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Late Weichselian-Holocene sediments and soils in mid-European calcareous areas

Pozdně viselské až holocenní sedimenty a půdy ve středoevropských vápnitých oblastech

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Abstract: Climatic and environmental development of the Postglacial can be traced in mid-European karstlands and other calcareous areas in depositional sequences of cave and slope sediments, tufas and valley floor deposits in correlation with zoostratigraphy (Mollusca, Vertebrata) and archaeology. The following events recorded in this depositional environment are of prime importance: (1) standstill phase in slope transport and sedimentation during the formation of the youngest loess, (2) maximum $CaCO_3$ migration in the late Boreal and early Atlantic associated with intensive downcutting, (3) intensive pedogenesis in the early Atlantic, (4) sudden desiccation immediately prior to the Neolithic occupation at 5,000 B.C., (5) intensive breakdown of solid rocks and scree formation associated with decline of tufa formation in the phase of dry and unbalanced climate corresponding to the Late Bronze Age. This event documented in numerous tufa deposits started the climatic deterioration in the Young Holocene.

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1. Introduction

At present, reconstructions of the course of the Last Glacial-Holocene transition are mainly based on palaeobotanical evidence from mire and aquatic deposits. Classical areas are the lowlands of Northern Europe as well as areas on the periphery of the Alps and moorlands in mid-European highlands (Firbas 1949, 1952; Krippel 1986). By contrast, there are no comprehensive works treating the development of terrestrial sediments in warm-dry uplands and lower part of highlands, although during recent decennia a number of sites in karstlands have been investigated where this time-span is well-differentiated in depositional sequences of various types of sediments (Kukla - Ložek, 1971; Ložek 1982c; Kordos 1978a). The purpose of this paper is to summarize the results of most recent studies of the development of Quaternary sediments and soils under predominantly terrestrial conditions in karstlands and other calcareous areas. Emphasis is placed on the following main problems:

- Climatic changes and their effect on sedimentation and weathering
- Climatic changes in correlation with soil formation
- Climatic changes and their control of the biological systems
- Environmental reconstructions based on the changes discussed above
- Sequence, intensity and chronology of particular development phases
- Comparison with transitional phases between Pleistocene glacials and interglacials.

2. Methodological approach

As pointed out before, a detailed chronology of this time-span was based mainly on palaeobotanical analyses from mire and aquatic sediments that include fossils appropriate for statistical treatment, especially pollen. A classical work for the area of Central Europe is the monograph by F. Firbas (1949, 1952) supplemented at present by a number of further data, however only in part comprehensively evaluated. Among recent works the monograph by E. Krippel (1986) on the Postglacial development of vegetation in the West Carpathians may be mentioned, since it deals with an area which has provided many important records discussed in this paper. From the works cited it is obvious that a great majority of palaeobotanical records come - particularly in the area of mid-European highlands - only from certain limited areas, which are mostly moist and have acid substrates, whereas other regions have not provided any evidence. This is particularly true of warm-dry lowlands and uplands with dense prehistoric settlement as pointed out already by Firbas (1949, 1952).

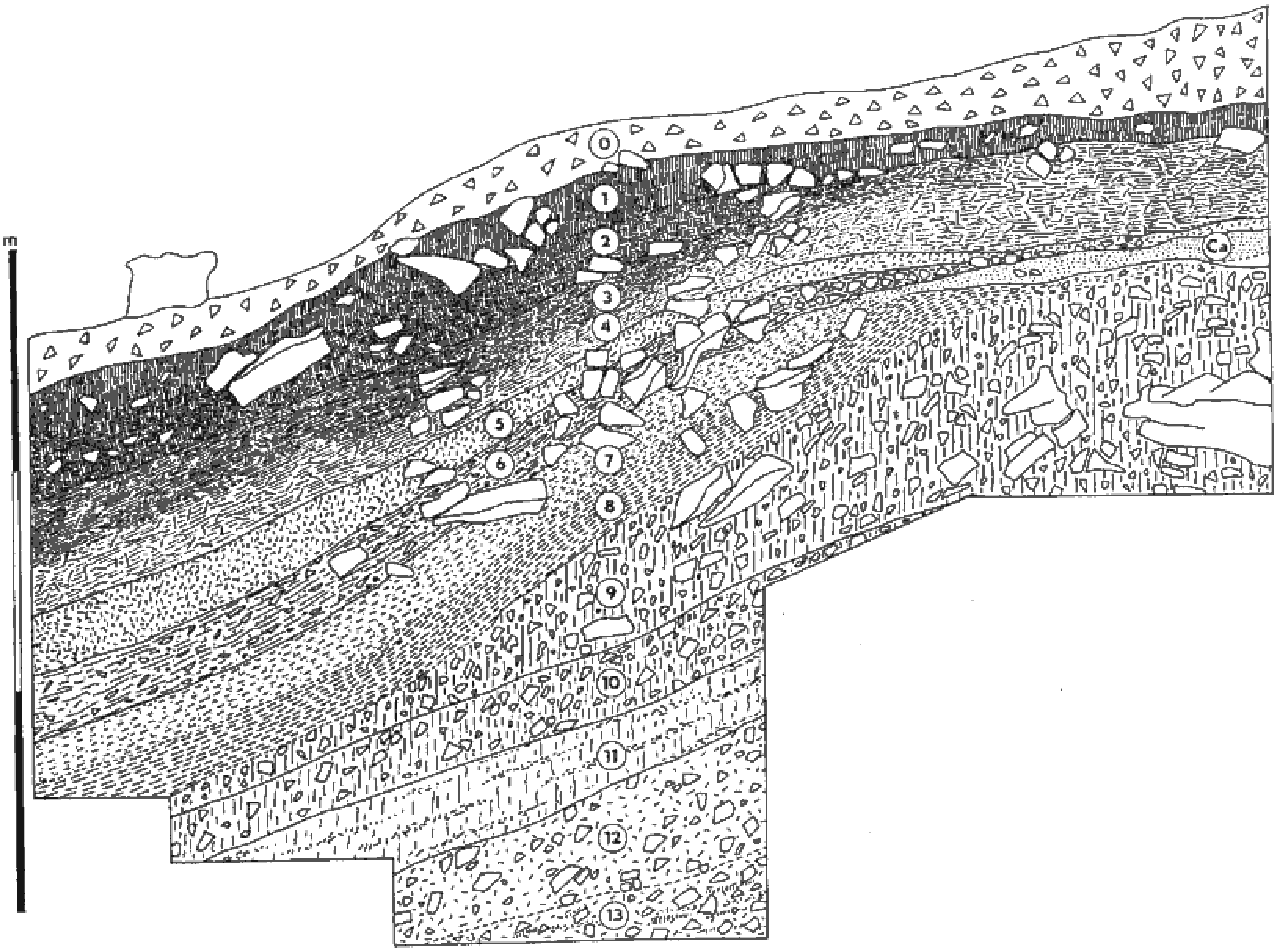
In areas poor in plant fossils, palaeozoology can play an important role - molluscs in all areas consisting of calcareous rocks and vertebrates mostly in karstlands which are rich in sites characterized by secondary concentrations of their remains, particularly in form of taphocoenoses (Horáček - Ložek 1988). Our study is thus based mainly on observations from karstlands, where molluscan and vertebrate fossils occur in a wide variety of facies and where the best possibilities for correlation with archaeological findings exist (Ložek 1960).

Data presented in this paper are based on biostratigraphical analyses of depositional sequences from a wide network of sites situated in karstland areas of the Bohemian Highlands and West Carpathians. These are particularly the Bohemian (Ložek 1992a) and Moravian Karsts, the Pálava Mts. as well as a number of other Carpathian areas, especially the Slovak Karst where during the last decade a detailed investigation has been conducted (Ložek - Horáček 1992). In addition, further sites in areas with calcareous rocks have been investigated, namely in the regions of Bohemian Cretaceous and Carpathian Tertiary Systems, supplemented by records from other countries of Central Europe (Alexandrowicz 1983, 1987; Fuhrmann 1973; Füköh 1991; Kordos 1978a, b; Mania 1972; Starkel 1991 etc.).

Evidence given by fossil molluscan and vertebrate assemblages supplement each other. Whereas molluscan communities generally represent a mixture of several original malacocoenoses and in certain cases only one malacocoenosis confined to a certain area characterized by certain habitat (e.g. woodland, steppe, slope covered by scrub, mire etc.), the great majority of vertebrate assemblages are taphocoenoses consisting of selected species brought by a predator from the surroundings which enables an environmental reconstruction for a broader area. The correlation of both groups has been made recently in a general manner (Horáček - Ložek 1988).

Particular problems which are treated here are the following:

- Decline of loess formation
- Dissolution and secondary precipitation of $CaCO_3$
- Changes in composition of slope sediments



1. Depositional sequence in the entrance of the Zazděná Cave (Moravian Karst) showing the early Atlantic foam sinter horizon (cp. Table 1).

Table 1. Description and interpretation of the depositional sequence at the entrance of the Zazděná Cave (cp. Fig. 1)

0 - Dump material 1 - Black, humus-rich, friable loam with coarse fragments (20-40 cm), charcoal accumulation towards the rock wall 2 - Very dark brownish grey, humus-rich loose loam with numerous smaller fragments; free interstices with accumulations of sheels/bones	YOUNG HOLOCENE Scree with large boulders, loose matrix of rendsina character Culmination of *Alinda biplicata* and *Helicodonta*, Appearance of *Oxychilus cellarius* and *Aegopis verticillus* Rather warm and moderately humid climate, similar to that of present time Mixed scree forest
3 - Greyish brown loam with medium fragments (10 cm), rather rich in fine debris 4 - Brown (locally greyish), rather loose with medium fragments (10 cm), poor in fine debris 5 - Brownish grey (to light grey) loam with sinter admixture and numerous small fragments (3 and 4 grade towards the rock wall into a brown loam with humic infiltrations)	EPIATLANTIC Medium to coarse scree, matrix of soil material formed under predominantly warm and rather moist climate, Minor decrease in species richness, but immigration of several species Predominantly closed woodland Traces of climatic deterioration in 3 - probably starting SUBBOREAL,
6 - Grey to dark grey, friable loam, rich in sinter incrustations, with coarser fragments (20-30 cm) 7 - Brownish grey, rather sinter-rich loam with very numerous slabs oriented downslope 6-7 grade towards the rock wall into a marked foam-sinter horizon	LATE BOREAL - ATLANTIC Small-sized and later coarse scree, intensive $CaCO_3$ - precipitation under warm and very moist climate Marked invasion of demanding forest snails: *Acicula, Bulgarica cana, Discus perspectivus, Cochlodina orthostoma, Ruthenica, Isognomostoma*; decline of *Discus ruderatus* Reversal to closed damp woodland
8 - Greyish brown loam with numerous downslope oriented slabs (little coarser than in 7)	PREBOREAL - EARLY BOREAL Small-sized scree, humic rendsina-like matrix Invasion of many snail species, *Discus ruderatus*
9 - Ochreous loam forming matrix in non-oriented medium scree (5-10 cm) 10 - Coarser, partly matrix-free scree, matrix yellowish brown	WEICHSELIAN LATE GLACIAL Scree and loam sedimentation under cool climate Open-ground malacocoenoses with first more demanding species: *Granaria, Chondrina, Truncatellina costulata* Karst parkland, patches of conifers
11 - More or less light ochreous loam with horizons of coarser and finer fragments and of rather pure loess-like material 12 - Coarser, non-oriented, towards the rock wall relatively matrix-free scree, rusty brown loamy matrix 13 - As above, lenses of loess-like loams and fine debris	WEICHSELIAN PLENIGLACIAL Congelifraction, accumulation of cryoclastic debris and loess dust under severe climatic conditions Very poor molluscan fauna consisting of a few tolerant open-ground species Glacial grassland with patches of stony soils poor in vegetation

- Development of sediments filling karst cavities
- Pedogenesis in correlation with deposition, erosion and weathering
- Structure of tufa deposits in relation to other kinds of sedimentation, particularly to slope deposition, and to erosion and soil formation
- Position of standstill phases in various kinds of depositional sequences
- Anthropogenic impact on the processes in question
- Comparison with older warm phases with emphasis on the characteristics of the cryomere/thermomere transition within the Quaternary climatic cycle and on the distinguishing anthropogenic effects which were lacking in Pleistocene interglacials.

3. Survey of investigated areas and selected sites

The purpose of this chapter is to review briefly the localities in the territory of Bohemia, Moravia and Slovakia which have provided evidence for the study of problems discussed above. We prefer areas where detailed biostratigraphic analyses have been carried out and published.

3. A. Karstland areas

3. A. a. Bohemian Karst

The Bohemian Karst is a peneplained upland consisting of folded Silurian and Devonian limestones. It is dissected by deep valley cuts of tributaries of the stem stream Berounka River with a terrace system linked with that of the Labe (Elbe) River. The whole area is markedly dry and warm (mean annual temperature 8-9 °C; precipitation 500 mm). Oak woodland with numerous xerothermic patches of karst steppe and *Quercus pubescens-Cornus mas* stands are predominating. Beech is confined to limited areas which have cooler habitats and deeper soils. Well-differentiated fossil-rich depositional sequences of all facies types are common: caves and rock-shelters, footslope and alluvial deposits, tufas. Loess occurs throughout the area and extends into cave entrances and floodplains. At present, this area has the highest number of biostratigraphically investigated sites (Ložek 1992a). The most important of them are:

Cave entrances and rock-shelters

- Martina Cave near Tetín (Ložek 1992b)
- Kobyla-West near Koněprusy (Ložek 1989a)
- Skála near Sv. Jan pod Skalou, Za Křížem Cave (Ložek 1992a)
- Skalka nad Čihovou Cave near Karlštejn (Ložek 1987)
- Bašta Cave (Hlubočepská jeskyně) near Prague (Horáček and Ložek 1982)
- Footslope sequence at the Nad Kačákem Cave (Kovanda 1965)

Footslope deposits

- Srbsko-Hřiště (Ložek 1969b)
- Krabina near Karlštejn, upper section (Ložek 1988)

Alluvial deposits (floodplain accumulations)

- Břesnice floodplain downstream of Vodopády near Srbsko (Ložek 1974a)

Tufas

- Svatý Jan pod Skalou (Kovanda 1971, Ložek 1992a)
- Krabina near Karlštejn, lower section (Ložek 1974b)

