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Martina Cave (Bohemian Karst) – biostratigraphy of the entrance sediments

Jeskyně Martina v Českém krasu – biostratigrafie vchodových sedimentů

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Abstract: In the entrance of the Martina Cave near Tetín (Bohemian Karst) a sedimentary sequence was exposed, which corresponds to the Late Glacial and Holocene and includes molluscan and vertebrate fauna. Serial sampling and quantitative analyses allowed detailed faunal successions to be reconstructed and correlated with changes in sedimentation and archaeological findings. Both animal groups reflect a progressive replacement of open country assemblages by those of woodland that covers the site also at present. Of particular concern is the molluscan fauna from the Late Glacial horizon which indicates a parkland and includes several more demanding open-woodland species (*Fruticicola, Euomphalia, Aegopinella minor*) associated with high amounts of steppe elements, particularly *Chondrula tridens*. There is also a number of aquatic molluscs including species that are indisputably derived from the near Berounka River (*Valvata, Bithynia*) and transported to the cave by any predator or man. Open-ground species (incl. *Granaria frumentum)* remained important even during the Preboreal and Boreal despite of major increase in semi-open woodland elements that dominated the area up to the final Boreal. Postglacial moisture culmination is represented by a brown soil with decalcified fine earth which corresponds to the Atlantic Period as well as to a standstill phase in slope sedimentation. Its upper part includes early Neolithic pottery. Important changes occurred towards the end of the humidity culmination, with the expansion of *Helicodonta obvoluta*, marked increase in *Monachoides incarnatus*, and the suppresion of the remaining Late Glacial and Early Holocene open-ground elements. The molluscan sequence corresponds to the general developmental pattern of biota in forested xerothermic hill countries of Central Europe. There are no traces of ecologic disturbances made by prehistoric population.

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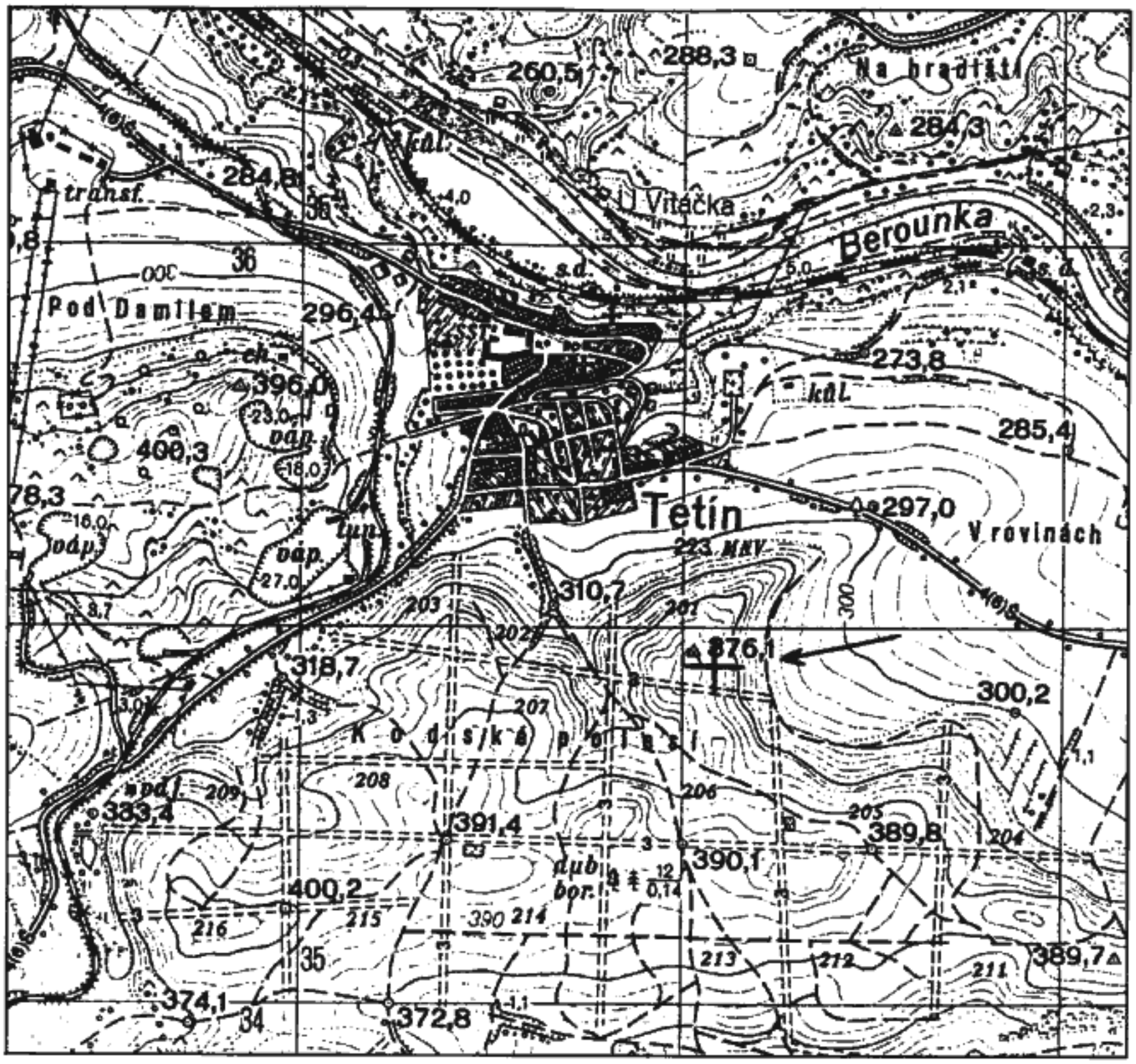
The Martina Cave is situated approximately 900 m SSE of the church of Tetín in the Koda National Nature Reserve (Protected Landscape Area Bohemian Karst, SW of Prague). Its rather small entrance was discovered by the research group of Tetín speleologists (LYSENKO – PLOT 1977) who partly removed the entrance infilling and found prehistoric pottery. For this reason, the further excavation was conducted by the archaeologist Slavomil VENCL (1996) who exposed the whole sedimentary sequence of the entry infilling and distinguished several archaeological horizons. The whole excavation profile yielded also vertebrate bones and molluscan shells that are treated in our paper which is focused on the following problems:

- Continuous development of molluscan and vertebrate assemblages since the Late Glacial.
- Mutual correlation of postglacial vertebrate and molluscan successions.
- Molluscan succession in purely terrestrial environments without extreme habitats (rocks, wetlands).
- Soil formation in relation to slope sedimentation (erosion in different postglacial phases).
- Replacement of early Postglacial open country by woodland.
- Impact of prehistoric humans.

