbonate concretions and iron pisoids from paleosols, loess snails, soil clasts and bone fragments. Beside several unidentifiable fragments, a broken radius was found in this layer about 1 m above the basement. After a relatively sharp boundary, the slope sediments were overlain with two loess layers separated with a paleosol bed (Figs 7, 8). The loess beds were light yellowish grey and seemingly typical loess. The paleosol was brownish grey, with diffuse lower and upper boundaries. The dip of these layers was gentler than that of the slope sediments. Above the loess layers further 1.5–2 m of sediment



Figs 6–8. Exposures at the Mokos Winery, Palkonya, with the locations of the large mammal remains. Both 7 and 8 are oblique views. See person at the right end of Figure 8 for scale

followed in another outcrop parallel with and a few metres behind the wall in Figure 8. They were built up of irregular patches and lenses of partly redeposited loess and paleosols, with numerous weathered, crumbling, unidentifiable large mammal bone fragments.

MATERIAL AND METHODS

We tried to dissolve the bone breccia from Siklós to obtain individual bones, but our attempts failed because of its hard cementation. Thus, it was only possible to investigate a few bones which could be separated from its surface.

The large flowstone blocks of the Siklós quarry had not come from exactly the same shaft as the large mammal fossils, though their location was very close. Despite of this, we sampled the flowstones in order to obtain an idea on the timing of karstification and existence of open cavities in the dolomite body (Fig. 5).

Uranium series dating has been done on one sample from the Siklós quarry (Siklós, Vízügy quarry). The analysed part of the sample was totally dissolved in diluted hydrochloric acid. After the spiking and conversion, the U/Th separation was carried out by extraction chromatography on UTEVA resin. The final fractions were measured by MC-ICPMS.

The bones from Palkonya had a relatively poor preservation. After excavation and cleaning, they were glued and impregnated with the two-component glue

Uwe Rapid 5. To constrain the age of the bones, the overlying loess layers below and above the paleosol (Fig. 8) were sampled for optically stimulated luminescence (OSL) dating. Samples were taken 15–20 m north of the fossils and not directly above them, because by the time of sampling that wall segment had been covered by the building, but the loess and paleosol horizons were continuous and well identifiable there as well. Bone size data were used only for the identification of the *Equus* metacarpus and were applied after Boulbes & van Asperen (2019).

Luminescence dating was carried out on two loess samples from Palkonya. Polymineral fine grain separates were extracted from the samples under subdued red light using 30% H_2O_2, 10% HCl and 0.01 N sodium-oxalate ($C_2Na_2O_4$) to remove the organic material, the carbonates and to disaggregate the grains, respectively. The post-IR $IRSL_{290}$ Single-Aliquot Regenerative-dose (SAR) protocol (Murray & Wintle 2003; Thiel *et al.* 2011) was used applying a preheat temperature of 320 °C for 60 s, and an IR stimulation at a temperature of 290 °C for 200 s. An illumination for 100 s at 325 °C was included between each measurement cycle to bleach any remaining signal in the sample. Luminescence measurements were carried out using an automated Risø TL/OSL-DA-20 reader. Equivalent dose (D_e) values of the samples were calculated by integrating the 2–4.4 s region of the IRSL decay curve and the last 60 s of the stimulation was subtracted as background. All dose-response curves were fitted using a single saturating exponential function. Both protocols checked the recuperation and recycling of the samples. An average a-value of 0.08±0.02 (Rees-Jones 1995) was used for the feldspar IRSL age calculation. 1 kg sediments were collected from the surroundings of the luminescence samples for dose rate determination. Dried and covered samples were stored and measured using high-resolution gamma spectrometry to determine the U, Th and K contents of the sediments. Dose rate conversion factors of Adamiec & Aitken (1998) were used. Calculation of the cosmic dose rate is based on Prescott & Hutton (1994). A potassium content of 12.5±1% (Huntley & Baril 1997) was applied to the K-rich feldspar fraction to account for the internal dose rate. Based on the water content measurements of sediments, the ages were calculated using 15±5% moisture content. All luminescence and gamma spectrometry measurements were carried out at the luminescence laboratory of the Research and Instrument Core Facility at the Eötvös Loránd University (Budapest, Hungary).

