THE EVOLUTION OF KARST AND CAVES IN THE KONĚPRUSY REGION (BOHEMIAN KARST, CZECH REPUBLIC), PART III: COLLAPSE STRUCTURES

RAZVOJ KRASA IN JAM NA OZEMLJU KONĚPRUSY (ČEŠKI KRAS, ČEŠKA), III. DEL: UDORNE STRUKTURE

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Abstract

Pavel Bosák: The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic), Part III: Collapse structures

Vertical and subvertical pipes are circular to ovate in shape with diameters from 2-4 m up to tens of metres and with proven depth up to 82 m. Some of them terminate by horizontal cave levels at depth. Pipes are filled with complicated sedimentary sequences with clearly developed collapse structures. The fill is composed of pre-Cenomanian, Cenomanian-Turonian and Tertiary deposits. Internal structures of the fill indicate multi-phase collapses. Cretaceous and pre-Cretaceous deposits are often subvertical with chaotic internal texture. In the centre of some of pipes, there are traces of younger collapses, most probably induced by continuing karstification and suffosion at depth. Tertiary deposits overlay the Cretaceous ones unconformably; they show gentler centripetal inclination, but in places they fill the central parts of collapsed fill. The origin of solution pipes is connected with hydrothermal activity most probably during Paleogene to Miocene, when the surface of limestones was still covered by slightly eroded cover of Upper Cretaceous platform sediments. Hydrothermal karst forms developed up to the surface of limestones as the piezometric level was situated within the Cretaceous cover. After the lost of buoyancy support of water, sedimentary cover started to move (collapse) down.

Key word: paleokarst, hydrothermal karstification, collapse, karst depression, Koněprusy region, Bohemian Karst, Czech Republic.
GEOLOGICAL BACKGROUND

The Koněprusy region is situated in the southwestern closure of the Siluro-Devonian core of the Barrandian (Prague) Basin between villages of Koněprusy, Suchomasty, Vinařice and Měňany (Fig. 1). The region, known also as the Koněprusy Devonian, is typical by special, shallow marine evolution of Pragian to Givetian formations (cf. Chlupáč et al. 1998). The prevailing part of the Lower Devonian sequence is built by massive organodetrital and, in the upper part, Koněprusy reef Limestones (Pragian) with the thickness up to 350 m. They are underlain by Kotýz Limestones (finely organodetrital with intercalation of marls and fine-grained siliciclastic often with densely packed chert nodules; about 60 m, Lochkovian). In the present geological configuration, the Koněprusy Limestones are overlain only partly in a narrow strip along the northern tectonic boundary of the Koněprusy Devonian by the Suchomasty Limestones (20 m, uppermost Zlíchovian to Dalejan), Acanthopygae Limestones (20 m, Eifelian) and by siliciclastics of the Srbsko Formation in small denudation relics (Givetian; cf. Chlupáč et al. 1998; Fig. 1). Koněprusy Limestones are

Fig. 1: Koněprusy Devonian, simplified geological map without young cover (completed and modified from Klein et al. 1989) and shape of karst depressions (A - Velkolom Čertovy schody-Quarry West, modified from Kukla 1953; B - Velkolom Čertovy schody-Quarry West, from Bosák 1999 unpubl).
well lithified, structurally homogeneous and brittle. The are folded into the system of open synclines and squeezed anticlines, often with overthrusts and highly faulted. Thick calcite veins of the N-S trend cut the whole area (Cílek, Dobeš & Žák 1994). The Lower Devonian sequences form an irregularly ovate synclinal basin-like structure isolated by underlying Silurian formations and tectonics from other occurrences of limestones. The NNE limit of the Koněprusy Devonian is formed by the major line of the Očkov Overthrust. Numerous rests of Upper Cretaceous (Cenomanian to Turonian) siliciclastics in karst forms (e.g., Kukla 1956; Cílek, Tipková & Kvaček 1992; Suchý, Zeman & Bosák 1996) indicate that the region was completely covered by Upper Cretaceous platform cover, now completely eroded (Zelenka 1981).

