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Dating of the Holštejnská Cave deposits and their role in the reconstruction of semiblind Holštejn Valley Cenozoic history (Czech Republic)

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Abstract: Large sections in cave deposits are exposed in the Holštejnská Cave in the Moravian Karst (Czech Republic). The study of the genesis and age of these cave deposits poses a clue to the reconstruction of this cave system and of local paleohydrographic history. The time of deposition was determined by U-series dating of speleothems, ^{10}Be and ^{26}Al dating of quartz pebbles, radiocarbon dating of charcoal, measurement of paleomagnetic record in both clastic sediments and speleothems and by archeological evidence.

Key words: cave deposits, Quaternary, U/Th dating, Moravian Karst, Czech Republic.

Introduction

The Moravian Karst is situated in eastern part of the Czech Republic 15 km NE of Brno (Fig. 1). The karst area formed by Devonian limestones has the shape of a belt 3–5 km wide and some 20 km long. The limestones are

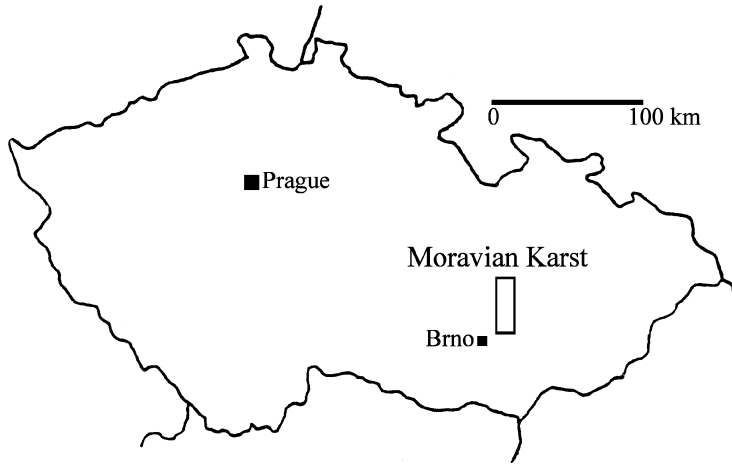

Fig. 1. Location of the Moravian Karst area in the Czech Republic.

bounded by faults against non-karstic, Lower Carboniferous sediments (Protivanov and Rozstání formations) in the north and in the east, and against Proterozoic granodiorites of Brno massif in the west. The karst area is divided into three segments called northern, central and southern parts of Moravian Karst. Cave systems draining these parts of the Moravian Karst were formed by subsurface rivers during the Cenozoic. The Amatérská Cave with its total length exceeding 30 km is the largest cave system draining the northern part of the Moravian Karst (Fig. 2).

The Holštejnská Cave is located in a semi-blind Holštejn Valley at the northern periphery of Moravian Karst (Fig. 2). The cave has a character of a horizontal, 40–50 m wide corridor nearly completely filled with three sequencess of fluvial sediments of different age. The Holštejnská Cave represents the upper level of the ponor cave system draining the Holštejn Valley during the Cenozoic. The lower level, called Cave No. 68, is situated 50–60 m below the Holštejnská Cave and was discovered by excavation of the sinkhole No. 68 in front of the entrance of the Holštejnská Cave (Fig. 3). Both levels are connected by vertical or subvertical karst shafts filled with fluvial deposits, too. Fluvial sediments inside the Holštejnská Cave are exposed in large sections excavated by local cavers during the last 30 years. Lithology and heavy mineral content of these fluvial deposits were studied by Přibyl (1973), Glozar (1979), Otava and Vít (1992) and Vít (1996).

The Holštejnská Cave sediments

The studied section in cave sediments is exposed in excavated corridor No. XV (see Fig. 3). The section is perpendicular to the flow of subsurface stream, which flowed through the Holštejnská Cave. The oldest fluvial sequence is formed by sandy gravel with strongly weathered greywacke pebbles. Relics of sandy silts are occasionally preserved on the surface of this sequence. These