The fossils from the Siklós quarry were deposited in the collection of the Hungarian Natural History Museum, Budapest under the inventory numbers VER 2019.7–9 (herpetofaunal remains) and VER 2022.595–599 (mammal remains). The bones from Palkonya were given to the owner of the winery after the investigations, who plans to display them in a small exhibition in the reception hall of the winery.

RESULTS

Siklós

Large mammal remains

The fossils found in the Siklós quarry were identified as one horse metacarpal bone, one bovid molar and three rhino tooth remains (Figs 2, 9–11). Their preservation suggests a rather old age, Middle Pleistocene or even older, because the remains are very strongly calcified, and this state is typical of older fossils of the region. Obviously, this does not provide exact data for dating, because sometimes the conditions of fossilisation can also result in similarly strong recalcification in the case of younger finds, but it is suggestive of older ages.

The identification of the horse metacarpal bone (Fig. 9; VER 2022.595.) is rather uncertain, but very probably it represents the Late Pleistocene wild horse *Equus ferus*. As the morphological characters of the metacarpals of different *Equus* species are very similar, the identification was based on the dimensions and proportions of the specimen. We compared the Siklós specimen with some other *Equus* remains from different localities from different stages of the Hungarian Pleistocene record housed in the Department of Palaeontology and Geology of the Hungarian Natural History Museum (Table 1). The data show that both the dimensions and the proportions have wide ranges, and some *Equus mosbachensis* remains were not available for measuring because those are in the permanent exhibition of the HNHM. However, some observations can be made. It seems that the Siklós specimen is a bit longer and more slender than the metacarpals of the more robust *E. mosbachensis* but much longer and less slender than the latest Pleistocene caballoid horses. On the basis of the above points, we can identify the Siklós horse metacarpal as *Equus* cf. *ferus* and we can estimate its age into the Early Weichselian. However, we have to note that this is a very uncertain estimation, in fact, more certainly we can only specify a wide time range between the late Middle Pleistocene and Middle Pleniglacial (between ca. 130 and 40 ka).

The bovid specimen from Siklós is a large-sized right second lower molar (Fig. 10; VER 2022.596.). Its length on the occlusal surface of the crown is 36.62 mm, the maximal height of the crown (at the back part on the labial side) is 48.70 mm. These dimensions would allow the identification of both *Bison priscus* and *Bos primigenius*, but it seems the latter is more probable based on Sala (1987), who mentioned that "The two principial columns of the lower molars of *Bison* are more compressed together than they are in *Bos*." As the Siklós specimen is not so compressed it is very probably a *Bos primigenius* m2 dext.

9

10

11

Figs 9–11. Large mammal remains from the shaft of the Siklós quarry. – **Fig. 9.** *Equus* metacarpal. – **Fig. 10.** Bovid tooth. – **Fig. 11.** *Coelodonta* teeth

The three rhinoceros tooth remains represent two unerupted teeth, a right p4 and a right m1 or m2, and a worn molar fragment (very probably also a right lower one) (Fig. 11; Inv. Nos. in the order of the list above: VER 2022.597., 598. and 599.). The lingual valleys on p4 have a narrow V-shaped morphology, buccal

Table 1. Measurements of *Equus* sp. metacarpals from some Hungarian localities. Abbreviations: Prox.: proximal width; Dist.: distal width; Diaphys.: Width at the middle of the diaphysis. SI 1: Slenderness index 1: Diaphys./Length ×100; SI 2: Slenderness index 2: Dist./Length ×100. Ca.: estimated measurement in the case of broken or gnawed specimens.

