THE EVOLUTION OF KARST AND CAVES IN THE KONĚPRUSY REGION (BOHEMIAN KARST, CZECH REPUBLIC) AND PALEOHYDROLOGIC MODEL

PALEOHIDROLOŠKI MODEL RAZVOJA KRASA IN JAM V KONĚPRUSYH (ČEŠKI KRAS, ČEŠKA REPUBLIKA)

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Pavel Bosák: Paleohidrološki model razvoja krasa in jam v Koněprusyh (Češki kras, Češka republika)

Z novim modelom paleohidrološkega razvoja jam v Koněprusyh je treba opustiti stari model, po katerem naj bi se jamski "nivoji" razvijali neprekinjeno, v skladu z razvojem teras ob glavnih rekah, od miocena dalje. Model "spuščajočega zakrasevanja" je treba zamenjati z modelom "zakrasevanja navzgor", ki temelji na globoki freatični cirkulaciji kraških voda tekom glavne faze razvoja jam v paleocenu spodnjem miocenu. Dviganje kraških voda je povzročala hidravlična bariera (nariv), ki omejuje sinklinalno zgradbo proti severu.

Ključne besede: paleokras, paleohidrogeologija, razvoj krasa in jam, Koněprusy, Češki kras, Češka republika

Abstract UDC 556.3(437.1)

Pavel Bosák: The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic) and paleohydrologic model

The new paleohydrological model of the evolution of caves in the Koněprusy region abandons up to now model based on the continual development of cave "levels" in accordance to the evolution of the terrace system of main rivers since Miocene. Descending model of karstification is substituted by the "ascending" model based on deep phreatic circulation of karst water during the main phase of cave evolution in Paleocene-Lower Miocene. Upwelling of groundwater was caused by hydraulic barrier (overthrust) limiting synclinal structure at the north.

Key words: paleokarst, paleohydrogeology, karst and cave evolution, Koněprusy region, Bohemian Karst, Czech Republic

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INTRODUCTION

The Koněprusy region is typical by special facies development of the Lower Devonian of the Barradian Basin. The reefal and organodetrital Koněprusy Limestones (Pragian) is overlain by the Suchomasty Limestones (uppermost Zlíchovian to Dalejan), Acanthopygae Limestones (Eifelian) and siliciclastics of the Srbsko Formation (Givetian, Chlupáč et al. 1992). Limestones show good lithification in the stage of deep burial to weak metamorphosis. The are folded into the system of open synclines and squeezed anticlines, often with overthrusts. Tectonization by faults and fissure systems is dense.

Up to now, the origin and development of karst forms in the whole Barradian region has been connected with the evolution of the terrace system of main rivers, i.e. Berounka and Litava Rivers and their paleoequivalents. The origin of caves has been linked with especially with the Quaternary geomorphological cycle.

The evaluation of exploration in the Koněprusy region (1952 to 1993) and of the speleological investigation of active and old quarries brought some new knowledge and interpretation possibilities (Bosák 1993) for the whole Barrandian Basin, whose limestones landscapes are known as the Bohemian Karst.

KARST FORMS IN LANDSCAPE AND BOREHOLES

Since 1950, totally 329 fully cored boreholes have been drilled, from with a total length of about 20 km. In them, more than 420 of karst cavities have been discovered concentrated in about 23 detectable altitudinal levels between 470 and 125 m a.s.l.! (Bosák 1993).

Register of the Czech Speleological Society contains total of 64 caves in two karst region. Karst region No. 11 contains 39 numbered caves, together with the larges caves in the region - the Koněpruské Caves with 2 km of passages. Karst region No. 18 totals of 25 numbered caves. From that number only 14 caves have been found by the speleological activity outside quarries.