Basic data

The site investigated is situated in the upper part of the east-facing slope of the Koda Plateau (Fig. 1) in a coppiced oak-hornbeam forest grading into a xeric Corni-Quercetum in the top part. The soil appears to be a brown rendsina or initial terra fusca with decalcified fine earth. There are scattered outcrops of Devonian limestone bedrock forming only very low rocky steps and patches of screes. Basic data on the topography and climate of the locality are listed below:
Latitude: 49° 56′ 43″
Longitude: 14° 06′ 26″
Altitude: 362 m
Mean annual rainfall: 520 mm
Mean annual temperature: 8.2 °C
Mean temperature of January: –1.2 °C



1. Location of the Martina Cave. The entrance is marked by the black cross.

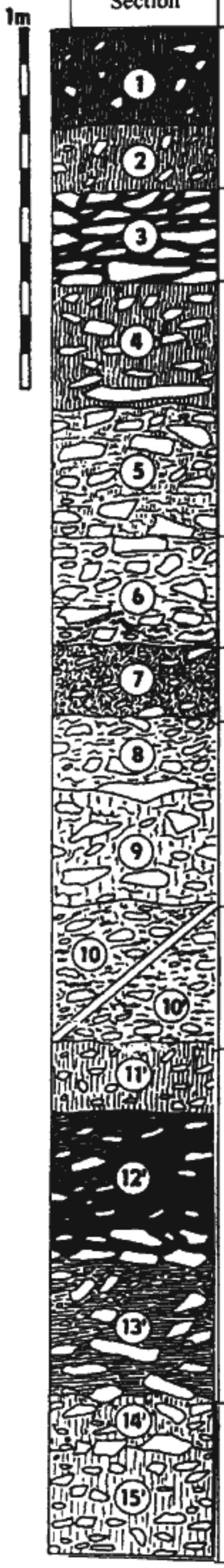
Mean temperature of July: 18 °C
Mean temperature of vegetational (IV–IX) period: 14 °C.

Samples for faunal analysis were taken both from the inner part of the excavation in the chasm-like space in front of the entrance (profile A) and in the pit situated deeper under the cave portal (profile B) where the oldest part of deposits was exposed. From all macroscopically distinguishable layers comparatively voluminous (at least 0.024 m^3) samples were taken to obtain a sufficient number of fossils for statistical analysis. The earth material was air-dried, wet-sieved and the molluscan shells and vertebrate bones extracted. This material was treated by standard techniques (Ložek 1964, Horáček – Ložek 1988).

The results are given in the table of molluscan fauna (Tab. 1), including also basic information on ecology and biostratigraphy of particular species, and in the table of Vertebrates (Tab. 2). The profile with description of particular layers and basic information on sedimentation, molluscan and vertebrate fauna as well as on habitat changes and chronostratigraphic subdivision are given in Fig. 2.

→

2. Profile in the entrance of the Martina Cave and its biostratigraphic evaluation.
Section in front of the cave portal: 1 – 5YR 2/1, black humus-rich loam of coarse crumb structure with numerous roots and partly corroded limestone fragments; 2 – 5YR 2/2, dark reddish brown humic loam of crumb structure with subangular fragments; 3 – 5YR 3/2, dark reddish brown compact humic loam forming matrix of coarse flag breakdown; 4 – 2,5YR 2,5/3, very dark reddish brown loam of crumb structure rich in subangular medium sized fragments; 5 – 2,5YR 2,5/4, dark reddish brown loam with humic infiltrations with rather coarse breakdown; 6 – 2,5YR 3,5/3, dark reddish brown clayey loam with sparse humic infiltrations and charcoal lenses in its lower part; 7 – 2,5YR 3,5/5, dark red clayey loam with rather numerous markedly corroded fragments; 8 – 5YR 3,5/4, dark reddish brown loam with $CaCO_3$ infiltrations; 9 – 5YR 3/4, dark reddish brown loam very rich in $CaCO_3$ efflorescences, subangular fragments with calcareous coatings; 10 – 5YR 3,5/3, reddish brown loam with irregular calcified parts rich in small limestone fragments.
Section under the cave portal: 10'– 5YR 4,5/3,5, paler reddish brown loam high in $CaCO_3$ infiltrations; 11'– dark reddish brown loam, moderately humic with numerous small fragments; 12'– 5YR 3/2–4,5/2, dark reddish grey humic loam with whitish strongly calcified parts and crumb structure; 13' – 5YR 3/3,5, dark reddish brown humic loam of fine crumb structure with charcoals; 14' – 5YR 5/4,5, reddish brown (ochreous) loam; 15' – 5YR 5,5/6, reddish yellow loess-like loam with white $CaCO_3$ pseudomycelia and smaller fragments.



Section	Sedimentation, soil formation	Zoofossils	Environments	Chro-nology
1 2	dark loams rich in humus scattered medium to small-sized fragments	slightly pauperized woodland fauna of present-day type *Isognomostoma* *Cepaea hortensis* *Helicigona lapicida*	coppiced woodland oak-hornbeam forest of present-day type	ATLAN-TIC SUB-
3	coarse breakdown with compact humic matrix		deterioration of climate increase in scree formation *middle bronze age occupation*	SUB-BOREAL
4 5	calcareous loams with medium humus content medium scree rather coarse breakdown	predominance of woodland fauna appearance of *Helicodonta* retreat of *Granaria* and *Cochlicopa lubricella*	closed forest woodland optimum last patches of warm karst steppe	EPIATLANTIC
6 7	dark reddish-brown loam with humic infiltrations charcoal lenses in basal part dark red clayey loam with delcalcified fine earth maximum decalcification	appearance of *Bulgarica nitidosa* *Rana* *Acanthinula* *Sphyradium* *Urticicola*	expansion of woodland *neolithic occupation* maximum humidity	ATLANTIC
8 9	light slightly humic loams with whitish $CaCO_3$ coatings and efflorescences	*Cochlodina, Alinda* *Pitymys, Lacerta vivipara* expansion of woodland fauna appearance of *Granaria*	increase in humidity parkland with warm steppe patches major increase in temperature	BOREAL
10 10'	light loam very rich in $CaCO_3$ efflorescences	open-ground species remain dominant *Pupilla triplicata* *Semilimax kotulae* *Discus rotundatus*	parkland (forest steppe) gradual increase in temperature and moisture	PREBOREAL
11' 12' 13'	decrease in humus content dark humic loams (rendsina sediments) high $CaCO_3$ crumb structure charcoals medium scree	predominance of steppe snails: *Chondrula, Helicopsis, Pupilla, Vallonia, Truncatellina* *Discus ruderatus* – fauna: *Perpolita petronella* appearance of: *Fruticicola fruticum, Euomphalia strigella, Aegopinella minor; Anguis, Lacerta* cf. *agilis* *Semilimax kotulae* *Sicista, Microtus oeconomus* increase in biodiversity	minor deterioration of climate moderate warming and increase in humidity (?Alleröd) parkland with patches of cold steppe and mesic grassland moderate climatic amelioration	LATE GLACIAL
14' 15'	humic infiltration medium to small-sized scree with light ochreous loess-like matrix	*Pupilla loessica* very poor *Pupilla sterri* in bones *Arianta* *Clausilia dubia*	glacial steppe climate dry cold-continental	PLENI-GLACIAL