MODEL OF KARST EVOLUTION

The evolution of caves and karst in the Koněprusy Devonian has been recently connected with hydrothermal karstification. The model was gradually developed by Bosák (1996-1998) on the basis of earlier models of phreatic mixing corrosion with an active role of upwelling groundwaters of deep karst circulation by Bosák, Cílek & Tipková (1992), and Bosák, Cílek & Bednárová (1993).

It is supposed that caves in the Koněprusy Devonian formed within a confined aquifer under phreatic and bathyphreatic conditions. Confinement was caused by less permeable overlying Devonian limestone formations and siliciclastic Mesozoic platform cover. Thermal conditions for heating of deeply circulating groundwater appeared when paleogeothermic gradient increased (Medaris et al. 1998) due to intensive neovolcanic activity (35-17 Ma; Kopecký 1978). The increased heat is confirmed by recent fission track studies for a period of 40-20 Ma (J. Filip 2000, pers.com.). Thermal waters invaded cold water caves, changed their morphology, created new spaces, leaving two-dimensional mazes with remains of original phreatic tubes along the boundary of permeable and less permeable formations, and phreatic morphologies at depth. The maximum temperatures were stated to 60-80 °C from large calcite crystals (Dublyanski & Bosák 1999; Bosák 1998a) precipitated under phreatic and deeply phreatic conditions. At that time, the piezometric level was situated above limestones in Upper Cretaceous platform siliciclastics, which caused the origin of numerous subvertical tubes (“depressions“) filled with sunken platform sediments after the support of water buoyancy decreased (Bosák 1998a).

REVIEW OF EARLIER RESULTS

Karst depressions with sunken (collapsed) Upper Cretaceous and Tertiary fills were subjected to investigation only rarely in the past, although they appeared in numerous old quarries. The most detailed study was prepared by Kukla (1953, 1956) from the region of the Zlatý kůň Hill. He described 41 vertical or steeply inclined channels of circular to elliptic section, whose diameter changes only slightly with depth (he described them as pockets; Fig. 1A). Their upper part was frequently funnel-shaped. Some of channels terminated by horizontal caves at depth; some of them were situated at the same level as the middle level of the Koněpruské Caves. Nevertheless, the relation of channels and caves were not specified. The time of origin of cavities was unclear and they could be formed under sedimentary cover or as free chasms. Some channels contained Upper
Fig. 2: Narrow cylindrical karst depression in Velkolom Čertovy schody-Quarry West (bench height of about 15 m; Photo by P. Bosák, April 1999).

Fig. 3: Large karst depressions filled with Upper Cretaceous sediments in Velkolom Čertovy schody-Quarry East (Photo by P. Bosák, September 1995).
Fig. 4: Large karst depressions with the central ridge filled with Upper Cretaceous sediments in Velkolom Čertovy schody-Quarry East (Photo by P. Bosák, September 1999).

Fig. 5: Unconformity between Upper Cretaceous and ?Tertiary fill in a karst depression in Velkolom Čertovy schody-Quarry East (compare Fig. 5B; Photo by P. Bosák, July 1995).
Cretaceous fauna correlated with Lower Turonian. Stratigraphic sequence was characterized as follows: gravels, coarse- to medium grained sands and sandstones, fine-grained clayey sands or sandstones with clay intercalations, galuconitic sandy claystones and kaolinic sandy claystones. Traces of in situ lateritic weathering were present in places.

Ovárov (in Ovárov et al. 1972) characterised very similar stratigraphic sequence of karst fills comparable with Upper Cretaceous platform cover. Sediments were redeposited only slightly and they were sunk to depressions. Tertiary sediments were represented by quartz gravels and variocoloured clays correlated with Lower Miocene terrace levels of the Vltava River.

Cílek, Tipková & Kvaček (1992) described Upper Cretacepous rocks from the Velkolom Čertovy schody-Quarry East. Sediments were interpreted as equivalents of the Peruc and Korycany Members (Cenomanian), sands to gravels, clays and claystones; glauconitic claystones contained root structures comparable with *Protopteris punctata*.

Suchý, Zeman & Bosák (1996) documented the profile of the Peruc and Korycany Members (Cenomanian) and Bílá Hora Formation (Lower Turonian) from the Velkolom Čertovy schody-Quarry East. Sediments were sunk into a to large depression. The upper part was covered by variocoloured highly clayey sands of probable Tertiary age. Varioocoloured weathering product below the Upper Cretaceous sediments were supposed to be pre-Cenomanian (Carboniferous to Cenomanian).