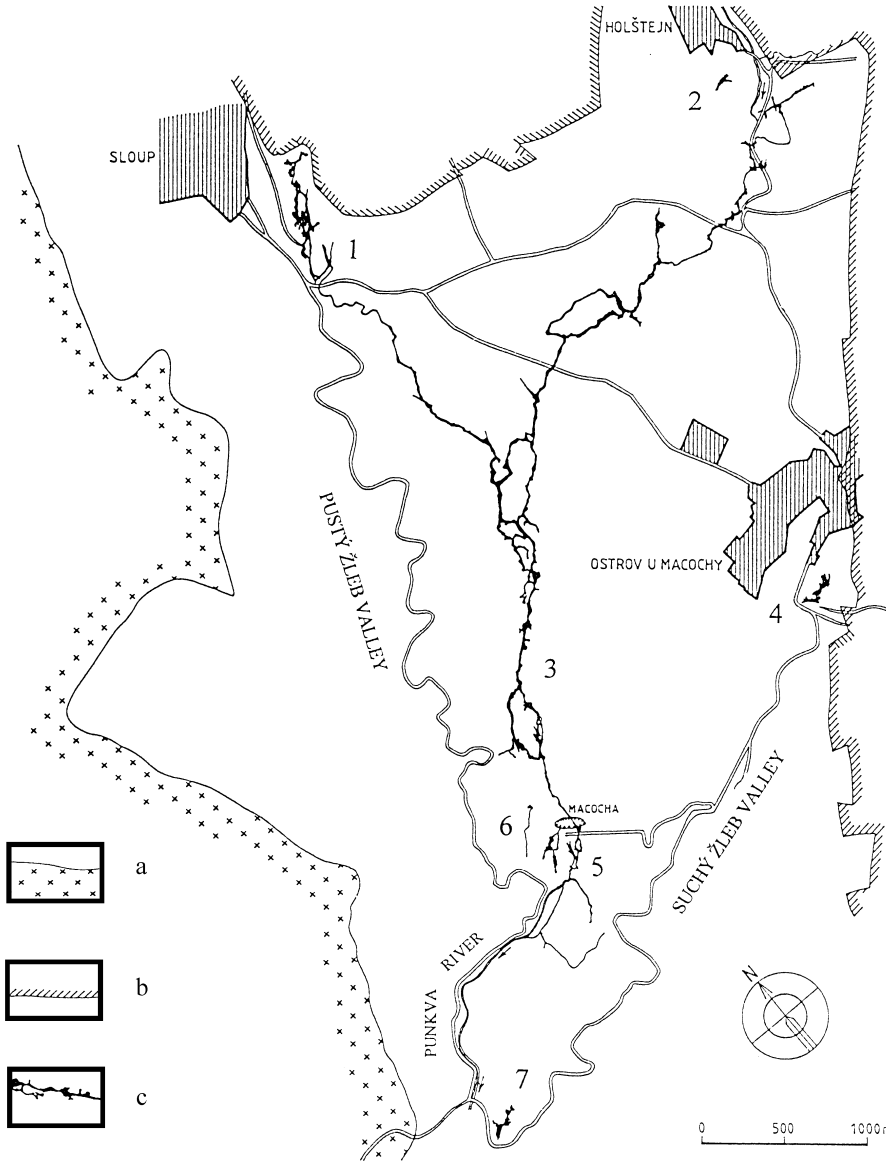

Fig. 2. Cave systems in the northern part of the Moravian Karst.

a – eastern boundary of Proterozoic Brno granodiorite massif, **b** – southern and western boundary of Lower Carboniferous non-karstic sediments, **c** – Devonian limestones with outline of caves; cave systems: **1** – Sloupsko-šošůvské Caves, **2** – Holštejnská Cave, **3** – Amatérská Cave, **4** – Balcarka Cave, **5** – Punkevní Cave, **6** – Zazděná Cave, **7** – Kateřinská Cave.

fluvial sediments are covered by relicts of eroded flowstone layer (Fig. 4). The middle fluvial sequence formed by clayey silts with carbonate concretions, limestone clasts and lenses of redeposited underlying sandy gravel is also covered by