The presence of caves in the northern part of the region, in the Zlatý Kůň Hill, is concentrated to the belt situated somewhat to the S-SW from the line of the Očkov ovethrust, limiting limestone outcrops. There are situated not only the Koněpruské Caves developed in 3 levels, but also about 19 smaller caves in levels corresponding to the middle and lower levels of the Koněpruské Caves. Caves in other smooth hills (Na Voskopì, Plešivec) are relatively small. The common feaures of all smaller caves can be summarized as follows: (1) they are more or less isolated without distinct known interconnection, (2) they have character of upward blind and inclined phreatic channels or irregular phreatic corrosional spaces. The part of caves is completely colmated by sediments as old as Upper Sarmatian to Lower Pliocene (Horáček 1980a, b).

Karst features in boreholes can be characterized into several categories: (1) *karst cavities,* i.e. space mostly filled with sediments - reworked Upper Cretaceous and Tertiary deposits and in situ Tertiary and Quaternary deposits, sometimes with speleothems. Only small percentage of cavities is completely or partially empty; (2) intergranular karstified carbonates represent in situ decomposed wackestone and grainstone into calcareous sandy eluvium during very intensive process deeply below the base level; (3) karstified zones, without detailed specification are reprezented by widened fissures, bedding planes or cracks, often representing the epikarst zone; (4) infiltration kaolinization when the carbonate rocks is altered to clayey-silty material by in situ cold metasomatosis with the transport of clayey-silty particle during calcite dissolution as a result of aggresive water percolation under wet-hot climate on the surface, and (5) epigenetic reddening caused by weathering processes and Fe transport. The process was tectonically controlled and influenced by lithology/porosity and its products occur in distinctive levels as the marker of fossil piezometric levels. The terms intergranular karstification, infiltration kaolinization and egigenetic reddening were introduced by Bosák, Cílek and Tipková (1992) and explained by Cílek, Bosák and Bednářová (1995).

KARST EVOLUTION

Evolution of karst forms has a long lasting trend. Here, only basic points will be summarized, having connection with discussed problem or influencing younger karstification "efforts".

Devonian

Local paleokarsts originated during Lower to lower Middle Devonian. Freshwater vadose and phreatic karstification was connected with reef emersions and the origin of freshwater lens. Several phases can be dated to the interval of Pragian (Lower Devonian) to Givetian (Middle Devonian). Originated macroporosity (vuggy and cavern types) was filled with clayey dolostone to dolomitic claystone, dark coloured (Bosák 1993). Connnected features of neptunic dikes filled with several generation of all lithostratigraphic units can be connected with blue holes of recent Bahamas (Smart et al. 1988). It seems that the system of this paleoporosity influenced all following subsurface karstification processes.

Carboniferous to Cenomanian

Pre-Cenomanian karstification period started in the Upper Carboniferous. No known subsurface karst forms have been known. There are only some relics of surface forms and sediments (kaolinic sands in depressions). The period was finished by extensive marine transgression.

Paleogene to Lower Miocene

Paleogene to Lower Miocene karstification was connected with gradual but rapid erosion of Upper Cretaceous platform sediments (siliciclastics prevail). Intensive subjacent karstification started when the Cretaceous cover was substantially thinned by intensive weathering (Paleocene and Eocene) and backward erosion to highly permeable Cenomanian sands and gravels. Ponors in multiple rank (Ford and Williams 1989) appeared at the margins of limestone subcrops and outcrops. The development of basic network of passages led in prolonged karstification period to the origin of extensive caves which presently contain various fill sometimes reworked completely. The time of cavern origin can be linked with the main phase of cave evolution defined by Bosák (1991) for the whole Bohemian Massif and dated to Middle to Upper Paleogene.

The evolution of caves was connected with prolonged periods of stabilized base level (cf. Palmer 1987) represented by the origin of extensive aluvial plains in the Bohemian Karst (Bosák, Cílek and Tipková 1992). This evolution was indicated also by older morphological analyses (e.g. Ovčarov 1973 or Lysenko 1987).