Geophysical (Bárta, Beneš & Hrubec 1996) and economic geological investigation (Štefek et al. 1997) supported by detailed documentation of quarry walls (carried out by the author) since 1994 (e.g., Bosák 1997) has brought interesting data concerning speleogenesis (Bosák 1998a, b) of the region. The brief conclusions on collapse structures are given here. The study is based especially on observations from large active limestone quarries belonging to the Velkolom Čertovy schody a.s. (Giant Quarry of Devil Steps).

**KARST DEPRESSIONS**

Karst forms filled with the sequence of presumably pre-Cenomanian, Upper Cretaceous and post-Cretaceous fill are described here non-genetically as karst depressions. They were also clearly indentifiable on maps of geophysical measurement (combination of detailed electrical resistivity method, vertical electrical sounding, gravity and seismic methods).

**Shape**

Karst depressions are vertical and subvertical pipes, which can be identified as „sinkhole-like“ forms on the surface. They are typically circular to ovate, sometimes with bizzare shapes elongated in direction of fissures and faults (cf. Fig. 1A and B), resembling collapsed caves in places. They are often funnel-shaped in the upper parts with diameter from 2-4 m up to tens of metres (commonly 30 to 40 m). Some depressions are sunk into a to large depression. The upper part was covered by variocoloured highly clayey sands of probable Tertiary age. Varioocoloured weathering product below the Upper Cretaceous sediments were supposed to be pre-Cenomanian (Carboniferous to Cenomanian).
stone exploitation, geophysical measurements and drillings is several tens of metres (max. 82 m). The bottoms of most forms are still hidden at depth. This feature was typically observed in the 1950’s and described by Kukla (1956). At the present time, such features can be observed only rarely, but they are appearing again. Depressions often follow thick calcite veins of generally N-S direction and intersection of tectonic lines of generally N-S, W-E, NW-SE and NE-SW directions (Jungbauer, Puffr & Bosák 1993; Bártta, Hrubec & Beneš 1996; Bosák 1997; cf. Fig. 1)). Such depressions are rather elongated. Some depressions show clearly developed horizontal steps (“terraces”). This feature is visible also on geophysical cross-sections. Some “terraces” are developed at altitudes in which bottoms of other depressions are interpreted in the geophysical picture. They are dominantly present on W-E trending geophysical profiles, i.e., those structures are developed along the N-S trending tectonic lines, which was proved by observations in quarry levels. Limestones below the step are highly corroded into forms resembling subcutaneous karren.

**Fill**

The fill of karst depressions is lithologically variable and shows clear features of vertical movements (Figs. 5 and 6). The structure of fill is sometimes chaotic, without any clearly visible bedding. Syncline structures resulting from collapses and vertical movements are common features (Fig. 5). Some parts of fill show narrow, cylindrical collapse zones, which are often situated outside the centre of the depression. The vertical movement is indicated by numerous fissures and fractures within sediments, sometimes with visible traces of movement direction. The walls of depressions are often covered by relatively thick Mn-rich crusts, which represent remobilised weathered hydrothermal Mn-bearing minerals deposited on geochemical barrier (for discussion see Bosák 1998a). The contact zone with limestones can be pulverized to the depth of first centimetres, especially when Mn-rich crusts are continuous and thicker.

The fill can be divided into three general parts: pre-Upper Cretaceous fill, Upper Cretaceous fill and post-Upper Cretaceous fill (e.g., Bosák 1996a, b; Suchý, Zeman & Bosák 1996). To distinguish the pre-Upper Cretaceous fill from the basal parts of Upper Cretaceous fill is mostly very problematic, as basal parts of the infill of karst depressions are highly disturbed. Post-Upper Cretaceous sequences overlay the former often with angular disconformity and differ in lithology.