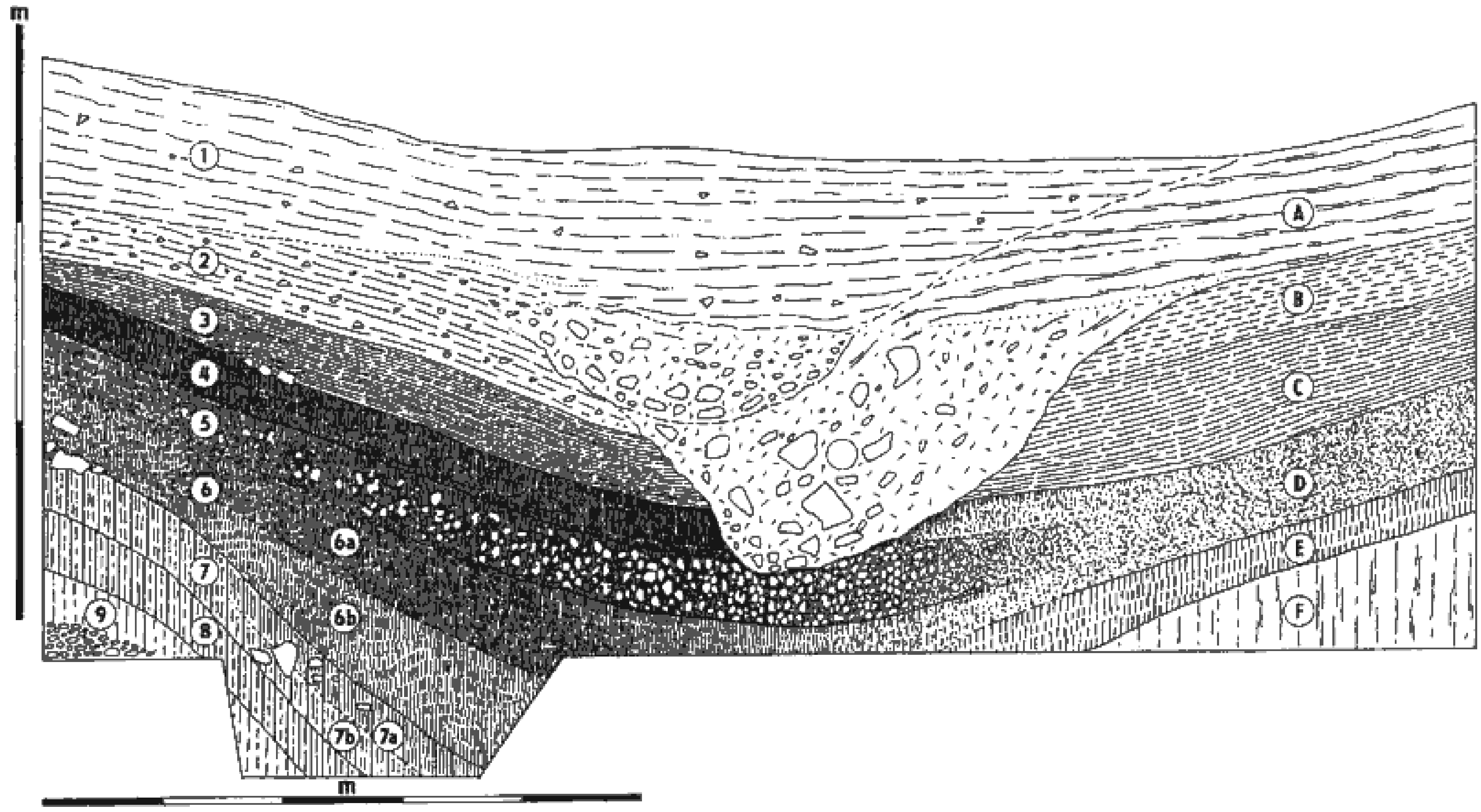
Mixed deposits

- Volfova rokle near Karlštejn (Fig. 4, Tab. 5, 6)

Besides these selected sites there is a whole network of further localities providing a number of important additional records (Ložek 1992a).

3. A. b. Moravian Karst

The Moravian Karst is developed on a peneplain consisting of folded Devonian limestones dissected by deep canyons and characterized by numerous caves with active allochthonous streams. The climate is moderately warm and considerably moister than that in the Bohemian Karst (an. temperature 7.5-8.5 °C, precipitation 550-650 mm). Xerothermic vegetation (*Corni-Querceta*) is more widespread



2. Dolní Věstonice, Nad cihelnou: Section through the hillwash fill of a small dry valley showing the soil development at the foot of the Pálava Mts (cp. Table 2 and 3).

Table 2. Molluscan fauna from Dolní Věstonice - Nad cihelnou

Ecologic and biostratigraphic characteristics				List of species	Layers											
					9	8	7b	7a	6b	6a	5	4	3	2	1	R
A	1		!	*Acanthinula aculeata* (Müller)	-	2	12	16	23	69	15	12	1	-	-	-
			!	*Acicula polita* (Hartmann)	1	2	7	17	40	54	9	1	1	-	-	-
			!	*Aegopinella pura* (Alder)	-	-	-	1	-	8	1	-	-	-	-	-
			!	*Cochlodina laminata* (Montagu)	-	2	2	14	25	48	46	6	3	2	2	-
			!!	*Discus perspectivus* (Mühlfeldt)	-	-	-	-	-	5	1	-	-	-	-	-
			(G)	*Discus ruderatus* (Férussac)	-	1	-	-	-	-	-	-	-	-	-	-
			!	*Ena obscura* (Müller)	-	-	-	-	-	2	1?	-	-	-	-	-
			!	*Macrogastra plicatula* (Draparnaud)	-	-	-	-	-	16	15	3	-	-	-	-
			!	*Monachoides incarnata* (Müller)	1	3	5	9	23	49	32	12	8	4	2	2
			(!)	*Vertigo pusilla* Müller	-	-	14	20	18	6	1	-	-	-	-	-
	2	W(M)	!	*Alinda biplicata* (Montagu)	-	-	1?	1?	3?	-	-	-	-	-	-	-
			(+)	*Arianta arbustorum* (Linné)	1	4	4	1?	1?	-	1?	-	1?	-	-	-
			!	*Discus rotundatus* (Müller)	-	-	2	-	5	23	2	-	-	1	-	-
				Limax sp.	-	-	-	-	1	-	-	-	-	-	1	-
			G	*Semilimax kotulae* (Westerlund)	-	-	-	-	-	1	-	-	-	-	-	-
		W(S)	!	*Aegopinella minor* (Stabile)	2	6	51	111	142	166	31	47	47	66	13	26
			(!)	*Bradybaena fruticum* (Müller)	1	3	12	10	18	27	24	7	5	6	2	-
			!	*Helix pomatia Linné*	1	-	4	12	21	14	12	8	8	5	3	-
	3		(G)	*Clausilia pumila* C. Pfeiffer	-	2	-	1?	3?	28	15	-	1?	(1?)	-	-
			!	*Macrogastra ventricosa* (Draparnaud)	-	-	-	-	-	-	2	-	-	-	-	-
B	4	S	M	*Cecilioides acicula* (Müller)	-	-	-	-	-	2	-	6	7	92	120	32
			(+)	*Granaria frumentum* (Draparnaud)	-	2	52	29	92	45	12	6	5	7	2	-
			+	*Helicopsis striata* (Müller)	6	17	11	12	6	2	2	-	(1)	(1)	(1)	-
			(+)	*Chondrula tridens* (Müller)	-	1	-	4	4	-	5	6	2	-	1	-
			M	*Oxychilus inopinatus* (Uličný)	-	-	1	-	1	4	3	3	11	28	14	1
			+	*Pupilla sterri* (Voith)	8	5	1	1?	-	-	-	-	(1)	(2)	-	-
			(+)	*Pupilla triplicata* (Studer)	5	1	4	1?	4?	-	-	1?	-	-	-	-
			M	*Xerolenta obvia* (Menke)	-	-	-	-	-	-	-	-	-	36	9	-
		S(W)	!!	*Cepaea vindobonensis* (Férussac)	-	1	-	1	4	3	5	18	13	7	6	-
			!!	*Truncatellina claustralis* (Gredler)	-	1	-	2	1	10	2	5	4	-	-	-
			!	*Truncatellina costulata* (Nilsson)	-	4	3	26	17	5	-	-	-	-	-	-
	5		+	*Columella columella* (Martens)	4	4	6	7	-	-	-	-	-	-	-	-
			+	*Pupilla alpicola densegyrata* Ložek	7	8	-	-	-	-	-	-	-	-	-	-
			+	*Pupilla loessica* Ložek	52	32	21	8	-	-	-	-	-	-	-	-
			+	*Pupilla muscorum* (Linné)	87	41	35	10	3	1	1	-	(2)	(6)	(9)	-
			(!)	*Truncatellina cylindrica* (Férussac)	2	21	70	168	140	100	4	34	83	572	48	870
			(+)	*Vallonia costata* (Müller)	7	111	894	1095	642	140	10	1	9	25	7	20
			G	*Vallonia pulchella* (Müller)	-	4	2	6	7	1	1	7	52	293	86	87
			+	*Vallonia tenuilabris* (A. Braun)	6	4	4	1	1?	-	-	-	-	-	-	-
			(G)	*Vertigo pygmaea* (Draparnaud)	-	-	-	-	1?	-	-	-	-	-	-	-

Table 2 (continuation)

C	6		(!)	*Cochlicopa lubricella* (Porro)	-	-	15	10	19	7	1	1?	1?	1	1	-
			(!)	*Euomphalia strigella* (Draparnaud)	1	11	28	60	113	178	97	42	27	49	11	8
	7	Me	(+)	*Cochlicopa lubrica* (Müller)	1	1?	-	-	-	-	-	-	-	-	-	-
			(+)	*Euconulus fulvus* (Müller)	-	-	-	1	-	-	-	6	3	-	-	-
			(+)	*Limacidae/Agriolimacidae*	-	-	4	5	9	12	10	4	5	4	-	-
			(+)	*Perpolita hammonis* (Ström)	-	-	4	-	3?	-	-	-	-	-	-	-
			(+)	*Punctum pygmaeum* (Draparnaud)	-	12	48	90	83	91	2	20	14	6	5	47
			+	*Trichia hispida* (Linné) agg.	2	5	6	3	4	2	1	-	(3)	(3)	(4)	-
			!	*Vitrea contracta* (Westerlund)	-	3	5	8	29	37	6	9	27	2	1	1
			(G)	*Vitrina pellucida* (Müller)	-	-	-	1	-	1	-	4	8	124	3	5
		R(W)	(+)	*Clausilia dubia* Draparnaud	-	2	6	3	3	2	3	-	-	(1?)	(1)	-
			!	*Laciniaria plicata* (Draparnaud)	-	-	-	-	-	10	3	-	-	-	-	-
			G	*Vertigo alpestris* Alder	-	-	1	1	-	-	-	-	-	-	-	-
	8		!	*Carychium tridentatum tridentatum* (Risso)	5	17	66	307	509	449	23	-	3	2	1	-
			(!)	*Columella edentula* (Draparnaud)	-	-	-	2	2?	2?	-	1	-	-	-	-
			G	*Perpolita petronella* (L. Pfeiffer)	-	-	-	5?	2	1	-	-	-	-	-	-
				Succinella oblonga (Draparnaud)	5	15	21	7	2	-	2	-	(2)	(3)	(4)	-
D	9		(+)	*Succinea/Oxyloma* sp.	-	-	-	-	-	1	-	-	-	-	-	-
			(G)	*Vertigo angustior* Jeffreys	-	-	-	2	3	1	-	-	-	-	-	-
	10		(+)	*Planorbis planorbis* (Linné)	-	-	-	-	-	-	1	-	-	-	-	-
				Unionidae	-	-	1	-	-	-	-	-	-	-	-	-
Number of individuals					205	383	1436	2089	2027	1624	402	270	358	1349	357	1099
Number of species					21	33	36	42	40	40	37	26	31	28	26	11
Chronostratigraphic interpretation					PG/TG	TG	PB	-	B	A	EA	EA/SB	SB	SA	SR	R

Ecological characteristics

Main ecologic groups: A - woodland, B - grassland, C - woodland/grassland, D - wetlands, water

Ecologic groups: 1 - closed woodland, 2 - predominantly woodland [W(M) - and mesic open habitats, W(S) - and xeric open habitats], 3 - moist woodland; 4 - steppes, xerothermic rocks [S(W) - and partly shaded habitats], 5 - grassland in general; Woodland/Open country: 6 - predominantly xeric, 7 - predominantly mesic (Me - catholic, R(W) - mesic rocks, screes, on trees), 8 - predominantly damp; 9 - wetlands, banks, 10 - aquatic habitats

Biostratigraphic characteristics: + - loess species, ++ - index loess species, (+) - local or accidental loess species, ! - species of warm phases, !! - index species of warm phases, (!) - eurythermic species of warm phases, G - surviving the glacial out of the loess zone, (G) - ditto, as relics, M - modern immigrants (Young Holocene index species), 1? - determination approximate, (1) - reworked from older or younger strata

Chronostratigraphy: PG - Weichselian Pleniglacial, TG - Weichselian Late Glacial, PB - Preboreal, B - Boreal, A - Atlantic, EA - Epiatlantic, SB - Subboreal, SA - Subatlantic, SR - Subrecent, RR - Recent

only in the southern part, while gorges with climatic inversion are penetrated by montane elements. In cave entrances, rock-shelters and at the foot of rocky slopes, well-differentiated fossil-rich deposits occur. But there is only one tufa occurrence (Štajgrovka) and the structure of floodplain deposits has not been investigated so far. At present, a network of excavations in cave entrances is available, however most of sites have not been studied or published in detail. Loess occurs in the southern half of the area, being replaced in the North by cryoclastic debris very poor in fossils. In view of its moister climate the Moravian Karst is much richer in foam sinter, particularly in its northern part, than the Bohemian Karst.

Cave entrances and cock-shelters:

- Pustožlebská Zazděná Cave (Fig. 1, Tab. 1)
- Srnčí Cave near Vilémovice (Ložek and Vašátko 1991)
- Barová Cave near Adamov (Seitl et al. 1986)

Tufa

- Štajgrovka in the Pustý Žleb Canyon (Vašátko and Ložek 1972).