The morphology of caverns shows, that they mostly originated in the phreatic regime. The cavern shapes have typical morphological features of batyphreatic caves or phreatic caves (sensu Ford and Eweres 1978) with multiple loops, and inclined ascending and descending passages connected by shorter or longer subhorizontal tunnels or channels. Phreatic corrosional fetures and widening of channels is also typical leading to the origin of irregularly shaped smaller or larger domed caverns. The horizon equivalent to the middle level of the Koněpruské caves was later morphologically reworked at oscillating piezometric level in the vadose regime. The concentration of cave close to the thrust limit of limestones at the north is most probably caused by paleohydrogeological and paleohydraulical fetures of underground drainage and hydraulic head towards the hydraulic barrier of the Očkov overthrust. Phreatic caves discovered in quarries and boreholes represented inflow channels connecting the ponor area with the barrier along tectonic directions of N-S and W-E directions.

Miocene

The gradual diminution in the karstification can be observed. It was caused by tectonic/morphological features leading to the shift in the position of the

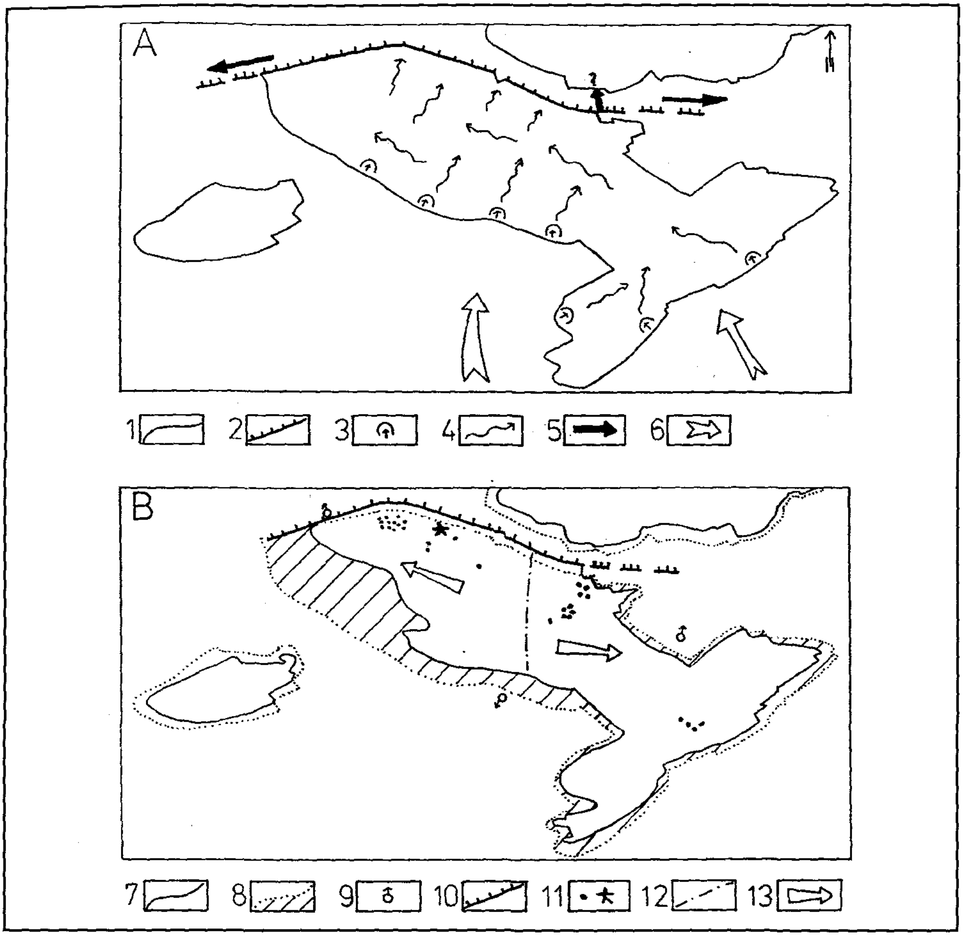

Fig. 1: Evolution of drainage in the Koněprusy region in plan
A. The main phase of cave origin; 1. limits of limestone subcrops and outcrops, 2. Očkov overthrust, 3. ponors (schematically), 4. main directions of water inflow to karst, 5. flow direction of karstwater
B. Present situation; 7. present limits of limestone outcrops, 8. limestone slope retreat, 9. karst springs, 10. Očkov overthrust, 11. caves, 12. water divide, 13. flow direction of groundwater