Pre-Upper Cretaceous fill consists mostly of brown clays with sandy and quartz gravel admixture. There also exist weathering products of lateritic type in places. Upper Cretaceous fill show clear characteristics of lithostratigraphical units known from the broader surroundings of Prague, where complete sequences are still preserved (Zelenka 1980, 1981, 1984, 1987; Ziegler 1994). Sediments can be clearly correlated with Cenomanian units of the Peruc Member (freshwater fluvi- and fluviolacustrine cycles), Korycany Member (marine transgressive sequence) and Lower Turonian Bílá Hora Formation. The Korycany Member is developed in highly condensed sequence of glauconite-rich rocks with total thickness of about 2-2.5 m (as compared to about 15 m SE of Prague; Zelenka 1987; Ziegler 1994). The age of Upper Cretaceous fill is proved by rare paleontological finds - remains of silicified woods and plant root structures (Cílek, Tipková & Kvaček 1992), and newly found microfossils (C. Sviták, pers. com. 2000).

Post-Cretaceous formations are represented mostly by variocoloured highly clayey sands with distinct intercalations of light grey to beige clays and silts. Fine-grained rocks contain remains of angular shards of bluish quartz. They resemble decomposed (argillitized) volcanic tuffs or tuffitic
Fig. 6: Examples of fill architecture of karst depression from Velkolom Čertovy schody-Quarry East. For explanations see the text (modified from Bosák 1994-1999, unpubl.).

rocks. Rocks overlay Cretaceous formations, sometimes with a clearly developed paleosoil horizon with clearly developed plant root structures and “bauxitic” clays. Preserved in place are fluvial terrace sediments composed of alternation of sands, sandy gravels and silts/calys. The age of those rocks has not been proved yet. They can represent Paleogene to Miocene lacustrine/fluvial sediments and weathering products. Typical cross-sections of some depressions are listed below.

**Depression I.** The depression was about 30 m wide and contained a sequence with steeply arranged lithological boundaries (Fig. 6A). The fill was composed of: Cenomanian, Peruc Mb.: A - white highly finely sandy kaolinitic clays, B - white and ochreous fine- to medium-grained, clayey sands, unsorted with bands of ochreous silty clays and their clasts, C - ochreous, very fine-grained clayey sands to silty clays with local ferruginization, D - ochreous to brown, whitish laminated silty clays, ferruginized, with laminae of white sands at top, marine Cenomanian, Korycany Mb.: E - light grayish green silty clays with glauconite, Lower Turonian, Bílá Hora Fm.: F - white to grayish white weathered spongilites, Tertiary?: G - variocoloured clayey sands, Upper Cretaceous (Cenomanian): H - grayish white very fine-grained sands with kaolinitic matrix, Upper-Cretaceous/pre-Cenomanian?: I - dark brown to ochreous clays with high fine-grained sandy admixture.

**Depression II.** The excavation of the fill of the depression (about 30 m wide) opened a profile with a typical bend of strata resembling squeezed syncline (Fig. 6B, C). The fill was composed of pre-Cenomanian(?): (1) brown to dark grey sandy clay with pebbles, Cenomanian, Peruc Mb.: (2) grayish white to whitish gray unsorted kaolinitic sands to sandstones forming 3 layers; the lower one was rather ochreous, (3) ferruginized zone 70 cm thick locally with schlieren of kaolinitic fine-grained sands, Cenomanian Korycany Mb.: (4) white fine-grained and well-sorted sands with grayish green glauconitic clays, Lower Turonian, Bílá Hora Fm.: (5) white to beige decalcified “opoka”, about 1.5 m thick, highly weathered, Tertiary(?): (6) paleosoil horizon with dark structures (?root forms), (7) ochreous clays with intercalations of pale red “bauxitic” clays, which prevailed in the upper part, (8) variocoloured sands and clays with interlayers of plastic grayish white and red clays/silts, sands were finely-grained and highly clayey, clays were finely sandy. The profile showed angular disconformity between Upper Cretaceous sediments and their overburden (Fig. 6B), indicating that collapse of material was polycyclic with different intensity (cf. photo on Fig. 5).