Table 1. Molluscan fauna, Tetín-Martina

Geologic and biostratigraphic characteristics			List of species	Profile B						Profile A	
				15'	14'	13'	12'	11'	10'	10	9
		!	*Acanthinula aculeata* (MÜLLER)	–	–	–	–	–	–	–	–
		!	*Aegopinella pura* (ALDER)	–	–	–	–	–	–	–	1
		!	*Cochlodina laminata* (MONTAGU)	1	–	–	–	1	–	1	3
		(G)	*Discus ruderatus* (FÉRUSSAC)	–	1	31	17	1	1	6	1
		!	*Ena obscura* (MÜLLER)	–	–	–	–	1?	–	–	–
	1	!	*Helicodonta obvoluta* (MÜLLER)	–	–	–	–	–	–	–	–
		!	*Isognomostoma isognomostomos* (SCHR.)	–	–	–	–	–	–	–	–
		!	*Monachoides incarnatus* (MÜLLER)	–	–	1	–	–	–	1	1
		!	*Sphyradium doliolum* (BRUGUIERE)	–	–	–	–	–	–	–	–
			Semilimax semilimax (FÉRUSSAC)	–	–	–	–	–	–	–	–
		(!)	*Vertigo pusilla* MÜLLER	–	–	2	2	1	7	9	165
	2	W(M)	!	*Alinda biplicata* (MONTAGU)	–	–	–	–	–	–	1?	2
			(+)	*Arianta arbustorum* (LINNÉ)	3	1?	–	–	–	–	–	–
			!	*Cepaea hortensis* (MÜLLER)	–	–	–	–	–	–	–	–
			!	*Discus rotundatus* (MÜLLER)	–	2	3	–	–	1	6	45
				Limax sp.	–	–	–	–	23	8	4	18
			(G)	*Semilimax kotulae* (WESTERLUND)	–	1?	1	–	–	–	1	–
		W(S)	!	*Aegopinella minor* (STABILE)	–	–	5	3?	3	14	23	304
			(!)	*Fruticicola fruticum* (MÜLLER)	–	1?	22	91	235	135	58	171
A			!	*Helix pomatia* LINNÉ	–	–	1?	–	1	–	–	–
	3		(G)	*Clausilia pumila* C. PFEIFFER	1?	–	–	–	–	–	–	–
			!	*Macrogastra ventricosa* (DRAPARNAUD)	–	–	–	–	–	–	–	–
			!	*Urticicola umbrosus* (C. PFEIFFER)	–	–	–	–	–	–	–	–
	4	S	(+)	*Granaria frumentum* (DRAPARNAUD)	–	–	–	–	–	–	3	48
			+	*Helicopsis striata* (MÜLLER)	14	8	21	26	6	11	7	1
			(+)	*Chondrula tridens* (MÜLLER)	–	–	60	204	76	20	158	86
			+	*Pupilla sterri* (VOITH)	2	1	–	–	–	5	–	–
			(+)	*Pupilla triplicata* (STUDER)	–	–	13	26	3?	5	8	3
		XC		*Chondrina avenacea* (BRUGUIÈRE)	–	–	–	–	–	–	–	1
			(G)	*Pyramidula pusilla* (VALLOT)	–	–	–	–	–	–	–	1
B		S(W)	!!	*Cepaea vindobonensis* (FÉRUSSAC)	–	–	–	–	–	–	–	–
	5	O	++	*Columella collumella* (MARTENS)	–	–	1?	–	–	–	–	–
			++	*Pupilla loessica* LOŽEK	6	3	–	–	–	–	–	–
			+	*Pupilla muscorum* (LINNÉ)	–	–	4	–	–	–	–	–
			(!)	*Truncatellina cylindrica* (FÉRRUSSAC)	–	–	1	55	12	10	9	130
			(+)	*Vallonia costata* (MÜLLER)	–	4	295	3613	707	484	1060	2044
			G	*Vallonia pulchella* (MÜLLER)	–	–	9	122	27	4	52	42
			(G)	*Vertigo pygmaea* (DRAPARNAUD)	–	–	15	20	3	3	1	14
C	6		!	*Bulgarica nitidosa* (ULIČNÝ)	–	–	–	–	–	1	–	–
			(!)	*Cochlicopa lubricella* (PORRO)	–	1?	142	146	67	44	38	151
			(!)	*Euomphalia strigella* (DRAPARNAUD)	–	1	6	34	48	32	27	62
			!	*Tandonia rustica* (MILLET)	–	–	–	–	1?	–	–	–
	7	M	(+)	*Euconulus fulvus* (MÜLLER)	–	–	21	26	7	12	6	38
			(+)	*Limacidae*	–	–	1	3	23	13	38	99
			(+)	*Perpolita hammonis* (STRÖM)	–	–	69	73	78	64	32	35
			(+)	*Punctum pygmaeum* (DRAPARNAUD)	–	–	43	41	13	25	9	132