Table 3. Description and interpretation of the depositional sequence at Dolní Věstonice - Nad cihelnou (cp. Fig. 2 and Tab. 2)

1 - Brownish grey loam with fine debris grading into ochreous ploughwash consisting of loess material (A); at the base a large erosional pocket filled by coarse scree with light ploughwash is developed 2 - Greyish brown humic loam with small fragments grading into brown without pseudomycelia (B)	SUBATLANTIC - SUBRECENT Marked increase in *Cecilioides*, *Truncatellina cylindrica*, *Vallonia pulchella*; appearance of *Xerolenta obvia*, culmination of *Vitrina pellucida* and *Oxychilus inopinatus*; disappearance of *Truncatellina claustralis* Open cultivated landscape, increase in soil erosion
3 - Dark greyish brown humic loam grading into brown loam with large pseudomycelia (C) 4 - Very dark greyish brown loam with large pseudomycelia (calcareous, partly colluvial chernozem)	SUBBOREAL General retreat of woodland species, depauperization; increase in Vallonia pulchella and costata, truncatellina cylindrica, appearance of Cecilioides Deforestation, deterioration of climate
5 - Dark greyish brown, humic loam with increasing number of light brown non-humic spots in central part of the section 6a - Dark brown (6a) to very dark greyish brown (6b) humic loam (calcareous, partly colluvial chernozem) (Layers 4-6 grade into a rusty brown decalcified loam of polyhedral structure with strong brown clay skins on peds - parabraunerde soil) (D)	EPIATLANTIC Optimum of forest malacocoenoses; appearance of *Discus perspectivus*, *Macrogastra plicatula* and *ventricosa*, *Laciniaria plicata*; marked decline of *Vallonia costata* and other open-ground species Closed woodland at the site; reduction of adjacent steppe patches; decrease in moisture in the final phase
6b - see above (well-developed chernozem)	ATLANTIC Forest species well represented; decline of open-ground elements; culmination of *Carychium tridentatum*, *Vertigo angustior* Woodland at the site, steppe patches in its surroundings, Climate very warm and moist
7 - Dark greyish brown loam; upper part poor in fragments (7a), lower part rich in fine debris	PREBOREAL - BOREAL Invasion of demanding, partly woodland snails, decline of loess steppe and open-ground fauna; *Truncatellina costulata*, culmination of *Vallonia costata* Culmination of species richness in the final phase Warming and increase in moisture
8 - Pale brown loam with dense pseudomycelia and minor amount of fine debris (Layers 7-8 grade into light calcareous loam containing shells (E)) 9 - Light yellowish brown loess-like loam with dense pseudomycelia (underlain by river gravels at the left margin of the exposure)	WEICHSELIAN LATE GLACIAL (PLENIGLACIAL) This complex includes replaced pleniglacial loess incl. incorporated shells Tolerant grassland fauna with first demanding immigrants Steppe parkland with moist patches covered by closed vegetation

3. A. c. Pálava Mts.

This small mountain range represents the westernmost promontory of the Carpathians. It consists of highly lifted blocks of Jurassic limestone emerging from the moderate flysh relief as a mountain islet surrounded by lowlands and low-lying uplands of the Vienna Basin. Its climate is markedly xerothermic (an. temperature: 8.5-9.2 °C, precipitation: 520-570 mm); only on NW-facing precipices dealpine vegetation with *Sesleria albicans* and *Saxifraga paniculata* and lower mesic scree woodland with predominating linden have been preserved. At the foot thick loess series occur which grade upslope into cryoclastic debris below the limestone cliffs. The main records come from talus accumulations at the foot of vertical cliffs and in gravitational chasms; other types of depositional sequences are not represented.

Deposits in rock-shelters and at the foot of vertical cliffs:

- Soutěska (Ložek 1985)
- Martinka, talus deposits (Ložek 1982a)
- Martinka, Velký Špunt Chasm (Horáček and Ložek 1990)
- Tři Panny Rock-shelter (Ložek 1989b).

Several sites are located in islets of Devonian limestones of Northern Moravia; among them the following ones are most important:

- Velká Kobylanka Rock-shelter (Ložek, Tyráček and Fejfar 1959)
- Průchodnice Cave near Lumírov (Svoboda and Ložek 1993).

Table 4. Description and interpretation of the valley floor sequence at Krabina near Karlštejn (cp. Fig. 3)

1 - Dark brownish grey, humic loam with small fragments 2 - Greyish brown, slightly humic loam with coarser limestone scree 3 - Strong brown, moderately clayey loam, poor in fragments 4 - As above, a little greyish, with medium coarse fragments incl. sparse rounded quartz pebbles	YOUNG HOLOCENE Accumulation of more or less humic colluvial material due to increasing man-made erosion Depauperized woodland malacofauna characterizing the basal layer 4 (*Monachoides incarnata, Cochlodina laminata, Cepaea hortensis*) is increasingly replaced by open-ground or catholic elements (*Cecilioides, Vallonia pulchella, Euomphalia strigella*, etc.)
Erosional event	
5 - Strong brown, lime-deficient clayey loam, without clasts	HOLOCENE CLIMATIC OPTIMUM (ATLANTIC- EPIATLANTIC) Decalcified clayey loams represent the colluvium deriving from intensively weathered brown forest soils, Woodland under warm and moist climatic condition - standstill phase in scree formation
6 - Complex of strong brown, ochreous (6a) to dark grey (6b) calcareous loams developed in lenses with diffuse boundaries within limestone scree including sandy intercalations	LATE GLACIAL - EARLY HOLOCENE Repeatedly redeposited loamy colluvia incl. loess with fine to coarse limestone fragments forming lenses, partly showing traces of initial soil formation Cold loess steppe characterized by *Helicopsis striata, Pupilla* spp. and *Succinella oblonga* is replaced by warmer parkland indicated by *Granaria frumentum*
7 - Coarse flags of dark limestones with matrix consisting of fine angular debris	FINAL WEICHSELIAN PLENIGLACIAL Open country under severe climatic conditions Intensive disintegration of rocks Erosion of the bedrock - last phase of intensive downcutting
Eroded limestone bedrock	

3. A. d. Slovak Karst

The Slovak Karst is a complex of karst plateaus with numerous sinkholes at elevations of 500-900 m dissected partly by old Tertiary canyons and partly by narrow gorges of Quaternary age.Extensive underground cave systems have autochthonous streams issuing as mighty resurgences which in most cases have formed thick tufa deposits. Xerothermic formations, widespread at lower elevations, grade upslope into Carpathian montane forests. Temperatures vary between 7.0-8.5 °C, precipitations between 650-750 mm. Fossiliferous sediments occur particularly in cave entrances and at the foot of steep slopes in young Quaternary gorges (Zádielská tiesňava Gorge). Loess has been found only in the Peskö Cave at the southernmost margin of the Slovak Karst. At present, in the Slovak Karst a network of sites was recently investigated (Ložek and Horáček 1992) of which the following may be cited.

Cave entrances:

- Maštalná Cave near Slavec (Ložek and Horáček 1988)
- Hámorská Cave near Plešivec (Horáček and Ložek 1993)
- Peskö Cave near Bretka (Ložek et al. 1989).

3. A. e. Mountain karstlands of West Carpathians

In addition, several sites from limestone mountains of Central Slovakia are listed, where cave entrances and rock-shelter sequences with a high proportion of foam sinter occur. These correspond to montane environments with average temperatures of 4-5 °C and precipitation about 1 000 mm.

- Mažarná Cave near Blatnica (Veľká Fatra Mts., Ložek 1980)
- Nad Medveďou Rock-shelter on the Veľký Rozsutec Mt. (Malá Fatra Mts., Ložek 1981)
- Sokol Rock-shelter in Svätojánska dolina Valley (Low Tatra Mts., Ložek 1982b; Fig. 5, Tab. 7).

Further evidence is provided by a number of sites widespread in various karstlands of Slovakia (Ložek 1982c).

Table 5. Molluscan fauna from Volfova rokle

Ecologic and biostratigraphic characteristics				List of species	Layers												
					10	9	8	7b	7a	6	5'	5	4	3b	3a	2a	R
A	1		!	*Acanthinula aculeata* (Müller)	-	-	-	-	-	-	-	-	-	1	2	6	1
			!	*Acicula polita* (Hartmann)	-	-	-	-	-	-	-	-	-	-	-	1	-
			!	*Aegopinella pura* (Alred)	-	-	-	-	-	-	-	-	-	-	-	8	12
			!	*Cochlodina laminata* (Montagu)	-	-	-	-	-	-	-	-	-	2	25	7	6
			(G)	*Discus ruderatus* (Férussac)	-	-	-	-	-	1	5	1	17	87	60	2	-
			!	*Ena montana* (Draparnaud)	-	-	-	-	1	-	1	-	2	2	30	7	-
			!	*Ena obscura* (Müller)	-	-	-	-	-	-	-	-	-	5	20	6	2
			!	*Helicodonta obvoluta* (Müller)	-	-	-	-	-	-	-	-	-	-	1?	1	-
			!	*Isognomostoma isognomostoma* (Schröter)	-	-	-	-	-	-	-	-	1	-	-	-	-
			!	*Macrogastra plicatula (Draparnaud)*	-	-	-	-	-	-	-	-	-	-	5	3	-
			!	*Monachoides incarnata* (Müller)	-	-	-	-	-	-	1	(1)	1	-	1	13	37
				Oxychilus sp. (?*depressus* Sterki)	-	-	-	-	-	-	-	-	1	-	-	-	-
			!	*Sphyradium doliolum* (Bruguiere)	-	-	-	-	-	-	-	-	-	-	-	12	-
			(!)	*Vertigo pusilla* Müller	-	-	-	-	-	-	-	-	3	11	20	6	-
			!	*Vitrea diaphana* (Studer)	-	-	-	-	-	-	-	-	-	-	-	-	5
	2	W(M)	!	*Alinda biplicata* (Montagu)	-	-	-	-	-	-	-	-	-	-	1?	2?	48
			(+)	*Arianta arbustorum* (Linné)	1	-	1?	-	-	1?	1?	-	1?	-	-	-	-
			!	*Cepaea hortensis* (Müller)	-	-	-	-	-	-	-	-	-	-	2	3	+
			!	*Discus rotundatus* (Müller)	-	-	-	-	-	-	-	-	1?	-	2	20	128
				Limax sp.	-	-	-	-	-	-	-	-	-	-	1	-	-
			G	*Semilimax kotulae* (Westerlund)	-	-	-	-	-	-	-	1	-	-	-	-	-
		W(S)	!	*Aegopinella minor* (Stabile)	-	-	-	-	-	-	-	-	4	1?	34	48	70
			(!)	*Bradybaena fruticum* (Müller)	-	-	1	-	-	-	2	7	13	29	47	12	-
			!	*Helix pomatia* Linné	-	-	-	-	-	-	-	-	-	-	1?	1?	+
		W(H)	(+)	*Vitrea crystallina* (Müller)	-	-	-	-	-	-	-	-	-	-	16	19	-
	3		(G)	*Clausilia pumila* C. Pfeiffer	-	-	-	-	-	-	1?	-	-	1?	-	-	-
			!	*Macrogastra ventricosa* (Draparnaud)	-	-	-	-	-	-	-	-	1?	1	8	4	-
			!	*Urticicola umbrosa* (C. Pfeiffer)	-	-	1	-	-	-	1	-	1	1	12	10	-
			G	*Perforatella bidentata* (Gmelin)	-	-	-	-	-	-	1?	-	1	-	-	-	-
B	4	S	M	*Cecilioides acicula* (Müller)	-	-	-	-	-	-	-	-	-	-	-	-	2
			+	*Helicopsis striata* (Müller)	-	12	13	22	9	12	8	4	-	-	1	-	-
			(+)	*Chondrula tridens* (Müller)	-	-	-	-	-	1	-	-	-	-	-	-	-
			+	*Pupilla sterri* (Voith)	-	2	-	10	4	-	-	-	-	-	-	-	-
			(+)	*Pupilla triplicata* (Studer)	-	-	1	1	1	-	-	-	-	-	-	-	-
		XC		*Chondrina avenacea* (Bruguiere)	-	-	-	-	-	-	1	-	-	-	-	-	-
	5		+	*Columella columella* (Martens)	-	-	-	-	-	3?	-	-	-	-	-	-	-
			+	*Pupilla loessica* Ložek	-	-	3?	18	-	-	1?	1	-	-	-	-	-
			+	*Pupilla muscorum* (Linné)	-	2	1	38	-	11	-	-	-	-	-	-	-
			(+)	*Vallonia costata* (Müller)	2	4	4	60	35	28	21	8	181	480	444	170	+
			G	*Vallonia pulchella* (Müller)	-	-	-	-	-	-	1	-	4	4	-	-	-
			+	*Vallonia tenuilabris* (A. Braun)	-	2	3	9	-	3	-	-	-	-	-	-	-

Table 5 (continuation)

			+	*Vertigo parcedentata* (A. Braun)	-	-	-	3	-	-	-	-	-	-	-	-	-
			(G)	*Vertigo pygmaea* (Draparnaud)	-	-	-	-	-	-	3	-	-	-	-	-	1
C	6		!	*Bulgarica nitidosa* (Uličný)	-	-	-	-	-	-	-	-	-	-	-	2	2
			(!)	*Cochlicopa lubricella* (Porro)	-	-	-	-	-	-	-	-	6	33	44	20	-
			(!)	*Euomphalia strigella* (Draparnaud)	-	-	-	1	-	-	2	1	12	16	45	1?	-
			!	*Tandonia rustica* (Millet)	-	-	-	-	-	-	-	-	-	-	-	-	+
	7	Mc	(+)	*Cochlicopa lubrica* (Müller)	-	1	2	53	19	1	7	3	9	6	1	4?	-
			(+)	*Euconulus fulvus* (Müller)	-	-	-	13	-	2	1	-	1	6	4	-	24
			(+)	*Limacidae/Agriolimacidae*	-	-	1	-	4	-	1	1	-	2	10	-	-
			M	*Oxychilus cellarius* (Müller)	-	-	-	-	-	-	-	-	-	-	-	-	97
			(+)	*Perpolita hammonis* (Ström)	-	1	1	4	4	2	2	-	25	53	42	2	-
			(+)	*Punctum pygmaeum* (Draparnaud)	-	-	-	1	-	-	-	-	18	41	48	20	77
			(+)	*Trichia sericea* (Draparnaud)	1	4	4	18	1	10	5	3	15	24	28	18	-
			!	*Vitrea contracta* (Westerlund)	-	-	-	-	-	-	1?	-	1	1	-	-	-
			(G)	*Vitrina pellucida* (Müller)	-	-	-	-	-	-	1?	-	-	4	2	-	15
		R(W)	(+)	*Clausilia dubia* Draparnaud	-	-	-	-	-	-	-	1	-	1	-	-	-
			!	*Helicigona lapicida* (Linné)	-	-	-	-	-	-	1	-	-	-	-	-	-
			G	*Vertigo alpestris* Alder	-	-	-	-	-	3	-	-	1	-	-	-	-
	8		!	*Carychium tridentatum* (Risso)	-	-	-	-	1	-	2	1	17	34	84	90	1
			(!)	*Columella edentula* (Draparnaud)	-	-	-	-	-	-	-	-	9	18	18	5?	-
			(G)	*Perpolita petronella* (L. Pfeiffer)	-	-	-	-	-	-	-	-	2?	8	5	3	-
			+	*Succinea oblonga* Draparnaud	-	6	5	16	4	3	1?	-	-	-	-	-	-
			(G)	*Vertigo substriata* (Jeffreys)	-	-	-	-	-	-	-	-	3	5	2	-	-
D	9		G	*Carychium minimum* Müller	-	-	-	-	1	-	-	-	2	1	2	-	-
			(+)	*Succinea putris* (Linné)	-	-	-	-	-	-	2?	-	-	-	-	-	-
	10		(+)	*Pisidium casertanum* (Poli)	-	-	-	-	-	-	-	-	1?	-	-	1?	-
				Radix peregra (Müller)	-	-	-	-	-	-	-	1?	-	-	-	1	-
Number of species					3	9	14	15	12	14	26	14	30	29	35	34	22
Number of individuals					4	34	41	267	84	81	75	34	354	879	1068	528	528
Chronological interpretation					Final Pleniglacial					Late Glacial			PB	B		A	R

Explanation (See Table 2)
XC - epilithic species living on limestone rocks

3. B. Non-karstic calcareous areas

Further evidence is available from depositional sequences in calcareous areas, particularly consisting of Cretaceous and Tertiary marls and Pleistocene loess. Their importance is due to the fact that they are located in warm lowlands with chernozem soils (an. temperatures of 8.5-9 °C, precipitation of about 500 mm) and dense prehistoric settlement. These were intensively cultivated since the Neolithic Age and thus represent environments different from those in karstlands.