**Depression III.** The depression was about 35 m wide. The fill had a complicated stratification (Fig. 6D): A - sand, fine- to medium-grained, clayey, red to ochreous red, with fissures, B - sand, unsorted, clayey, yellowish ochreous, with quartz pebbles, C - sand, fine-grained, sorted (?eolian), slightly clayey, yellowish ochreous, D - siltstone, clayey, highly glauconitic, greenish gray, fissured, E - sand, very fine-grained, kaolinitic, variocoloured, locally pebbles of quartz, F - sandstone, quartzose, very fine-grained, slightly kaolinitic, grayish white, clasts of white kaolins, fissured, Fe - ferruginized horizon with broken ferricretes and concretions, G - sand, pebbly, unsorted, clayey, ochreous, H - clay, locally slightly sandy, brown. The sequence represents chaotically mixed rocks belonging both to Peruc Member and Korycany Member. Some rocks can represent pre-Cenomanian weathering products.

**Depression IV.** The depression was about 25 m wide (Fig. 6E). The fill was formed by several layers containing clear features of sinking: Cenomanian, Peruc Mb.: A - brown sandy clay, locally with laminae and bans of ochreous unsorted sands with pebbles, B - orange clayey medium-grained unsorted kaolinitic sands, C - grayish white kaolinitic sandstones, dominantly coarse-grained and unsorted, with ochreous shlieren and clearly developed system of fissures, Cenomanian, Korycany Mb.: D - greenish brown medium-grained clayey sandstones with glauconite, Quaternary: E - brown loams of (?) frost wedge.
CAVES

Some of depressions terminate by horizontal caves in the depth. This feature was described by Kukla (1953), although without details on relations of both forms and without characteristics of cave fill. Another examples appeared only in 1995 and again in 1999. Those caves were horizontal tube-like with diameter of 3-6 m. They could be traced for several tens of metres. In places, the tectonic displacement of passages was detected (movement of max. 6-8 m). Cave passages followed approximately W-E and N-S directions. The fill was composed of reddish brown compact and massive kaolinitic clay, similar to fills of outer zones of karst depressions. The clay was later irregularly eroded and a sequence of interlaminated ochreous fine-medium-grained sands, silts and clays was deposited. Sands contained rich heavy mineral assemblages and tiny ferrugineous concretions. No fossil remains were found. The laminated, fluvial cave fill can be lithologically compared with upper Sarmatian cave fill from the Červený (Red) Quarry, which filled horizontal and vertical tunnel-shaped caves of N-S direction (Horáček 1982) but at much higher altitude.

Bosák (1988b) described two lesser cylindrical chimneys with diameters of 2 to 4 m filled with Upper Cretaceous light gray massive clays. Walls of chimneys were covered by phreatic speleogens (scallops, etc.). Their character corresponds to shafts developed below epikarst zone without clear opening to the surface with blind termination (Klimchouk 1995; Klimchouk, Sauro & Lazzarotto 1996). The fill squeezed to them through the slightly open fissure system of the epikarst zone.

DISCUSSION

Karstogenetic models developed after the first detailed geophysical measurements (Puffr 1991; Jungbauer, Puffr and Bosák 1993) resulted in three general hypotheses. **Corrosional hypothesis** defined the origin of karst depressions by corrosional activity of circulating meteoric waters (model of geological organs). This model was supported by some kinds of shapes of depressions (ridges, cones, circular section, etc.). According to Žák (1999) such a mechanism is only responsible for the origin and development of pipes.

**Collapse hypothesis** explained the origin of karst depressions by collapses of older free subsurface cavities due to changes of mechanical properties of limestones by continuing karstification, e.g., decrease of piezometric level, change of artesian confinement to to regime with free groundwater level. The changes influenced the stability of rocky massif and led to collapses of roofs of subsurface cavities. The process rapidly propagates upwards (cf. Meiburg 1980; Weinrich & Sutphin 1994; Quinif 1995). This model supported e.g., traces of speleogens on depression walls (sections of caves, scallops).

**Hydrothermal hypothesis** modified corrosional hypothesis, introducing _per ascendum_ model of speleogenesis by upwelling warmer groundwaters of deep karst circulation (Bosák 1996a-c, 1997, 1999a). The mechanism of mixing corrosion by meteoric and deeply circulating karst waters in the phreatic zone was indicated already by Bosák, Cílek & Tipková (1992), and Bosák, Cílek & Bednárová (1993). Numerous facts detected both by detailed geophysical measurement and by field observations support this view (e.g., fluid inclusion and paleotemperature study of Dublyanski & Bosák 1999).