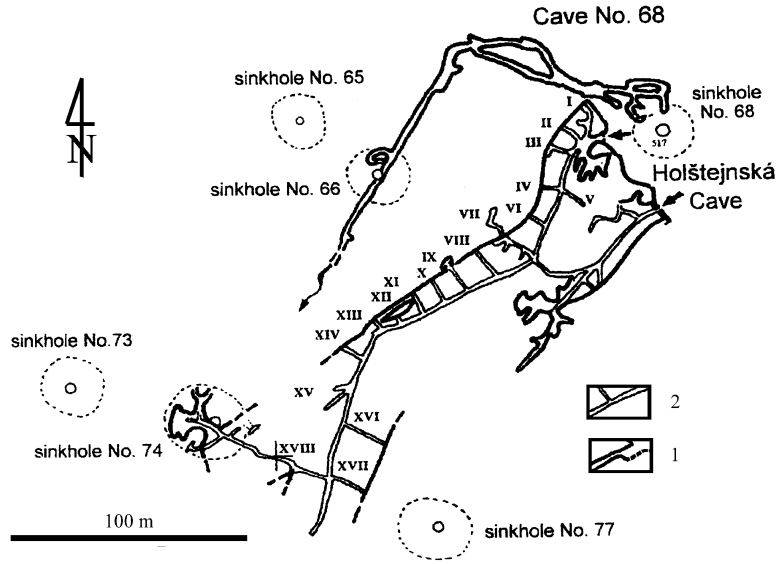

Fig. 3. Horizontal map of the Holštejnská Cave and Cave No. 68.

1 – cave walls, **2** – excavated corridors in the cave sediments, I–XVIII – numbers of excavated corridors.

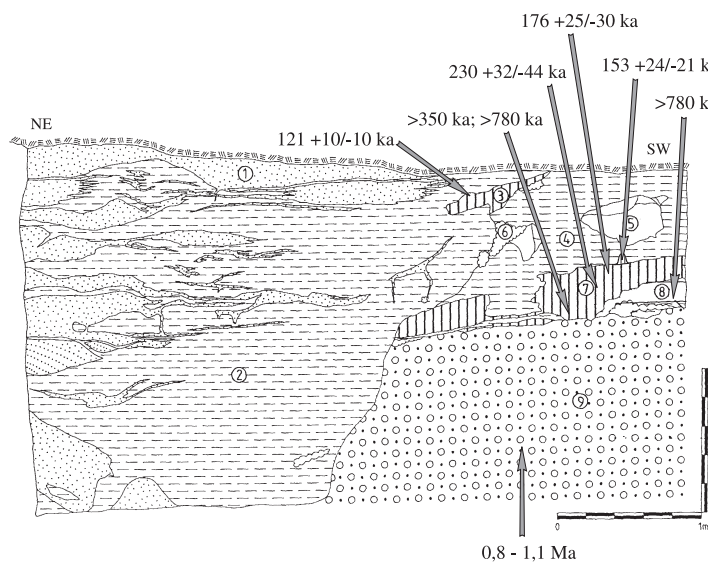

Fig. 4. Section of sediments in excavated corridor No. XV.

The youngest fluvial sequence: **1** – medium to coarse sand, **2** – fine clayey silt, **3** – relic of flowstone layer; middle fluvial sequence: **4** – fine clayey silt, **5** – limestone block, **6** – calcareous concretion, **7** – relic of flowstone layer; the oldest fluvial sequence: **8** – sandy silts, **9** – sandy gravel

flowstone layer relics. The third fluvial sequence fills channels incised into older fluvial bodies. These youngest fluvial deposits are formed by clayey silts with horizontally lying, locally cross-bedded sands.

A thin flowstone layer was deposited on the surface of these youngest sediments in some parts of the cave corridor. Fine laminated infiltration sediments were deposited in the southern part of the Holštejnská Cave (below sinkhole No. 74 – see Fig. 3) These clayey silts were transported by meteoric waters to the cave through karst chimneys connecting the sinkholes on the karst plateau surface with the cave corridor.

Dating of the Holštejnská Cave sediments

Several dating methods were used for age determination of fluvial processes and speleothem deposition in the Holštejnská Cave. The flowstones were dated in Uranium-Series Laboratory of the Institute of Geological Sciences PAS, Poland and in the Centre d'Etudes et de Recherches Appliquées au Karst, Faculté Polytechnique de Mons, Belgium. The ^{10}Be and ^{26}Al dating of quartz pebbles was performed in the laboratory at Purdue University, USA. The paleomagnetic record in clastic and chemogenic sediments was measured in paleomagnetic laboratories at Michigan Technological University, USA and in the Institute of Geology AS CR, Czech Republic. Radiocarbon dating of charcoal was performed in Beta Analytic Radiocarbon Dating Laboratory, USA. The age of pottery fragments was determined at Masaryk University in Brno, Czech Republic.