Sl. 1: Razvoj odtoka v Koněprusih, tloris.
A. Glavna faza nastanka jam; 1. rob apnenčevih izdankov, 2. Očkov nariv, 3. ponori (shematizirano), 4. glavne smeri vodnega odtoka v kras, 5. smer toka kraške vode
B. Sedanje stanje; 7. sedanje meje apnenčevih izdankov, 8. odmik apnenčevih pobočij, 9. kraški izviri, 10. Očkov nariv, 11. jame, 12. razvodnica, 13. smer podzemeljskega toka

piezometric level. Gradual decrease of the base level led to the fossilization of some of inflow channels, the evolution of vertical connections and vadose invasion caves. The main periods of fossilization can be dated since upper Middle Miocene (Sarmatian and younger colmatage of Oligo-Miocene caves). Younger caves were connected with mixing corrosion under further about two to three phases of the stabilization of broad alluvial plains. Large lakes

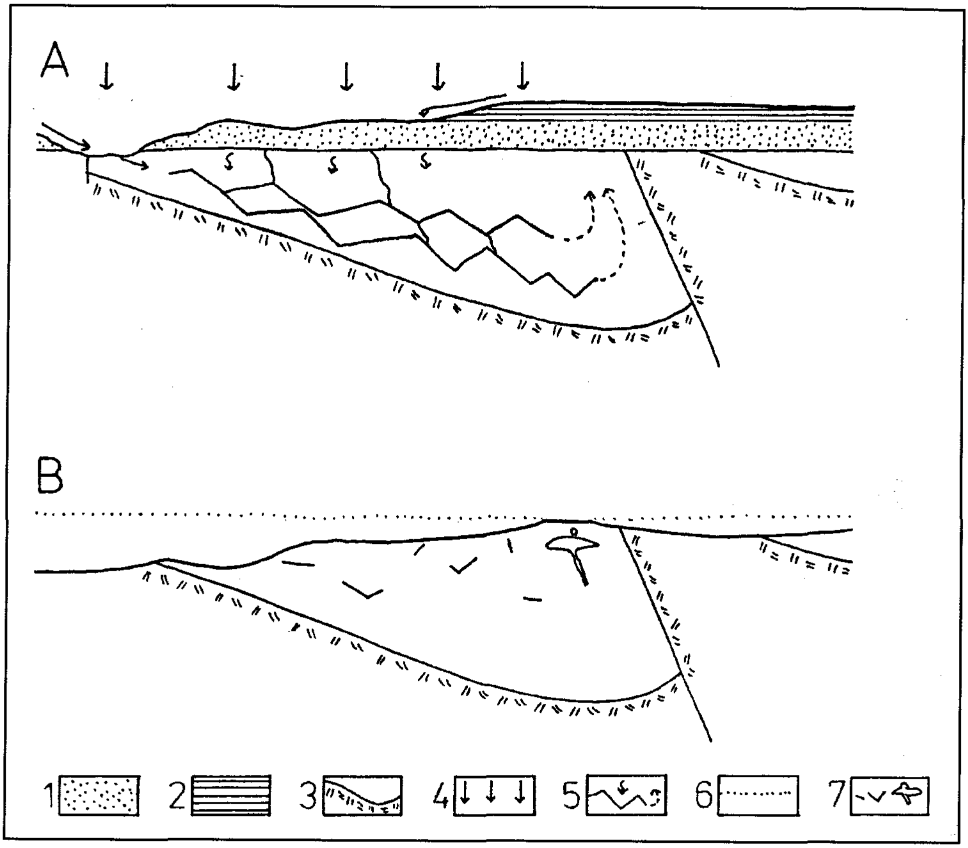

Fig. 2: Schematic section of the syncline structure of the Koněprusy region in the time of the main phase of cave origin
1. Silurian and Devonian limestones, 2. Cretaceous siliciclastics, 3. Očkov overthrust, 4. ponors, 5. groundwater circulation paths, 7. caves (known at present)

Sl. 2: Shematski prerez sinklinalne strukture Koněprusev v času glavne faze nastajanja jam
1. silurski in devonski apnenci, 2. kredni silikatni klastiti, 3. Očkov nariv, 4. ponori, 5. poti podzemeljske cirkulacije, 7. jame (znane danes)

developed in caves. Some older ones were dissected and somewhat displaced by neotectonic movements (Ovčarov et al., unpubl. 1972).