Name	Locality	Inventory number	Age	Length (mm)	Prox. (mm)	Dist. (mm)	Diaphys. (mm)	SI 1	SI 2
Equus cf. *ferus*	Siklós, Vízügy quarry	VER 2019.7.	Pleistocene	259.30	ca. 60.19	54.65	42.04	16.2	21.1
Equus sp. (? cf. *mosbachensis*)	Szuhogy	V.63.1674.	Middle Pleistocene	246.30	62.18	59.13	44.18	17.9	24
Equus sp. (? cf. *mosbachensis*)	Szuhogy	V.63.1674.	Middle Pleistocene	240.70	60.83	56.30	41.19	17.1	23.4
Equus sp.	Kunpeszér	V.84.108.	Pleistocene	246.30	66.00	57.25	44.10	17.9	23.2
Equus sp. (? cf. *ferus*)	Lambrecht Cave	V.58.1497.	Early Weichselian	259.20	ca. 51.90	ca. 55.26	46.10	17.8	21.3
Equus sp. (? cf. *ferus*)	Lambrecht Cave	V.58.1497.	Early Weichselian	241.80	53.33	59.08	42.84	17.7	24.4
Equus sp. (? cf. *ferus*)	Lambrecht Cave	V.58.1497.	Early Weichselian	–	–	ca. 55.60	ca. 48.5	–	–
Equus sp. (? cf. *ferus*)	Dorog	V.58.65.	Middle Pleniglacial	–	–	54.28	ca. 41.46	–	–
Equus sp. (? cf. *ferus*)	Dorog	V.58.60.	Middle Pleniglacial	–	60.08	–	44.82	–	–
Equus sp. (? cf. *ferus*)	Dorog	V.58.67.	Middle Pleniglacial	–	ca. 55.12	–	ca. 43.37	–	–
Equus sp. (? cf. *ferus*)	Dorog	V.58.73.	Middle Pleniglacial	–	62.20	–	40.92	–	–
Equus sp. (? cf. *ferus*)	Tokod-Nagyberek I.	V.64.837.	Middle Pleniglacial	239.45	58.47	ca. 54	41.16	17.2	22.5
Equus sp. (? cf. *ferus*)	Tokod-Nagyberek I.	V.64.837.	Middle Pleniglacial	258.00	57.15	53.71	38.61	15.0	20.8
Equus sp. (? cf. *ferus*)	Lengyel Cave	V.63.1708.	Middle Pleniglacial	240.30	62.90	59.70	43.95	18.3	24.8
Equus sp. (? cf. *ferus*)	Lengyel Cave	V.63.1708.	Middle Pleniglacial	ca. 262	62.40	ca. 58	41.53	15.9	22.1
Equus sp. (? cf. *ferus*)	Lengyel Cave	V.63.1721.	Middle Pleniglacial	–	–	58.54	ca. 45	–	–
Equus sp.	Szendehely	V.60.1328.	Pleistocene	239.00	ca. 64	57.03	44.90	18.8	23.9
Equus sp. (? cf. *ferus*)	Pilisszántó Rock shelter No. 2	V.60.1347.	Late Pleniglacial	ca. 219	48.13	ca. 49.70	36.96	16.9	22.7
Equus sp. (? cf. *ferus*)	Pilisszántó Rock shelter No. 2	V.60.1346.	Late Pleniglacial	229.80	52.85	54.83	37.51	16.3	23.9
Equus caballus	– (comparative material)	–	recent	247.75	55.58	53.22	44.90	13.4	21.5

and lingual cingula are absent, and the trigonid is buccally rather flat. The molar lacks the buccal cingulum on the anterior loph and the lingual cingulum. Lingual valleys have a narrow V-shaped morphology, the mesial cingulum is present and the trigonid is buccally rather flat. The teeth have the following dimensions: p4: length: 42.07 mm, height of the crown: 59.13 mm; m1/m2: length: 49.14 mm, height of the crown: 60.93.

The specimens differ from *Pliorhinus megarhinus*, *Stephanorhinus jeanvireti* and *S. etruscus*, which are characterized by low-crowned teeth, different morphologies of the lingual valleys, and, sometimes, the presence of buccal cingula. The morphological characters of the studied teeth are not common in the Pleistocene species of the genus *Stephanorhinus* (in particular for the p4). The molar has a hypsodonty index (HI) of approx. 135; this value falls only into the range of *Coelodonta* reported by GUÉRIN (1980). *Stephanorhinus* is characterized by a HI < 120. In addition, narrow V-shaped lingual valleys are documented normally in *Coelodonta*. The dimensions of the studied teeth fall within the variability of the woolly rhinoceros, *Coelodonta antiquitatis* (cf. GUÉRIN 1980).