Profile A							
8	7	6	5	4	3	2	1
–	1	1	3	–	3	7	97
–	–	–	–	–	–	–	–
–	4	6	21	43	24	39	19
–	–	1?	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	1	4	23	66	18
1	–	–	–	–	5	6	–
2	6	6	17	16	37	115	71
–	–	1	–	–	–	–	–
–	–	–	1	–	1	–	–
23	1	3	4	–	–	–	–
4	10	18	36	22	13	38	148
–	–	–	–	–	–	–	–
–	–	–	1	–	3	9	5
55	53	106	344	206	291	322	60
12	17	42	93	58	26	23	4
–	–	–	–	–	–	–	–
135	167	65	70	22	27	95	149
90	54	188	78	18	34	27	16
–	–	1?	2	1?	1	1?	1?
–	–	–	–	–	–	–	–
–	–	2?	1	–	–	–	–
–	–	–	1	1?	–	–	–
52	44	154	23	7	6	1	–
1?	–	–	–	–	–	–	–
28	7	2	1	–	–	1	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	3?	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	1?	1?	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
9	3	10	1	–	–	–	–
345	32	23	4	–	–	–	–
16	16	14	2	–	–	–	–
2	–	–	–	–	–	–	–
–	–	1	2	–	–	–	–
41	8	16	9	–	–	–	–
35	10	30	20	12	21	14	15
–	–	–	–	–	–	–	1
5	2	–	8	–	1	1	–
73	43	116	149	132	167	147	45
4	–	–	–	–	–	–	–
16	5	–	1	2	2	11	90

Analysis of the fauna

In the depositional sequence including both profile sections several units have been distinguished which differ from one another in its composition and faunal assemblages.

A. The basal layers 15' and 14' are very poor both in species and individuals. Particularly important are *Helicopsis striata* and above all *Pupilla loessica* which are common in pleniglacial loesses; also the associated species occur in pleniglacial phases. In view of the fact that *Pupilla loessica* disappears with the beginning of the Late Glacial and of the composition of the assemblage in question this fauna is attributable to the final part of the Vistulian pleniglacial characterised by the predominance of loess steppes and grasslands covered by cryoclastic debris.

B. The complex of humic strata 13'–11' exposed only in the inner part of the entrance area is characterised by a dramatic increase of faunal richness. The assemblage consists both of a steppe component with *Helicopsis striata, Chondrula tridens* and *Pupilla triplicata* associated with Vallonias as well as *Truncatellina cylindrica* (appearing in 12') and of a group of species which are able to live in mesic grassland (*Perpolita hammonis* and *petronella, Trichia* cf. *sericea, Euconulus, Vertigo alpestris* and *substriata, Semilimax kotulae, Pupilla muscorum, Succinella oblonga*). There are also parkland elements such as *Fruticicola fruticum* and *Euomphalia strigella* indicative of more favourable climatic conditions, which is also confirmed by the occurrence of *Vertigo pusilla* and *Cochlicopa lubricella*. Of particular importance is *Discus ruderatus* as an index species of the Late Glacial and Early Holocene. A feature of interest at the site is the high number of aquatic species in layer 13' among which several ones come undoubtedly from the near Berounka River (*Ancylus, Bithynia, Valvata piscinalis*), which suggests a secondary transport (by predators or by man?). Despite this, the malacological evidence indicates a parkland of cold forest-steppe character which is supported by the absence of less tolerant woodland snails as well as of the xerothermophilous element *Granaria frumentum*.

The above environmental pattern is supported also by the composition of the vertebrate fauna with high numbers of *Lacerta* and *Anguis*, important occurrence of bats and a surprising high proportion of woodland indicators such as *Apodemus (Sylvaemus)* and *Clethrionomys*, associated, however, with well represented open-ground species such as *Microtus arvalis/agrestis* as well as *Sicista* and *Microtus* cf. *oeconomus* which occur in this site only in layer 13'. There is also *Pitymys* indicating comparatively favourable temperature conditions during the deposition of this layer.

In comparison with 13' and 12' the layer 11' shows a

Table 1, continued

Geologic and biostratigraphic characteristics				List of species	Profile B						Profile A	
					15'	14'	13'	12'	11'	10'	10	9
C	7	M	+	*Trichia "hispida/sericea"*	–	1?	–	1	1?	–	1?	1?
			(G)	*Vitrina pellucida* MÜLLER	–	–	12	63	8	3	7	53
		R(W)	(+)	*Clausilia dubia* DRAPARNAUD	2	–	2	–	–	–	–	–
			!	*Helicigona lapicida* (LINNÉ)	–	–	1	–	1?	1	–	–
			G	*Vertigo alpestris* ALDER	–	–	4	–	–	–	–	–
	8		!	*Carychium tridentatum* (RISSO)	–	–	1	–	1	–	–	–
			(!)	*Columella edentula* (DRAPARNAUD)	–	–	–	1	–	–	–	–
			(G)	*Perpolita petronella* (L. PFEIFFER)	–	–	151	203	20	5	17	12
			+	*Succinella oblonga* DRAPARNAUD	–	–	3	–	–	–	–	–
			(G)	*Vertigo substriata* (JEFFREYS)	–	–	1	1	–	–	–	–
D	9		G	*Carychium minimum* MÜLLER	–	–	1	–	2	–	–	–
	10	F	G	*Ancylus fluviatilis* MÜLLER	–	–	18	–	–	–	–	–
		StF		*Bithynia tentaculata* (LINNÉ)	–	–	1	–	–	–	–	–
				Pisidium milium HELD	–	–	3	1	–	–	–	–
				Pisidium subtruncatum MALM	–	–	6	–	–	–	–	–
				Sphaerium corneum (LINNÉ)	–	–	2?	–	–	–	–	–
				Valvata piscinalis (MÜLLER)	–	–	3	–	–	–	–	–
		FPpR	(+)	*Pisidium casertanum* (POLI)	–	–	30	4	5	–	–	–
				Pisidium personatum MALM	–	–	–	1	–	–	–	–
		St(F)	(+)	*Radix ovata* (DRAPARNAUD)	–	–	28	1?	3?	–	–	–
				Radix peregra (MÜLLER)	–	–		–	–	–	–	–
		St		*Gyraulus crista* (LINNÉ)	–	–	12	–	–	–	–	–
				Gyraulus albus (MÜLLER)	–	–	7?	–	–	–	–	–
			(+)	*Pisidium obtusale* (LAMARCK)	–	–	2	–	–	–	–	–
		P		*Valvata cristata* MÜLLER	–	–	–	1	–	–	–	–
		Pp	(+)	*Anisus leucostoma* (MILLET)	–	–	1?	–	–	–	–	–
		StPpR	(+)	*Galba truncatula* (MÜLLER)	–	–	–	1	5	–	–	–
Number of individuals					29	25	1056	4780	1383	908	1583	3664
Number of species					7	12	45	28	31	24	27	29
Assemblage zone					A			B		C_1	C_1	C_2
Chronology					W			LW		PB	PB	B

Ecologic and biostratigraphic characteristics: A – woodland in general, B – open ground, C – woodland/open ground (indifferent), D – marshes, banks, water.