Pliocene to Early Pleistocene

The continuing fossilization with Middle Pliocene and Biharian phases is typical for this phase.The last neotectonic movements are dated back to Biharian (cca 1.1 Ma) in the Konìpruské Caves (Horáček 1980a).

Quaternary

Pleistocene to Holocene was characterized by intensive backward erosion owing to rapid entrenchment of main river of the region (Berounka) some 90 m down at the end of Biharian and by continual evolution superficial karstification (epikarst zone). Some minor caves were maybe inserted during shorter stabilization of base levels.

PALEOHYDROGEOLOGICAL MODEL

The presented paleohydrogeological model of the evolution of caves in the Konìprusy region abandons up to now prefered theory on continual evolution of cave levels in the connected with the origin of terrace river system (e.g. Hromas 1968). It is based on following postulates:

(1) The predisposed network of Lower - Middle Devonian diagenetic porosity was several times utilized by younger karstification phases influencing the space arrangement of subsurface karstification processes. Strong tectonic controll can be stated.

(2) The evolution of some karstic porosity to macroporosity during pre-Cenomanian (mostly Upper Jurassic - Lower Cretaceous) evolution of landscape cannot be completely excluded. It was connected with the stabilization of broad alluvial plains characterized by mixing corrosion of river and ground waters in limestones.

(3) The destruction of Upper Cretaceous platform sediments underwent in wet and hot climates during Paleocene to Oligocene. This was connected with the evolution of (a) ponors at margins of limestone core of synclines; (b) infiltration routes under a cover of permeable Cenomanian sediments (mostly sandstones), and (c) ponor network in multiple ranks and multiple lines at the margins of Silurian and Devonian subcroops and outcrops.

(4) The evolution of cave systems was in deep phreatic zone with cave horizons with multiple loops and local horizontal features. The cavern origin (and the karst groundwater circulation) followed main tectonic scheme, i.e. NNE-SSW to NNW-SSE tension open fractures and faults and WNW-ESE to WSW-ENE compressional faults to overthrusts. The main characteristics of caverns can be summarized as follows: (a) in areas close to ponors cave have mostly character of circular, mostly phreatic tunnels.

Their diametre increases with the distance from ponor areas, and (b) in area close to the main hydraulic barrier, caves are irregular, vertical with subhorizontal "levels". They are characterize by maze to labyrinth nature and irreular morphology of shallow phreatic to vadose lake-filled rooms.

(5) The main hydraulic barrier has been representing by the Očkov overthrust forming the NE closure of limestone syncline. It caused the upwelling of water, the increase in piezometric level and water discharged along the thrust line in NW and SE directions. The zone, tens to first hundreds of metres wide along the overthrust is typical by the absence of caves due to the compressional nature of fissure network.

(6) The evolution of lower deep phreatic cave horizons was later dependent on the decrease of piezometric level as a consequence of climate aridization and/or change of regional base level. Base level subsided due to uplift connected with Miocene volcanic phases. Old piezometric levels are marked by precipitates of Fe inside the carbonate massif. Complete removal of Cretaceous platform cover led to formation of carbonate outcrops and resulted in the retreat of limestone slopes and shift of ponors in the centripetal manner.