U-series dating of speleothems

The U-series measurements of the speleothem from the Siklós quarry gave a most probable age of 209 ka (Table 2). The main source of the uncertainties is the detrital contamination.

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

Sample	Age (ky)	Uncertainties (ky, 2)	$^{230}Th/^{232}Th$ activity ratio	Sample mass (g)	U-content (ppm)
Siklós, Vízügy quarry	209	−22/+26	15.1	0.043	0.167

Bone breccia

The bone breccia (Fig. 12) was hard, cemented by calcite. The red clay matrix contained angular limestone clasts, many small mammal bones (mostly snake vertebrae), and a flowstone fragment. A few identifiable small bone fragments were recovered from the bone breccia. Among these the presence of anurans was indicated by a fragmentary tibiofibular (Anura indet.), *Natrix* sp. snake as a presacral vertebra fragment and colubrid snakes (Colubridae indet.) as three presacral vertebra fragments.

Fig. 12. 10 cm long bone breccia fragment from the Siklós quarry

Palkonya

Large mammal remains

The two vertebrae, which were lying on the Triassic dolomite (Figs 13, 14–21), are identified as an atlas and a seventh cervical vertebra of a bovid species. Based on the observations that the shape of the wings of the atlas is rounded rectangular and the shape of the vertebral foramen of the cervical vertebra is not perfectly circular but tapers slightly upwards in a bit triangular shape, they belong to the *Bison* genus and not to *Bos*. They were lying together and showed no signs of transport; they were not broken or worn. They might have belonged to the same individual, also supported by their similar size and preservation.

The broken bone is a right tibia fragment. It was 4.5 cm thick in the middle, while its maximum thickness was 6.5 cm. It can also be identified as a small-sized *Bison* and based on its size it could have belonged to the same species as the two vertebrae. If the remains had not been found so far apart and in different strati-