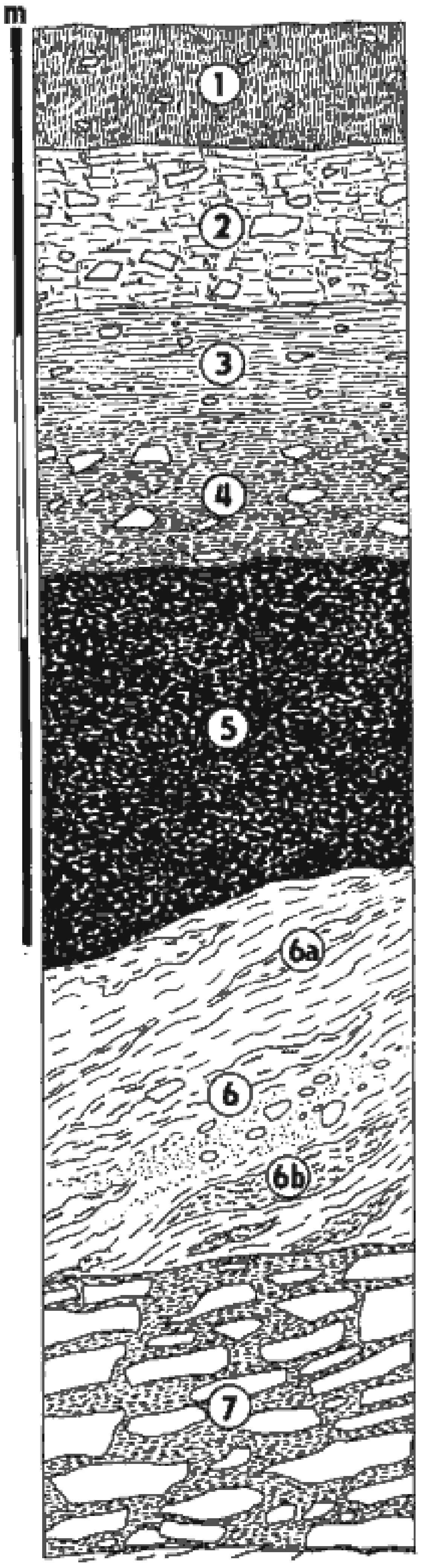
3. B. a. Northwestern Bohemia

- Poplze near Libochovice, fill of a loess dell (Smolíková and Ložek 1978)

- Štětí-Zdymadlo, footslope deposits on the lowest Labe-terrace (Smolíková and Ložek 1978)
- Štětí-Pod Hošťákem, footslope deposits at the foot of a marlstone slope (Ložek and Šibrava 1968)
- Bílá Stráň near Pokratice footslope deposits at the foot of an marl slope with bare patches (Ložek 1982c)

3. B. b. Southern Moravia (foot of the Pálava Mts.)

- Pavlov, cut-bank of the Dyje River, colluvial fan (Vašátko and Ložek 1973)
- Dolní Věstonice - Nad cihelnou, fill of a loess dell (Fig. 2, Tab. 2, 3).



3. Depositional sequence at the floor of the dry Krabina Valley near Karlštejn showing the decalcified Middle Holocene soil (cp. Table 4).

3. C. Sites providing evidence of weathering processes

The character and intensity of weathering processes can be studied not only in well dated fossiliferous profiles in karst areas where most of the processes are blocked by a carbonate geochemical barrier but also in poorly dated unfossiliferous outcrops of sandstones and crystalline complexes.

- karst areas (Bohemian Karst, Javoříčko, Low Tatra Mts.) - formation of Ca phosphate coatings of flowstones, rhizoconcretions and carbonate clasts, birnessite formation (Cílek and Komaško 1984, Cílek and Fábri 1989)
- Bohemian Cretaceous Basin, fillings of rock-shelters dated by archaeological methods - SiO_2 and Fe^{3+} mobilization, salt weathering
- The study of surface weathering of mineral grains in soils and loess sequences
- Proterozoic area near Prague - debris cones with ferrugineous cement, sulfide weathering and sulphate production
- Variscan crystalline complexes (Podyjí) - opal coatings, K-Al-Fe hydrosilicates origin, MnO_2 and K goethite precipitation.

4. Analysis of selected problems

4. A. Chronological and stratigraphical position of the youngest loess deposition

The most recent easily distinguishable fossil soil of the last glacial formed before 30 ky is a rather thick but weak pale brown, decalcified soil (so called Stillfried B or PK I). It is exposed at a number of localities in Central Bohemia and Southern Moravia. The young Palaeolithic settlement in Dolní Věstonice and Pálava - Pavlovian (equivalent of Eastern Gravettian) is associated with the topmost layer of this soil and the beginning of the youngest loess deposition. The conventional radiocarbon data thus date the lowest limit of this youngest loess to 24-27 ky (Mook in Svoboda 1991) but the termination of the loess formation in open country remains obscure since the uppermost part of its strata was reworked to Holocene soils.

Fortunately, there exist a set of localities located in lowlying hilly karstlands where the youngest loess emerges in cave entrances, abris, at the foot of overhanging cliffs or steep rocky slopes. It is generally overlain by a complete sequence of Late Glacial and Holocene screes often with loess-like matrix, fine-grained cryoclastic sediments, loams and humic soils (Ložek 1988).

Of the principal importance for the dating of the termination of loess formation is the stratigraphic position of Magdalenian. The Magdalenian sites (Kůlna, Barová Cave, Pekárna - Moravian Karst, Hostim - Bohemian Karst) are restricted to the uppermost part of the loess and they are accompanied by typical loess malacofauna and glacial mammals such as reindeer. The weak soils and slope deposits resting directly above the loess layer are dated by conventional radiocarbon data as Old Dryas-Bölling- Middle Dryas (Svoboda 1994):

Pekárna 12 940 ± 250 B.P.
Pekárna 12 670 ± 80 B.P.
Kůlna 11 590 ± 80 B.P.
Hostim 12 420 ± 470 B.P.

The weak Bölling loessic soil with numerous Magdalenian finds is under- and overlain by cold loess. The thin upper loess can be ascribed to Middle Dryas and represents the ultimate termination of loess deposition. However the

Table 6. Description and interpretation of the depositional sequence at Volfova rokle near Karlštejn (cp. Fig. 4 and Table 5)

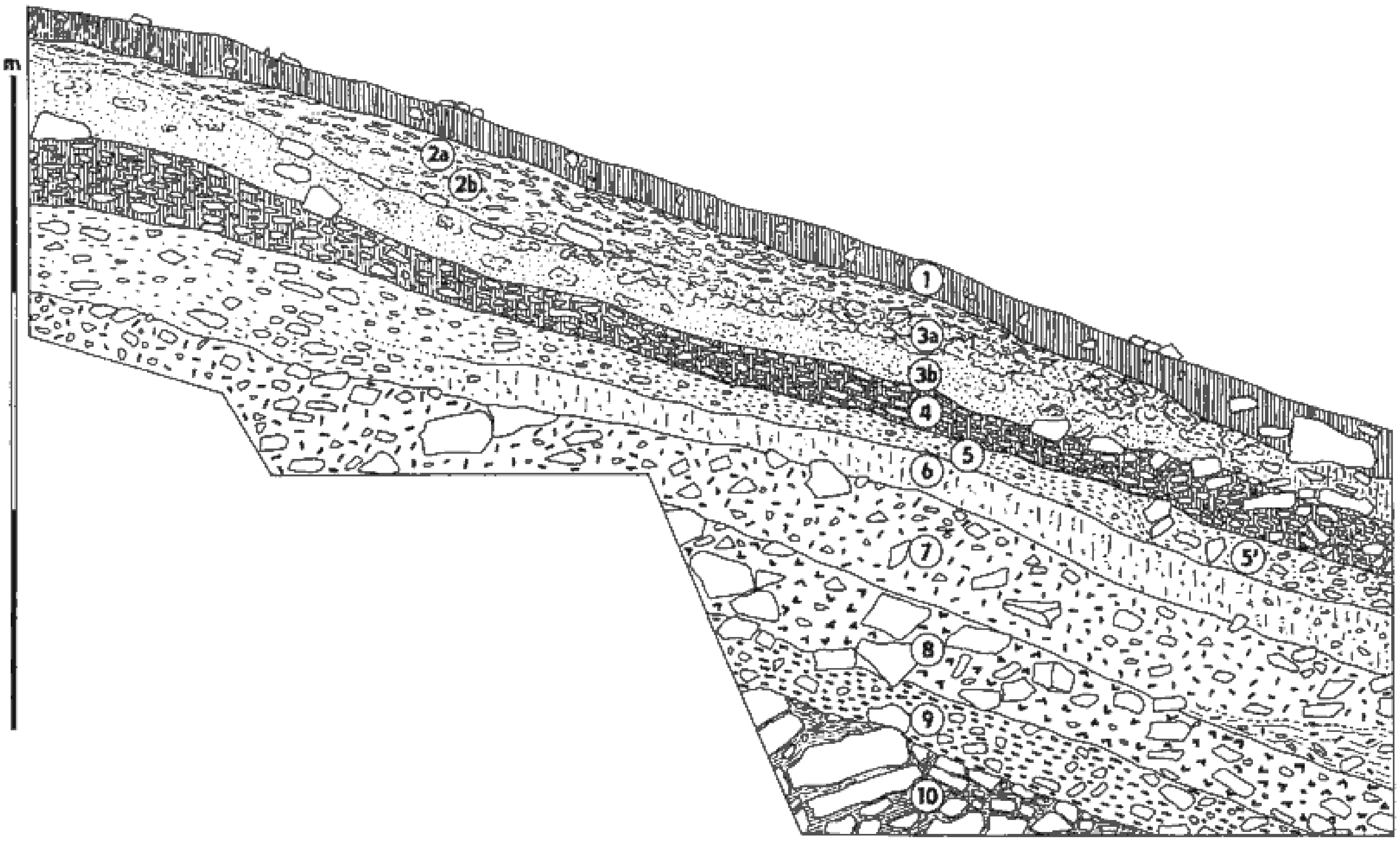
1 - Greyish black humic loam with tufa pellets - modern rendsina	YOUNG HOLOCENE Formation of rendsina soil under terrestrial conditions
Erosional hiatus due to downcutting of the brook - MIDDLE HOLOCENE	
2 - Pale greyish yellow to brownish tufa consisting of medium coarse nodules and pellets	ATLANTIC Tufa precipitation under warm and moist climatic conditions Expansion of woodland malacofauna, decline of open-country and catholic elements Marked retreat of *Discus ruderatus* and increase of *Carychium tridentatum* Closed woodland
3a - Whitish grey, loose tufa with numerous cemented parts (to 30 cm) parallel to the slope 3b - As above, but poor in cemented parts	BOREAL Tufa precipitation, decline of scree formation Marked warming and increase in moisture Progressive invasion of woodland malacofauna, high numbers of *Discus ruderatus, Bradybaena, Aegopinella minor*; culmination of *Vallonia costata* Open decidous woodland
4 - Medium coarse limestone scree with grey, slightly humic, loamy matrix (rendsina material)	PREBOREAL Scree and rendsina soil formation First woodland and numerous catholic snail species Warming and moderate increase in moisture Richer parkland vegetation
5 - Brown loam with numerous small fragments, weak prismatic jointing; grading into a thicker scree layer (5') which might be a little younger 6 - Brown loam with diffuse rusty vein lets and whitish $CaCO_3$ - pseudomycelia, more or less stone-free	WEICHSELIAN LATE GLACIAL Predominantly loamy sedimentation under cool conditions Retreat of loess snails; appearance of *Discus ruderatus, Bradybaena, Vertigo alpestris*
7 - Medium coarse (2-20 cm), chaotically bedded scree with rather dark greyish brown loamy matrix 8 - Coarser scree (20-30 cm), matrix as above 9 - Coarse scree with blocks oriented downslope and rather dark grey matrix 10 - Displaced coarse limestone beds with ochreous loamy matrix including numerous slabs of Daleje shales	WEICHSELIAN PLENIGLACIAL Scree formation under severe climatic conditions Tolerant open-ground molluscan fauna with several index loess species: *Pupilla loessica, Vallonia tenuilabris, Vertigo parcedentata, Succinea oblonga, Helicopsis striata*

geological record from terrestrial environments usually does not allow more precise information about the number and nature of climatic oscillations. The scarce palynological data from Barová cave (Svobodová and Svoboda 1992) suggest a more complex development - at least three oscillations of forest and steppe environment during Late Glacial.

The later phases of Magdalenian (10-11,5 ky) occur in Late Glacial slope deposits containing a different, more demanding malacofauna. Corresponding conditions were observed, besides Moravian Karst (Malý lesík and Liščí caves), also in Bohemian Karst (Za křížem, Skalka nad Čihovou, Kobyla, Zadní Kopanina, Zlatý Kůň, Rudolfova Cave, Krabina-upper site, Axamit's gate), Pálava (Soutěska, Martínka, Tři panny, Dolní Věstonice - Nad cihelnou) and in Northern Moravia (Průchodnice, Velká Kobylanka). The Late Glacial rock debris intercalation containing this type of malacofauna is embedded at all these localities between loess and palaeontologically verified Holocene strata.

Fine-grained cryoclastic aeolian and gravitational sediments together with loessic soils containing cryoclastic admixture substitute loess in the belt lying outside the loess area, i.e. higher than apr. 350 m a.s.l. and in moister environments. Well developed greze litées can be observed in the northern part of the Moravian Karst (Pustožlebská Zazděná, Srnčí Caves), in hilly areas of Western Carpathians (Medvedia Cave in Slovakian Paradise, Muránská Cave in Belianské Tatry) to contain incomplete reduced glacial malacofauna.

A remarkable exception was observed by the Mažarná cave in the Veľká Fatra Mts. (380 m a.s.l.) where loess was



4. Depositional sequence at the mouth of the ravine called Volfova rokle near Karlštejn showing the change in sedimentation during the early Holocene (cp. Table 5 and 6.).

replaced by calcareous non-humic loam filling spaces among large limestone boulders. It contains a rich mountain malacofauna with a large proportion of the Fatra endemite *Faustina cingulella* (Rssm.) and some karst species such as *Pyramidula* or *Chondrina* suggesting the existence of a transitional zone between loess and higher more humid, grassland belt resembling modern sub-alpine zone but essentially drier. By contrast, the equivalent of loess in Medvedia Cave is developed as fine-grained scree totally inconvenient to molluscs. These concentrate in finer material probably originally covered by plants.