1 – closed woodland, 2 – predominantly woodland: W(M) – woodland to mesic open habitats, W(S) – woodland to xeric open habitats; 3 – damp woodland, 4 – steppe and xerothermic rocks: S – steppe, rocky steppe, XC – xerothermic limestone rocks, S(W) – steppe to xerothermic woodland; 5 – open ground in general (O); woodland and open ground habitats: 6 – xeric; 7 – mesic or diverse: M – mesic or diverse in general (catholic elements), R(W) – mesic rocks or woodland (on trees); 8 – damp; 9 – very damp habitats (swamps, banks, fens etc.); 10 – aquatic habitats: F – flowing waters, St – stagnant waters, StF – stagnant or flowing water, St(F) – predominantly stagnant water, P – marshes, swamps, Pp – ephemeral swamps, R – springs.

moderate decrease in faunal richness which indicates a minor deterioration of climate.

C_1. The horizon including the layer 10' and 10 shows environmental conditions resembling in general those in the underlying complex 13'–11'. Steppe elements *Helicopsis* and particularly *Chondrula tridens* remain important, *Vallonia costata* occurs in high quantities and the typically heliophilous *V. pulchella* is also rather abundant. The appearance of *Semilimax kotulae* is particularly noteworthy. Of prime importance is the first appearance of the submediterranean xerothermophile *Granaria frumentum* as well as the start of continuous occurrence of *Discus rotundatus* and the increase in *Vertigo pygmaea*. The adjacent area is a parkland under a climate becoming gradually milder.

C_2. In the overlying strata 9 and 8 several shade-demanding woodland species appear: *Cochlodina laminata,*

Profile A							
8	7	6	5	4	3	2	1
–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	4
–	–	–	–	–	–	–	–
–	1	–	–	1	3	15	5
–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–
–	–	–	1	–	–	–	–
1?	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
960	477	806	894	545	689	942	748
24	20	22	27	15	20	21	17
	D		E		F		
	A		EA		SB	SA	SR

! – species characteristic of warm phases, !! – index species of warm phases, (!) – eurythermic species of warm phases, + – loess species, ++ – index species of loess, (+) – occasional or local loess species, G – species which survived the glacial out of the loess belt, (G) – species which survived the glacial out of the loess belt as relicts.
Representation: 6 – number of individuals, 2? – determination approximate.

Monachoides incarnatus, Alinda biplicata; Discus rotundatus, Aegopinella minor and temporary also *Vertigo pusilla* show a marked increase. *Helicopsis* is decreasing, and *Granaria* becomes rapidly important and *Chondrula* remains rather abundant. Steppe assemblages are thus dominated by *Chondrula* and *Granaria; Pupilla triplicata* remains still present. A number of indifferent and less tolerant species (*Fruticicola, Truncatellina cylindrica, Vallonia costata*, both *Perpolita* etc.) abundant at the beginning later decrease or disappear.

Among Vertebrates *Lacerta* cf. *vivipara* and *Pitymys* are biostratigraphically important, *Microtus arvalis* increases, while *Microtus agrestis* decreases.

The above evidence indicates an increase in temperature and moisture supporting the expansion of woodland. However, open and partially open areas remain much more extensive than at present. Of particular interest is the isolated occurrence of epilithic calcicoles *Chondrina avenacea* and *Pyramidula pusilla* which obviously expanded with gradually improving climate, but later were suppressed by forest.

D. In layers 7 a 6 further woodland snails start their continual occurrence and the numbers of several woodland elements increase (*Acanthinula, Monachoides, Alinda biplicata*). *Bulgarica nitidosa* appears, whereas *Chondrula* disappears and *Vallonia costata* shows a dramatic decrease. A marked decrease of the richness of malacofauna in the layer 7 may be linked with the decalcification of fine earth culminating in this horizon. Among xerothermophilous open-ground elements only *Granaria* remains important. From this layer a continual occurrence of *Pitymys* begins, whereas *Microtus arvalis* attains its maximum. Our data demonstrate that a vegetational break characterised by definitive woodland predominance took place, although a number of open patches remained preserved at favourable habitats. Traces of corrosion on molluscan shells due to decalcification document the extraordinarily high moisture during the formation of layer 7.

E. In the complex of strata 5–4 the woodland fauna acquires its present-day character as documented by the presence of *Helicodonta obvoluta, Sphyradium doliolum, Semilimax semilimax* or *Helicigona lapicida* associated with *Cochlodina laminata, Monachoides incarnatus* and *Discus rotundatus* in markedly increasing amounts. Records of hygrophilous elements *Macrogastra ventricosa, Urticicola umbrosus* and *Columella edentula* indicate comparatively damp environments. Open-ground species (*Truncatellina, Vallonia, Cochlicopa lubricella*) are retreating or disappear, *Granaria* markedly decreases. *Bulgarica nitidosa* temporarily increases, but then disappears. In layer 4 the decrease in the richness of vertebrate fauna starts; *Pitymys* has its last occurrence. Woodland species definitively become dominant, whereas steppe and indifferent species decline or disappear.

F. The surface complex 3–1 is dominated by woodland snails; *Isognomostoma isognomostomos* appears, whereas a number of species attain their maxima – *Helicodonta, Monachoides* and *Helicigona* in 2, *Acanthinula* and *Alinda* only in the surface layer 1. Open-ground species were not recorded. The vertebrate component shows a general pauperization

which is particularly true of bats, reptiles and amphibians.

Biostratigraphic interpretation

In comparison with faunal sequences from other sites in the Bohemian Karst, particularly at Skalka nad Čihovou (LOŽEK 1987) and Kobyla-West (LOŽEK 1989) which have a similar position, i.e. they are located high above the valley cuts, the fauna from the Martina Cave shows a comparatively monotonous development, particularly in the case of Vertebrata. *Microtus gregalis, Ochotona* and *Dicrostonyx* which play an important role at the Pleistocene/Holocene boundary were not recorded.