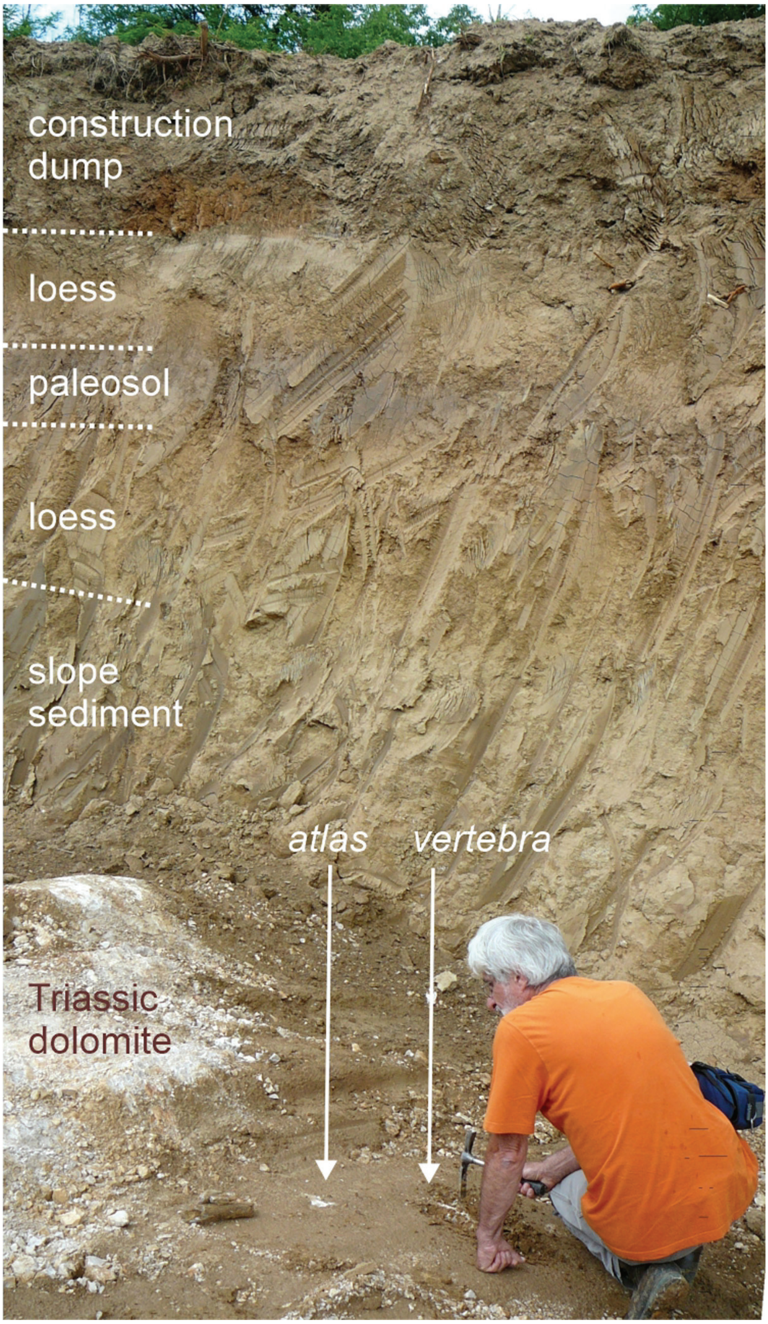


Fig. 13. Sedimentary succession of the southern wall of the Palkonya exposure at the location of the *Bison* bones

Figs 14–21. Large mammal remains from Palkonya. – **Figs 14–16.** *Bison* sp. atlas. – **Figs 17–19.** *Bison* sp. 7th cervical vertebra. – **Figs 20–21.** *Bison* sp. tibia

graphic levels, they could have even been part of the same individual. All three finds belonged to a small-sized bison, which would suggest the identification of *Bison schoetensacki*. However, because of the rather large size variation of bison species, only a *Bison* sp. determination can be considered certain.

OSL dating of loess

The dose rates of the samples are 4.24±0.23 Gy/ka (Palkonya-1) and 5.11±0.27 Gy/ka (Palkonya-2), which are quite high values compared to the usual dose rate (3.5–4 Gy/ka) measured from loess in the Pannonian Basin (Table 3). As negligible fading rates were detected for post-IR $IRSL_{290}$ signals, fading correction was not applied. D_e of each sample was calculated by taking

Table 3. Results of luminescence dating of the loess samples. Errors represent standard errors.

	Dose rate (Gy/ka)	**Equivalent dose (Gy)**	**Age (ka)**
Palkonya-1	4.24 ± 0.23	93.99 ± 1.08	**22.2 ± 1.2**
Palkonya-2	5.11 ± 0.27	46.77 ± 0.41	**9.2 ± 0.5**

the mean of the individual D_e values of the same sample. The D_e of the dated two samples are 93.99±1.08 Gy (Palkonya-1) and 46.77±0.41 Gy (Palkonya-2). The post-IR $IRSL_{290}$ age of the two samples are in stratigraphic order: 22.2±1.2 ka for Palkonya-1 and 9.2±0.5 ka for Palkonya-2.

DISCUSSION

Large mammal remains and host cavities of Siklós

The shaft and the neighbouring fissure with flowstone deepen into a dolomite succession. This lithology is not prone to karstification, especially under cold climate; therefore the fissures are probably not of karstic origin, in contrast with most vertebrate fossil sites of the Villány Hills. A possible explanation to their formation can be gravitational mass movement, the opening of fissures in the not very stable dolomite body due to its downward movement and extension along the steep southern hillslope. This might have even been a sudden event, e.g., during an earthquake. The fossiliferous cavity must have opened to the surface, it was filled up with dolomite debris, fossils and reworked loess. The second fissure was probably not open to the surface, thus it did not become filled with clastic deposits, and instead it provided a sheltered room for speleothem precipitation. The material of flowstones in the cavities could have originated from the carbonate content of the loess cover.

The U-series age determination of flowstone showed that around 209 ka (187–235 ka), during the Marine Isotope Stage (MIS) 7a, at least one of the shafts was already open and speleothem precipitation could occur. MIS 7 was an interstadial interval, so carbonate precipitation happened under relatively mild climate.