Rather special relations were found in the Slovak Karst - the only place where a typical loess was discovered in the Peskö Cave near its southern margin. A relatively poor tolerant molluscan fauna with several more demanding species occur in the light loess-like loam representing the stratigraphical equivalent of loess in the Maštalná Cave (Ložek - Horáček 1992). It means that the Slovak Karst could serve as a refuge for species and even whole biocoenoses which did not survive in other regions the glacial conditions of the mid-European Weichselian pleniglacial.

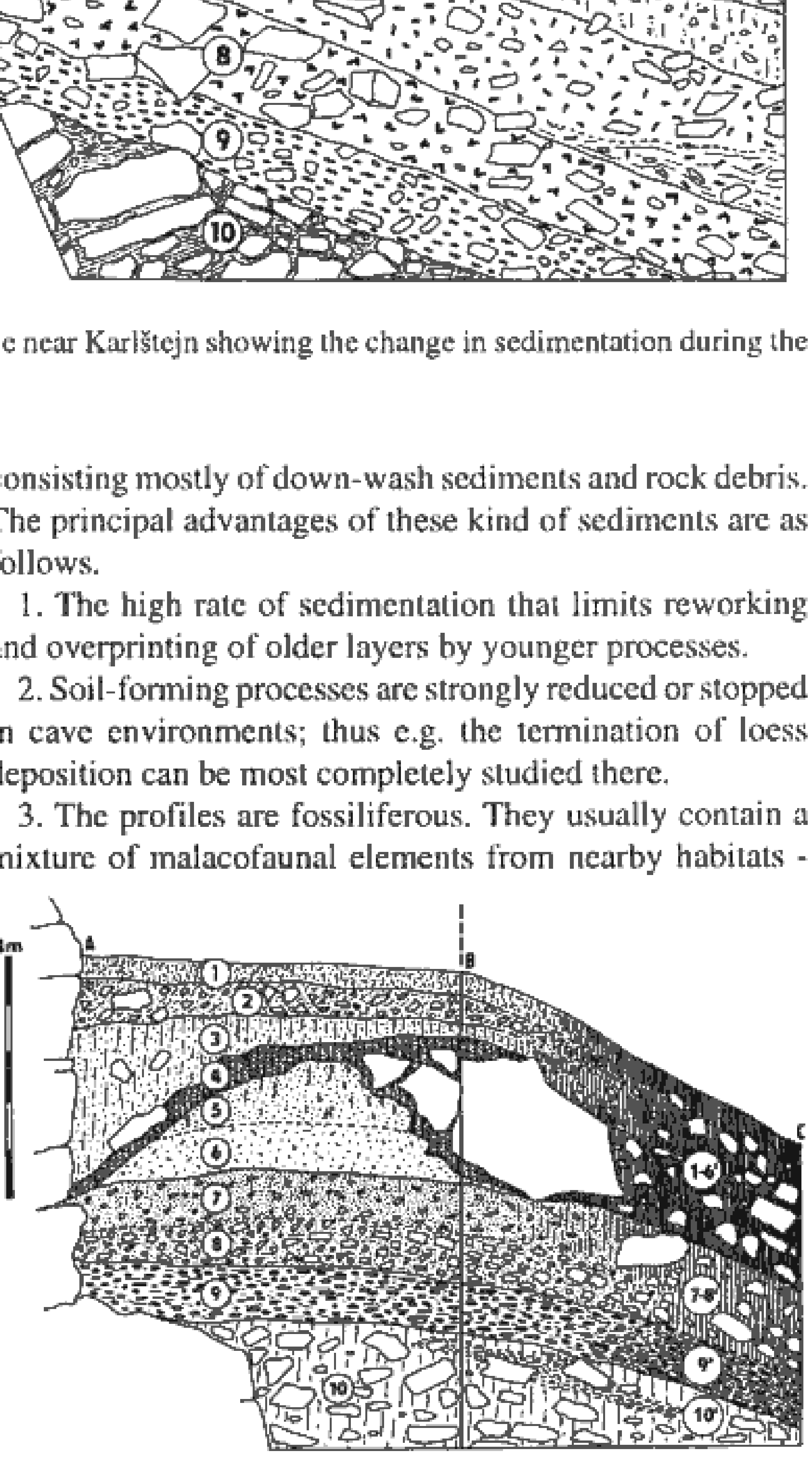
4. B. Phases of pedogenesis and the position of soils in sedimentary sequences

The cave entrances, limestone rock-shelters and some footslope deposits preserve detailed sedimentary sequences consisting mostly of down-wash sediments and rock debris. The principal advantages of these kind of sediments are as follows.

1. The high rate of sedimentation that limits reworking and overprinting of older layers by younger processes.

2. Soil-forming processes are strongly reduced or stopped in cave environments; thus e.g. the termination of loess deposition can be most completely studied there.

3. The profiles are fossiliferous. They usually contain a mixture of malacofaunal elements from nearby habitats -



5. Sedimentary fill of the rock-shelter in the Sokol-Cliff (Low Tatra) showing a Holocene sequence dominated by foam-sinter precipitation (cp. Table 7).

Table 7. Description and interpretation of the sedimentary sequence in the Sokol Rock-shelter (cp. Fig. 5)

1 - Greyish brown, friable, sinter-rich loam with angular debris 2 - Brown, sinter-rich loam with coarser angular debris 3 - Light greyish brown, loamy foam-sinter	YOUNG HOLOCENE (SUBATLANTIC-SUBRECENT) Sinter precipitation combined with accumulation of fine clastic material Rich woodland malacofauna with several new immigrants - *Oxychilus orientalis*; later a slight decrease in *Vitrea* Woodland under comparatively moist and warm climate; traces of deforestation in the uppermost horizons
4 - Dark grey, sinter-rich loam with diffuse lower boundary, including a pocket of boulder breakdown with partly free interstices [Layers 1-4 (sect. A-B) grade into black, humus-rich loams in front of the entrance (sect. B-C)]	SUBBOREAL Limited sinter precipitation, humus accumulation; coarse breakdown - destruction of the cave entrance Malacofauna similar to that of 5-6, but poorer, both in individuals and species Marked decrease in moisture under unbalanced climatic conditions
5 - Whitish grey foam-sinter with dark infiltrations and fine debris 6 - Greyish white foam-sinter with fine debris	EPIATLANTIC Continuing foam-sinter precipitation, limited formation of clasts Species-rich woodland fauna with a number of new immigrants: *Vitrea diaphana, Platyla polita, Clausilia cruciata, Cl. pumila succosa, Isognomostoma, Discus ruderatus*; decrease in *Faustina cingulella* Overall expansion of closed woodland under warm and moist climate
7 - Light grey to grey foam-sinter with diffuse brownish spots and fine debris	ATLANTIC Intensive foam-sinter precipitation, decrease in clastic sedimentation Expansion of demanding woodland species: *Vitrea subrimata, Aegopinella pura, Ena montana, Cochlodina orthostoma;* decrease in *Chondrina* and other heliophiles Warm-moist well-balanced climate supporting the expansion of closed forest
8 - Grey to brownish grey, rather loamy foam-sinter with debris (2-10 cm)	BOREAL Increase in foam-sinter precipitation, breakdown; malacofauna as in 9, but higher in *Discus ruderatus* and *Chondrina;* expansion of further demanding species: *Trichia unidentata, Vitrea transsylvanica* Subalpine parkland increasingly replaced by woodland under warm climate, rapid increase in moisture
9 - Greyish brown loam of pellet structure, numerous horizontally oriented slabs	PREBOREAL - BOREAL Start of the foam-sinter formation Dominance of tolerant open-ground species, first demanding elements *Chondrina, Discus ruderatus, Vertigo pusilla* Subalpine parkland, expansion of woodland; warming, increase in moisture
10 - Coarser angular scree with compacted (loess-like) loamy matrix	LATE GLACIAL - PREBOREAL Predominantly clasts - breakdown Poor tolerant open-ground malacofauna: *Pyramidula, Orcula dolium, Clausilia dubia, Euconulus, Vertigo alpestris* Alpine grassland under severe climatic conditions

open rock, steppe and woodland species together with inhabitants of cave entrances. The total palaeoenvironmental evidence is thus reasonably substantial.

4. The footslope deposition copies the original surface which is at present often eroded or damaged by younger processes. The palaeontological evidence remains almost untouched during downslope transport but pedological features are to some extent wiped off (Kukla - Ložek 1957).

Brown soil horizons of early climatic optimum containing corroded limestone clasts in decalcified matrix were found in many profiles of the Bohemian Karst. The molluscan shells are deeply corroded or absent. These decalcified horizons rest on intensively calcified slope deposits with rendzina admixture of Early Holocene age and they are overlain by scree horizons containing calcareous humic crumby matrix of rendzina type (Krabina - upper profile, Zadní Kopanina - Desort's Quarry, Martina Cave, relict of slope deposits in the southern slope of Zlatý Kůň near Koněprusy). It is necessary to stress that all these profiles are located at the foot of steep rocky slopes and therefore loaded with limestone detritus of various size.

Two principal processes had to take place during the genesis of decalcified brown soils: a - the leaching of calcium carbonate during extremely humid climatic phase, b - minimum debris accumulation due to strongly limited slope transport. Such conditions are widely recognized as important causes of pedogenetic events (Ložek 1988).

The stratigraphic position of decalcified brown soil corresponds to that of the foam sinter layer in present-day dry caves of warm-dry karst uplands. The leaching of carbonate in soil horizons is associated with its precipitation in some other suitable parts of the same system, i.e. in caves and rock-shelters. The caves were not inhabited during this wet phase, but directly on the surface of foam sinter we found Neolithic settlements formed in times of a moderately humid climatic phase. High accumulation rates of limestone detritus prevented in some sites the total decalcification of these soil horizons (Axamitova brána in Bohemian Karst, Pustožlebská Zazděná Cave in Moravian Karst, several sites in Slovak Karst).

The decalcification phase is widespread even in different sedimentary environments - e.g. the sedimentary filling of the dry upper part of the Krabina Valley is composed (in descending order) of a moderately humic topsoil bearing Late Holocene malacofauna, underlain by a thick layer of brown decalcified soil sediments. At the base a relict of Early Holocene weakly humic soil is preserved (Fig. 3, Tab. 4). Some profiles in the peripheral zone of the chernozem area (Velký Hubenov-Hříbárna, Smolíková - Ložek 1973) follow the same pattern of sedimentation. The completely developed parabraunerde on loessic parent material in Velký Hubenov is characterized by a dark zone of secondary humification probably caused by Neolithic deforestation and by the subsequent expansion of anthropogene steppes. This parabraunerde is overlain by a calcareous deluvial cone containing Young Bronze Age pottery.

The termination of chernozem formation can be studied in colluvial series exposed in the bank of the Dyje River in the vicinty of Pavlov and around the Labe and Ohře rivers close to Štětí and Poplze. The archaeological evidence points to an Early Neolithic age of the Holocene chernozem formation. The Neolithic chernozems are to some degree decalcified despite the fact that they are located in highly carbonaceous environments. We may conclude that the important humid phase of the Early Holocene caused very intensive and fast sedimentological changes uncomparable to the rest of the Holocene and accompanied by decalcification, leaching of elements and soil formation (see next chapters).

5. Weathering processes

The role of cryoclastic processes under glacial climates is widely recognized. The congelifractal sediments and windblown grezes liteés are typical and common products. The formation of rock debris takes place mostly during the marginal phases of cold climates and during interglacials. This situation is probably caused by the stabilizing effect of underground ice and thoroughly frozen rock massif, whereas pergelation or defrostation usually means destabilization. Full-glacial loess deposited under steep rocky slopes and walls often does not contain any scree.

According to heavy mineral assemblages, the source of about 70 to 90 % of silt in loess lies nearby, i.e. within several tens to up to one hundred kilometres from the place of deposition. South Moravian and Middle Bohemian loesses contain fluvial and less often aeolian quartz grains (sensu Krinsley and Doornkamp 1973) but needle like rutile or idiomorphic zircon crystals typical of Southern Moravia evidence that the main source of loess silt were rather bedrock outcrops than river terraces. On the other hand, volcanic material from neoidic volcanoes of České středohoří and minerals from Cenozoic alluvial plains are more common in Prague area (Sedlec-Suchdol).

Sharp fractured shape of the loess quartz grains suggests the role of salt weathering. The presence of salts during loess formation is indicated by brackisch ostracods (teste A. Absolon), by salt marshes developed in some parts of Southern Slovakia loess plateau and minute gypsum aggregates found in loess. The efflorescences of K-Mg-Al soluble sulphates are sometimes found on loess, however the least soluble products such as gypsum or alunite are most common.

The loessification represents by far the most important process of chemical weathering during glacial phases. The blown-in calcareous Tertiary plankton fossils as well as fossil molluscs usually do not bear any marks of corrosion.Therefore we suppose the most important source of carbonate is atmospheric aerosol or ground water (see also Ambrož 1947) A few accessory authigenic minerals besides calcite were found: dolomite (Dolní Věstonice), opal phytolithes and limonitic tubes formed by metasomatic reaction between original calcite fibers and Fe^{2+} solutions.

The weathering conditions of warm phases including the Holocene represent a different regime of weathering. Two principal environments each characterized by a distinct set of processes must be recognized in terrestrial subaerial sedimentation:

1 - the carbonate environment drastically limits the solubility and reactivity of Fe^{2+} and Mn^{2+} and since migration

of many trace elements depends upon the equilibrium between solution and the goethite or MnO_2 phases, calcium carbonate inhibits most of the weathering reactions (Drever 1982). The stabilizing effect of carbonate on iron migration reduces the postdepositional colour changes of sediments. Profiles in calcareous sediments can be well dated on the basis of malacozoology but do not provide reliable evidence for the study of weathering processes.

2 - on the other hand the non-carbonate or acidic environments may lead to intensive migration of iron and other compounds but dating remains obscure. One must be especially aware that the same weathering phase may cause intensive reddening of sediments in acidic environment but almost no changes in calcareous environment.

The colour changes are one of the most striking features of Quaternary sediments and important descriptive tool. We observed however intensive and rapid changes of the colour - e.g. red terra rossa washed down to the humid conditions of intra-cave facies changes to brown and yellow clayey sediment. This instructive example of colour changes was observed in the filling of a sinkhole in the upper level of Hosťovce quarry in Slovak karst. The light grey calcareous siltstones changed near the contact with zone of infiltration close to the limestone wall of the sinkhole first to yellow-brown and then to red sediment. The colour of karst sediments is less dependent on total iron content (red soils and sediments have sometimes less Fe^{3+} than the yellow ones) than on hydrological regime. Brown and yellow colours usually indicate a humid phase and descendent movement of the solutions. The red colour often indicates the combination of wet and dry season and prevailing ascending movement of the solutions caused by evaporation.