Despite this, the development of molluscan fauna reflects the main developmental trend characterising the time span Late Pleistocene-Holocene, i.e. the gradual transition between assemblages dominated by open-ground and indifferent species and those consisting of closed-woodland elements. In Martina both extremes – on the one hand, glacial open-country species, on the other, the later woodland elements – are poorly represented. Of glacial species, *Vallonia tenuilabris* (A. Br.) was not recorded and *Columella collumella* was represented only by one hardly determinable fragment, the woodland assemblage is not markedly richer than the present-day fauna at the same point. A peculiar feature is the high amount of aquatic species in layer 13'as well as the faunal richness of layers 13' and 12' including also an admixture of several demanding species, although the general character of this fauna corresponds to environments of the declining glacial. Another remarkable feature is the long survival of a number of open country species, which documents that the area in question had a parkland character till the Neolithic time. Of prime chronostratigraphic importance is the decalcified horizon (layer 7) immediately underlying the layer including the Early Neolithic pottery and corresponding to Holocene moisture maximum. This is reflected by a rapid decrease and disappearance of open-ground species.

In view of the above facts the biostratigraphic units can be chronologically attributed to the following phases:

A. The basal complex 15'–14' corresponds to the decline of the Vistulian pleniglacial, i.e. to the time span of declining loess formation, which is supported by the lithological character.

B. The humic complex under the cave portal (13'–11') is generally attributable to the Late Glacial (= Late Vistulian). A certain problem is presented by the rich malacofauna from layers 13' and partly 12' with first occurrence of several demanding species in small amounts, later disappearing for a short time, which indicates a temporary warming. We cannot exclude that this fluctuation provides evidence for the Alleröd Interstadial which however was nowhere identified in this area and facies, so that such interpretation must be considered only preliminary. Thus the decrease in faunal richness in the layer 11'might corresponds to the Younger Dryas.

C[1]. The horizon 10'–10 represents the level of immigration and gradual expansion of demanding elements and thus can be attributed to the Preboreal.

C[2]. The expansion of demanding and woodland elements associated with a rather abundant occurrence of open-ground species, high $CaCO_3$ content of the fine earth as well as the stratigraphic position below the horizon of maximum decalcification indicate the Boreal age.

D. The moisture maximum documented in the horizon (7) immediately underlying the early Neolithic level and a dramatic decrease in open-ground species indicate the Atlantic sensu JÄGER (1969). Its close analogues have been reported from Karlštejn-Krabina (LOŽEK 1988) and Zlatý kůň (LOŽEK 1996) situated in near surroundings.

E. The overlying complex 5–4 is again richer in $CaCO_3$ and humus; woodland species definitively become predominating over open-ground elements which disappear during this phase. The development of woodland fauna culminates as documented by temporary occurrence of moisture- and shade-demanding species *Macrogastra ventricosa, Urticicola, Columella edentula*) which later again disappear. This developmental pattern corresponds to the Epiatlantic.

F. Three surface layers represent the Late Holocene with definitive predominance of woodland malacofauna of present-day character which has survived at this place till now. Of stratigraphic importance is the basal horizon 3 consisting of accumulated limestone flags, which indicates the destruction and retreat of the cave portal. This event as well as the general position of the layer in question correspond to the Subboreal sensu JÄGER (1969).

Two important conclusions of relevance to Postglacial development can be inferred from the biostratigraphic analysis of sedimentary fill of the Martina Cave entrance:

– The most intensively decalcified layer (7) immediately underlying the horizon of Early Neolithic pottery gives evidence of the Postglacial humidity maximum corresponding to final Boreal and older half of the Atlantic. It also corresponds to a standstill phase in slope sedimentation.

– Faunal evidence of a parkland character of landscape up to the Neolithic in the zone of woodland which is the dominating vegetation formation in the area of Bohemian Karst. This provides indirect evidence that in the adjacent chernozem area of inner Bohemia which is drier and more fertile and thus preferred by first Neolithic cultivators, larger open areas of steppe character could exist even in this time period.

Table 2. Vertebrata from the Martina Cave

List of species	Layer															
	15'	14'	13'	12'	11'	10'	10	9	8	7	6	5	4	3	2	1
Pisces gen. sp. indet.	–	–	+	1	–	1	–	–	–	–	–	–	–	–	–	–
Amphibia, Anura	–	1	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Bufo cf. *viridis*	–	–	–	3	4	3	–	–	–	–	–	–	–	–	–	–
Bufo cf. *bufo*	–	–	–	–	2	–	–	–	–	–	–	–	–	–	1	1
Rana cf. *temporaria*	–	–	–	–	2	–	–	–	–	–	–	1	–	–	–	–
Rana cf. *ridibunda*	–	–	–	–	2	–	–	–	–	–	2	1	–	–	–	–
Reptilia, Lacertilia																
Lacerta cf./gr. *agilis*	–	–	–	10	10	–	1	–	1	–	3	1	1	–	–	–
Lacerta cf. *vivipara*	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
Anguis fragilis	–	–	+	10	150	50	–	1	1	1	–	2	–	–	1	1
Reptilia, Ophidia																
gen. sp. indet.	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Aves, Passeriformes																
cf. *Coccothraustes coccothraustes*	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
cf. *Parus*	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
gen. sp. indet.	–	–	+	3	+	–	–	–	–	–	–	–	–	–	–	–
Mammalia, Chiroptera																
Rhinolophus hipposideros	–	–	–	1	1	–	–	–	–	–	–	–	2	–	–	1
Myotis bechsteini	–	–	–	3?	2?	1?	1	1	–	1	2	2	–	–	–	–
Myotis nattereri	1	–	4	–	–	–	–	–	1	–	2	1	–	–	–	–
Myotis cf. *daubentoni*	–	–	2	–	–	–	–	–	–	–	–	–	1	–	–	–
Eptesicus serotinus	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Plecotus cf. *auritus*	–	–	3	–	1	1	1	–	–	–	–	2	–	–	–	–
Vespertilio murinus	–	–	–	1	3	–	–	–	–	–	–	–	–	–	–	–
Barbastella barbastellus	–	1	4	–	–	1	–	–	1	–	–	–	–	–	–	–
Mammalia, Insectivora																
Talpa europaea	–	1	1	3	2	1	1	–	–	–	1	1	–	–	–	–
Sorex araneus	1	2	7	–	–	–	1	–	–	–	–	–	–	–	2	1
Sorex minutus	–	1	2	1	–	–	–	1?	–	–	–	–	–	–	–	–
Crocidura suaveolens	–	–	–	–	3	1	–	1?	1?	–	–	1?	–	–	–	–
Mammalia, Rodentia																
Sicista sp.	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Apodemus (Sylvaemus) sp.	–	–	3	10	45	7	4	6	5	7	8	5	3	1	3	3
Clethrionomys cf. *glareolus*	–	2	16	4	4	–	4	1	2	7	2	3	4	2	1	1
Arvicola terrestris	–	–	4	3	7	3	1	3	3	3	4	2	2	1	–	–
Microtus cf. *Oeconomus*	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–
Microtus cf. *Arvalis*	–	1	21	9	14	12	6	15	18	27	25	6	7	1	3	3
Microtus arvalis/agrestis	1	2	18	21	54	18	–	–	–	–	–	–	–	–	–	–
Microtus cf. *Agrestis*	–	1	5	–	–	–	1	1	7	?	?	–	–	–	–	–
Pitymys subterraneus	–	–	1	–	–	–	–	1	–	2	2	1	1	–	–	–
Mammalia, div. ord.																
Lepus europaeus	–	1?	1?	–	1?	–	–	–	–	1	–	–	–	–	–	–
cf. *Putorius* sp.	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	
Sus scrofa	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
cf. *Cervus* sp.	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Number of individuals	3	11	78	73	295	89	22	34	33	52	51	29	22	6	11	12
Number of species	3	9	21	14	19	13	11	12	9	10	10	14	9	5	6	8