The fossils accumulated in the other shaft refer to a younger age. *Equus ferus* sensu lato has an age range from MIS 7 (ca. 140 ka) to present day (Boulbes & van Asperen 2019), while *Bos primigenius* lived from around the Early/Middle Pleistocene boundary (~700–800 ka) until the 17th century (Gliozzi *et al.* 1997). The woolly rhinoceros is well-documented in Hungary during the Pleistocene (Jánossy 1986; Pandolfi & Gasparik unpubl. data), in particular during the Late Pleistocene. However, in Europe the species occurs during the late Middle Pleistocene as well, since at least 0.45 Ma. These data overlap in the interval from the late Middle Pleistocene to Late Holocene (140 ka – 17th century). However, as it was presented above in the results section, with the measurements of *Equus* metacarpal bones from different localities of Hungary we can narrow down the possible age of the finds between 140–40 ka. The identified taxa refer to a cold (glacial/stadial) climatic interval within the above range, to one of the Weichselian stadials or the latest Saalian.

Bone breccia of Siklós

The poorly preserved herpetofaunal elements do not allow a precise taxonomic identification, therefore, no palaeoecological conclusions can be drawn from them, nor is the biostratigraphic dating of the assemblage possible. The unearthed frog bone does not necessarily indicate the presence of a permanent water body, because, for example, toads do not require proximity to water all year round, only during their reproduction. The presence of *Natrix* sp. may indicate permanent water next to the depositional place, but the poorly preserved vertebra is weak evidence for this suggestion. However, the bone breccia found here indicates that Plio-Pleistocene vertebrate localities can be more numerous in the Villány Hills, and is another example of a karstic cavity acting as a fossil trap. The enclosed flowstone fragment refers to reworking of speleothems, reported from other vertebrate sites of the area as well (Pazonyi *et al.* 2018). The abundance of snake vertebrae indicates that the cavity where the bone breccia accumulated was directly open to the surface and snakes could fall into it, similarly to several other fossil sites of the Villány Hills (Szentesi 2016; Pazonyi *et al.* 2016, 2018, 2019).

Large mammal remains of Palkonya

As we were not able to identify the *Bison* remains precisely, the age estimation is not possible. If we suppose that the small-sized remains belonged to the *Bison schoetensacki* (this species was somewhat smaller than *B. priscus*), the age of the finds cannot be younger than ca. 500 ka based on Sorbelli *et al.* (2021). However, we have to note that *Bison schoetensacki* also occurs in the fauna of a famous Middle Pleistocene hominid locality from Hungary (Vértesszőlős), and the age of this locality was determined with U/Th method to be ca. 315 ka (Tanaka *et al.* 2021). The bones therefore must be Middle Pleistocene or late Early Pleistocene (Sorbelli *et al.* 2021).

The stratigraphic position of the bones allows for some age constraints as well. The vertebrae were lying on the dolomite surface, indicating that the Triassic basement was subaerially exposed at the time of their deposition. They cannot have been transported long, as they were not broken or worn. The upper end of the cervical vertebra is only missing because the bones were weathered and it was not possible to extract them intact from the sediment. The bones were embedded in the slope sediment, but this might be a later cover as well, therefore the deposition of the bones predated or was coeval with the slope sediment.

The tibia occurred within the slope sediment. The latter must postdate the beginning of loess deposition in the area (1 Ma, Pazonyi *et al.* 2018) because it contained redeposited loess and loess snails. The mixed lithology of the slope sediment including loess, carbonate gravel and red and brown paleosols indicates that all these materials were available for erosion and transport at that time. The outcrop presently exposes deposits at the bottom of a small valley incised into the basement rocks, and this must have been the situation during the accumulation of the bone-bearing sediments as well. The tibia was broken already before its deposition, obviously during transport: the joints were missing, the edges were broken and worn, and the bone was filled with loess and gastropods. Thus, the slope sediments must have accumulated in a valley whose floor and sides were not only composed of basement rocks but – at least in its upper section – also of the Plio-Quaternary sedimentary cover. The appearance of slope sediments indicates a change in environmental conditions: the previously exposed Triassic surface, kept clean probably by a regular flow of water (watercourse?) started to become buried under an increasing amount of sediment. This may have happened because of decreasing precipitation and the shift from linear to areal erosion (surface wash) and less effective sediment transport.