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PALEOHIDROLOŠKI MODEL RAZVOJA KRASA IN JAM V KONĚPRUSYH (ČEŠKI KRAS, ČEŠKA REPUBLIKA)

Povzetek

Analiza temelji na popolnih jedrih 329 vrtin v skupni dolžini okoli 20 km, na preko 420 kraških votlinah, odkritih ob vrtanjih in na 64 jamah iz registra Češkega speleološkega društva. Jame v severnem delu ozemlja so zgoščene v pasu, ki je približno severo - severozahodno od črte nariva Očkov, ki omejuje izdanke apnenca. Jame so druga od druge bolj ali manj ločene in kažejo značilnosti strmih in nagnjenih slepih freatičnih kanalov ali neenakomernih freatičnih korozijskih votlin različnih velikosti; največje med njimi kažejo sledove vadoznega preoblikovanja.

Kraške oblike kažejo dolgotrajno smer razvoja s temeljnimi fazami in periodami v devonu, pre-cenomaniju, paleocenu-spodnjem miocenu, miocenu, pliocenu do spodnjem pleistocenu in v kvartarju.

Predstavljeni paleohidrogeološki model razvoja jam v Koněprusih temelji na sledečih predpostavkah:

(1) Domnevna mreža spodnje - srednje devonske diagenetske poroznosti je bila večkrat ponovno uporabljena med mlajšimi fazami zakrasevanja in je tako vplivala na prostorsko razporeditev podpovršinskih procesov zakrasevanja. Opazen je močan vpliv tektonike.

(2) Nastanka kraške poroznosti do makroporoznosti v času, ko je nastajal predcenomanijski (največ zgornjejurski - spodnjekredni) relief, ne smemo v celoti izključiti. Povezan je bil z ustalitvijo velikih aluvijalnih ravnin, kjer je na apnence delovala mešana korozija rečne in talne vode.

(3) Razpad zgornjekrednih sedimentov platforme je potekal v vročem in vlažnem podnebju tekom paleocena in oligocena. S tem je bil povezan nastanek (a) ponorov na robu apnenčevega jedra sinklinal; (b) smeri prenikanja pod pokrovom prepustnih cenomanijskih sedimentov (največ peščenjakov) in (c) mreže ponorov v več vrstah in več nivojih na robu silurskih in devonskih izdankov.

(4) Jamski sistemi so se razvijali v globoki freatični coni z jamskimi horizonti s številnimi zankami in lokalnimi vodoravnimi oblikami. Nastanek jam (in kraške podzemeljske cirkulacije) je sledil glavni tektonski zasnovi, to je

SSV-JJZ do SSZ-JJV usmerjenim odprtim nateznim razpokam ter prelomom in ZSZ-VJV do ZJZ-VSV usmerjenim prelomom in narivom. Glavne značilnosti jam lahko strnemo kot: (a) na področjih blizu ponorov so okroglega prereza, pretežno freatični tuneli. Z oddaljenostjo od ponorov se njihov premer povečuje in (b) na področjih, blizu hidravličnih pregrad so jame nepravilnih oblik, navpične, s subhorizontalnimi nivoji. So mrežaste do labirintaste narave in so plitvo freatične do vadozne votline nepravilnih oblik, zapolnjene z jezeri.

(5) Očkov nariv, ki s SV strani zapira apnenčevo sinklinalo, predstavlja glavno hidravlično pregrado. Povzročil je dviganje vode, naraščanje piezometričnega nivoja in vodni odtok vzdolž narivnih črt v smeri SZ in SV. Za to cono, široko od nekaj deset do prvih sto metrov vzdolž nariva, je značilna odsotnost jam zaradi stisnjene mreže razpok.

(6) Kasnejši razvoj spodnjih globokih freatičnih horizontov je bil povezan z zniževanjem piezometričnega nivoja kot posledice sušnejšega podnebja in oziroma ali spremembe lokalne erozijske baze. Ta se je znižala zaradi dviganja ozemlja, povezanega z miocenskimi vulkanskimi fazami. Stare piezometrične nivoje označuje odloženo Fe znotraj karbonatnih masivov. Zaradi popolne odstranitve pokrova kredne platforme, so se pokazali izdanki apnencev, apnenčeva pobočja so se odmikala, ponori pa se centripetalno oddaljevali.