For chronostratigraphic intepretation see Table 1.

General conclusions

The major conclusions may be summarized as follows:

- During the Postglacial land snails appear to have colonized the Bohemian Karst in a relatively ordered sequence. However, in rocky sites and wetlands this developmental pattern may be more or less obscured by excessive amounts of certain rupestral (e.g. *Chondrina, Granaria, Pupilla*) or marshland elements (*Carychium, Vertigo*). In the Bohemian Karst such sites are rather numerous.
- The Late Glacial is characterized by parkland malacocoenoses that include a number of more demanding species such as *Fruticicola fruticum, Euomphalia strigella, Aegopinella minor* or *Vertigo pusilla* associated with several thermophilous steppe elements, particularly *Chondrula tridens* and *Pupilla triplicata*.
- The Martina Cave is situated out of the chernozem zone, within the region of mid-European deciduous forest which has been covered by woodland since the beginning of the Holocene. However, the Early Holocene snail communities reflect the persistence of semi-open woodland or dense parkland up to the major increase of moisture at the Boreal-Atlantic boundary, when the semi-open woodland became replaced by closed forest, which is reflected by the decline of open-ground malacocoenoses.
- The Postglacial humidity culmination is documented by horizons of brown soils with decalcified fine earth that occur even in slope positions with permanent supplying with calcareous material. This peculiar feature thus reflects a standstill phase in slope transport.

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References

HORÁČEK, I. – LOŽEK, V. (1988): Palaeozoology and the Mid-European Quaternary past: scope of the approach and selected results. – Rozpr. Čs. Akad. Věd, Ř. Mat.-přír. Věd, 98, 4. Praha.

JÄGER, K.-D. (1969): Climatic Character and Oscillations of the Subboreal Period in the Dry Regions of the Central European Highlands. – Proc. VII. Congress INQUA, 16, 38–42. Washington.

LOŽEK, V. (1964): Quartärmollusken der Tschechoslowakei. – Rozpr. Ústř. Úst. Geol., 31. Praha.

– (1987): Biostratigrafický výzkum jeskyně ve Skalce nad Čihovou (Biostratigraphic investigation of the cave in the hill Skalka nad Čihovou). – Čs. Kras, 38, 55–69. Praha.

– (1988): Slope deposition in karst environments of Central Europe. – Čs. Kras, 39, 15–33. Praha.

– (1989): Postglaciální souvrství v převisu na západním svahu Kobyly u Koněprus (Postglacial sedimentary fill of the rock-shelter in the western slope of the Kobyla Hill near Koněprusy). – Čs. Kras, 40, 57–72. Praha

– (1996): Přírodní poměry na jižním svahu Zlatého koně během holocénu (Environmental conditions on the south-facing slope of the Zlatý Kůň Hill during the Holocene). – Bohemia cent., 25, 127–137. Praha.

LYSENKO, V. – PLOT, J. (1977): Jeskyně Martina – nový objev v Českém krasu. – Čs. Kras, 28, 88–90. Praha.

VENCL, S. (1996): Archeologický výzkum jeskyně Martina (Archaeological excavation of the Martina Cave). – Tetín historický a speleologický, Knih. Čes. speleol. Společ., 30, 63–67. Praha.

Jeskyně Martina (Český kras) – biostratigrafie vchodových sedimentů

(Resumé anglického textu)

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Vchod jeskyně Martina se otevírá ve svrchní části východního svahu Kodské planiny zhruba 900 m jjv. od věže kostela v Tetíně. Svah i širší okolí pokrývá dubo-habrová pařezina, přecházející při horní hraně planiny do suché dřínové doubravy. Nenápadný vchod pod nízkou skalkou byl objeven tetínskými jeskyňáři, kteří při jeho rozšiřování nalezli zlomky pravěké keramiky. Po tomto objevu zde Slavomil Vencl z Archeologického ústavu ČSAV vedl archeologický výzkum, během něhož bylo odkryto celé souvrství vstupní výplně, tvořené různě hrubými sutěmi vápenců vyplněnými hlínami s různě vysokým podílem humusu i $CaCO_3$. Veškeré vrstvy obsahovaly ulity měkkýšů v množství umožňujícím statistické zpracování (tab. 1) i kosti a zuby převážně drobných obratlovců (tab. 2).

Naše práce se zaměřila na podrobný rozbor této fauny s cílem řešit následující otázky:

– Souvislý vývoj společenstev měkkýšů a obratlovců od pozdního glaciálu.
– Vzájemná korelace postglaciálních sledů měkkýší a obratlovčí fauny.
– Sled malakocenóz v čistě suchozemském prostředí bez extrémních stanovišť, jako jsou skály nebo mokřady.
– Vývoj půd ve vztahu ke svahové sedimentaci i odnosu v různých fázích poledové doby.
– Přechod časně postglaciální otevřené krajiny do zapojených lesů.
– Vliv pravěkého osídlení.

Obě živočišné skupiny vykazují postupné nahrazování společenstev otevřené krajiny z konce glaciálu společenstvy lesními, která se na nalezišti i v širším okolí udržela dodnes, čili obraz vývoje, jakým se vyznačuje pásmo zonální středoevropské vegetace (mezofytikum botanické literatury). Zvláštní zmínku zasluhuje bohaté společenstvo pozdního glaciálu odpovídající parkovité krajině, v němž se již objevují některé náročnější prvky jako *Fruticicola, Euomhalia* nebo *Aegopinella minor* ve společnosti některých silně zastoupených stepních druhů, především trojzubky *Chondrula tridens*. Vrstva obsahuje překvapivé množství vodních druhů, které nepochybně pocházejí z údolí Berounky, některé přímo ze samotné řeky (*Valvata, Bithynia*). Jejich přítomnost na tomto vysoko položeném suchém místě lze vyložit jen druhotným transportem prostřednictvím nějakého predátora nebo snad pravěkého člověka.