Interpretation of detailed geophysical measurements (Bárt, Hrubec & Hrubec 1996) by Bosák
(1997) indicated that the distribution of irregularities in model specific gravity can be explained both by the presence of limestone breccia with matrix of karst sediments or by the existence of karst sediments in the depth or by intensively karstified fissured limestones with fill of karst sediments (corrosional karst macroporosity). Kukla (1953) did not described any collapses and the bottoms of karst depressions and new drilling operations and mining did not discover remains of collapses at the base of depressions, as assumed earlier by Bosák (1996c, 1997). The presence of collapse breccias is therefore questionable, but it cannot be fully excluded.

The shape of depressions, their elongation and size could indicate that they represent collapsed or erosionally cut old cave systems. Some forms represent vertical karst forms (chimney-like or shaft-like) of corrosional origin. Similar oblique forms were described by detailed geophysical measurements (Jungbauer, Pufir & Bosák 1993) and observed on exposed quarry walls. Some pipes terminated like blind chimneys within the rock. Their character could indicate that they were formed by rising thermal water or by mixing corrosion within the phreatic zone aligned to structural elements in rocks up to the piezometric level. Some forms (free or filled by sediments) were not developed along any fissure or crack, neptunian dyke or calcite vein. This fact indicates rather the effect of thermal waters enriched in carbon dioxide and other corrosive substances (cf. e.g., Forti 1996; Hill 1996).

Karst depressions represent polygenetic and polycyclic form. In some cases, they represent older endokarst forms filled during younger evolution phases, i.e., older hydrothermal cavities, blind epikarstic shafts, products of classical speleogenesis (caves). The genesis of numerous depressions can be connected with the speleogenesis in Koněprusy Limestones within hydrothermal phreatic conditions. Limestones were perforated up to their top, as the water table was lying above their interface with overlying Upper Cretaceous sediments. After the buoyancy support of water decreased, overlaying siliciclastics collapsed to open steeply inclined forms. The presence of metahalloysite in basal parts of siliciclastics, originally interpreted as a stress-derived product from slow movement of sediments into the depression (Cílek & Šťastný 1996), represents the product of hydrothermal alteration of clay minerals (especially kaolinite) in fact (Melka et al. 2000) and prove that the movement of sediments down to cavities was connected with the hydrothermal speleogenesis.

Depressions were filled by several types of processes: (1) intensive evolution of epikarst zone connected with lowering of karst surface by chemical denudation. The origin of corrosionally enlarged fissure porosity enabled the infiltration (suffosion) of surface sediments into older karst forms and their complete infilling. The suffosion was active also below the cover of permeable or partly permeable platforms sediments (pre-Cenomanian weathering products, Cenomanian to Turonian sequences, etc.) in places of infiltration of meteoric waters. Such fill is characteristic of homogeneous structure without distinct bedding and other sedimentary structures. (2) Slow sinking of sedimentary cover into endokarst cavities caused by damage of cavity roofs. Such movement is often polycyclic with variable intensity of the process. On some depressions, more intensive sinking of pre-Cretaceous and Cretaceous sediments is followed by less intensive movement of Tertiary cover. Both phases can be separated by angular disconformity and evolution of pedogenic horizons. Some depressions show more intensively moved centres of depression with chimney-like collapsed form. Such forms could be generated by the termination of active speleogenesis owing to lowered piezometric level causing the lost of buoyancy support within the endokarst connected with gradual or sudden sinking and/or collapse (cf. Bosák et al. 1989; Beck ed. 1984; etc.).
CONCLUSIONS

The karst developed in Lower Devonian (Pragian) skeletal limestones is characterized by numerous vertical and subvertical pipes with lithologically varied fill. Pipes (so-called karst depressions) are identifiable as „sinkhole-like“ forms on the surface. The intensive exploitation of limestones in huge quarries has been offering excellent cross-sections through such karst forms. They are typically circular to ovate with diameter from 2-4 m up to tens of metres. They are sometimes divided by sharp ridges and cones. The walls are often overhanging and rarely contain clear speleogens (e.g., niches, large-scale scallops or phreatic half-copulas). The depth proved by geophysical measurements and drillings is several tens of metres. The bottoms of most of the forms are still hidden at depth. Some of them terminate by horizontal cave levels at depth.