The leaching of various compounds and their precipitation during the Holocene has been observed in favourable places such as caves or rock-shelters. Special insight into the processes underway in soils and on the outcrops can be detected by study of widespread but often overlooked rock varnish. We use the term "rock varnish" instead of more common "desert varnish" to stress the existence of desert-like coatings found in various environments. For example the closest analog to desert varnish of birnessite composition can be found around the underground stream of Punkva River in the Moravian Karst (Tipková - Cílek 1992).

The most important rock varnish are thin opal coatings and even flowstones found on areas up to several tens of m^2 on the walls of sandstone canyons of Bohemian Cretaceous. Opal concentrates by evaporation on the surface of rock or more frequently it cements the 10-15 cm thick outmost layer of sandstone. It forms resistant incrustations which are often responsible for the formation of isolated sandstone pillars and some other prominent morphological forms. The rock varnish containing well crystalised aggregates, coatings and incrustations of organic filaments and spores is composed of allochthonous Mg-Al-Fe hydrosilicates derived from nearby Bíteš orthogneisses close to Ledové sluje (Vranov area, Southern Moravia).

A rather common type of rock varnish is represented by Fe, Fe-Mn and Mn coatings. Their origin is associated with fluctuating water level in terrace accumulation. They occur typically since Miocene-Lower Pleistocene but sometimes - mostly near the contact with limestone rock or clasts on pH barrier - we find them throughout the entire Holocene. Pure MnO_2 coatings were found in the Brdy Mts. on Late Holocene rock debris formed by very pure quartzose Cambrian conglomerate. Their position indicates they are not derived from underlying rock. The decaying leaves and organic matter seems to be the source.

One of the striking features of Holocene weathering is the ferruginous peak of the early Holocene (see Starkel 1991). Some early Holocene rock debris formed by dark Proterozoic shales (Károv near Zbraslav, Prague area) are cemented by ferruginous, probably goethite, cement adsorbed on clay minerals of the illite type. An analogous rock debris cemented by sulphate-rich limonite can be found in various localities near Prague (Kazín, Štěchovice) but the source of iron may be different - sulfide weathering and oxidation. We are not able to date exactly the ferruginous peak but the comparison with calcareous areas where debris is cemented by calcium carbonate and underlies the Atlantic travertine (Císařská Gorge in Bohemian Karst, Myší Gorge) points to the Preboreal - Early Atlantic.

Phosphate coatings consisting of carbonate-hydroxyl apatite were discovered in several caves and cave entrances (Javoříčko, Múriková cave in Slovak Karst, Záskočie and Starý hrad in Low Tatra Mts., Hlubočepská cave in Bohemian Karst). They appear mostly as thin dark brown intercalations of glassy, almost metallic lustre in cave flowstones. The oldest phosphate coatings were discovered in Javoříčko Caves in flowstones of Plio-Pleistocene age, but other occurrences are, according to their position, of Holocene age and now they are often in a stage of destruction (Cílek and Komaško 1984). The calcium phosphate coatings precipitated on carbonate clasts and rhizoconcretions were detected in Svatý Jan pod Skalou (Za křížem Cave) and in the Hosťovce (Slovak Karst) talus sequence. The presence of Ca^{2+} ions leads to precipitation of calcium phosphate. Therefore P-rich sediments are sometimes found near cave bedrock bottom. They were exploited as fertilizer (Jáchymka, Výpustek caves in Moravian Karst). The youngest authigenic calcium phosphate of young Holocene age was observed in humic soils of the karst steppe some 30-40 cm below the surface and under the zone of leaching (Cave Za Křížem). Organic relicts are probably the source of phosphorus and the precipitation takes place on the carbonate barrier. Where no Ca^{2+} is available, some Fe-Al phosphates are sometimes formed. Cave apatite intercalations in flowstones probably indicate the change of hydrological regime and intensive leaching.

A special feature of modern cave environments never detected in older Quaternary sediments are coatings of Al-hydroxide on dripstone decoration found in two Czech caves. They may originate by decay of clay minerals caused by acid rains.

The general pattern of weathering processes during Late Glacial-Holocene may be summarized:

1 - the weathering processes of warm oscillations of the Late Glacial seem to be almost negligible. The start of weathering is probably associated more with Early Holocene humidification than with the rise of temperature.

2 - the peak of weathering falls into the older part of the Holocene, probably in the time span Preboreal - Early Atlantic. There are apparently three important reasons for favourable conditions of weathering:

a - opening of the grains by mechanical cryoclastic weathering

b - leaching caused by humidification of climate

c - presence of humic acids and organic compounds released by biological activity such as forest development and possibly the expansion of soil edaphon.

6. Migration of calcium carbonate

The migration of calcium carbonate represents one of the most important processes of the Late Glacial-Holocene transition. The tricky and complex behaviour of carbonate was called by K. D. Jäger (Jäger and Ložek 1983) the "metabolism of calcium carbonate" to stress the overall interjoint anorganic as well as biologic character of the process. While on a local level the zones of leaching and carbonate precipitation can be attributed to peaks of humidity events representing some stratigraphical markers, on the teoretical level the situation is more complex since it touches the carbon cycle and the global carbon budget (Marino et al. 1992).

The migration of $CaCO_3$ starts during the Late Glacial and/or during the Lower Holocene up to the first half of Holocene. It can be directly observed in various subaeric environments - in foam sinter and flowstone formations of cave entrances and caves, in fresh-water limestones-tufas formed near karst outflows or on the surface of calcareous rocks. In the latter case we found tufas in the areas formed by Cretaceous marls, Tertiary sandstones and even volcanic rocks such as Cambrian andesites of Křivoklát-Rokycany Belt and even by Proterozoic metavolcanites of Jílové Belt. Typical dissolution products are soils with decalcified matrix and etched surface of carbonate clasts.

The most important profiles are located under overhanging cliffs, in cave entrances and in tufa deposits. The spelean archaeologists have known since the end of last century the creamy, archaeologically sterile horizon of loose sinter separating the younger strata containing ceramic cultures from Upper Palaeolithic horizons (Skutil 1939). It has been described from the Pekárna Cave in Moravian karst (Absolon and Czižek 1926, 1928, 1932) and from other localities such as Capuš-Koda and Nad Kačákem Caves in Bohemian Karst (Petrbok 1929, 1944). The Moravian geologist Zapletal (1930) called this substance "pěnitec" - foam sinter. The term is appropriate since the foamstone represents the soft, creamy form of flowstone resembling the loose Holocene fresh water limestones - tufas (pěnovec) formerly often called "travertine" in general (e.g. Petrbok 1944). The term travertine would be reserved to diagenetically changed, i.e. lithified tufas (Jäger in Kovanda 1971).

Foam sinter forms in low-lying karstlands thin but striking and stratigraphically important horizons, whereas in mountain areas with high annual precipitation (800-1000 mm, mean temperatures 4-5 °C) the foam sinters occur as 1-2 m thick deposits formed during the major part of the Holocene (Ložek 1984). It is mostly accepted that the calcium carbonate precipitates as hydrated $CaCO_3$ "gel" on lichens and organic filaments. Its composition is close to pure calcium carbonate but often no crystals can be observed even under high resolution electron microscope - instead we found a chaotic mixture of clay-like carbonate or intricate network of tiny needle crystals sometimes oriented around organic fibres. Foam sinters originally precipitate as pasty wet substance usually few millimetres thick on lichen carpets of overghanging cliffs. As this crust grows thicker or during dry seasons the organic carpets decompose and the foam sinters gradually fall down and accumulate on the ground. They are rich in malacofauna typical for wet surfaces of the rock shelter (Ložek 1965b). The humid environment of such rocks-shelters is not favourable for human settlement or concentration of vertebrates. This fact explains the apparent hiatus of prehistoric settlement in caves (cp. Skutil 1939).

The lower boundary of foam sinter layer in caves is stable but often diffuse. It runs through the faunal zone C 2 (Horáček and Ložek 1988) in the phase of forest expansion accompanied by immigration of demanding species during classical Boreal development. The sediments contain small-sized scree with loessoid slightly humic or non-humic crumby matrix. The rate of calcification suddenly increases and the sediment grades into the pre-Neolithic foam sinter horizon. The lower limit of these strata never reaches beyond the lowermost Holocene. Their upper limit depends on the local degree of humidity. The Neolithic and younger pottery above the foam sinter indicates the return of drier phase at low to middle elevations but continuation of wet climatic conditions above apr. 800 m a.s.l.

The most important profile with foam sinter is located in the chernozem area of Southern Moravia in Soutěska, Pálava Mts. The unexpected extremely rich forest malacofauna is associated with foam sinter layer but abruptly declines as the steppe wave hits back. The prehistoric pasture, climate deterioration and deforestation leads to the secondary expansion of nature-promoted but otherwise anthropogene steppes. The modern steppe malacofauna dominates then all later layers including that of the modern era (Ložek 1985).

The surface sediments display comparable successions of events. The key locality of this kind lies in the floodplain of the Břesnice Brook under the Waterfalls (Vodopády) near Srbsko. The basal unit consists of pleniglacial loessic layers with fluvial gravel intercalations. These are overlain by Late Glacial scree with loessoid matrix covered by early Holocene chernozem. The subsequent sudden humidification of climate is indicated by horizon of Atlantic tufa which is again overlain by brown flood- plain loams with slope scree admixture (Ložek 1974a).

A similar situation is observable in the erosional cut through the proluvial cone of the Volfova rokle (Volf's Gully) (Fig. 4, Tab. 5,6) near Karlštejn in the Bohemian Karst. The pleniglacial to late glacial screes with typical loessic malacofauna are overlain by early Holocene tufas containing more demanding woodland species. The layer in position of the Late Glacial/Preboreal chernozem is developed, even on rather steep slope, as humic scree with rendzina-like matrix. The dark humic horizon resembles the so called "Basistorf" underlying many tufa deposits of Southern Germany, but its character is according to malacofauna purely terrestrial. It corresponds to AC soils of rendzina group which developed under open woodland.

The precipitation of fresh water limestones (tufas) at karst springs starts in the same period (Štajgrovka in Moravian Karst - Vašátko and Ložek 1972, Súľov - Čierný potok - Ložek 1974c, Gombasek-Zákruta in Slovak Karst - Ložek and Horáček 1992) and a similar situation can he observed even in small carbonate deposits of non-calcareous areas (Křivoklátsko - localities Eremit - Ložek 1976, Čertův luh and its branch).

However, the limnic and palustrine precipitation and sedimentation of calcium carbonate (alm, lacustrine chalk) in marshes and shallow water pools started earlier. Numerous localities in such environments (Liblice, Lysá-Hrabanov in the Labe Valley, Dobroměřice near Louny) provide reliable malacofaunal and palynologic evidence of earlier Late Glacial start of intensive carbonate metabolism (Losert 1940, Ložek 1962, 1982c).

7. Retreat of open-ground zoocoenoses and expansion of woodland assemblages

In preceding chapters we have discussed the basic changes of deposition and soil-forming processes reflecting the development of climate during the transition from the Pleistocene, i.e. from the Last Glacial to the Holocene. These changes were crucial for the development of biota and they are reflected in depositional sequences treated in this paper mainly by the succession of molluscan faunas.

Assemblage zone A corresponding to the loess phase of the declining pleniglacial includes exclusively such species which live or are able to live in grasslands and are adapted to large fluctuations in temperature and moisture. This is particularly true of loess steppe snail communities which have no modern analogy in the fauna of Europe (Ložek 1965a). In the context of various aspects treated in our paper the question what composition the malacocoenoses had at higher elevations, for instance in karst uplands or even highlands, i.e. out of the loess steppe zone, may be discussed. In sites where locally loess-like deposits still occur, very impoverished loess assemblages have been found (e.g. the near-monocoenosis of *Pupilla loessica* Lžk in Kobyla-West). In other places, where the pleniglacial is represented by loamy (Mažarná) to fine-clastic sediments (Martinka - Velký Špunt), the assemblages have been recorded in which, besides several loess elements, also species never occurring in the loess are included. These are characterized by higher moisture requirements and probably indicate a more balanced microclimate [*Pyramidula, Chondrina, Faustina cingulella* (Rssm.), *Vertigo alpestris* Ald., *Chilostoma achates* (Rssm.) etc.]. Nevertheless, all these species are equally able to live in a treeless country under very severe climatic conditions. However, such records are rather sparse, since at higher elevations the loess phase in mostly represented by cryoclastic debris (northern part of the Moravian Karst, Medvedia cave in the Slovak Paradise) which are usually very poor in fossils. This corresponds to present-day conditions in the alpine zone of high mountains (e.g. in limestone Tatra) where areas covered by fine limestone debris are extremely poor in snails.

Assemblage zone B corresponding to the Late Glacial is characterized by a marked change in fauna due to higher habitat diversity which induces the increase in species number and a differentiation of malacocoenoses. Besides steppe communities including still a number of loess elements more mesic assemblages appear, rather corresponding to meadow habitats [*Cochlipora lubrica* (Müll.), *Perpolita, Punctum, Arianta, Vitrea crystallina* (Müll.) etc.] as well as to a wide range of wetland and small water habitats. Characteristic woodland and thermophilous species are however absent.

Assemblage zone C shows a similar composition as Assemblage zone B except for small numbers of some more demanding elements which reflect the initial expansion of woodland (C 1). Later, these elements show a marked rise, being progressively supplemented by further species, among which a number of thermophiles occur. Above all, it is a case of open woodland species which can live also in scrub or even in smaller open areas: *Helix pomatia* L., *Aegopinella minor* (Stab.), *Ena obscura* (Müll.), *Vertigo pusilla* Müll., *Cochlodina laminata* (Mtg.) etc. (C 2). Of particular importance since the beginning of this stage are two species indicating a parkland character of the landscape with high proportion of ecotones, especially of mantle zones and scrub formations - *Euomphalia strigella* (Drap.) and *Bradybaena fruticum* (Müll.). At the same time xerothermic species also appear forming the main body of communities living on karst steppes and rocks. These are southern immigrants such as *Granaria frumentum* (Drap.) or *Chondrina* species as well as elements of continental steppes, for instance the aboriginal *Helicopsis striata* (Müll.), surviving from the glacial, and *Chondrula tridens* (Müll.). High amounts of further xeric species, such as *Vallonia costata*

(Müll.) and *Cochlicopa lubricella* (Pr.) are also striking. Many species survive from the Late Glacial: *Discus ruderatus* (Fér.) and its assemblage as well as several inhabitants of the loess steppe, for example *Pupilla sterri* (Vth), *P. triplicata* (Stud.) and *P. muscorum* (L.).