Podstatné je, že druhy otevřené krajiny (včetně *Granaria frumentum*) se udržují ve významném zastoupení i během celého preboreálu a boreálu vzdor značnému zvýšení podílu obyvatelů polootevřených hájů, kteří podrželi převahu až do konce boreálu. Postglaciální maximum vlhkosti dokládá hnědá půda s odvápněnou jemnozemí (7), která odpovídá atlantiku a ukazuje na klidovou fázi ve svahové sedimentaci. V její povrchové poloze byl zjištěn starší neolit. Během kulminace vlhkosti probíhá významná změna charakterizovaná příchodem čistě lesního druhu *Helicodonta obvoluta* a výrazným zvýšením podílu vlahovky *Monachoides incarnatus* současně s ústupem pozdně glaciálních a časně holocenních obyvatel otevřené krajiny. Je pozoruhodné, že ve vývoji fauny nelze zjistit stopy antropických vlivů vzdor dokladům pravěkého osídlení.

V kontextu celého souboru malakologicky analyzovaných postglaciálních souvrství v Českém krasu představuje sled měkkýších společenstev z Martiny obraz průměrného vývoje v lesnatých teplých pahorkatinách střední Evropy, neboť není rušen nadměrnými podíly některých druhů vázaných jak na skalní, tak na mokřadní lokality. Pozoruhodné jsou nálezy z pozdního glaciálu, které patrně pocházejí z některého z jeho teplejších výkyvů, nejspíše alleröd u. Martina leží mimo černozemní zónu, což odpovídá celkem nerušenému vývoji směrem k souvislým lesům, i když opravdu zapojený les s příslušným lesním a půdním mezoklimaten se zde utváří až během vlhkostního maxima, tedy v atlantiku. Z hlediska sedimentace je atlantická hnědá půda významným dokladem klidové fáze ve svahové sedimentaci, jakou známe i z dalších lokalit v této oblasti (Karlštejn-Krabina, Zlatý kůň-jižní svah, Zadní Kopanina). Závěrem lze říci, že Martina patří k nalezištím s nejúplnějším bohatě členěným vývojem v rámci terestrické facie pozdního glaciálu a holocénu.

Vysvětlivky k obrázkům

1. Poloha jeskyně Martina. Vchod označuje černý křížek.

2. Profil ve vchodu jeskyně Martina a jeho biostratigrafické vyhodnocení.
Úsek před portálem: 1 – 5YR 2/1, černá, silně humózní, hrubě drobtovitá hlína s hojnými kořeny a zčásti korodovanými vápencovými úlomky; 2 – 5YR 2/2, tmavě narudle hnědá drobtovitá hlína s tupohrannými úlomky; 3 – 5YR 3/2, tmavě rudohnědá, ulehlá, humózní hlína – výplň sutě hrubých desek; 4 – 2,5YR 2,5/3, velmi tmavá rudohnědá drobtovitá hlína s hojnou subangulární střední sutí; 5 – 2,5YR 2,5/4, tmavě rudohnědá s humózními záteky a dosti hrubou sutí; 6 – 2,5YR 3,5/3, tmavě rudohnědá jílovitá hlína s nečetnými humózními záteky, čočky uhlíků naspodu; 7 – 2,5YR 3,5/5, tmavočervená jílovitá hlína s výrazně korodovanými úlomky a zčásti odvápněnou jemnozemí; 8 – 5YR 3,5/4, tmavě rudohnědá hlína s $CaCO_3$ infiltracemi; 9 – 5YR 3/4, tmavě rudohnědá hlína s velmi četnými $CaCO_3$ výkvěty a subangulárními úlomky s vápnitými povlaky; 10 – 5YR 3,5/3, narudle hnědá hlína s nepravidelně provápněnými úseky a hojnými drobnými úlomky.
Úsek pod portálem: 10' – 5YR 4,5/3,5, světleji narudle hnědá hlína, silně provápněná; 11' – tmavší narudle hnědá hlína, mírně humózní, s hojnými drobnými úlomky; 12' – 5YR 3/2–4,5/2, tmavě narudle šedá humózní hlína s bělavými silně provápněnými partiemi, drobtovité skladby; 13' – 5YR 3/3,5, tmavě rudohnědá humózní jemně drobtovitá hlína s uhlíky; 14' – 5YR 5/4,5, narudle okrová hlína; 15' – 5YR 5,5/6, narudle žlutá sprašovitá hlína s bělavými $CaCO_3$ pseudomycelii a drobnějšími úlomky.

Vysvětlivky k tabulkám

Tabulka 1. Měkkýši v jeskyni Martina. Ekologická a biostratigrafická charakteristika.
A – les (všeobecně), B – bezlesí, C – les/bezlesí, D – mokřady, břehy, vody.
1 – zapojený les; 2 – převážně les: W(M) – podružně svěží otevřená stanoviště, W(S) – podružně suchá otevřená stanoviště; 3 – vlhké lesy; 4 – stepi a xerotermní skály: S – stepi a skalní stepi, XC – xerotermní vápencové skály, S(W) – stepi až xerotermní lesy; 5 – bezlesí (všeobecně); lesy, bezlesí: 6 – převážně suché; 7 – svěží nebo různé: Me – různého druhu, R(W) – vlhčí skály, suťové lesy; 8 – převážně vlhké; 9 – mokřady, břehy; 10 – vody: F – toky, St – stojaté, StF – tekoucí až stojaté, St(F) – převážně stojaté, P – močály, bažiny, Pp – periodické močály, R – prameny.
! – význačné druhy teplých období, !! – vůdčí druhy teplých období, (!) – eurytermní druhy teplých období, + – sprašové druhy, ++ – vůdčí druhy spraší, (+) – místní nebo náhodné sprašové druhy, G – přežívající glaciál mimo sprašové pásmo, (G) – přežívající glaciál jako relikty.
Zastoupení: 6 – počet jedinců, 2? – přibližné určení.

Tabulka 2. Nálezy obratlovců v jeskyni Martina.