The age of the oldest fluvial deposits from the cave was determined on the basis of the content of ^{10}Be and ^{26}Al isotopes generated in quartz pebbles during the last exposure of fluvial sediments to cosmic radiation outside the cave (see Nishiizumi *et al.* 1986). ^{10}Be and ^{26}Al dating of quartz pebbles from the oldest fluvial sequence in the Holštejnská Cave indicates the time of sandy gravel transportation into the cave between 0.8 and 1.1 Ma. Fluvial sandy silts preserved in relics on the surface of the sandy gravels yielded reverse paleomagnetic direction from the time of deposition. The lowermost part of the overlying flowstone layer also displays reverse paleomagnetic direction (Šroubek and Diehl 1995) and ^{230}Th/^{234}U age exceeding 350 ka (Hercman *et al.* 1997). However, the ^{230}Th and ^{234}U ratio from this flowstone indicates the age lower than 1.2 Ma. Consequently, the ages of the flowstone and the underlying fluvial sediments are older than paleomagnetic boundary Brunhes/Matuyama – i.e., 780 ka. The age of the upper part and the top of the same flowstone layer is 230 +32/–44 ka and 176 +25/–30 ka, respectively based on ^{230}Th/^{234}U dating.

^{230}Th/^{234}U dating of speleothems underlying and covering the middle fluvial sequence evidences deposition of fluvial sediments between 153 +24/–21 ka (Głazek *et al.* 1995) and 121 +10/–10 ka, respectively. The time of deposition of the youngest fluvial sands and silts is constrained by the ^{230}Th/^{234}U age of a speleothem relic at the base of these sediments. This flowstone layer was

deposited at 121 +10/–10 ka. The thin flowstone horizon covering the youngest fluvial deposits is exposed in excavated corridor No. XVIII in the southern part of the Holštejnská Cave (see Fig. 3). The age of deposition of this flowstone is 29 +4/–4 ka and marks a termination of last fluvial activity in the cave.

Laminated infiltration silts deposited in the southern part of the Holštejnská Cave (below sinkhole No. 74 – see Fig. 3) form the uppermost portion of the sediment fill of the Holštejnská Cave. Radiocarbon age of charcoal from these fine sediments is younger than 1665 A. D. Pottery made in the 14th century was found in fragments in these youngest cave deposits (Zatloukal *et al*. 1996).

Significance of sediments of the Holštejnská Cave for the reconstruction of cave system development and local paleohydrography

Fluvial deposition in the Holštejnská Cave was closely linked with the Holštejn Valley development. This semiblind valley has been formed since Late Paleogene (Panoš 1963; Štelcl 1963, 1964). During the Lower Miocene (before the Badenian marine transgression), the valley was deepened and drained by lower cave level (Cave No. 68) to the Amatérská Cave system, which originated at the end of Lower Miocene (Panoš 1963; Kadlecová & Kadlec 1995). The Holštejn Valley was subsequently filled with fluvial sediments up to 60 m thick (Dvořák 1961; Kadlec 1996). The entrance and horizontal corridor of the Holštejnská Cave lies at the same level as the surface of this fluvial fill. The age of the oldest fluvial sediments in the Holštejnská Cave documents that at 0.8–1.1 Ma ago, the Holštejn Valley was filled with fluvial sediments and a stream could to enter the Holštejnská Cave (see Fig. 5).

Based on dating of the Holštejnská Cave sediments a local paleohydrographic history could be reconstructed. The heavy mineral content of the oldest fluvial deposits in the Holštejnská Cave documents their source in the Protivanov Formation greywackes located north of the Holštejn Valley (Otava & Vít 1992; Vít 1996). This heavy mineral assemblage (with dominating epidote) is typical for modern fluvial sediments transported from non-karstic Lower Carboniferous area by the Sloup Stream sinking underground in the Sloupsko-šošùvské Caves (see Fig. 2). Also pebble lithology of the oldest deposits in the Holštejnská Cave (see Přibyl 1973; Glozar 1979) supports this idea about a catchment located north of the Holštejn Valley. The younger fluvial sequences in the Holštejnská Cave contain heavy mineral assemblage with dominating garnet (Otava & Vít 1992) – typical for fluvial sediments of the Bílá voda Stream coming from the area formed by greywackes and shales of the Rozstání Formation located NE of the Holštejn Valley. The age of the oldest fluvial sediments preserved in the Holštejnská Cave indicates that local hydrological situation has changed after 0.8–1.1 Ma.