The overlying package of the two loess layers with the weak paleosol interbed point to even dryer conditions: not just the deposition of loess as glacial sediment, but also the more gentle dip of the paleosol layer relative to the underlying slope sediment indicates a decrease of local relief, the filling up of topographic depressions with loess. Based on the OSL age of 22±1.2 ka, the lower loess layer was deposited during the Last Glacial Maximum, under the glacial climate of MIS 2. The weak paleosol between the two loess layers can be correlated with either the h1 or the h2 humic horizon (Pécsi 1993) within the ideal Quaternary loess-paleosol succession of Hungary (Novothny *et al.* 2023). The luminescence age of the upper loess layer is 9.2±0.5 ka (MIS 1). As dust deposition and loess formation ceased by the end of the Pleistocene in the Pannonian Basin, this age indicates that the layer might have been exposed to post-depositional mixing, the sample was collected from a younger crotovina, or it might have been exposed to more destructive light during sample preparation which might cause age underestimation.

The abundance of bone fragments in the slope sediments both below and above the loess-paleosol package points to a preferred transport route of coarse clasts (fossils) along the valley. This is reinforced by further observations. In 2003 large bones were reported by locals from the road cut just north of the northern outcrop presented in this paper, at the outlet of the valley. In the field, a large limb bone with a ~10 cm wide epiphysis was visible in reworked loess that contained also red clay fragments. The bone was very weathered and thus not extracted from the sediment and not identified. A much older description of fossils here is that of Rónai (1911), who reported about the retrieval of mammoth cranial bones, teeth and tusks along the road leading to the vineyards, probably the same site as or very near to the one described in this paper. The excavation was carried out by the museum of the city of Pécs. Unfortunately, the remains are not available in the museum anymore; they were probably destroyed during wars in the 20th century (Tibor Kisbenedek *ex litt.*). Rónai (1911) also wrote that petrified bones were abundant along the road, down to a depth of 5–6 metres, and were called "Drachenstein" (dragon stone) by the German-speaking inhabitants of the village. This means that the studied valley holds a peculiar concentration of large mammal remains.

At present the saddle above the valley head lies at an elevation of 186 m a.s.l., 300 m to the south of and 50 m higher than the here described remains. Redeposition of the bone fragments found in the slope deposits including the here presented tibia could have happened from this area or the direct surroundings, before the deposition of the lower measured loess layer, which is ~22 ka old according to the OSL age determinations.

CONCLUSIONS

The presented results extend the list of Pleistocene vertebrate sites for the Villány Hills with three new sites and add information to the evolution history of the region.

The lithofacies and fossil content of the bone breccia found in the Siklós quarry are similar to those of other well-known karst infills of the region. As it contained mostly snake vertebrae, its age could not be constrained precisely.

The vertical shafts in the southern part of the same quarry are unusual in several respects. They formed in a dolomite succession, a rock generally not prone to karstification. These fissures might have been created by gravitational deformation of the relatively steep slope, probably at different ages. One of them was closed from above and contained flowstones precipitated during the late Middle Pleistocene, during the late Rissian interstadial MIS7. The other one was filled from above with loess, rock fragments and remains of large mammals – *Equus* cf. *ferus*, *Bos primigenius* and *Coelodonta antiquitatis* –, possibly between 140–40 ka, during one of the stadials of the Weichselian (Würmian) or the latest Saalian (Rissian). The site shows that fossil-bearing cavities could also form in lithologies not favourable for karstification, which then trapped fossils in a similar way karstic cavities do.

In contrast with the previous two and with most of the other known vertebrate sites of the Villány Hills, the Palkonya outcrop is not a karst cavity fill but was deposited on the (palaeo)surface. The *Bison* bones on the basement surface are probably Middle Pleistocene or late Early Pleistocene, older than ~300 ka. The overlying slope sediments originate from the redeposition of various older deposits. They were covered with loess in the Weichselian (~22 ka ago), then again with slope deposits. The abundance of bones in and around the outcrop suggests that this site acted as a fossil trap as well. Bones probably enriched in the sediments during reworking of older deposits of various ages and lithologies. In cold periods, loess deposition decreased (subdued) the relief through infilling the depressions.

*

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