This malacofauna documents the dynamic changes in the biota which are reflected by a considerable increase in species and habitat diversity. Mollusca clearly indicate that even the upper soil horizons remain calcareous which is consistent with the quality of sediments formed during this time span.

Assemblage zone D is characterized by the expansion of many species preferring mesic to moist closed forests, such as *Platyla polita* (Htm.), numerous *Clausiliidae, Helicidae* and *Zonitidae*. Woodland elements recorded already in the zone C equally become much more important. Elements of the *D. ruderatus*-fauna, of continental steppes as well as some relicts from the loess steppe are still present, but gradually decline or withdraw to extreme habitats of relictual character. A number of them finally occupy open habitats in cultivated areas which formed since the invasion of Neolithic farmers. In favourable places, mainly on sunny limestone rocks, populations of xerothermes (*Chondrina, Granaria*) increase due to warm climate. The malacofauna thus reflects a marked moisture increase, expansion of woodland and later also a progressive decalcification of upper soil horizons. Habitat diversity shows a moderate decrease, but in areas where environmental conditions support both the expansion of woodland fauna and the survival of older open-ground elements the species richness culminates (e.g. Soutěska in the Pálava Mts. - Ložek 1985).

This development pattern does not apply to chernozem areas where the expansion of woodland fauna documented by records of several species was stopped by the Neolithic landnam which supported a re-expansion of continental steppe elements and hindered the forming of woodland assemblages (Ložek 1982). A good example is the site of Pavlov-Dyje (Vašátko and Ložek 1973) where woodland assemblages did not develop, whereas in adjacent sites of Dolní Věstonice-Nad cihelnou, Soutěska and Martinka forest malacocoenoses existed, but declined already during the following phase.

Assemblage zone E is typical only in areas unaffected by human activities. It is characterized by full development of rich forest malacocoenoses, in which further demanding species appear, for instance *Helicodonta obvoluta* (Müll.) or in Bohemia the alpine immigrant *Macrogastra densestriata* (Rssm.) or in Moravia the Carpathian element *Macrogastra latestriata* (A. Sch.), both species very sensitive to anthropic disturbances. In areas with purely natural ecosystems we can record a forest optimum, which was not affected by short episodes of more severe drier climate evidenced by terrestrial soils with scree intercalations within the tufa deposits. In areas continually inhabited since the Neolithic, the woodland communities are gradually reduced and replaced by secondary steppe assemblages in which some Early Holocene elements, for instance *Chondrula tridens* (Müll.) survive and where modern immigrants [*Oxychilus inopinatus* (Ul.)] or thermophilous re-immigrants [*Cepaea vindobonensis* (Fér.)] appear.

Assemblage zone F comprises communities of the Late Holocene which begins with the dry Subboreal oscillation (sensu Jäger 1969). This is characterized in karstlands by rapid accumulation of coarse scree corresponding to disintegration of rock outcrops and collapses in cave and rock-shelter entrances. The slopes are thus covered by limestone waste which supports the formation of rendsina soils that overlie older more or less decalcified soils.

In areas non-affected by human activities this zone is characterized by a moderate depauperization of malacocoenoses due to the retreat of several sensitive species. For instance the alpine *Macrogastra densestriata* (Rssm.) disappears in the highlands north of the Alps, the carpathian *M. latestriata* (A. Sch.) in Central Moravia (Moravian and Javořičko Karsts), *Bulgarica cana* (Held) in whole regions, particularly in Bohemian Highlands. A number of species become extinct locally: *Platyla polita* (Htm.), *Macrogastra plicatula* (Drap.) etc. By contrast, the numbers of certain species show a marked increase [*Alinda biplicata* (Mtg.) and *Discus rotundatus* (Müll.) in central Bohemia]. Also the limits of ranges are changing, for instance *Discus rotundatus* (Müll.) disappears in central and eastern areas of West Carpathians, whereas *Monachoides incarnata* (Müll.) invades this region. Only at that time several eastern elements expand deeper to the West Carpathians [*Vestia elata* (Rssm.) in the Slovak Karst]; also the appearance of the alpine-dinarian *Aegopis verticillus* (Lam.) in the Moravian Karst falls into this phase.

During the Subboreal, which corresponds to the Young to Late Bronze Age, a considerable expansion of cultivated areas took place. Woodland communities were thus reduced and replaced by open-ground malacocoenoses. This process, locally interrupted after the beginning of the Christian Era, became much more intensive during the Middle Ages, when the cultivation even of less fertile areas at higher elevations and a progressive deforestation in low-lying regions induced the expansion of a number of modern immigrants [*Helicellinae, Zebrina detrita* (Müll.), *Monacha cartusiana* (Müll.)]. Among them several species may be considered neoindigenous as, for instance, *Oxychilus cellarius* (Müll.) in the area of Bohemian Highlands.

Of particular interest from the sedimentological point of view, is the formation of coarse screes with free interstices which occur in a number of sites in karst uplands, for example in the Bohemian Karst. Such screes were inhabited by rich snail communities [*Helicodonta, Isognomostoma, Oxychilus glaber* (Rssm.) and *O. depressus* (St.), *Alinda biplicata* (Mtg.), *Discus rotundatus* (Müll.), etc.] whose shells occur in high numbers in the interstices. Since they use to be unbroken and well preserved, we can suppose that the snails perished at places of their occurrence which suggests that the scree have remained stabilized. Of particular concern is the fact that according to the evidence given by the incorporated fauna these screes formed in forest environments (Ložek 1988).

8. Erosional and soil-forming phases recorded in tufa sequences

Tufa deposits are of prime importance to the knowledge of Holocene stratigraphy and palaeogeography in view of their thickness and richness in fossils. Molluscs play the major role since they occur in well-subdivided successions of characteristic assemblages. In comparison with clastic sediments, particularly with slope deposits, there is a very limited possibility of secondary replacing of shells, for instance of thermophilous elements of the climatic optimum even into Late Glacial layers, which enables the first occurrences of expanding species or surviving of older relicts to be traced in detail.

As concerns the problems studied the tufas are of importance in following aspects:

1. Their rate of sedimentation reflects the course of dissolution and secondary precipitation of $CaCO_3$ incl. climatic factors which controlled this process, i.e. the temperature and moisture (Jäger and Ložek 1968, 1983 - see Chapter 12).

2. In sites where tufa deposits are situated at the foot of steep slopes or at mouth of ravines and grooves (Svatý Jan pod Skalou, Volfova rokle) pure carbonate horizons correspond to phases of minimum slope sedimentation. By contrast, scree intercalations and buried soils, which are in most cases closely associated, indicate the decrease of $CaCO_3$ precipitation due to cooling or decrease in moisture, less frequently also to intensive transport of clastic material.

3. Similar evidence is provided also by deposits lying in floodplains (Kovanda 1983).

The structure of several hundred tufa deposits investigated in Central Europe (Jäger 1982, Kovanda 1971) have been used in this paper as a basis for inferring the conditions under which they were laid down:

- Thick layers of pure tufas deposited from the late Boreal to the Atlantic in footslope and valley floor positions document a phase with strongly limited slope, proluvial, and alluvial clastic sedimentation.

- Intercalations of scree and soil material or feeble rendsina soils in the overlying Epiatlantic complex indicate climatic oscillations characterized by movement of clastic slope material or by short breaks in deposition.

- This process culminates during the Subboreal sensu Jäger (1969), at which time marked horizons of buried rendsinas with scree admixture are formed. In many cases they are dated by Late Bronze Age pottery. Later the tufa formation decreases and in most sites it declines very soon. Most deposits are then affected by erosion or subrosion which corresponds to the climatic break at the close of the climatic optimum (Jäger and Ložek 1968).

- From the stratigraphic point of view the mid-European deposits can be subdivided into two groups: (1) Deposits in which strata formed in the time span prior to the younger Atlantic (incl. the underlying Late Glacial) are strongly developed, whereas younger phases are poorly represented or lacking (e.g. Štajgrovka, Volfova rokle, Švarcava); (2) Deposits predominantly consisting of a complex formed since the late Atlantic to the present which in a number of cases overlie the old eroded bedrock (e.g. Trojanův mlýn, Krabina). This suggests a short phase of intensive downcutting in the earliest Atlantic which may correspond to the maximum of moisture recorded at that time (Jäger and Ložek 1983, see also Chapter 12).

9. Standstill phases in slope sedimentation

Stratigraphic analyses of depositional sequences in cave and rock-shelter entrances, at the foot of rock walls or in footslope and valley floor positions demonstrate that the clastic slope sedimentation was not continual being interrupted by phases of maximum limited slope transport. These standstill phases can be described as follows:

- Loess layers poor in coarser clasts at the foot of steep rocky slopes (Zadní Kopanina, Krabina - upper section, Srbsko-Hřiště) or vertical walls (Soutěska, Martinka) as well as in cave entrances (Barová, Průchodnice, Liščí Caves etc.) covered by coarse clastic deposits from the Late Glacial and particularly Holocene evidence that the late pleniglacial in low-lying warm areas of Central Europe was characterized by a standstill phase in slope deposition associated with a corresponding standstill phase in proluvial and alluvial accumulation (Pavlov, bank of the Dyje River, Štětí).

At higher elevations and in moister areas this phase corresponds to frost debris formation.

- A further standstill phase at the final Boreal/early Atlantic boundary is documented by horizons of pure tufas at the foot of slopes and in floodplains, by foam sinter layers in cave entrances and by horizons of brown forest soils with decalcified fine earth in footslope accumulations.

Whereas the first phase corresponding to the loess formation shows not only a limited formation and gravitational movement of scree material, but also very reduced karstification (i.e. dissolution and secondary precipitation of $CaCO_3$), the second phase is characterized by maximum migration of $CaCO_3$ which indicates a high intensity of karstification undisturbed by physical weathering and associated processes such as breakdown accumulation in cave and rock-shelter entrances, at the foot of slopes and cliffs as at valley floor.

10. Increase in erosion during the Late Holocene due to ploughing and grazing

In addition, the increase in erosion must be mentioned. It manifests itself in inhabited areas after their cultivation.

Among sites providing such records Pavlov-Dyje, Štětí and Poplze in the chernozem zone as well as Velký Hubenov at its periphery may be cited. In the first three sites the preneolithic phase of the Holocene is represented by a thick chernozem, in Velký Hubenov by a parabraunerde with a tirsoid humic horizon. These fully developed soils are covered by hillwash deposits that include at Pavlov and Velký Hubenov a buried secondary chernozem. This is at Pavlov associated with limestone scree derived from the top part of the Pálava Mts. The development pattern of these sequences resemble that of Pleistocene soil complexes (PK) whose upper part consisting of chernozem soils and hillwash intercalations formed, however, under open-ground conditions during the early glacial, whereas during the Holocene it is controlled by man-made deforestation.

In dissected karst uplands to highlands similar evidence is provided by a number of profiles which show tufa deposits covered by loamy colluvia consisting mostly of rendsina material. Important examples are Rudolstadt in Thuringia (Jäger 1969, 1982) and the footslope sequence in Čierna dolina near Súlov where the scree covers document the deforestation of taluses at the foot of conglomerate cliffs (Ložek 1974c). Progressive erosion due to ploughing is observable also in the site called Nad Cihelnou near Dolní Věstonice, where the youngest complex consists of rapidly deposited slightly humic loams with scree, whereas during the Middle and Early Holocene chernozems and their derivates were formed under rather quiet conditions. In low-lying cultivated areas of Central Europe there are a number of similar sequences, in areas continually covered by forest only downcutting removing valley fills in certain regions can be observed (Havlův luh in the Křivoklát Upland).

11. Comparison with transitional phases between Pleistocene glacials and interglacials

In considering events occurring at the boundary Last Glacial/Holocene, a comparison with analogous time span at Glacial/Interglacial boundaries may be an important key.

In the loess series the interglacial is mostly represented only by the basal decalcified soil of soil complexes. Zoofossils have been preserved only in sites where early interglacial slope sediments are developed at its base (Ložek 1965 - phase 1) or where calcareous channel and burrow fills occur. A more detailed subdivision is exceptional - for instance, in the profile of Litoměřice-Richard a slightly developed chernozem corresponds to the beginning of the interglacial (Ložek 1969a).

More favourable conditions occur in karstlands, where depositional sequences in a number of caves show a similar subdivision as the Postglacial ones. Zlatý Kůň - karst pipe C/718 (Ložek 1972) or the footslope sequence at Stránská skála near Brno, where the whole course of interglacial subdivided into development phases can be observed, are good examples. In both cases it is the Cromerian Interglacial, a rather old warm period, which nevertheless shows a development analogous to the Holocene. The whole sequence of the same interglacial is recorded in the tufa deposit on Holý vrch near Únětice (Záruba, Bucha and Ložek 1977). Further records are evidenced in various interglacial travertines in which often early interglacial phases incl. the transition from the preceding glacial are well developed (Gánovce, Tučín). By contrast the transition into the following glacial has been preserved only exceptionally (Bojnice - the castle mound).

From the viewpoint of problems discussed in our study it is important that the depositional pattern at the boundary glacial/interglacial is analogous to that during the Last Glacial/Holocene transition. In some interglacials, particularly in the last one, the thermophilous fauna appears earlier than in the Holocene. The declining phase is more quiet which is obviously due to the absence of human impacts. Another character in which interglacials, mainly the younger ones, differ from the Postglacial, is the overall expan-sion of woodland, even in areas which remained open or semi-open (parkland) during the Holocene. This is documented both by fully developed interglacial woodland fauna in areas, where the forest optimum has not been reached during the Holocene, and by parabraunerde soils, which characterize the interglacials even in areas, where chernozem persisted during the Postglacial. Only Early Pleisto- cene interglacials, particularly in karstlands, were partly dominated by a vegetation resembling present-day xeric semi-open woodland with *Quercus pubescens* and *Cornus mas* as documented by numerous records of *Granaria frumentum* (Drap.). Differences between the development of interglacials and of the Holocene suggest that the whole younger half of the Holocene was markedly affected by human activities which hindered the expansion of woodland and supported the preservation of the mid-European chernozem region.

12. Evidence of changes in temperature and moisture

Temperature and moisture fluctuations during the time span in question were mostly inferred from the state of vegetation and changes in regional range of certain plant or animal species. Also changes in the water regime of lakes and mires played an important role (Lamb 1977). Numerous records were published and interpreted documenting that the Holocene was characterized by a number of oscillations which do not markedly differ from each other in intensity (also Kordos 1978b - "Vole thermometer"). Our paper summarizes the evidence based particularly on malacological data in correlation with certain sedimentation processes, mainly with $CaCO_3$ migration and soil formation.