During the Early, Middle and Late Pleistocene, the stream repeatedly entered

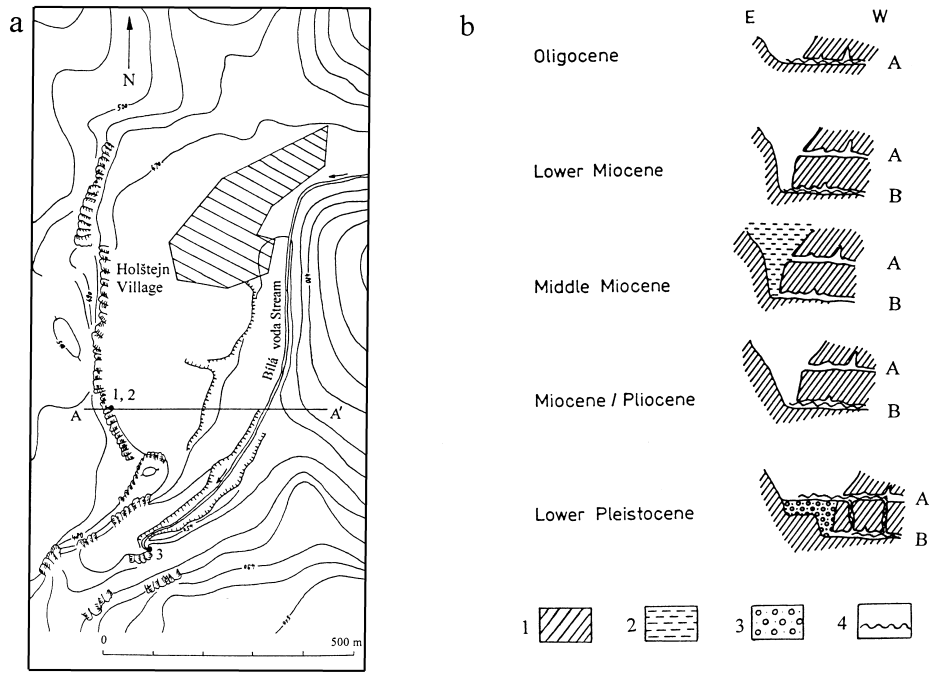

Fig. 5. The Holštejn Valley and its development during the Cenozoic:

a) Topographic situation of semi-blind Holštejn Valley: **1** – Holštejnská Cave (upper cave level), **2** – Cave No. 68 (lower cave level), **3** – ponor of the Bílá voda Stream in the Rasovna Cave, **A – A'** line of the cross-section shown in Fig. 5b; **b)** Schematic development of the Holštejn Valley and its drainage through upper and lower cave levels: **1** – Devonian limestone, **2** – marine sediments, **3** – fluvial sediments, **4** – stream; **A** – Holštejnská Cave (upper cave level), **B** – Cave No. 68 (lower cave level)

the Holštejnská Cave. Water generated vertical karst connections between the Holštejnská Cave (upper level) and Cave No. 68 (lower level). This pre-Badenian lower cave level was reached by the stream through these vertical karst paths during the Pleistocene.

Conclusion

Dating of the Holštejnská Cave deposits documents periods of subsurface fluvial activity in the cave. The periods of fluvial activity alternated with periods of speleothem deposition. The oldest cave sediment sequence was deposited by a subsurface stream at 0.8–1.1 Ma. The middle fluvial sequence was deposited between 153 +24/–21 ka and 121 +10/–10 ka. The youngest fluvial sequence deposition covers a time span of 121 +10/–10 ka to 29 +4/–4 ka. Laminated infiltration silts represent the youngest clastic deposits in the Holštejnská Cave. These sediments are younger than the 14th century.

The time of deposition of the oldest fluvial sediments in the cave indicates

that the semiblind Holštejn Valley must have been filled with fluvial sediments at about 0.8–1.1 Ma. Heavy mineral assemblage in the oldest cave fluvial deposits documents that the stream from the catchment located north of the Holštejn Valley flowed to the Holštejnská Cave at that time. After 0.8 Ma – probably at the beginning of the Middle Pleistocene – the local hydrography changed and the Bila voda Stream has started to flow both to the Holštejn Valley and the Holštejnská Cave, too.

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