The pipes are filled with a very complicated sequence of sediments in which collapse structures are visible. In the lower part, sediments are represented by pre-Cenomanian weathering products (varicoloured clays, sandy clays, etc.). The Cretaceous is represented by the Peruc Member (freshwater fluvial and fluvo-lacustrine deposits, Cenomanian), Korycany Member (marine sequence with glauconite, Cenomanian), the Bílá Hora Formation (marine marls, spiculites, sandstones, Lower Turonian) and by the Jizera Formation locally (sandstones, Middle Turonian). Cretaceous ages are proved by some paleontological finds (microfossils, silicified woods) and by lithological correlations. Cretaceous and pre-Cretaceous sequences are disconformably overlain by Tertiary sequences. The boundary of both units is often marked by paleosoil horizons. Tertiary sediments are composed of variegated and multicoloured sands, clayey sands and sandy clays, often intercalated by gray clays resembling weathered volcanic tuffs. The Tertiary age has not yet been proved by any paleontological evidence. The youngest fill is represented by Quaternary screes, solifluction horizons and soils.

The origin of solution pipes is connected with the hydrothermal activity most probably during Paleogene to Miocene, when the surface of limestones was still covered by slightly eroded cover of Upper Cretaceous platform sediments. Hydrothermal karst forms developed up to the surface of limestones as the piezometric level was situated within the Cretaceous cover. After the loss of buoyancy support of water, sedimentary cover started to collapse down. Internal structures of the fill indicate multi-phase collapses. Cretaceous and pre-Cretaceous deposits are often subvertical with chaotic internal texture. In the centre of some of the pipes, there are traces of younger collapses, most probably induced by continuing karstification and suffosion in the depth. Tertiary deposits overlay the Cretaceous ones disconformably, they show gentler centripetal inclination, but, in places, they fill the central parts of collapsed fill.

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REFERENCES


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**Povzetek**

Značilne oblike za kras, nastal v spodnjedevonskih (praških) skeletnih apnencih, so številne vertikalne in subvertikalne cevi, zapolnjene z litološko različnim polnilom. Na površju je te cevi (t.i. kraške depresije) mogoče zaznati kot vrtačaste oblike. Intenzivno izkoriščanje apnenca v velikih kamnolomih je odkrilo odlične prereze teh oblik. So tipično okrogle do ovalne oblike premera med 2-4 do nekaj 10 m. Včasih te oblike med seboj ločujejo ostri grebeni in stožci. Stene so pogosto previsne in le redko kažejo jasne speleogene (to je niše, velike fasete ali freatične kupole). Globina teh cevi, potrjena z geofizičnimi meritvami in vrtanj, je več 10 m. Nihova dna so še skrita v globini. Nekatere izmed cevi se na dnu končujejo z vodoravnimi jamskimi rovi.

Čevi zapolnjujejo zelo zamotana zaporedja sedimentov, v katerih so vidne udorne strukture. Spodnje dele teh odkladnin sestavljajo predcenomanijski produkti preperevanja (pisane in peščene gline idr.). Kredo predstavljajo lokalni členi Peruc (sladkovodni rečni in rečno-jezerski sedimenti; cenomanij), Korycany (marinska sekvenca z glavkonitom; cenomanij), Bila Hora (morski laporji, spikuliti, peščenjaki; spodnji turonij) in Jizera (peščenjaki; srednji turonij). Kredno starost potrjujejo paleontološke najdbe (mikrofosili, silificiran les) in litološka korelacija. Kredne in predkredne sekvence so običajno odložene preko terciarnih. Mejo med obema enotama često nakazujejo hORIZONTALNO paleoprsti. Terciarne odkladnine sestavljajo pisani in večbarvni peski, glinasti peski in peščene gline, često z vmesnimi vložki sivih glin, ki spominjajo na razpadle vulkanske tufe. Za zdaj ni paleontološkega dokaza, ki bi potrjeval terciarno starost. Najmlajšo zapolnitev sestavljajo kvartarni grusči, soliflukcijski hribozi in prsti.