12. A. Changes in ranges of selected animal species

The rise in temperature from the decline of glacial to the climatic optimum is markedly reflected by the expansion of thermophilous fauna during this time span. By contrast, the moderate decrease in temperature during the Late Holocene cannot be documented so convincingly in view of the invasion of southern elements to Central Europe which continues also at present: *Xerolenta obvia* (Mke), *Cernuella neglecta* (Drap.), *Zebrina detrita* (Müll.) etc. Nevertheless, the retreat of a number of thermophiles from the subalpine zone [e.g. *Aegopinella minor* (Stab.), *Chondrina*] and the expansion of several alpine elements at lower elevations [*Columella columella* (Mart.)] recorded in high limestone Carpathians (Ložek 1978) as well as the disappearance of *Granaria frumentum* (Drap.) in a number of regions (East Bohemia, the Ohře Valley) confirm this fact. It is documented also by the retreat of some thermophilous reptiles (*Elaphe, Emys, Lacerta viridis*).

Mollusca reliably reflect the change in moisture as shown by fossil occurrences of moisture-demanding elements at places which do not provide a sufficient moisture at present. This is evidenced for instance, by rich woodland faunas known from several Early Atlantic localities tn the Pálava Mts. that include a number of hygrophilous species (Soutěska, Martinka, Milovice), which later disappear not only in the Pálava but also in the whole xerothermic region of South Moravia (Ložek 1985). The same development is locally indicated for example by *Carychium tridentatum* (Rs.) which appears during the climatic optimum in many sites, where it again disappears during the Late Holocene (e.g. in summit habitats in the Bohemian Karst - Za Křížem and Martina Cave). The retreat of some species highly sensitive to environmental changes, such as *Macrogastra densestriata* (Rssm.) from Bohemia or *M. latestriata* (A. Sch.) from central Moravia is mainly due do decreasing humidity during the Late Holocene. However, in this time span the human impact must be also taken into account. More obscure is the interpretation of the retreat of *Discus rotundatus* (Müll.) from eastern and central areas of the West Carpathians. Since its present range may be considered subatlantic, the reason for this reduction is probably a rise in continentality.

12. B. Evidence from tufas and cave sinters

The precipitation of $CaCO_3$ is of prime importance for interpretation of moisture fluctuations since it strongly depends on sufficient water supply. The best evidence is given by carbonates formed under terrestrial conditions, i.e. by the foam sinter (Ložek 1984). This can form only in sites, where the ceiling of caves and rock-shelters or overhanging rock walls are at least seasonally moistened, which enables $CaCO_3$ to be precipitated on mosses, lichens or algae. Therefore, foam sinter horizons in caves of xerothermic uplands or at places with markedly xeric character, such as Soutěska in the Pálava Mts., represent reliable records of a highly humid phase having no analogy in earlier or later phases of the Postglacial. Together with the incorporated moisture-demanding fauna (Soutěska) they document the Holocene humidity maximum corresponding to the final Boreal and Early Atlantic (sensu Jäger 1969). Thermophilous species, abundantly occurring in the assemblage, indicate that it is controlled by rise of precipitation and not at all by temporary decrease in temperature, which would heighten the relative humidity.

Spring and brook tufas provide evidence both of moisture and temperature. Their formation requires a sufficient yield of springs which is due to the humidity. The precipitation of $CaCO_3$ is supported by temperature, particularly during the vegetation period, as documented by the tufa distribution in climatic and altitudinal zones. In Central Europe most of tufa deposits are situated in hill-country and submontane belts. At higher elevations tufas are sparse and in the subalpine belt they occur only exceptionally. By analogy most of tufa deposits in the Russian Plain are associated with the zone of deciduous forest, whereas in the taiga their number considerably decreases and basinal deposits become predominant (Bartoš 1963).

Also the chronological position of tufa formation is in good agreement with conditions discussed above. The great majority of tufa deposits begins to form during the Early Holocene, mostly at the beginning of the Boreal, as documented by the appearance of thermophilous and woodland species (Volfova rokle - Fig. 4, Tab. 5, 6). Its culmination corresponds to the Holocene climatic optimum, when both temperature and moisture are high. During the Subboreal most deposits become dry and later the tufa formation continues only in a reduced extent mostly in particularly favourable places (Jäger and Ložek 1968). The formation of basinal lime deposits, i.e. of freshwater chalk or marl as well as of swamp tufas and marls, starts however already during the Late Glacial, documenting thus the increase in moisture at that time. This is in good accordance with the above observation from the Russian Plain.

12. C. Evidence from soils

Records from mid-European xerothermic areas show that the chernozem formation starts already towards the close of the Late Glacial and culminates during the Early Holocene (Poplze, Štětí, Dolní Věstonice). Of importance is the fact that at that time chernozem obviously developed in larger regions than today, as documented particularly by the chernozem horizons within the floodplain sequence Pod Vodopády near Srbsko in the Bohemian Karst (Ložek 1974a). At present, in this area brown forest soils like parabraunerde or braunerde predominate. Partly also terra fusca appears, whose intensive formation started somewhat later, during the beginning of climatic optimum, which chronologically corresponds to the phase of maximum humidity.

The high intensity of this pedogenesis is indicated by brown soils with decalcified fine earth recorded either in a number of footslope sequences (Zadní Kopanina, Krabina - upper section) or cave entrances (Martina and Rudolfova Caves) and locally even in accumulations covering rock steps on steep karstland slopes (Zlatý Kůň - southern slope). Later, these soils were overlain by humic calcareous sediments.

From these observations and many others of similar kind, we can infer that the presented evidence of temperature confirms the classical conception based mostly on palaeobotanical data (e.g. Vorwärmezeit-Wärmezeit-Nachwärmezeit of Firbas 1949 or Anathermal-Megathermal-Katathermal of Hafsten 1969). Temperature fluctuations which would markedly disturb this curve have not been recorded so far (cp. Kordos 1978b).

A different situation appears in the case of moisture, where - as already noted - the literature presents a number of oscillations in various phases of the Holocene, which do not markedly differ from one another by their intensity. Evidence given by the foam sinter and supported by its malacofauna however clearly documents an extraordinarily moist phase at the beginning of climatic optimum which starts during the close of Boreal and abruptly declines immediately before the invasion of Neolithic farmers in Central Europe. This relatively abrupt decline of the humid phase is markedly expressed only in cave- and rock-shelters in warm-dry areas, i.e. in low-lying karstlands characterized by abundant occurrence of xerothermic formations (Bohemian Karst, southern part of Moravian Karst, Little Carpathians). In higher and moister areas the foam sinter formation continues and in the montane belt the foam sinter mostly forms even at present (Ložek 1984) (Sokol - Fig. 5, Tab. 7). In sites where the foam sinter occurs only as a sharply bordered horizon of preneolithic age, its formation does not repeat any more what indicates that mentioned moist oscillation was much more intensive that in any other phase of the Holocene.

13. Conclusion

Analyses of mid-European depositional sequences corresponding to the phase from Late pleniglacial to Holocene climatic optimum show the following chronological succession confirmed by biostratigraphic data:

1. Loess formation, which is characteristic of late pleniglacial, terminates during the pre-Alleröd phase of the Late Glacial at the time of Magdalénian settlement.

2. During the Late Glacial a moderate slope sedimentation predominates and is associated with initial pedogenesis and precipitation of $CaCO_3$ in basinal areas.

3. Slope sedimentation continues to the Early Holocene being increasingly affected by soil forming processes.

4. At the same time an increasing migration of $CaCO_3$ occurs as documented by the start of tufa formation and foam sinter infiltrations in clastic cave and slope sediments.

5. According to malacological evidence the Pleistocene/Holocene boundary lies within the complex of slope sediments separating the end of the formation of the youngest loess from the start of intensive precipitation of $CaCO_3$.

6. At the transition to the climatic optimum, i.e. during final Boreal, an intensive precipitation of $CaCO_3$ begins both in the facies of foam sinter in cave entrances and rock-shelters and of pure carbonates in lower parts of tufa deposits.

7. In warm-dry uplands the foam sinter formation abruptly declines immediately prior to the immigration of Neolithic farmers and does not repeat later, what indicates the most humid phase of the Holocene - the humidity maximum.

8. This maximum is confirmed by the invasion of a number of warmth- and moisture-demanding snail species which later partly retreat.

9. The humidity maximum is also documented by horizons of brown soils with decalcified fine earth forming intercalations in slope deposits.

10. The final loess phase corresponds to a standstill phase in clastic slope sedimentation and the maximum reduction of the karst process.

11. A further standstill phase in slope sedimentation corresponds to the maximum formation of foam sinters or decalcification of soils. But on the other hand this phase is associated with intensive karstification.

12. The above discussed processes are well marked in warm-dry uplands, at higher elevations their traces are less pronounced.

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Pozdně viselské až holocenní sedimenty a půdy ve středoevropských vápnitých oblastech

(Résumé anglického textu)

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Dosavadní představy o vývoji postglaciálu vycházejí převážně z paleobotanických rozborů bažinných a jezerních sedimentů. Rozsáhlá území, kde se tyto sedimenty nevyskytují, se donedávna vyznačovala nedostatkem údajů o tomto období, přestože jde o oblasti významné z hlediska jak vývoje prostředí, tak pravěkého osídlení. Naše souborná studie hodnotí výsledky z rozsáhlé sítě nalezišť ve vápnitých oblastech Čech, Moravy a Slovenska s přihlédnutím k obdobným dokladům ze sousedních zemí. Naše úvahy se opírají o členěné vrstevní sledy pozdně glaciálního až holocenního stáří, zpracované zoostratigraficky (*Mollusca, Vertebrata*) v korelaci s vývojem sedimentů, půd i s pravěkým osídlením. Cílem bylo podchytit celkový vývoj přírodního prostředí v těchto oblastech v závislosti na podnebí a osvětlit tak některé otázky postglaciálu, které dosavadní přístupy nebyly s to řešit. Rozhodující úlohu zde sehrály husté sítě lokalit v krasových oblastech, především v Českém, Moravském a Slovenském krasu, na Pálavě a v některých dalších oblastech Karpat. Studie shrnuje materiál ze starších, zčásti již uveřejněných výzkumů a nově je hodnotí na základě dalších výzkumů i hledisek.

Průběh postglaciálního vývoje v uvedených oblastech lze stručně shrnout takto:

Ve starším (předallerödském) úseku pozdního glaciálu vyznívá tvorba spraše, které odpovídá klidová fáze ve svahové sedimentaci. Později nastupuje tvorba sutí drobnějšího zrna pokračující i ve starším holocénu. Jejich hlinitá výplň má zprvu ještě sprašovitý, později však stále humóznější ráz, takže může nabýt i povahy rendzinových sedimentů. Současně se na vhodných místech již tvoří černozem. Sprašová step tak přechází do parkové krajiny, v níž stále vzrůstá podíl dřevin a teplomilných prvků. Ve vchodech jeskyní a převisů jsou tyto klastické uloženiny stále silněji prosyceny vysráženým $CaCO_3$ v podobě sypkého sintru - pěnitce. Jeho tvorba vrcholí na sklonku boreálu a ve starším atlantiku, kdy vznikají nápadně bělavé sintrové horizonty, které však v otevřeném terénu přecházejí do půd s odvápněnou jemnozemí, a to i na svazích s velkým přínosem vápencového detritu, který jinak odvápnění brání. Sintrové horizonty tak dokládají období nejvyšší vlhkosti, maximální migrace a srážení $CaCO_3$, i další klidovou fázi ve svahové sedimentaci. To potvrzuje i intenzivní tvorba čistých pěnovců při vápnitých pramenech v témže období.

Tvorba pěnitce v jeskyních náhle končí těsně před příchodem neolitických rolníků, jejichž stopy již leží v nadložních hlinitokamenitých humózních sedimentech ostře nasedajících na podložní pěnitec. Klastická sedimentace pak pokračuje s kolísavou intenzitou až do současnosti. Její průběh lze sledovat v ložiskách pěnovců na úpatí strmých svahů, kde epiatlantické období vyznačují vložky sutí a půdních sedimentů, což dokládá, že svahový transport byl přerušován obdobími klidu, jimž odpovídají polohy čistého pěnovce. Tyto oscilace jsou význačné pro epiatlantik. Tvorba sutí a půd vrcholí v pozdně bronzové době. V téže době dochází k řícení jeskynních vchodů a rozpadu skalních výchozů. Po této fázi, která odpovídá subboreálu sensu Jäger (1969), tvorba pěnovců rychle vyznívá a většinu ložisek zasahuje eroze nebo subroze.

Z uvedeného je zřejmé, že v holocénu střední Evropy lze rozlišit několik významných fází sedimentace a pedogeneze vázaných na klimatické výkyvy:

1. fáze klidu ve svahové sedimentaci i pedogenezi v době tvorby nejmladší spraše (předallerödská),
2. fáze maximální migrace $CaCO_3$ na sklonku boreálu a ve starším atlantiku, která je spjata s holocenním maximem vlhkosti a intenzivní pedogenezí,
3. náhlé vysušení bezprostředně před neolitickou okupací kolem r. 5 000 př.n.l.,
4. nápadné vysušení a nástup nevyrovnaného podnebí v pozdně bronzové době, zahajující obecné zhoršení klimatu v mladším holocénu.

Tento vývoj je charakteristický zejména pro sušší teplé oblasti v planárním až submontánním stupni střední Evropy; směrem do výše položených a vlhčích oblastí intenzita popsaných výkyvů klesá.

Text k obrázkům

1. Sled usazenin ve vchodu jeskyně Pustožlebská Zazděná (Moravský kras) s horizontem atlantického pěnitce (podrobnosti v anglickém textu v tab. 1)
2. Dolní Věstonice, Nad cihelnou: průřez splachovou výplní suchého úpadu ukazující vývoj půd na úpatí Pálavy (podrobnosti v angl. textu v tab. 2 a 3)
3. Sled usazenin na dně bezvodého údolí Krabina u Karlštejna s odvápněnou středoholocenní půdou (srov. tab. 4 v angl. textu)
4. Sled usazenin v ústí Volfovy rokle u Karlštejna ukazující změnu sedimentace v časném holocénu (podrobnosti v tab. 5 a 6 v angl. textu)
5. Výplň převisu ve stěně Sokola (Nízké Tatry) s převažující pěnicovou sedimentací (podrobnosti v tab. 7 v angl. textu)

Text k tabulkám

Tab. 1 - Popis a vyhodnocení sedimentárního sledu ve vchodu jeskyně Zazděná (srov. obr. 1)
Tab. 2 - Měkkýší fauna z profilu Dolní Věstonice-Nad cihelnou
Tab. 3 - Popis a vyhodnocení sedimentárního sledu na lokalitě Dolní Věstonice-Nad cihelnou (srov. obr. 2 a tab. 2)
Tab. 4 - Popis a vyhodnocení výplně údolního dna v Krabině u Karlštejna (srov. obr. 3)
Tab. 5 - Měkkýší fauna z Volfovy rokle
Tab. 6 - Popis a vyhodnocení sedimentárního sledu v ústí Volfovy rokle u Karlštejna (srov. obr. 4 a tab. 5)
Tab. 7 - Popis a vyhodnocení sedimentárního sledu v převisu ve skále Sokol (srov. obr. 5)